

Mineral Industries

PUBLISHED DURING THE COLLEGE YEAR BY

THE DIVISION OF MINERAL INDUSTRIES EXTENSION

THE PENNSYLVANIA STATE COLLEGE

Volume 3

STATE COLLEGE, PA., OCTOBER, 1933

Number 1

THIRD PENNSYLVANIA MINERAL INDUSTRIES CONFERENCE

Ceramic Section Holds Its First Meeting in the School of Mineral Industries in Cooperation with the Pittsburgh Section of the American Ceramic Society

Three successful Mineral Industries Conferences have been held at the Pennsylvania State College during the past three years. These conferences have all dealt particularly with petroleum and natural gas problems in Pennsylvania. The interest in these conferences has grown from year to year. At the last meeting the attendance was well over one hundred. These meetings have been so successful and have attracted so much interest that the School of Mineral Industries now plans to sponsor conferences in all fields of activity for which it offers curricula.

The Ceramic Conference is to be held on Friday and Saturday, October 20 and 21, under the joint auspices of the School of Mineral Industries and the Pittsburgh Section of the American Ceramic Society. The Conference will take the form of a symposium on the subject of Heat Treatment of Ceramic Materials, with emphasis on structural changes occurring during the firing and annealing operations, and on the importance of a proper schedule of heat treatment. During the past ten or fifteen years, heat treatment of alloys has advanced rapidly from an art to an exact science as a result of our increased knowledge of the fine structure of metals and alloys, which the microscope and the X-ray have given us. It is known that if special attention is given to structural changes occurring in the firing and annealing of ceramic materials, real improvement in manufacturing technique will result.

In the early days of glass making, for example, milky products were often obtained as a result of some mysterious factor in manufacture, and these products were discarded. Nowadays, knowledge of devitrification rates and identification of the little crystallites, makes possible the production of opal glass under exact control at all times. A better knowledge of structure changes will solve the old-time problem of spalling of refractory brick which is the cause of serious economic loss at the present time.

The symposium will be opened by Dr. R. B. Sosman of the Research Laboratory of the United States Steel Corporation. Dr. Sosman is internationally known as an authority on silicate chemistry and physics, having been for many years a member of the Geophysical Laboratory at Washington. He was for two years Acting Director there. Since 1928 he has been with the United States Steel Corporation. Dr. Sosman has been President of the Washington Section of the Chemical Society, President of the Washington Philosophical Society and President of the Washington Academy of Sciences. He is a member of the Geo-

graphical Society, the Physical Society, the Ceramic Society, the American Institute of Mining and Metallurgical Engineers, the American Iron and Steel Institute, the New York Mineralogists' Club, the British Ceramic Society and the Keramische Gesellschaft. He is the author of a monumental work on "The Properties of Silica." All of the other speakers are experts, likewise, in their respective fields and have many friends who will be glad to take this opportunity to hear them.

A number of companies manufacturing heat control equipment and several makers of petrographic microscopes will have exhibits in the Mineral Industries Building at the time of the conference and this should be of considerable interest to visitors.



DR. NELSON W. TAYLOR

With regard to the less serious aspects of the meeting, an informal dinner at the Nittany Lion Inn is scheduled for Friday night, and on Saturday visitors will have the opportunity to attend a football game between Lehigh University and Penn State. The College golf course will also be open to visitors at the Conference on payment of the special faculty greens fee. Special entertainment will also be provided for the ladies.

The Penn State Student Branch of the American Ceramic Society will furnish guides for inspection tours of the Mineral Industries Building and the other parts of the campus.

Pennsylvania takes first place in the United States as a producer of ceramic materials, with its immense refractories and glass industry, not to mention enamels, porcelain, abrasives, lime, cement, and heavy clay products.

The State College campus is always an attractive place and is particularly so in the latter part of October, when maples and elms are flaming with color and when student activity on the campus is in full swing.

All who have an interest in any aspect of ceramic activity are given a cordial invitation to attend this first meeting of the ceramic group at The Pennsylvania State College. It is believed that with the brilliant aggregation of speakers, the meeting will be of considerable interest and profit to all who attend.

Reservations may be made at the Nittany Lion Inn, and it is requested that those planning to come will get in touch with Dr. Nelson W. Taylor, Room 111, Mineral Industries Building.

The program for the Conference is as follows:

FRIDAY MORNING, OCTOBER 20

Registration, Lobby of Mineral Industries Building.

FRIDAY AFTERNOON, OCTOBER 20

General Session, 1:30 p. m., Room 315, Mineral Industries Building.

"Change of Phase and Change of Constitution in the Solid State" by Dr. R. B. Sosman, Research Laboratory, United States Steel Corporation.

Discussion.

"Progress in Heat Treatment of Alloys Resulting from Structure Studies" by Dr. D. F. McFarland, Head, Department of Metallurgy, The Pennsylvania State College.

Discussion.

"Petrography and Heat Treatment of Chromite Refractories" by Dr. G. E. Seil, Technical Director, E. J. Lavino Company.

Discussion.

"Notes on the Effect of Heat Treatment on the Spalling Properties of Clay Brick," by Stuart M. Phelps, American Refractories Institute Fellow, Mellon Institute.

Discussion.

Dinner (Informal) 6:30 p. m., Nittany Lion Inn. Price \$1.00. Secure tickets upon registration.

SATURDAY MORNING, OCTOBER 21

General Session, 9:15 a. m., Room 315, Mineral Industries Building.

"Some Aspects of Glass Annealing" by Dr. J. T. Littleton, Chief Physicist, Corning Glass Works.

Discussion.

"Developments and Trends in the Heat Treatment of Electrical Porcelain" by E. H. Fritz, Manager, Engineering Department, Westinghouse Electrical and Manufacturing Company.

Discussion.

"Influence of Heat Treatment on the Diffusion Properties and Color of Glasses," by Mr. H. H. Blau, Director of Research, MacBeth-Evans Glass Company.

Discussion.

"Effect of Temperature Treatment on Abrasive Materials and Products," by Mr. Ross C. Purdy, Secretary, American Ceramic Society.

Discussion.

Mineral Industries

Published monthly by the Division of Mineral Industries Extension from October to April, inclusive.

THE PENNSYLVANIA STATE COLLEGE
Division of Mineral Industries Extension
H. B. NORTHRUP, Director

Pennsylvania's School of Mineral Industries and Experiment Station

Dedicated to the finding, exploration, development, exploitation and conservation of Pennsylvania's natural mineral resources, and their preparation, processing, and efficient utilization.

FIELD OF WORK

Geology, Mineralogy, Geography
Petroleum and Natural Gas
Mining and Quarrying
Mineral Economics
Fuel Technology
Metallurgy
Ceramics

DIVISIONS OF SERVICE

Resident Instruction
Extension Instruction
Mineral Industries Research

Entered as Second Class Matter at State College, Pa., November 7, 1931, Under the Act of February 28, 1925.

OCTOBER, 1933

EXTENSION

Last year, in spite of the so-called depression, the Division of Mineral Industries Extension experienced the most encouraging year of its existence. Not only was greater interest evidenced by the men attending the evening extension classes, but the numbers enrolled evidenced the fact that the mass of workers in Pennsylvania's basic mineral industries are anxious to progress.

The summary of the work of this division is expressed by the following table:

	No. Classes	No. Enrolled	No. Finished	Per Cent Finish
Anthracite Classes	11	775	536	69.2
Bituminous Classes	38	923	539	58.4
Petroleum and Natural Gas Classes	7	455	313	68.8
TOTAL	56	2153	1388	64.5

The curtailment in Federal and State assistance to the work this year is a serious drawback to the plans of the College for continuing and expanding the extension work. Class organization is, however, being continued on the curtailed basis and also as an independent project, with the assistance of interested employers and the cooperation of the extension students.

It is expected that all organization work will have been completed by October 15 and that our program will continue uninterrupted during the school year.

NEW EXTENSION STAFF

During the last few months, the extension staff has been entirely reconstructed and three new men have been added to the force.

Mr. Donald C. Jones will have charge of all extension work in mining, including the supervision of evening mining classes and the preparation of text material to be used in conjunction with those classes. Mr. Jones is a graduate of the Carnegie Institute of Technology, receiving his B. S. in Mining in 1925, his M. S. in 1927 and his professional Engineer of Mines degree in 1928. Mr. Jones is the author of several technical papers pertaining to mining and comes well prepared and recommended.

Mr. Elbert S. Rowland will have charge of all extension work at the present time in metallurgy, ceramics, and fuel technology. Mr. Rowland is a graduate of the College of the City of Detroit, receiving his B. S. in Chemical Engineering from that Institution in 1930. He received his M. S. in Metallurgical Engineering from the University of Michigan in 1932. He has completed all of his graduate work for his doctorate and will receive his Ph.D. degree from the University of Michigan in February, 1934. Mr. Rowland has had both teaching and plant experience and also comes well qualified and recommended for the particular work.

Mr. Rex W. Woods was graduated from The Pennsylvania State College in the curriculum in Petroleum Engineering in 1930. Since that time, he has been employed in the oil fields of Oklahoma, and in the Bradford and Oil City pools in Pennsylvania. Mr. Woods will handle all supervision work in connection with the petroleum and natural gas extension classes. During the past year, he has written the second year extension class book in petroleum and natural gas engineering with the collaboration of members of the resident staff. He is now engaged in writing the third year extension book, and is taking advanced work at the College in the Graduate School for his Master's degree.

The Division of Mineral Industries Extension feels that it has now the nucleus of a very capable and efficient force of young men who are well prepared to meet the task imposed upon them and who have sufficient vision to anticipate some of the future needs of Pennsylvania's basic mineral industries.

GRADUATE STUDENTS IN THE DEPARTMENT OF CERAMICS

Three men are registered this fall for advanced degrees in Ceramics.

Mr. Roy W. Maize, who was graduated from Penn State a year ago, is studying structure changes which occur in the firing of aluminum oxide at various temperatures. He has constructed an interferometer for exact expansion measurements of solids at high temperatures. Mr. Maize is a candidate for the M. S. degree.

Mr. Sanford S. Cole, who was connected with the Koppers Research Organization at the Mellon Institute for a number of years, is a candidate for the Ph.D. degree. Mr. Cole is the author of a number of papers on silica brick and mortars. He recently obtained his M. S. degree at Alfred University. Mr. Cole is measuring vapor pressures of certain glass constituents.

Mr. Gordon R. Pole is a candidate for the Ph.D. degree in Ceramics. His experience covers several years with the Mellon Institute, the U. S. Bureau of Standards, and the Pittsburgh Plate Glass Company.

THE CORROSION PROBLEM

By PROF. O. A. KNIGHT

The problem of combating corrosion is one which confronts practically all users of metals and particularly those who use large amounts of the more easily corroded metals in environments conducive of corrosion. Most metals and alloys that are used on a large scale are subject to corrosion and only the more expensive "noble" metals, gold, platinum, and the like are immuned from the ordinary attacking agents. Iron and steel of the more common forms are especially subject to corrosion. The natural state of iron is in combination with elements such as oxygen, sulphur, and others. In the metallurgical operations employed for producing the enormous quantities of iron and steel processed in this country, the first step involves the separation of iron from the oxygen with which it is combined in the ore. Every time thereafter that an opportunity is available, that iron does its very best to again unite with oxygen. We are attempting to use iron in a state that is contrary to nature and when we are opposing the laws of nature we always have a battle on our hands. Nature never lets up.



PROF. O. A. KNIGHT

It has been stated by one well known authority that if we were to discontinue the use of iron and steel, little evidence of its present extensive application would be in existence one thousand years hence. This is further emphasized by the fact that only doubtful evidence exists of its use only 5,000 or 6,000 years ago, although indirect evidence points to the fact that it was used even earlier than the "Bronze Age." One has only to observe iron and steel structures in order to understand the seriousness of the corrosion problem. The upkeep of steel bridges, telephone and telegraph lines, wire fences, agricultural machinery, metal roofing, oil and gas pipe lines, automobiles, railway materials and many other things, necessitated by corrosion, runs into millions of dollar annually.

No less an authority than Sir Robert Hadfield, world famous English Metallurgist, stated in 1922 that the annual loss due to corrosion was probably no less than 700,000,000 pounds sterling and in 1932 he estimates the loss to be 67,000,000 tons or 19,000,000 tons in excess of the production for that year. It is impossible to make an accurate statement concerning the cost of corrosion loss for obvious reasons, but some

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FUEL TECHNOLOGY

Members of the Department of Fuel Technology attending the meeting of the American Chemical Society at Chicago, September 11-15 included Dr. A. W. Gauger, Professor of Fuel Technology, Dr. C. C. Wright, National Research Fellow, and Mr. T. S. Spicer, senior student in Fuel Technology. Dr. Gauger presided at the sessions of the Division of Gas and Fuel Chemistry as Chairman of the Division.

A paper entitled "The Hydrogenation of Coal and Tar" was presented by Dr. Wright and Dr. Gauger before the Symposium on Twenty-five Years Progress in Gas and Fuel Chemistry. This paper, which was read by Dr. Wright, sums up the progress in this important field of research, all of which was made during the past twenty-five years.

H. G. Turner and G. S. Scott attended the sessions of the Pennsylvania Sewage and Water Works Association at State College early in September. Mr. Turner presented a paper on the use of anthracite as a filter medium in water purification.

METALLURGY

Dr. D. F. McFarland, Head of the Department of Metallurgy, spent three weeks in attendance at the Seventh Meeting of the Society for Promotion of Engineering Education held at Madison, Wisconsin. Dr. McFarland was a speaker at the conference and upon his return to the College entertained the faculty of the School of Mineral Industries with a detailed account of his visit at the conference.

Professor O. A. Knight of the Department of Metallurgy is preparing a serial article on "Corrosion," the first number of which appears in this issue. Professor Knight has made a detailed study of this problem and his serial articles should be of interest to industry in general.

MINING

Due to poor conditions in the mining industry during the past several years, enrollment in mining courses slacked off at Penn State as at all other institutions offering a curriculum in mining. With a slight upturn in business in general, it apparently has become evident to parents of prospective mining students that in three or four years there will be a dearth of men trained for the mining industry. This has resulted in not only the return of practically all of the undergraduate mining students of last year but it apparently accounts for an increase in enrollment of first year men sixty-three per cent greater than last year's entering class.

Plans are approaching maturity for a conference November 10 and 11 at State College on certain phases of mining, coal preparation, and fuel technology. More detailed information will be ready in a short time.

Professor William R. Chedsey, Head of the Department of Mining, is the author of an article in September "Coal Age" which summarizes the work of agricultural investigators showing that American bituminous coal is neither a plant food nor fertilizer. Many mining operators have hoped that some such outlet for coal might occur but it certainly is not promising at present.

J. W. Stewart, Assistant Professor of Mining, spent a considerable portion of the summer vacation completing his research on certain phases of the preparation of small sizes of coal by froth flotation. He also visited, in company with D. R. Mitchell and J. L. G. Weysser, some of the interesting new preparation plants in the anthracite region.

Mr. D. R. Mitchell is a graduate in Mining of 1924 and is now on the teaching staff of the Mining Department of the University of Illinois.

Mr. J. L. G. Weysser, Instructor in Mining, spent most of his summer visiting various anthracite operations and made a particular study of the problems encountered due to the heavy rainfall and flooding of many of the mines.

PETROLEUM AND NATURAL GAS

Dr. George H. Fancher, Head of the Department of Petroleum Research, spent a summer month in the West studying the production problems throughout all of the oil fields in Texas, California, and Oklahoma. He took the occasion to spend two days at the University of Southern California discussing oil problems and research with Professor Lacey at the California Institute of Technology, where one of the A. P. I. research projects is being pursued. At Berkeley, California, it was his privilege to visit Professor Uren's Laboratories and discuss with Professor Uren problems pertaining to petroleum engineering and research. He also visited the petroleum laboratories of the Colorado School of Mines as a guest of Professor Clark F. Barb of that Institution. Professor Barb will be remembered as a previously popular instructor in Petroleum and Natural Gas Engineering at The Pennsylvania State College. Dr. Fancher also visited the refinery of the Humble Oil Company at Baytown, Texas, and later had a conference with the Company research staff, headed by Drs. Wild and Moore in Houston, Texas. Dr. Fancher reports that he found great interest in Pennsylvania oils throughout his entire trip in the West.

Mr. Kenneth B. Barnes, Instructor in the Department of Petroleum and Natural Gas Engineering, spent the summer doing petroleum engineering work in the Oil City area, principally on redeveloping problems, repressuring plants, lay-outs, and appraisals. Mr. Barnes obtained considerable repressuring data on the several sands in various localities of the Venango field which will be used in cooperation with Mr. Norman E. Maxwell in constructing a repressuring data map of the area.

Mr. J. E. Miller, Pet. E. '33, is now working for the Oil Well Supply Company, Oil City, Pennsylvania.

Mr. C. H. Feldmiller, Pet. E. '33, is now employed by the Equitable Gas Company, Pittsburgh, Pennsylvania.

Mr. Marshall T. Johnson, Pet. E. '33, is now employed in the Production Department of the Kendall Refining Company at

Farmers Valley, Pennsylvania.

During the early summer month, Mr. J. A. Lewis of the Petroleum and Natural Gas Research Laboratory, examined several samples of the Bradford sand from continuous cores in connection with the continuation of the studies of that department on permeability. Later in the summer, Mr. Lewis visited the Tulsa and McPherson oil fields of Oklahoma and the petroleum engineering school of the University of Oklahoma. His return trip was made by way of the Century of Progress Exposition in Chicago.

EXPERIMENT STATION

A paper entitled "Physical Tests and Properties of Oil and Gas Sands" was prepared by Messrs. G. H. Fancher, J. A. Lewis and K. B. Barnes for presentation before the World Petroleum Congress, organized by the Institution of Petroleum Technologists and held at the Imperial College of Science and Technology, South Kensington, London, July 19-25, 1933. This paper sums up the result of three years research in the petroleum and natural gas laboratory. A limited number of copies are available and may be had by addressing the Mineral Industries Experiment Station and enclosing a three-cent stamp to cover cost of mailing.

Dr. A. W. Gauger, Director of Mineral Industries Research, and Dr. G. H. Fancher, Assistant Professor of Petroleum Research, met with members of the Research Committee of the Bradford District Pennsylvania Oil Producers' Association on August 25, for the purpose of discussing the research work on secondary recovery of petroleum from Bradford sand. The Bradford District supports a fellowship devoted entirely to this study.

New members of the Experiment Station staff are Dr. William S. Walls, and Dr. D. R. Blumer. Dr. Walls was graduated cum laude, St. John's College, Annapolis, and received his Ph.D. degree from Princeton in January, 1933. He is working on the secondary recovery of petroleum from Bradford sand under the auspices of a fellowship sponsored by the Bradford District Pennsylvania Oil Producers' Association.

Dr. Blumer received his undergraduate training at the University of South Dakota, followed by graduate work in physical chemistry at the University of Minnesota from which institution he received the Ph.D. degree in 1931. Dr. Blumer holds a fellowship sponsored by the Pennsylvania Natural Gas Men's Association for fundamental work on the chemical treatment of natural gas.

EXTENSION AND CORRESPONDENCE INSTRUCTION
AVAILABLE AT THE PENNSYLVANIA STATE COLLEGE

The Pennsylvania State College offers many courses in both correspondence and extension instruction through its Agriculture, Engineering, Education, and Mineral Industries extension divisions. Correspondence instruction in any subject falling under either of these extension divisions is not limited to residents of the Commonwealth; extension instruction is limited solely to residents of Pennsylvania.

Through these four extension divisions of The Pennsylvania State College, you are offered one of the most complete correspondence and extension services available. If you are interested in any subject included within the scope of these four extension divisions, kindly address a letter to the Director, Mineral Industries Extension, describing your previous educational experience, the subject in which you are interested, and the type of course which you desire to study.

If your interests are outside of the scope of the Division of Mineral Industries Extension, your letter will be transmitted to the proper extension division of the College.

THE CORROSION PROBLEM

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authorities² state that for ferrous metals which are exposed to rather severe conditions, it is as high as 2 per cent per year. The actual loss of the corroded article is, in many cases, not by any means the total cost, because it may be that the operation costs of removing the spent one and inserting a new part will be more than the original cost of the article. In certain industries this may necessitate a shut-down which will be many times more expensive than either the replaced article or the replacement cost. We all know that the engineering literature is full of sad stories concerning the losses caused by corrosion. We should be equally willing, not only to admit that it is time something was done about it, but to start a definite program for combating corrosion.

The oil industry and gas industry have suffered terrific losses from corrosion. In some instances, these losses were realized and efforts are being made to minimize them, while in others, little attention is being given to the subject. H. S. Christopher³ estimated the life of pipe used in gas systems in California as being twenty-five years. He also estimated the annual corrosion loss to gas companies in that state as being about \$4,000,000 on an invested capital of \$50,000,000, and that his own company could save about \$25,000 per year if it were able to prolong the average life of its pipe as much as one year. We can hardly expect such an appalling loss as this in our Pennsylvania lines since soil conditions are different here and not so corrosive in character as are the California soils. The present writer's experience in gas pipe line appraisal in Pennsylvania leads him to the conclusion that Pennsylvania soils, particularly in the northwestern portion of the State are rather mildly corrosive. However, even here, there are to be found many so-called "hot-spots" where pipe lines deteriorate rapidly and require frequent replacement. A careful study by any agency will no doubt reveal how many possible savings can be effected by scientifically combating corrosion. The U. S. Bureau of Standards^{4,5,6,7,8,9} has carried on extensive work on soil corrosion, and valuable information concerning relative resistance of various metals to like corrosive conditions, relative corrosive rates of like material exposed to different soils, methods for measuring soil corrosivity and much more, is to be found in the references cited. This work alone should be sufficient to convince any one of the seriousness of the problem of corrosion and of the benefits to be derived from a careful study of the subject. Kendall and Speller¹⁰ state that losses due to corrosion in the oil industry have been estimated as being upwards of \$125,000,000 annually and they further point out a fact well known to most of us, but often ignored, "After a problem of this kind is thoroughly understood, its solution is usually not far away." Gill and Karl¹¹ discuss corrosion losses in petroleum production in considerable detail. They classify the corrosion losses as follows:

A. DESTRUCTION OF EQUIPMENT. This applies to losses caused by corrosion actually destroying material. It is pointed out that corrosion is sometimes erroneously blamed for losses since wear and other factors play an important role and when replacement is necessary, the failed part has a certain value as junk. Considerable detail is gone into regarding methods for determining the life expectancy of each class of petroleum production equipment.

B. COST OF REPAIRS. This includes the outlay necessary to offset losses caused by

corrosion. In some instances corrosion is entirely responsible for the failure of equipment, for example, by the corrosion puncture of tubing, although in most cases the cost of repairs has to be distributed between that caused by corrosion and that resulting from normal depreciation aside from corrosion. As an example, a fatigue failure in a string of sucker rods is cited. Corrosion fatigue may have caused the failure. Fifty per cent of the normal life of the rods had been obtained; therefore, fifty per cent of the repair costs is due to corrosion and fifty per cent is due to other causes. Some cases are more difficult to compute than the above, but a careful study usually permits a fairly representative distribution.

C. LOSS OF PRODUCTION. This includes the value of oil lost, during periods of shut-down, which might have been recovered had it not been for corrosion causing the shut-down. It is pointed out that to determine this is not an easy matter and says: "The common practice of charging a prorata share of a well's normal daily production is, in most cases, entirely erroneous." Considerable detail is then given as to how to go about making reasonably accurate estimates.

D. INDIRECT INCREASES IN PRODUCTION COST. Under this heading, it is pointed out that the following costs are caused by corrosion: (1) Water Troubles resulting from punctures of casing, (2) Extra pulling jobs to replace cups cut by accumulation of corrosion products from rods or tubing, (3) Decreased pump efficiency due to corrosion of working barrels and balls and seats, entailing an increased power consumption, (4) Increased cost for treating the emulsion formed by excessive fluid slippage past corroded balls and seats.

E. WATER FLOODING OF SANDS, CAUSED BY CORROSION PUNCTURE OF CASING LETTING WATER IN. It is pointed out that great difficulty is encountered in evaluating the losses from water flooding, and that there are other causes of water flooding aside from corrosion.

F. ACCELERATED PRODUCTION DECLINE. The corrosion of certain items of equipment may result in a rapid decline in production rates and in extreme cases it may result in the loss of a well, thus necessitating the drilling of additional wells in order to drain the field. Corrosion fatigue, corrosion punctures of casing and the corrosion of oil well screen pipe in the fields of the Gulf Coast are discussed in considerable detail. In the summary it is pointed out that there has not yet been developed a uniform system of determining the magnitude of corrosion losses, and the need of such a system is emphasized. The points brought out in the paper are such as to make quite an accurate appraisal of corrosion losses possible.

Kendall¹², previously referred to, also discusses production corrosion as well as refinery corrosion and points out that, in the former, all classes of corrosion problems are encountered—atmospheric, soil, water, hydrogen sulphide, etc. With regard to refinery corrosion problems, they point out desirability of dividing them into two classes, namely (1) Low Temperature Problems and (2) High Temperature Problems. They state that hydrochloric acid resulting from decomposition of calcium and magnesium chlorides is largely responsible for damage in the low temperature range whereas in the high temperature range, the damage is largely the result of oxidation of the metal on the fire side and action of sulphur compounds in the crude oil.

(To Be Continued in November Issue)

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