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THE EFFICIENCY OF COLLEGE TRAINING OF MEN FOR THE CHEMICAL INDUSTRIES.

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An estimate of the efficiency of college training of men for the chemical industries must necessarily be based upon the qualifications which the men possess during the first years immediately following their college course, and not upon the work done either by undergraduate or graduate students.

According to observations of the writer, fully 90 per cent. of college graduates who enter the industrial chemical field make their beginning in analytical chemistry, and of these men an even greater percentage are ambitious to get beyond this stage into the works where they may have charge of productive operations.

As a typical example of the graduate who achieves success, let us follow one for a few years after graduation. His career began with an appointment as chemist in the analytical laboratory of one of the branches of a large chemical industry operating a number of plants throughout the country.

On a salary of $12 per week, and his bare living expenses being thereby assured, he gave his undivided attention to the chemical work constituting his assignment. This consisted of sulfur determinations in each of a large number of samples of ore supplied daily to the laboratory. No freedom was allowed in the choice of methods, but he was given careful instruction in a method, new to him, which had been adopted as the standard of this department. As he grew proficient, he became weary of this task, but through constant repetition he found opportunity for reflection and observation. It was a revelation to contrast the number

of analyses which could be made in a given time with the determinations obtained in like time in the college laboratory.

The head of the laboratory, who held the title chief chemist, was his instructor, and was far more insistent upon accuracy and despatch than had been any of his college instructors. He was evidently a man of long years of experience in analytical chemistry, who had acquired the knack of handling a laboratory force so that it could turn out analyses at a remarkably low cost per determination. Although college bred himself, he did not hold this to be an essential requirement for analysts, since he had taken young apprentices from the shop and offices and successfully trained them to perform their daily duties of analytical determinations with accuracy and speed.

As diversion from the daily routine grind, new materials were occasionally submitted for analysis, and these required the use of new methods and an examination of the very limited literature available in the laboratories. This new work was turned over to those of the laboratory force who had received college training, their results being checked carefully by the head chemist. Presently it was rumored that the accuracy of some of the analytical results turned out in the laboratory was being questioned at the head office, where a lack of agreement between figures obtained in the company's different laboratories had been detected. This resulted in an uneasy feeling until the arrival of a representative from headquarters known as the chemical auditor. He was a man of national reputation as an analytical chemist, the owner of a Ph.D. degree, and his duty consisted in gleaning the results of research work appearing in the chemical journals, in working out and standardizing methods best adapted to use in the branch laboratories, and in a general supervision of these analytical laboratories to insure that they were all working in harmony and coöperation. He began a careful inspection of the details of the methods employed in this laboratory, and soon found some causes for discrepancies.

His acquaintance with this noted authority gave our young student his first contact with a chemist whose position he envied, but his envy was tempered by the reflection that there were few positions of this rank and responsibility in the country, while a large army of analytical chemists were competing for them. This did not discourage him, however, but he had his moments of discontent. One of these came one day when he was seated at a balance, making a moisture determination. On one side of him sat a former office boy making an ash determination, and on the other a man recently taken from a labor gang was weighing an ore sample. An official of the company looked in upon them, commenting jocularly on the "three little chemists sitting in a row." Our young man saw the

joke, but that night he wrote to his former friend and adviser, the Professor of chemistry of his Alma Mater, as follows:

I have been in this laboratory to which you recommended me for nearly a year, and have now come to the conclusion that it will be advisable to make a change. Can you advise me of an opening? All of the employees of this department are ranked on the pay-roll as chemists, though less than half of them have had any chemical training whatever before coming here. There seems to be no opportunity for advancement. The four other college graduates with whom I am working are likewise discouraged. Delay in promotion does not come from mediocre ability; the head of the laboratory is one of the ablest chemists I have known. He has been here for eleven years, and is now getting but $125 per month. I have had a good training in general and analytical chemistry, but even if I had spent my entire college course in the study of this branch, my opportunities would be no better than they are at present. All of the real thinking is done for us by a few men whom we seldom see.

"In contemplating the numerous uneducated men in the laboratory who are called chemists, I do not take as much pride in holding that same title as I had expected to while in college. It seems to me that if it were only possible to get into the works as assistant to a department superintendent, the chances for advancement would be greatly improved, but such opportunities are seldom presented.

All his old professor could say in encouragement was to assert that the majority of college graduates in chemistry get into analytical work as a stepping stone to something better; that in the analytical laboratory the employers practice a weeding-out operation, separating the men of ordinary ability from those possessing enterprise, persistence, resourcefulness, and other qualities contributary to success; that although this process is frequently a slow one to a man really deserving, promotion is bound to come; and that, therefore, he should not resign, but try to make himself so proficient that when an opportunity presented itself, he would be ready to make the most of it.

Not entirely convinced that his professor really understood the situation, the young man determined to prepare himself for opening the door for opportunity when it should knock. First he took up a general study of the manufacturing business in which the company was engaged—the economic factors which had determined the location of his branch at that particular point, such as labor conditions, transportation facilities, source of raw material supply; the costs of generating steam and power. He further studied the details of the manufacturing operations as far as he could get to them; the relation of the analytical laboratory to the works at large, etc.

He found that the library facilities were decidedly inadequate for this study, consisting of a few books and several scientific publications, and that none of his associates, not even the head chemist, was familiar with the works operations. They had no interest in their work after the re-

sults had been recorded and sent to the office, and the significance of analyses upon the larger problems of the company did not concern them.

Thrown, therefore, upon his own resources, he made a survey of his college training, hoping to determin what portion of it might now be of assistance. Because of his meager salary, he could not afford to subscribe for the best scientific and technical publications, but he had learned that a large amount of useful literature was available for the asking, and so appealed to such agencies as the census bureau, various other government departments and laboratories, the state geological surveys, the bureau of labor and industrial statistics. Using what they sent him he resumed the course in economics which he had taken at college. He reviewed his work in steam engineering and power generation in the light of application to the conditions of his plant. His old work in mechanical drawing and machine design enabled him to produce working drawings of a labor- and time-saving laboratory device. Metallography had taught him the value of the microscope in the study of materials, and getting out the dust-covered microscopic equipment, he found he could determin quickly some of the properties of the materials which the slower chemical analyses were revealing. This study of costs of chemicals and other materials received and manufactured, not from laboratory supply lists but from wholesale quotations of trade publications, gave him an idea of opportunities for manufacturing profits. Out of such diversified lines of studies as these came a gently increasing interest in his routine work.

Finally opportunity knocked at his door, and he was placed in charge of the filter-press room, where a comparatively simple operation was kept going night and day. This consisted in treating a ground ore with a chemical solution yielding an insoluble, valueless filter cake and the valuable filtrate. This new foreman found that the principal item of cost was the renewal of filter cloths, amounting to a total of $1.50 per ton of ore treated, and he began a study of the possibilities of decreasing this item. The rapid wear on the cloths was due to the action of the solution on the fibers, and more especially to the wear on the upper edges of the plates where they were pulled apart for dumping. He satisfied himself by a study of the action of this chemical solution on various kinds of fibers that they were employing the best material. By subjecting the cloth in different directions to a strength-testing machine, he found that a stress elongation diagram was obtained which taken in one direction of the cloth was similar in shape to that for mild steel, and in the other direction to cast iron, as he had obtained these curves in his college testing laboratory. This yielded a method of drawing specifications for cloth best suited to the requirements, and resulted in some small reductions in cost, but not enough to be satisfactory. Since the wear

was directly proportional to the time, and to the frequency of dumping the presses, it was evident that this could be reduced per ton of ore only by more rapid working, and by making a thicker filter cake. To this end the pressure of the feed was increased by changes in the pumping machinery. The principal hindrance to more rapid working was found to be the hard, flinty precipitate which formed on the plates and filled up the grooves. It was the custom to remove this coating by a pneumatic chipping hammer, requiring several hours of labor per plate. An attempt was then made to find a labor-saving solvent, but solubility tables gave our young man no assistance. Solvents which would dissolve this precipitate were either too costly, or would attack the iron as well as the scale. He discovered, however, that a caustic soda solution of certain strength, while not dissolving the scale, would in four days' time soften it so that it could be brushed off readily. A calculation of the interest and depreciation on investment in plates tied up while under this treatment showed the sum to be far less than the labor involved in the older method, which method was then discarded. The cleaner plates, higher pressures, and better cloths enabled the filter cake to be doubled in thickness in equal time, and the cost of cloths per ton of ore treated was reduced one-half, resulting in a daily saving of $50.00 in this one item alone.

With such a record of reducing cost, it naturally followed that our young man was given other opportunities to exercise his abilities. He was transferred to a branch plant, where sulfuric acid was being made by a newly developed contact or catalytic process. His problem now was to assist in the determination, if possible, of some way to prolong the life of the contact mass, upon the solving of which was dependent the commercial success and, therefore, the continuance of the use of the process.

In undertaking this problem, our protegé recalled his college thesis work, in which he had been trained in systematic procedure beginning with a statement of the problem, a summary of the state of knowledge based upon the literature and other sources of information, an outline of proposed experimentation, the execution of the work, the significance of the results in application to the problem in hand, and conclusions or recommendations based upon the investigation.

In applying this method to the new problem in hand, he found himself involved in work of a highly scientific order, comparable with the best of that done in university laboratories. He became as deeply interested in it, through an appreciation of its practical importance, as any pure scientist can become in his labors, even though appreciating that his results would not, on account of the company's policy of secrecy, be given out for publication.

Such is a narrative typical of the progress of a successful industrial chemist who benefits by his college training. The industrial people

claim that the colleges are not doing all that is possible to fit men for industrial work. The educational chemists are divided in opinion as to what methods they should pursue in meeting these demands. The majority of them believe that more of a student's time should be devoted to chemistry; that they should turn out men more skilled in analyses, while others hold that it is no more the function of a university course to turn out skilled analysts than it is that of a mechanical engineering course to turn out skilled machinists or draughtsmen, or of an electrical engineering course to graduate proficient electricians. The recent introduction and present multiplication of courses in chemical engineering is in line with the views of the latter class of educators who are designing a course of study which will give to its graduates numerous viewpoints from which to regard chemical work; to acquaint them with the most useful tools for attacking industrial problems; and to qualify them not as skilled engineers or chemists upon graduation, but as men capable of learning and progressing after getting into industrial work, so that they may earn the title which is too frequently bestowed upon the graduate at commencement time.

Shall college training for chemists be intensified or diversified? Shall the training in chemistry be such as to entitle its possessor to call himself an analytical or organic, or metallurgical chemist upon graduation and limit him to pursuit in his already chosen field; or shall the training in chemistry be reduced in quantity and supplemented by study in allied subjects, so as to give a broader training, a greater versatility, and a wider range of opportunities for employment?

There are few teachers of chemistry who will deny that a broader scope of study is desirable, but there are equally few who will agree to any reduction in the amount of attention to their particular subjects. This is the basis of the growing sentiment favoring a five-year college course for industrial chemists. The writer is unable to see a solution of the problem through a lengthening of the course of study, and believes that if the fields of the technical applications of steam, electricity, hydraulics, mechanics, and the like, can be occupied successfully by men having four years of college work, there is no fundamental reason for requiring a longer course for men for industrial chemistry. The remedy for apparent crowding should come, therefore, through redesign or improvement of the four-year courses. One way of accomplishing this is through less intensification in purely chemical studies, and the time-consuming laboratory practice accompanying them. While proficiency in some particular lines might thus be sacrificed, the student could be given an interest in and knowledge of the basic principles of those lines which will enable him to continue his studies after graduation; and in

the additional studies thus made room for, his total efficiency may be materially increased.

It is a fundamental error to introduce courses in industrial chemistry, or chemical manufacture, in the belief that they will give a man a working knowledge of the technical details of some particular manufacturing business which he may enter. Should a student know that he is going into the cement business, it would be time poorly spent in his college course to devote part of it to a study of technical details of cement manufacture. The manager of a large telephone company employing many college graduates each year specifies that he wishes men broadly trained rather than those who have spent time in studying the details of telephone practice, since instruction of the required kind can be given most efficiently while in the pay of the employer.

There are, however, other and good reasons for giving courses in industrial chemistry, and especially if they can be given in such manner as to increase a student's interest. The work should give him a general view of the field of technical chemistry, and of the interrelationship between the important chemical industries. It should give him the beginning of an appreciation of the commercial factors which are inevitably linked with the production of chemical materials. Such a course should teach how and where to find information as to chemical processes rather than aim to impart information about such processes. The books used should be reference rather than text-books. The student of chemistry usually finishes his course with but little appreciation of costs and values. The price lists with which he may have become familiar are those of the dealers in supplies for chemical laboratories. "The introduction of the dollar sign into the chemical equation," and the necessity of keeping the balance upon the right side of the equation, opens to the student an entirely new and a most interesting view of the field of chemistry. Frequent reference to lists of wholesale prices of chemicals such as are given in the *Oil, Paint, and Drug Reporter*, and other similar trade publications, with explanation of trade usages in making trade quotations, the influence of freight rates, the method of packing as influencing rates, import duties, insurance risks, and the like, may well constitute an important part of the teaching of technical chemistry.

The differences of opinion of the chemistry teachers and the industrial men on educational methods are due in large part to the attitude of the former toward industrial work. There is undoubtedly a tendency for the college chemist to regard his technical brother as one immersed in routine work and to whom chemistry has become a trade rather than a profession. A statement of significance in showing the attitude of the one class of chemists toward the other is taken from a presidential ad-

dress which concerned the welfare of the American Chemical Society and the publication of its Journal:

Those engaged in industrial pursuits must always remember that although they equal in number the educators and other students, or may even form a majority of the society, it is none the less true that the former are, and no doubt will continue to be, the greater producers of new and original matters, and hence deserving of greater consideration in proportion to their numbers than those who are less productive.

Any one who has had an opportunity to review the new and original work being done in industrial fields cannot help but feel a profound admiration and respect for the high-grade research work which forms the basis and the immediate means of realization of much of the industrial progress on which the present age prides itself. While the writer does not assume authority to reply for all industrial chemists, he believes that if they were not restricted by commercial policies of secrecy, their publications of new and original scientific work would be just as numerous, and quite as valuable, as those of their unrestricted brothers in the educational laboratories. Investigation work carried out to meet industrial needs may be, and frequently is, as distinctly scientific as that which is done to fulfil the requirements of a doctor's thesis.

This attitude of chemistry teachers toward the industrial field is shown by the fact that a large majority of students taking advanced graduate work have done so in preparation for teaching positions. But that graduate work is not merely a means of getting into educational work is demonstrated by the large and increasing numbers in the graduate departments of our engineering schools, who are looking forward to industrial pursuits.

In conclusion, the writer asserts his belief that there is in general an inefficiency in the college training of men for industrial chemistry; that this training is largely in the hands of men who have an insufficient acquaintance with and appreciation of the requirements of the industrial workers; and that when educational chemists and industrial chemists finally come together on common ground, some of the present difficult educational problems will disappear.

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A LABORATORY COURSE OF CHEMICAL ENGINEERING.

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In order that the suggestions as to the make-up of a course of Chemical Engineering contained in this paper may be as concrete as possible, we have made a number of assumptions which it will be well to state at the outset. First, the work here outlined is intended to form a part of a *four*-year course such as is given in our engineering schools, and no attempt