SCIENCE

25 September 1970

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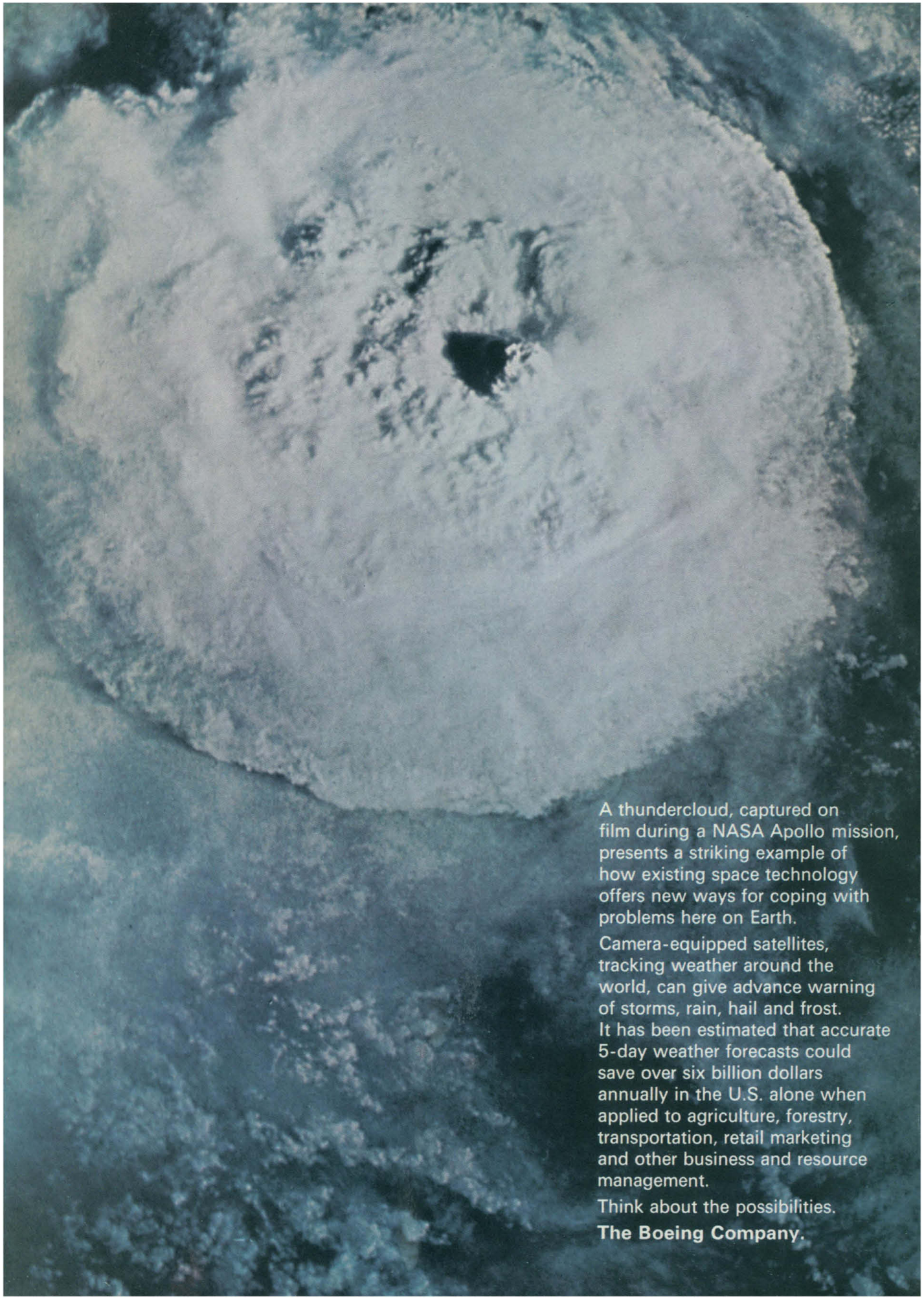
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Index Issue



A thundercloud, captured on film during a NASA Apollo mission, presents a striking example of how existing space technology offers new ways for coping with problems here on Earth.

Camera-equipped satellites, tracking weather around the world, can give advance warning of storms, rain, hail and frost. It has been estimated that accurate 5-day weather forecasts could save over six billion dollars annually in the U.S. alone when applied to agriculture, forestry, transportation, retail marketing and other business and resource management.

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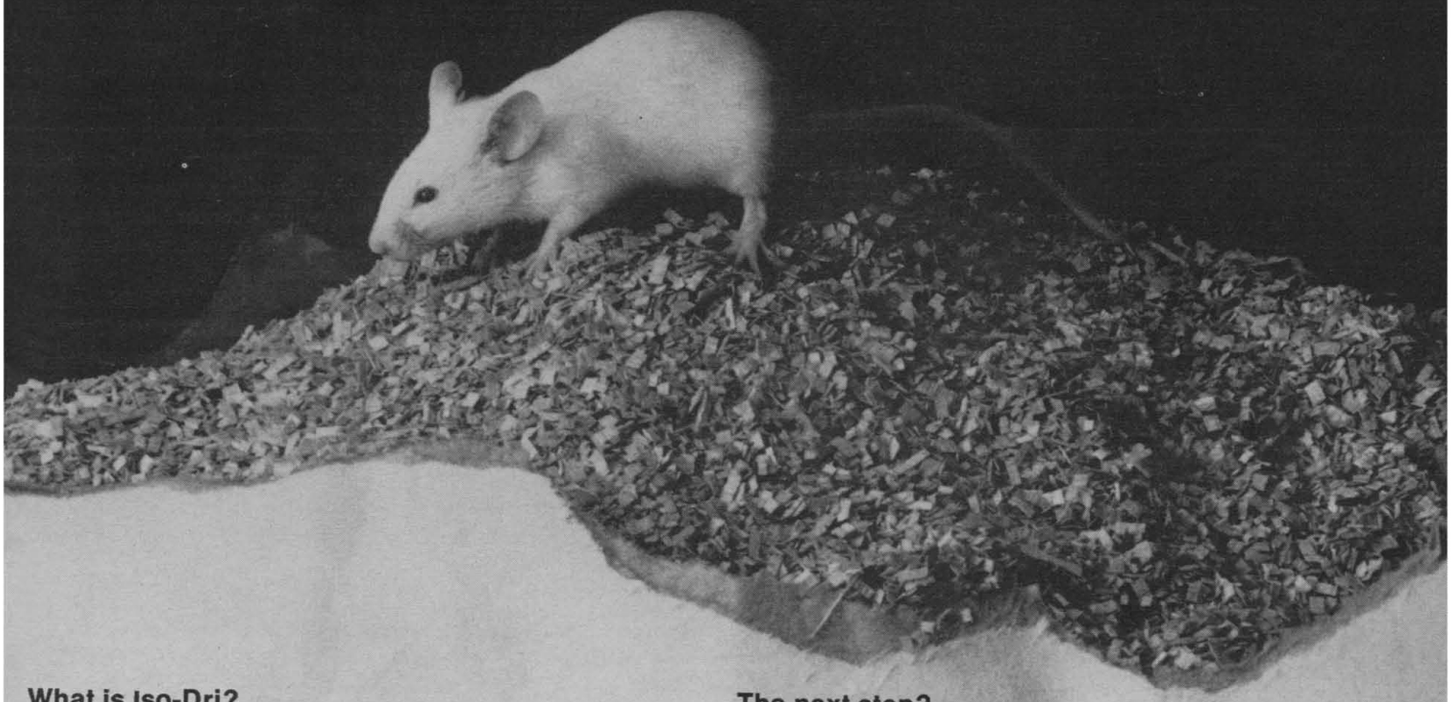

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SCIENCE

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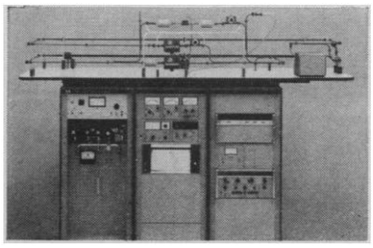
COVER

American elm (*Ulmus americana*) in winter on the St. Paul Campus of the University of Minnesota. Living branch tissues survive −196°C without injury in winter but endure only a slight frost in summer. See page 1269. [Photographic Laboratories, University of Minnesota, St. Paul]

Some things are changing for the better...

Many of the most troublesome gaseous air pollutants can now be measured directly and accurately



"To measure is to control"—*Lord Kelvin.*

Regardless of our clear national resolve and even of a developing body of tough laws, air pollution remains a difficult problem. There will be no satisfactory solution until there is a reliable way to measure each pollutant that enters our atmosphere and affects our health and comfort . . . because you cannot control adequately what you cannot measure accurately. The truth is that some of the most noxious and dangerous air pollutants—especially some of the highly reactive gaseous products of combustion that are readily assimilated by humans—cannot yet be measured reliably in the complex mixtures which pollute the air that surrounds our largest cities.

Although medical research has already provided some specific definitions of acceptable levels of these pollutants, no real progress towards abatement can be made until there is a measurement capability for each. Only then will the government agencies charged with the responsibility for abatement be able to answer reliably the really tough questions: is a specific pollutant present in the air, is it above the acceptable level, where does it come from? All of these answers depend on measurement.

Here again, a generalized attack won't do the job: no single analytical technique, no single instrument can provide a measurement capability for all the air pollutants that defile our environment. Air pollution research labs and regional control centers must be equipped with a wide range of measurement capabilities. Until now, traditional colorimetric methods, gas chromatographs, infra-red and mass spectrometers have given them many answers . . . but not enough.

An Effective Weapon Against Air Pollution

There are some gaping holes in the analytical arsenal for air pollution measurement. A measurement technique with a great potential for filling one of these holes is rotational microwave spectroscopy, which has a unique capability for the analysis of small, polar, gas phase organic and inorganic air pollutants. This method can provide qualitative and quantitative measurement of these pollutants in complex mixtures without interference from other pollutants or chemical interaction with them.

The specific pollutants that rotational microwave spectroscopy detects most ably are precisely those which are the most injurious to human life because they are easily absorbed by the moist tissues of the body . . . and the most difficult to detect otherwise because they are readily dispersed in the atmosphere, due to their low molecular weight and volatility. Most of the ubiquitous gaseous products of combustion—e.g. oxides of sulphur and nitrogen, mercaptans, small hydrocarbons, aldehydes — have a characteristic microwave absorption spectrum.

In rotational microwave spectroscopy, a polar molecule absorbs energy at specific frequencies when it is a freely rotating body. The absorption spectrum for each individual molecular species—even for isomers and isotopes—is therefore unique for that species, even in the presence of other polar and nonpolar molecules; the spectrum therefore is a "fingerprint" of the species.

Reliability of the technique is quite high owing to the sharpness of the spectral lines. These lines are typically about 0.5 MHz wide and the peak frequency can easily be measured to better than ± 0.05 MHz. As a comparison, infra-red bands are generally measured to ± 1 CM^{-1}; 0.05 MHz corresponds to about *one millionth* CM^{-1}.

SO_2: Specificity Even in the Presence of Other Sulfides

The ability of rotational microwave spectroscopy to identify SO_2 directly, even in the presence of other sulphur compounds such as ethyl and methyl mercaptans, is demonstrated in the upper series of spectra on the right. The top trace is a fast scan of a mixture of 10% SO_2 with 45% EtSH, and the one below was made from a sample of 99%+ pure SO_2. A careful comparison of the absorption frequencies of SO_2 in the mixture spectrum with those in the pure SO_2 spectrum reveals that they occur at precisely the same points in both. Thus the MeSH and EtSH have no solvent effect whatever on the spectral signature of SO_2 . . . and vice versa.

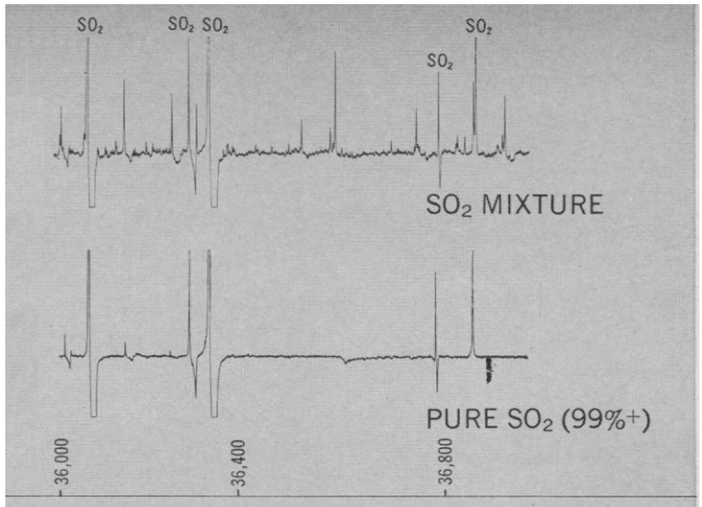
Regarding its sensitivity to SO_2, the HP rotational microwave spectrometer (MRR) can detect 0.01 millitorr partial pressure in an arbitrary mixture like the one just described. Typical sample cell pressures range from 20 to 100 millitorr.

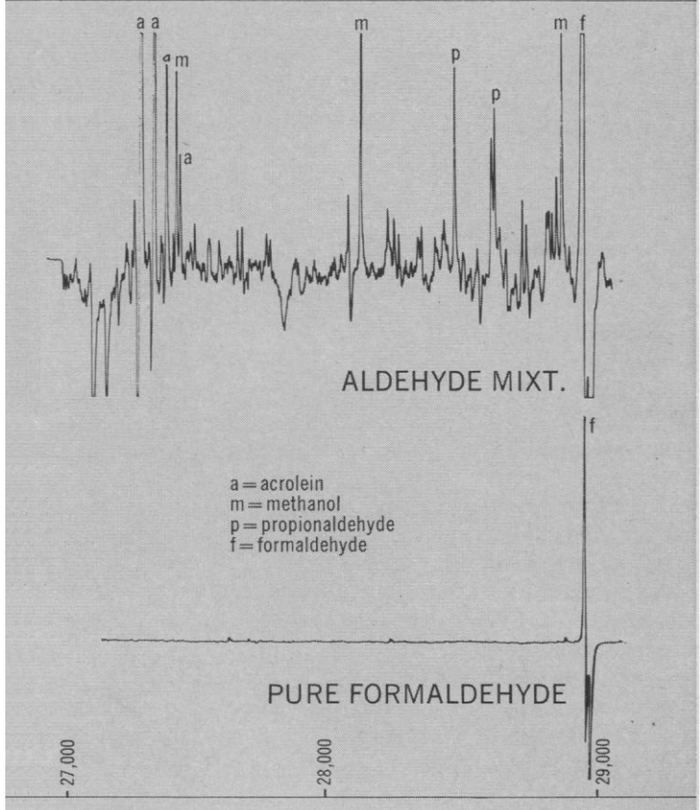
Aldehydes: 'Fingerprinted' in a Difficult Mixture

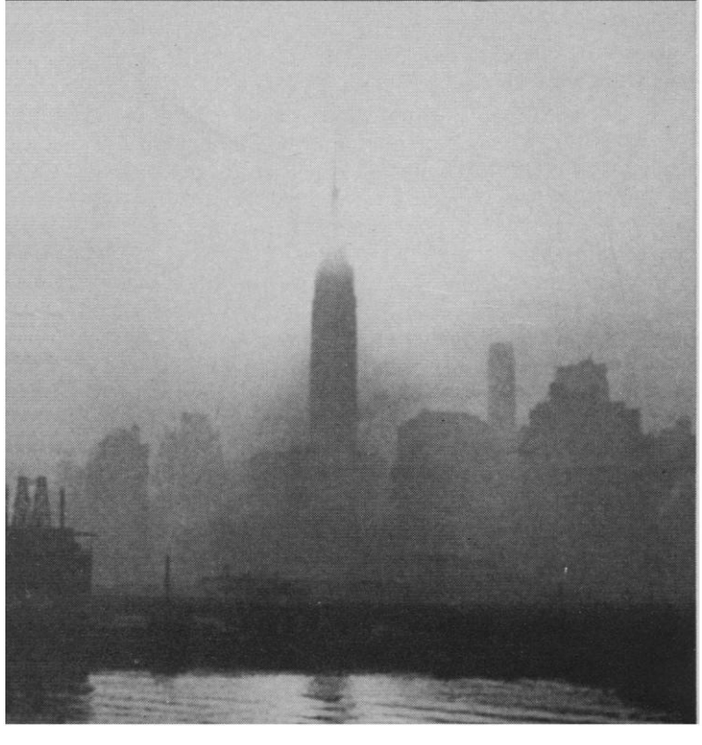
This low total sample pressure in the spectrometer minimizes the tendency of air pollution mixtures to react chemically: this is precisely the greatest difficulty in analyzing aldehydes—especially formaldehyde, a most reactive pollutant.

The aldehyde scans (lower series at right) demonstrate the capability of the technique to detect formaldehyde, propionaldehyde and acrolein directly in a mixture, without the need for prior separation of the other aldehydes. All of the absorption lines for each of the aldehydes are completely resolved. As in the SO_2 example, the absorption line of formaldehyde in the mixture scan is precisely the same as in the pure formaldehyde scan, completely unchanged by the presence of other aldehydes.

This characteristic of the technique derives from two important facts: the microwave absorption frequencies for a particular compound are fixed and unchanging, at typical sample pressures, and these low pressures keep the sample at a low chemical potential virtually eliminating the possibility of polymerization or chemical interaction with other pollutants.







Quantitative Analysis: Linear to 100% The technique is sufficiently sensitive to detect most gas phase pollutants as they occur at the source. Furthermore sample concentration methods are being developed in order to detect many pollutants at the extremely low concentration levels in which they sometimes exist after dispersal in the atmosphere. Such sample handling approaches are aided by the fact that this technique has been shown to be quantitatively linear from the minimum detectable limits to 100% pollutant concentration.

Boundary conditions for this linearity have been investigated and can be readily achieved experimentally. While this characteristic has obvious importance for the quantitative analysis of a particular mixture, it may be even more valuable to assess sample concentration methods and to detect adsorption taking place within the sample container.

Second-generation Spectrometer Now Available After some 5 years of application experience with the original MRR (Microwave) Spectrometer, HP scientists have completed the design of a second-generation instrument which is now available as the 8460 MRR Spectrometer. The new instrument incorporates a number of improvements that increase its usefulness and simplify its use.

It generates only a few milliwatts of microwave energy and does not require cooling water, air conditioning or other special services.

The 8460 is a research instrument with broad-band capability that extends its application to the qualitative and quantitative analysis of most of the small, gas phase pollutants that are currently in the limelight, and many that are not but may soon be. For example, most of the gases that have a bad odor or are toxic to human life are small molecules with a nitrogen or sulfur atom. The great majority of these have a permanent dipole moment and are therefore susceptible to MRR analysis. As we get the current problems in hand, these will almost certainly be included more forcefully in future air quality standards.

The HP MRR Spectrometer is being used presently as a research tool. Intramolecular forces are evaluated through exact structural determination, line splitting and accurate intensity measurements. Intermolecular forces can be determined from absorption line shapes.

HP scientists are constantly accumulating information on rotational microwave spectroscopy, in the study of molecular structure, air pollution analysis and other fields. We'll be happy to send you the recently published Data Booklet on MRR technique, the Data Sheet on the 8460 MRR Spectrometer, or to place you on the mailing list for *Molecules and Microwaves* which periodically reports results of experimental work with the MRR Spectrometer. Hewlett-Packard, 1507 Page Mill Road, Palo Alto, California 94304. In Europe: 1217 Meyrin-Geneva, Switzerland.

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25 September 1970, Volume 169, Number 3952 **SCIENCE**

Scarcity of Energy

The United States is now faced with serious short-term and long-term problems in satisfying its needs for energy. In the short-term, there is a scarcity of fuels that meet antipollution regulations; in the long-term, we are faced with depletion of our petroleum and natural gas reserves.

The major air pollutant from stationary sources, SO_2, comes largely from thermal electric power plants. About 57 percent of the fuel for such plants is coal that typically contains 2 to 3 percent sulfur. To diminish air pollution, a number of cities, including New York, have adopted regulations that require in effect that fuels have no more than 1 percent sulfur. The result has been a curtailment of the use of coal in such cities, for only limited amounts of coal with 1 percent sulfur or less are available.

In an effort to comply with the regulations, many utilities have switched to fuel oil. This year the demand for residual fuel oil has already risen sharply but supplies have not increased correspondingly. The United States makes little residual fuel oil. More than 90 percent of the needs of northeastern United States are derived from foreign sources. Most comes from Venezuela, which produces high-sulfur oils that must be specially treated. Although new refining units have recently been installed, their capacity is not sufficient to meet demands. Another source is the low-sulfur oils of Africa, but their availability is limited by production cutbacks in Libya and by a worldwide shortage of tankers created partly by these cutbacks and partly by Syria's refusal to permit reopening of the Trans-Arabian pipeline. As a consequence of these developments, the cost of residual fuel oil in New York has already increased by more than 50 percent.

Faced with a shortage of oil, some utilities have attempted to turn to natural gas as an alternative. They have found that large supplies of this fuel are not available. Many gas companies are fearful about their ability to supply all the needs of their present customers this winter.

Somehow we will muddle through this present shortage—if necessary, by relaxing somewhat the antipollution regulations. However, the long-term energy problem will require more substantive actions. Not only is the United States depleting its reserves of petroleum and natural gas, but it is not moving decisively to fill the gap. About 74 percent of our total energy requirements are met by oil and natural gas. Importing our total supply of these products would at present cost us about $20 billion a year. We cannot afford such an adverse contribution to the balance of payments. Nor can we permit ourselves to become subject to economic or political blackmail.

Some intermediate-term relief could be obtained by granting higher prices to gas producers and by opening additional areas of the continental shelf. However, there is little visible evidence that higher prices could bring out substantial amounts of either oil or gas, and additional drilling of the continental shelves would increase our environmental problems.

The longer-term solutions to our energy problems involve becoming more prudent in the use of energy. The solutions also demand the skillful employment of coal and atomic energy. In principle, all our energy needs could be met for a long time with coal. This raw material could be processed to yield sulfur-free fuel, liquid hydrocarbons, and methane. In practice, however, the development of the use of coal is limping along and is underfinanced. A few hundred million dollars a year devoted to research, development, and demonstration plants could be the most valuable expenditure the government could make.—PHILIP H. ABELSON

AAAS ANNUAL MEETING

26–31 December 1970, Chicago

Registration badges will be required for admission to all sessions, except for a few special programs to which the public will be invited.

ADVANCE REGISTRATION FORM

Mail to: American Association for the Advancement of Science, Dept. R, 1515 Massachusetts Ave., NW, Washington, D.C. 20005

☐ Enclosed is $10 Registration Fee (*Program* and Convention Badge)

☐ Enclosed is $15 Registration Fee (including spouse) (*Program* and Convention Badges)

☐ Enclosed is $5 Student Registration Fee (16 years and older) (*Program* and Convention Badge)

☐ Enclosed is $5 for the *Program* only AAAS Member ☐ Non-member ☐

(Mailing date of Program and badge—1 December)

NAME: _____
(Last) (First) (Middle Initial)

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COMPANY AFFILIATION: _____

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CONVENTION ADDRESS: _____

Office and Session Locations

Conrad Hilton: AAAS Headquarters Office; AAAS Registration Desk; AAAS Lecture Aides; AAAS Television Room; AAAS Press Headquarters; AAAS Council Meeting; AAAS Exposition of Science and Industry; AAAS Invited Lectures (Special Lecture; Distinguished Lecture; Sigma Xi–Phi Beta Kappa Lecture); AAAS Commission and Committee Symposia (Commission on Science Education); AAAS General Science Symposia ("Mood, Behavior and Drugs"; "Man's Impact on the Global Environment"; "The Teaching of Science"; "Techniques and Status of Modern Parapsychology"; "Is there a Generation Gap in Science?"); AAAS Sections—A-Mathematics; C-Chemistry; FG-Biological Sciences; H-Anthropology; I-Psychology; N-Medical Sciences; Nd-Dentistry; Q-Education; American Society of Zoologists Office; Sigma Delta Epsilon Office.

Sheraton-Blackstone: AAAS Invited Lectures (RESA Annual Address and Panel Discussion); AAAS Committee on Council Affairs (Open Hearing); AAAS General Science Symposia ("Science and the Federal Government—1970"; "Science and Man: Values and Expectations"; "Crime, Violence, and Social Control"; "Contributions of U.S. Minority Groups to the Development of Science"; "Women in Science"); AAAS Sections—H-Anthropology; K-Social and Economic Sciences; L-History and Philosophy of Science; P-Industrial Sciences; T-Information and Communication; U-Statistics.

Pick-Congress: AAAS Science Film Theatre; AAAS Film Lectures; AAAS Commission and Committee Symposia (Commission on Population and Reproduction Control; Committee on Arid Lands; Committee on Environmental Alteration); AAAS General Science Symposia ("Public Policy for the Environment"; "Large-Scale Use of Defoliants"; "Scientific Organizations, War-Peace Issues, and the Public Policy Process"); AAAS Sections—B-Physics; D-Astronomy; E-Geology and Geography; FG-Biological Sciences; K-Social and Economic Sciences; M-Engineering; Np-Pharmaceutical Sciences; O-Agriculture; Q-Education; W-Atmospheric and Hydrospheric Sciences; Society for General Systems Research Office.

Field Museum of Natural History: AAAS Invited Lectures (Address of the Retiring AAAS President and following Reception; Frontiers of Science Lecture).

Adler Planetarium: AAAS Section D-Astronomy ("On Teaching Astronomy").

University of Illinois Medical Center: Alpha Epsilon Delta.

Essex Inn: Beta Beta Beta—Biennial National Meeting; Association of Academies of Science; American Junior Academy.

Ascot House: Beta Beta Beta—Biennial National Meeting.

HOTEL RATES*
(Per Day)

The American Association for the Advancement of Science will hold its 1970 Annual Meeting in Chicago, Illinois, 26–31 December. The AAAS registration desk will be located at the Conrad Hilton Hotel. The following hotels will be used for housing.

HOTEL	SINGLE	DOUBLE	TWIN	SUITES
1) Conrad Hilton	$15	$21	$21	$55 and up
720 South Michigan	17	23	23	
	19	25	25	
2) Pick-Congress	15	21	21	45 and up
520 South Michigan	17	23	23	
	19	25	25	
3) Sheraton-Blackstone	15	21	21	40 and up
636 South Michigan	17	23	23	
	19	25	25	
4) Essex Inn	15	21	21	45 and up
800 South Michigan	17	23	23	
	19	25	25	

*Illinois Room Tax, 6%; rates for suites: parlor plus one-, two-, three-bedrooms; $5.00–$8.00 additional charge for cots.

HOTEL RESERVATIONS FORM

Mail To: AAAS Housing Bureau, Chicago Convention Bureau, 332 South Michigan Ave., Chicago, Illinois 60604

(Reservations received after 13 December cannot be assured.)

CHOICE OF HOTEL: First_____ Second_____ Third_____

ROOM: ☐ Single ☐ Double ☐ Twin ☐ Suite Preferred rate $_____

NAME: _____
(Individual requesting reservation)

ADDRESS: _____
(Street) (City and State) (Zip Code)

ARRIVAL: Date_____; _____a.m._____p.m.

DEPARTURE: Date_____; _____a.m._____p.m.

Be sure to list definite arrival and departure date and time. Hotel reservations will be held *only* until 6 p.m. unless otherwise specified.

Number in party_____sharing this room will be (list name and address of each person, including your own):

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