A RESEARCH AND INVESTIGATION SECTION FOR THE PUBLIC WORKS DEPARTMENT.

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Introduction.

The idea of proposing the formation of a Research and Investigation Section in the Public Works Department was inspired by an informal conversation with Messrs. Ward and Ashford at Marala shortly before the former left for Siam, and was developed in subsequent discussions with members of this Congress, and others. The general result showed that it had the sympathy of officers of all grades, and that there was a growing body of opinion in its favour.

This, together with the intimation that the Congress Committee was prepared to accept a paper on the subject, decided the author to articulate what he thought was generally felt to be a need in the Department.

Need of an investigation section

This need has come about gradually, and in our profession, as in all others, modern progress has outrun rule-of-thumb methods, and it is essential to adopt scientific methods, if we are to keep abreast of the times.

Every business concern must have its thinking section, and thinking takes time as well as talent, as the private history of such men as Farrant and Kennedy, who thought in spite of official opposition, would tell, and although we come across men with talent, it is seldom that we meet one with spare time. The quantity of work, which is required nowadays of a Public Works engineer, admits of little more than keeping things going, and allows little time for reflection, and thinking out problems in detail.

A plethora of routine work and an overgrowth of aggravatingly superfluous accounts work robs the engineer of the leisure which he would willingly devote to professional study. It behoves us therefore to deliberately set apart men for the special object of thinking—departmental thinking—and for the investigation of special subjects by original research, and calling for information from all available sources.

Type of men required.

Even if only from the point of view of economy, it appears advisable to make use of the special talents of such men as Kennedy, Farrant, Bellasis, Bligh, and Garrett (of another province), whose light, but for its very intensity, would have remained hidden under the bushel of our present system of "General Post." It was either Prof. Kennedy of Westminster, or Sir Benjamin Baker—both talented engineers—who said, "Buy your mathematician," which is a terse tribute to the value of the specialist in a complete organization.

For an investigation section such as the author contemplates, the following types of men would be required :—

(*a*) Patient investigators of existing data.
(*b*) Original research workers.
(*c*) Practical mathematicians.

Work to be undertaken.

The work to be undertaken would, broadly speaking, be as follows:—

1. To carry out special experiments and investigations under the direction of the Chief Engineer.

2. To collect particulars of any local experiments made for a special purpose, and to put them into useful form.

3. To obtain existing statistics, &c., and collate them with regard to special subjects.

4. To initiate the carrying out of experiments, and the collection of information on points of special interest, professional or economic, with reference to new methods of work.

5. To undertake the testing of materials on scientific and departmentally standardized lines.

6. To undertake the analysis of materials and of raw material, for use in the manufacture of construction materials.

7. To write the Revenue Report, in collaboration with Superintending Engineers.

8. To write technical papers, and also treatises similar to the works of Bellasis and Bligh.

9. To formulate tables and diagrams, such as those of Kennedy, Bellasis, Higham, Garrett, and others.

10. To form a library, on the lines of the Imperial Library, Calcutta, obtaining the latest books of all nations bearing on engineering problems.

11. To produce a Quarterly Journal embodying the more generally interesting results arrived at, and including matter both from within the Department and from outside sources, at the same time giving full opportunities for discussion by correspondence.

Detailed Proposals.

In amplification of the foregoing points the following notes are put forward :—

Items 1 to 3.—Among the problems to be dealt with under these terms are hydraulic problems, such as :

(*a*) Erosion and alluviation of channels and rivers,
(*b*) Effect of weirs on rivers.
(*c*) Application of knowledge available from the annual river surveys and annual reports of all headworks.
(*d*) Regulation and training of rivers at headworks.
(*e*) Hydraulic gradient and sub-soil hydraulics.
(*f*) Rainfall, run-off, and discharge of catchments.
(*g*) Modules.
(*h*) Silt problems.
(*i*) Absorption and evaporation losses.
(*j*) Impervious lining of channels.

For the majority of the above subjects, there is a mass of information existing in official files, which nobody has the time, and few the talent, to put into useful form, not only as a record, but as a foundation upon which to build future procedure and design.

Taking the first four named, the headworks divisions alone have years and years of information and matter stored up, in the form of gauge-readings, discharges, annual river surveys, and annual river reports, &c., which would provide material for a systematic study of the Punjab rivers upon which an expert could spend some years, converting what is now merely of local interest into valuable general information, and building up some theories to assist our somewhat hazy knowledge of the science of river control.

The hydraulic-gradient problem (concerning which the Chief Engineer of the Irrigation Branch stated in this Congress as recently as last year, that very little is known about the subject) has been dealt with by individual engineers—Gordon and others - spasmodically, and was only recently put into some sort of working form by Bligh. Indeed, two of the latest and most

important works in the Punjab appear to have been designed by some of our best men without a full appreciation of this problem, with the result that subsequent additions and alterations became necessary, which can never be so satisfactory as if the works had been correctly designed at the outset.

The question of run-off and discharge from catchments is so little understood in the Punjab, that it is not possible to calculate with any certainty the discharge to be expected from a catchment, over which the rainfall has been recorded ; and at least one of our leading engineers characterized the results observed by local officers as "impossible," because they did not tally with his preconceived notions of what "ought to be."

Modules are at present the subject of much difference of opinion and prejudice, whereas a systematic investigation of the whole question would probably result in a satisfactory solution of the problem. In this, as in other cases, the results are often clouded from want of a clear statement of the problem ; *e. g.* with a module, do we aim at a fixed discharge with varying head between certain limits, or a proportionately varying discharge with varying heads for all gauges.

The silt question, both in respect of irrigation channels and of rivers, has been attacked by various men, amongst whom the name of Kennedy stands out victorious against apathy and opposition, but even now we have no accepted satisfactory means of measuring in a simple manner the quantity of silt passing through a head regulator during a flood.

Evaporation, absorption, and percolation are so imperfectly known, that extraordinary results are sometimes termed 'impossible,' and reports on impervious-lining experiments require to be standardized.

Item 4.—Points of special interest are always cropping up, varying from technical engineering methods to agricultural problems and matters of economics. New methods of work, such as reinforced concrete, mechanical aids to labour, &c., cannot be efficiently dealt with in the experimental stage by the ordinary staff, who are overburdened with routine work, but who would gladly use up-to-date methods, if some tangible results were available for them.

Items 5 *and* 6. *Materials and manufacture.*—A laboratory is badly needed for testing both mechanically and chemically the material from which it is proposed to manufacture lime, cement, bricks, &c., and for carrying out authoritative

tests of the finished article, as well as of all kinds of stone, timber, iron, or other material used in construction. At present, experiments are carried out for individual canals, divisions, or even for separate works, sometimes at great labour and expense, and the results are lost to posterity, or else are preserved without a sufficient amount of detail to make them of any real value. For instance, the author, when making some comparative lime tests, consulted a man who had been previously on lime-testing experiments for over a year, and was told that some of the essential items in the process had not been definitely laid down, and were left more or less to chance.

Item 7.—It is thought by some capable of judging, that the Revenue Report could be much improved, both with regard to its utility and interest, if written by a man able to give his whole time and thought to it, instead of its being one amongst a basketful of other matters, to be disposed of by an already overworked official in the Secretariat.

Items 8 *and* 9.—The technical papers written by the Investigation Section would be of more value than those with which we are familiar, as they would be on a broader basis, free from prejudice, and would be the cream of the experience of many individuals, instead of being chiefly the experience and opinions of one man. They would also be to a certain extent authoritative, and would enable junior men to act with more confidence, by relying on them in preference to their own limited experience.

The author, when starting important masonry works in this country, and with experience limited to works constructed with Portland cement and Thames ballast, after vainly seeking for an authoritative statement of what was considered by the P. W. D. to be a suitable strength of lime or mortar for a given class of work, had to institute his own standards.

Item 11.—If the proposal of the Government of India, mooted at the last Simla Conference, for the establishment of a Quarterly Journal for the P. W. D. bears fruit, the Provincial contribntion could be collected and edited by the Investigation Section before submission to headquarters.

Other problems for consideration might include special chemical, mechanical, electrical, and mathematical problems, such as :—

(1) The treatment of kallar-soil, for (*a*) cultivation and (*b*) construction of canal banks.

(2). Forestry.

(*a*) The placing of canal plantations on a systematic footing.

(*b*) The analysis of soil for ascertaining its suitability for special plantations or crops.

(3) Crop experiments.

(4) Hydro-electric schemes.

(5) Development of canal falls.

(6) Mechanical methods of work.

Organization.

The proposed section, which might be called the Research and Investigation Section, or the 'Technical Circle,' could be organized on the following broad principles :—

1. To be constituted on the same lines as a canal circle, headed by a 'Superintendent of Investigations' of the rank of a Superintending Engineer.

2. The Superintendent to have power to obtain information from other circles, and to send his Deputy Superintendents or their assistants to gather information and carry out observations where necessary.

3. His sphere of action to be the whole Province, with power to travel in other Provinces, and to communicate with the Superintending Engineers of those Provinces.

4. The Superintendent to have power, in special cases, to send his Deputy Superintendents to visit foreign countries in order to study special problems, or to depute them while on furlough to study special subjects, for which there are no opportunities of first-hand observation in India.

5. His Deputy Superintendents, assistants, and clerical and subordinate staff to have qualifications suited to this class of work.

6. Suitable junior men to spend part of their service in this section, and thus become expert in the methods of collecting information, &c, so as to be available later for any special enquiry, that required a temporarily increased staff.

7. Unless they so desire, men not to be kept in this section during the whole of their service, but to serve for a period of three to five years, as at present in the case of deputation work.

8. The section to be kept as free as possible from the trammels of routine-work, and unnecessary accounts.

Kindred Bodies.

In order to ascertain if similar bodies existed in other lands, the author wrote to certain important countries, with the following result :—

1. No reply was received from France, Germany, Russia, Italy, Belgium, Australia or South Africa.

2. No useful information was received from England.

3. Negative replies were given by Canada and Egypt.

4. In Canada, however, the organization of such a section has been advocated from time to time in connection with the Canadian Department of Public Works, and is considered very desirable by the present Assistant Deputy Minister of Public Works.

5. In France such a body is believed to exist, but no details are available.

6. In India, the formation of such a section has been advocated in the press in connection with railways, and one is said to exist in a very primitive form in Madras, of which, however, particulars are not forthcoming,

7. In America such sections are quite common. The Director of the Department of the Interior, United States Reclamation Service, wrote that engineering and other data, together with various agricultural and irrigation statistics, &c., are collected and kept on file in the Central Office at Washington. The Engineer Department is that branch of the War Department of the United States, charged with fortification construction, works of river and harbour improvement, and protection in the interests of navigation, conducted by the Federal Government. It is under the charge of the Chief of Engineers, United States Army, and its officers are all commissioned officers of the Corps of Engineers. In this Engineer Department there is a Board of Engineers, whose members are detailed from time to time from among the senior officers of the Corps of Engineers, and whose functions are the investigation of engineering and other problems, and the collation of statistics and other data in regard to matters pertaining to fortification construction and similar subjects, for the information and guidance of the several individuals in charge of sections of the work. Its conclusions and recommendations are submitted to the Chief of Engineers, and are distributed to the officers of the Corps of Engineers, usually in the form of mimeographed circulars from the office of the Chief of Engineers

The status of the members of this Board is, as far as pay and emoluments are concerned, the same as that of officers of equal rank serving on other duty.

In connection with works of river and harbour improvement, another Board of Engineers for rivers and harbours is maintained by the authority of Congress, the members of which are also detailed from the senior officers of the Corps of Engineers ; and the duty of this Board is to report on all projects for works of improvement, not only as regards their engineering features, but also with reference to their economic factors. In the course of its investigations the Board collated a great deal of valuable data, which is rendered available to the officers of the Corps of Engineers for use in the conduct of their several works. The status of the members of this Board is the same as that of the one above mentioned.

Each of these Boards has a permanent existence, with a staff of employees, including engineering assistants, draftsmen, and clerks. When any work of an unusual character or magnitude is to be undertaken, it is customary to convene a special board of officers, usually of three members, to consider the work and submit recommendations thereon, and often to make general plans for the work. These boards include those officers of the Corps of Engineers, who have had special experience on the work in question, and the results of their investigations are made available to the entire Service.

After a few years' service with battalions of engineer troops, and on detail in engineer districts, officers are ordered to the United States Engineer School, for instruction, research, and study. In connection with this school there is published a bi-monthly magazine—"The Professional Memoirs, Corps of Engineers, United States Army, and Engineer Department at large"—which deals with special problems of the Engineer Department, and thus renders available much valuable and interesting data.

The office of the Chief of Engineers distributes to the Corps of Engineers and the several offices of the Engineer Department at large, information regarding works, and prepares standard specifications for different classes of work and materials. It will thus be seen that the dissemination, as well as the collection of information, is thoroughly accomplished.

In the United States Department of Agriculture there is an Office of Experiment Stations worked by the Chief of

Irrigation Investigations. The law providing for irrigation investigations includes studies of the laws and institutions relating to irrigation, and under that authority the Department has studied various phases of irrigation, devoting about seven per cent. of its funds to such studies. The man who devotes the most time to this subject is second to the Chief in salary and authority. There are two men who devote their time largely to such studies, and whose college training was directed with this end in view.

The last three decennial censuses have included statistical studies of irrigation, somewhat on the lines of our Revenue Report. For the special census of irrigation made in connection with the Census of 1910, there was a force of about fifty field-men, consisting of engineers with experience of irrigation work, employed for about six months, and a clerical force of about forty members employed for about two years under a 'Special Agent' of the same standing as the Chief Statisticians in charge of each line of investigation of the Census Bureau.

Conclusion.

What we require, then, is a section of the Department specially entrusted with research and the collection of information. The results of its labour to be authoritative and of unimpeachable quality, and those results to be widely disseminated amongst the members of the P. W. D. Other professions and other countries have their experimental and research committees, and why not the Indian P. W. D.? That it is a want, which is widely felt, is evidenced by the growth of the Simla Irrigation Conference, the Punjab P. W. D. Congress, and the proposed establishment by the Government of India of a P. W. D. Quarterly Journal.

In conclusion, the author acknowledges his indebtedness to the Canadian, American, Siamese, and Egyptian officials, who have provided much interesting material and food for reflection; and also to the Editors of Technical Journals and the Secretaries of Engineering Societies, who have put him in communication with those officials.

DISCUSSION.

MR. GIBB in opening the discussion on Mr. Colyer's paper said that the idea which formed the subject of the paper was not so new as the author's opening remarks would lead one to suppose. From time to time officers had been specially employed on investigation, usually of some specific subject, but sometimes with a more general programme, and thus the department was not entirely without experience of such work and its results. So little, however, was known generally of these efforts, and so fruitless did they appear to have been in most cases that the author might be excused for bringing the subject up as if it were an entirely new one.

So far as the irrigation branch of the department was concerned, the position amounted almost to a scandal. In spite of the fact that canals provided a vast hydraulic laboratory such as existed nowhere else in the world, so little use had been made of these opportunities that cast-off American formulæ were still employed, the only merit of which was that they were very complicated and could be made to give almost any result one liked. He had seen a very different state of affairs in the north of Italy the previous year on the Canale Cavour, where a most elaborate experimental station had been built at Santhia, and discharges up to about four hundred cusecs were measured by actual tank measurement.

It would be interesting to discuss why the few efforts made had been so lacking in results, and he would suggest that among the principal reasons was an absence of progressive spirit among those in power, which showed itself in a general fear of the new and the unknown, and a disinclination to take risks.

More serious, however, was the absence throughout the department of real and frank criticism. In organised services and departments, such as they had in this country, full and frank criticism of ideas and work hardly existed. He was afraid that this condition was almost inevitable because their equals in rank did not see or know very much about their work, and it was not their business to criticise it, while their superiors had power to enforce their orders without giving reasons, and so could defy logic, and dispense with criticism. Of course there was a good deal of criticism of the ideas and work of the men in the high posts by those under them, but it was apt to be of the futile, yapping pie-dog kind, and was often as irresponsible as it was ineffective.

Perhaps some might think that the criticisms the speaker had just been making were very much of that nature, but they were meant seriously, and what had been said about the result of all the power being with the older, and therefore more conservative members of the department had an important bearing on the subject. He gave precedence to no one in the matter of respect for his elders, but that respect was for the qualities appertaining to age and experience, and did not involve attributing to age qualities it obviously did not possess. He maintained that all those who had held or now hold high posts in the department, would have done much better if they had held these posts when they were ten or twelve years younger. This was certainly the case, at any rate, so far as progress by the adoption of new ideas was concerned. However no change, in this respect, was to be looked for in their time, and it was therefore necessary for them to take existing conditions fully into account, and make their arrangements accordingly.

Another reason why so little was known of research work done was that those in authority had power to order the application of the results of investigation without telling anyone how, where, or when, the results had been obtained. This would not matter so much if the same men remained in authority always,—but it produced chaos when chiefs succeeded each other so quickly that it was almost as much as one could do to remember the names of the heads of the department at the moment.

The result, then, of being organized in such a department, with a rapid succession of elderly gentlemen at its head, who had reached the age of caution, was that their record was littered with abortive and forgotten efforts at research, half hatched ideas, unsolved problems, untested inventions ; in fact they worked in a cloud of question marks,—questions asked but never answered, or of which the answers had been lost or forgotten.

In countries where their profession was not organised as it was in India these conditions did not prevail. Comparatively young men of venturesome spirit were often in positions of power. There was much frank and keen criticism, and though the arrangements for publishing and making known the results of work were not all that could be desired, yet they were vastly superior to anything existing here.

There were, however, many and obvious advantages in being organised as they were, which probably far outweighed

the disadvantages to which attention had been drawn, but it was important to remember that extreme conservatism and over-caution were inherent attributes of all organised departments.

Would a research and investigation section counteract this influence ? The speaker thought it would help a little if started and worked in such a way as to supply, what they most needed. The word research, however, covered a great deal of ground, and on that account its use was apt to lead to some confusion.

If he were permitted a short excursion in psychology it would help him to give a clearer idea of what he thought they really wanted. The process of thought consisted in putting things up and trying to knock them down again. Imagination, intuition, inspiration, or whatever they liked to call the power human beings had to think new and original thoughts, put up something new and original ; then the intellect, the critical faculty, set upon the new thing tooth and nail and tried to destroy as much as possible of it. Usually the poor little infant idea was torn to shreds in a very short time, but occasionally it survived ; logic said it was sound and the intellect having been unable to destroy it, accepted it. One step of progress had been made, and something added to human knowledge There was no dearth of new ideas : the human mind was most prolific, but a vast proportion of them were so obviously absurd that the intellect, *i. e.* the critical faculty, promptly demolished them. It was the survivors that were important, for they were the source of all progress, and it was possible to have too large a supply of sound, new ideas. Failure to apply and make use of these ideas, from whatever source they might come, meant that the progress of the human race was retarded by just so much, and theirs was a heavy responsibility who failed in this respect. New ideas could not be produced to order, they just came. This mysterious power to think new thoughts was one over which they had practically no control. They could welcome them, or slam the door on them when they did come, but they could not call them up when they wanted them.

The research section, then, must not attempt to be exclusive in the matter of new ideas ; they were its raw material and it must welcome them when they came, no matter from where ; it must encourage them, and when not otherwise to be found, it must hunt them out of their hiding places. New ideas were often very shy. Again the functions of the new section must be critical and selective. It must study requirements,

point out directions along which progress was needed, indicate possible and advantageous applications, but above all it must select and criticise, honestly and keenly, all new ideas that it could get hold of, whether they were from its own members or from outside. In fact the proposed section must be the department's intellect, *i.e.* its critical faculty, and it must use, as its raw material, the inspirations and new thoughts, not exclusively of its own members, but of the whole world.

It would be a great advantage if the section were staffed with men of fertile brain, but they must claim no monopoly of initiative. Even if they had a great discoverer in the department it was doubtful whether he would be of much use in a section such as they needed. He would need only opportunity and space to work in, but could not be organised and worked to order.

Sir Ray Lankester had given his opinion on this subject in an essay published in the *Daily Telegraph* of December 15th 1914, when he wrote that "the rare individuals known as 'scientific discoverers'—a variety of humanity impossible to drive or to co-ordinate, inevitably paralysed by official programmes, and stultified by ignorant, though well-meaning superintendence." . . . "There is a widespread but erroneous belief in official circles and among wealthy philanthropists, to the effect that you can hire a scientific discoverer and then say to him, 'discover me this' or 'discover me that' (naming to him a possible and greatly desired piece of knowledge), and that he will proceed thereupon right away to make the discovery which you want . . . . . but valuable and important scientific discovery cannot be produced directly in response to orders given and money expended. You cannot manufacture scientific discovery like soap. The great difficulty, in the first place, is to catch that rare and evasive creature,—a scientific discoverer—and when you have found him you have to humour him and let him do as he fancies. Then he will discover things, but probably not the things either you or he wanted or expected."

The proposed section could supply the need for that criticism which was one of the wants from which the department was suffering so badly; it could also, obviously, supply the need for adequate publication of results and for the spreading of knowledge; but could it inculcate the spirit of progress where it did not now exist, or revive the ardour of man's prime,

when its time was past ? Would it remove the fear of the unknown and of the new ? Would it spur the over-cautious to bold action and to the acceptance of reasonable risks ? No, he did not think it would, nor did he see how it could, because it could not make the old young again, and it was only in the young, and in those who had remained young, that the spirit of progress resided, and was a compelling emotion. The section might, he thought, do much that was good, and much that was needed, but his sympathies were all for the men who would work it. Though they might do much, to them it would appear that they had effected little as compared with what they felt should be possible, and a soul-killing sense of utilit would be upon them.

MR. RADHIKA NARAYAN said that the subject which Mr. Colyer had taken up was of far-reaching importance, and he for one had always keenly felt the great necessity of systematic research work in India, especially in the engineering department. One of the most important problems which confronted the Indian engineer was the control and training of the Indian rivers, and he found that five out of the ten problems given by the writer of the paper as awaiting solution were directly or indirectly connected with river action. In the course of an address given before the Engineers' Association, Lahore, in October 1910, he had himself dealt with the necessity for scientifically conducted investigations, and again in his memorandum for the Royal Commission on the Public Services in 1913 he had pointed out that very little research work had been done in India owing to the want of regular training for this class of work, and the very limited time available for such work amid the press of official duties ; and he had suggested that in every province there ought to be at least one engineering research division, and that the engineers attached to this division should devote their whole attention and time to research work of various kinds.

Thus the idea was not new, but it was a very natural idea, which probably had occurred to many engineers in India from time to time. The only wonder was that it had not assumed a practical shape long before this. Perhaps there were serious objections against the creation of a government department for engineering research. One such objection, which had actually been advanced, was that the government could not be expected to do everything, and that research work, being essentially a work for individuals, could only be done successfully, by those persons, who had a natural aptitude for it ; and that those who felt a real keen

interest in this sort of work, were always able to find sufficient time for carrying it on under all circumstances. This objection seemed to find support in the fact that most of the research work of various kinds was usually done in Europe and America by private persons with little or no help from government.

In India, however, the circumstances were altogether different. Engineering of all kinds was wholly controlled by government. Private individuals, even when possessing the capacity for research work, were greatly handicapped by the absence of those resources and facilities which were essential for carrying it on successfully. A concrete example might be cited in illustration of this fact.

There was in the Patiala State, an ingenious, but poor man possessing real mechanical talent, and an inventive bent of mind. After assiduously working for a long time, and spending all that he had in the furtherance of his ideas, he was able to exhibit at the Allahabad exhibition of 1910 a clever contrivance for the prevention of railway collisions. He made a complete miniature model of a long line of railway, stations, signals, engines, &c., and was able to show by actual repeated experiments that railway collisions could always be successfully prevented by a system of judicious electric connections. The man, however, never met with any encouragement from competent quarters, and at last had to give up in sheer despair.

As regards engineers in government service, even they were unable to do much in the way of real scientific research without neglecting their own proper work and duties. The case of civil and mechanical engineering in this country was analogous to that of military engineering in Europe and America, as in both cases entire control was in the hands of the government. Hence just as most of the research work in connection with military engineering was done everywhere, directly or indirectly, by the government, it was essential that real engineering research work of all kinds in this country must be done by government if it was to be done at all.

This naturally led to the need for research work. Engineers in India were at present face to face with a number of difficult problems, on a correct and satisfactory solution of which the rate of their future progress greatly depended, and for the successful and speedy solution of these problems the establishment of an engineering research institute was badly needed. One such problem had been dealt with in Mr. Schonemann's remarkable

paper of last year on the design of canal heads. That paper had clearly shewn that for want of any system of scientific research work in the department, even eminent engineers of great ability and experience had had to fall back upon mere guess work in trying to cope with the pressing demands of the moment, and in order to be on the safe side they had to take action in all likely directions so as not to miss the real cause. The only sure and safe way in which that difficulty could be successfully overcome was the establishment of a regular research institute, whose business would be exhaustively to investigate the pressing problems of the day in a strictly scientific spirit, and to solve them completely for the guidance of the engineers in charge of the works.

MR. CARNE said that on page 68 the author had commented on the use of modules and had stated that results were often clouded from want of a clear statement of the problem. With this he quite agreed, and some time ago had tackled the problem with a view to finding what was the variation in the discharge of a distributary channel with relation to the depth, and secondly with reference to that relationship what was the variation in discharge, (with reference to the variation in the depth of the distributary), for the three usual forms of outlet, and which outlet best served the purpose.

In regard to the first he found that a distributary discharge, using Kennedy's diagrams, was a fixed function of the depth to the power of 1·67, or $1\frac{2}{3}$ as nearly as possible, and a similar result had been obtained for the main line of the Sirhind Canal.

In regard to the most suitable type of outlet the three forms referred to were : (*a*) the ordinary drowned outlet, (*b*) Kennedy's gauge outlet, and (*c*) a module such as Gibb's. Kennedy's was, he believed, the only outlet at present in use, except free fall outlets of ordinary form, in which the discharge varied as a direct fanction of the depth in the distributary. Outlets of form (*c*) seemed to require a constant distributary discharge equal to the total discharge of all the outlets plus an allowance for absorption in the channel, since if the distributary discharge were to increase above that amount, there would be an excess at the tail, while if the discharge were to decrease, there would be a shortage at the tail. Outlets of form (*a*), as could be readily seen by working out a few examples with varying depths in the distributary, were very unsatisfactory, and had proved so in practice.

Speaking generally of the author's proposals, he understood that the difficulty so far had been that all officers required training in each and every kind of work in the department, so that deputing men to special investigations for any lengthy period would deprive them of the necessary opportunity to qualify for the higher posts.

The same trouble had been frequently felt as regards sub-divisional officers for head works sub-divisions, as it was not advisable to keep a young and suitable assistant engineer on such a job for as long as was expedient for the work, because he had also to qualify in a revenue division before being able to obtain divisional charge. However, the necessities of the department seemed to demand an adoption of the author's proposals, more especially because investigations when ordered to be done by some individual, who had not the time or opportunity to do them himself, did not always appeal favourably to the man ordered to do them, and were apt, therefore, to receive too little individual attention.

The author at page 67 placed the hydraulic problems (*i*) absorption and evaporation losses and (*j*) impervious lining of channels, at the end of his list. With the exception of item (*d*) regulation and training of rivers at head works, he thought the two items above mentioned should be placed at the top of the list and that the investigation section should take up these items first.

RAI BAHADUR BISHAMBER NATH continuing the discussion said that, in his opinion, a research section would supply a long felt want ; he had thought the matter out and had come to the conclusion that it was very desirable. It required more than one person to carry on experiments of different kinds, and he therefore suggested that one circle should have one selected executive officer, who was fond of experimental work, and this executive engineer should be given an experienced and intelligent overseer to carry out experiments under his supervision. A smart overseer, attached to a division solely for the purpose of experimenting, would be very useful, as the S. D. Os, whose hands were generally full, could not afford to pay proper attention to such experiments, or carry them out in time. Another point was that at present any spirit of encouragement was entirely wanting in the department. Many useful things had been discovered by members of the department, and senior officers were full of praise on the spot, but there these matters always ended. According as any invention or discovery by a member of the profession was considered to be important, that

member should receive the thanks of his superintending engineer, or chief engineer, or a money reward. The speaker gave his own experience in the case of an estimate for Rs. 21,000 in connection with automatic locking arrangements of cells in a jail at Lahore, which had come before him. He spent three nights in thinking out and three days in experimenting, and on the fourth day showed a new device to his superintending engineer in working order, and explained that this new device would cost Rs. 2,000 against the estimated amount of Rs. 21,000, thereby effecting a saving of Rs. 19,000 to government. His superintending engineer was, of course, full of praise, and that was all, but he thought it would have been a good idea if he had been allowed to share in the saving !

MR. WADLEY here took up the discussion saying, that after Mr. Gibb's humorous onslaught upon the elderly men he felt he must speak for them. He reminded Mr. Gibb of the proverb : " Wisdom comes from the future as well as from the past ", which, while indicating that the rising generation had valuable knowledge to contribute, also admitted that the elderly men of the past had contributed their share. Departmental operations often extended over such vast areas that caution and moderation, in accepting new ideas, were not only excusable but necessary. Close and frequent supervision, on the part of officers, of small outlying works was extremely difficult.

There were numerous subjects in which their experience was very limited at present. The paucity of information available with regard to the materials of construction in India and constructional principles generally, was very marked. In the case of type designs, for instance, upon the economical design of which so much depended, since any extravagance in design was liable to be repeated many times over, there was room for careful research as to the best designs to adopt and the best materials to employ. Or again in the case where a ravine with broad sloping sides had to be crossed by a canal distributary, the designer had to work out how far it was economical to proceed with embankments, and how far with tube siphons, or masonry, or reinforced concrete aqueducts, and then to compare the cost. In many instances he had no time to work out all these details, whereas if there were a special research section to examine the details and suggest the best design, considerable economy might result.

Amongst other items, with regard to which their presen knowledge was deficient, the following could be mentioned :—

the saving to government in annual repairs to plaster and pointing would go a long way towards its upkeep.

MR. SCHONEMANN said that scientific research was a thing that ought to be encouraged within reasonable limits by every goverment ; but Mr. Colyer's suggestions were not such as could be considered practicable, or likely to lead to increased efficiency in the public service. *Poeta nascitur non fit* ; and they could no more manufacture science, than poetry, by departmental process. Scientific research could only be satisfactorily carried out by experts and specialists ; and experts could only be evolved by special experience. The experience requisite for such experts was the ordinary every day experience of the engineer who came into touch with practical problems of administration in the course of his executive duties in charge of railways, roads, canals, &c. Even Mr. R. G. Kennedy could never have evolved his hydraulic diagrams from his inner conciousness, as a member of a scientific research section. It was only the worry of silt clearance and water distribution, which he experienced in the course of his work as a canal officer, that drove him to consider some means of reducing that worry. A department of scientific research, created *ad hoc*, would be as likely to be officered by elderly cranks and faddists, as by men of the Kennedy type ; human nature being what it was. Mr. Kennedy acquired his experience, and his data on the subject of silt carriage by currents, in the years 1883-1885 ; but it was not till the year 1894 that he got to the stage of writing a report on the subject, and presenting it to the Institution of Civil Engineers.

In 1895 his theory on the subject was disputed by a brother officer of great reputation as a mathematician ; and when Mr. Higham, as Chief Engineer, in 1896 tentatively endorsed Mr. Kennedy's views in Irrigation Branch Paper No. 7, he still accorded authority to the views of Mr. Kennedy's critic. In the years 1896-1899 Mr. Kennedy's views had found so little acceptance that the distributaries of the lower reaches of the Chenab canal were designed altogether at variance with those views.

It was not till Mr. Kennedy had attained the rank of chief engineer that he came to be recognized as a hydraulic expert ; and by that time his views would have found acceptance even if he had not been an expert. A scientific research section would not necessarily be officered by Kennedys ; whilst it was

(*i*) The impingement of water against obstructions and the re-actions therefrom.

(*ii*) Vortices, their use, causation, and prevention.

(*iii*) The use of water jets, in sinking piles, etc.

(*iv*) The use of hydraulic nozzles for sluicing materials.

(*v*) The use of the cement gun.

(*vi*) The development of lift irrigation by means of direct driven pumps, without the use of steam, oil, petrol or electricity.

(*vii*) The reclamation of sandy wastes.

(*viii*) Subsoil flow, and percolation gradients.

In addition to the above, however, there were investigations for the many secrets which water had yet to unfold.

MR. DORMAN suggested that pending the formation of an investigation section, anyone having an idea to exploit might embody it in a note and send it in to the Congress to obtain such publicity as they could give it.

The other day the speaker was anxious to ascertain a possible reason for a marked decrease with age in the strength of a number of lime mortar briquettes which he had made, the tensile strength at six months being only about half what it had been when tested at three months. Suspecting the action of saltpetre he had sent briquettes of different ages to an analyst, but the only information he got was that there was so much oxygen, and so much hydrogen in the composition of the mortar, and he had been left to form his own conclusions. (Laughter).

Similarly there had been several recent failures of flat mud roofs in Lahore, which had been attributed to the action of the lime in the brickwork or concrete on the iron. If kunkur lime had any such action it was a matter of the very gravest importance to all engineers and would form a suitable subject for investigation by such a section as was proposed, but for such problems the assistance of skilled chemists and physicists would be required, as well as practical engineers conversant with the problems to be solved, and able to devote their whole time to the problems in hand.

A well found laboratory would be an essential part of the scheme, but even if some certain method could be found for checking the ravages of saltpetre round the plinths of buildings,

easy to imagine its head dumping erroneous ideas or unsaleable patents on unwilling fellow engineers. It appeared from Mr. Colyer's paper that no civilized country in the world, except the United States of America kept a scientific research department that it considered worth mentioning; whilst even the engineer department of the War Office of the United States did not appear to be any improvement on our own corps of Royal Engineers, or our own P. W. D.

Of the eleven classes of work* which Mr. Colyer would entrust to his research section, the first four could be, and were, adequately dealt with under the existing system. Of the other items the idea that a superintending engineer conld not write a revenue report without the assistance of the staff of a department not trained to revenue work, was fanciful. Item No. 8 on Mr. Colyer's list was the writing of technical papers, and of treatises similar to those of Bellasis and Bligh, but it was conceivable that engineers trained on out-door works would write better technical papers than the staff of a research section; whilst the works of Bellasis and Bligh were not such as the ordinary staff of the P. W. D. could not effectively produce. The same might be said of the preparation of tables and diagrams like those of Kennedy, &c. The formation of a library and the production of a quarterly journal did not need a scientific research section for its success, which in such matters would depend on the support given by the rank and file of the whole department, rather than on the speculations of the philosophers of the special section.

Mr. Colyer's reference to the hydraulic gradient problem suggested that he had not read the principal literature on the subject, or he would have mentioned others than Gordon and Bligh as the chief authorities; while his references to the design of important works that had recently been constructed in the Punjab, and to the opinions or observations of anonymous engineers on the subject of the flood discharge of torrents, were too cryptic and indefinite to be of value in the discussion. He had said that the question of run-off and discharge from catchments was so little understood in the Punjab, that it was not possible to calculate with any certainty the discharge to be expected from a catchment over which the rainfall had been recorded; yet he found fault with a "leading engineer" who declined to accept results "observed" by local officers. If the said results, however, were really reliable, they would have furnished the correct calculation of discharge, which the author had declared to be impossible.

**vide* pages 66-67.

The meetings of the congress afforded ample scope to the discussion of such problems, and on the whole, Mr. Colyer's suggestions were not, to his mind practical, nor likely to be in the interests of the public service. The establishment of a science section in the department would probably lead to friction, and would certainly divorce theoretical research from practical administration. Scientific research ought to be encouraged in the direction of assisting individual engineers, who have shown an aptitude for useful research, to perfect their ideas, rather than by attempting to grind out science, like sausages, from any sort of material.

When all had been said and done, however, there remained room for the belief that the government might do more than it had yet done in actively encouraging engineers of a scientific turn of mind.

COLONEL CRA'STER said he was sorry Mr. Colyer was not present ; and it therefore devolved on him to make a few remarks on some points which had occurred to him. First he felt he must refer to Mr. Gibb's remarks on the subject of the elderly men. According to Mr. Gibb, the "55" in the fifty-five year rule should be considered a printer's error, and made to read "45" ; whilst on the other hand he would keep men, who had risen to the top of the tree, in that position for years, so as to avoid the confusion resulting from transfers, etc., Mr. Gibb had, however, said there was no reason why the elderly men should be at the top. He quite agreed with Mr. Schönemann that the practical man had the best opportunity of understanding a problem and tackling it. The scientific research section would be of great value provided it were kept within strict limitations. There should, however, he considered, be a constant change of officers so as to prevent the section being laden with a number of scientific faddists.

MR. Radhika Narain had made particular reference to the case of an inventor in the Patiala State. He happened to be in Lahore, however, at the time this gentleman brought his invention for practical demonstration, and the conclusion arrived at by the railway officers, who examined it, was that while the success of the invention depended largely on electrical appliances, the human element was such a considerable factor in the efficient working of this particular appliance, that too much reliance could not be placed upon the claim of the inventor that his proposals would absolutely preclude accidents. It was generally a low paid man who had to be placed in charge of such apparatus and

a series of mistakes, which appeared small enough in themselves, might result in a big blunder. For instance, in the accident which had recently occurred to the Bombay Mail at Sambhu three or four slips had been made, culminating with the responsible station master not having taken rest when off duty and consequently was unfit for work when he resumed duty, with the result that one train crashed into the rear of another. Each mistake by itself might not have terminated in anything serious ; but unfortunately it was a concatenation of mistakes that caused big accidents.

Rai Bahadur Bishamber Nath had suggested, that where a large saving was effected by an invention or by careful forethought, the official who brought about that saving, should be allowed to share in it. Was it not possible that this would lead to extravagant estimates in the first instance in order that the profits might be somewhat larger ?

Mr. Wadley had raised a point which struck him as being important, namely that all data, etc., for the design and construction of any particular work might be made over to the research section, who would work out a satisfactory and economical design, but speaking from railway experience in connection with the bridge engineering department, and the remodelling or strengthening of girders, which it was considered advisable to retain in the road, he found it was very difficult for the bridge engineer to get such full and accurate details of the various sections, joints, groupings of rivets and thicknesses of plates from the engineers on the work as would enable him to design with economy.

They must, however, hammer on with the subject, and endeavour to persuade government that it would be a real economy to establish an efficient technical section ; as it was felt that knotty problems cropped up from time to time which could be more satisfactorily solved by such a section, than by the men on the spot. Extravagance of design, as Mr. Wadley had said, was a thing to which they were all prone, and the results were far reaching. If they could persuade themselves that they were determined to get the best value for their money, and were careful in the selection of officers for their research section, they should make considerable progress.

MR. COLYER in reply to the various speakers wrote that he thought Mr. Gibb was a little hard on those approaching the time for retirement under the fifty-five year rule. If an investigation section achieved even a part of what the speaker hoped

for it, would be a great deal. As for the soul-killing sense of futility which would be upon the men who would work it, that would but bring them into line with the many who appeared to themselves to have effected little in comparison with what they felt was possible. Fortunately there were many men who worked for the sake of working, and who until they reached the times for retiring had little opportunity for morbid introspection. Replying to Mr. Radhika Narain he said he had expanded the idea of a research section and also to a great extent expounded it. There were two methods of overcoming the difficulties mentioned by Mr. Carne. The first was to shorten the period of work in the investigation section: the second was to have correspondingly high posts in that section. As for the exact order of progression, that was a matter of detail, but its discussion implied the acceptance of the principle that the establishment of an investigation section was advisable. He thought Rai Bahadur Bishambar Nath's idea splendid, but this was a hard world. Mr. Wadley like Mr. Carne had gone straight to detail, showing that he approved the principle.

It would certainly be a good thing if, pending the formation of such a section, members took advantage of Mr. Dorman's invitation to send in to the Congress a note upon any idea which they wished to exploit; and he would suggest that if an already hardworked honorary secretary were willing to arrange it, a list of those notes, if not their entire contents, might be made known to members when the advance copies of the papers were circulated, and time given for the discussion of such matters after the papers proper.

Mr. Schönemann appeared to have misconceived his idea. He had not intended to give the department '*fits*' but only to organize its '*nascitur*s'; paragraphs 6 and 7 under organization showed that no mere sausage-grinding was proposed. The superintendent and most of the deputy superintendents should be men who had gone through the practical part of the work, and who would be glad of a few years 'in retreat' to work out the details of ideas which had occurred to themselves or to others. He quite agreed that cranks and faddists were not required, with the reservation that a man with ideas out of the common must not, as is too often the case, be labelled 'crank.' He regretted he could not agree with his critic that the first four classes of work to be undertaken were adequately dealt with under the existing system. It was not the intention that the revenue report should be dealt with by untrained men,

quite the reverse. In the case of item No. 8, it would be quite essential for the writers of technical papers to have been trained on out-door works, and drafted into the research section for a sufficient period to enable them to commit their well-considered conclusions to paper. It was true that the ordinary staff could do these things, but that they rarely do, shows that they lack the opportunity which it is now proposed to afford them.

As regarded the hydraulic-gradient problem, he would be glad if Mr. Schönemann would favour him with a list of the principal works and the chief authorities on the subject. He still held that there was no approved method in the Panjab of calculating with any certainty the discharge that might be expected from a catchment over which the rainfall had been recorded, *i. e.*, no method short of actually observing the discharge.

If, as in the case quoted, the discharge had been observed, no further calculations were necessary for that particular intensity of rainfall for that catchment, but as far as the writer was aware, there was no accepted formula for the probable discharge of a catchment in terms of its area and declivity, and the assumed or observed maximum intensity of rainfall. If one existed he would be glad to hear of it.

It was gratifying to find that such a practical engineer as Col. Cra'ster thought that a scientific research section would be of great value, provided it were kept free from faddists, and that he considered it worth while hammering on with the subject, and endeavouring to persuade government that such an establishment would make for economy.