Making use of the table given:

q at 39.57° is 59.585 by interpolation between 39° – 40° .
 q at 20.82° is 20.379

19.206

Then the correct upper heating value is

$$\frac{1863 \times 19.206}{7} = 5112 \text{ small calories per liter.}$$

The possible variations are from 0.13–0.25 per cent. This means that in the report on an oil having 18,000 B. t. u. per pound, the heating value would be from 23–45 B. t. u. too high.

To summarize: The correction above considered when applied to work on bomb calorimeters is one-half that due to change in density of water, and equals in magnitude any one of the other corrections: fuse wire, titration and sulphur.

TROY, N. Y.,
 Nov. 22, 1910.

ADDRESSES.

ON CERTAIN PROBLEMS CONNECTED WITH THE PRESENT-DAY RELATION BETWEEN CHEMISTRY AND MANUFACTURE IN AMERICA.

By ROBERT KENNEDY DUNCAN.

In presenting some reflections on the present-day relation between chemistry and manufacture in America, it is necessary, both because of the large scope of the subject and because the quotation of individual instances would be offensive, to proceed in a spirit of broad generalization; the validity of these generalizations will depend on the reasonableness of their context. Furthermore, it should carefully be prevised that there is no attempt to take a dogmatic, *ipse dixit* attitude, and, related to most of the statements that will be made, there should be carefully understood the words *exceptis exceptiendis*.

The problems to be discussed are in large measure the result of a lack of mutuality between the factory organizations on the one hand and the universities and technical institutions on the other. This lack of mutuality depends primarily upon a lack of understanding on the part of factory organizations of the advantages that are to be derived from the employment of sensible chemical research, and of a corresponding lack of understanding on the part of institutions of learning of the proper training and type of men that are requisite for the successful practice of chemical industrial research in these factories. A mutual understanding, in America at least, might speedily lead to coöperation, and coöperation to a sensibly functioning coördination. The American factories, taking them by and large, and making such distinguished exceptions as could be numbered on the fingers of both hands, certainly do not have coördinating relations with the universities, such, for example, as we find developed in Germany. Furthermore, in so far as industrial research is concerned, they do not have coördinating relations with one another. There exists no common consciousness among the corporation officials of this country of the proper methods of conducting factory research. In

order to show how true this is, permit me to place before you the results of a preliminary inquiry which was initiated last spring as to the conduct of factory bureaus of research:

First, the entirely significant fact should be stated that at that time there existed no available list of the research bureaus of this country connected with factory organizations. After writing unavailingly to various reasonable sources, such as the *Journal of Industrial and Engineering Chemistry*, the *Bureau of Commerce and Labor*, the *Census Department*, etc., it became necessary to inquire here and there everywhere among industrial colleagues for individual and incidental information. Owing to their kindly coöperation, there was eventually provided a list of some seventy-five corporations possessing either bureaus of research or individual research chemists. From these corporations there were received some forty-five frank replies, given on the understanding that each reply was to be confidential and was to be used only in a summation of results. The results of this preliminary inquiry are illuminating of the chaotic conditions that pervade factory research.

It may be interesting to know that in very few instances are contracts made with chemists. In general the chemist is "hired" by the week or by the month. There are a few, a very few, instances of contracts of one or two years duration, and one instance of three years. Of security of tenure, there is virtually none, except in the rare instances of contract. With reference to the question of security of tenure, one meets constantly such statements as "Yes; if ability and energy are shown;" "Yes; if he makes good, otherwise not;" "A man's record and value are his only security;" "As long as work is satisfactory;" etc., statements which seem reasonable until one considers, as will be seen below, the lamentable conditions under which, too often, these men work.

Next, as to the salaries, or, as a term which is more fitting on the whole, "wages."

In most instances wages are paid by the week: translated into terms of monthly payment, the young graduate receives sums ranging from \$45–100. This latter statement exemplifies the extraordinary diversity of conduct and the chaotic conditions that everywhere prevail in factory research. So far as one may strike an average among such qualitatively different factors, \$60 would perhaps be representative. The question, "Does the initial salary vary with the degree possessed?" elicited the surprising information that in a large number of cases the corporation cares very little, or not at all, what degree the man may have; as one official said, "We call them all doctors, anyhow." What is important to the corporation—vice-president—general manager or what not, is his individual impression of the man and of the likelihood of his "making good." Of course, here, as elsewhere, there is the widest diversity of practice: in one bureau of research, "the degree of B.S. corresponds with \$50–75, while the Ph.D. as nearly as can be stated varies from \$100–200;" or, again, "Yes; a man with a higher degree than B.S. starts with greater salary, though it depends on his other qualifications."

In industrial practice, the particular degree possessed is of much less value than young men understand.

In practically no instance is there any mechanism of promotion.

Related to salaries, and as a natural sequence, there are the hours of labor: and typical of the diversity of practice and the lack of any common agreement as to what is fitting, I append here a fraction of the list of answers: 8-12, 1-5.15; 7½ hours per day; 9 hours; 8-12 M., 1.15-5.15; 9-4.30; 9 hours; 8 hours; 8-5; 8-5; 7.30-5; 9-12, 1-5; about 8 hours daily; 7.30-11.30, 12.30-5.30; 7.30-11.30, 12.30-4.30; 8.45-5.30; up to 24; 8 hours daily; 8½ hours daily (etc., etc.).

Is the research man on the same basis as factory employees in being held rigidly to these hours? There are as many *Yeses* as *Nos*. Relative to hours of labor, and because often enough the young graduate has to choose between an industrial and an academic career, there is the question of vacations. The answers run along as follows:

Two weeks; ten days; two weeks to month; two weeks; seven weeks; generally get what they demand; two weeks for men who have been with us 6 mos.; two weeks; one month; two weeks; ten days if we can spare him; two weeks; two weeks; two to three weeks; ten days (etc., etc., etc.).

The question: "Do researchers take a half-holiday on Saturday?" is answered mostly in the affirmative, though there are some negatives and answers such as follows:

"Yes, during June, July and August."

"During summer months the research men take a half-holiday on alternate Saturdays," etc.

You will probably be surprised to know that there is practically no mechanism of promotion for chemists such as often obtains in factories for officials. One corporation does state that "each man is considered every six months, and if previous work warrants the action, he is recommended to the manager for a raise of salary." Another corporation "is governed only by results," still another says that "promotion is entirely for merit; seniority counts for little with us." One corporation adds one dollar per week every six months up to a maximum of \$40 per week.

An interesting result of this inquiry appears in the reply to the question: "Do the members of the bureau sign a contract resigning all rights to any discoveries made while in your employ?" The prevailing answer is "Yes." It is a matter of surprise that contracts embodying resignation to rights of discovery were so prevalent. In reply to the question as to whether any additional remuneration was granted to successful researchers, the prevailing answer was "no," with an occasional "increased pay." Two corporations speak of "opportunity to acquire stock" or "a cash present," but there is no instance of royalties or a share in the profits.

The responsibility of the Director of Research to a corporation is generally responsibility to one official therein; but it may be to the president, the vice-president, the superintendent, the consulting engineer or the manager of the works; in certain cases his re-

sponsibility is apparently quite indefinite. The directive power of the director is curious in its indefinite character; often it is not directive at all.

The short time afforded for this address might be wholly taken up through a consideration of the interesting answers offered to many questions.

The inquiry, however, was for personal purposes, was wholly unauthorized and preliminary in character. Reference is made to it here merely to an extent sufficient to justify a statement which will be made later on. The results obtained, while sufficiently demonstrative of uninformed and indeed chaotic conditions, are only inferentially demonstrative of inefficiency in contemporary factory research.

Personal observation, however, for several years leads me to state that presumably 95 per cent. of so-called factory research is worse than loss, *worse than loss* because the failure of the individual instance places a *finale* on the possibility of that particular factory to understand the advantage of applied science. The normal failure that attends factory research is due to ignorance of the canons of judgment in choosing chemists, inexperience in dealing with them, and a generous lack of knowledge of the facilities with which it is necessary to furnish them—laboratory, library, and living facilities. I have met tragical instances of chemists possessed of high training, creative power, and practical character, working under the most shameful conditions, burdened with routine drudgery, subjected to the interference, and orders even, of factory foremen, and what is even worse, working under an entire misapprehension and ignorance on the part of the officials of the company, as to their possibilities and value. I have seen them working under every circumstance of discouragement, inadequate facilities and bad treatment.

On the other hand, I have met equally tragical instances of good corporations employing chemists, or "chemists," who were unfitted or unqualified for the work they had to do—"fakirs" masquerading as chemists, chemists of the "Brahmin" type—analytical chemists trying to do synthetic work and *vice versa*—chemists with scholarship but no creative power and chemists with creative power but no scholarship—chemists with both scholarship and creative power but lacking in the personal or masculine qualities necessary to govern workmen, manage foremen, or to commend themselves to the company's officials.

On the basis of the inquiry which I made, a fraction of which is inserted above, and on the basis of a fairly extended personal observation, I urge upon this society the advisability of establishing an authorized comprehensive investigation into the present conditions that obtain in industrial chemical work, as these conditions refer both to routine and to research work.

I suggest that a commission formed for such a purpose should investigate not only elementary matters, such as salaries, contracts, hours of labor, vacations, laboratory space and equipment, library facilities, relations of chemists to workmen, foremen

and officials, etc., etc., etc., but that it should proceed to investigate the living conditions of factory chemists, *i. e.*, their homes; their social status in the factory family; the degree to which they are permitted to give publicity to their researches; the extent to which they are encouraged to attend the meetings of the learned societies; the time they are given for reading contemporary discovery; the extent to which routine men are attempting research and the amount of routine work required of real researchers; the extent to which corporation chemists are admitted to the results of their researches, etc., etc.

The results of an accredited commission on such a subject could hardly fail to be illuminating and important to the 5000 members that constitute this society. If, further, this commission, on the basis of the best practice discovered, were to build out of this investigation a carefully formulated statement of recommendation, it would be welcomed by chemists and corporations alike. The fact is that at this time many corporations are deeply puzzled as to what to do with their chemists—how to fit them into the discipline of the organization without injuring their spontaneity.

An inquiry recently instituted among the universities enables me to state that the young men pursuing the study of chemical engineering are few in number when compared with those in mining, electrical, civil and even sanitary engineering. The reason for this lies in large measure at the door of the manufacturer, for as stated above he does not understand the conditions he must meet to insure the chemist he employs successful and happy functioning. In some measure, too, it may lie at the door of the university, for it sometimes happens that the director of the courses in chemical engineering is an engineer, not a chemist, and in cases where its responsibility is under the chemical department the director is generally "academic" in quality; in either instance the course may lack the training and inspiration necessary to send good men into industrial chemistry.

This is unfortunate at this time, for in the coming business contraction which informed opinion leads us to expect, while constructional work will diminish with a consequent lessened demand for engineers, industrial research will flourish. It is in hard times that a wise corporation spends money for the elimination of waste and for progressive factory practice.

Let us now consider briefly the extent to which this wide-spread inefficiency in industrial research is due to the university. The present-day vice-president, or general manager of a corporation, however astute he may be, and in fact practically always is, is extraordinarily ingenuous when it comes to "hiring" a chemist. Not infrequently he will write for one to the university which, let us say, his son attends. I do not speak disparagingly, nor with the least hint of disrespect, of my university colleagues, when I say that the importance of the matter and mere candor impel me to state that it is at this point that his troubles begin. His application to the university is handed to the professor of chemistry. Speaking in

generalities, and speaking most decidedly *exceptis exceptiendis*, the professor of chemistry, no matter how distinguished he may be, is not infrequently a gentleman interested and concerned wholly with pure science. He has sometimes, either consciously or unconsciously, the attitude that the utilization of science to human needs is more or less degrading to science itself. In addition, he is a man who vibrates between his home and his laboratory and generally has but little, if any, real knowledge as to the requisites for an industrial chemist. He is, often enough, fundamentally, both through temperament and education, incapable of making a wise choice for the manufacturer concerned, and he may proceed to nominate for the position in question some man for whom he has the least use. He does not understand that success in genuine industrial research presupposes all the qualities which are applicable to success in pure science, and, in addition, other qualities more or less unessential in the university laboratory. Perhaps I may be permitted to suggest that the difference between industrial chemistry and pure chemistry may be compared to the difference between poetry and prose, in the sense that in order to write good poetry it is essential to possess all the qualities of the prose writer, together with others superimposed upon them. The canons of judgment in the choice of an industrial chemist appear to be:

- (1) Training (Scholarship).
- (2) Creative Power.
- (3) Masculine Qualities, which enable the chemist in the factory to deal with workmen and govern foremen.
- (4) Personal Qualities, as they affect his relations with colleagues and officials.
- (5) Personal Integrity.
- (6) Practicality.
- (7) Health.

In proceeding to nominate a candidate for an industrial position, it has too often been obvious to me that the professor of chemistry has nominated his man on the basis of scholarship alone.

I venture to suggest that a committee authorized to investigate the conditions that obtain in present-day industrial chemistry could not do better than to include in its investigation the relations that the universities have to industry—or the lack of these relations. There are many and puzzling important problems in this connection. As stated above, there are the canons of judgment which a university should exercise in nominating men for industrial positions. Then there is the question as to how much a university should regard its own selfish interests in refraining from nominating men who are actually or potentially on its instructional staff. Still again, there is the question of "release;" *i. e.*, the conditions on which a university may legitimately be expected to release a member of its staff to accept a more advantageous offer. There is certainly no consensus of opinion on this subject, for where the head of one chemical department may regard it as an exasperating compliment, another is likely to consider it an outrage.

Personally I believe, *pace* the Carnegie Foundation, that a university, outside of its business offices, is not a business organization and that the question of release should be looked at from the standpoint of the best interests of the man concerned, with, of course, an eye to a more or less suitable substitute.

A problem of extreme importance, and one to which I have never seen attention drawn, is the extent to which outside industrial or commercial work is permissible to the instructor in the chemical department of a university. Most professors or assistant professors of chemistry have from time to time offers of routine or research problems, generally attended with the offer of a microscopic remuneration, for industrialists are prone to believe that professors "love" to do such things. Now, we all know that the more the professor becomes involved in money-making outside the less value he is to his students; we know, too, that unless he is engaged in research of some kind, whether "pure" or "applied," he is possibly of still less value to his students, and, finally, we know that his university salary, whatever it may be, is inadequate to his needs. An extrinsic, but important consideration is the fact that carrying on outside work at the expense of the university plant and at a low remuneration, because of his salary, he is taking the bread out of the mouths of his professional brethren, who have to pay for *their* laboratories, apparatus, reagents, and books. I ask again, to what extent may the professional chemist do commercial work and what should be the scale of his remuneration?

Closely allied with this problem is another that lies within the university itself. I refer to the differences existing in the university between instructors having vocational opportunities outside and those that have not. There seems to be a tendency on the part of universities, in order to obtain first-class men, particularly in engineering, physics and chemistry, to pay higher salaries to men having vocational opportunities and at the same time to permit them to exercise their vocation. This, not unnaturally, the professor of Latin or philosophy resents. It would be interesting to see the whole matter threshed out.

Another matter of serious moment, particularly as it refers to commercial routine laboratories, has to do with academic instruction in chemical analysis. I may say advisedly, on the basis of numerous communications, that there is considerable dissatisfaction over the type of instruction that in many instances is offered young men who after graduation enter commercial laboratories in positional capacities—dissatisfaction with antiquated and cumbersome methods that are taught and with the neglect of the time element in making analyses—dissatisfaction, too, over the tardiness with which university laboratories adopt new valid methods and apparatus, and over their neglect to teach their students some sense of proportion in distinguishing between accuracy and *practical* accuracy. Now, it is within the knowledge of us all that young men can never become chemists until they are first trained and disciplined into the exercise of the last fraction of accuracy that is in

them. On the other hand, the university can no longer consider itself as apart from life, or as other than, in part, an institution for fitting young men with opportunities for life. It would seem that it is the duty of a university to fit men for positions as practical analysts as well as to fit them for practical engineering. To what extent should the schools conform in their methods of teaching analysis to practical considerations? This is a problem.

Finally, in this connection, and as a matter of personal opinion, it seems regrettable that chemical instruction should be so largely analytic in character; I mean by this that there seems to be not so much a disproportionate amount of chemical analysis taught in the academic courses, though certainly there is a great deal of it, but that the other courses partake to such an extent of the analytic character in their methods. One wanders through course after course—not formally analytical—courses such as metallurgy, advanced inorganic chemistry and physical chemistry and physiological chemistry, only to find that they are taught analytically by analytic-minded men.

It is for this reason that I attach so much importance to the discipline and methods of organic chemistry, for organic chemistry is almost the sole subject in the chemical curriculum in which a student gains educational training in synthetic working and synthetic thinking. Now, in industrial chemistry the fields that most need research, and that in consequence offer the best opportunities, are in large measure organic—tanning, starch, glue, soap, essential oils, petroleum, and so on almost indefinitely. Furthermore, both in the organic and inorganic fields of industrial chemistry, and outside of the routine testing-laboratories, the problems that are perhaps most important to industrialists are *synthetic* problems. This is naturally the case, for the art of manufacture is fundamentally "making things." Yet the men whom the schools furnish to solve these problems are for the most part men so drilled in analytic habits of thought and work that they cannot naturally and efficiently act or think synthetically. Glass men want new glasses, the metallurgical people new alloys, the enamel workers new enamels, and so on; and yet too often the men appointed to the task are beaten before they begin by their very habits of thought. I do not wish to attach too comprehensive a validity to this remark, but I believe that there is "a soul of truth" contained in it. Presumably, the ideal industrial chemist would be a synthetic man, carefully grounded in analytic work.

At the conclusion of these remarks on the relation of chemistry to industry in America, some reference ought perhaps to be made to the progress and development of the scheme of industrial fellowships which I initiated at the University of Kansas. The essentials of this scheme were published first in the *North American Review*, for May, 1907, and its subsequent progress was indicated in the *Journal of the Society of Chemical Industry*, 28, No. 13, and in *THIS JOURNAL*, 1, No. 8, as well as in *Science*, 29, No. 749.

These publications appeared in the summer of 1909, since which time I have made no report. Owing to the fact that the period of publication has in no one instance yet arrived, I may refer to the progress of these researches only in the briefest possible terms:

Fellowship No. 1. On the Chemistry of Laundering.—Mr. F. W. Faragher's fellowship was extended for six months beyond its termination, at double the value, at the end of which time he entered the factories of his donating corporation, where he is doing capable work. On the basis of a part of his researches, the University of Kansas conferred upon him the degree of Ph.D.

No. 2. On the Study of Diastase.—Mr. R. C. Shuey had his fellowship extended by the donating corporation for one year beyond its termination. At the end of this time he had perfected a method for drying alfalfa, in such a way as to conserve its diastatic content, as well as its taste, odor, color, etc. If he succeeds in proving the practicability of his process from the standpoint of cost, his work will amply satisfy his donors.

No. 3. On the Chemistry of Bread.—The donors of Mr. H. A. Kohman's fellowship, the National Association of Master Bakers, in recognition of the value of his other work in behalf of the association, at the termination of his fellowship conferred upon him all proprietary rights in his process of standardizing the large-scale manufacture of salt-rising bread. Mr. Kohman discovered the efficient bacillus for its manufacture, isolated it, grew it in large quantities, and through its use has been able to turn out salt-rising bread, of beautifully uniform quality, at the rate of a thousand loaves a day for over a week. He has been offered large considerations for the rights of this process, and on the basis of his general work and at the request of a certain corporation, he has been offered a new fellowship, yielding \$2500 a year, to continue his researches. His original fellowship was \$500 a year.

No. 4. On the Utilization of the Constituents of Butter-milk.—Mr. E. L. Tague, on the termination of his fellowship, has succeeded in extracting from butter-milk veritable casein. This casein, in quantities of over a hundred pounds at a time, was forwarded to the paper-makers for actual commercial practice. Their reports afforded a complete vindication of his methods.

No. 5. On the Extraction of the Utilizable Constituents from Crude Petroleum.—Dr. F. W. Bushong, through two years' labor upon petroleum, has placed the matter of this fellowship upon such a footing that I have recently been offered a multiple fellowship, providing for the employment of at least six men, to take full advantage of his work. This fellowship I shall accept so soon as rooms are provided for its efficient working.

No. 6. On Enamel-lined Steel Tanks.—On the basis of the work accomplished by Mr. A. J. Weith and Mr. F. P. Brock, the donors of this fellowship insisted upon taking them over into the corporation six months before its expiration. They have succeeded in con-

structing an enamel which lies beautifully on steel, which is of extraordinary resistivity and which affords good promise of being adapted to large-scale application. In addition, they have developed a substance which is not glass or enamel at all and which also lies beautifully on steel and seems remarkably well adapted in its resistivity, etc., for use as a coating for steel tanks.

This completes the list of Fellowships which have expired.

Of the Fellowships which are now in operation:

No. 7. On the Relation between the Physical Properties of Glass and its Chemical Constituents.—Dr. E. Ward Tillotson is making splendid progress in this fellowship, both from the standpoint of practical results and, as well, along lines of great academic interest. He has won the full regard and confidence of his donors and it is expected that it will soon be possible to publish some of his more important results that do not have a direct practical application.

No. 8. On the Chemistry of Cement and Lime.—Dr. J. F. Mackey is carrying out through this research a comprehensive investigation into a certain phase of cement manufacture after a fashion such as has never before been attempted, and, in addition, seems well on the way to the solution of the large-scale manufacture of slaked lime—a problem which has been of serious annoyance to lime manufacturers.

No. 9. On the Extractive Principles from the Ductless Glands of Whales.—Mr. E. R. Weidlein was sent up to Newfoundland and Labrador early in June, for the purpose of collecting material. He returned in September, completely successful in his quest. He brought back with him over a hundred pounds of suprarenal glands, over a hundred pounds of thyroids, some thymus glands and a large quantity of other very interesting material. He has already discovered that the extractive principles from the suprarenal glands of whales differ in an interesting fashion from the extractive principles obtained from land animals.

No. 10. On the Chemical Treatment of Wood.—This fellowship began considerably less than a year ago, but Dr. L. V. Redman has already succeeded in devising and developing a remarkable and promising process for the improvement of the finish on wood. The finish he obtains, while brilliant and entirely resistive to all ordinary chemical reagents, is forty-three times harder than varnish. He already has patents pending.

No. 11. On Utilities for Borax.—This fellowship, unlike the others, was but of one year's duration. On the basis, however, of what Mr. B. C. Frichot has accomplished, I am just in receipt of a letter from his donors, expressing their cordial appreciation and eagerly requesting a continuance of the fellowship.

No. 12. On the Chemistry of Vegetable Ivory.—Mr. J. P. Trickey is taking full advantage of the opportunities for investigation which lie in this subject and, on the basis of results already achieved, has won from his donors their entire confidence and appreciation.

In recognition of the progress and demonstrated value of this work as a whole, the University of Kansas

this spring constituted it a department by itself. The university has built almost a dozen laboratory rooms for the accommodation of the fellows and, in recognition of the value of their instructional services, has, through action by the board of regents, determined that every fellow shall in his instructional work receive the titular distinction which his fellow-ship stipend warrants.

In the University of Pittsburgh, in which this work is to be carried on as well, I have already received several important fellowships:

No. 1. *On the Chemistry of Baking*, yielding \$750 a year for two years, with an additional cash bonus of \$2000.

Nos. 2, 3 and 4. *On the Abatement of the Smoke Nuisance*, yielding \$2000, \$1500 and \$750 for three men per year respectively, for 2 years, with an additional consideration of not more than 10 per cent. of the net profits.

These fellowships have been established, but not yet assigned.

Additional fellowships have been signed by donors and are now in the hands of the board of trustees for acceptance. It gives me great pleasure to announce them here for the first time:

No. 5. *On the Relation of the Pots to the Glassmaking and the Elimination of "Strea,"* yielding \$1500 a year for 2 years, with an additional cash bonus of \$2000.

Nos. 6, 7 and 8. *On the Chemistry of Baking*, wholly independent of, but with the acquiescence of, No. 1— for three men, yielding respectively \$2500, \$1500 and \$750 a year for two years, together with an additional consideration of not more than \$10,000 cash.

In addition to these fellowships, I have pending, as stated above, one providing for 6 men, in petroleum research and another multiple fellowship of \$10,000 a year for 2 years, for 3 men, yielding \$5000, \$3000 and \$2000 per year respectively, together with a large additional consideration.

It is apparent, on the basis of the work already initiated at Pittsburgh, that the building, when obtained and completed, will not be large enough to accommodate the demands that will be made upon it. It ought to be said, however, that this building is not yet provided.

From a consideration of the results obtained in the University of Kansas, it seems entirely warrantable to say that the scheme has been so far demonstratively successful in its working, and on the further consideration of the readiness with which industrialists enter into these arrangements, as evidenced both in the University of Kansas and in the University of Pittsburgh, it seems equally obvious that the scheme itself meets with the approbation of the shrewd and capable men who are at the head of these industries.

The scheme itself, as expressed in the agreement between the various corporations and the universities concerned, has undergone a remarkable development. These fellowships, beginning with \$500 a year, have gone progressively up through \$650, \$750, \$1000, \$1500, \$2000, \$2500, and now I am threatened with

fellowships yielding \$5000 a year and \$3000 a year to the fellow appointed.

One remarkable phase of its development lies in the creation of multiple fellowships, designed for the intensive work of several men upon one problem.

Perhaps the most important change which I have made in later agreements relates to the time of publication. This will be seen in the following agreement for a multiple fellowship, which I announce for the first time and which is now typical of the arrangements it seems to me fair and reasonable to make from the standpoint of an advantageous mutuality:

MULTIPLE FELLOWSHIP AGREEMENT NOS. —

For the purpose of promoting the increase of useful knowledge, the University of Pittsburgh accepts from the A. B. C. COMPANY,¹ having head offices at Pittsburgh, Pennsylvania, the foundation of a Multiple Industrial Fellowship, to be known as the A. B. C. FELLOWSHIPS.

It is mutually understood and agreed that the conditions governing this Multiple Fellowship shall be as follows:

To this Fellowship three Fellows shall be appointed.

The exclusive purpose of this Fellowship is an investigation with a view to improvements in the process and products of baking, to the furtherance of which the holders thereof shall give their whole time and attention, with the exception of three hours a week which each shall give to instructional work in the University.

The Fellows shall work under the advice and direction of the Director of Industrial Research, and they shall forward periodically, through the Director of Industrial Research, reports of the progress of their work to the A. B. C. COMPANY.

For the support of this Fellowship, which shall extend through a period of two years, A. B. C. COMPANY agrees to pay Four Thousand Seven Hundred and Fifty Dollars (\$4,750) per year, payable to the University annually in advance on the date of appointment of the first Fellow. This sum shall be paid by the University in monthly installments to the three holders of the Fellowship, and in the following proportions: to one \$2,500, to another \$1,500, and to the third \$750, per year respectively.

Any and all discoveries made by these Fellows during the tenure of this Fellowship shall become the Property of the A. B. C. COMPANY, subject, however, to the payment by it to them of an additional consideration. This additional consideration to the Fellows, considered as a unit, shall depend upon the value of the services rendered and shall not exceed the sum of Ten Thousand Dollars (\$10,000). The character of this additional consideration (whether royalties, gross amount, or what not), its amount, the time or times of its payment, and the proportions in which it shall be distributed to the three Fellows concerned, shall be determined by the Board of Arbitration provided for herein. At any time during the tenure of this Fellowship, any holder may, at the option of the donor, take out patents at the expense of the donor, on condition that at the time of making application therefor he assigned all his rights to the donor under the conditions of this Agreement.

At or before the expiration of the Fellowship, the business services of any or all of these Fellows may be secured by the donor, for a period of three years, on condition that the terms of such services are satisfactory to the parties at interest.

The University extends towards the A. B. C. COMPANY the privilege of establishing a new Fellowship on the expiration of this.

In the event of any disagreement between the donor and

¹ Name of Company concealed.

the holders of this Fellowship, it is understood and agreed that such disagreement shall be settled, in so far as the dispute relates to matters of fact, by a Board of Arbitration, consisting of a Representative of the University, a Representative of the donor, and a Third Person whom these two shall select, that the decisions of this Board shall be binding upon the parties at issue and that they shall obtain such decision before having recourse to the Courts.

It is also understood and agreed that during the tenure of this Fellowship, the holders may publish such results of their investigations as do not, in the opinion of the donor, injure his interests, and that, on the expiration of the Fellowship, the holders thereof shall have completed a comprehensive monograph on the subject of their research, containing both what they and others have been able to discover. A copy of this monograph shall be forwarded to the A. B. C. COMPANY and a copy shall be signed and placed in the archives of the University until the expiration of three years from that date, when the University shall be at liberty to publish it for the use and benefit of the public. In the event that, in the opinion of the donor, publication three years after the termination of this Fellowship would unduly injure his interests, he is at liberty to appeal for an extension of time to the Board of Arbitration provided for herein which, after consideration of this appeal, shall extend the time of publication to a period which, in its belief, conserves the interests of all concerned.

Signed on behalf of University of Pittsburgh

Date: _____

Signed on Behalf of A. B. C. COMPANY.

Date: _____

Altogether, the outlook for the establishment of this scheme of industrial research on the basis of permanency seems cheerful. It appears, in so far as one can say, to be a sane, practical scheme, to the advantage of all concerned.

January 6, 1911.

DISCUSSION OF PROFESSOR DUNCAN'S PAPER.

By ALLEN ROGERS.

It has often occurred to me, in observing the methods followed by many of our technical schools and universities, that we are expending a great deal of energy and valuable time on abstract scientific research, which time might be spent to far greater advantage if it were devoted to the solving of some of the many industrial problems which are constantly before us. I have watched with much interest the development of Professor Duncan's plan, and feel that it is a work deserving of great consideration from the manufacturers' standpoint. There is another field, however, which deserves more of our consideration, and that is the field of *practical* industrial chemistry.

By practical industrial chemistry I do not mean instruction given from a textbook, but rather the carrying out of manufacturing operations on a scale sufficiently large to reproduce a fair approximation of the actual working conditions. What our manufacturer most needs is not so much the highly trained analytical or research chemist, but rather the man with sufficient chemical knowledge and practical training to work into such positions as foreman, superintendent, or head of a department; and above all things he should be a man who knows the value of a dollar, and is not afraid of dirt or work.

Ninety per cent. of the foremen, superintendents, and heads of departments in our industries to-day are men of practical experience only, and have no knowledge of the chemical principles underlying the processes over which they have control.

Consequently, when unusual conditions arise, they are at a loss to understand the reason, and unable to suggest a remedy for the same.

With the knowledge of existing conditions, and feeling that there is a demand for men with practical training, the course in applied chemistry at Pratt Institute was inaugurated in September, 1905. Our chief aim is to fit young men for practical work in the various chemical industries.

In the first year of the course in applied chemistry the student is given instruction in general chemistry, qualitative and quantitative analysis, together with a certain amount of physics, mathematics, shop work, and design. In the second year he is given instruction in industrial and organic chemistry supplemented by chemical mathematics, steam and power transmission, shop work and factory design. In our second year analytical instruction we differ radically from other schools in that all of the substances examined are those which are commonly met with in a typical technical laboratory. The following shows some of the materials which are given for analysis: water, gas, fuel, cement, fertilizer, foods, sugar, liquor, alloys, tanning materials, oils, fats, soaps, pigments, paints, boiler compounds, etc., etc.

It is on our industrial laboratory work, however, that we lay especial emphasis, as it is through this method of training that we hope to prepare young men to fill the positions of foremen, superintendents, and heads of departments in the various chemical industries. In order to provide for the practical experience which is necessary in this kind of instruction, we have installed six miniature factories, consisting of a chemical works, a soap factory, a paint works, a dry color and ink works, a dye works, and a tannery.

To meet the demands of a large number of young men who cannot afford the time or money for a four-year course with college requirements, our course has been made but two years in length. At the beginning of the second year one man is appointed as foreman of the chemical works and has four of his classmates as assistants, one acting as oiler. He is told to make an estimate on the manufacture of some chemical, see that his machinery is in perfect condition, and that his factory is kept clean. Before undertaking the preparation he has all materials tested for purity, looks up the market price of the raw and finished products, takes into consideration the wear and tear of machinery, interest on investment, cost of containers, and freight f. o. b. New York. Having determined that the substance can be manufactured at a profit, he then starts its preparation. As soon as one preparation is well under way, a second one is undertaken, as we wish to impress upon our students that an idle factory earns no money and that idle men are sure to develop into strike breeders. By means of this kind of instruction our students learn to handle steam and power, and become familiar with some of the typical forms of apparatus common to all industries. The equipment of the chemical works consists of one 10-gallon steam-jacketed iron kettle, one 10-gallon porcelain-lined, steam-jacketed kettle, one 10-gallon porcelain-lined, steam-jacketed kettle with arbor, one 30-gallon vacuum pan, one vacuum pump, one 3-gallon vacuum copper still, one 5-gallon extractor, one 10-inch centrifugal machine, one vacuum filter, together with drying ovens, and crystallizing tubs.

After one week in the chemical work, the first group goes back to technical analysis, and a second squad takes its place, and so on through the entire class. Squad number one, after spending two weeks in the technical laboratory, is again assigned to the industrial laboratory, but this time to work in the soap factory. The second in line becomes a foreman, and the various processes are conducted in the most practical manner possible.

The equipment of the soap factory consists of a 100-gallon lye tank, a 200-gallon soap kettle, a 100-lb. crutcher four 100-

lb. frames, slabber, cutting machine, chipper, stone roller mill, plodder, and press. Last year our students manufactured 3600 lbs. of toilet soap, all of which found a ready market.

Next in order comes the paint and color works. Here the students are given instruction in the manufacture of pigments and lithographic inks, and become familiar with the process of mixing, grinding, and thinning of ready-mixed paints, together with a knowledge of varnish-making and preparation of enamels. Last year we made and sold 200 gallons of mixed paint. This year, through arrangements with the American Society for Testing Materials, we will grind 160 different kinds of white paints which will be applied to test fences at Roanoke, Va. The amount will be equivalent to about 1000 gallons, the raw materials for which have been furnished by various manufacturers.

The equipment for our dry color works consists of three 5-gallon precipitating tanks, four 10-gallon settling tanks, four 20-gallon sedimentation tanks, a filter press, a ball mill, and a roller mill.

The equipment for the paint factory consists of a 5-gallon paste mixer, a 10-inch iron mill, a kneading machine, two 20-inch water-cooled burr stone mills, and one 20-gallon propeller blade change can mixer.

The work in dyeing is carried along simultaneously with the other work and is conducted by groups of three students. The equipment consists of three 2-gallon steam-jacketed copper kettles, an eight-hole salt bath for silk dyeing and for use with sulphur colors, several dozen dye pots, rods and tripods, a reel, a full-sized jigger, four 15-gallon dye vats, a printing machine, and a steam box.

The instruction in tanning is conducted along the same practical lines as indicated in the other work. Through the affiliation with the National Association of Tanners, however, we have been able to materially add to our equipment during the past year, and have greatly extended the scope of this department. The new installation, which will be completed in a few weeks, will consist of three pits $1\frac{1}{2} \times 5 \times 5$ feet deep for soaking and liming, a paddle for rapid depilation and puering, a fleshing machine, three pits as above for vegetable tannage, two larger pits for layers, an eight-foot drum, three-foot drum, large paddle for chrome tannage, slating table, shaving machine, union splitter, rolling jack, staking machine, buffing machine, and measuring machine. In addition to this equipment we have added a special room for finishing, as well as a room for tacking out and one for drying.

Each student is required to work in all these factories, which takes him into the middle of the Winter term. The remainder of the year his work is confined to that department in which he intends to specialize.

That the kind of training which we are offering is a success is proven by the fact that of the seventy-four graduates and eight special students who have taken the course, there are seventy-eight engaged along chemical lines. Of this number, about seventy-five per cent. are doing practical work. What is more to the point, however, is the fact that of the twenty-three men who finished the course last June, twenty-one were placed before graduation. Eight of these men went to factories where men from the same course were already employed.

Another point which shows the success of this kind of training is evidenced by the fact that when the course was inaugurated in 1905 there were eight men who applied for it, and we had to make up the class from those who had come to the Institute for other lines. Last October, fifty-five men applied for the same course, of which number we could only take thirty-five.

From personal observation, therefore, and from exchange of ideas with many manufacturers all over the country, I am firmly of the opinion that what we most need in this country

is the young man with sufficient chemical knowledge to intelligently supervise our manufacturing operations, and at the same time work in harmony and sympathy with the chemist

By M. C. WHITAKER.

Professor Duncan's plans for the encouragement and development of industrial research opens up an enormous field, and one which will be of immense benefit to the manufacturers. The subjects undertaken should be selected with the greatest care, and should be limited to those branches which can be handled in properly equipped laboratories. Business men may be interested in supporting an industrial research when it can be shown that the laboratory equipment is of a character to offer them superior facilities to those found in their own works laboratories. But it would be a difficult matter to interest a keen business man in an industrial research where the laboratory equipment is no better, or, as in the case of many institutions, even less than may be found in his own works. Plenty of industrial problems may be found, and generous support will be given by industries as fast as it can be demonstrated that qualified men and satisfactory equipment may be enlisted for their solution.

As to the conditions under which chemists have to work in factory laboratories, Professor Duncan's investigation is very interesting and instructive. There are, no doubt, many places where conditions are as bad, or even worse than those described by him. On the other hand, many works laboratories exist where conditions for research and development are far better than those offered by many schools and universities. Some of the industries pay better salaries than the universities; give perfect freedom of working hours; furnish better and more efficient laboratory equipment; provide mechanics, electricians, carpenters, pattern-makers, pipe fitters, plumbers, and all other necessary assistants for the conduct of experimentation on a large scale.

Suppose we consider the position of the works chemist referred to by Professor Duncan from the standpoint of the average works manager. It has been my experience, first, that the chemistry involved in the ordinary manufacturing process is not very profound nor involved, but what there is of it must be sound. Second, that equally important with the chemistry is a knowledge of physics and its application. Third, the principles of thermodynamics are basic in most every manufacturing process at some stage or other. Fourth, a knowledge of the application of mathematics and mechanics is a matter of daily need. Therefore, one of the most important things to be considered in the education of the chemists for manufacturers is the fundamental education.

Equally important and essential to the young chemist in making himself indispensable to the manager is a knowledge of certain other subjects, such as works equipment, works organization, works labor, and works economics.

The margin between a profit and a loss in a chemical manufacture is often very small and no matter how perfectly the chemical reaction may be developed, a poorly equipped works may convert it into a losing venture. Again, a losing chemical process may be, and often is, converted into a dividend-payer by improving and developing the organization for its execution.

Then comes in the question of labor. Of what consequence is the chemical reaction which depends upon labor to make it work, if the chemist does not know how to make a "Dago" work? Now in the education of men to fill the position of works chemists are the schools giving as much care and attention to the training in physics, elements of electricity, thermodynamics, mechanics, and mathematics as they are giving to chemistry? Are the men ever taught the *applications* of these sciences to manufacturing problems with real live factory appliances? Do the students ever realize that the organization factor, the labor factor, the general process economics

are all equal in importance to their chemical knowledge when it comes to producing the results for which the manager is held responsible and for which he employs the chemist to assist him? The chemist is not discriminated against in the factory. He is employed on the same basis and is favored with the same opportunities as the mechanical, electrical, or civil engineers. To be sure, the field he is expected to cover is larger, but from this very fact it also follows that it is a field of greater possibility. It is a field where failure comes easier to the poorly equipped man, and success is more marked for the properly equipped man.

I think that the factory managers are not altogether to blame for the state of affairs Dr. Duncan has described. The chemists are not altogether to blame either. The education of the men to solve the problems of chemical manufacture is a great undertaking, and one which is not to be considered on the same basis as in other engineering fields.

The subject is broader in its scope, the education must be broader, must consume more time than at present, and leave less for the employer to complete. When this phase of the subject is appreciated and the proper remedy applied, the chemist will assume a position of indispensable importance in every factory. The question of his relation to the pay-roll, hours of labor, security of position, and share of profits will solve itself on the only secure basis for any adjustment—*efficiency*.

By DR. L. H. BAEKELAND.

One of the main reasons why the work of the chemist is not properly understood nor properly appreciated is that the average public, even including educated men who are not chemists themselves, is not in a position to grasp the scope and the purposes of chemical investigation. The man of average intelligence can easily understand a mechanical proposition involving the work of the engineer, but it requires chemical knowledge, besides intelligence, to have some understanding of chemical problems and their difficulties. The average man has only the haziest conceptions of this subject.

Chemical research work, at its very best, is slow in practical results, and what is still worse, the real visible difficulties begin only after the initial research work is over, and the subject is to be reduced to practice. Therefore, to an uninformed person, the value of all the preliminary painstaking research work is not very apparent.

Ramsay stated that "The country which is in advance of the world in chemistry will also be foremost in wealth and general prosperity." It is a great advantage for this country to have at last a man like Professor Duncan, who is able to initiate the public at large into the mysteries and the scope of chemical problems. The fact that he has succeeded in treating these subjects in a popular and brilliant style increases his merit.

Research in industrial chemistry involves work of no less high order and no less difficulties than that required for purely scientific investigation. In fact, the man engaged in purely theoretical work has a great advantage over the industrial chemist because he has to take into consideration the cost of production, the market conditions, and the factor of superiority of quality. If the theoretical investigation of the subject becomes too difficult, or does not bring in results, or does not please him, he does not have to pass sleepless nights over it, but he can simply drop it then and there, and quietly select some other line of work more to his liking, and carry it out according to his own fancies and without submitting himself to the drastic criticisms of the consumer or the market at large.

The question of suitable compensation for research chemists was touched upon this evening. This is a difficult matter to discuss, and depends on many factors. It is quite natural that a chemist, who receives a fair salary from his employer for doing chemical research work, should assign to his employer

any patents he takes out, the subject of which is the direct or indirect result of the opportunities thus furnished by his employers and the study of which is at the latter's expense. Furthermore, an invention or an improvement is often made piece-meal and is the work of several collaborators. Sometimes it becomes very difficult to decide to whom belongs the merit of the final practical results. While I believe that it is fair for an employer to claim the ownership of any invention or work performed by his chemists while they are in his service, it may be to the better interest of the employer to find a suitable way to stimulate initiative by recompensing any valuable work, either by an increase of salary, or better, by some small, but fair participation in the benefits of the undertaking.

An arrangement which simply compels the chemist to forfeit all claims on improvements introduced by him, and which, at the same time, offers only an insufficient salary, is simply antagonistic to the interests of the employer, and gives the chemist no inducement whatever to exercise his initiative or best endeavors.

It is difficult or inexpedient to embody all this in a contract, but the employer may find it to his advantage to convince his research chemists that their successful work is to be taken as a basis for advancement.

Too few chemical inventors realize the enormous distance which lies between a laboratory conception and its successful application to practice. Many problems which are solved in the laboratory after great effort often require years of painstaking work, not to speak of immense financial sacrifices, before they are acceptable in current practice and become a basis for a paying commercial operation. By the latter I do not mean, of course, the so-called "rake-off" of promoters, who frequently begin by smothering a good thing under too heavy charges.

And now a word as to the value of the patents. If you do not patent your inventions and if you prefer to work them secretly, you take the risk of having your work interfered with at any time, not only by others copying it, but by somebody else taking out very disturbing patents, which afterwards may cost you much time and money in litigation.

If, on the other hand, you are protected by patents, but do not possess the financial means to defend your rights against infringers, some unscrupulous parties may harass you on the chance that you lack financial support for defending your rights.

In the United States we have an excellent patent law, which is very broad and very fair to the inventor, but we have a most absurd and wretched system for settling infringement suits. Patent litigation has become a huge force in this country, and at the same time, a very expensive pastime for both patentees and infringers. It gives a splendid chance for unscrupulous lawyers and experts to reap enormous fees, and gives little satisfaction to the litigants. This state of affairs arose from the day when the Supreme Court could no longer find the time to act as a court of appeals, and had to leave the whole matter to the different Circuit Courts, who often reach entirely contradictory decisions.

Let us hope, therefore, that the long pending bill for a Patent Court of Appeals may finally become a law and put a stop to this utterly nonsensical condition of affairs. Later on, such a court of appeals will naturally be led to discourage the present prevailing dilatory system of taking testimony in patent cases, and thus put a stop to a situation which has become well-nigh intolerable, and which conflicts greatly with the interests of our industries.¹

PROFESSOR DUNCAN'S CLOSE OF THE DISCUSSION.

Dr. Baekeland's reference to my interpretative work in science is deeply appreciated by me. This work of scientific exegesis, if I may so call it, is not easy.

¹ See "Symposium on Patents," *THIS JOURNAL*, April, 1909.

I have listened with interest to Professor Rogers' presentation of his scheme of instruction. It represents a sensible, coherent, practical scheme of service, particularly apposite to the ideals of the type of institution to which he belongs.

It does strike me, however, that this work might be carried out with much less expense to the institution and, possibly, with just as large an efficiency, by arranging coöperative relations with neighboring industrial plants, by which the student might alternate in his time between the plant and the laboratory.

It is, however, certainly a fact that next to the need of real scientific research in the factory organization, there lies the necessity of foremen and superintendents trained into an intelligent appreciation and knowledge of the practical bearing and utility of science. Who can tell how much ruin has been wrought to applied science through the ignorant prejudice and stupid opposition of factory foremen?

But it is to the application of Professor Rogers' ideas to the university type of instruction that I should make particular objection.

That is, in fact, what seems to be the trouble with many of the departments of so-called industrial chemistry in the universities. They teach a student to make a little paint, a little dye, a little soap, a little glass, etc., etc., and thus after having taken him away from some good courses in physical, organic or analytic chemistry, they turn him loose as an industrial chemist. In other words, in teaching him industrial chemistry, most inadequately and inefficiently, they teach him *multa not multum*. As I have said before,¹ it is not the function of a university to limit men but to free them to the exercise of their maximum powers. In a trade school men enter already limited.

This brings me to Professor Whitaker's remarks. It is undoubtedly true, as he says, that the successful conduct of my work under these industrial fellowships depends upon adequate facilities of laboratory equipment. But it is just as true that success depends upon the maintenance of a certain spirit favorable to research which is seldom found in the "common or garden" type of factory laboratory. Again, it depends upon our power to obtain, rapidly and accurately, exclusive information, and, still again, it depends upon the sympathetic coöperation in each individual case of the university with the factory. Fundamentally, success depends upon the men chosen. In coming to me they are fully informed that they are not entering upon a work intended for old ladies or little children.

Professor Whitaker's statements that there do exist in America good factory laboratories for research are of course perfectly true and I have an uneasy feeling that in the statements made in the body of my address I did not sufficiently differentiate the good examples that we have. We undoubtedly have in this country factory laboratories the peer of any that exist. They are, however, connected with just a few large organizations and, numerically, are unable to leaven the whole lump.

Professor Whitaker's ideas as to the education of a chemical engineer are ideal, though he seems to be referring to the creation of an executive works chemist rather than to a true industrial researcher. As for the latter, instead of needing chemistry "not very profound but sound," my experience is that he needs all the contemporary chemistry that God has given him power to absorb.

The education of the executive works chemist along the lines suggested by Professor Whitaker while ideal would, it seems to me, take twenty years to realize. Certainly it cannot be accomplished in a period of gestation of four years. The fact of the matter is that on leaving the university the industrial chemist's education is of simple necessity just beginning. Personally, I believe that the solution of the university training of the industrial chemist lies in the scheme of industrial fellowships,

the development of which I have indicated above. I was late in understanding this, but it is obvious since going to Pittsburgh that the building when erected will be unable to accommodate the demands that will be made upon it.

On the possession of this building there will be at least fifty chemists highly trained and specialized for sustained research in various industries. These fifty men, through their instructional duties provided for in the agreements, will constitute a unique staff for the teaching of undergraduates or graduates for service in specific industries and even for specific organizations.

This seems to me, without attempting to minimize the splendid methods of Professor Whitaker or Dr. Rogers, the suitable solution of the problem of teaching industrial chemistry in the universities. It removes the inconsistency of trying to teach general industrial chemistry to young men at the expense of their chemical and cultural education.

CHEMISTRY AND THE ENGINEER.¹

By GEORGE BORROWMAN.

As a factor in engineering, chemical knowledge has had, in the past, comparatively little significance for practising members of the profession. To-day it is rendering a service that is recognized as of great and increasing importance and in some branches of work, second only to mathematics. This is not charging the pioneers with stupidity. The change is but one evidence of the wonderful growth of engineering activity.

The early gold seeker refused to take seriously a knowledge of geology and metallurgy. These subjects were "frills." All he needed was an eye for gold, a pan, a little mercury and water. But the time for gathering surface nuggets passed and to-day the vast underground achievements and complex ore treatments testify to the increased knowledge and equipment of the modern mining engineer.

Civil, mechanical and electrical engineers are no longer in the day of surface nuggets. Human activity, the history of which presents a growth from the simple to the complex, is manifested in no small degree by the development of these three branches of the profession. The farther we get from primitive conditions, the less easy it becomes to satisfy our physical needs. The obvious applications of natural resources no longer suffice and as a consequence, new methods of utilizing energy, new artificial materials are devised. This means increased knowledge, a study of the more intimate relations between forces and substances. In short, physics and chemistry become of vital importance. Thus, much that was yesterday considered extraneous is counted necessary in the widened vision of to-day.

The chemical composition of the materials of engineering is being extensively studied, throwing light on such questions as: the effect of phosphorus and sulphur on high-speed tool steel; the influence of aluminates on the setting and strength of cements; the electrical conductivity of alloys, etc.; the changes brought about in materials exposed to certain environments. Through chemical investigations we are learning more about the corrosion of iron embedded in concrete; the deteriora-

¹ This JOURNAL, Aug., 1909.

¹ An address delivered before the Nebraska Section of the A. I. E. E., December 8, 1910.