Evaluation of Present-Day Mining Instruction
By Edward Steidle

Fuel Technology — Curriculum and Career
By A. W. Gauger

Mineral Industries Experiment Station
Circular 14
FOREWORD

Critical shortages of technical men trained and in training for engineering and administrative positions in the mining, preparation, and utilization of coal have existed for several years. Young men are being attracted to other industries and other professions to the detriment of the coal industry. This trend has been taking place during a period in which mechanization and increased technology have created more opportunities for capable young men than ever before in the history of the coal industry. The war effort has made a bad situation worse.

Forward-looking executives in the coal mining industry, in manufacturing companies serving coal mining, coal preparation, and coal utilization; and in coal-consuming industries have at various times expressed concern over conditions existing for recruiting capable, properly trained, technical graduates. Methods and training facilities have been criticized.

These two papers are timely. They represent the considered opinions of men having years of experience in various phases of the coal industry and in the training of technical men for the coal industry. Details of procedures and specific suggestions are made for improving existing conditions. Executives having to do with personnel and staff should find much of interest and value to them in these papers.

A nation's greatest asset is its young men. Is it not also true that the greatest potential asset for the coal industry is the sons of men in the industry? Why not conserve this asset for the coal industry by programs designed to attract these young men to a lifetime of work in the industry rather than away from it as is the present condition?

DAVID R. MITCHELL
Head, Department of Mining
The Pennsylvania State College
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*By David R. Mitchell, Head of the Department of Mining, School of Mineral Industries, The Pennsylvania State College*

*By Edward Steidle, Dean of the School of Mineral Industries, The Pennsylvania State College*

*By A. W. Gauger, Professor of Fuel Technology and Director of Mineral Industries Research, School of Mineral Industries, The Pennsylvania State College*

*By E. G. Bailey, Vice-President, The Babcock and Wilcox Company, New York*
EVALUATION OF PRESENT-DAY MINING INSTRUCTION*

By Edward Steidle†

The Mining Committee of the Society for the Promotion of Engineering Education commissioned the author to write this paper. The title and related subjects were proposed and it was indicated that "this title implies an unimpassioned and impartial criticism (both good and bad) of mining instruction as we supply it to the American college student today." I was reluctant to prepare a paper of this character. It does not seem possible to generalize on the topics involved, especially in terms of present-day requirements.

The character of an institution, the varying demands made upon it, its geographical location, its own internal organization, all these are factors that predispose against rigid standards of evaluation, whether to measure the adequacy or the excellence of the service rendered or contemplated. It would undoubtedly be a glamorous experience for me to set myself up in the role of critic and to survey the practices of perhaps 50 institutions in this country alone. Such a plan would require qualifications to which I do not believe I can completely rise—certainly not if the assignment implies that I know all there is to be known about mining engineering or the techniques of preparing for it! My experience tells me that in the long run I am going to be most helpful to you if I base my remarks upon the territory in which I have administered in recent years, make a few points that seem to me to be particularly noteworthy, and minimize those observations where I have not had access, through prolonged study and acquaintance, with those background facts which must of necessity condition observations to make them valid as sound advice.

In focusing my emphasis upon the experiences which have been closest to me, I realize that I run the risk of repeating things which seem to me to be consequential but might have less universal applicability than the construction of a set of values which could be applied nationally or internationally to seemingly similar problems. But, as I have already said, the problem differs so much from

* Presented at S.P.E.E. meeting, Mineral Technology Division, Columbia University, New York City, June 27, 1942.
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institution to institution, that I am hopeful that you will obtain from these remarks, more from inference and implication perhaps than from direct statement, those things that will be of benefit to you.

Speaking first of the objectives of my own institution, may I say that we refrain from setting before ourselves objectives which are too broad to permit of practical realization. Again, it would be more in accord with the suggestions I have received if I could talk broadly of all aspects of mining education, in the fields of both metals-mining and coal-mining. But I should be exaggerating if I gave you to believe that the emphasis at The Pennsylvania State College lies equally in both fields. Quite the contrary! As the land-grant institution of the Commonwealth of Pennsylvania, we feel that we shall be discharging our obligation of the objectives of the mandates we received many years ago to an excellent degree if through resident and extension instruction and thorough research we train our young mining engineers to cope with the manifold problems of our great basic industry of coal mining. I do not mean to infer that we provide such instruction to the complete exclusion of an interest in other types of mining, but I do mean to record the sphere of our greatest emphasis. I do not mean to say that we are unmindful of the desirability of idealism, especially insofar as the social significance of our instruction is concerned, but I do mean to say that it is high time to talk about mining instruction in terms of realistic detail instead of idealistic vagaries. If this seems on first sight to be a restricting philosophy, I might say that such an impression is readily counterbalanced by the fact that in our School of Mineral Industries, training for mining engineering flourishes in the midst of such allied and interdependent fields of instruction as the earth sciences, mineral economics, mineral engineering, and mineral technology. Mining instruction, likewise, is closely identified with extension instruction and research in this and allied fields. We pride ourselves upon this integration!

While we advocate a realistic approach to mining education, we are aware too of the fact that our graduates—who constitute, after all, the proof of the pudding—are also measured by their capacity as citizens, as men who recognize their social obligations to others, who are trained to view technical advances in the light of social effect and to observe social trends in terms of technical requirements. We believe that these abilities, as well as technical skills, are essential to success. And we know also that the success or failure of our students reflects directly on our enrollment and the demand for our graduates.

Training the Undergraduate

The process of undergraduate instruction in mining engineering is complex since the industry is in a constant state of flux. Before I finish, I hope to return to this dynamic concept of living to tell you why I think we must keep our own objectives relatively fluid. At this point, perhaps some general observations about the training of the student are in order:

We believe that a freshman in mining must be taught from the outset that he is in training for a profession; consequently, must live and tackle the undergraduate program like a professional man.

We believe that classroom training, supplemented by practicums in the laboratory and in industry, must arouse sustained professional interest, must point the way to the solution of the more intricate problems of engineering and of management, and must demonstrate the application of fundamentals to the solution of the everyday practical problems of mining operations. The responsibility of laying for these young men their technical foundation rests with the college; that of training them in plant practices and operations devolves on industry.

We believe that the focus should be thrown on the individual student in mining engineering so that the particular qualifications and interests of individual students obtain expression. This is made possible by offering a variety of approved technical electives in the sciences and in all branches of engineering beginning with the junior year. The selection of electives, however, is made under guidance so that the student’s individual needs are realized. In this way specialization can be and is being introduced into a curriculum previously conceived to be one of a general engineering nature only.

We believe in emphasizing problem and design work. We believe these should replace descriptive instruction wherever possible. For example, in teaching “systems of working,” an outline of systems in general use, with information regarding essential physical conditions, and their advantages and disadvantages can be given students and they can then be required to design systems for actual conditions. Details can be taught satisfactorily under this system.

In its essence, formal education is society’s endeavor to put old heads on young shoulders, to implant the experience of centuries in the youthful generation. Seen in this light, it is evident that isolated facts have little place in formal education; that presentation of any subject without co-relating it to other material, and to life itself, fails of its purpose.

We experience what is perhaps the usual difficulty in seeking to strike a balance between liberal and professional subjects. Profes-
sional curricula can be presented in detail, but liberal subjects can be offered only in general outline. For one thing, the element of time is against their complete presentation.

This, however, should in itself be a challenge to the teachers of liberal arts subjects. They must find new ways to reintegrate their material, to weave individual subjects together so as to develop a perspective for the student. They must present the past so that it becomes vital today; they must link cause to effect through the ages; they must delineate the ends for which man struggled, the ideals which motivated him, the results he obtained, and show how all this affects the present. Certainly it is now apparent that the subjects of history, of democracy, and of American institutions have been neglected generally in the process of higher education. The curriculum in mining engineering is no exception.

Finally, we realize that employers are willing and often anxious to discuss the subject of course material with the administration and instructional staff. Naturally we encourage such contact and the suggestions which it provides. We believe the subject matter of the practical courses, especially, should be under constant scrutiny and open to revision to keep abreast of the times, and to meet the changing needs of the industry and of society in general.

**Curriculum Building**

Curriculum building is a popular educational pastime. No curriculum has ever been perfect and the addition or deletion of any professional course will not make or break an undergraduate. The college must supply to industry promising young men who have received a foundation of pure science on which applied science has been erected as a superstructure. To this the college adds also a cultural background, a studious appreciation of human nature, including the problems of working with labor and of meeting consumer demands.

An outline of study for a four-year period, or accelerated programs leading to a Bachelor of Science degree in mining engineering is suggested below. I trust you will not think it unseemly when I tell you that this is the course substantially in effect at The Pennsylvania State College.

<table>
<thead>
<tr>
<th>FRESHMAN YEAR</th>
<th>Credits</th>
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<tr>
<td>First Semester</td>
<td>Second Semester</td>
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<tr>
<td>Inorganic Chemistry</td>
<td>5</td>
<td>Inorganic Chemistry and Qualitative Analysis</td>
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<tr>
<td>Engineering Drawing</td>
<td>2</td>
<td>Descriptive Geometry</td>
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<tr>
<td>Composition and Rhetoric</td>
<td>3</td>
<td>English Composition—Ex-Position</td>
</tr>
<tr>
<td>Physical Geology</td>
<td>3</td>
<td>Historical Geology</td>
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<tr>
<td>Plane Trigonometry and Algebra</td>
<td>4</td>
<td>Analytic Geometry</td>
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<tr>
<td>Orientation—Survey Lecture</td>
<td>1</td>
<td>Physical Education</td>
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<tr>
<td>R.O.T.C.</td>
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<td>R.O.T.C.</td>
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<th>SOPHOMORE YEAR</th>
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<tbody>
<tr>
<td>First Semester</td>
<td>Second Semester</td>
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</tr>
<tr>
<td>Differential Calculus</td>
<td>3</td>
<td>Integral Calculus</td>
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<tr>
<td>Introductory Mineralogy</td>
<td>3</td>
<td>Quantitative Analysis</td>
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<tr>
<td>General Physics</td>
<td>3</td>
<td>Petrology or Fuel Testing and Calorimetry</td>
</tr>
<tr>
<td>Physical Measurements</td>
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<td>General Physics</td>
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<tr>
<td>Plane Surveying</td>
<td>4</td>
<td>Physical Measurements</td>
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<tr>
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<td>R.O.T.C.</td>
</tr>
<tr>
<td>American History</td>
<td>3</td>
<td>R.O.T.C.</td>
</tr>
<tr>
<td>American Institutions</td>
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(It will be noted that 15 credits of chemistry are required)

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<tr>
<th>JUNIOR YEAR (Required)</th>
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<tr>
<td>First Semester</td>
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<tr>
<td>Dynamo Machinery</td>
<td>2</td>
<td>Industrial Electrical Applications</td>
</tr>
<tr>
<td>Electrical Engineering Laboratory</td>
<td>2</td>
<td>Electrical Engineering</td>
</tr>
<tr>
<td>Elementary Mechanics</td>
<td>4</td>
<td>Applied Mechanics</td>
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<tr>
<td>Elements of Power Engineering</td>
<td>2</td>
<td>Systems of Mining</td>
</tr>
<tr>
<td>Power Laboratory</td>
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<td>Mine Surveying</td>
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<tr>
<td>Principles of Mining</td>
<td>3</td>
<td>Junior Field Trip</td>
</tr>
<tr>
<td>Approved Electives</td>
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Mine Surveying—Summer Field Work—3

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<tr>
<td>First Semester</td>
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<tr>
<td>Carbon Compounds</td>
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<td>Foreign Language</td>
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<td>Introductory Physical Chemistry</td>
<td>3</td>
<td>Economic Geology</td>
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<td>Principles of Economics</td>
<td>3</td>
<td>Nonmetallic Minerals</td>
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<tr>
<td>Foreign Language</td>
<td>3</td>
<td>Geophysical Prospecting I</td>
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<tr>
<td>Structural Geology</td>
<td>3</td>
<td>Engineering Economy</td>
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<td>Geophysical Prospecting</td>
<td>3</td>
<td>Mathematics of Finance</td>
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<tr>
<td>Kinetics of Machinery</td>
<td>2</td>
<td>Machine Design</td>
</tr>
<tr>
<td>Pyrometallurgy</td>
<td>3</td>
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<tr>
<td>Physical Mineralogy</td>
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(Spanish may be desirable since new mineral resources frontiers are south of the Rio Grande.)

<table>
<thead>
<tr>
<th>SENIOR YEAR (Required)</th>
<th>Credits</th>
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<tbody>
<tr>
<td>First Semester</td>
<td>Second Semester</td>
<td></td>
</tr>
<tr>
<td>Hydraulics Laboratory</td>
<td>1</td>
<td>Physics of Mining</td>
</tr>
<tr>
<td>Hydraulics</td>
<td>2</td>
<td>Physics of Mining Laboratory</td>
</tr>
<tr>
<td>Mine Mechanization</td>
<td>3</td>
<td>Mining Design</td>
</tr>
<tr>
<td>Mining Design</td>
<td>2</td>
<td>Advanced Mineral Preparation</td>
</tr>
<tr>
<td>Mine Preparation</td>
<td>2</td>
<td>Advanced Mining Design</td>
</tr>
<tr>
<td>Mine Preparation Laboratory</td>
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<td>Senior Field Trip</td>
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<tr>
<td>Undergraduate Seminar</td>
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<td>Approved Electives</td>
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<tr>
<td>Mine Examination and Valuation</td>
<td>2</td>
<td></td>
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<tr>
<td>Approved Electives</td>
<td>4</td>
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SENIOR YEAR (Approved Electives)

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<tr>
<th>First Semester</th>
<th>Credits</th>
<th>Second Semester</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Elementary Accounting</td>
<td>3</td>
<td>Electrical Railways</td>
<td>3</td>
</tr>
<tr>
<td>Electronics and Electron Tubes</td>
<td>3</td>
<td>Geology of Oil and Gas</td>
<td>3</td>
</tr>
<tr>
<td>Metallic Mineral Deposits</td>
<td>3</td>
<td>Mineral Economics</td>
<td>3</td>
</tr>
<tr>
<td>Industrial Organization and Administration</td>
<td>2</td>
<td>Time and Motion Study</td>
<td>3</td>
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<tr>
<td>Machine Design</td>
<td>2</td>
<td>Engineering Metallurgy</td>
<td>2</td>
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<tr>
<td>Nonferrous Metallurgy</td>
<td>3</td>
<td>Mine Safety Engineering</td>
<td>1</td>
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<tr>
<td>Stresses and Structural Design</td>
<td>4</td>
<td>Advanced Mine Mechanization</td>
<td>2</td>
</tr>
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(High ranking students should be encouraged to do graduate work leading to advanced degrees.)

Course material in mining is not only developed and given in a quantitative rather than a descriptive manner, but material presented in each course is reviewed each year by a department committee and revised to give emphasis to those subjects currently important in industry. For example in the course in mine ventilation, problems and experiments on such obsolescent topics as furnace ventilation and photometric properties of miner’s lamps have been eliminated and are covered only in a brief descriptive manner, while the currently important subject of mine dusts and methods of making dust surveys are given in detail. Graduates are trained not only to interpret the results of dust surveys, but are able to use standard equipment for sampling, analyzing and testing, and hence can make their own dust surveys. Numerous other examples of changing emphasis could be cited.

Planning Mining Instruction

I have indicated before that each mining department must fix an objective in order to take its place in the sun and that the objectives of no two departments will be exactly alike. I have also warned you that whatever I could tell you of the mining engineering curriculum in the institution with which I am connected would emphasize coal mining as opposed to metals mining. Since coal mining predominates in Pennsylvania, we believe our position is well taken. We are interested in being recognized as offering the best instruction in coal mining to be found anywhere. If and when industrial demand changes, this policy will be changed to meet these demands.

You will ask, perhaps, what of the individual student who does not wish to accept coal mining as a career—what of the obligation to him as a resident of Pennsylvania? Such cases are handled through individual classroom instruction and electives. For example, if a student is definitely interested in metal mining, his problem assignments in Mining Methods and Mining Design courses are so arranged that he studies the details of metal mining as thoroughly as others study the details of coal mining. Or, if he is interested in explosives, and has the desire to enter the explosives field as a technical sales representative, the system of electives permits him to receive training in chemistry exceeding the standard requirements. Again, if he is mechanically inclined and selects the mine equipment field as his objective, a proper choice of electives gives him training in mechanical and electrical engineering in addition to the normal amount required for graduation. Similar schemes are possible for specialization in safety, mineral preparation, and management. It is strange, however, that after a student becomes thoroughly acquainted with the opportunities which are offered by a career in coal mining, either in management, production, safety, preparation, or sales, he generally loses his interest in becoming a metal miner.

During the past two years an effort has been made to interest at least a few students in the mining of metallic and industrial minerals because of urgent requests for graduates in these fields. Thus far the coal mining influence is so great that only a few are available for the many requests for graduates in other fields.

The suggested scheduling of Spanish in the curriculum outline is to facilitate employment in the Latin Americas in the capacity of either coal or metal miner. Many of the metals mining companies have their own coal mines and we have had numerous requests to supply not only metal miners but also coal miners for employment in other countries!

Laboratory Facilities

A glance at the curriculum I have outlined or almost any other conceivable curriculum in mining engineering shows the need for adequate practicum work. There is no place in laboratory instruction for antiquated, out-of-date, “white elephant” equipment.

We believe that mining laboratories should be of the small unit type in order that students may work independently. Apart from the more successful teaching possible under this plan, there is the saving in investment and in waste if the laboratory equipment is to be kept up-to-date and in good working condition. There is little hope for standardization or for the instructor who can find no way to improve laboratory teaching each year.

We stress laboratory exercises of the project type based on a brief but definite outline of the objectives. The student works out the details and reports on his findings. The data are checked at the end of the class period by the instructor in charge. Some of the work is performed under actual mining and plant conditions.
but this can be carried out only in a limited way. For example, students determine the resistance of our experimental mine tunnels to air flow in one of the exercise periods in mine ventilation. We advocate this as being more realistic than determining the resistance of a metal duct. These tunnels, the College service tunnels, and the Power Plant, are used in a number of courses to acquaint the student as far as possible with actual conditions.

"Wherever possible, students should be required to consult ready reference texts currently in use and work out the procedure for a given experiment. Students thus become not mere data takers but develop ability to analyze problems and arrive at solutions. Under this plan, instructors become guides and counsellors and a close student-faculty relationship can be maintained. Experiment No. 1—Testing for size Distribution—of our course in elementary mineral preparation is as follows:

"The material assigned is to be sampled and then tested for size distribution, using a mechanical sieve shaker and Tyler standard sieves in a 2 ratio. Make duplicate tests. Outline procedure to follow and have it approved by the instructor before proceeding with the test."

References: Gaudin—Principles of Mineral Dressing, Chap. III.
The W. S. Tyler Company Catalogue 53.
Taggart—Handbook of Ore Dressing, Art. 1-6, Sec. 22.
2. Define: mesh, screen-scale ratio, elutriation, sedimentation, and micron.
3. Plot results on Tyler standard screen-scale paper.
4. Calculate the average size of your sample, neglecting the material through the final retaining sieve. See Gaudin p. 67 and Taggart p. 1197.
5. Calculate the efficiency of screen No. 1 or No. 2, p. 25, Tyler catalogue by the standard recovery equation at the size designated by the instructor in charge of the laboratory.

Examples of material assigned for this experiment to conform somewhat to a student's major interest follow:
Coal—Mining engineer: Coal screenings and mine dusts.
Fuel technologist: Pulverized coal.
Metallurgist: Foundry sand, abrasives.

Experiment No. 1 is outlined in detail for a very definite purpose. An instructor need not be afraid to let an undergraduate imagine that he is a researcher. Every class exercise and laboratory experiment must teach students to think or else the time and effort is wasted.

Students must perform exercises designed to acquaint them with air conditioning and ventilation of mines, mine gases, mine air analysis, flame safety lamps, ventilation surveying and design of ventilating systems, designing and testing of mine fans, "permissibility" tests, mine safety appliances, theory of mine rescue equipment, sampling and testing mine dusts both for safety and health, drilling and blasting, handling of explosives and accessories, mine lighting, underground communication, subsidence, mineral preparation in the full meaning of the term—from the microscopic determination of minerals to the design of the mineral preparation plant, analysis and determination of characteristics of fuels, and mine surveying both for flat work and pitch work, performed in mines under actual mining conditions. A fully equipped machine shop must be available in which to build instruments and apparatus for special experiments.

Should students be given actual training in mine rescue work—work with self-contained breathing apparatus and the like? We question this, for we have found that while training can be done easily with the aid of the U. S. Bureau of Mines it is not wise to train inexperienced young men in work, the practical use of which perhaps very soon after their graduation might easily result in serious injury or death. It would appear that such training is the responsibility of industry and should be given to experienced men under special training conditions similar to those which will be met in the field.

We believe too that students should gain some practical work experience before they graduate. This is possible if close contact is maintained with potential employers. The summer work program can start at the end of the freshman year in order to acquaint students with the work in a mine or mine plant and to provide some balance between theory and practice. Students will be given consideration when there are vacancies and paid the scale rates for the tasks which they perform. With such opportunities it will not take long for students to decide whether mining is to their liking. Some instinct and aptitude obviously are necessary for their success.

**Requirements for Teachers**

The trend toward fundamental science in mining curricula, and the teaching of the specialized subjects as the application of a particular science, turns the attention automatically to the teaching staff. Perhaps no statement of the requirements sums up the particulars better than does that of Dr. Edward Orton, Jr., in an address he made at the dedication of the Edward Orton Memorial Library at Ohio State University, October 15, 1920. Dr. Orton said:

"The teacher cannot only teach—he must be taught. He cannot always give out—he must himself take in. He must rejuvenate his jaded faculties with new contacts with the world about him."
Research and study are the only avenues to this replenishment of his soul, and hence contact with scientific research and opportunity for study are a *sine qua non* for good teaching. They must be made not only possible, but necessary to a good teacher's environment."

In facing the new era in mining education more consideration is being given to contents of courses and to methods of teaching. Classroom and laboratory instruction are being scrutinized in detail; "cook-book" methods no longer suffice. There must be less story telling and more searching. It is possible that many mining instructors are not adequately trained for the work ahead of them. This may mean sabbatical leave for the purpose of doing graduate work or work experience in industry. There can be no hope for any instructor, particularly a young man, who wastes long vacation periods, who has to be prodded, and who cannot create his own opportunity. The mining instructor who has a true teaching and scientific spirit will spend his time in industry, on a research problem, or in creative writing. Results only will tell the story.

More attention must be given to library facilities in the mineral industries. Such libraries should be in charge of technically trained librarians who know how to make books useful tools and can impart this knowledge to the students.

**Choosing a Faculty**

There is no standard yardstick, mining instructors must fit the job and the job must fit the men. No misfits can be tolerated and instructors must guard in every way possible from falling into a rut which so often happens to them. One thing found in a rut is an inferiority complex.

Two vacancies occurred nearly simultaneously in the Mining Department at Penn State in 1937. In accordance with the policy of the School of Mineral Industries, a group of coal industry leaders in Pennsylvania, both management and labor, bituminous and anthracite, together with representatives of the State Department of Mines were brought together for consultation. These men urged that the vacancies be filled temporarily in order to provide time to completely reorganize the department, courses of study, laboratories, and personnel. As a result of the study the mining instruction at Penn State was divided into (1) systems of mining; (2) mineral preparation; (3) safety and health, all three branches pointing to coal mine mechanization. The group insisted also that the vacancies be filled with men who were experienced, recognized leaders in the several branches; consequently, pure academic training alone did not meet specifications for the jobs. There was a definite problem and a specific remedy.

Two men with Ph.D. degrees in Geophysics were permanent members of the staff. These men were thoroughly qualified to teach the theory of the chemistry and physics of mining in the various ramifications including air conditioning of mines, analyses and studies of dust concentrations, gas detecting equipment of all kinds, mine subsidence, geophysical prospecting, etc. It so happens that these men are active industrially as consultants in this field of work and aided in the air-conditioning problems during the construction of various tunnels which were required for the Pennsylvania Turnpike. They built several types of convergence recorders and portable seismographs for subsidence studies; also instruments to study the effect of moisture on shale roof. These instruments were used in certain investigations in coal mines in Central Pennsylvania.

In filling the two vacancies existing on the staff, it was necessary to find men who held Master of Science degrees and were thoroughly experienced in mining operations. Obviously, one of the men who would head the department would require extensive experience in higher education. To make a long story short, a man was found to head the department who has his Master's degree, first-grade mine foreman papers in the bituminous regions of Pennsylvania, 15 years of teaching experience, and who was a recognized authority in the field of mineral preparation, especially coal. A second (Tau Beta Pi) was found who had a Master's degree, first grade mine foreman papers in the anthracite region, 5 years teaching of night mining classes and who had been employed by one of the largest anthracite companies for introducing mechanized mining in various mines of the company. This mechanized mining experience necessarily involved problems in labor relations, mine safety, mechanics, electricity, and mine laws and regulations. Both men engage in consulting practice and have had occasion to carry on studies inside mines or mine plant regularly throughout the year. Industrial contacts widen their experience so vital in keeping in step with the needs of a fast-moving industry. These men are responsible for directing student interests and advising on employment problems. The years of actual work experience are indispensible in extra-curricular aid of this character. All members of the staff take an active part in the Experiment Station work of the School and publish at least one technical paper each year.

**Evaluating a Mining Instructor**

Shadow boxing is not required in evaluating a mining instructor. All that is required is to look at the facts. A record should be kept of each instructor and corrected annually. A sample of the form used by the author is given below:
I. Preparation and Professional Standing
   a. Education: Took work at ............................................
      Well known...... known...... little known...... schol-
      astically.
      Holds Bachelor's...... Master's...... Doctor's...... Hon-
      orary........
   b. Experience:
      1. Practical, industrial, field, etc.
      none...... short...... medium...... long...... time.
      2. Teaching:
      none...... short...... medium...... long...... time.
      3. Consulting:
      none...... short...... medium...... long...... time.
   c. Reputation in profession:
      Unknown...... known only to small group...... well
      known...... distinguished by honors, medals, etc........

II. How up-to-date is teacher?
   a. Reads current journals: never...... occasionally......
      usually...... always......
   b. Goes to professional meetings: never...... occasion-
      ally...... usually...... always......
   c. Does creative work of his own: never...... occasion-
      ally...... usually...... always......
   d. Publications in past five years: none...... of little im-
      portance...... well received...... widely quoted......

III. How is his teaching?
   A. General
      a. Preparation of classes: haphazard...... routine......
      well-planned...... painstaking......
      b. Notes: uses old notes...... reworks notes occasion-
      ally...... reworks notes annually......
      c. Expression: poor...... fair...... good...... excelle-
      nt......
      d. Spots student's weaknesses: never...... rarely......
      usually...... always......
      e. Willing to answer questions: never...... rarely......
      usually...... always......
      f. Aptness to answer questions: never...... rarely......
      usually...... always...... intelligible.
      g. Consultation and counsel: never...... rarely......
      usually...... always...... available......
      h. Stimulation of student thinking: never...... rarely......
      usually...... always......
      i. Examinations co-ordinated and supervised: poor......
      fair...... good...... excellent.
   B. Laboratory and Field Work
      a. Amends lectures: rarely...... usually...... always......
      b. Improves student's proficiency: rarely...... usually......
      always......
      c. Strengthens observation: rarely...... usually......
      always......

IV. How effective is teaching?
   a. Matters taught are remembered: not at all...... partly......
      well......
   b. Graduates from his courses find jobs: with difficulty......
      usually...... always......
   c. Graduates hold jobs: poor...... reasonable...... good......
      usually...... always......
   d. Former students consult and visit him: never......
      rarely...... frequently......

The information required in Groups I and II can be secured from superiors; III from present students, group IV from graduates. In this fashion a fair picture may be obtained. The questions in group III, section B, may not fit all types of laboratory work and have to be used with discrimination.

Extra-curricular Aids

The responsibilities of instructors do not end in the classroom, or once the student has received a degree. In fact, graduates in mining must feel free to call on their old teachers for advice on various problems, personal, technical, or otherwise, especially during their apprenticeship period.

Students are urged to familiarize themselves with mining extension work to the extent that they can serve as instructors of night mining classes and mine mechanics' training courses if called upon to do so. Experience has proved that extension teaching is good training and provides a seasoning process through contact and intimate acquaintance with the more ambitious mine workers, and this is a field where the technically trained man can assume his rightful place as a leader and teacher, and be of valuable assistance to those less fortunate in the matter of formal education. Further, extension teaching will develop a recognition of the necessity for and satisfaction or pride in knowing accurately those things for which he has assumed responsibility.

Certain courses and researches in fuel technology and coal mining engineering are closely allied. Complete fuels testing laboratories are available to all mining engineering students at Penn State who elect work in this field as a part of their preparation for the coal mining industry. The research in fuel technology provides first-hand opportunity for undergraduates to secure the
latest available information on the requirements of industry and uses of fuels.

**Stimulating the Interest of the Prospective Student**

In recent years sons of coal mining men, and boys from coal mining communities generally have avoided coal mining engineering curricula. That this attitude was affecting the coal industry adversely was realized by the Coal Division, A.I.M.E., several years ago, and a special committee on Promotion of Student Interest in Coal Mining was appointed in 1936 to study this problem. At Penn State in 1937 only 2 students out of a total enrollment of 17 in mining engineering came from coal mining communities. Today there are 30 boys from a total enrollment of 58 who have a coal mining background.

There are 10 undergraduate scholarships in coal mining sponsored by coal mining companies. The Pittsburgh Coal Company has appointed six of these so far and expects to continue to appoint two each year for an indefinite period. The Lehigh Navigation Coal Company has appointed four scholarships under a somewhat similar plan. Of the scholarship men, one senior is in the upper tenth of his class (all-college average); one junior is in the upper twentieth; and one sophomore is the highest ranking Mineral Industries student.

The Mining Engineering curriculum is attracting high-ranking students. During the regular school year just passed, one-half of the senior, junior, and sophomore mining students were in the upper three-tenths of their respective classes (all-college averages). Two out of seven seniors are members of Tap Beta Pi, Sigma Gamma Epsilon, and Sigma Tau. One was president of the latter honorary. One senior made Phi Lambda Upsilon and Pi Mu Epsilon, chemistry and mathematics honoraries respectively, and was president this year of the latter group. He was also Student Colonel, R.O.T.C. One junior was all-college class treasurer, and a second was elected president, student chapter A.I.M.E.

In addition to the scholarship men, about 30 undergraduates are given summer employment regularly by mining companies. By the beginning of their senior year, nearly all of the students have made commitments regarding employment upon graduation.

Many freshmen enter the college with considerable mining experience. Two members of the senior class and one sophomore took their fire boss examinations this year and passed with exceptionally high grades. A sophomore had completed all the work offered by our Extension Division in night mining classes, and had his first-grade mine foreman papers prior to entering college. His resident work may be definitely rated as superior. A number of students have miner's papers, one cutting machine papers, and one is rated a mine mechanic, first-class.

Last year the Philippine Government sent one of their employees to Penn State for graduate training in coal mining. Another student, whose residence is Washington, D. C., was advised by a government official to enroll at Penn State for coal mining. In the future similar instances will appear commonplace.

I have tried to make the point that we cannot safely assume that young men will become inflamed with a desire to become mining engineers or coal mining engineers without some effort on the part of industry. In our older settled communities, the growing boy is influenced toward other professions and trades since his teachers have been trained in other fields and naturally talk about these fields to their classes. His teachers have no intimate knowledge of the needs of the mining industry or of the opportunities for technically trained young men in the mining industry. The fact that the daily newspapers and radio play up labor disputes and mine disasters and hence create in the minds of our youth thoughts that the mine worker leads a life comparable to that of the galley slave of old does not make the problem any easier.

Unfortunately, there is competition within the profession for young men trained in coal mining engineering. Various government bureaus and agencies actively bid against industry for the services of these young men. The Civil Service Commission recognizes that a young technical graduate classed as a junior engineer is worth $2000.00 a year. Some officials of coal companies do not recognize the potential value of technically trained coal mining engineers and salaries as low as $100.00 a month are offered in isolated cases.

The existence of a need for college-trained coal mining engineers does not imply that sufficient young men will take a course in mining engineering to satisfy this need. Quite the reverse is true, since requests for graduates have been of the order of ten times the number graduating for several years. In order to progress, the mining industry with its particular problems must recognize that there are also particular problems in interesting the right kind of young men in the mining industry, and in educating and training these young men for a successful career in the industry. Fortunately officials of progressive companies do recognize this problem and it is largely by reason of the activities and co-operation of these companies that our Department of Mining has grown in a period in which most schools were showing a downward rather than an upward trend.
The day is past when a department of mining can hang out its shingle and take the business that happens to come its way. Here are things that can be and are being done by officials of operating companies in Pennsylvania to interest young men in the industry and to develop an outstanding department of mining at Penn State to train these young men:

1. Confer with public school superintendents and high school principals on methods of educating promising boys into mining engineering, especially in mining communities where the schools depend on the prosperity of the mining industry.

2. Urge school authorities to provide for some elementary work as early as the sixth grade, covering suitable information about the mining industry. In connection with the popular science courses in the high schools, additional work in regard to mining might be given to offset the influence on youthful minds of the radio, automobile, airplane, et cetera.

3. Urge higher standards in high schools and strong college preparatory courses for promising boys.

4. Assist in vocational guidance clinics in the high schools.

5. Sponsor prize papers for high school students on topics relating to the mining industry.

6. Provide loans to young employees desirous of studying mining engineering at a recognized college.

7. Provide undergraduate scholarships. This is in accordance with the recommendation of the committee on Student Interest in R. E. Mining I. M. E. Since 1936, six coal mining companies and two coal mining societies in the United States and Canada have adopted the scholarship plan of the committee.

8. Arrange for student vacation employment.

9. Offer graduate fellowships to encourage students of exceptional ability to continue their studies into the post-graduate years.

10. Support research projects in mining to aid in developing teachers of ability and vision to train these young men.

11. Participate in student activities by furnishing speakers for student meetings, and attend student meetings.

12. Assist in inspection trips, prepare exhibits for the school, and furnish material for instruction purposes.

13. Develop a company apprenticeship training program for graduates and publicize it.

14. Establish a suitable salary scale for junior engineers and publicize it.

**Conclusions**

To the work of pioneer mining engineers, the United States owes much of its greatness. Even today the wealth of the Nation rests basically on its mineral resources. The pioneer had to be prepared to meet all eventualities, to locate and develop in a crude way the mineral resources of the Nation. Today mining men are still in great demand, but now usually for a different purpose: to exploit and utilize our limited and waning mineral resources to the best advantage. The mining industry needs today specialized mineral engineers and technologists rather than the adventurer type of the earlier day.

Mining engineering education as presented in American colleges covers two fields for students: cultural and professional, both of which must be considered. In institutions dependent upon public support, mining departments must produce graduates who are, primarily, better citizens, and secondly, trained technologists. The ideal graduate will be imbued with sufficient social conscience to realize the social significance of the solutions which his technical training supplies.

Immediate trends in the professional side of mining engineering instruction are: (1) Concentration on pure sciences in the earlier years; (2) the limitation of professional instruction to the upper years and to graduate work; (3) the approach to professional work as application of fundamental sciences; (4) greater staff-conducted research; and, in publicly supported institutions, (5) full co-operation with the experiment stations which serve as an organized expression of the research spirit; and (6) the dissemination of information through the extension service.

If we agree with the definition and obligation of education as it has been outlined here, and accept the obvious responsibilities of the college, then we may conclude that the major trends in mining education, by facilitating this movement, are sound.

The mining industry is of supreme importance in the war effort. Traditions in education are being shattered; programs and objectives must be altered; consequently, some thought must be given to post-war conditions. This is what I meant when I said earlier that I would return to the dynamic concept of the mining industry.

In the period of adjustment the mining industry will continue as before to supply the raw materials upon which our civilization depends to such a great extent.

The total drain of war demands on the remaining mineral resources will be very great. More and more of the highest grade and most easily accessible minerals are being exhausted. The problems of conservation are, therefore, sure to be of increasing importance and significance to a greater percentage of the population than in the past. Conservation will become largely a technical problem and the responsibility of the research worker in providing new materials and new uses for old materials will require increasing attention.

The mining industry spurred by the demands of war is demanding more and more trained technical men. The requirements vary from the experienced graduate of a technical school to the man who
is trained in one operation so that he can take his place in the production line. The former is the product of years of education and training. The latter can be produced from proper material in a few months of intensified extension training.

When the war is over, how can this pool of trained men be used for the best good of the entire nation?

It is evident that these men can become a great national resource and the skills which they have developed under the stress of war can be utilized in the more prosaic pursuits of peace. That resource must not be wasted. Mining men throughout the country must seek new mineral frontiers beyond the borders of the United States and take every other precaution to forestall a “have not” position in the world.

Mining is the second basic industry. The opportunities in the post-war period will be many. Investment in education for the mining industry may well supply one of the best, most permanent, and financially profitable programs for promising youth today.

FUEL TECHNOLOGY—CURRICULUM AND CAREER*

By A. W. Gauger†

It is with some trepidation that I approach my subject, for I know that I shall at once incur the suspicion of the mechanical engineer, with his concern for boiler tests and efficiencies; of the mining engineer, with his mechanization problems; and of the chemical engineer with his unit processes. Nevertheless, it must be recognized that the technology of fuels, the systematic body of knowledge relating to the production, processing and utilization of mineral fuels, has grown to such proportions and involves so many widely diverse applications of fundamental science and engineering that it behooves us to stop and consider just what its status is in relation to other technologies, as well as in relation to the present and future needs of the social order. The time has come when technologists, applied scientists, and engineers must consider the possible effects that their achievements may have on society. The development of a machine to replace several hundred men is a fine achievement when considered solely from the point of view of creative endeavor. But what of the men who are displaced by the machine! Does not the responsibility for the development of this machine embrace as well the consequences of obsolescence and technological unemployment resulting from such development? I believe that it does and that we must recognize this fact in our practice of engineering and technology as well as in the training of future engineers and technologists.

Magnitude of the Fuels Industry

Fuel technology is the body of knowledge that relates to the mineral fuels. The fuels industry is by far the most important of all our mineral industries. The chart in Fig. 1, reprinted from U. S. Bureau of Mines Information Circular No. 6643, indicates the comparative values of metals, fuels, and other nonmetallic minerals for the year 1929. Of the grand total of 13½ billions of dollars in value of minerals at the mines, the mineral fuels contributed 48 per cent. Coal, with 34.4 per cent, exceeded the value of any other single mineral. In fact, the value of the production of the Pennsylvania anthracite mines alone annually exceeds the value

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receive a major fraction of their income from the transportation of the solid fuels. And huge sums of money are paid into the public coffers in the form of taxes directly by the industry and indirectly through the medium of taxes on people employed by the industry or, in connection with petroleum products, through taxes on consumers.

If this record of an industry could be translated into a more graphic picture, which would show the jobs created, the homes heated, the ores reduced to metal, the engines moved, the cities and villages lighted, the drugs, dyes, explosives, plastics, and other chemicals manufactured, the freight and passengers transported, we would have some indication of the economic significance of the mineral fuels in modern civilization.

**Need for Technologists**

The need for technologists specially trained for the petroleum industry has been recognized for at least 15 years and petroleum (and in some instances natural gas) engineering curricula are now well established in a number of universities. The petroleum industry early made use of technology and constant research and application of improved methods have resulted in steady improvement in quality of wares and in decreased cost as well. Petroleum is in some respects an ideal raw material, for it is possible, within certain natural limits, to change the yields of the various products by varying the processes of treatment—temperature, for example. The petroleum industry has been flexible and has always been able to meet the demands made upon it by the ultimate consumer. Thus when the demand was for kerosene, the industry produced principally kerosene. When the lighting market was lost to gas and electricity and the demand for motor fuel and lubricants stepped up at an increasing pace, the industry found ways of increasing the yields as well as improving the quality of these products.

The coal-mining industry (referring now to all ranks of coal), on the other hand, has no similar history of technological advance, except in so far as mining is concerned. There, indeed, it has made phenomenal progress in mechanization and other improved mining methods. One of the reasons for this failure of the industry to plow part of its profits back into the business in the form of research is undoubtedly the scarcity of technical men in responsible positions of management. I know of only one coal company that has as its president a man who is a scientist in his own right. This is one of the obstacles to a full appreciation of the value of scientific work and to the selection of properly trained technologists to conduct the work. Very few coal companies, including
those maintaining laboratories, have technologists qualified to originate, pass upon, or carry out research programs. Small wonder then that accumulation of data is mistaken for research and that the management of companies is often poorly advised with reference to matters of research policy.

However, it must not be assumed that no technologic advances have been made in the utilization of fuels, for great improvements have been recorded for all types of consuming equipment. These have been most marked in central electric power stations where the coal required per kilowatt-hour has decreased from over 6 lb. in 1902 to 1.37 in 1940. Good economies have been effected in the operation of steam locomotives (180 lb. of coal per 1000 gross ton-mile in 1917 to 112 lb. in 1940), and iron blast furnaces (3400 lb. coking coal per gross ton of pig iron in 1915 to 2846 lb. in 1940). In fact, most of the large industrial consumers of coal have increased the efficiency of utilization, with a subsequent decrease in their tonnage requirement. These advances have been made by the consumers themselves, largely without any aid on the part of the coal industry. Moreover, little attention has been paid by the producer or any one else to the needs or desires of the small consumer—nor has any agency given attention to coal as a foremost raw material for manufacture of organic chemicals. On the other hand, the petroleum industry has come to regard crude oil as just that, and now makes chemical products that are in competition with products from coal; toluene, for example.

The technology of all fuels has grown enormously during the past several decades. At the same time every phase of recovery, preparation, transportation, marketing, and utilization has become more technical and complex. Hence, the need for well-trained men of many types is increasing. There is room for a few well-placed curricula in Fuel Technology, so that men trained in fundamentals and speaking in the terms of the fuel industry will be available in the future.

**Historical Development of the Curriculum**

Such courses have long been an important part of European university instruction. The curriculum originated, naturally enough, out of demands of the gas industry, which, owing to the nature of the processes involved, required the services of men with a thorough understanding of the scientific principles underlying the processes of manufacture. Thus, in Germany, at the instance of the gas industry, the now famous “Gazinstitut” in Karlsruhe was founded in 1904. Three years later a department for teaching and research in Fuels and Metallurgy, the first of its kind in the British universities, was established at the University of Leeds. This department had the support of the West Yorkshire coal owners as well as of the Institution of Gas Engineers. The scope of the curriculum is indicated by the present title of the department—Coal, Gas and Fuel Industries with Metallurgy. Somewhat later a Department of Fuel Technology was established at the University of Sheffield.

In the United States, on the other hand, although courses relating to fuels have been offered in a number of universities and colleges for many years, these have usually been given in other departments, as for example chemistry, mechanical engineering, or metallurgy. Until very recently, there has been no general recognition of the fact that there exists a distinct need for a curriculum in Fuel Technology in a few institutions of higher learning strategically located with respect to the major fuel-producing and fuel-consuming areas. And yet the American gas industry recognized this need at least 17 years ago when a curriculum in gas engineering was established at The Johns Hopkins University. The support of the gas industry was later withdrawn but the curriculum is still being maintained.

In The Pennsylvania State College, coal washing was an important subject in the mining engineering curriculum as long ago as 1893. This was extended in 1894-1895 to include the erection of “a gas producer, regenerator and furnace for investigation into the economical use of fuels” (quoted from the general catalogue of that year). By 1906, the importance of instruction in the technology of fuels was generally recognized by the College. At that time lecture and practicum courses in coal washing and washing machinery, the preparation of coal for the market, and an elective 10-weeks summer practical course in coal washing were offered under the heading of ore dressing and coal washing. A course in mining was concerned with mechanical treatment and preparation of anthracite and bituminous coal; one in mining geology included the origin, occurrence, distribution, and properties of coal; and courses in metallurgy involved the study of gas producers as well as fuels and fuel testing.

Before the academic year 1908-1909, the courses offered by the School evidently were reorganized. During that year the Department of Mining offered a course titled “Mechanical Preparation of Coal and Dressing of Ores,” which suggests that a consolidation of courses must have been effected. A practicum course pertaining to this subject was also offered. Under Metallurgy there was offered a course in Principles of Metallurgy, Fuel Testing, and Calorimetry. The following year, however, a separate course in fuels and fuel testing again appeared in the College catalogue.
From 1910 to the college year 1918-1919, the courses relating to fuel technology remained substantially unchanged. During the latter year several changes in course title and designation were made and specific courses on fuel testing and calorimetry and on coking were added. During the decade 1920 to 1930, there was growing recognition on the part of the faculty of the importance of advanced instruction and research as well as undergraduate instruction in fuel technology. This is evidenced by the introduction of graduate courses in coal carbonization in 1921 and in utilization of fuels in 1922, by the Department of Metallurgy, and by the publication of several bulletins.

These developments resulted in 1930-1931 in an option in Fuel Technology as part of the metallurgy curriculum. In this option courses were offered to undergraduate students in fuel testing and calorimetry, coking, classification of coals, liquid and gaseous fuels, carbonization and processing of coals, combustion and utilization of solid, liquid, and gaseous fuels. A graduate course was offered in metallurgical utilization of fuels.

Fuel technology had now come of age. Its particular importance as an integral part of mineral industries education in Pennsylvania was recognized by the Board of Trustees of the College and in 1932 a separate curriculum was established for the first time. With minor changes, the courses offered were the same as those offered under the metallurgy option. The Department of Mining offered a lecture course in coal preparation, a practicum course on the same subject, and another course in coal cleaning. The courses offered by the new Department of Fuel Technology were given in the junior and senior years but before that the student had acquired a thorough background in chemistry, mathematics, physics, engineering, geology, and certain cultural subjects.

Although curricula in fuel technology have been offered in English and German universities for many years, the curriculum at The Pennsylvania State College was and is the only general program of this type offered in this country. It was created because of the importance of the fuel-producing and fuel-consuming industries in the state of Pennsylvania and the growing need for men trained in the technology of fuels. At the very outset graduate instruction and training in research methods were offered.

At present, by a process of careful selection and revision of courses in accordance with experience and the needs of the fuels industry, the curriculum in fuel technology has been well established. It has been accredited and has received the commendation of men in the fuels industry who are in a position to appreciate the necessity of a source of young men possessing a knowledge of the origin, constitution, preparation, processing, and utilization of fuels—especially coal.

Scope and Content of the Fuel Technology Curriculum

The scope and content of the fuel technology curriculum is a problem of the first magnitude, and one for which there is no single solution. It involves consideration of needs and trends of the industry, some of which have already been cited. The fuels industry, prior to the present emergency, was faced with a highly competitive situation within itself, which threatened it with disaster. Instead of suffering from the oft-predicted shortage of coal, petroleum and natural gas, the country had a capacity for production greatly in excess of its needs. Coal began to meet greatly increased competition from petroleum, natural gas, and water power. The total energy demand had increased steadily during the past several decades, but the proportionate share of this demand met by coal decreased markedly. During this time the petroleum and natural gas industry expanded enormously and in 1929 supplied about 19 per cent of the world's total demand for energy. In spite of this, however, the oil and gas industries during the past decade were in much the same position as was the coal industry. Over-production, falling prices, financial losses and unemployment characterized the entire fuel industry. Conditions in 1941 were different, to be sure, but there is every reason for expecting after the present war a recurrence of the situation extant in the 1930's. These are economic factors that must be given very serious consideration in future education programs for the training of scientists, engineers, and technologists.

There is still another factor, which, heretofore, has been largely if not entirely neglected; that is, the factor of social utility. In the history of science and invention, the social consequences have been given little consideration. Now, however, mastery over material forces has far outdistanced the old moral and legal controls and the future welfare of society demands a type of scientific leadership that is fully awake to the importance of some sort of moral or social control: whether this will or will not lead to further public regulation than exists at present is an open question. There seems no doubt, however, that the engineer of the future will have to consider factors of economic effects and social expediency to a much greater extent than the engineer of the past. Other factors that must be considered are ones concerned with changing consumer habits, as exemplified by the desire for fully automatic heat.

I have spoken at some length concerning matters which at first glance may appear to be irrelevant. Those of you who have read
“The Education of Henry Adams” may remember his complaint in after life that his years at Harvard College did not prepare him for his life work. Although there may be differences of opinion concerning the objectives and methods of the college and the purpose and advantages of a college training, there can be no doubt that the college training to be effective must fit one not for the present environment but for one that is yet to come. In studying curriculum problems, therefore, it is of greatest importance to project oneself into the future and attempt to anticipate, however inadequately, some of the demands that may be made upon graduates in the future. These matters are of general application to all applied sciences. The fundamental scientist need not be concerned therewith except insofar as support for his researches depends upon any changes that may take place in our national habits of underwriting such work. Since he is engaged in increasing the world’s supply of knowledge, he may rest assured that sooner or later his work will reach some utilitarian application.

How, then, shall we train our future fuel technologists so that they are equipped to meet the demands that the future will make upon them? That is indeed a difficult question to answer, since no one, especially during these times, can foretell what the future will be like. Furthermore, other limitations are placed on our choice of subjects to be included. One of these is the duration of the curriculum. Here we are limited to the fact that the majority of the engineering schools and colleges still adhere to the four-year curricula and industry seems to feel that the engineering student should secure his essential academic preparation in a terminal four-year program. Yet, it is increasingly apparent that four years of collegiate preparation are not enough to accomplish more than a superficial outline of the professional field. Five years would make possible a much more thorough training. The gas industry has recognized the shortcomings of a four-year program and has established an Institute of Gas Technology—in reality a graduate school for the industry—of which the objectives are: training of men for the industry, fundamental and applied research, collection and dissemination of scientific information and encouragement of further research by others in the business.

Regardless, however, of the length of time allotted to the curriculum, the difficulties of predicting the future make it imperative that any curriculum devote a large part of its program to the basic subjects that time has demonstrated to have lasting value; that is, mathematics, physics, chemistry, earth sciences and English. To these, then, will be added the general engineering subjects that are a part of every engineer’s training, economics and the profes-

Table 1.—Curriculum in Fuel Technology at the Pennsylvania State College

<table>
<thead>
<tr>
<th>First Semester</th>
<th>Credits</th>
<th>Second Semester</th>
<th>Credits</th>
</tr>
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<tr>
<td>Chem. 1, Inorganic Chemistry</td>
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<td>Chem. 2, Inorganic Chemistry and Qualitative Analysis</td>
<td>5</td>
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<td>Dr. 1, Engineering Drawing</td>
<td>2</td>
<td>Engl. Comp. 5, Exposition</td>
<td>3</td>
</tr>
<tr>
<td>Engl. Comp. 1, Composition and Rhetoric</td>
<td>3</td>
<td>Geog. 9, Geography of Mineral Resources, or Dr. 2, Descriptive Geometry</td>
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<tr>
<td>Geol. 31, Physical Geology</td>
<td>3</td>
<td>Geol. 32, Historical Geology</td>
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<td>Math. 7, Analytic Geometry</td>
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<td>Physical Education 2</td>
<td>1</td>
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<td>Physical Education 1</td>
<td>1</td>
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</tr>
<tr>
<td>R.O.T.C. 1</td>
<td>1 1/2</td>
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SOPHOMORE YEAR

<table>
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<tr>
<td>Math. 29, Differential Calculus</td>
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<td>Chem. 20, Quantitative Analysis</td>
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<td>Min. 31, Elementary Mineralogy</td>
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<td>Math. 30, Integral Calculus</td>
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<td>Phys. 221, General Physics</td>
<td>3</td>
<td>Fuel T. 1, Fuel Testing and Calorimetry</td>
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<tr>
<td>Phys. 232, Physical Measurements</td>
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<td>Phys. 281, General Physics</td>
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<td>C.E. 111, Plane Surveying or approved electives</td>
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<td>Phys. 232, Physical Measurements</td>
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<td>An approved elective</td>
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**JUNIOR YEAR**

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<tr>
<td>Chem. 32, Carbon Compounds</td>
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<tr>
<td>Chem. 40, Introductory Physical Chemistry</td>
<td>3</td>
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<tr>
<td>Chem. 42, Experimental Physical Chemistry</td>
<td>1</td>
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<tr>
<td>E.E. 8, Dynamo Machinery</td>
<td>2</td>
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<tr>
<td>El. Lab. 8, Electrical Engineering Laboratory</td>
<td>2</td>
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<tr>
<td>Fuel Tech. 2, Advanced Fuel Testing</td>
<td>3</td>
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<tr>
<td>Fuel Tech. 3, Solid and Liquid Fuels</td>
<td>2</td>
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<tr>
<td>Mchs. 7, Mechanics</td>
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<tbody>
<tr>
<td>Chem. 33, Carbon Compounds</td>
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</tr>
<tr>
<td>Chem. 41, Introductory Physical Chemistry</td>
<td>2</td>
</tr>
<tr>
<td>E.E. 9, Industrial Electrical Applications</td>
<td>2</td>
</tr>
<tr>
<td>Engl. Comp. 23, Report Writing</td>
<td>2</td>
</tr>
<tr>
<td>Fuel Tech. 6, Distillation of Coals</td>
<td>2</td>
</tr>
<tr>
<td>Fuel Tech. 80, Junior Field Trip</td>
<td>1</td>
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<tr>
<td>Mchs. 8, Mechanics</td>
<td>3</td>
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<td>Mng. 1, Elements of Mining</td>
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**SENIOR YEAR**

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<tr>
<th>First Semester</th>
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<tbody>
<tr>
<td>Fuel Tech. 4, Thermal Reactions of Fuels</td>
<td>3</td>
</tr>
<tr>
<td>Fuel Tech. 99, Seminar</td>
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</tr>
<tr>
<td>Fuel Tech. 401, Gas Manufacture</td>
<td>3</td>
</tr>
<tr>
<td>Fuel Tech. 403, Energetics of Fuel Technology</td>
<td>3</td>
</tr>
<tr>
<td>Mng. 85, Mineral Preparation</td>
<td>2</td>
</tr>
<tr>
<td>Mng. 86, Mineral Preparation Laboratory</td>
<td>1</td>
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<tr>
<td>M.E.101, Elements of Power Engineering</td>
<td>2</td>
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<tr>
<td>M.E. 103, Power Laboratory</td>
<td>1</td>
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<tr>
<td>Met. 58, Engineering Metallurgy</td>
<td>2</td>
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<table>
<thead>
<tr>
<th>Second Semester</th>
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<tbody>
<tr>
<td>Chem. Eng. 3, Chemical Engineering</td>
<td>4</td>
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<tr>
<td>Fuel Tech. 5, Fuel T. Design</td>
<td>3</td>
</tr>
<tr>
<td>Fuel T. 81, Senior Field Trip</td>
<td>1</td>
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<tr>
<td>Fuel T. 100, Thesis</td>
<td>3</td>
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<tr>
<td>Fuel T. 402, Processing of Coals</td>
<td>3</td>
</tr>
<tr>
<td>Mchs. 3, Engineering Materials</td>
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<tr>
<td>Mchs. 5, Testing Materials</td>
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<td>Mng. 492, Advanced Mineral Preparation</td>
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**Table 2.—Undergraduate Program in Fuel Technology**

<table>
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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>Mathematics</td>
<td>14</td>
</tr>
<tr>
<td>Physics</td>
<td>10</td>
</tr>
<tr>
<td>Chemistry and Chemical Engineering</td>
<td>30</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>12</td>
</tr>
<tr>
<td>English</td>
<td>8</td>
</tr>
<tr>
<td>Electives, Foreign Languages, Humanities, Administration, Management</td>
<td>10</td>
</tr>
<tr>
<td>Drawing, Mechanics and Strength of Materials, and General Engineering</td>
<td>30</td>
</tr>
<tr>
<td>Fuel Technology</td>
<td>30</td>
</tr>
<tr>
<td>Physical and Military Training</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>154</td>
</tr>
</tbody>
</table>

Fourteen credit-hours of advanced algebra, plane trigonometry, analytic geometry, and the integral and differential calculus should be sufficient mathematics for all ordinary problems that the fuel technologist will meet in his professional career. As preparation
for graduate work it would be desirable to include three credit-hours of differential equations, if the time were available.

Ten credit-hours of physics and 30 of chemistry and chemical engineering cover the various fields of physics needed for engineering work as well as general chemistry, qualitative and quantitative analysis, physical chemistry, introductory organic chemistry, and the basic principles underlying unit operations in industrial chemical processes. This is very much more chemistry than the average engineer is exposed to—a weakness in much of our engineering training—but most of the processes through which fuels go in the course of their preparation and ultimate utilization are chemical processes.

Twelve credits of earth sciences include physical and historical geology, geography of mineral resources, and elementary mineralogy. Some engineers and fuel technologists may question so large an allotment of time to these subjects but geology is essentially a cultural subject. We live on the earth and everyone should have some knowledge of it. Furthermore, the mineral fuels are obtained from the earth and the fuel technologist may run up against problems related to their occurrence. It is doubtful whether an introduction to these subjects can be obtained in less time.

The allowance of 8 credit-hours for English and 10 credit-hours electives in foreign languages, humanities, administration and management is admittedly less than might be desired. It does, however, permit an introductory course in economics, some work in English composition and report writing, and some opportunity for election of courses by the student.

The 30 credit-hours of drawing, mechanics, and general engineering subjects are adequate for groundwork in mechanics and strength of materials, as well as an introduction to mechanical, electrical, and mining engineering, and metallurgy and mineral preparation. It is conceivable that some work in ceramics (on refractories) and in petroleum and natural-gas engineering would also be desirable, but once more we are faced with the limitation impressed upon us by the restriction of a four-year program.

The 30 credit-hours of fuel technology are designed to give a thorough grounding in fuel sampling and analysis, the reactions that fuels go through on heat-treatment, the manufacture of gas from solid and liquid fuels, the miscellaneous processing of coals such as briquetting or hydrogenation, application of thermodynamic principles to fuels problems, and fuel technology design. Opinions will vary as to the time to be allotted to the purely professional subjects as well as to their nature. Thus the curriculum in gas engineering at The Johns Hopkins University gives par-

icular attention to that specific branch of fuel technology. The tendency there is to give more chemical engineering subjects. On the other hand, at the University of Iowa there is an option in Fuel Technology in the Department of Mechanical Engineering. The fuel technology courses are decidedly meager and there is a woeful lack of training in chemistry. The curriculum is in reality one in mechanical engineering with the election of a few specific courses in fuel technology during the junior and senior years. These include fuel production and utilization, theory of combustion, heat transfer and design of industrial furnaces, and preparation of fuels and disposal of wasted products of combustion. While such training may be satisfactory for a mechanical engineer who is going into power-plant operation or furnace design, it will hardly suffice for an all-round fuel technologist. The course leans entirely too heavily on mechanical engineering, and illustrates one of the difficulties arising from considering fuel technology as a stepchild of some established curriculum, whether metallurgy, chemical, or mechanical engineering. I have heard one engineer and educator question the need for a specialized curriculum, although he did not question the opportunities in the fuels field. This man believes that:

Any engineering student gets all the basic science that is necessary as a foundation. Either a chemical engineer or a mining engineer has most or all of the supplementary chemistry that is needed but could probably profit by additional courses in heat power engineering and fuels. Mechanical engineers have abundant training in the heat power field but usually are somewhat deficient in quantitative and fuel chemistry, and have only a sketchy idea of fuels. For a young man in any one of these engineering curricula who looks forward to fuel engineering as a career, the proper selection of a few hours of elective work in the fields in which his curriculum is short would be sufficiently well prepared.

I consider this attitude to be exceedingly short-sighted; such a policy can only produce inadequately trained men, whereas the fuels industry needs technologists with first-class training and with a feeling for the dignity of the profession of fuel technology.

Rose has another point of view, to which I subscribe. To quote from his remarks before the Gas and Fuel Division of the American Chemical Society in April 1940:

Some educators and executives favor a training in fundamentals, with no technologic courses during undergraduate years. Others favor offering, to a limited number of interested students, fundamental training plus courses intended to prepare them for special work such as fuel technology. In the writer's own experience, which has included all three major types of solid fuels, both methods of training have produced valuable men.

Large engineering or research organizations, which are well staffed and progressive, can take a young engineer or research man who has had no previous contact with their field of work,

1 Transactions Third Annual Anthracite Conference of Lehigh University, 1940, p. 42.
and train him to become a valuable member of their organization. Executives who favor this procedure sometimes forget that for every organization which is qualified to do this, there may be a dozen or more small producers, consumers, retail dealers, etc., who need a single technical man badly. They are in no position to give him engineering training; instead they must look to him for information. If they are in a position to hire an experienced man away from a competitor, they will prefer a young technical man who has already shown interest in their industry, and who has invested some of his own time preparing for it. They will want a man who already has some familiarity with their problems, if only through textbooks. He will at least have a few reference books of his own, and will know where to go for specialized technical help when he needs it.

This is one reason for the existence of a somewhat specialized curriculum like Fuel Technology (which is the science of preparing and utilizing fuels). Another purpose is to provide elective or post-graduate courses for students majoring in other lines of engineering or science, who recognize the basic importance of fuels.

It seems evident that if fuel technology is to develop and fulfill its mission it must do so through the efforts of fuel technologists. It must be recognized as a technology in its own right and it must be favorably spoken of and placed before the industry and the secondary schools.

The writer has yet to touch upon the development of a sense of social responsibility as part of the training of engineers. Table 1 reveals no courses in this subject—nor does it seem possible that there can be such specific courses. Each faculty member must strive in each course to instill in his students a sense of social responsibility. The titles of courses, are, after all, unimportant. The quality of higher education depends upon faculty, equipment, and students. The faculty must be alert, familiar with industrial processes in its field, alive to new developments, active in research and above all sympathetic and friendly with students. If, in addition, the faculty members themselves have a sense of social responsibility, they can do much in their respective courses to awaken such a sense in the students. This is particularly true if the classes are not too large.

**Who Employs Fuel Technologists**

At this point it seems only reasonable to inquire who employs fuel technologists. Certainly the solid fuels industry will require an increasing number of fuel technologists. Such men are needed by the producing companies, sales agencies, and equipment manufacturers who design and manufacture equipment for preparation, treatment, and utilization of coal. The railroads use them to promote the sale of coal originating on their lines and to aid in the selection of coals and the design of combustion equipment. By-product coke plants and gas companies, power plants, steel companies and other metallurgical plants, also have extensive use for fuel technologists.

The sale of fuel by retailers and by wholesalers in the future will be guided by technologists. The installation of oil burners and coal stokers, the development of air conditioning as well as other modern advances in home heating, hot-water supply, etc., will make it necessary for progressive fuel dealers to sell service rather than merely to take orders. There will be excellent opportunities in this field for the young technical man who can make simple layouts and cost estimates, advise builders and architects and develop the ability to sell service as well as competitive engineering products.

A large number of fuel technologists, including some of the best known, are connected with federal and state agencies, or with colleges and universities, or are connected with the research and development programs of various trade and marketing associations.

That there is a demand for the graduates is evident, for at no time during the past 9 years have we had enough at The Pennsylvania State College to fill all the requests from companies seeking to employ them.

**Graduate Study and Research**

Graduate study and research are also important in modern education. To serve society adequately in the solution of the social and economic problems facing the mineral industries, our colleges must educate leaders by graduate as well as undergraduate instruction and must supply leadership in the solution of technical problems by research.

During the early part of the present century the need for research was not felt by the fuels industry, particularly the coal industry. Enormous deposits of high-grade coal were available and the best seams and those most easily worked were being mined with profit. Coal was king and oil and natural gas were just beginning to offer serious competition. Today the picture is changed and the dominant need of the industry is for research.

The two chief objectives in graduate study are to strengthen the student's grasp and to broaden his knowledge of his general subject; and to develop his ability to apply existing knowledge in new directions. The primary approach in the first instance is made through supervised study; in the second, through original research. To accomplish these objectives, the student is advised to select courses in those fields of science and technology in which he is deficient. Specific courses in fuel technology are limited in number,
but the student is required to devote a considerable share of his time to research on some problem in this field. It is believed that "learning by doing" offers the best method for research training. At the same time the student is encouraged through seminars and individual conferences to read widely in the current literature in fuel technology.

To sum up, the writer has shown that the body of knowledge that comprises the technology of fuels has become so extensive that its consideration as a separate branch is warranted; conditions in the fuels industries have changed during the past several decades, so that men specifically trained in fuel technology are needed; there is a need for a curriculum in fuel technology in a few colleges and universities strategically located with reference to fuel resources; the objectives, scope, and content of such a curriculum are discussed; opportunities for employment are indicated.

DISCUSSION

E. G. Bailey,* New York, N. Y.—There is much in Dr. Gauger's paper with which I fully agree, but I would like to take the liberty of discussing some points with a view to clarification and others from the viewpoint of constructive criticism.

The metallurgist was the first user of coal requiring knowledge of its chemistry. The usual analysis is largely based on the needs of the metallurgist, and such analyses, tabulated in many forms from various sources, comprise the most complete chapter in coal technology. In fact, many people have a misconception that chemical analyses in themselves are the end instead of only the first stepping stone toward other knowledge so urgently needed by many users. The gas and coke industries have done well in carrying the chemistry and properties of coal further for their specific requirements.

Due largely to the mechanical engineer and the use of coal for steam generation, the chemical laboratory work has been extended to include calorific value, then the fusible temperature of coal ash, and later grindability, friability, agglutinating properties. We still need more knowledge of clinkers and slag behavior under different conditions and atmospheres in which coal is burned.

We know much about the making of gas and coke and the complete combustion of the fuel elements, but we must rapidly learn much more about the combustion and chemical reactions of the impurities, such as the FeS₂, FeS, Fe, FeO, Fe₂O₃ series, as well as the alkalies and their reactions in oxidizing and reducing atmospheres.

* Vice President, The Babcock & Wilcox Co.

We must know more about ignitibility, reactivity of coal and coke in pulverized form. We know much less than we should about accurate furnace temperatures, gas stratification, and the actual path of gases in furnaces and its effect upon results.

Dr. Gauger sees great advance in the use of coal by central electric companies made by themselves largely without any aid on the part of the coal industry. He seemingly overlooked the part played by the manufacturers of coal-burning and steam-generating equipment. The early stoker development was largely by manufacturers of stokers without much aid from the boiler manufacturers, and little from the users except as the latter bought and tried out new developments in an effort to use cheaper coal, obtain better efficiency, and to save labor. Modern development of water-cooled furnaces for pulverized coal, and the multi-fuel burning equipment for coal, oil, and gas, can only be brought about through a unifying of design by the manufacturer of fuel-burning and steam-generating equipment. Central stations, with their rapid expansion, have been the best purchasers of this rapidly developing line of equipment, because it paid them well to follow such advances. Smaller power users have also followed this progressive trend, but more slowly.

This development has not been done by mining engineers, chemical engineers, mechanical engineers, nor even by "fuel technologists," as Dr. Gauger trains them, but by groups of men and individuals who have combined knowledge of fuels, combustion, ash and slag behavior, thermodynamics, heat transfer, boiler circulation, water treatment, steam purification, and the flow of fluids under a large variety of conditions. A modern steam-generating unit cannot be an aggregation of parts of an equipment of which each is designed by a specialist; it must be an integrated whole wherein all of the many requirements are met in a satisfactory and economic manner.

In the conventional steam locomotive, for instance, the coalburning and steam-generating problems are so closely linked together that one cannot be changed without seriously affecting another. As a result of the lack of men trained well enough in modern developments of both lines jointly, the iron horse has remained a most inefficient coal-burning unit, requiring the most elaborately prepared and expensive fuel for its highest possible capacity, and at the same time limiting the power and efficiency of the boiler because of the low steam pressure, low superheat, and high carry over of moisture and solids from the boiler to the engine.
Who Employs (or Should Employ) Fuel Technologists?

A. Coal Producers
   1. There is no disagreement on this question, but it is my observation that in this industry the fuel engineers now employed are better trained in production, cleaning, and simple chemistry than in the use of coal.
   2. Those contacting or servicing users should be well versed in the broad field of the use of coal in the plants of their customers. The present college training facilities are inadequate for the best service to this industry. Men for this class should have postgraduate courses in the way of jobs with equipment manufacturers or large consumers.

B. Equipment Manufacturers
   1. Mining, loading, preparation, crushing, screening, cleaning, treating, etc.
   2. Processing, gas, coke, etc.
   3. Metallurgical and ceramic.
      The present training in many schools is inadequate to start satisfactorily in these industries, but a still better curriculum is desirable.

   Present training is inadequate, and Dr. Gauger's curriculum might well be modified to include less geology, surveying, mining, and even processing, and include more thermodynamics and power engineering.
   5. Domestic and small direct-heating units.

   Dr. Gauger's curriculum probably adequate, with some reduction mentioned for B-4, and more inspiration to invent and develop and market a real worth-while domestic coal-burning unit.

C. Consumers
   1. Processing, gas, coke, etc.
   2. Metallurgical and ceramic. Requirements similar to B-1, 2, 3.
   3. Steam-power plants: (a) central stations; (b) industrial plants. Requirements similar to B-4.

D. Railroads
   1. Extension work as partners with coal producers. Requires similar training and experience to A-2.
   2. Locomotive, design and operation. Training should be more like that desired for B-4.

E. Technical—Laboratories
   1. Commercial laboratories.
   2. Consulting engineers.
   3. Teaching.

   Dr. Gauger's curriculum is probably adequate for beginners in E-1, but of course for E-2 and E-3 a wider experience is needed, and that carries us beyond curriculum for bachelor's or even doctor's degree.

   The classifications and requirements given above may be reclassified regardless of employment by producer, equipment manufacturer, user, etc., into the three major uses of coal, viz:

   **Approximate Percentage of Total Coal Production**

<table>
<thead>
<tr>
<th>Uses</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>1. Process (steel, coke, metallurgy, etc.)</td>
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</tr>
<tr>
<td>2. Steam power and larger heating boilers:</td>
<td></td>
</tr>
<tr>
<td>Electric utilities</td>
<td>12</td>
</tr>
<tr>
<td>Railroads</td>
<td>20</td>
</tr>
<tr>
<td>Manufacturing industries</td>
<td>25</td>
</tr>
<tr>
<td>3. Domestic and retail</td>
<td>20</td>
</tr>
</tbody>
</table>

   In my opinion Dr. Gauger's curriculum is better for training men for work in the process uses than for the steam-power group. The importance of the latter fully justifies a curriculum previously stated in discussing B-4.

   The definite importance of thermodynamics and power engineering for certain work, beyond that now prescribed in any known chemical engineering, fuel engineering, or fuel technology course, has made it seem necessary for us to select mechanical engineers, preferably with the maximum of chemistry as electives, and teach them more of the chemistry and metallurgy and ceramics as needed and from actual experience, than to take and try to ground him in thermodynamics and power engineering.

   Most engineering courses need more than is now prescribed in physics, economics, English (spoken, written, and vocabulary), as well as management and administration.

   In my opinion, Dr. Gauger's history of the development of fuel engineering or technology is inadequate, if not actually misleading. It is a subject of sufficient importance for a committee to take up the task of compiling a fairly complete and accurate chronology of development in fuel engineering curricula.

   Such a history would indicate that while certain progress in Europe preceded that in this country the greater progress has been
made here. Great credit goes to the geologists, viz: M. R. Campbell, J. A. Holmes, I. C. White; to the U. S. Geological Survey—1904—later U. S. Bureau of Mines; also to Professors Parr and Breckenridge, of the University of Illinois, and Professors N. W. Lord and Hitchcock, of The Ohio State University.

Undoubtedly more fuel chemists and engineers gained their early inspiration and training from the men mentioned above than from all others combined.

**Author’s reply**

A. W. Gauger.—Mr. Bailey’s stimulating and provocative remarks seem to me to be a potent argument in favor of a specialized curriculum in fuel technology. His admission that the advances in the use of coal that have been made by equipment manufacturers were accomplished “by groups of men and individuals who have combined knowledge of fuels, combustion, ash and slag behavior, thermodynamics, heat transfer, boiler circulation, water treatment, steam purification, and the flow of fluids under a variety of conditions” certainly bears out my fundamental thesis, which is that there is an increasing need for specialized training in the technology of fuels.

Mr. Bailey’s suggestions as to content of the curriculum are both suggestive and interesting. They reflect the point of view of his very considerable experience and must be given serious consideration. However, to eliminate such a cultural subject as geology (the writer believes that since man lives on the earth he should know something about it) does not seem wise. Surveying can well be eliminated and is optional in our curriculum. Some knowledge of mining and preparation is desirable even for combustion engineers, because it indicates limitations beyond which the “manufacturers of coal” cannot go without adding to the cost of the fuel. Even design of fuel-burning equipment must take cognizance of the fuels that are available.

With reference to Mr. Bailey’s final remarks on the history of the development of fuel technology, may I point out that the section referred to is entitled “Historical Development of the Curriculum.” We have had excellent fuel technologists and Mr. Bailey himself is one of the pioneers. However, these men have been strong personalities with a consuming interest in fuels. They accomplished their results despite the prevailing attitude toward the science of fuels. And following the passing of men like Parr and Lord there was no continuity such as would have been provided had they been heads of established departments of fuel technology or fuel engineering.