The Late Professor W. C. Kernot, M.A.

Lecture to Students, 1893

The Manuscript, in the handwriting of the Late Professor W. C. Kernot, of this lecture given by him to third year Civil Engineering students at the University of Melbourne, is in the possession of Mr. L. R. East, Past President. The available evidence appears to indicate that this lecture was first given in 1893.

The present lecture constitutes the commencement of an acquaintance which will in all probability last at least two years, and during which you will receive impressions and undergo a mental discipline at my hands, the effects of which may be expected to remain during your whole professional life. Such being the case it appears to me desirable that I should formally introduce myself to you in order that you may know what I am, and what is my standpoint with reference to certain much debated questions of engineering interest. With this object I propose to briefly relate to you my personal history, in order that you may know the various experiences I have passed through, and how I have come to hold my present views, views I would add that have been violently combated by the most influential members of the engineering profession, and a large section of the engineering press.

I desire to make this narration without egotism or boastfulness. I freely admit many mistakes and much weakness on my part. I think it a matter of regret that my position was not held by someone of sturdier and less sensitive nature, better fitted than I for a career of continual conflict. However, such a one did not come forward. I have the satisfaction of knowing that I have not been the means of excluding any better man for when I first obtained my position of Engineering teacher in this University there was no other applicant.

Placed in a singularly difficult and peculiar position I have at least endeavoured to do my best, and you gentlemen are the judges to whom I submit this apology pro vita mea.

The family to which I belong is of French extraction and the name was originally spelt Carnot, and will be familiar to all students of thermodynamics. The members of the family have been in most cases medical men or dispensing chemists, and several of them have shown a decided leaning toward engineering, or mechanical intuition. I was myself born in a small provincial town in England, but came with my parents to Victoria at an early age [1], so that by education, but not by birth, I am Australian.

From earliest childhood I have had, I know not why, an extraordinary predilection for physical science and its practical applications. Experiments of all kinds, machinery, steam engines, the construction of buildings and so forth have always been my delight, and many were the attempts that I made in a crude and painful way with most inadequate appliances to construct model machines of various kinds. Some specimens of my early handiwork are in existence still.

I spent my school days under three different masters, all worthy and excellent men, two of whom still survive (1894) (G. Hanson, G. W. Brown, G. Morrison). The first of these is deserving of special note. To a large extent self-educated, he presided over a school corresponding to a comparatively small state school at present. His great idea was to teach us boys to *think*. Mere memory cram he eliminated. He taught us mathematics up to and including practical plane trigonometry and logarithms, and each made an attempt to do a little differential calculus. As I left his school before I was thirteen, and as the rest of the class differed little in age from myself, it will be seen that the work done in those early days was by no means so elementary as is often supposed, and when I say that it was done without any outside pressure from examinations, or the payment by result system, you will see that it is possible for advanced educational work to be done purely for the love of learning.

My second school master I was under for but a little while, but during that time was well drilled in higher algebra including the theorems, series and the computation of logarithms; we also evolved questions in maxima and minima by differentiation, but mechanically and without understanding the principles involved. I also studied Latin, Greek, French and German.

To my third master I owe an untold debt of gratitude, as he was the means of my entering the University, then in its infancy. This I did some months prior to my sixteenth birthday. Of my career at the University, I need say but little as its results are all duly recorded in the published class lists. I studied various subjects under four eminent professors, two of whom still survive (F. McCoy and M. H. Spring) though only one, the veteran Sir F. McCoy is now in active service. Of these men I owed most to the late Mr. P. Wilson, the first professor of mathematics in this University and the founder of the physical and engineering schools. Wilson was the senior wrangler of his year at Cambridge, and was a most excellent teacher, and a most accurate and conscientious investigator. The discipline I underwent at his hands was always laborious and sometimes painful, but as mental training was incalculably valuable. I completed the Arts and Engineering courses, the latter being little more than two years surveying partly under a lecturer and partly under Prof. Wilson himself. There was nothing analogous to the third and fourth years work as we have it at present. Then there was an ingenious and versatile gentleman (I. G. Knight) appointed as lecturer in Civil Engineering but he never gave a single lecture. However, I should be ungrateful did I fail to acknowledge his genial disposition and many acts of kindness including giving me access to a large mass of most valuable professional information contained in documents he had collected during a tour in Europe. This I studied with intense interest, and when at the end of the year he set me a comparatively easy paper and passed me with first class honours, you will I think agree that he laid me under a very deep obligation.

My University career was a happy and satisfactory period of my life—I succeeded beyond my anticipations [2], and I felt all through that I was doing good and useful work, calculated to aid me in endless ways in my future career. I left the University buoyed up with hope and perhaps a little over elated by my success and endeavoured to find a market for my services in the outside works, and now my troubles and conflicts began. I tried the foundries and engineering workshops but they were firmly convinced that nothing learnt at the University was of slightest use to them, and when I exhibited my drawings of steam engines etc. at once rather illogically concluded that because the draughtsmanship was rough my knowledge was defective. I then looked to the Government which then as now was a great employer of professional labour, but found no welcome or encouragement whatever. No

(1) 6 years.

(2) Five Firsts and one Second in 5 years.

recognition or consideration would they grant in view of University distinctions. It seemed to me then and it seems to me now both strange and cruel that the Government should largely subsidise the University and to help to attract young persons to it, and then when the said young persons have spent valuable years of time, and not inconsiderable sums of money at the University, refuse to allow them any advantage or claim over those who have done nothing of the kind. A fairly wide experience of life and public affairs has at length however caused me to cease to look for either kindness or consistency from large public bodies. The only avenue to the Govt. Service was, I found, through the Civil Service Examination, a very elementary examination requiring but little knowledge, but demanding a high degree of mechanical proficiency in spelling and simple arithmetic—an examination at which the most highly educated man might easily fail, which a comparatively uneducated person who happened to have been well drilled in spelling and ciphering would certainly pass. I passed the examination without trouble, and therefore beyond the loss of a few hours time, have no personal grievance. On that account, however, I feel myself more fully at liberty to protest against what I hold to be a wrong principle, a vicious system. It is I hold an altogether improper thing to again subject to the degradation and risk of an elementary examination persons who have completed the requirements of a lengthy and elaborate course. Here certainly should the time honoured legal maxim apply—Nemo debet vis.

After considerable delay[3] I succeeded through the aid of an influential acquaintance in obtaining a position in the Department of Mines at what would be now considered a very liberal remuneration for a beginner, and entered upon my new duties with joyfulness. I certainly thought that an honourman in physics, chemistry, geology and surveying, possessing a considerable acquaintance with the practical details of machinery would have splendid opportunities for usefulness in the Department of Mines but I had not been many days in my new office before I found that my laboriously acquired scientific qualifications were as useless as a punkah would be at the South Pole or a pair of snowshoes in the Red Sea. The circumstances were these. A mining "boom" as it would at present be called was on. Land was being taken up under Mining Lease at the various gold fields. The lessees were at liberty within wide limits to take whatever size or shape of block they fancied, and they had a remarkable predilection for complex forms. Polygons of 6, 8, 10, 15 or even 20 sides continually occurred. These blocks were then surveyed by the mining surveyors, and the plans forwarded to the Melbourne Office when they were checked by latitude and departure computation, plotted on the locality plans to guard against inadvertent encroachment upon sold land, public reserves or previous lessees, and technical descriptions with accompanying plans drawn up and appended to the legal documents that were handed to the lessees. The work was in one aspect simple and easy, requiring no more mathematical knowledge than I possessed years before I entered the University, and no other scientific knowledge whatever. On the other hand, it was to me at least almost unendurably tedious and laborious, while the penalty of allowing the slightest error to pass undetected was so excessively heavy that the mental strain of guarding against mistakes became terribly severe (at one time a £5 fine).

The work came pouring in day by day and the whole office was strained to the utmost to keep pace with it. The press and the public metaphorically kept applying the lash to the Heads of the Office for delay in issue of leases and they in turn applied the lash to their subordinates. For months together we had to work from 1 to 2 hours daily over and above the regulation office hours and every month each man's amount of work performed was scrutinized, and those below the average reprimanded. The whole state of things was one that in the eyes of a rabid Civil Service Reformer would be regarded as highly satisfactory, but from the point of view of a subordinate officer it was decidedly unpleasant, altogether too much like slavery. In fact, the expression "nigger-driving" was in common use as descriptive of it.

Accustomed as I had been at the University to variety and alternation of studies, I found 7, 8 or 9 hours a day at latitude and departure computation an almost intolerable burden. For the first hour or two I could get on fairly well, but after that a splitting headache usually supervened, my rate of progress became excessively slow, and I made endless mistakes. With me it was a question not of scientific knowledge or even technical skill but simply of physical endurance. I may add that the system adopted and enforced upon us for making these calculations was very crude and unscientific. Had I had but a little leisure, opportunity and encouragement I could easily have arranged an equally effective system involving little more than half the labour. The proof of this is that I ultimately *did* bring out such a scheme which years afterward the Department recommended in "their" printed instructions [4]. As it was, however, I had at the time no heart or strength for such work, and felt sure that any such attempt would have been looked upon as savouring of insubordination, an unpardonable sin in a Government office.

The men with and under whom I worked were comparatively uneducated persons who by long practice had acquired an extraordinary facility at computing, plotting and lettering. Socially and intellectually I could not help regarding most of them as altogether my inferiors, though I envied and in vain tried to emulate their skill and rapidity in routine work. They on the other hand did not scruple to describe me as a kind of fraud, a person of great professions but poor and unsatisfactory performance—and so we did not love each other.

I was much struck with the unwillingness or inability of my immediate superior to give me clear and intelligible instructions as to what he wanted done. Almost every direction was conveyed in curiously laconic and enigmatical language, and the simplest matters invested with an air of quite unnecessary mystery. I have since noticed a similar thing with persons of small general education elsewhere. They may know a particular subject very well themselves, but are quite devoid of the power of expressing or teaching others. They are quite unable to place themselves in the position of an intelligent person ignorant of the special matter in hand. They commonly assume that it is discreditable for another not to know what they know, but do not realize that they are subject to any criticism for not knowing what others know. This is a fault that a good all round education is the best cure for. After the most unpleasant 18 months I have ever spent, the work suddenly dropped off, and the Head of the Department showed his appreciation of my services by giving me the first notice to quit. I as the least useful man received the first dismissal, and thus ends Chapter 1, showing how the first civil engineer that the Melbourne University ever produced proved a miserable failure when practically tested in the Head Office of the Mining Department of the Colony of Victoria. Before finally leaving this portion of my narration, I might mention that the unpleasant feeling in the office was greatly intensified by the peculiar temper of the Head of the Department, who was very uncertain, wayward and occasionally tyrannical; and against whom several years afterward his officers rebelled and secured his removal from the Service. I should also say that this gentleman some years after dismissing me came to the conclusion that he had made a mistake and invited me to return. I, however, declined with thanks.

My sojourn in the Department of Mines though a painful and humiliating contrast to my University career was not without its compensating advantages. I acquired while there a much greater amount of arithmetical facility than I previously possessed, my drawing, lettering and handwriting certainly improved, I became familiar with departmental customs and routine, and also gained a knowledge of the geography of Victoria that has been of great use ever since. Further, as I said before, my salary considering the simple nature of my work was a very good one.

Through the unsolicited intervention of a gentleman held in great honour at Ormond College (Hon. I. Balfour) and for which I shall ever feel grateful, I almost immediately obtained employment in the Victorian Water Supply Office which was then actively engaged in carrying out the Coliban Geelong and Echuca Waterworks. This office was in every respect a total contrast to

(3) 1865.

(4) Trans. Inst. Surv., Vol. 1, p. 63. Instructions to Mining Surveyors prepared by C. W. Langtree Esq. no date given. Refers to Irrigation Act 1886.

the other. A pleasant friendly feeling prevailed throughout, and such of the officers as still survive are in several cases at present amongst my most intimate and esteemed friends. The pace there was much slower than in the Mines and might, I think, have been accelerated without hardship to the officers and with advantage to the Government. The Resident Engineer who was the actual head of the Melbourne Office, for we rarely saw anything of the Chief Engineer, was an amiable and well-meaning man, but hardly of sufficient calibre for his responsible position. We used in fact to use him, to take advantage of his little weaknesses to gain our own ends, and though in many cases I am satisfied that what we did was for the advantage of the department, still it was not an altogether right and healthy state of things. The first five or six months I spent in plotting longitudinal sections, a very monotonous task but good practice in line drawing, scaling and lettering. Getting tired of this I asked for some variety in my tasks, and was handed some elaborately finished drawings of ironwork and machinery connected with the reservoirs under construction of which I was to compute the weights. While doing so my attention was caught by the, as appeared to me, peculiar proportions of the mechanism for actuating the large valve through which water is allowed to escape from the reservoir supplying Castlemaine. Applying a mathematical investigation entitled "the screw with friction" that I had learnt from Prof. Wilson, I came to the conclusion that that machinery was altogether inadequate to open or close that valve. And now see what an awkward position I had got into by meddling with things that did not concern me. If I said nothing and the machinery failed, I should blame myself for my silence. On the other hand, if I spoke should I not be rebuked as presumptions and damage my prospects of advancement—a very delicate and important consideration to a Govt. official. And what if after all I had made some mistake and my discovery was what is vulgarly called a "mare's nest". In that case I should become a laughing stock to the whole office. To any commonsense person the idea of a mere novice finding a fatal error in the careful and deliberate work of engineers of 20 or 30 years experience would be absurd—simply laughable. Well, I carefully checked my calculations to make sure that there was no arithmetical slip, and could find no escape from the conclusion that either the system of statistics taught at this University was a cunningly devised fable or that these most experienced and skilful engineers had made a fatal mistake. So with much trepidation, and expecting an angry rebuke for my presumption, I ventured mildly to suggest to the Resident Engineer that the machinery as designed could not possibly work. To my utter astonishment he evinced neither surprise nor anger but in the quietest and most amiable tone said "Well, suppose you design a machine that will answer". Of course I got to work at once. My machine was designed and made, was perfectly successful and is in use to the best of my knowledge to this day. Emboldened by this success, I continued my critical investigations and detected and remedied quite a number of similar errors in important mechanical details of the schemes, the other officers and resident engineer making no objection or attempting to justify the designs for which they were responsible, and thus I saved a number [5] of costly and discreditable failures that otherwise must have ensued. But how, you will ask, could respectable and experienced engineers realising the responsibility of their position commit such errors? This question I cannot answer; the matter is and always has been a profound mystery to me. But the facts are undeniable. These engineers were experienced careful men taking an interest in their work and honestly desirous of its success. They were well acquainted with all the routine of engineering business, with the practical processes of manufacture. They knew a vast deal more than I did about casting, forging, turning and planing iron—about the usual proportions of screws, bolts, keys, nuts and other practical details, but as far as I could discern were perfectly unconscious even of the existence of physical laws. Their knowledge was entirely of isolated facts—generalizations—principles they did not grasp. Things that were always under their notice they knew well, but other things requiring a little search, study or reflection they never dreamt of. In one direction they could see clearly enough—in another they were afflicted with the most absolute mental blindness. As long as there was plenty of money and none of the larger works were sufficiently complete to be subject to a practical test of their soundness and efficiency, all went merrily enough, but I, inexperienced as I was, could not help having some apprehensions of coming disaster. At last the crisis came. Four large reservoirs (Malmsbury, Stoney Creek, Expedition Pass, Spring Gully) were completed and began to fill simultaneously, and before long from one after the other came most alarming reports of serious leakage. Desperate and objectionable expedients [6] were adopted to stop the leaks, with but partial success. The Great Malmsbury Reservoir had to be emptied hurriedly to avoid utter destruction and the embankment at Stoney Creek on the Geelong scheme sank several feet. The newspapers as usual did endless mischief by alarming and confusing the public mind with sensational statements, and the Government, perplexed beyond measure, got rid of the Chief Engineer, and sent to the Indian Government for the services of their most experienced hydraulic engineer. The genial and kindly Resident Engineer died of vexation and worry.

In due course the great Indian expert arrived, examined the works, and sent in an elaborate report. I was directed to place myself under his instructions, and he shortly asked me to check a number of his calculations of the flow of water in various pipes and channels. On going through them I found them to be hopelessly in error, displaying a total ignorance of the most elementary principles of the subject, and ignorance which would be utterly fatal to a University student in any ordinary examination. Here again I was in a most delicate and difficult position. Did one of you gentlemen make such mistakes, I should tell you in very plain terms that you were a disgrace to the University. But I could not so deal with a man many years my senior and receiving eight times my salary. Well, I wrote out my calculations in full detail explaining carefully every step, as I would to a person learning the subject for the first time and gave it to him and a few days afterwards he told me that he had abandoned his own calculations and adopted mine. But a few days later he made a further set of calculations, and repeated the old error in a most glaring form, showing that he had completely failed to understand my calculations, although he had adopted my results. This time he was obstinate and refused to alter his figures, and it stands to this day in his published report, the most startling exhibition of ignorance of first principles that ever came under my notice. He left the Colony highly remunerated and publicly thanked for his distinguished services, and having nominated a new Chief Engineer to carry out his recommendations. As the new Chief could not arrive from England for some months, the Water Supply Office was disbanded and now I was the last, not the first as before, to be dispensed with. So it looked as if I was appreciated better than at the Mines.

I next obtained employment at the Railway Department. This was a much larger organization than either of those I had previously been connected with. There were many grades of officials, and a complete division of function. A subordinate officer like myself rarely came into contact with those in the highest rank, and we might be months or years in any one branch of the office and yet know little or nothing of what went on in other branches.

At the head of this great organisation as Engineer-in-Chief was a gentleman of very marked individuality. He was a strong man in every way, firm and yet courteous, thoroughly reliable as to anything he promised, and capable of holding his own against any pressure that might be brought to bear upon him. As the administrative head of a great office expending millions of money employing an immense number of men, and having business transactions with the outside public of the very first magnitude he was admirable. Immediately under him were three other men like minded with himself but of less strength of character, under these came yet another grade and under these last I was placed, my work being of the simplest and most mechanically routine kind. The most notable circumstance that impressed itself in my memory was the extraordinary antipathy that the Engineer-in-Chief showed to

(5) Back Creek Syphon. Valve gear at Barkers Ck. Reservoir. Lovely Banks. Malmsbury Tower.

(6) Horsedung at Stoney Creek, etc.

anything in the shape of University education for Engineers. Both by word and by action did he evince his intense opposition to it. When Professor Wilson consulted him as to the establishment of an Engineering School at the University he did all he could to dissuade him urging that it is useless and unnecessary—this Wilson himself told me repeatedly—and when I, the first University Engineer, entered his office he never missed an opportunity of impressing upon me the uselessness and undesirability of University training for engineers—for lawyers and doctors and for persons of means and leisure the University was he said all very well —but it was far better for the young engineer to go straight from the school to the office or workshop. He would then be far more use than if he wasted 3 or 4 intervening years at the University. Boys straight from school could be asked to do work of a mechanical or even menial character, that we would hesitate to employ an educated gentleman upon, and furthermore said schoolboys would not think they knew more than their superiors, which the University man would be very apt to do on the grounds of his useless theoretical training. There were no real advantages, and many disadvantages, he insisted, in University education for engineers.

Holding these views he did his best to make me give up the engineering lectureship at the University which I had then recently obtained. He also positively refused to give me a few surplus lithographs of no value to his department which I desired to illustrate my lectures with, and after I had been about 6 months in the office he one day sent for me and told me he had arranged for me to return to the Victorian Water Supply, now being reorganised under the new Chief Engineer, saying " Your scientific knowledge Mr. Kernot is of no use to us but possibly may be of some value to the Water Supply ". And so like the proverbial bad penny I returned to the place whence I came—and the Engineer-in-Chief of Railways was evidently most thankful to get rid of me. What he said of me behind my back of course I don't know, but should be very much surprised if something of this sort did not pass between him and his second in command—" That young Kernot is a dangerous man in the office; wants to know too much, asks awkward questions, does not confine himself to his own business—thinks because he has learnt a little theoretical science at the University he knows more about engineering than the most experienced engineers in the Colony. His presence was bound to injure the tone and discipline of the department. Let us be very thankful we have got rid of him without fuss or unpleasantness ". I am not a little proud of having been in even a most insignificant way a martyr for truth and freedom of enquiry, and of being able to claim brotherhood, though at an infinite distance, with him who drank the hemlock and him who said—" E pur si muove ".

I spent about 3 years in the Water Supply [7], very comfortably. The new Chief Engineer was a far better man than his predecessors, and was also a courteous gentleman. He is still living and we are on very friendly terms. But while I was well enough treated I felt I was wasting my time. No new works were in progress or contemplated. I was learning nothing, being occupied with the merest routine clerical work. Meanwhile my University classes increased, and my remuneration also increased as I was partly paid by the students fees. It became very difficult to fulfil my official and also my University duties and so in July, 1875, just ten years after I first entered the Mining Dept., I voluntarily resigned my position in the Government Service and left the scene of my labours without regret. It was not the place for me or for any man of enterprise and originality—I should call it the paradise of respectable mediocrity, the place for decent honest men of no special ability or ambition. As for its effect on those who enter it, you may read the works of Herbert Spencer with whose views I heartily agree. In no department that I passed through was scientific knowledge really appreciated or encouraged. The little scientific work I occasionally had the opportunity of doing was never recognised or rewarded. I ranked from first to last simply as a draughtsman and was in no way distinguished from those whose only qualifications were the mere handicraft skill in handling drawing instruments, and that knowledge of routine that comes with a few years ordinary office work. At the University as a student I was very happy and successful, and since I left the Government I have on the whole been very prosperous, but during my ten years [8] with the Government I was always like a plant placed in an arid soil and an uncongenial climate which existed, but did not grow and bore but little fruit.

Relieved of the burden of office work I largely developed my University teaching, and also spent some time in private consulting practice. I did a certain amount of work testing and reporting on the performance of large steam engines and boilers, and gained much useful information. About this time I had a visit from Mr. Louis Brennan, the famous torpedo inventor. He had devised his torpedo and made a small and crude model, and wanted me to say how it would work if made on a larger scale. I made all the calculations and advised and assisted him in the construction of two torpedoes respectively 9 and 25 ft. long. These bore out my calculations very well, and Brennan ultimately took the larger one to England when, after several years further experimenting, he succeeded in complying with the stringent requirements of the War Office, and sold his invention to the British Government for the magnificent sum of £110,000. I am happy to say that in the day of his success and prosperity Brennan did not omit to remember and reward his old friend who years before had without any payment whatever spent many anxious and laborious hours assisting and encouraging him in the early stages of his enterprise.

In 1878 I visited Europe, inspected a number of Engineering Schools and manufacturing establishments and formed the acquaintance of several eminent scientific and engineering authorities, notably Clerk Maxwell and Cawthorn Maurice. In 1880 I had the honour of being made Chairman of two and a member of a third jury at our first International Exhibition, our departments being machinery and scientific instruments. I spent all the time I could spare from the University for several months on the work of adjudication and gained a vast deal of valuable information while so doing. I was, however, so dissatisfied with the way the juries were treated by the Exhibition Commissioners, and so convinced of the impossibility of arriving at thoroughly reliable and satisfactory awards under existing conditions that, though strongly urged by influential friends, I absolutely refused to take any part in the judging at the Second or Centennial International Exhibition of 1888.

In 1884 I was asked by the New South Wales Government to join a Royal Commission to enquire into the security of a number of large railway bridges—I worked at this investigation at intervals for two years. Then I became intimate with my good friend and co-examiner Prof. Warren of Sydney University. Together we spent much time examining, testing and measuring the bridges and calculating their strength. It was an interesting and instructive investigation and the results are embodied in an elaborate report to be found in the University and College libraries.

I also have had the honour of advising and reporting upon railway bridges for the Tasmanian and South Australian Railway Departments.

In 1891 I again visited Europe and for the first time extended my travels to America, examining carefully many engineering schools and colleges, with the object on my return of building a suitable engineering school in the University grounds in which the best features of all those I had seen should be combined. But alas before I returned the great financial collapse took place, and not a penny was to be had for the purpose, and so today [9], gentlemen, you as well as I are under the most serious disabilities owing to the utterly inadequate accommodation available for this large and growing branch of the University. When the new Engineering School will be built I cannot tell, but until it is we must get on as well as we can in these very cramped and insufficient apartments. I deplore it but see not what to do to remedy matters.

Toward the end of 1892 I was asked by the Premier to act as Chairman of the Board of Enquiry into the management of the Locomotive and Rolling Stock Branch of the Victorian Railways. This enquiry involved the reviewing of the expenditure of the best part of a million of money, and gave me an insight into many

(7) 1872-1875.

(8) 1865-1875.
(9) Probably 1893.

matters of detail about which I had long desired further information. Amongst other things I discovered that the designers of our locomotives had, through want of appreciation of the principles of dynamics, failed in a large number of instances to balance the engines properly. I then proposed to the Department a method of balancing the engines which will make them run more smoothly, consume less fuel, last longer and do less damage to the lines they travel over—and this reform I hope shortly to see carried into effect.

In the year 1882, in company with the Hon. Ian Service and the late Mr. Primi, one of the most brilliant students the University has produced and my first pupil here, I was instrumental in introducing electric light into Melbourne. Mr. Service has long ago ceased to interest himself in the matter, and Mr. Primi was accidentally killed by a fall from his horse 12 years ago. I, however, remain and am now the chairman of the largest electrical enterprise in Australia. The work has been exceedingly interesting though often very anxious and harassing—I shall have an opportunity I hope before very long of introducing you to our works.

Here then is my history up to date—and I have no other desire but to go on in the same way continuing to teach my classes at the University and doing what I can outside to render engineering practice most intelligent and scientific. And when in course of time failing powers render me unable to keep pace with the requirements of my position I trust I shall have sufficient good sense to retire, and allow a younger and more vigorous man to carry on the work which I have originated.

It was only with much hesitation and after long consideration that I decided to intrude upon you this account of my career. I feared that I might be accused of egotism and bad taste in occupying so much of your valuable time with my private affairs. But on the other hand important considerations suggested themselves in favour of such action.

First—it is impossible in the course of lecturing to avoid making occasional references to my own experiences, and as such disjointed references may not be always very intelligible it appeared prudent and reasonable to give you the whole consecutive story at the outset carefully and deliberately compiled, and expressed in the clearest language at my command. I therefore, laying aside other work, sat down quietly and calmly, and devoted a portion of a long vacation to writing this systematic account of myself and my doings.

Second—knowing that I have been and am still an object of intense dislike to a certain section of the engineering profession, and that I am constantly described as a busybody, an interfering and meddlesome person, a mere theorist with no practical knowledge of engineering whatever and so forth, and considering that you may not improbably meet with some of my critics and opponents from time to time, it appeared a good thing to supply you at the outset with a carefully prepared statement of my antecedents and qualifications so that you could at once and positively refute these prejudiced and untruthful statements if they happened to be made in your presence.

Third—remembering that you are about to commence the battle of life, that your troubles and conflicts are yet to come, it seemed that the adventures and experiences of one who had already undergone the fatigues of the journey, and the pressure of the conflict, and especially when that one was the pioneer, the first man that the University sent out to attack single handed the fortress of professional ignorance and prejudice, could not fail to be of sufficient interest and value to you to justify the expenditure of an hour on their narration; that from his difficulties and troubles you might gain useful information to guide and encourage you when you yourselves begin to feel the stress of battle.

These considerations therefore constitute my justification in taking a somewhat unusual course for a University teacher.

I now desire to bring under your notice in a more detailed way some of the many controversies in which I have been involved, controversies arising from the desire on my part to apply the scientific principles and logical methods I had learned at the University to the problems of engineering practice, a course which brought me into direct collision with a large and influential section of the profession, who refused to recognise or admit the truth and validity of the principles and methods, alleging that they possessed another guide of a far more reliable character, which they designated practical experience, mechanical instinct, trained judgment, etc.

The first of these controversies was with the railway engineers about the design of bridges. It will be remembered that the gentleman then occupying the distinguished and responsible position of Engineer-in-Chief of Railways (the most important professional position in the Colony) never lost an opportunity of impressing upon me, when a junior draughtsman in his office, the uselessness of University training, maintaining that his subordinates were good practical men, fully capable without such training of executing works that should be both safe and economical. This statement naturally led me to avail myself of every opportunity to examine, measure and criticise such of their works as were accessible in order to see how far the forms and proportions adopted by their so-called practical men corresponded with those that I arrived at by scientific means. Of their works the costliest and most important were the bridges, and these also were the ones, the failure of which would lead to most appalling accidents and upon the design of which therefore the greatest care and skill would naturally be expended. Some [10] of their structures I found to be excessively and uselessly strong and massive, representing therefore a culpable waste of money. Others [11] my calculations showed to be alarmingly weak, and quite devoid of that judicious margin of strength which all scientific authorities agree in recommending—and in some cases one and the same structure would present in various parts the opposite errors of undue massiveness and perilous slightness. About the time of my six months sojourn in the Department a structure [12] was designed with great care and deliberation by one of the most experienced draughtsmen and checked and approved by the Engineer-in-Chief himself, which presented this peculiarity in a marked degree. It was not so important and costly a work as many others—still it represented several hundred pounds of money and its failure would probably have been accompanied by loss of life. Some parts of this structure which was a bridge whereby foot passengers crossed over several lines of railway were four times as strong, while others equally vital were barely half as strong as my calculations required. The structure being of comparatively simple character it appeared possible to make models of it as it was and as it should be and by loading and breaking them down, to determine definitely whether it was I or the railway engineers that was right. After considerable delay due to the difficulty of obtaining suitable material, the models were made, loaded and broken. They were identical in size and so similar in appearance that had the one bridge been replaced by the other not one person in twenty would have noticed the difference. Nevertheless my model contained rather less iron, owing to its greater simplicity requiring less than half the time to make, and carried 771 lb. while the other carried only 208. This result was most satisfactory and entirely removed from my mind a haunting suspicion that had caused an occasional uneasiness, that there might be some conditions unknown to me, but known to the railway engineers modifying or reversing the results of my calculation. These experiments were published and excited a good deal of comment and some most extraordinary criticism. The first objection taken was simply astounding. It was that I had been guilty of a breach of etiquette, an act of great discourtesy and unkindness. The author of this strange view, an engineer of large experience in bridge work, plainly thought that the public safety and the proper expenditure of the public funds were matters of no moment in comparison with the feelings of a number of shamefully incompetent engineers. This was followed by some sarcastic references to "toy models" the authors of which had not the honesty or manliness to accept a challenge I then made to repeat the experiments the full size of the bridge paying all the cost myself if proved wrong provided my opponents paid if I came out right.

(10) 15-ft. strutted opes Ballarat and Ararat Rly.

(11) Moorabool viaduct.

(12) Spencer St. Goods Station Footbridge.

I also pointed out a way in which at an expense of a very few pounds the strength of the bridge might be doubled but no pressure could induce the departmental engineers to adopt my suggestion, though they went to ludicrous extremes in the next bridge they built in their endeavour to avoid the errors I had exposed.

My attention was next directed to the great viaduct over the River Moorabool near Geelong over which the Geelong and Ballarat Railway passes. This is the largest and costliest bridge in the Colony, and the appreciation it was held in by the Railway Department is evidenced by its being, though placed in a secluded site, where few people are likely to see it, adorned by much costly and elaborate ornamental work cut in solid bluestone. On analysing it in detail I discovered serious errors in the proportion of the parts, and a most unscientific system of jointing, which, taken together, robbed the structure of about half the strength that it might in view of its cost and the quantity of material it contained have possessed. In fact, though containing 25 per cent more metal than would be necessary for a scientific bridge its strength was fully 30 per cent below what all scientific bridge engineers now consider desirable. I reported these conclusions to the Department, and though the older officers were very loath to believe that there could be anything wrong with such a marvel of engineering skill, yet through the services of younger and better educated men who were gradually acquiring influence in the office, my statements were not scouted and a series of experiments were made which as far as they went bore out my allegations fully. In spite of this there was an extraordinary reluctance evinced to adopt the measures that I advocated as necessary to ensure perfect safety. Every plea that could be thought of in way of extenuation was urged. It was maintained (which has subsequently been proved incorrect) that the material and workmanship was of such unusual excellence that the ordinary margin of safety against contingencies might be dispensed with. However, at last after years of pressure I am happy to say that I have accomplished my object, and within the last three months the Moorabool viaduct has been altered as recommended by me years ago from a double to a single line bridge, which was all it was ever really fit for, despite its immense cost, and the large amount of iron it contains. And so a most serious danger to the travelling public has been removed.

At a period rather earlier than my first attack on the Moorabool viaduct, a bridge (Victoria St. Bridge) was needed across the Yarra at a peculiarly difficult site, and designs were invited by the local authorities, the cost being limited to an amount much below what previous bridges had involved. To my great surprise and pleasure the choice fell upon a very original and ingenious design by two young gentlemen who had only just completed their University course. Though in no way directly suggested or inspired by me, the design was fully in accord with my teaching and showed that its authors had made the best possible use of my instructions, and when as an extra security I was asked to check the calculations of the sizes of the various parts and guarantee the security of the structure, I did so with confidence and pleasure. The bridge was built under the supervision of the local Engineer, and he unfortunately introduced a modification in the way the earthen embankments at each end of the bridge were supported. This proved a failure and portions of the embankments slipped away. The bridge itself was perfectly uninjured but a gap of some 5 yards at each end intervened between it and the road, and effectually stopped the traffic. Things being in this state the local council asked one of the most experienced of the railway engineers to report upon it, and he not only concerned himself with the embankments that had failed, but went out of his way to condemn the bridge which showed no sign of weakness whatever as liable to overturn under wind and flood pressure, supporting his contention by a fragment of a calculation, which if properly completed and applied would have proved the bridge to possess a very much larger margin of stability than scores of other structures about which no one had the slightest apprehension. The designers of the structure and I myself endeavoured to explain matters to him but without avail. He was utterly impervious to either statics or logic. Roused by our clamour the local council called in a second engineer, but he was if possible more ignorant and obstinate than the first and, wisely avoiding giving any reasons whatever, he concurred in the condemnation.

It was impossible to do any more and so the first really satisfactory and scientific bridge in the locality had to be abandoned to the tender mercies of these most unscientific men. Hundreds of pounds were spent in adding huge plates and bars of iron in places where it was perfectly inconceivable that they could be of any real use, while the gaps in the embankments, after being first unnecessarily enlarged, were spanned by extensions of the bridge in which erroneous proportioning of parts and needlessly complicated construction were prominent. The structure was completed and opened, it being alleged that the defects and weakness were quite cured. Taking an early opportunity of carefully examining and measuring the new work, I found in one of the extensions several points of serious weakness where the metal would be as heavily stressed by the passage of an 8-ton waggon, as the original bridge would be by a 15-ton steam road roller—the test load for which it was designed. I wrote calling attention to these defects, but was met by direct insult from the local body and the engineer who carried out the alterations. However, the matter reached the ears of the officers of the Public Works Department which had supplied a portion of the money, and they, finding my contention correct, compelled the recalcitrant local people to make alterations which partially but not wholly removed the weakness. This is the correct account in a condensed form of the first conflict which raged about the well known, but little understood, Victoria St. Bridge. A second conflict of similar but less acrimonious character and involving a similar alteration at my instance of the reconstructed work, took place when the tramway engineers added 16 ft. to the width of the bridge several years later.

The Victoria St. Bridge, originally carefully and scientifically designed has thus become a perfect museum of interesting and instructive errors, and a most striking illustration of the endless mischief resulting from the entrusting of scientific problems to the hands of persons of no scientific training.

The last controversy with the railway engineers that I shall call to your attention was very speedily settled. Although I had been some months in the Department, and had made myself familiar with the construction of their bridges and other works, it happened that the specification of a large bridge, prescribing the tests with which the iron was expected to comply, had never come under my notice. At last, however, by pure accident I came into possession of a printed copy of the specification of one of our very largest iron bridges, a bridge that had been designed and executed under the immediate supervision of the same engineer as first condemned Victoria St. Bridge. This specification I found to be in more than one way a most remarkable and interesting document. But the gem of the whole thing was the test for the quality of the iron. This was given in great detail, and was insisted upon in the most exacting way, all material that failed to comply with it being rejected without appeal. This test was of such a peculiar nature that I have never seen or heard of any iron that would comply with it (and in saying this I speak from a very large experience in testing iron and other materials) and further the iron which of all that I have tested approaches most nearly to its requirements is the worst, the most utterly unsuitable of all I have ever seen for use in any structure upon which human life depends. I called attention to this test by asking two very simple questions in a letter to the Journal "Engineering". These questions the Editor did not answer, but the journal being read by the railway engineers woke them up out of their fools' paradise, and caused them to enquire into the matter. They then discovered that the specification they had used for a large number of important bridges absolutely forbade the use of any good iron whatever and that if there was any suitable material in the structures it was in direct opposition to the clearly expressed test. This caused great consternation, and an immediate reform as regards tests of iron. Lest you should be so alarmed as to be prevented from travelling by railway any more let me tell you that I have good reason to believe that the contractors have generally of their own accord used iron of fair average quality in direct defiance of the specification, and that the engineers have entirely neglected to take the trouble to ascertain whether the iron

was in accord with the specification or not—which is creditable to the contractors, but infinitely discreditable to the engineers.

In concluding the account of my most notable disputes with the Railway Department, it is only fair and right to state that the men with whom I found myself most constantly in collision have during the last few years been all removed by death or resignation, and that there has been an infusion of new blood, in the form of well trained men from our own and other Universities. A total change of front has thus taken place, and the recent work of the railway engineers is on the whole sound and intelligent, while the bad and unscientific work done during past years of ignorance and darkness is being quietly and gradually strengthened or replaced by new and satisfactory work, a process which now and then excites criticism and complaint from outsiders who do not understand the significance of what is being done.

Another controversy in which I have been engaged and one which has the advantage of being on record in a conveniently accessible form took place with a certain section of the professional press. Current engineering literature has never realized to any adequate degree the importance of scientific knowledge and the grave evils consequent upon its absence, and one journal published in London has set itself deliberately to disparage scientific training on every possible occasion. All the errors and failures according to it are due to too much theory and the absence of that instinctive appreciation of fitness that comes with long practical experience. Not long since a bridge of no special consequence collapsed harmlessly in Germany, and at once the readers of the journal mentioned were treated to a long diatribe as to the misdeeds and general unreliability of the "over-educated unpractical continental engineer". But the most glaring and incredible exhibitions of ignorance, even when eventuating in appalling disasters and terrific loss of life have failed to draw the smallest criticism upon the "under-educated highly practical" British engineer. No—he like Kings of old can do no wrong. A few years since this precious journal brought out a leading article in which scientific knowledge was compared to *crutches*, and the scientific engineer to a *cripple* who even with his crutches cannot get along nearly as well as the man who has sound limbs and needs no crutches, which latter simile was explained as meaning that idol of this journal, "the experienced practical man". Incensed by this outrageously misleading representation I attacked the journal through its correspondence columns alleging that engineering practice teems with examples of serious errors due to the want of scientific knowledge on the part of the most esteemed and experienced practical engineers. Challenged to submit an instance I forwarded a carefully prepared drawing of the footbridge previously mentioned of which I had tested a model with such striking results. The Editor suppressed the drawing and in lieu of it gave a deliberately falsified description followed by a most discourteous comment. Of course I gave him a rather bad time in my next letter, and followed the matter up by other examples which after my rebuke he put in but without comment. However, as far as he was concerned my time was wasted. After a short interval he was again warning his readers about the danger of science and insisting upon the reliability of practical experience. Still I am not sorry that I wrote the letters for the correspondence will enable you to see for yourselves what a tremendous power prejudice has over the human mind, rendering it impervious to the most striking and undeniable facts. It will also show, what has been infinitely painful to me during so many of these conflicts, to what depths of meanness and dishonesty men will descend rather than abandon a cherished delusion or accept an unpalatable truth. Another conflict which as yet has not assumed an acute form but which looms largely in the future, is that between the teaching institutions and the engineering societies as to what constitutes a proper professional qualification.

Of these societies the one that holds by far the highest position and exercises the most overwhelming influence, is the Institution of Civil Engineers, whose headquarters are at Great George Street, Westminster, London. This is the oldest, wealthiest and most influential of such organisations in the British dominions. It has comprised in its membership the great majority of the most famous British engineers, it publishes voluminous transactions containing papers of great value and interest, and does much admirable work of a social and benevolent character. But the difficulty about it is thus that its membership, though highly select and greatly esteemed as a guarantee of competency, is based on a purely experience qualification and is often conferred on persons of no scientific training whatever. In the conflicts previously referred to, my opponents have almost always been members of this great Institution, and in two notable cases men have been welcomed to its highest grade without passing through the lower stages who immediately before had published reports displaying the greatest ignorance of elementary statics. I appealed some years since to the Council of this body to aid me in exposing some unscientific and dangerous work perpetrated by their members—but the reply was that it was "contrary to their rules and practice to entertain any such question". After this you will not be surprised to hear that one of the most unscientific constructions that I have experimented with (Model C) was designed by a *President* of this Society. How and in what way the change is to be made I don't clearly see, but certainly it is high time that what is commonly called experience, and which a very eminent scientist has defined as "doing a thing wrong a great many times and thinking you have done it right" should not by itself and quite apart from all real scientific training be regarded as a sufficient qualification for a profession to which is entrusted the spending of millions of money and the construction of works upon which the lives of the public often depend.

Another difficult question is as to the attitude of the Victorian and other Governments toward the University engineer. Unlike England and America where engineering is almost entirely in the hands of private persons, in Victoria the experiment has been tried of the Government owning and constructing railways, bridges, roads, waterworks, harbour works etc. As to the desirability of this from the point of view of political economy it is not my business to speak. What at present interests me is the fact that the great bulk of surveying and engineering work in this Colony is dominated and controlled by the Departments of the Government service, and these departments have established systems of training and testing engineers, that stand in a peculiar and not always satisfactory relation to the University. That the Govt. departments should so act is of course only natural and reasonable from their point of view. Nevertheless what they have done often constitutes an impediment and discouragement to what *we* consider the properly trained engineer. The peculiarities of the Government system are: 1. That there is no direct and systematic teaching. The student simply learns by a process of picking up while engaged in very subordinate and routine work, aided possibly by a little private study or the services of a coach. 2. The examinations which are as a rule very strict are almost entirely practical. There is no adequate provision for instruction or examination in the scientific branches that underlie professional work.

Hydrology Symposium

Melbourne, August, 1965

The Institution of Engineers, Australia, through its Technical Committee on Hydrology, is holding the 1965 Hydrology Symposium at the University of Melbourne on 23rd and 24th August, 1965.

In addition to the Technical Sessions at which the preprinted papers will be discussed, there will be open sessions for informal discussions on topics of current interest. The programme will include conducted inspections of the weather radar equipment at the University of Melbourne, and an informal buffet dinner on Monday, 23rd August.

The Symposium is open to all interested persons and further information may be obtained from the Secretary of The Institution of Engineers, Australia, Science House, 157 Gloucester Street, Sydney. The Symposium Bulletin, with programme and registration form, was included as a supplement to the Apr.-May, 1965, issue of THE JOURNAL.