SCIENCE

23 June 1961

Vol. 133, No. 3469

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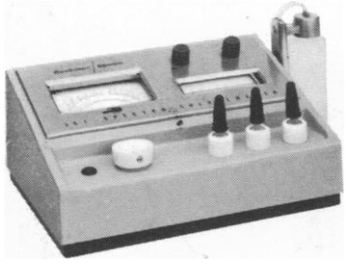

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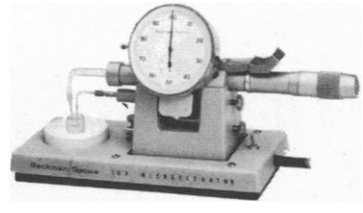

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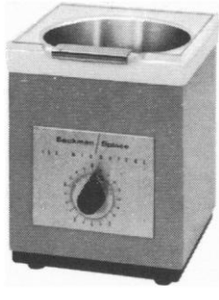

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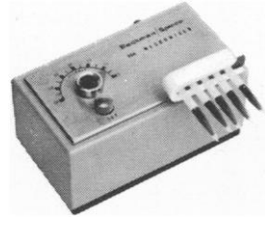

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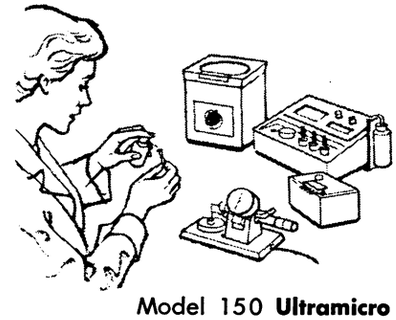

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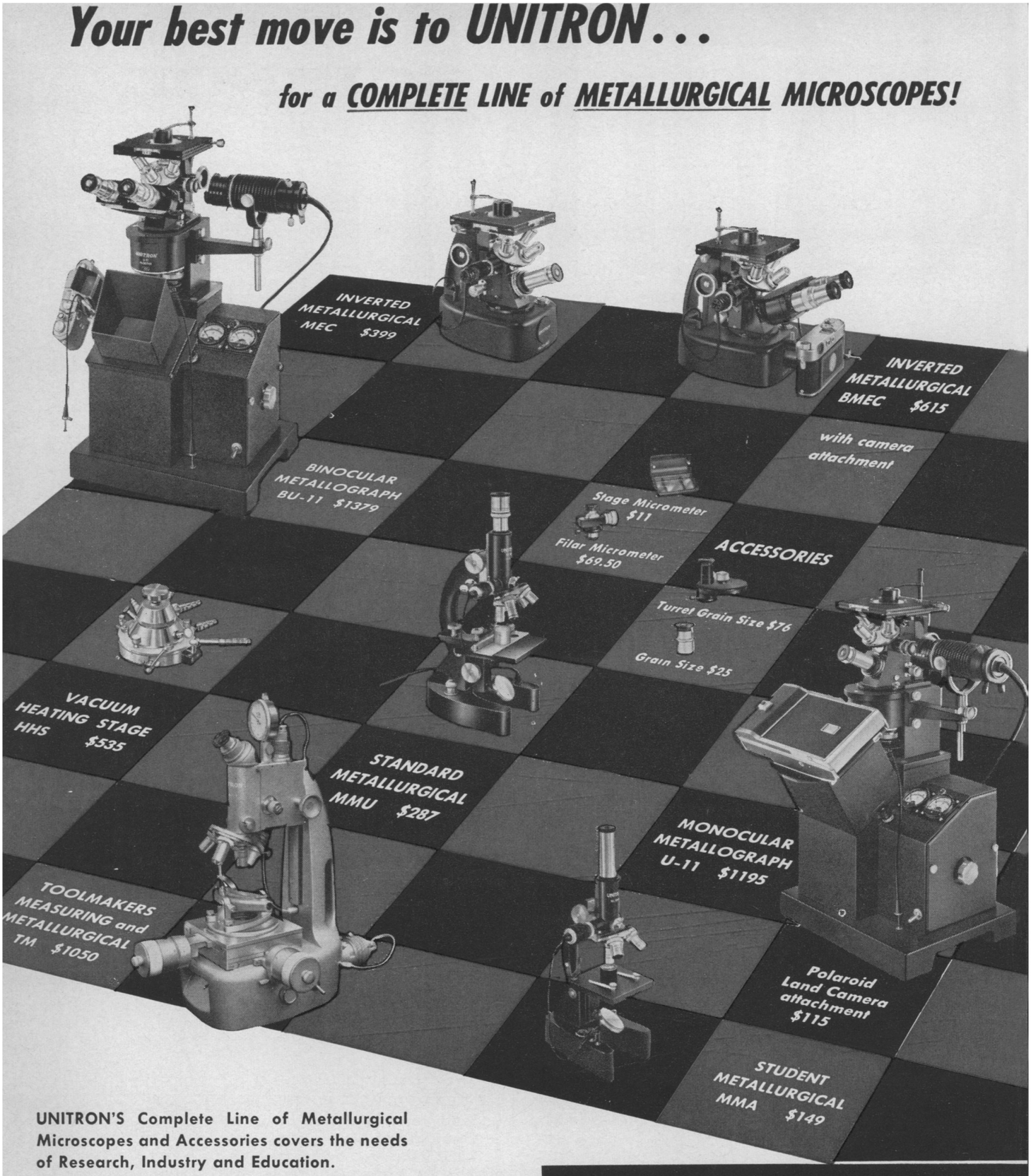

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SCIENCE

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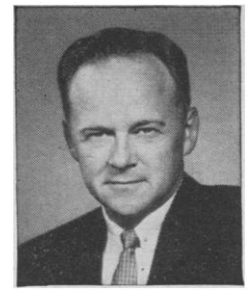
Dr. Finn Larsen
Vice President for Research



The Nature of Oxidation: Studies In The High-Temperature Oxidation of Alloys

Under high temperatures, oxidation is accelerated. While some pure metals deteriorate rapidly, certain of their alloys oxidize much more slowly. Accurate prediction of alloy oxidation rates, however, awaits development of a reliable mathematical model. At Honeywell Research, new techniques have produced data that make a start toward a universally applicable theory.

With the single exception of gold, oxidation limits the use of all metals at high temperatures. This is true because the products of corrosion do not have the properties of the parent metal. In addition, corrosive products occupy more space than the parent metal they replace, affecting dimensions and tolerances.

Corrosion is greatly accelerated by high temperatures, putting serious limitations on progress in heat generating equipment such as internal combustion engines, rockets, nuclear reactors and electrical contacts.

At the present time the accepted method of inhibiting corrosion is to apply a protective coating to the metal to prevent the migration of oxygen atoms to the surface of the material. This, however, is expensive and in many cases not practical.

We know that when an oxide free surface is exposed to ordinary air at room temperature the upper layers of the metal combine with the oxygen atoms to form a thin film or scale (oxide). For further oxidation to occur the thin oxide film must be penetrated by either oxygen atoms migrating down to the fresh metal surface or by metal atoms migrating outward to the air. In most cases, one of these reactions predominates.

For about 40 years metallurgists have worked with several classical equations that predict the rate of oxidation. However, these equations apply rigorously only under idealized conditions. They do not fully equate the mechanical and microstructural features of a multi-layer oxide or the dislocations and stresses that affect the oxidation process. For example: Is the oxide film ductile or brittle? A change of temperature puts thermal stress on the oxide and if it is brittle it will probably break off. These properties modify the classical theory. All of these problems multiply and each influence is changed when an alloy is introduced.

Honeywell scientists hope to learn more about these altering influences in order to extend the classical equations. They are analyzing multi-layer oxide scales with a number of different laboratory methods to build support for new, predictable behavior.

Multi-layer scales are caused by the ability of metals to have multiple valences. The balance between these layers is controlled by temperature. When a multi-layer scale exists, oxides are often unable to relax the stresses that occur. These stresses are caused by the differences in specific volume and the differences in thermal coefficients of expansion between the oxide and the metal. When they cannot be relaxed, stresses may build up and affect the rate of oxidation. Also, if external stresses are applied to the material the rate of oxidation may be affected.

The approach to this study quickly becomes a mixture of metallurgy and physical chemistry. One technique in studying rate of growth of the scale has been to measure the weight gain of alloys during oxidation. Reliable data on oxidation has been obtained in this manner.

To determine the direction of the migration of ions and also measure the growth of individual layers, Honeywell scientists are welding thin platinum wires to a specimen prior to heating. These marker wires give a point of reference to the original surface. If oxygen ions are moving inward, the wire remains outside the surface. If cations are moving outward, the marker wire will be under the surface. This method has yielded valuable new information on the formation of oxides.

Microscopic examination also has been helpful in identifying layers, and X-ray diffraction has given positive identification of the oxide phases.

Ideally we would like to completely inhibit even the first monatomic oxide layer. At the present state of knowledge, this seems unattainable. Our approach then is to utilize the natural oxidation process but control it. By doing this we permit the formation of a thin film but seek to make it impermeable to further ion migration.

In our experiments Honeywell scientists have effected radical changes in oxidation rates by changing the oxide microstructure through heat treatment of its alloy. For example, with an alloy of .87 Mg—.62 Cu, the oxidation rate can be retarded and the resulting oxidation reduced by a factor of ten with proper heat treatment.

We now know that in a polycrystalline structure, stress and mechanical properties affect both the rate and the mechanism of oxidation. Also we know that the mechanical properties of the oxide have a decisive effect on the tendency of the oxide to either spall or adhere.

This is a start toward the derivation of a general theory explaining the oxidation of alloys. Though our research is basic at this point in time, we expect it to yield many practical answers to assist the design engineers working on high temperature problems confronting today's nuclear and space projects.

If you are engaged in scientific work relating to oxidation of metals and would like to know more about Honeywell's research on this subject, you are invited to correspond with Dr. J. A. Sartell, Honeywell Research Center, Hopkins, Minnesota.

If you wish a recent paper, "The Role of Oxide Plasticity in the Oxidation Mechanism of Pure Copper," by Dr. Sartell, write to Honeywell Research, Minneapolis 8, Minnesota.

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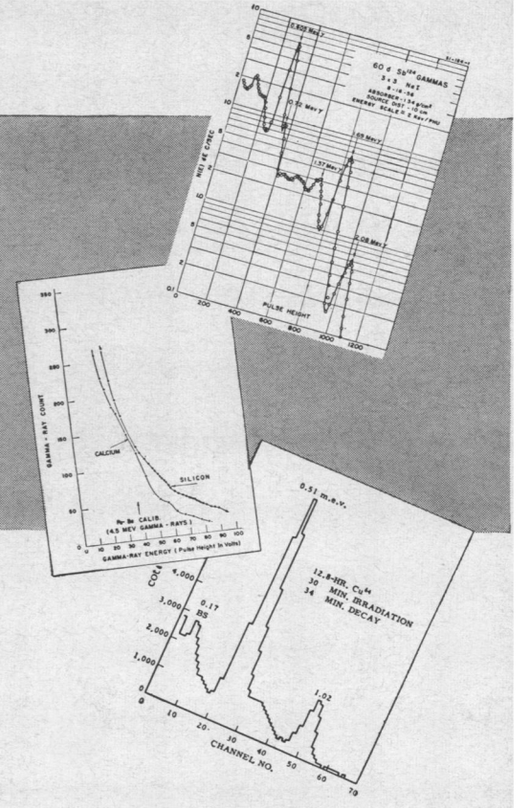

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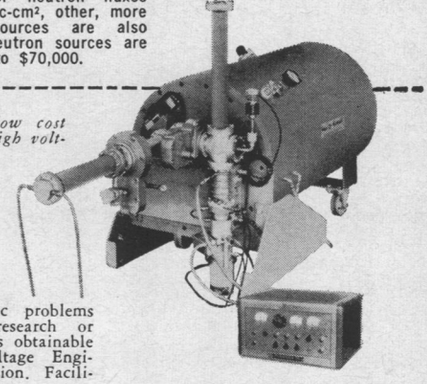

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23 June 1961, Volume 133, Number 3469

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SCIENCE, now combined with THE SCIENTIFIC MONTHLY, is published each Friday by the American Association for the Advancement of Science at National Publishing Company, Washington, D.C. SCIENCE is indexed in the *Reader's Guide to Periodical Literature.*

Editorial correspondence should be addressed to SCIENCE, 1515 Massachusetts Ave., NW, Washington 5, D.C. Manuscripts should be typed with double spacing and submitted in duplicate. The AAAS assumes no responsibility for the safety of manuscripts. Opinions expressed by authors are their own and do not necessarily reflect the opinions of the AAAS or the institutions with which the authors are affiliated. For detailed suggestions on the preparation of manuscripts, see *Science* **125**, 16 (4 Jan. 1957).

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How To Let Go and Still Hold the Line

Although the demand for mathematics teachers with Ph.D.'s has greatly increased in recent years, the supply, contrary to the familiar economic law, has been diminishing. Enrollment in mathematics courses is growing much faster than total enrollment in college, with the greatest growth in advanced courses. At the same time, although the number of new Ph.D.'s turned out each year has also grown, with so many mathematicians going into government or industry, the number becoming teachers is not even enough to balance annual losses. This surprising situation was reported by Edwin Moise, of Harvard University, in the April issue of the American Mathematical Society's *Notices*. Moise was speaking for a special committee of mathematicians. What is also surprising is that the committee goes on to suggest that the remedy does not necessarily lie in redoing the entire value structure of American society, but in redoing some of the values entertained by the mathematical community.

To get a doctorate in mathematics, the candidate must now pass preliminary examinations and then write a dissertation offering some new and interesting mathematical proofs. The idea behind this procedure is that to teach mathematics you have to be a creative mathematician yourself. The committee questions this assumption. It suggests an alternative program of study in which the creative dissertation is replaced by "a scholarly dissertation which could be historical, critical, or philosophical," with history understood to include very recent history. Such research, it is claimed, would also be sensible preparation for effective teaching and would result in something of value to the mathematical community. To distinguish the new program from the traditional one, there would also be a new graduate degree in mathematics, the Doctor of Arts.

Official groups of the American Mathematical Society and of the Mathematical Association of America have approved these sentiments in principle, but not all mathematicians are so happy about the proposal. Some criticisms are expressed in a letter to the editor in the June issue of the *Notices*. One criticism is that there has not really been a study of why, with B.A.'s in mathematics comparatively plentiful, Ph.D.'s are so scarce, and that such a study might well show that the hurdle is not the dissertation but the preliminary examinations. A second criticism is that the introduction of a new program of study would mean the introduction of class distinctions among mathematicians, with the upper and lower classes regarding each other with condescension on the one side and envy on the other.

The proposal does have a certain appeal, however. In another field, no necessary connection is expected between being a good novelist and being a good teacher of literature. A key question about the proposal is whether its proponents really mean it when they say that the new kind of dissertation would be both preparation for teaching and a contribution to scholarship. If so, then why not accept the new dissertation but drop the idea of a new "Doctor of Arts" degree, and let the Ph.D. degree serve here as well? The number of additional teachers that would result is not known, but the idea would then seem quite worth pursuing. Differences in status we will always have with us. There are differences now regarding universities, supervisory professors, and dissertation topics. But neither these differences nor those between creative and scholarly work need be shouted from roof tops to be appreciated.—J.T.

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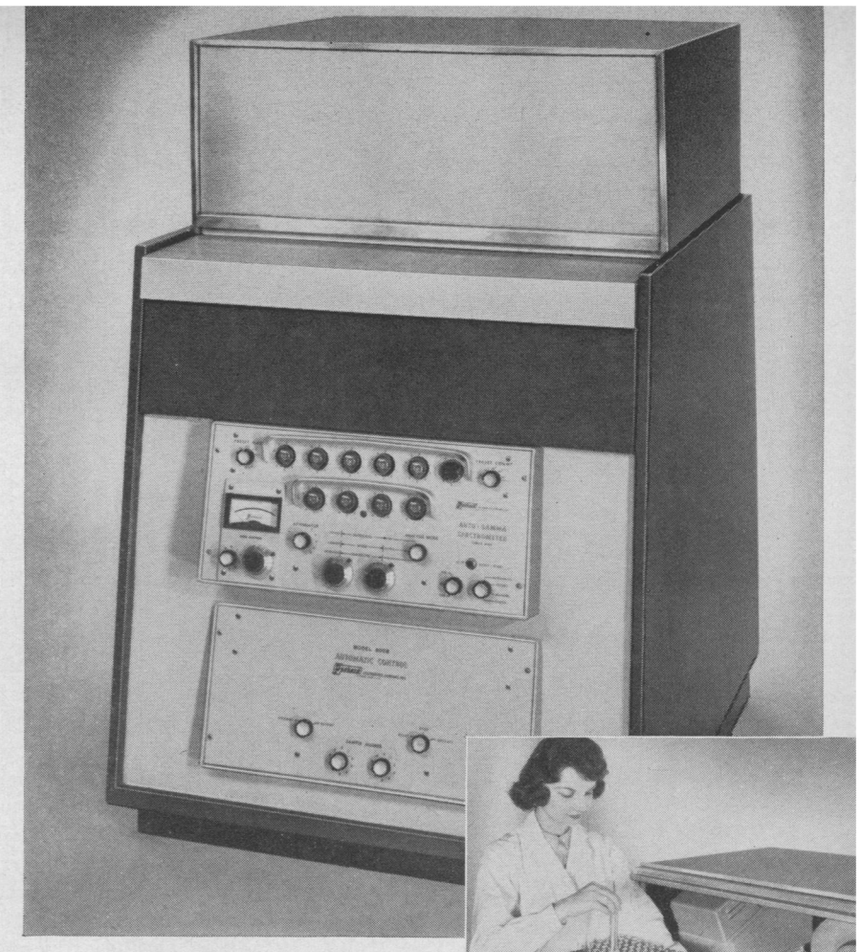

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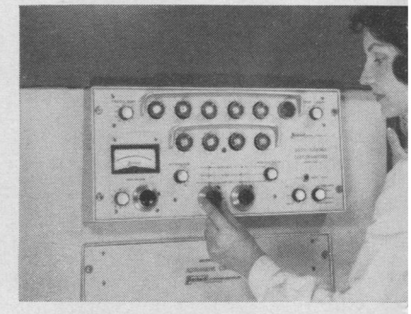

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terfere with other, independent efforts aimed at the same goal. While such independent studies are unlikely to attain the national attention that would be given to a more massive attack, they may well turn out to be more imaginative and bolder in conception and method of attack. Such independent studies should be encouraged, not discouraged, by the existence of a large and coordinated effort.

An Observation

A most encouraging aspect of the three conferences was the ease and satisfaction with which scientists, representing all of the major scientific disciplines, and educators, representing teacher education, administration, and the classroom, were able to reach agreement about needs for improvement of early science education and ways of bringing about that improvement. It was heartening to both scientists and educators to find such a high degree of agreement upon the importance and the feasibility of the task. The general spirit of the conferences was one of enthusiastic acceptance of joint responsibility and confidence that a large-scale, coordinated, and cooperative attack would produce major improvements in science education at the elementary and junior high school levels.

Reference

1. The background papers appear as articles by the authors in *School Science and Mathematics* (Apr., May, and June 1961).

Forthcoming Events

July

16–21. International Conf. on Medical Electronics, 4th, with Electrical Techniques in Medicine and Biology, 14th annual conf., New York, N.Y. (L. E. Flory, RCA Laboratories, Princeton, N.J.)

16–22. International Soc. for Clinical and Experimental Hypnosis, Rio de Janeiro, Brazil. (ISCEH, 33 E. 65 St., New York 21)

17–22. Soil Mechanics and Foundation Engineering, 5th intern. conf., Paris, France. (E. Caminade, Secretaire General, 23 rue de Cronstadt, Paris 15)

18–20. Pulmonary Structure and Function, Ciba Foundation Symp. (by invitation only), London, England. (Ciba Foundation, 41 Portland Pl., London, W.1)

18–21. Inorganic Polymers, intern. symp., Nottingham, England. (General Secretary, Chemical Soc., Burlington House, London, W.1, England)

21–22. World Power Conf. (members only), Moscow, U.S.S.R. (Central Office, 201-2 Grand Buildings, Trafalgar Sq., London, W.C.2, England)

23–28. Otolaryngology, 7th intern. congr., Paris, France. (H. Guillon, Secretary General, 6 Avenue Mac-Mahon, Paris 17)

24–28. Nematology Symp., 6th intern., Ghent, Belgium. (J. van den Brande, Soc. of European Nematologists, Rijkslandboushogeschool, Coupure links 235, Ghent)

24–29. Medical Electro-Radiological Societies, Latin Federation of, 5th congr., Paris, France. (C. Proux, Secretary, 9 rue Daru, Paris 8)

24–30. Urology, 12th intern. congr., Rio de Janeiro, Brazil. (J. Silva de Assis, Secretary, P.O. Box 1275, Belo-Horizonte, Brazil)

26. International Commission for the Prevention of Alcoholism, 7th annual meeting, Washington, D.C. (International Headquarters, 6840 Eastern Ave., NW, Washington 12)

26–28. Detection and Assay of Hormones by Immuno-Clinical Means, Ciba Foundation Colloquium (by invitation only), London, England. (Ciba Foundation, 41 Portland Pl., London, W.1)

27–1. Macromolecular Chemistry, intern. symp., Montreal, Canada. (Organizing Committee, P.O. Box 816, Sarnia, Ontario, Canada)

28–29. Linguistic Soc. of America, Austin, Tex. (A. A. Hill, Box 7790, University Station, Austin 12)

30–2. Soil Conservation Soc. of America, Lafayette, Ind. (H. W. Pritchard, 838 Fifth Ave., Des Moines 14, Iowa)

30–3. International Psycholanalytical Congr., 22nd, Edinburgh, Scotland. (Miss C. de Monehaux, 53 York Terrace, Regents Park, London, N.W.1, England)

31–4. Biophysics, 1st intern. congr., Stockholm, Sweden. (B. Lindström, Dept. of Medical Physics, Karolinska Institutet, Stockholm 60)

31–4. Differential Equations in Non-Linear Mechanics, Air Force Acad., Colorado Springs, Colo. (J. P. Lasalle, 7212 Bellona Ave., Baltimore 12, Md.)

31–11. Physics of the Solar System and Re-entry Dynamics, conf., Blacksburg, Va. (Bureau of Public Relations, Virginia Polytechnic Inst., Blacksburg)

31–12. Electric Power and Problems of Nuclear Power, seminar, U.N. Economic Commission for Latin America, Mexico, D.F. (A. Dorfman, Chief, Energy and Water Resource Program, Avenue Providencia 871, Santiago, Chile)

August

1–26. Functional Analysis, 8th American Mathematical Soc. summer institute, Stanford, Calif. (P. D. Lax, AMS, 190 Hope St., Providence 6, R.I.)

2–5. International Conf. of Pure and Applied Chemistry, 21st, Montreal, Canada. (R. Morf, Hoffmann-LaRoche, S.A., Grenzachterstrasse 124, Basel, Switzerland)

3–5. Canadian Chemical Conf. and Exhibition, 44th, Montreal. (Chemical Inst. of Canada, 48 Rideau St., Ottawa 2, Ont.)

5–9. International Rorschach Soc., 5th congr., Fribourg-en-Brisgau, Germany. (A. Friedemann, Chemin des Pêcheurs 6, Bienne, Switzerland)

6–10. Occupational Medicine and Toxicology, 3rd Inter-American conf.. Miami, Fla. (W. B. Deichmann, School of Medicine, Univ. of Miami, Coral Gables, Fla.)

6–12. Atmospheric Ozone and General Circulation, symp., Arosa, Switzerland. (H. U. Duetsch, 20 Carl Spittelerstrasse, Zürich 53, Switzerland)

6–12. Chemical and Thermodynamic Properties at High Temperatures, symp., Montreal, Canada. (N. F. H. Bright, Natl. Research Council, Ottawa, Canada)

6–12. International Congr. of Pure and Applied Chemistry, 18th, Montreal, Canada. (L. Marion, Natl. Research Council, Ottawa 2, Canada)

7–9. Guidance and Navigation Conf., American Rocket Soc., Palo Alto, Calif. (J. J. Harford, ARS, 500 Fifth Ave., New York, N.Y.)

7–9. International Committee of Electro-Chemical Thermodynamics and Kinetics, 13th meeting, Montreal, Canada. (N. Ibl, Eidg. Technische Hochschule, Laboratorium für Physikalische und Elektrochemie, Universitätsstrasse 6, Zürich 6, Switzerland)

7–9. Space Age Astronomy, intern. symp., Pasadena, Calif. (D. W. Douglas, Jr., Douglas Aircraft Co., Inc., Santa Monica, Calif.)

7–10. National Medical Assoc., New York, N.Y. (J. T. Givens, 1108 Church St., Norfolk, Va.)

7–11. High Temperature Chemistry and Thermodynamics, symp., Montreal, Canada. (L. Brewer, Dept. of Chemistry, Univ. of California, Berkeley)

7–11. Seminar on Fast and Intermediate Reactors, International Atomic Energy Agency, Vienna, Austria. (IAEA, 11 Kärtner Ring, Vienna 1)

8–11. Poultry Science Assoc., State College, Pa. (C. B. Ryan, Texas A & M College, College Station)

8–16. Society of Protozoologists, Prague, Czechoslovakia. (N. D. Levine, College of Veterinary Medicine, Univ. of Illinois, Urbana)

10–16. International Congr. of Biochemistry, 5th, Moscow, U.S.S.R. (N. M. Sissakian, Leninsky prospekt, 33, Moscow, B-71)

10–16. International Union of Biochemistry, 4th general assembly, Moscow, U.S.S.R. (R. H. S. Thompson, IUB, Dept. of Chemical Pathology, Guy's Hospital Medical School, London, S.E.1, England)

12–19. Fast Reactions, summer school, Cambridge, England. (Secretary of the Summer School, Dept. of Physical Chemistry, Lensfield Road, Cambridge)

13–18. Microchemical Techniques, intern. symp., University Park, Pa. (H. J. Francis, Jr., Pennsalt Chemical Corp., P.O. Box 4388, Chestnut Hill Post Office, Philadelphia 18, Pa.)

13–18. Theoretical Aspects of Magnetohydrodynamics, seminar, University Park, Pa. (Conference Center, Pennsylvania State Univ., University Park)

13–19. International Assoc. of Applied Psychology, 14th congr., Copenhagen, Denmark. (Congress Secretariat, 19 Sankt Pederstraede, Copenhagen K.)

13–19. Training for Research in the Processes of Vision. 1st intern. conf., Rochester, N.Y. (Office of Public Information, River Campus Station, Rochester)