Mineral Industries

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NUMBER 2

College of Mineral Industries

EXTRACTION UTILIZATION EXTENSION INSTRUCTION RESEARCH DISCOVERY CONSERVATION

The Pennsylvania State University

STATE COLLEGE, PA., NOVEMBER, 1954

New Chemical Industries Utilizing Coal

C. R. Kinney*

The President's Materials Policy Commission predicts that more than 15 billion pounds of aromatic chemicals will be consumed annually by 1975. Since this is about 5 times the present rate of consumption of these important chemicals, new methods must be found to produce the additional quantities needed. The present major sources of these chemicals are the light oils and tars produced by the manufacture of coke for the smelting of iron. But since the expansion in the demand for steel is expected to be only a fraction of that for aromatic chemicals, this source will be definitely inadequate. In fact for the last several years, the ubiquitous petroleum industry has been extracting certain aromatics from petroleum which have materially aided the expansion of the aromatic industry. However, additional sources are needed, and the Department of Fuel Technology, recognizing this trend, has been directing a part of its research program into this area. This work has been concentrated largely upon the constitution of coal which is composed of predominantly aromatic structures. With a better knowledge of the constitution of coal, means should be found for producing aromatics in larger yields than those obtained by decomposing coal in the coke oven.

By far the most promising industrial development of converting coal to aromatic chemicals is the process of limited hydrogenation used at Carbide and Carbon Chemical Company's plant at Institute, West Virginia. By means of this process, many of the aromatic chemicals required by the chemical industry for the manufacture of large volume products, such as synthetic rubber, plastics, resins, and detergents are produced.

In Carbide's process, clean powdered coal is heated to about 900°F. with hydrogen under pressure and a catalyst. The purpose of this is to introduce the hydrogen required to form the products wanted in larger quantities than may be obtained by heating the coal alone in the coking process. Coal consists of giant molecules which disintegrate when heated. In the presence of hydrogen and a suitable catalyst to

(Continued on Page Two)

* *Professor of Fuel Technology*

Mineral Industries Auditorium

A welcome addition to the College of Mineral Industries is the auditorium located in the new wing of the Mineral Sciences Building. While the room will provide a meeting place for groups such as the Pennsylvania Ceramics Association, the American Society for Metals, and the annual Technical Conference on Secondary Recovery Methods, it will also be used for meetings of organizations other than those associated with the mineral industries.

Dean Edward Steidle, who retired last year after serving 25 years as dean of the College of Mineral Industries, and members of the staff planned the auditorium when the new wing to the building was developed. The unit, which was completed early this year, was one of the General State Authority's projects at Penn State.

Stuart Frost, a 28-year-old artist whose home is in State College, painted the murals. He is a Penn State graduate and has completed advanced work at New York University. He assisted Henry Varnum Poor when he painted the Land-Grant Fresco at Penn State and more recently worked with Allyn Cox in his completion of the famous fresco in the dome of the Capitol in Washington, D. C.

The basic colors in the murals in the auditorium are gray and gray-blue, sparked with accents of red, yellow, and light blue. Red seats add to the color scheme. To add life to the murals, which consist largely of maps and printing, Frost devised a series of texturing wheels. These included one, three, or five small wheels mounted on a common axle. They were used instead of brushes to produce cross-hatching patterns that give the effect of a textured surface.

On the front wall of the auditorium are two large maps of Pennsylvania, one showing the mineral wealth with which the State was endowed, the other depicting the mineral industries that have been developed in Pennsylvania.

To the left, a large map of the United States indicates the flow of minerals from nearly every state to Pennsylvania, while on the opposite wall a map of the world depicts the flow of minerals from all parts of the globe to the United States.

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View Toward Right Wall

Mineral Industries

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PENNSYLVANIA'S
COLLEGE OF MINERAL INDUSTRIES
Dedicated to

Instruction and research in all fields of mineral discovery, extraction, and utilization to the end that true conservation—the efficient exploitation of known mineral deposits, the discovery of new deposits, and the development of new techniques for using mineral raw materials not now industrially employed—shall be achieved now and in the future.

DIVISIONS OF SERVICE

EARTH SCIENCES: Geology, Mineralogy, Geography, Geophysics, Geochemistry, and Meteorology.

MINERAL ENGINEERING: Mining Engineering, Mineral Preparation, Petroleum and Natural Gas Engineering, and Mineral Economics.

MINERAL TECHNOLOGY: Metallurgy, Ceramics, and Fuel Technology.

FIELDS OF WORK

Resident Instruction
Research
Extension Instruction
Correspondence Instruction

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NOVEMBER, 1954

Industries Utilizing Coal

(*Continued from Page One*)

help the reaction, the fragments combine chemically with the hydrogen gas pumped in to form molecules which can be separated readily by distillation. In the coking process only the fragments that are volatile and can stabilize themselves by some chemical shift in their structure escape from the oven, the major part remaining and undergoing progressive decomposition until nearly pure carbon remains. With hydrogenation, however, a large part of the coal substance can be converted to products which are used in various chemical processes. By continuing the hydrogenation a little further, gasoline and other liquid fuels can be obtained. This "know how" and plant equipment could be of inestimable value in a national emergency in which our supplies of liquid fuels were impaired.

Carbide's process is not essentially new or unique, but required an expenditure of some eight million dollars, beginning nearly twenty years ago, before the difficulties of the process were finally worked out in their research laboratories, and an additional eleven million dollars to build the first plant. This plant has a capicity of 300 to 600 tons of coal per day depending on the type of operation and is considered to be the prototype of 3000-tons-per-day units.

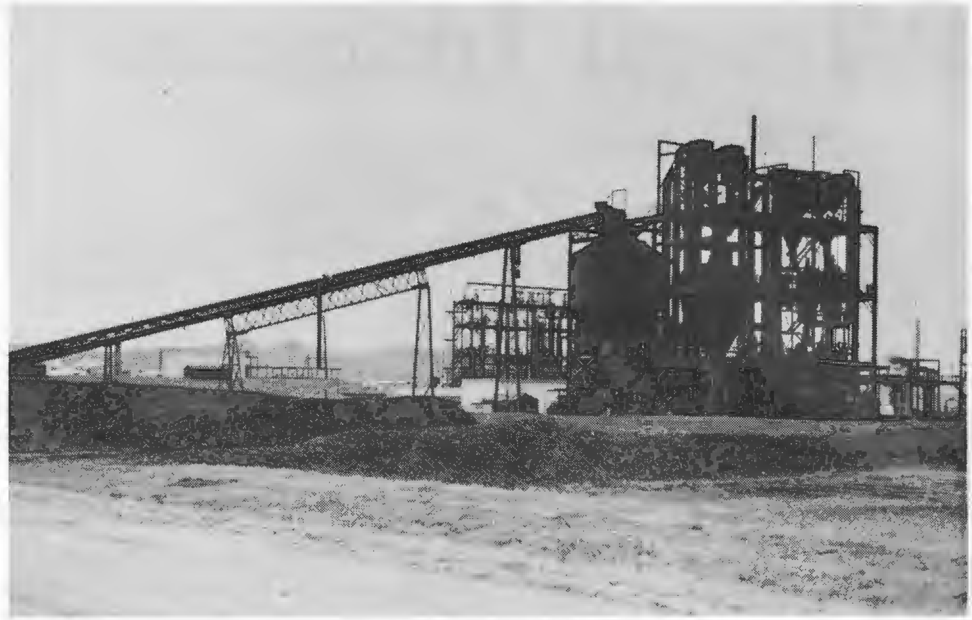

Figure 1. Coal-Oil Slurry Compounding Unit.

The plant involves five main operations. The first is the coal preparation unit shown in Figure 1. Here the coal is crushed to 20-mesh size, dried, and mixed or pasted with two to three times as much aromatic oil. The oil is later recovered. This coal-oil slurry is then pumped through a preheater which is located within the left-hand tower in Figure 2. Here the slurry is brought up to reaction temperature. From the preheater it passes into the bottom of the center reaction vessel where it is mixed with hydrogen at about 5000 pounds per square inch pressure. The mixture of coal, oil, and hydrogen flows upward through the reactor at about 900°F. and with a residence time of only about three minutes. The mixture then passes into the hot separator on the right where the excess hydrogen and vaporized products are separated from the hot nonvolatile liquid products, unreacted coal (fusain and opaque attritus), and mineral matter.

The latter solids are separated while the mixture is still hot and the liquid portion run to pitch in a continuous still. These operations are accomplished in the equipment shown in Figure 3. The volatile oils distilled from the pitch are taken to the fractionating column where a cut having the highest solvent action on the coal is removed and recycled for pasting with fresh coal entering the process. The low-boiling oil taken from the top of the column is used for washing the residue of mineral matter and unreacted coal. The pitch obtained from the process is charged to coking stills where it is converted to pitch coke. This is a major product amounting to about 40% of the total. It is high-grade metallurgical coke and, having properties similar to petroleum coke, is available for the manufacture of graphite electrodes.

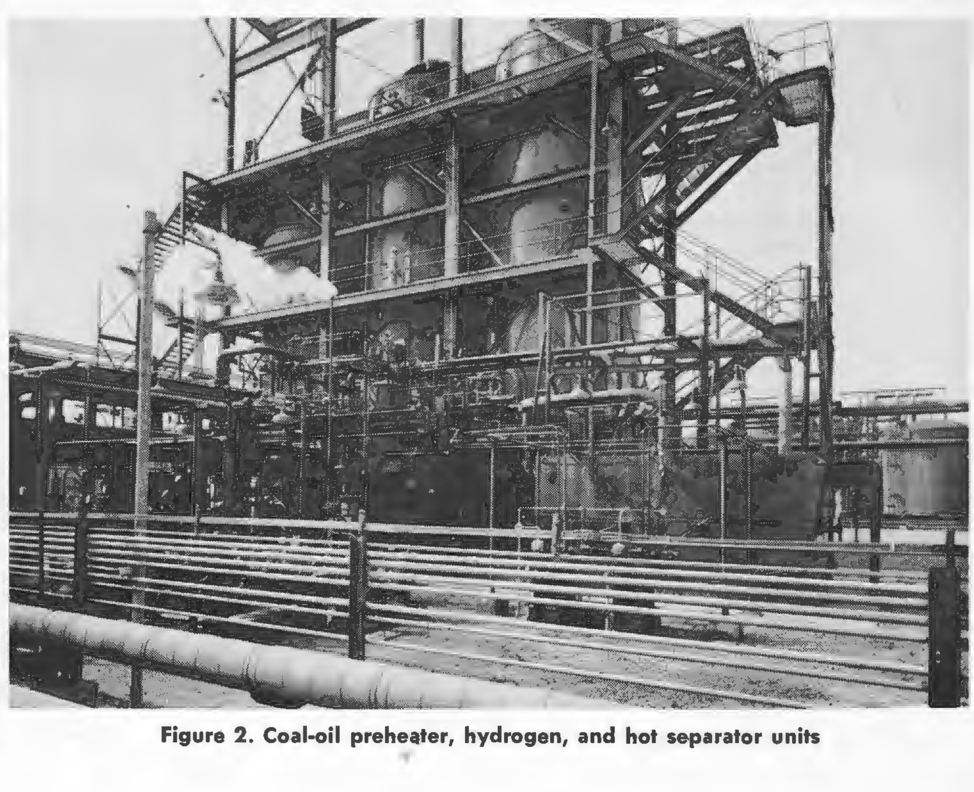

Figure 2. Coal-oil preheater, hydrogen, and hot separator units

The overheated steam from the hot separator passes out through heat exchangers and condensers at the ground level and then into a horizontal cold separator behind the steel barricade in the right foreground of the photograph. Here the pressure is released and the stream is separated into gas and liquid phases. The gas is largely hydrogen which is recycled. However, hydrogen sulfide, ammonia, and gaseous hydrocarbons from the methane to butane are formed, which if continually recycled, would build up to the point where they would interfere with the reaction of the hydrogen with the coal. Furthermore, since these products are valuable chemicals, it pays to remove them. The hydrogen sulfide may be converted to sulfur or sulfuric acid, the ammonia to ammounium sulfate for fertilizer or it can be used for other purposes such as making ethanol amine, etc.; and the hydrocarbon gases can be cracked to make more hydrogen for the process and olefinic gases for the manufacture of aliphatic chemicals.

The liquid-phase stream, however, contains the aromatic chemicals of greatest interest and is separated into a large variety of products in the maze of fractionation and extraction columns shown in Figure 4. Figure 5 shows the fractionating columns from the opposite side with the product receiving tanks in the foreground. Four main fractions are obtained: (1) volatile hydrocarbons; (2) bases; (3) phenols; and (4) residual oils.

The hydrocarbon fraction is a distillation cut including benzene, toluene, and the xylenes. The bases and phenols are removed by continuous solvent extraction processes. The bases are further fractionated in a distillation column giving cuts containing aniline, toluidines, xylidines, and quinoline. Higher boiling fractions contain methyl quinolines and high boiling pyridines. These sustances are also being studied for possible uses. The phenol extract is fractionated into phenol, cresols, xylenols, cresylic acid, and high-boiling phenols.

The residual steam, after removing the bases and phenols, is further fractionated to remove naphthalene and the final residue cut into low- and high-boiling aromatic solvent oils. From the latter many additional aromatic chemicals are being separated and purified. Whether these will become important raw materials for industry will depend on the ability of future generations of organic chemists to find uses for them, but considering the rapid expansion of the synthetic chemicals industry this seems to be a foregone conclusion.

Many of the aromatics now being produced in large volume by coal hydrogenation fit into a number of important phases of chemical industry. And increased production of these chemicals, as the larger plants envisioned by Carbide are built, will help attain the goals set by the President's Materials Policy Commission.

Major uses for the compounds obtained by coal hydrogenation include many important products. Benzene is used for the manufacture of styrene which is used in large tonnages for making synthetic GR-S rubber for automobile tires, and other rubber goods, rubber based paints, concrete water proofing in basements, adhesive tapes, etc. Another important use of styrene is for making polystyrene plastics used for many molded items.

Large quantities of benzene are also used for converting to phenol, aniline, and many other chemicals, all of which have many diverse uses. Oxidation produces maleic anhydride used in making alkyd resins. Benzene may also be used as a starting material for synthesizing the chemicals needed for making nylon, for many of the chlorinated chemicals used as insecticides, and for numerous other products of lesser importance volume-wise.

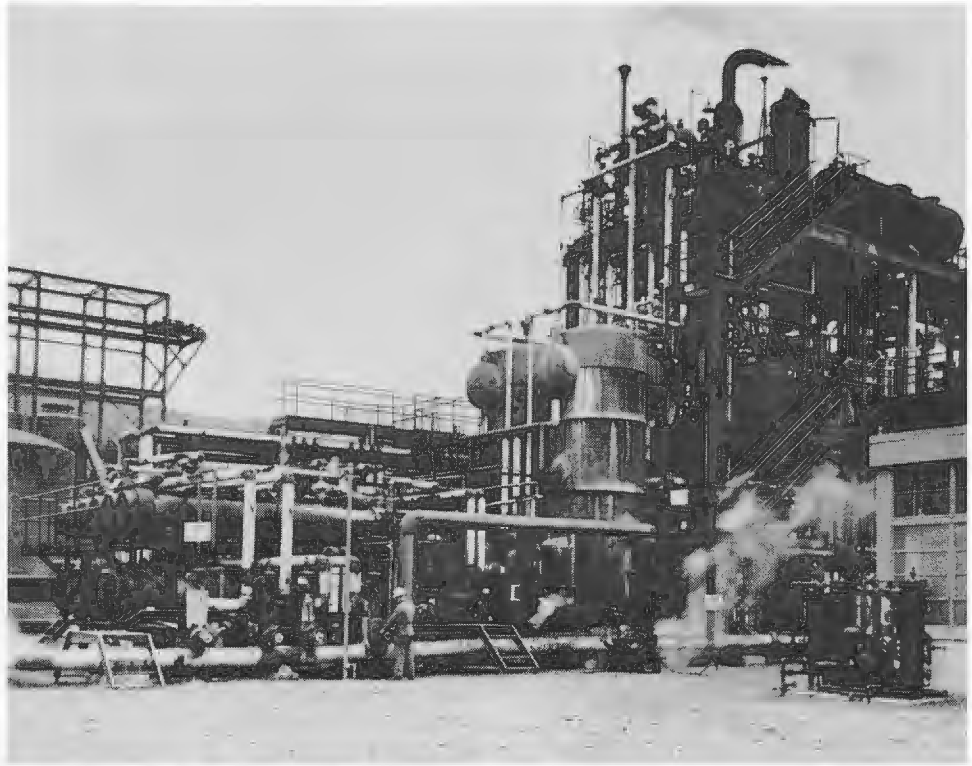

Figure 3. Units for separation of unreacted solids, distilling the heavy products to pitch and the recovery of recycle and wash oils.

Toluene is used for making TNT, benzoic acid and derivatives, benzaldehyde, benzyl compounds, toluidines, solvent mixtures for lacquers and is a useful component of high-octane auto and aviation gasoline. The xylenes find use in making phthalic anhydride resins, terephthalic acid used for making fibers of the dacron type, colored pigments for printers inks, solvents for lacquers, and as a compound of high-octane gasoline.

Naphthalene is one of the important coal tar chemicals and has been in short supply as evidenced by the substitution of orthoxylene obtained from petroleum and even the importation of naphthalene from Europe at times. It is significant, therefore, that as much as eight times as much naphthalene can be made by coal hydrogenation as by coking. The uses for naphthalene are many and diverse. A major use is the manufacture of phthalic anhydride, from which many products are derived, but the most important are alkyd or glytal resins used for refrigerator and stove finishes and the like. With monohydric alcohols, instead of the polyhydric alcohol used in making the resins above, many additional esters are synthesized that have very extensive use—such as plasticizers or softeners for plastics which must resist flexing as in shower curtains, draperies, upholstery, and auto seat covers; also insect

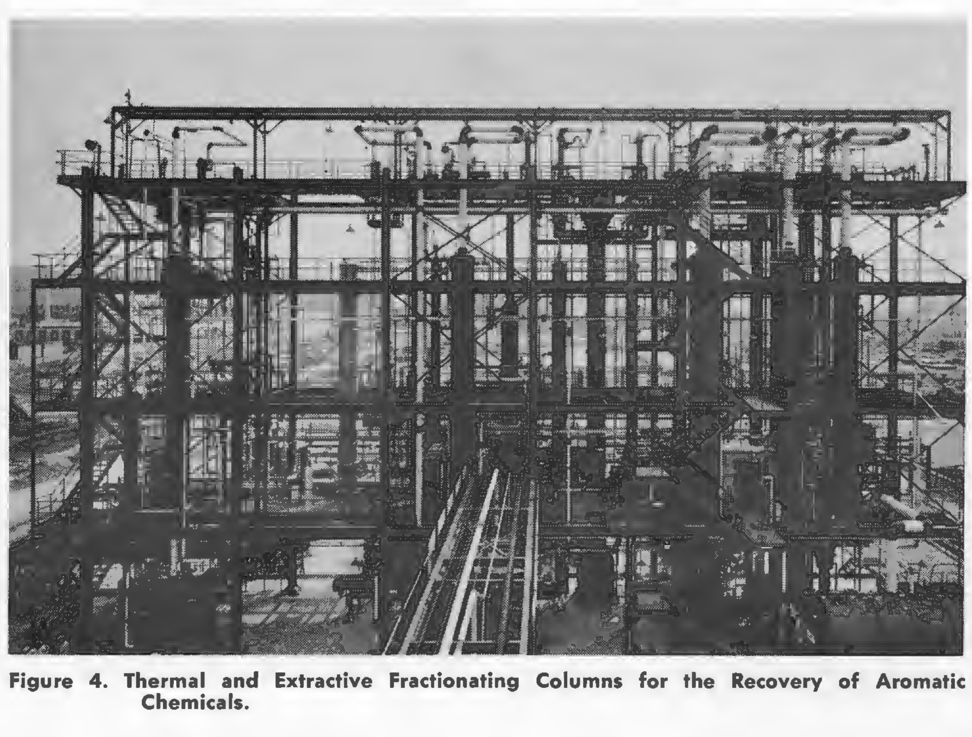

Figure 4. Thermal and Extractive Fractionating Columns for the Recovery of Aromatic Chemicals.

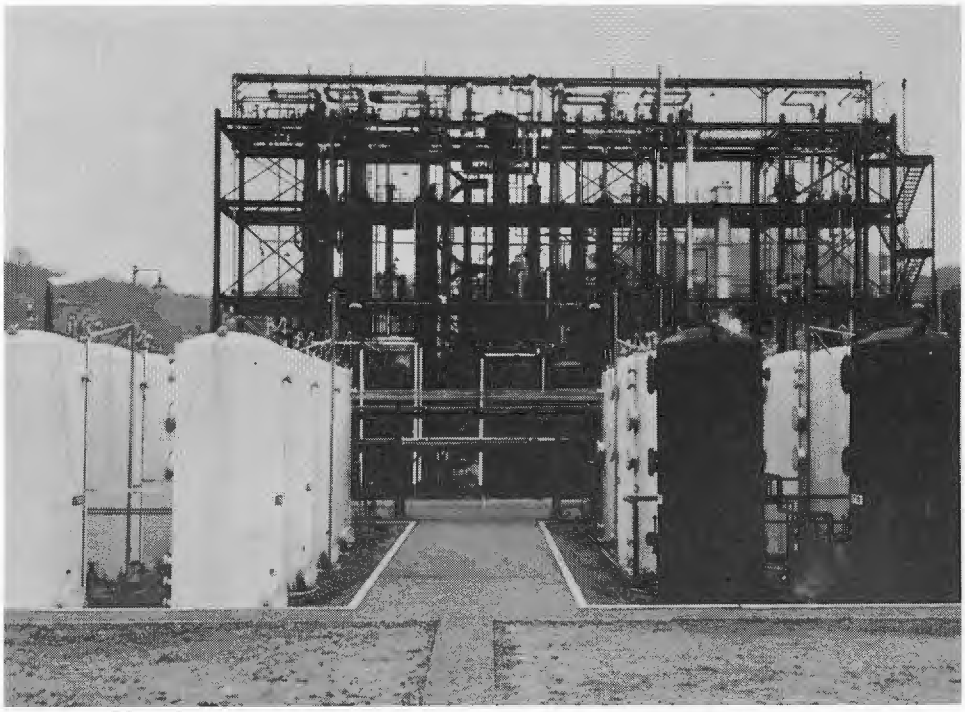

Figure 5. Product Receiving Tanks in Foreground.

repellents; furniture lacquers; and additives for smokeless powder for rifles and shot guns. Phthalic anhydride is also used for making anthraquinone dyes, while other dyes are made using other derivatives of naphthalene such as the naphthols. Alpha and beta naphthylamine are used as anti-oxidants or anti-aging materials in most rubber products such as automobile tires, and they perform an extremely important service to the consumer even when added in very small amounts. Many other diversified uses may be typified by the manufacture of vitamin K starting from naphthalene. These taken together constitute a large demand for naphthalene which a generation ago was largely limited to its use in the form of moth balls. Incidentally, this use has now been superseded by the pleasanter smelling para dichlorobenzene derived from benzene.

In addition to naphthalene, relatively small amounts of alpha and beta methylnaphthalene are cut out of the aromatic solvent oils for special uses such as specific solvents for the chlorinated insecticides: DDT, chlordane, toxaphene, BHC (benzene hexachloride), etc.; for the weed killers, 2, 4-D and 2, 4, 5-T; and for the synthetic fungicide, pentachlorophenol.

The phenols produced in the process are obtained in large quatities, 100 to 200 times as much as in the coking process. These substances are used in large volume by the chemical industry; in fact, phenol is synthesized in large tonnages to meet the requirements. The major use of phenol is in the manufacture of of phenol-formaldehyde (Bakelite) type of resin, but large amounts are also used in making synthetic detergents 2,4-D, and many other chemicals, drugs, and dyes. It is also used in one process of refining lubricating oils.

The cresols also find use in making resins, disinfectants, flotation reagents for concentrating copper and other ores, antioxidants, and solvents for cleaning engines, etc. Tricresyl phosphate, TCP, is used for making flameproof drapes, electrical insulation; and recently it has been adopted by one company as a gasoline additive in place of tetraethyl lead to reduce knocking in high-compression engines.

A large portion of the phenols obtained from coal hydrogenation are more complex than the cresols. A part of this product can be used in ore flotation reagents, preservatives for wood, etc., but further research is needed to find better utilization of these phenols.

Aniline is one of the bases obtained from coal hydrogenation. This is particularly interesting because the amount obtained by carbonization of coal is so small that it is not economic to recover if from this source. Otherwise aniline is manufactured by two-step processes from benzene. It has many uses in making chemicals for the rubber, photographic, drug, and dye industries. A new use is in rocket fuels which might increase the demand for this chemical very greatly. The toluidines (methyl anilines) are also produced by coal hydrogenation and have many uses similar to those for aniline.

Quinoline is another base produced in large amounts by coal hydrogenation. This substance finds use in manufacturing nicotinic acid and nicotinamide, members of the viamin B complex, and 8-hydroxyquinoline, a particularly effective fungicide for preventing the rotting of canvas tents, awnings, and similar goods. Many other nitrogen derivatives are found in the hydrogenation oils, but important uses have not been found for them as yet.

All of these products, derived from aromatic starting materials, are but a relatively small number of the thousands of these compounds used in incerasing quantities daily, and are indicative of the range and importance of these compounds in everyday life. By 1975 it would be surprising indeed if the conservative predictions of today were not exceeded by wide margins. Whether coal hydrogenation will supply a large portion of these future needs, only time will tell, but certainly the future looks bright for this process at the moment.

Department of Fuel Technology

T. S. Spicer, professor of fuel technology, served as chairman of the technical session on "Air Pollution Problems with Heat Drying of Fine Coal" at the 17th annual Fuels Conference of ASME in Pittsburgh on October 28 and 29.

Contributions

(The papers listed below are contributions by members of the staff of the College of Mineral Industries and have appeared in recent journals.)

Bacon, L. O. "Gravity Surveys of Central Pennsylvania." *Transactions American Geo-Physical Union,* Vol. 35, No. 3. (June 1954)

Bissey, L. T., and Villarreal, J. F. "Natural Gas Pipeline Deposits." *Mineral Industries Experiment Station Bulletin* 63, The Pennsylvania State University. (June 1954)

Brindley, G. W. "The Structural Formula of an Antigorite from Venezuela." *American Mineralogist,* Vol. 39, No. 3 and 4. (March-April 1954)

Brindley, G. W. "Structural Aspects of Some Thermal and Chemical Transformations of Layer Silicate Minerals." *Proceedings of the International Symposium on the Reactivity of Solids, Gothenburg, 1952,* Vol. 1. Published Gothenburg (Sweden), 1954.

Comer, J. J., and Skipper, S. J. "Nuclear Emulsions for Electron Microscopy." *Science,* Vol. 119, No. 3092. (April 1954)

Duecker, J. C. "Gravity Traverse in Northeastern Pennsylvania." *Transactions American Geophysical Union,* Vol. 35, No. 3. (June 1954)

Harker, R. I., "The Occurence of Orthoclase and Microcline in the Granite Gneisses of the Carn Chuinneag-Inchbae Complex, East-Ross-shire." *Geological Magazine,* Vol. 91, No. 2. (March-April 1954)

Harrison, D. E., Mc Kinstry, H. A., and Hummel, F. A. "High Temperature Zirconium Phosphates." *Journal American Ceramic Society,* Vol. 37, No. 6. (June 1954)

Kinney, C. R. "Thermal Behavior of Aromatic Hydrocarbons." *The Chemistry of Petroleum Hydrocarbons* Chapter 26. Reinhold Publishing Company, New York. (1954)

Langenberg, F. C. and Lindsay, R. W. "Removal of Copper from Iran-Copper-Carbon Alloys." *Journal of Metals,* Vol. 6, No. 9. (September 1954)

Lindsay, R. W., and Hoke, J. H. "Effects of Graphite Flake Size on Tensile and Fatigue Properties of Gray Cast Iron." *American Foundrymen's Society Preprint* Number 54-20. (May 1954)

Miller, E. Willard. "Recent Trends in the Pattern of European Manufacturing." *Journal of Geography,* Vol. 53, No. 5. (May 1954)

Roy, D. M., Roy, R., and Osborn, E. F. "Fluoride Model Systems: IV, The Systems $LiF-BeF_3$ and PbF_2-BeF_2." *Journal of the American Ceramic Society,* Vol. 37. (July 1954)

Roy, Rustum, and Shafer, M. W. "Phases Present and Phase Equilibrium in the System $In_2O_3-H_2O$." *Journal of Physical Chemistry,* Vol. 58. (May 1954)

Sun, S. C., Fisher, H. M., and Snow, R. E. "Rapid Estimation of Mill Product Purity by Transparency Measurement." *Mining Engineering,* Vol. 6, No. 9. (September 1954)

Villarreal, J. F., Bissey, L. T., and Nielsen, R. F. "Dew Point Water Contents of Methane Mixtures at a Series of Pressures and Temperatures." *Producers Monthly,* Vol. 18, No. 7. (May 1954)

Walker, P. L., Jr., McKinstry, H. A., and Pustinger, J. V. "X-Ray Diffraction Studies on Carbon Gasification." *Industrial and Engineering Chemistry,* Vol. 46. (1954)

Warshaw, I., and Keith, M. L. "Solid Solution and Chromium Oxide Loss in Part of the System $MgO-Al_2O_3-Cr_2O_3-SiO_2$." *Journal of the American Ceramic Society,* Vol. 37, No. 4. (April 1954)

Mineral Industries Auditorium

(Continued from Page One)

Five panels are painted on the wall in the rear of the room. Two of these list historical events in the mineral industries of Pennsylvania, one showing those which were first in the world, and the other including those which were first in the United States.

The remaining three panels briefly summarize Pennsylvania's mineral resources, Pennsylvania's mineral industries, and Pennsylvania's mineral needs.

One panel points out that 67 per cent of the primary wealth of the State is provided by irreplaceable minerals and that Pennsylvania mineral production represents 10 per cent of the mineral production of the Nation.

Such tremendous mineral production in the Commonwealth can be maintained, but only if the State's known mineral reserves are efficiently and completely exploited and if processes are developed for upgrading its presently low-grade reserves and for utilizing its now unused minerals, the text says.

The mural also points out that more than 600,000 workers in the State treat raw materials imported from nearly every State and most of the countries of the world and that without her mineral industries, Pennsylvania would be an economic desert.

The third panel emphasizes that minerals of all kinds must be brought into Pennsylvania for processing if these industries are to prosper.

"These additions to the Commonwealth's mineral resources, however, will continue to be brought into the State only as long as the energy from Pennsylvania's fuels, the capacity of its plants, and the skills of its workers are made readily and efficiently available," the text reads.

In addition to the educational murals in the auditorium, the room includes 216 comfortable seats, a blackboard and a screen which may be moved into place automatically, a projection room with facilities for slides or 16mm. film, and a communications system from the projection room to the speaker's rostrum.

A room without windows, the auditorium is equipped with a combination of dire :t and indirect lighting and with an air-cooling system.

Rear Wall Panel

View Toward Left Wall

Looking Toward Front

Reservoir Engineering Courses

During the summer two extension courses were given on campus by the Department of Petroleum and Natural Gas for engineers from the Sun Oil Company and the Standard Oil Company of California. Each was a four-week course in Advanced Reservoir Engineering design as a refresher and to acquaint the enrollees with the latest developments in the subject. The first was attended by 21 engineers from the Sun Oil Company and the second by 19 engineers from the Standard Oil Company of California and associated companies. All major oil-producing areas of the United States and Canada were represented.

Subject matter covered in the courses included behavior of porus media, material balance equations, solution gas drive reservoir, reservoir fluid flow equations, and fluid injection and transfer processes.

Instructors were Dr. John C. Calhoun, Jr., head of the department of Petroleum and Natural Gas, Dr. Ralph Nielsen, Dr. Drew Stahl, Messers D. T. Oakes and F. W. Preston, all of the Department of Petroleum and Natural Gas.

A third course, of an introductory nature, will be given for engineers of the Standard Oil Company of California from November 14 to December 11, 1954.

Department of Meteorology

Dr. Charles L. Hosler, assistant professor of meteorology, attended the meetings of President Dwight Eisenhower's Advisory Committee on Weather Control at the Massachusetts Institute of Technology on September 22, 23, and 24. Dr. Hosler addressed the Committee on "Predictions of the Future of Weather Control." The meetings were held to aid the Committee in making a report to the President and recommendations to Congress.

Raymond Deland of Melbourne, Australia, has been appointed research assistant in the Department of Meteorology.

Included among the fall regisrations for the curriculum in Meteorology were four students from Ethiopia and one each from Cuba and Liberia.

Conference on Petroleum Production

The 18th Annual Technical Conference on Petroleum Production was held in the Mineral Industries Auditorium October 6, 7, and 8. One hundred and fifty-seven registered for the conference. They represented 68 organizations including oil companies, research laboratories, service companies, publications, educational institutions, consulting engineers, and government agencies.

The papers presented were:—

"Progress in Electric Logging Research at The Pennsylvania State University During 1943-54" by Dr. E. J. Moore, assistant professor of geophysics.

"Some Factors Related to the Measurement of the Electrical Properties of Porous Sandstones" by C. R. Holmes, research assistant in geophysics.

"Definition of an Oil Sand by Quantitative Petrographic Analysis" by J. R. Emery, graduate student in mineralogy, and Dr. J. C. Griffiths, professor of petrography.

"Further Tests of Dimensional Orientation and Directional Permeability" by J. Hutta graduate student in mineralogy, and Dr. Griffiths.

"The Preparation of a Subsurface Injection Water from a Sour Brine" by Dr. T. M. Doscher and Dr. R. N. Tuttle of the Shell Oil Comapny.

"The Inhibition of Gypsum Precipitation by Sodium Polyphosphates" by Dr. E. J. Burcik, associate professor of petroleum & natural gas engineering.

"Use of Radioactive Tracers in a Study of Displacement in a Model 5-Spot System" by R. E. Wainerdi, graduate student in petroleum and natural gas engineering, and Dr. R. F. Nielsen, associate professor of petroleum and natural gas engineering.

"Interrelationship Between Oil and Gas Relative Permeabilities" by Dr. A. T. Corey, Gulf Research and Development Company.

"On the Behavior of Linear Floods" by Dr. J. Jones-Parra, a former graduate student, and Dr. J. C. Calhoun, head, Department of Petroleum and Natural Gas.

"The Inlet Saturation Distribution Transient in a Water Flood" by J. E. Warren, graduate student in petroleum and natural gas engineering, and Dr. Calhoun.

"Relationships Between Oil Recovery, Interfacial Tension, and Pressure Gradient in Water Wet Porous Media" by Jose Paez, a former graduate student, P. W. Reed, research assistant, and Dr. Calhoun.

"Determination of Effective Formation Permeabilities and Operational Efficiencies of Water-Input Wells" by J. C. Joers and R. V. Smith, formerly with U. S. Bureau of Mines.

"New Concepts in Reservoir Heat Engineering" by Dr. R. Jenkins and Dr. J. Aronofsky, Magnolia Field Research Laboratories.

"A Study in the Three-Phase Equilibria for Carbon Dioxide-Hydrocarbon Mixtures" by Dr. A. H. Meldrum, a former staff member, and Dr. Nielsen.

Members of the Penn Grade Research Advisory Committee served as chairmen for the sessions.

In conjunction with the Technical Conference, an open dinner meeting of the Eastern District A.P.I. Study Committee on Secondary Recovery was held at the Nittany Lion Inn October 6. The dinner speaker was Dr. Charles L. Hosler, assistant professor of meteorology. The annual dinner of the Technical Conference was held October 7 at the Nttany Lion Inn. Dr. Calhoun acted as toastmaster.

Research Agreements

New research grants approved by the Board of Trustees at the University in support of research in the College of Mineral Industries are:

Continental Oil Company, October 1, 1954, to September 31, 1955, for research in Petroleum Production, directed by Dr. J. C. Calhoun, Jr., head of the Department of Petroleum and Natural Gas.

Gulf Corporation, July 1, 1954, to June 30, 1955, for research in the "Study of Underground Rock Structures," directed by A. W. Asman, head of the Department of Mining.

Office of Naval Research, September 1, 1954, to August 31, 1956, for research on "Relations between Silicate-Carbonate Liquids and the Crystallization of Carbon," directed by Dr. O. F. Tuttle, chairman of the Division of Earth Sciences.

St. Joseph Lead Company, September 1, 1954, to August 31, 1955, for research in the "Influence of Group II Sulphides Upon Distribution of Copper Between Iron-Copper-Carbon Melts and Sulphide Slags," directed by Dr. R. W. Lindsay, professor of metallurgy.

The American Iron and Steel Institute, U. S. Steel Corporation, and Sharon Steel Foundation have established a research grant for a visiting professorship in steel making under the direction of Dr. A. J. Shaler, head of the Department of Metallurgy.

Department of Ceramics

Dr. E. C. Henry, head of the Department of Ceramics, has been granted an extension of his leave of absence to October 1, 1955, to continue his work in the laboratories of the General Electric Company at Syracuse, New York. Dr. F. A. Hummel will continue as acting head of the Ceramics Department during this period.

Dr. M. C. McQuarrie has been appointed an assistant professor in the Department of Ceramics, effective September 1, 1954. Dr. McQuarrie received his B.S. degree in Engineering Physics at Lafayette College in 1948, his M.S. degree at California Institute of Technology in 1949, and in 1952 was awarded the Sc. D. degree in Ceramics from the Massachusetts Institute of Technology. Since graduation he has been employed in ceramic research at the Sprague Electric Company in North Adams, Massachusetts. He will continue his research in the field of physical and electrical properties of ceramic materials at Penn State and also contribute to the graduate and undergraduate instructional program.

Dr. T. E. Currie, a native of Manchester, England, has been appointed research associate in ceramics. In 1951 Dr. Currie received a B.Sc. degree in Fuel Technology at Leeds University, England. He then undertook research in the Ceramics School of Leeds University and was awarded the Ph.D. degree in March, 1954. Dr. Currie will do research on the mineralogical and ceramic properties of structural and refractory clays, particularly those occurring in Pennsylvania.

Mr. Mark Harnish, who received his B.S. degree in ceramic engineering from Penn State in 1951 has returned to the Department of Ceramics as a research assistant working for his M.S. degree on a problem in special refractories. He had been employed by the Bethlehem Steel Company at Lackawanna, New York, since graduation.

Department of Metallurgy

The University Board of Trustees has approved the appointment of professor Willy Oelsen as visiting professor of metallurgy. Professor Oelsen, Director of the Institute of Ferrous Metallurgy of the Bergakademie Clausthal in Germany, is Europe's leading authority in the field of ferrous metallurgy. He will arrive at Penn State some time in December.

A meeting of representatives of the Cooperative Research Program was held September 10 to discuss the results of past research on the role of boron in steel and to select a subject for research during the coming year. The topic selected for this year's work was "The Production Function Analysis," and Mr. Jack D. Wolf was chosen as the Cooperative Program Fellow.

The first meeting of the Penn State Chapter of the American Society for Metals took the form of a social get-together. R. M. Atkinson, instructor in metallurgy, acted as chairman and arranged a showing of the Penn State-Illinois football movie. Dr. A. J. Shaler, head of the Department of Metallurgy, announced the winners of scholarships awarded by ASM, AIME, and the Cooperative Program.

Dean Osborne Speaks at Colloquium

E. F. Osborne, dean of the College of Mineral Industries, presented an address before the Mineral Industries Colloquium on Friday, October 8, on "High Temperature Reactions Among the Common Oxides—A Program of Research Bearing on Steelplant Refractories." The purpose of the Colloquium is to develop interest in all branches of science and technology related to the activities of the Mineral Industries College and to bring together different departments of the College to discuss work of common interest.

Department of Mineralogy

Dr. J. C. Griffiths, professor of petrography, and J. C. Ferm, formerly of the College of Mineral Industries, attended the Mid-West Conference on "Quantitative Sedimentology" held by the Illinois Geological Survey at Urbana, Illinois, on October 1, 2, and 3. On October 4, Dr. Griffiths addressed the Department of Geology of Indiana University on "Definition of an Oil Sand by Quantitative Petrography."

At the 18th Technical Conference on Petroleum Production Mr. J. R. Emery and Dr. J. C. Griffiths presented the paper entitled "Definition of an Oil Sand by Quantitative Petrographic Analysis." Also presented at this conference was the paper entitled "Further Test of Dimensional Orientation and Directional Permeability," by Mr. J. Hutta and Dr. Griffiths.

Dr. J. S. Runcorn of the Department of Geology and Geophysics of Cambridge University, England, was a recent visitor for the purpose of obtaining information concerning the origin of iron oxide in red beds from Dr. P. D. Krynine, head of the Department of Mineralogy. This knowledge is important in determining the validity of Cambridge's new concept of major shifts of the magnetic poles through geologic time.

Mineral Economics

John D. Ridge†

CERAMIC RAW MATERIALS RESOURCES OF PENNSYLVANIA*

The ceramic industries of Pennsylvania, whose products are as different as drainage tiles and spark plugs, refractory brick for steel furnace linings and optical glass, glass wool and welding rod coatings, are a vital part of the economic system of the Commonwealth. The annual value of Pennsylvania's ceramic products is about 600 mililon dollars, and the industry provides employment for upwards of 60,000 persons in the State.

As is true of any of the mineral technologies, the future existence of this important segment of the Commonwealth's prosperity depends in large measure on the continued availability of the raw materials used in ceramics at the places where they are needed. A complete list of these mineral raw materials is a long one and is one that is continually being increased as new products are developed and ways of employing still other presently unused raw materials are found. The most important ceramic raw materials, however, remain the various varieties of clay and sand. It is from these basic mineral substances that most ceramics are entirely or in large part made.

Fortunately for the continued and increasing prosperity of the ceramc industry in the State, these basic materials are abundantly available and widely distributed within its boundaries. Almost any type of clay and sand is to be found here, and there are sufficient quantities and varieties in the Commonwealth's reserves of these materals to fill the industry's requirements for thousands of years. When to this favorable situation are added the tremendous coal supplies of the State, it is apparent that the energy requirements for the making of ceramic products can be met for centuries to come. New methods of mining or otherwise removing the energy of coal from the ground may have to be developed to insure power for the ceramic and other industries of the Commonwealth in the more distant future, but there is sufficient time to solve these problems before the fuel problem could have a deleterious effect on industrial activity.

The most important ceramic raw material presently produced in Pennsylvania is fire clay. Fire clays are defined by Ries as all clays having a fusion point of cone 19 or higher. By this definition alone kaolins and ball clays would be included with fire clays, but these two types are considered separately because they fire white and command a considerably higher price than run-of-the-mine fire clay. Included as a type of fire clay in production and use statistics is flint clay which is chemically similar to the plastic kinds of fire clays but which must be subjected to a long period of grinding to develop the plasticity necessary in making refractories.

† *Head, Department of Mineral Economics*

* *A condensation of a paper presented by Dean Ridge at a meeting of the Pittsburgh Section, The Pennsylvania Ceramics Association, Nov. 9, 1954.*

The fire clays now mined in Pennsylvania are dominantly flint clays and are almost entirely the under clays associated with the various bituminous coal measures of the State. From this it follows that the mining of coal and clay are carried on in the same general areas, although coal mining is much more widespread than is that of clay because of the great difference in the tonnage demands for these two materials.

Most fire clays in the Commonwealth will contain from 33 to 45 per cent of alumina, but will have enough iron and/or manganese that they will not fire a dead white, low though the absolute amounts of these elements are. Some of the fire clays will contain nodules of diaspore (a mineral which contains no silica) which raises the alumina content of clay and permits the making of refractories which will withstand temperatures of more than 3300°F. The highest alumina content clays come from the eastern and northern parts of the bituminous coal area, while farther west the clays, although more plastic, are lower in alumina, and the products made from them cannot withstand as high temperatures. At the present time the mining of the flint and nodule clay is largely confined to the eastern part of Clearfield County, but the belt in which these materials are found extends from Cambria to Lycoming Counties and contain tremendous reserves of high-alumina clay. The objection has been raised that much of the clay in this belt contains too high percentages of iron and other harmful impurities for high grade refractory products. It is, however, certain that mineral beneficiation methods which would reduce the impurities to within acceptable limits could be applied to such of these clays as need them, thus opening a huge volume of ceramic reserves to the industry. The ceramic industry, however, can expect competition for these high-grade clays from other interests for they are high enough in silica-free minerals to be potential sources of alumina and aluminum. The present ease of access to bauxite supplies reduces the likelihood of these clays being exploited for aluminum in the near future, but a war or even an intensification of the cold war could force the United States to begin the production of aluminum from clay. It follows, therefore, that the ceramic industry should investigate thoroughly its requirements of high alumina clay and make certain that adequate supplies will be available to it, no matter what competition there may be from other users, actual or potential.

To give some idea of the magnitude of the clay raw material requirements of the Pennsylvania ceramic industries, the 1951 production figures for the State are given here:

Type of clay	Production (short tons)	Value
Kaolin	75,415	$ 306,045
Fire Clay	2,205,794	11,653,734
Miscellaneous Clays	1,949,358	2,127,771
Total	4,230,567	$14,087,550

Although the total value of all the raw materials used in all varieties of Pennsylvania ceramic products in 1951 was many times the value of all clays, it still falls far short of the $600,000,000 value of all Pennsylvania ceramic products in 1951. This indicates the tremendous increase in value imparted to non-metallic raw materials by processing and manufacture. It also points up the fact that nonmetallic raw materials have little value in the ground, that it is extraction, beneficiation, and processing near the places of both origin and use that give value to such materials. Nevertheless, unless the needed raw material is available for exploitation, no industry built upon it can be supported.

Although all clays contain greater or lesser amounts of the mineral kaolinite, only those very slightly impure, nonplastic white clays which are close to 100 per cent kaolinite are known as kaolin. The amount of true kaolin produced in Pennsylvania is small, less than 100,000 tons a year, and the reserves are not large. It is doubtful that further geologic work would uncover any important additional resources of kaolin, but more work on the beneficiation of kaolinite-bearing materials might well result in a process which would enable the Comonwealth to fill its domestic kaolin needs from local sources.

Most of the silica used by the Pennsylvania industry is actually derived from the relatively gentle crushing of friable sandstones or from the much more vigorous crushing of strongly cemented sandstones or quartzites. The former rocks are mainly located in Elk, Jefferson, Venango, and Westmoreland counties and lie at the base of the Coal Measures. The latter are mainly from the Oriskany and Tuscarora formations in the folded Appalachians. Some small amounts of ceramic sand come from superficial glacial depostis in the northeastern and nortwestern parts of the State and from main river valleys, but these sources are of minor importance. The silica brick made of this sand is essential to the making of steel, it being used almost exclusively as the roof material in open-hearth furnaces and in by-product coke ovens. The quantities of sand required are, therefore, huge and, in 1950, Pennsylvania produced over 600,000 tons of ganister (crushed sandstone), which is over 50 per cent of the U. S. output, valued at about $2,500,000. The reserves of sandstone in Pennsylvania are practically inexhaustible and can be found in nearly all counties of the State, although those just mentoned are now, and in the future probably will be, the most important.

Some difficulty in the use of Pennsylvania ganister has been caused by the presence of clay which raises the Al_2O_3 content above that acceptable in silica brick. In most instances this clay, which is a producet of surface weathering, can be quite easily removed by washing, although locally the problem is somewhat more complex. The presence of iron oxides along fracture planes in the quartzite formations may, in the long run, have more serious consequences because the iron minerals must be removed by flotation, a process possible only if the rock is finely ground. There are, however, still huge reserves of ganister which contain little or no clay or iron oxides.

Limestone is mainly calcium carbonate ($CaCO_3$), although magnesium carbonate may be included in varying percentages up to 45. Clay or shale may be present, having been deposited along with the $CaCO_3$ in the original formation of the bed. Another common, though generally minor, impurity is iron oxide. The two main uses of limestone in ceramic materials are in the making of cement and lime. The type of limestone required for these two purposes is not the same. In limestone used for cement, the presence of clay is useful and not harmful because alumina and silica must be added anyway. Magnesia (MgO) is, however, deleterious in cement, ASTM specifications requiring that the MgO content not exceed 5 per cent. On the other hand, in making lime (CaO), magnesia is quite acceptable, some commercial lime containing up to 45 per cent MgO, but nonalkali forming materials such as clay and silica cannot be present in more than minimal quantities.

The amount of limestone in the State is tremendous and much of it can be used for the production of lime; much less of it, however, can be used for cement making because of its magnesia content. Recent detailed geologic studies, nevertheless, have shown that the supplies of high-calcium limestones in the State are greater than had been supposed and further work may result in even greater increases in reserves of limestone suitable for cement.

Although clay, silica, and limestone are plentiful in Pennsylvania and of good quality, there are two important refractory raw materials which the State does not possess. These are magnesite ($MgCO_3$) and chromite ($FeCr_2O_4$) which are used in about equal quantities in the production of refractory brick (some 350,000 tons each in the U. S. in 1950) and for which no adequate substitutes have been developed. However, the State contains tremendous and widely distributed reserves of dolomite, $CaMg(CO_3)_2$, and much work has been done to make possible either the extraction of MgO from dolomite or to make refractory brick directly from dead-burned dolomite. At the present time a considerable part of the magnesite used in making magnesite brick is recovered from partially burned dolomite, but refractory brick made directly from dolomite has not been very satisfactory. Further work on producing a refractory fire brick from dolomite is, however, justified, and there is reason to suppose that eventually these efforts will meet with success.

Thus, the State's lack of magnesite resources well may not be a problem indefinitely, but such unfortunately is not true of chromite. At one time, Pennsylvania was the world's largest producer of chromite, and the chromite belt, running from Lancaster County to Baltimore, was a center of mining activity. Foreign competition and the small size of the deposits, however, have long since put the Chrome Belt out of business, and geologic data do not suggest that operations can be renewed on any appreciable scale. As long as it is necessary to use chromite in refractory brick, the Commonwealth must expect to import what it needs.

Still other ceramic materials, such as feldspar, fluorspar, and cryolite, are also missing, or largely so, from the rocks of Pennsylvania, but they are used in such small amounts in ceramic processes that the necessity of obtaining them from other states or from abroad is no handicap to the growth of the industry in times of peace.

Thus, the raw material resources of the Commonwealth present a picture of good, bad, and in-between, but the basic materials, with the exception of chromite, are present in the rocks in quantities sufficient for thousands of years, the types and qualities are more than adequate, and the processes needed to use them are available or (for refractory brick from dolomite) should be so in the near future. Minor constituents can be readily imported now and could be substituted for if political or economic exigencies should cut off the Commonwealth's supplies.

THE PENNSYLVANIA STATE UNIVERSITY
ENROLLMENT
FALL 1954
College of Mineral Industries

	Geol & Min.	Geophy & Geochem.	Meteor.	Geog.	Min. Econ.	Mng.	Min. Prep	PNG	FT	Met	Cer	Ttl.
Freshmen	21	9	11	2	-	8	1	40	1	29	12	134
Sophomores	18	8	4	5	1	11	-	24	1	21	4	97
Juniors	12	9	13	5	1	8	3	22	2	17	5	97
Seniors	11	5	21*	9	1	7	5	23	5	31	3	121
TOTAL	62	31	49	21	3	34	9	109	9	98	24	449
Special	2	-	6	1	1	-	-	3	-	-	1	14
Graduate	G-30 M-20	27	11	13	2	4	1	18	25	13	17	181
GRAND TOTAL	114	58	66	35	6	38	10	130	34	111	42	644

* Includes 15 Air Force students.

M. I. Experiment Station

Dr. J. A. Hipple, director of the Mineral Industries Experiment Station, presented a talk at the First International Instrument Congress and Exposition in Philadelphia on September 26, 1954. The subject was "The Application of Mass Spectroscopy in Trace Anlysis."

The National Bureau of Standards has loaned a mass spectrograph to the Mineral Industries Experiment Station for an indefinite period. This instrument will be employed in the development of a method for analyzing solid samples under the direction of Dr. Hipple, who had been engaged in research with this instrument while a member of the staff of the National Bureau of Standards. This generous loan makes possible the continuation of this work at Penn State. Applications in metallurgy, ceramics, and geochemistry appear particularly attractive.

Department of Geology

Dr. Robert Scholten, assistant professor of petroleum geology, spent part of the summer in field work in the Rocky Mountains of Central Idaho with support of a grant from the Geological Society of America. Accompanied by his wife and family, he camped in the more remote portions of the Beaverhead Range, where there was frost and even some snow in mid-August. Except for a brief visit from Dr. Ian Harker of the Department of Geophysics and Geochemistry, the only other inhabitants of their field area were a few sheepherders. Dr. Scholten's work continues his studies in Southwestern Montana, begun before coming to Penn State. It is hoped that the investigations will throw light on the geologic evolution of a little-known portion of the Rockies and may, therefore, clarify some concepts of its tectonism. Interesting data were also obtained concerning the nature of the Tertiary rhyolites of the area.

Department of Petroleum and Natural Gas

Dr. J. C. Calhoun, Jr., head of the Department of Petroleum and Natural Gas, presented a paper entitled "A Summary of Reservoir Engineering as Applied to Water Procurement" before the meeting of the National Water Well Association in Minneapolis, Minnesota, on September 30.

Mr. Robert C. Newman, former research associate, has received a year's appointment as a National Science Foundation Fellow. The subject of his research is the Elasticity of the Surfaces of Surface-Active Agent Solutions.

Dr. H. C. Meldrum, former research associate has accepted a position on the staff of the University of North Dakota.

Richard E. Wainerdi, of North Atherton Street, State College, Pennsylvania, has been awarded the Stanolind Foundation fellowship in petroleum engineering for the academic year, 1954-55. The fellowship carries a stipend of $1500 for the year in addition to University fees.

Department of Mineral Preparation

Professor D. R. Mitchell, chairman of the Divison of Mineral Engineering; Dr. H. B. Charmbury, head of the Department of Mineral Prepaartion; Dr. S. C. Sun, associate professor of Mineral Preparation; and William L. Deppe spent several days in Wilmington, Delaware, recently with officials of the Atlas Powder Company. A research project on the "Application of Surface-Active Agents to Mineral Beneficiation" is being sponsored by the Atlas Powder Company in the Department of Mineral Preparation.