

arises or improvements are made. We must also have at hand skilled mechanics who can repair or, if necessary, construct delicate mechanisms.

When industrial research is to be conducted, there must also be provision for carrying on processes on a semi-commercial scale.

It is a fact often overlooked that conditions which obtain in the "test tube stage" of a new process frequently cannot be duplicated when the scale of operation is enlarged to that of commercial manufacture, and it is always wise to make a trial on a scale approaching the commercial, but still not so big as to make experiments too costly. When the process is developed enough to pass this stage it is then ready for the full exploitation by the manufacturer, and is no longer a research problem in itself, though doubtless there will be many problems still to be solved in connection with it.

Having arranged for an adequate supply of equipment, the next and greatest need is men. Given good men valuable research can be carried on, though with a loss of efficiency, even when the equipment is very meager; but no research can be successful without good men. Good research men are not plentiful in any country, and are certainly scarce in this one, where for so long a time it has been almost impossible for any one not possessing independent means to indulge in research. Our manufacturers have taken as a matter of course the discoveries made in our colleges and elsewhere and have seldom realized that such work is at the foundation of our national prosperity. Our legislators are equally at fault. For the most part, they are of the legal profession and are often unblushingly ignorant of even the rudiments of science. Without a direct call from the country at large, which is even more ignorant, such governments as we have had could not be expected to appreciate the value of scientific training or to spend the money of the people in developing it. The war has caused a great awakening in this respect, and things are changing rapidly for the better. For the purposes of this paper it suffices to recognize the fact that research men are scarce. From the point of view of the young man about to take up a life's work, research in some line or other is very attractive, but in the past he has been deterred from going into it on account of the extremely poor financial outlook. He simply could not afford the luxury of being a research man. We must then expect to pay our research men much more liberally in the future than we have in the past, if we are to put research on a permanent basis. No longer can the country be allowed to consider its research men of less value than bricklayers, as it officially does at present. Research men must be paid, and paid well. They are entitled to good rewards not only on account of the necessity of increasing the supply of such men, but also from the view point of efficiency. What man can do creative scientific work while worrying as to the price of baby's shoes or the latest increase in rent?

The prime requisites of a good research man are keen observation and an inquiring mind. These are attributes of youth which are all too easily lost by most of us unless continually stimulated and exercised. He must also have a broad education, particularly, but not entirely, along scientific lines, and be able to appreciate and understand discoveries and advances in fields other than his own. He should have a thorough training in his own field, particularly as regards the fundamental principles, and should be well acquainted with all the scientific literature of the day. He should have sufficient acquaintance with the processes in industrial use to appreciate their value, but this should not be so extensive as to blind him to the possibility of advantageous alterations. Too much familiarity with one way of doing things tends to block the mind and prevent progress. He must ever be open to learn from anyone, the obscure laborer as well as the eminent scientist. He must not be discouraged by set-backs for these are bound to come, and frequently. The failure of one scheme may be the starting point of something else that is bigger and better if he can only appreciate the lesson it teaches.

ORGANIZATION AND OPERATION OF A RESEARCH LABORATORY.

From the above considerations it will be realized that an ideal research laboratory is bound to be a rather large and extensive undertaking. If a laboratory is to have a really comprehensive library and an extensive supply of apparatus, it must be on a big scale, a scale too big to be considered by any except the largest of corporations. Certainly this scale can be reduced considerably without very much loss of efficiency, if the activities are limited to a narrow field, but some loss of efficiency is inevitable, even

then. If we, as a nation, have our research conducted piecemeal, as it were, by corporations individually or even by associations of manufacturers in particular lines, we will be wasteful of effort and of money, for none of the institutions will provide the advantages of our ideal or if they do it will mean that there is a lot of useless duplication of equipment, of library facilities, and of effort. If it be possible to formulate a scheme, therefore, by which this work can be centralized without other loss, it should be done. This is well realized by nearly all our research men, but every scheme so far proposed brings with it difficulties which, to a greater or less extent, counteract its advantages.

The scheme of the Research Council of Great Britain contemplates the establishment of a number of research laboratories, each on a fairly extensive scale and each interested in a particular industry and governed by a Research Association composed of the corporations interested in that industry, the government assisting by financial help and being represented on the executive. This scheme has several good points. It is particularly designed to interest the manufacturers in research by bringing them into close touch with the work. Since it is intended that the government assistance will be gradually withdrawn as the strength of the Research Association increases, the chance of too much paternalism is avoided. By concentrating the whole of each laboratory on one field there is a possibility of more intensive work in that field. On the other hand, there are some disadvantages. The executive of any such association is more than likely to be composed of the executives of the firms comprising the association, and in the majority of cases the interests and training of these men are financial rather than technical. They would naturally tend to consider too closely the possible dollars and cents value of an investigation to the detriment of the scientific value. Certainly this point of view must be considered, but the time to consider it is when the research is passing from the laboratory to the commercial stage, rather than when the whole thing is dimly conceived as a thing to be investigated. At this stage the possible value of a research can only be appreciated by a mind trained to know the value of scientific knowledge. The immediate difficulty of an industry must not be allowed to interfere with the laying of a sound foundation of scientific knowledge, on which may be reared a great structure of permanent value. This difficulty in the way of the Research Association scheme has been well discussed by a writer in "The Engineer," from which article the following paragraph is quoted:

"It must be recognized at the outset that these associations have an extremely difficult task before them. The difficulties lie both in the human elements involved, and in the technical and scientific problems which they will be called upon to solve. And these two types of difficulty interact with one another in a manner which may easily bring to nought the entire results of such an effort. To appreciate this point, we must bear in mind that one is too apt to think of "Research" in a vague way as the royal road to success; so it may be and often is, if properly directed and utilized. But if, in the direction of research, short views are taken, with the result that efforts become concentrated on the really minor problems of the moment instead of being guided into, and permitted to follow the great lines of natural development, then the whole stream of research becomes sterilized, and nothing but minor results can follow. This is perhaps the chief danger which faces the whole scheme of Research Association."

In addition to this difficulty, there is also the objection which we have mentioned above, viz., that of working on too small a scale. Even if some industries are sufficiently extensive to furnish the funds necessary to equip their laboratories with library and apparatus to a degree approaching the ideal, it would be a waste of money for them all to do so, if it could be avoided by co-operation with each other. If the different associations' laboratories were all established in one place with library and moveable apparatus in common, this objection would disappear to some extent, though not altogether. Such co-operation would also remove the objection of too much specialization, which tends naturally to narrowness of view. There is no industry to-day which cannot with advantage to itself learn from other industries, and bringing research laboratories together in this way would certainly help a great deal to bring to each the best ideas which have been developed in other fields, which are, perhaps, only very remotely related.

This scheme of Research Association Laboratories is intended very largely to cover only one phase of

the Research field—that of industrial research. Coupled with it the Research Council purpose the subsidizing of scientific research by workers at the Universities. Research scholarships and fellowships are to be instituted so that promising research work may be continued. At first glance this part of the scheme may appear attractive. Without doubt the greater part of our present scientific knowledge has been developed in a way almost identical with that which it is purposed to perpetuate. Scientists of great ability and enthusiasm for their various fields of work have devoted their lives to the development of scientific knowledge, and have discovered for us the fundamental laws of nature on which modern industry has been built. These men were enabled to pursue their chosen work, either through the happy chance of having independent means of their own or through the philanthropic aid of wealthy patrons. Occasionally, but not often, government aid has been granted, usually as a mark of appreciation of the discoveries rather than as a help while the work was in progress. All too frequently work of the greatest promise has had to be dropped on the very eve of success on account of the lack of financial support at the critical moment. One of the latest instances of this is the case of Langley and the aeroplane. For years Langley had made a scientific study of flight in a heavier than air machine. He secured through public subscription sufficient capital to allow of a demonstration with a small-sized model. At the launching of this on the trial flight a slight accident occurred—a very minor thing—and, instead of flying as expected, the machine dived into the river. Public interest turned to ridicule, no money was left for a repetition of the experiment, and Langley died of a broken heart. Only a short time ago his experiment was repeated, and a model identical with his made very successful flights at Hammondsport, demonstrating beyond a doubt that it was only lack of public appreciation of Langley's work that had retarded the birth of the aeroplane as we now know it.

Reasoning from past experience, then, it would seem that subsidizing research at universities would be a good scheme. One advantage is that the research reacts to the benefit of the university in that it provides a stimulant to the mental attitudes of the science teachers and prevents their falling behind the march of the times. Post graduate work in science is almost synonymous with research, and as an educational activity should be encouraged. But the question arises: "Is this an adequate appreciation of research in pure science? Is it the best way to encourage scientific research?" Universities are primarily teaching institutions, and however desirable scientific research may be it should not be allowed to take precedence over teaching as a university activity. As Dr. Mees* has pointed out, research on fundamental problems requires the continuous application of the same investigators over long periods, and this cannot be obtained at a university without detriment to the interests of teaching. Moreover, such devotion to one problem is undesirable as tending to one-sidedness. We may conclude then that though encouragement of scientific research at universities is advisable that in the interests of teaching it should be limited, and that there should be additional help given to research in pure science, but by some other method.

Dr. Mees suggests that a National Research Laboratory be formed on the lines followed by the Eastman Kodak Company, or the General Electric Company, but on a greatly enlarged scale. As he conceives it, such a laboratory would have a staff of at least two thousand men and other facilities in proportion. A laboratory of this kind, if well directed, would be able to do as the laboratories mentioned have done, follow their problems straight back to fundamentals with results far-reaching in their importance. Such a laboratory would serve, as do the Eastman and the General Electric laboratories, both for industrial and scientific research. However, the character and quality of work of an institution organized along these lines will depend very largely on the characteristics of the director. In the case of the laboratories mentioned, this is quite a satisfactory condition, since each of the laboratories has a field of activity which is not too extensive to receive adequate supervision by one director. But if the field be enlarged to include all the industries of the country, then, if the director is anything short of a superman, a lack of balance is bound to occur. Some industries will receive greater attention than others, some sciences will be better represented than others, and a host of jealousies and unhealthy rivalries will follow. If, for instance, the director has had

*"The Engineer," June 28, 1914.

*Science, June 2, 1914.