were built with the internal loads hanging from the roof. The
strongest part of such a structure must necessarily be at the top.

Mr. E. J. Michaelson said that in erecting steel buildings it
was common in America to concrete the top first, to expedite the
installation of the lift. Then the lower floors could be com-
pleted, and let long before the rest of the building was com-
pleted.

Mr. G. G. Robert said that, in New Guinea, those buildings
erected on concrete piles, spaced about eight feet apart and
about four feet high, with zinc slip plates on the pile heads
beneath the soleplates, had all survived the 1914 earthquake;
the buildings had been able to slide about relative to their
supports.

The discussion was closed, subject to the author’s right of
reply.

Erratum.—On page 28, line 9: For “Hawker” read “Hawksley.”

PAPER

THE CO-ORDINATION OF PRACTICE AND THEORY IN
CIVIL ENGINEERING.

By J. T. Noble Anderson (Past President).

Foreword: The following discursive paper is intended to
give as fully and candidly as possible the personal gleanings of
a very varied career, the last fifty years of which have been
exclusively devoted to the Theory and the Practice of Engineer-
ing Science. Indulgence for its personal character is expected,
because its chief value, in the author’s mind, is that it is an
attempt to give accurate statements of actual people’s reactions
to real happenings, and to record their results. Some of the
characters are, if not themselves famous, closely linked with
historic achievements. For instance, the Professor was the late
Maurice Fitzgerald, brother and, for a while, co-worker with
George Fitzgerald, whose anticipations of the Quantum Theory
are now well known; and the late Randall Joseph Nixon was
the first tutor to (Sir) Joseph Larmor, and, so far as mathem-
atical investigation was concerned, a co-worker with Dr.
Andrews in his epoch-making discoveries concerning the liquifi-
cation of gas, and the enunciation of the triple point theory.
Macassey was probably better known as the barrister of Parlia-
ment Place, Westminster, and the co-author of a well-known
treatise on the Law of Contracts, than as an engineer. All of
these, as well as James Thomson and Kelvin, who continued
their association with their native town, were unfailing in their
efforts to engage team work in all they did. And it is the
author's steadfast conviction that the one thing needful for team work is absolute confidence in the wholehearted devotion to the work of every member of the team. "Self" is the discordant note which will shatter every edifice, and without honest and humble co-operation nothing really valuable is likely to be achieved.

The present century has experienced a complete reversion between the respect to be given to what used to be known as the practical and the theoretical engineer. Just fifty years ago the general opinion of the intelligent public was expressed by my mathematical tutor, Randall Joseph Nixon, a Fellow of Peterhouse, Cambridge, when I told him that I was abandoning a mathematical scholarship for one in one of the leading engineering schools in the land: "The theoretical education in engineering science is waste of time. You want to do what my brother did, who is designing engineer to a big locomotive works. He knows every link and bolt, as a surgeon knows your bones, because he has gone right through all the workshops for a seven years' apprenticeship before he started to design." When I explained I wanted to be a civil engineer, and had spent all my holidays in factories, foundries, and shipbuilding yards, he replied: "Then pay five hundred guineas premium and work up social influence, but don't waste your time at the University."

Notwithstanding that question of patronage, then, as now, the key to the best engineering appointments was generally found more easily by the man with the practical utilitarian instincts, belonging rather to the tradesman type than the philosopher. The reason is not far to seek. The higher intelligence revolts against the drudgery of learning through one's hands, and, except when it is necessary to follow up some line of investigation on which all its energies are set, will not give the meticulous care to achieve accurate results in the affairs of everyday life, while the "practical" man from drudgery acquires an instinct which enables him to achieve results almost without knowing how.

Less than three years after, when, as a young graduate, with a rather swelled head, I was apprenticed to the late L. L. Macassey, he gave me the text for this paper, somewhat as follows:—"'Up to now you have been learning engineering only as a science; now you must study it as an art. Do you know the difference? Well, don't flounder, but admit you don't. In acquiring a science you have learnt to understand something, while in acquiring an art you must learn to do something. Then he went on to illustrate it by giving me something to be done so often that it became second nature: First three months exclusively at quantity surveying, followed by several months, every
day, snow or shine, surveying and levelling, from 8 a.m. till 6 p.m. Then, on large works, laying off, and later, recording progress, and comparing actual cost with estimates, to qualify as a contractor’s resident engineer. This was regarded as the ideal training of that day.

Then came in standardisation, and much of the practical work, which was so preciously passed on from master to apprentice, became crystallised in by-laws and standard specifications, and a close regard to their provisions to a considerable extent eliminated the necessity to follow the “experience” of the man trained in the old practical school. It was then that testing Portland cement in large briquettes (2½ inches area) for tension came into use, and a good impression of the different reactions of the scholar and the practical man can be got from the following: Twelve months after leaving the University my former engineering professor and Macassey came together to my testing laboratory, on a large waterworks concern, and I put the question, “Why do we submerge in water our cement briquettes to prepare them for test?” The professor explained elaborately the necessity to have exactly uniform treatment of each specimen for comparison of the strength assumed in all our calculations. The practical man said, “Oh, I must be sure my cement will stand water, and if it does that, I am not particular about any usual variation from standards, because we design with a large factor of safety.”

At this time I still had a hankering after pure science, and was reading advanced mathematics for what is now known as a science degree, when I came under the influence of a student who had been placed third or fourth wrangler—the Cambridge final arts degree. Finding his health to suffer, he had obtained an engineering inspector’s post. This man took me severely to task for trying to follow two masters, and strongly counselled me to choose the way of happiness, with good health and happy slumbers as the reward for practical work, rather than the worn nerves and ambition-goaded long hours of the University student. I chose the middle course, and, while no longer studying mathematics, I subsequently graduated in the arts school, so that to-day I am still able to claim a place in both camps.

Just twenty years after I was offered the choice between continuing as Deputy Professor under the former, with a sheltered life position, or coming in as a junior partner in the practice of the latter, who, however, strongly advised me to remain in the sheltered position, but to move with the times and see that more “practical” and “rule of thumb” teaching was adopted in the University.
With the cordial assistance of the Professor, I started in these lines of reform. Luckily, I felt uncertain of my understanding of the true needs of my engineering school to take so grave a responsibility, and finally applied for the post of water supply and sewerage engineer at Rangoon. I was recommended, with four others out of over 200 candidates, to the Indian Government for this. At that time, under new local government conditions, natives already were elected to the Rangoon Municipal Council, consequently an engineer with local knowledge was preferred, but I was informed that I could have another appointment under the Indian Government on its hydro-electric staff. On my inquiring how they knew that I was qualified for such work, they said "the training under Professor Fitzgerald is sufficient warrant for us. His men are well known in India." I realised that to alter a system so notably successful would be a mistake, and that, after sixteen years' absence, I was no longer really qualified to take so responsible a post as to be his successor. I regretted later, however, when I found the trend of world affairs, that I was not able to shake his conviction that his successor should be a more practical engineer than himself, and did not accept his gracious offer to act as Professor for two years under his tutelage. It is notable that both the practical and the academic man felt uneasy, and visualised the need of change of methods, due to altered conditions. It was obvious, since each was always anxious for the assistance of the other to this end, but they were held apart by some subtle spell, the practical man being too sure of the futility of advanced views, because he had generally found that the theoretical man failed on some simple but essential detail.

Much serious discussion has occupied every leading engineering association on the problem of how best the engineer should be educated and trained. In the past the term "Civil Engineering" embraced every pursuit of the science of engineering—and up to now that has been the meaning adopted in this paper, in contradistinction to the older branch of "Military Engineering." Leaving now the schools of the last century, which aimed at giving the civil engineer some knowledge of all engineering, and all attainable knowledge of some one pursuit, I propose, in the following, to speak of the profession of the "Engineer," admitting that the marvellous advance in the wealth and knowledge of humanity to-day has compelled such specialisation that even a professor can no longer claim much more than the rudiments of any branch except what he has himself concentrated on.

To-day the paramount question would seem to be the adequate co-ordination between specialists in the different branches, but,
for certain reasons, such co-ordination is of less importance than a good understanding, and individual co-ordination between the speculative engineer who designs the work, and the working engineer, who gives the results to the world.

The Office Man Preferred Before the Outside Man. No longer does the so-called practical engineer gain the place of popular regard. The educated public, which constitutes the ruling bureaucracy, can only understand the engineer who can write and adequately manage his draftsmen and office staff. The fact that the great advances in electrical engineering and chemistry—the causes of our marvellous modern achievements, have had their origin in laboratories attached to universities and government research stations—has caused the degradation of the old so-called "practical" school of engineers. To-day the result is a half-formed profession consisting mainly of relatively narrow specialists, who have not yet learnt how to co-ordinate, and who jealously stand on the unquestioned acceptance by the powers that be of their decisions on almost every practical question.

The Medical Profession as a Precedent. While the cases are not by any means parallel, the public, whose touch with the medical profession is so much closer than with ours, will understand the simile better—if we compare our present position with that of the profession of healing, if there were no sharply-defined distinctions between doctors, surgeons, apothecaries, dressers, sisters, and nurses. The custom in last century as adopted by the Macassey type was to keep in close touch with such of his subordinates whose judgment he respected, whether surveyor, draftsman, mason, carpenter, or transport officer, and before maturing his plans to submit the outlines for a candid and full criticism. Such a system, though wanting in the co-ordination with the scientific man, carried out works which, though sound enough to win Great Britain her reputation of reliable work, is the byword to-day of the scientific critic on account of its extravagance. Instead of the first big dam, whose construction occupied me, being approved for its sound execution, when ten years later it was found by its designer, Macassey himself, to be able to be raised to contain nearly 50 per cent. greater storage, this fact was used by his jealous critics as proof of ignorant extravagance. Thus to-day the old, conscientious, practical engineer is at a discount, and his stories of the futility of the office man on the works are hardly heeded, being attributed to professional jealousy. The need for a searching enquiry into the qualifications of the "outside" or resident engineer is an important link in the chain which is seldom tested, as is attested by every coroner's inquest which finds the designer and executor
of the work guiltless. Here the essential for conviction, the observance of the rudimentary principle, "Qui fecit per alium per se fecit," is nullified by the method by which the subordinate is appointed.

In his appendices the author cites cases illustrating the need for co-operation between the "practical man" and the "theoretician." The theory of no science is ever complete, and it is when on the borderland of knowledge that the practical man comes to the aid of the theoretic. For instance, in the eighties Macassey was called in to ascertain why a pipe line was not discharging its full capacity. His experience indicated air-lock, a condition not revealed by the use of standard formulae of the mathematicians of the day, but which could arise under conditions of fluctuating demand.

Another example was that of a very skew arch bridge being erected some years ago over a creek in Victoria, where, following the theory of the subject as set forth by Professor Rankine, that the lines of stress would be skew also, failure during construction had occurred. At the same time the practical instincts of the foreman in charge of one portion of the work had saved that part from failure by advising certain precautions.

An example was also cited of how the unwarranted use of mathematical formulae without due regard to incident circumstances may lead to absurd results in the design of a reinforced concrete floor. These examples all point to the moral that co-ordination requires close sympathetic and informed collaboration to be effective. The word "co-ordination" is the great panacea of all political pundits, but in practice something far more intimate than what is understood by this word is needed, and at present it is just that essential something that is wanted to give life to mere formal co-ordination.

As an additional appendix the author donates to the library of the Institute a copy of a brochure, "Notes for Assistants and Foremen," issued by the Dunedin Drainage Board, N.Z., 1904, which he had compiled.

The Chairman said they had listened to a most interesting lecture on a subject upon which Mr. Anderson spoke from great experience. He had shown that men whose training was solely academic were not fully equipped for absolute control. The co-operation between the technical and the practical man was essential.

Mr. R. J. Bennie said that he was in thorough accord with the author's plea for co-ordination of theory and practice. Mr. Anderson, himself, had had the advantage of both the theoretical and practical training, and was one of those best fitted to form
an opinion. He thought that the paper called for the consideration not only of the training of engineers and their co-operation, but also what were the desirable limits to which standardisation should be carried.

Mr. F. C. Hall stressed the difficulty of placing young graduates fresh from technical schools or University, on account of their not possessing sufficient practical knowledge to be of much immediate use to their employers. He suggested that the position might be improved by a review of the situation.

Mr. W. E. Pyke agreed with the author and Mr. Hall, that frequently the engineer had become subservient to the community. In Australia the great body of engineers was absorbed by public bodies and government departments, where, he suggested, too many important decisions of a technical nature were made by non-technical heads, and he emphasised the necessity for the engineer, through his institutions, to prevent such encroachments, and to preserve his proper sphere.

Mr. W. R. Pollock suggested that the ideal training might appear to be a practical training first, followed by a University course.

The Chairman said the author had raised a very important question in advocating a system of providing a more practical training with the academic. He believed, in spite of the pessimism of previous speakers, that the status of the engineer would improve automatically. Even if consulting practice were diminishing, due to the advent of large corporations, the latter possessed their own highly trained technical staffs, and this did not imply that the engineer was not appreciated. The Institute could, with advantage, take up again the question of engineering education. It had been pointed out that both the technical school and the University graduate, fresh from their studies, were handicapped by a lack of practical knowledge. On the whole, he thought that the University man, finishing at the age of twenty-two, had the greater difficulty, for he could not be entrusted with responsible work around a works until he had sufficient practical experience, such as many of his less technically-trained rivals already possessed before attaining his age. He believed that the future engineers would best be trained by a course at the technical school, followed by absorption into industry at the age of eighteen, and subsequently, according to their capacity and temperament, perhaps completing a higher academic training while part-time engaged in the industry. Engineering institutions had to think of the coming generation, and should formulate a scheme to set before the public, to
be more in conformity with the present day and future necessities. This Institute had always aimed at co-operation among its members of the practical man and the academically-trained specialist.

Mr. G. G. Robert thought that the main plea of the paper was supported by the practice in the navy, where those ultimately destined to be engineer officers were first trained as executive officers, and then specialised and received their technical and practical training.

Mr. E. J. Michaelson said there was no doubt that the young man who went through the University got his training when he could grasp things more readily than the boy who left school early, and after some years in the workshop, went on to the University. He went on to cite a number of engineers who were respected technical heads of Government departments and corporations in Australia, and whose training had consisted of a workshop apprenticeship, supplemented by a technical school training.

Mr. R. J. Bennie thought they might sum up the situation thus: There were many branches of engineering. There were many grades of engineer. The community required them all, from the technical man, who specialised in higher theory, to the practical man, who specialised in some detail. Then there was the artisan. Each of these required a different training. The few who were capable of thoroughly grasping both aspects might be given the opportunity of a combined system of practical and theoretical training, as is done in some of the larger firms in Great Britain. It was too often forgotten that, in mechanical engineering particularly, a knowledge of the properties of materials was gained through the fingers of an experienced man, a knowledge not expressible by ordinary physical test figures, yet equally valuable and quite indispensible. To acquire this capacity one must have acquired his mechanical training very early. He felt that one of the advantages of this Institute was that it afforded the opportunity of bringing together all the classes of professional engineers previously mentioned, so that they were in a position to see all sides of the question.

Mr. A. C. Mitchell said that in discussing the subject of engineering training, one must not lose sight of Mr. Anderson’s plea for co-operation between the theoretical and the practical engineer.

The discussion was adjourned.
Mr. W. H. Cumming wrote as follows:—

We must all feel indebted to Mr. Anderson for opening in such an able manner a subject of extreme importance to our profession, as he has just done in his paper now under discussion. His unique experience, covering both the practical and theoretical sides of engineering, places him in a position to speak authoritatively on the subject, and I trust that an interesting and profitable discussion may result.

There can be little doubt that both the purely practical and purely theoretical engineer despise each other; for, while the practical man can point to his own experience, he considers that the theoretical man has no more than a secondhand knowledge of other folks' practical experience. That there is some justification for this attitude must be admitted when we remember that many of the formulae from which our designs spring are often resting on an empirical basis and derived from research work on the testing machine.

The extreme specialisation of engineering work to-day has made it more difficult for both types of engineer to cope with the problems they may meet in the course of their work. The man of practical experience is liable to get out of his depth when the class of work presented may be slightly different from that on which he has previously been engaged. He is apt to mistrust the theoretical man's training, and probably errs, as in the case referred to by Mr. Anderson, on the side of excessive safety.

The best way in which co-operation between types can be achieved would be to train the individual both practically and theoretically, so that one might then say that the individual had only to co-operate with himself. Undoubtedly this would present many difficulties, for individuals differ so widely that, while one may be able to envisage a job as presented in new designs and compare it readily in his mind with earlier experience, many others can only feel that the job looks right after they have checked through reams of figures, and the two types of men will accordingly drift further apart as the years go on.

The advantages to be gained by some system of giving both theoretical and practical training to young engineers should be
sufficient to make it well worth while, even though the training period might need to be extended slightly. They would be better able to understand each other’s viewpoint, and so more readily bring their varied abilities to bear on the many problems confronting engineers at all times.

The difficulty of finding employment for University graduates, mentioned by Mr. Hall, would then disappear, as they would have the practical experience to make them able to return value immediately for the wages they expected.

That it is within the bounds of practical industrialism to get such combined training is shown by the fact that a system of this type has been adopted on the north-east coast area of England—that is, the section running from the Tyne to the Tees. It may be opportune here to remind members that this area, in addition to sharing with the Clyde the position of Britain’s principal shipbuilding district, has also in it such widely diversified industries as the famous Elswick armament works of Armstrong’s, the turbine and telescope works of Sir Charles Parsons, with the great iron works of Dorman, Long & Co., as well as hundreds of smaller industrial undertakings. From this it will readily be seen that any system adopted there would have to suit a wide variety of engineering industry.

The principal firms there have adopted a system whereby those apprentices who show special aptitude are permitted to get workshop experience through the summer six months, and their technical training during the winter at the technical colleges of the various towns. In addition, the apprentices can gain increases of pay roughly up to 1/- weekly for the whole of the following year based on a scale of points for time keeping at work, school class passes, and shop work.

Those who desire to win greater honours than the diplomas of the technical colleges generally go on to Armstrong College, Newcastle-on-Tyne, the engineering school of Durham University, where degree courses in engineering subjects are taken.

That the possibility of their students desiring to go on through a University course is kept well in mind by the technical college authorities may readily be inferred from the fact that when I was attending the technical college of Sunderland the first-year day class students doing their six months at the college were expected to pass the entrance examination of London University on the conclusion of the six months. As many of you are aware, this examination is accepted by most British and many other Universities in lieu of their own entrance examination.
For men trained there on this "sandwich" system, the employers of the district are only too anxious to find positions in the engineering industry.

It may be mentioned that, as far back as 1900, in training their men for the higher positions, the Japanese Naval Dockyards were employing a similar system, though there it was by half-days, instead of half-years.

If I may be permitted to digress a little from the immediate subject of our paper, I should like to draw attention to the fact that it is by sound education, both general and technical, that the nation's ability to get quickly out of the present depression will largely depend.

It is particularly interesting to point to the case of Switzerland, whose engineering industries are examples of careful technical training overcoming the difficulties of a country without natural coal or iron deposits, and winning for her a high place among the world's engineers.

The drawing up of the English scheme mentioned above and the negotiations necessary for its acceptance by the various firms and many county and borough educational authorities over this tract of country was carried out by the North-East Coast Institution of Engineers and Shipbuilders, with whom, it may be mentioned in passing, we exchange Proceedings.

The training of the engineer is a matter of such importance that I feel it incumbent on all responsible bodies of engineers and others interested to do their best to see that our coming generation is properly catered for in this regard.

The President said he agreed in general with Mr. Cumming's views. He was not aware of the alternate six months system of training. Where he lived in England, apprentices were allowed one day per week at a technical school, and, if a satisfactory report were received from the school, the student's school fees were refunded him by his firm. He had read Mr. Anderson's paper with considerable interest. About the time when he had joined the firm of Dorman, Long & Co., in Middlesbrough, his firm wanted specialists, and, because they felt that the training of the local technical schools was too general, they had instituted a school of their own; after passing through the school the boy was apprenticed as a draftsman. At the same time, the more advanced students were given the opportunity to qualify for a University course. Also the Universities sought to place their more brilliant students with them. He had found that the boy with the secondary school education, followed by
the technical school course, was able to compete with the University man until the latter attained the age of about 26 years, when his higher training gave him the lead.

Mr. G. O. Simcock, Vice-President, said that the boy compelled to work all day and attend evening classes was very handicapped as compared with the student devoting all his time to his studies. He agreed with the President that the former had the advantage for a number of years, i.e., was more useful to his employer, for it required some years for the University graduate to feel his way from his first misplaced confidence to a sound confidence based on experience. He felt that there was much more need for practical training in academic courses, and, as indicated in the paper, more need for closer co-ordination between the practical and theoretical training in general. If the discussion resulted, as seemed probable, in the formulation of some scheme for that purpose, it would be a great service to Australia.

Mr. G. E. Gamble said that in one large British electrical company it was customary to indenture a lad for seven years, during which time he would have two years at the works, eighteen months in the drawing office, and then proceed through the various departments. At the end of seven years he had a general idea of the realities of the job, and if he cared he could then proceed to study for his B.Sc. in Engineering at the London University or the City Polytechnic.

Mr. R. J. Bennie pointed out that there were many types and grades of engineers required by the community, and comparison of their relative merits would be meaningless. Referring to University training, there was no doubt that greater contact with the practical affairs of engineering life throughout the course would be beneficial; for, although it was true that the graduate progressed rapidly after the age of thirty years, how much further might he have got if he had received a training including more of the practical manipulative part of engineering? It was necessary to distinguish also between the various branches of engineering: the civil engineer, concerned in earthworks, roads, dams, and other static structures, could acquire, by the agency of books and lectures, a vastly higher percentage of his requisite stock of knowledge, than could the mechanical engineer, intending to specialise in the design or maintenance of engines, machinery or industrial plant in general. The latter required a knowledge of the behaviour of materials that he could not acquire from books alone. He agreed that the whole subject of Mr. Anderson's paper should be taken up by a standing committee, to continuously review and revise engineering training in keeping with changing times.
Mr. J. T. Noble Anderson, in reply, said the welfare of the people at large was the point to bear in mind. The man content to earn his living at eighteen was no better than a navvy; they must have some educational standard. In his native town scholarships to the University were available for apprentices, and many eminent engineers could be mentioned whose education had been greatly assisted by those scholarships. Something like that was needed here, so that young men could start right at the bottom and have the opportunity to go right on. That would produce the best co-ordination. He had presented his paper simply in order to secure ideas leading to the better practice of the profession in the community.