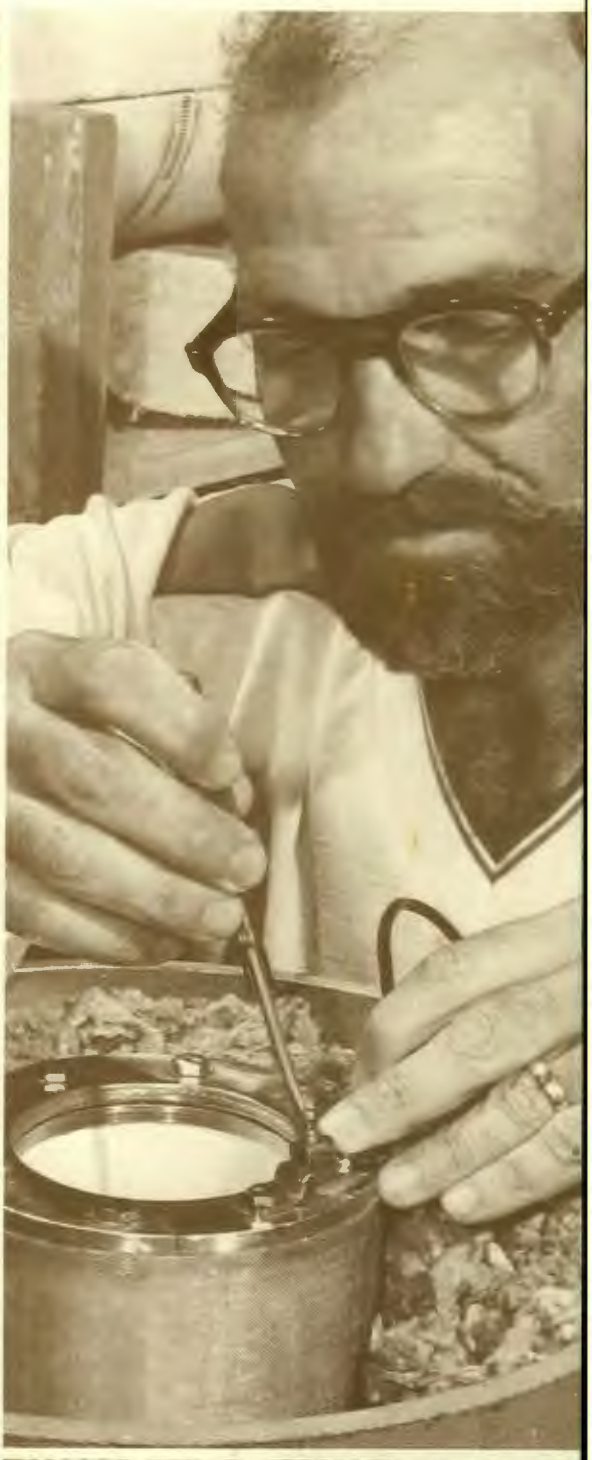
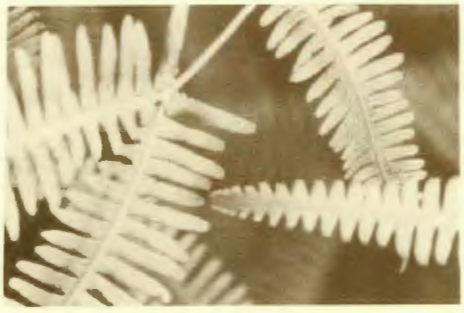
Summer 1980

Oak Ridge National Laboratory review





THE COVER: Beginning at the left, the cover features the mixture of articles in this issue: Wally Koehler's small-angle scattering facility, the only one of its kind in the world; Eli Greenbaum's use of solar energy to get the hydrogen out of the water; and Carolyn Krause's story of insulation research at the Laboratory. Interspersed are sprigs of Australian fern that Hank Shugart photographed during his year on that continent described on page 18.

Oak Ridge National Laboratory

review

VOLUME 13 NUMBER 3 **SUMMER 1980**

Editor
BARBARA LYON

Staff Writer
CAROLYN KRAUSE

Consulting Editor
ALEX ZUCKER

Art Director
BILL CLARK

Publication Staff: Technical Editing/Cindy Sullivan; Typography/Edna Whittington; Makeup/Betty Jo Williams; ORNL Photography and Reproduction Departments.

The *Review* is published quarterly and distributed to employees and others associated with the Oak Ridge National Laboratory. The editorial office is in Building 4500-North, Oak Ridge National Laboratory. P.O. Box X, Oak Ridge, Tennessee 37830. Telephone: Internal 4-7183; commercial (615) 574-7183; FTS 624-7183.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION FOR THE U.S. DEPARTMENT OF ENERGY

Ron Graves of the Metals and Ceramics Division checks the screen heater developed at ORNL for measuring resistance to heat flow in loose-fill insulations.

The Promise of Energy-Efficient Buildings

By CAROLYN KRAUSE

There are few actions that American consumers can take to help control runaway inflation, including the rapidly escalating cost of energy. What we can do is insulate and weatherize our homes, which account for 20% of the nation's energy consumption. Only about one-third of the nation's residences are adequately insulated, so in 1977 the President set a goal of having 90% of American homes weatherized by 1985. It is argued that the energy savings from a mass effort to add insulation, caulking, and weather stripping to our homes could help reduce the nation's dependence on foreign oil since one-fifth of American homes burn oil for heating and some utilities use oil-fired generators to help meet residential demands for electricity. Cutting back our purchases of expensive foreign oil could slow the inflation rate.

Inflation has prompted utilities to encourage home energy conservation. Faced with the high cost of borrowing money, utilities

Ted Lundy (left) pores over budget figures along with Marjorie Matthews and Dave McElroy. Lundy is manager of the Building Thermal Envelope Systems and Insulating Materials program. McElroy is leader of the physical properties group in the Metals and Ceramics Division. Matthews, a secretary, assists Lundy with administrative responsibilities.

are finding it more economical to subsidize programs of insulating their customers' homes than to build new generating capacity. The Tennessee Valley Authority, the nation's largest supplier of electricity, says that investing $200 million in insulating 345,000 homes will obviate the need for a 1000-MW nuclear power plant, which would cost more than $1 billion.

Inflated energy prices are motivating increasing numbers of consumers to insulate their own homes. Homeowners are finding that, by installing insulation, they can save 20 to 30% of the energy used to heat their homes in winter and about 10% of the energy used to cool rooms in summer. The money they save by using less fuel pays for the insulation in as little as three to five years. Other consumers will be stimulated to insulate their homes if proposed incentives such as state income tax credits are enacted into law in certain states.

To help the President meet the 1985 goal, the Department of Energy is setting up a Residential Conservation Service program to go into effect nationally later this

The photograph on page 25 of the Winter 1980 issue of the *Review* carried an erroneous caption. The photograph is not a TVA picture, as stated, but instead was provided us by the National Coal Association.

year. Designed to induce Americans to weatherize their homes, this program offers consumers evaluations of what cost-effective measures are needed to make their homes more energy efficient. ORNL is involved in managing the technical aspects of this conservation program.

In addition to encouraging use of energy-conservation technologies, the federal government has become increasingly active in conducting tests to determine the potential health and safety hazards of current insulations and to assess the factors that can cause a loss of insulating value. ORNL is contributing to some of the research, which could guide policymakers in formulating standards to ensure that insulations on the market are safe, effective, and durable and that insulation contractors follow proper installation procedures.

The needed tests and standards have been identified in a national plan issued recently by DOE's Office of Conservation and Solar Energy and the Department of Commerce's National Bureau of Standards as part of the national program for Building Thermal Envelope Systems and Insulating Materials, managed by Ted Lundy of ORNL's Metals and Ceramics Division.

"The BTESIM program," says Lundy, "deals with the total building shell and provides research, development, and demonstration output needed for implementation of energy-conservation actions in existing and new buildings. This includes information for voluntary programs and governmental regulatory programs, such as RCS and Building Energy Performance Standards. The task on thermal insulating materials represents one-quarter to one-third of the BTESIM program funded by DOE." The program's financial resources are allocated to numerous research institutions, with ORNL, DOE's Lawrence Berkeley Laboratory, NBS, and various universities playing key roles.

Although there has been some scare publicity on indoor air pollution and insulation-related fires that might cause some consumers to wonder whether to weatherize, ORNL researchers in the BTESIM program say that most insulating materials, when properly installed, are safe and effective. Says Dave McElroy of the Metals and Ceramics Division, "There are many good products on the market that have proven satisfactory for many years. It is not difficult for the consumer to insulate intelligently."

The BTESIM and RCS programs aim at helping consumers use conservation measures wisely.

Energy Auditing

Many people want to cut their home energy losses to save money, but they have difficulty deciding which conservation measures are the most cost effective. Fortunately, a number of utilities are offering services in which energy advisors, or auditors, examine homes on request, determine the extent and cause of energy leakages, and recommend appropriate measures to keep the warmth in during winter and out during summer. Several utilities offer customers interest-free loans or defray the total cost of installing insulation and weather stripping and caulking to reduce air infiltration.

TVA has a model home insulation program that offers a free home energy survey to residential customers requesting it. The trained advisor examines the residence from attic to basement and gives the consumer a detailed explanation of needed conservation measures. Consumers with electric heating or air conditioning can obtain TVA no-interest loans of up to $2000 to cover the costs of such weatherization as attic and floor insulation, storm windows, and insulated doors. The loan may be repaid over a period of as long as seven years as part of the monthly electric bill.

The RCS program being established in response to a provision of the National Energy Conservation Policy Act, part of the National Energy Act of 1978, will become effective later this year. Under the program, each state will monitor the residential energy-conservation activities of utilities, home heating suppliers, contractors, material suppliers, and money lenders. Currently, DOE is reviewing plans submitted by states on how they propose to offer conservation services to consumers.

The heart of the RCS program is the home energy audit, which utilities are required to offer. Upon a homeowner's request, an auditor will visit the home and recommend cost-effective conservation and renewable resource measures such as insulation of the building shell and hot water heater, furnace efficiency modifications, furnace and air conditioner replacement, active solar space heating and hot water heating, passive solar heating, and small wind machines.

The RCS program will require TVA and other utilities to expand their approaches to include visits to gas- and oil-heated as well as all-electric homes and to consider the feasibility of solar energy and wind measures. The auditor will give the customer detailed written estimates of the cost of each measure, both self-installed and

Fred Dycus of TRW, Inc., uses a flue gas analyzer to determine the efficiency of the gas furnace at the Oak Ridge home of Peggy Whitehouse (center), a TRW employee. Jennifer Bartley of ORNL's Engineering Technology Division checks off an energy audit form similar to what will be used in DOE's Residential Conservation Service program. TRW is an RCS program subcontractor that assisted ORNL in developing the energy audit to be used in people's homes in the near future.

contractor-installed, and an estimate of the first year's savings for each measure. The auditor will also give the customer a list of qualified contractors, lenders, and materials suppliers.

At the customer's request, the utility will help arrange for a contractor and a loan, which can be repaid on the utility bill. Customers who accept these arrangements are also entitled to three-year warranties on material and installation, random inspections of contractor installations, and consumer complaint procedures.

The auditors will recommend inexpensive conservation practices such as changing filters, installing flow restrictors, sealing leaks in pipes and ducts, and adjusting thermostat settings. The utilities can provide information on tax credits, make arrangements for weatherization assistance, and offer loans of up to $300 to be repaid on the electric bill. The audit may be free to the customer or cost up to $15, depending on the state. The actual cost to the utility may be about $100.

ORNL manages all technical aspects of the RCS program, which is staffed by personnel from several divisions at ORNL, the Solar Energy Research Institute, and many subcontractors. Ray Johnson of the Metals and Ceramics Division is the RCS principal investigator. Johnson works with Tony Schaffhauser, also of the Metals and Ceramics Division, who is manager of that division's conservation programs. ORNL has contributed to the RCS program by analyzing technical issues during the development of the DOE regulations and by providing technical assistance to the states and utilities in the implementation of the program. Members of ORNL's Information Division helped develop a comprehensive guide to assist the states in interpreting the regulations and developing their implementation plans. They also developed informational material to assist the states in briefing their utilities, oil dealers, bankers, and materials suppliers.

A model energy audit that can be used by the states and utilities has been developed. Says Schaffhauser, "We tried to develop a model audit that could be done in a reasonable length of time, at a reasonable cost, by people without highly technical backgrounds who had been trained to do audits with inexpensive equipment." Model training curricula and materials are currently being developed. ORNL has assisted DOE with numerous workshops for state and utility people, and several in-house research and development activities support the program. For instance, an effort is under way in the Engineering Technology Division to study the actual operating efficiency of gas furnaces. The Energy Division is performing economic and environmental investigations, as well as studying the effectiveness of the program. The Health and Safety Research Division is investigating indoor air quality health problems that might result from reducing air leakage in houses. And the Metals and

Ceramics Division is performing field studies of insulation effectiveness and materials problems with insulation.

Although the RCS program has been restricted to residential homes, an act of Congress this year extended it to apartments and small commercial buildings. In the meantime, in the home sector alone, the RCS program has the potential of saving the energy equivalent of 29.1 billion liters per year (180 million barrels per year) of imported oil by 1985. This represents an annual savings of $7 billion in current oil dollars.

The energy consumed in all American buildings accounts for about 35% of the nation's energy budget. To reduce this consumption, DOE is interested not only in having existing buildings retrofitted through energy-conservation measures (as in the RCS program), but also in developing standards to ensure that new buildings will be energy efficient. Thus, DOE is developing Building Energy Performance Standards for new buildings. The proposed BEPS are based on performance and do not prescribe any particular design or construction detail. They set overall energy performance requirements, but give wide latitude to architects and construction engineers in meeting these requirements. If they can do the job without insulation, none is required.

Insulation and R-value

When a consumer considers buying insulation, he is faced with a variety of choices of material. The available types include batts, blankets, or loose fill of mineral fibers (fiberglass or rock wool); loose-fill cellulosic insulations; organic materials, such as urea formaldehyde, that are foamed into walls; cellular plastic boards such as polystyrene, polyurethane, or polyisocyanurate formed from gases such as freon; loose-fill perlite or vermiculite; and reflective foils such as thin aluminum sheets separated by small air spaces.

The consumer should be particularly interested in one property of these materials that allows a comparison of their insulating values. That property is the R-value, a technical term that describes the ability of a material to resist or retard the flow of heat, which tends to migrate from warmer to cooler areas. It is expressed as

$$\text{R-value} = \frac{\text{thickness}}{\text{thermal conductivity (apparent)}}$$

at 75°F. The higher the R-value, the greater the insulating ability of the material. Higher R-values for a given material are obtained by increasing the thickness of the installed insulation. For example, a 3.5-in.-thick fiberglass blanket will have a labeled R-value of R-11, whereas a 6-in.-thick blanket will have a value of R-19 and provide about 70% more insulating value than the R-11 blanket.

The R-value for a piece of insulation can be divided by the thickness of the piece to obtain the R-value per inch of insulation. For the fiberglass blanket example, the R-value per inch is about 3.1. This R-value per inch ranges from 2.2 to 7 for the available types of material listed above. This factor is similar to the price per pound used in comparison shopping in a grocery store.

But, cautions McElroy, "Always compare insulating materials' R-values and R-values per inch at the same temperature—75°F. This is because the R-value and the R-value per inch increase with decreasing temperature, a natural phenomenon which is to the customer's advantage. However, a property comparison of one material at 40°F to another material at 75°F is unfair."

ORNL and certain BTESIM subcontractors have been looking into the question of whether consumers get what they think they are paying for in insulation. Is the actual R-value of the insulation the same as the advertised R-value? Does the insulation lose its R-value because of shrinkage, settling, warping, and aging? How does thermal resistance vary with changes in thickness and density? How much does thermal resistance decline if the insulation is improperly installed? How does the R-value change with temperature and humidity?

The most commonly used insulating materials are mineral fibers—rock, slag, or glass processed from a molten state into fibrous form. Fiberglass and rock wool are available as loose fill or as blankets or batts [blankets are continuous rolls and batts are miniblankets precut to lengths of 1.2 to 2.4 m (4 to 8 ft)]. Mineral fiber insulations have several advantages: they are insectproof, fireproof, and decayproof and they do not melt except at extremely high temperatures. However, they do pose problems for installation contractors and do-it-yourselfers because the fiber particles can cause skin irritation and might present a health hazard if inhaled into the lungs. Installers are advised to wear protective clothing and dust masks.

Mineral fiber insulations have been on the market for years. They are manufactured by large

corporations with their own research facilities—companies like Owens-Corning Fiberglas Corporation, Johns-Manville Sales Corporation, Certain-Teed Products Corporation, and Rockwool Industries, Inc. For quality control, they measure their own insulations for R-value and participate in a product certification program with the National Association of Home Builders. This provides one basis for marking their products with an advertised R-value. But how can the consumer be sure he is receiving the R-value he has paid for?

The traditional procedure currently used to label R-values for insulations of various thicknesses is to determine the R-value for a thin or sliced specimen that is 1.5-in. thick and to linearly extrapolate this value to obtain the full-thickness R-value. In other words, if the 1.5-in. specimen has an R-value of 3.5, a 3-in. specimen should have an R-value of 7.

This procedure is under intensive examination because, for low-density building thermal insulations, the apparent thermal conductivity increases with increasing thickness because of heat transport by radiation, heat flowing from warm to cold materials without heating the air in between. Thus, the R-value per inch decreases with increasing thickness, and an R-value obtained by linear extrapolation using data for a thin specimen is greater than that obtained by testing a full-thickness specimen. The question is, how much greater? According to McElroy, "The difference is dependent on the thickness and the particular type of insulation involved, but appears to be less than 10% for 6-in.-thick fiberglass blankets." The BTESIM program is supporting several efforts to

establish an accurate data base to resolve the issue of R-value and thickness.

ORNL is concerned with testing by full-thickness and thin-thickness procedures, the variability of R-11 and R-19 mineral fiber batts, the relationship of insulation thickness to R-value, better methods to measure R-value, and the need for standard reference materials so that industry can calibrate its instruments for accurate measurements of insulating value.

Recent studies involving McElroy and Dave Yarbrough of the Metals and Ceramics Division and measurements made by Dynatech R/D Company showed that the customer usually got what he paid for in mineral wool and fiberglass products made in 1977 when the thin-thickness test procedure was used. These products, however, have R-values lower than the labeled value when the full-thickness test procedure is used. Some mineral wool products were found to have R-values below 90% of the advertised value. That is, the consumer may think he has bought an R-19 insulation, which in reality has a value of R-17. While the ORNL-Dynatech report is not flattering to mineral wool manufacturers, the industry can take comfort in the fact that current specifications allow actual insulation values to be up to 10% less than the marked R-value. This may change in light of recent Federal Trade Commission rulings calling for "truth in R-value advertising."

The FTC has proposed a rule calling for full-thickness testing which the insulation industry backs. This means that R-values for insulations of various thicknesses would be determined not by extrapolation from 1-in. measurements but by measurements of full thickness.

ORNL researchers recently

Al Kaiser at Tennessee Technological University installs loose-fill insulation (left) in a test attic and operates a vibrating platform to determine how much settling and density change occur in loose-fill insulation as a result of vibration.

participated in preparation of an American Society for Testing and Materials position paper on the need for standard reference materials. McElroy says that standard reference materials are needed for low-density fiberglass products because they exhibit greater heat transfer by radiation than do high-density fiberglass products. Thus, it is difficult to calibrate measurements for materials of different densities. The NBS is developing standard reference materials for any thickness and for different types of insulation. Currently, the NBS has only one standard reference insulating material, a 1-in. fiberglass board of high density.

ORNL and Tennessee Technological University (under subcontract to BTESIM) are investigating the effect on R-value of settling in loose-fill insulating materials such as fiberglass, rock wool, and cellulose. When insulation settles, its thickness decreases and its density increases. The R-value is decreased primarily by the reduction in thickness, with a secondary increase in R-value because of the increased density, which makes the material a poor conductor of heat (decreases the apparent thermal conductivity).

Settling of loose-fill insulation may be caused by household vibrations. TTU found that settling occurred when blown fiberglass and rock wool were subjected to vibration. McElroy and his associates have performed similar vibration tests on cellulose to study settled density. "The blower-cyclone-shaker test," says McElroy, "has provided data that offer guidance on how many bags of loose-fill insulation are needed in an attic of a specific size with blown-in insulation at the right density to give the desired R-value." Other studies have shown that cellulose insulation blown into attics at a very low density settled up to 12% in the first month and up to 25% after 18 months.

ORNL has embarked on a project to check the validity of laboratory tests on insulation density changes due to vibration by comparison with field results. McElroy and Yarbrough are studying how much settling occurs in attic insulation, as a result of normal household vibrations, in 20 Knoxville homes whose owners have received interest-free loans from TVA and the Knoxville Utility Board to cover insulation costs. Some of these homes have low-density fiberglass on which denser insulation material such as rock wool or cellulose has been piled. ORNL researchers are seeking answers to these questions: Do vibrations cause significant settling of home attic insulation? How much compaction of fiberglass occurs and to what extent does this compaction reduce R-value and overall insulation effectiveness? How much does density change over time?

Variability in R-value is also evident in the case of plastic insulations, including urea-formaldehyde foam. Plastic foams have been reported to shrink as much as 10%, causing an increase in heat transmission by up to 30%. The U.S. Department of Housing and Urban Development requires that thermal performance of plastic foam be derated by 28% because of shrinkage.

In addition to doing paper studies analyzing the problems of insulation and R-value and measuring density changes in settled insulation, ORNL researchers have developed a technology that could help resolve some problems in R-value measurement. McElroy, Peyton Moore, and Stan Jury, of the Metals and Ceramics Division, have developed a screen heater, originally devised for testing insulation on pipes of varying diameters, that can measure thermal conductivity of insulation batts up to 12-in. thick. This unguarded insulation tester consists of a resistively heated stainless steel mesh screen to which thermocouples are attached. It is simpler and much more versatile than the guarded hot plate—the "daddy" of R-value measurement devices used by NBS since 1929—and could possibly be the tool to resolve the insulation thickness issue.

Fire and Corrosion

In 1974 several homes in a low-cost housing development in Denver, Colorado, burned down. An investigation revealed that these homes had been retrofitted with cellulose insulation that had inadequate fire resistance.

Fred Weaver determines the airflow resistance of fiberglass using an apparatus constructed at ORNL and described by the American Society for Testing and Materials.

Cellulose insulation is normally made from macerated waste paper or raw forest products containing fire protection chemicals. The investigators could not prove that the insulation caused the fires, but it was clear that it contributed heat to the fires. In 1976 the investigators filed a petition asking the Consumer Product Safety Commission for a ruling on flammable insulations. CPSC carefully weighed the petition during a time when it was receiving other reports of fires in homes with cellulosic insulation in the attics. In 1977, when cellulose accounted for 40% of home insulation sales, partly because of a shortage of fiberglass insulation, the Senate subcommittee that oversees CPSC became concerned about the problem and passed an emergency interim standard on September 8, 1978, requiring that all cellulose insulation containers be labeled to show that the material meets the federal flammability standard.

The standard requires manufacturers of cellulose to add the proper amount of fire retardants to make the insulation resistant to flame spread and combustion by smoldering (slow, incomplete burning). CPSC also requires labels that warn consumers of possible fire hazards when cellulose is installed too close to heat sources, such as recessed light fixtures. CPSC has the authority to buy and test cellulose and other insulations for fire resistance in its Rockville, Maryland, laboratory; it also has the power to take unsafe products off the market.

Fire testing of cellulose has also been conducted under the BTESIM program managed by ORNL. Studies at TTU showed that recessed light fixtures can be a fire hazard if thermal insulation is

piled upon them and that a 200-W light bulb installed in a fixture that should have only a 100-W light bulb could cause a fire if surrounded with cellulose insulation. Even fiberglass insulation too near an overpowered light fixture can be a problem because the fixture heats the wood and the insulation could permit a hazardous heat buildup.

Furthermore, other electrical fires are possible because of improperly installed thermal insulation. Says Lundy, "In houses built before 1940, the wiring has rubber electrical insulation, much of which has deteriorated by now. If thermal insulation is piled on old

Peyton Moore of the Metals and Ceramics Division checks the thermocouple on the screen heater, an ORNL development that can be used to measure thermal conductivity in flat insulations, including batts up to 30 cm (12 in.) in thickness.

house wiring, there is a fire hazard even if the thermal insulation is nonflammable."

Other insulations that may pose fire hazards are plastic materials and rigid boards frequently used in mobile homes because these materials are thin and have high insulating value. Firemen have complained that polyurethane insulation not only makes home fires worse by speeding up and intensifying the fire's heat, but also endangers the lives of firemen by emitting poisonous fumes during combustion. Manufacturers of rigid boards are required to cover them with material such as gypsum to give 15 min of fire protection.

Although cellulose is required to have fire-retardant additives, there is still some question about the resistance of various products to smoldering. In 1978 McElroy and Warren Harris of the Metals and Ceramics Division conducted a series of smoldering combustion tests. In each test, a lit cigarette was placed in a box filled with cellulose insulation. An insulation passed the test if there was no evidence of flaming and if there was less than 15% weight loss due to combustion. McElroy found that only about one-quarter of the 51 commercially available cellulosic insulations passed this test.

Are fire retardants in cellulosic insulations permanent or could they be leached out by moisture? Using environmental chambers with wet atmospheres, Harris has demonstrated that moist air causes the transfer from cellulose of boric acid, the most commonly used fire retardant in cellulosic insulation. Harris has studied the transfer of boron compounds in cellulose by using a nuclear counting apparatus. Because boron absorbs neutrons, it can be tracked by bombarding cellulose insulation with neutrons and detecting the number of neutrons emerging from the material.

The ORNL research has shown that boric acid will decompose and release water at temperatures above that normally expected for home attics. Studies continue here and elsewhere to answer this question: Does the leaching of boric acid from cellulosic insulation continually exposed to a wet atmosphere reduce the retardant content to a point that lowers the insulation's resistance to smoldering and flame spread?

Fire retardants that solve one problem may create another—namely, corrosion. In 1977 in Black Creek, Wisconsin, the ceiling of a commercial building made of steel collapsed. An investigation showed that the building was insulated with cellulose whose fire-retardant additive was aluminum sulfate. According to a report obtained by CPSC, moisture that accumulated in the building's attic combined with the aluminum sulfate to form

Warren Harris of the Metals and Ceramics Division adjusts a nuclear counter used to study the movement of boron compounds from cellulose insulation that has been exposed to moist air. ORNL researchers are trying to determine if moisture contributes to boric acid removal from cellulose. Boric acid is a compound deliberately added to this insulation to make it fire-resistant.

sulfuric acid, which destroyed a metal panel. Similar corrosion problems have been identified at a cheese warehouse in Hartland, Wisconsin, and CPSC has received reports of insulation-related corrosion in nails and other fasteners holding buildings together.

CPSC is now testing insulations for corrosion resistance to make sure that these materials comply with a federal corrosion standard. A recent study done for the BTESIM program by Stevens Institute recommends research to find corrosion inhibitors, less-corrosive fire retardants, and suitable substitutes for boron compounds, which are not corrosive but which may be in short supply. The Stevens study offers compelling evidence that the corrosion behavior of fire retardants is enhanced under conditions of high moisture content.

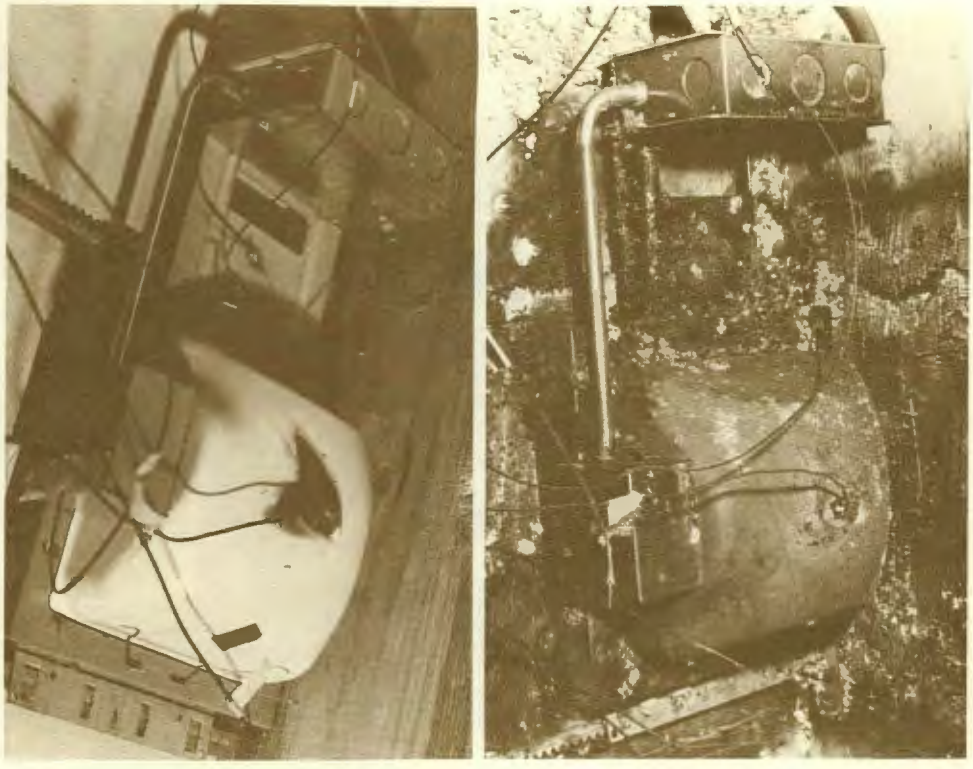
Moisture is clearly an enemy to insulations and building materials. In addition to causing loss of fire-retardant additives and enhancing corrosion, moisture causes odors, increased formaldehyde emissions from urea-formaldehyde foam, rotting of building materials, and loss of insulating value. The best protection against moisture is to ventilate attics and crawl spaces and install vapor barriers between the insulation and the living space. Besides putting in vapor barriers, consumers are advised to install a smoke alarm, make sure there is at least a 7.6-cm (3-in.) clearance between thermal insulation and recessed light fixtures (which should not be overpowered), and install 0.09 m^2 (1 ft^2) of vent for every 28 m^2 (300 ft^2) of attic space.

Sealing the Thermal Envelope

The ORNL-managed BTESIM program is concerned with the total thermal envelope—the outer shell of a building, including the roof, ceiling, walls, floors, and basement. The research conducted under the guidance of this program is intended to contribute to better standards for new building design and for altering existing buildings. Jim Robinson of ORNL's Energy Division, who leads the thermal envelope systems task of BTESIM, is involved in both in-house research and program management for DOE. ORNL is focusing its research efforts on three technical problems affecting thermal envelopes: (1) building-to-earth heat transfer, (2) thermally efficient roofing, and (3) thermal dynamics related to mass.

In percentage terms, heat loss from building to ground is small if a building has no insulation in the attic and walls. If the walls and attic are well insulated, however, this percentage of loss to the ground can be significant because of the large area of the building's heat transfer boundary in contact with the ground.

"Heat loss to the earth becomes more significant when attics and walls are insulated," says Robinson. "So we're looking at methods for calculating heat loss to the earth more precisely." Ken Childs of the Computer Sciences Division is developing an experimental plan for measuring heat loss to the ground in the earth-sheltered Joint Institute for Heavy Ion Research building. When completed later this year, this building will be instrumented with thermocouples to measure the heat



In tests conducted by Tennessee Technological University under contract to ORNL, it was found that a 200-W light bulb installed in a recessed light fixture that should have only a 100-W light bulb can cause a fire if cellulose insulation is piled on the fixture. These before and after pictures show why consumers should not overpower light fixtures and why they should leave at least a 7.6-cm (3-in.) clearance between thermal insulation and recessed light fixtures.

loss to the ground.

Of the 2600 km^2 (1000 miles^2) of flat roofs in the United States, 30% lack insulation. Because the roof represents 25 to 33% of a building's surface area, a similar fraction of a building's heat loss occurs through an uninsulated roof. "In some cases, the cost of thermal energy being lost may make it economical to remove the roof, install insulation, and replace the roof," says Robinson. His program is conducting an assessment on roofing for DOE and will make recommendations to UCCND Engineering, which is studying the need to replace roofs and add insulation in buildings at DOE's three Oak Ridge plants.

ORNL is investigating the concept of thermal mass—the ability of certain dense materials to absorb and retain heat. For example, houses with adobe bricks in the Southwest absorb and store heat during the day and radiate it to the living space at night, when it is cool.

Childs has looked at the M-factor concept cited by the brick and masonry industry in its argument that a house with masonry walls requires less insulation than a house with frame walls. In his study of the extent to which bricks conserve energy, he has concluded that additional mass in a building structure does not have a great potential for reducing overall energy consumption. However, there are special situations where additional mass can lead to energy savings. In these cases either the mass is incorporated in a passive solar design for heating or the diurnal temperature swing causes a building to become extremely hot during the day and extremely cold at night.

Properly designed windows offer the potential of reducing energy use. At LBL a group under Steve Selkowitz is studying the thermal and optical properties of various glazing materials and novel window designs, such as reflective blinds and ceiling-diffusing screens that bounce light deep into a room. At ORNL, Hanna Shapira and Randy Barnes, an architect and an engineer, respectively, in the Energy Division, have designed a reflective insulating blind, which resembles a venetian blind with curved slats made of plastic foam insulation sandwiched between aluminum sheets. When open at the proper angle, the RIB reflects sunlight to the ceiling, where the solar heat is absorbed and later radiated to the room as it cools off. When closed at night, the RIB is an insulator. The blind, which has a potential manufacturer, will be tested in the Joint Institute for Heavy Ion Research. Preliminary evidence indicates that RIBs are economical on south-facing windows because they provide space heating in winter, reduce nighttime heating losses, and cut air-conditioning loads in summer.

Government and Industry

The federal government takes the position that Americans should weatherize their homes to save energy, but it is advocacy tinged with concern. There are no perfect insulations, and airtight buildings can pose health hazards. Part of the BTESIM program is aimed at developing improved test procedures, specifications, and standards to ensure that insulations are safe, durable, and

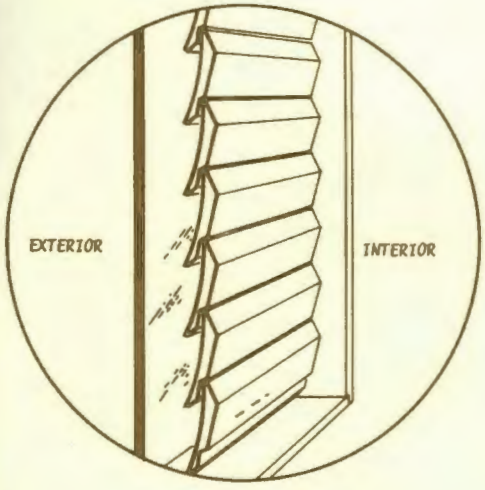
Heat loss to the ground will be measured in the Joint Institute for Heavy Ion Research after it is completed later this year. This innovative, energy-conserving building will be sheltered by the earth and have reflective insulating blinds on its windows. Visiting scientists will live and work there.

effective. As the BTESIM national plan puts it, "The insulating material should not increase the fire risk of a structure, it should not be rendered thermally ineffective by moisture, it should not cause corrosion, it should be strong enough to provide intended structural stability, and it should not present a hazard to health."

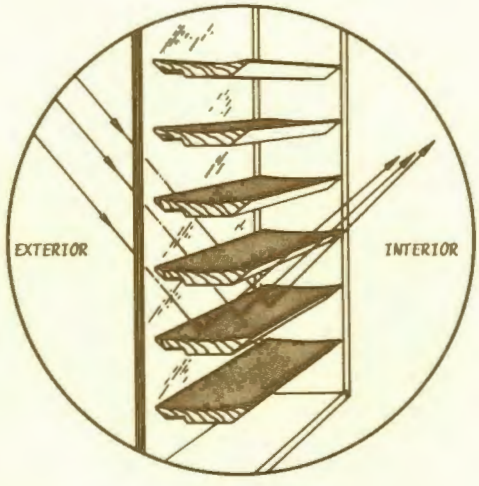
In the BTESIM program, there is strong interaction between government and industry. Government researchers' evaluations of insulations influence the private firms that make up the $8 billion insulation industry. One example of joint effort is the Department of Commerce's National Voluntary Laboratory Accreditation Program for Thermal Insulating Materials. NVLAP's accreditation committee, of which McElroy is a member, helped establish criteria for private laboratories in the insulation-testing business to ensure accurate measurements of R-values of thermal insulation. NVLAP has accredited 30 laboratories to test thermal insulating materials.

Industry and government do not always see eye to eye on insulation matters. This occurred to McElroy when he observed that batts of black mineral fibers might be more effective as insulation because the black fibers would absorb more heat than clear mineral fibers. He mentioned this to a former fiberglass company executive who had already suggested the same idea. The executive's proposal had been vetoed by marketing and public relations officials, who argued that pink or green insulation was more aesthetically pleasing and would sell better.

The established insulation companies do agree with government that many fly-by-night operators, in the insulation business to make a fast profit, have given the industry a bad name. The established companies take a responsible view, perhaps best reflected in McElroy's comment, "Consumers want safety as much as conservation. It's to everyone's benefit that the technology improves and that all insulation producers realize the serious consequences of insulation-related fires and health hazards." ornl



NIGHTTIME MODE



DAYTIME MODE

Reflective insulating blinds developed by ORNL's Hanna Shapira and Randy Barnes are designed to keep out heat in summer, to keep in heat at night, and to provide heat in winter by reflecting sunlight to the ceiling where it is absorbed and later released to the room. To save energy, each RIB is closed at night and open during the day.

Indoor Air Pollution

THE FEDERAL GOVERNMENT has the responsibility for ensuring that the energy-conservation technologies it promotes are safe as well as effective. This can be done through development of standards. For example, new ventilation standards may be needed to reduce possible health hazards due to indoor air pollution in energy-efficient buildings.

In 1979 Ernie Freeman of DOE and Ted Lundy of ORNL instigated a government and industry ad hoc task force on the epidemiology of formaldehyde. This task force initially addressed questions about formaldehyde emissions from urea-formaldehyde foam insulation and gradually expanded to include the whole subject of indoor air pollution. One output of the task force's work is a "white paper" on problems of indoor air pollution, including formaldehyde. Phil Walsh and Charles Dudney of ORNL's Health and Safety Research Division are the prime authors of the white paper. It states that residents of tightly insulated homes may have increased exposures to potentially hazardous pollutants such as nitrogen oxides from gas ovens and stoves, carbon monoxide from cigarette smoke and combustion of oil and natural gas, and radioactive radon from building materials and domestic water. In some cases, these exposures may exceed health guidelines. As Walsh puts it, "There is no risk-free technology, and energy conservation is no exception."

Americans spend more than 80% of their time indoors and more than 50% of their time in their homes. During this time they may be exposed to levels of pollutants higher than outdoor levels if the buildings they occupy are tightly constructed to reduce energy losses. A common source of indoor pollutants such as nitrogen dioxide and carbon monoxide is combustion, which in 1975 was used in 75% of American homes for space heating and nearly 50% of all residences for cooking. Nitrogen dioxide, which comes from gas stoves and ovens, may cause respiratory irritation. A recent study in England showed a higher incidence of respiratory illness among children from homes with gas stoves than among children from homes with electric stoves. Gas stoves and oil furnaces are sources of CO, elevated levels of which may contribute to heart and circulatory disease. Studies show that NO_2 and CO in homes with gas appliances may be reduced to acceptable levels if gas stoves are vented to the outside.

PERHAPS THE MOST STUDIED source of indoor air pollution is radon, an inert radioactive gas produced by the decay of radium. The main sources of indoor radon are (1) ^{226}Ra (radium) in the soil, which decays to ^{222}Rn that diffuses up through building floors and around pipes into the building and is trapped in elevated concentrations; (2) domestic use of potable water, especially from wells and underground springs; (3) natural radioactivity from radium-containing building materials such as granite, rock, stone, brick, and phosphorus-gypsum wallboard; and (4) unusual sources of radon such as uranium mill tailings.

The daughter products from radon decay cling to dust particles that are easily inhaled and deposited in the human lung. Alpha radiation from the daughter products wreaks havoc in lung tissue and can set off a chain of events leading to cancer. In 1978 Walsh

estimated that background exposures to radon and its daughters could account for up to 10 to 20% of lung cancers in nonsmokers in the United States, based on current risk estimates.

Studies have shown that exposure to radon inside many homes may be three times as great as exposure to radon outside. According to Walsh, measurements of radon inside inadequately weatherized homes can exceed existing health guidelines even when there is no unusual source. Thus, indoor exposures to radon are likely to increase and become even more of a health hazard as people reduce ventilation and plug up air leaks to cut energy losses.

A research group led by Craig Hollowell of Lawrence Berkeley Laboratory has found that radon levels can exceed health guidelines in test energy-efficient houses. (However, when Fred Haywood of ORNL's Health and Safety Research Division measured radon levels at the control conservation house near the Knoxville airport, he found its radon concentrations to be barely above background levels.) Hollowell recommends that tightly sealed homes use expensive, heat-recovering ventilation systems to ensure that indoor air is rapidly exchanged with fresh outdoor air. Haywood, who has studied the indoor radon problem at the industrial park in Canonsburg, Pennsylvania, says that less energy-intensive options for reducing levels of radon diffusing through building floors include ventilating just the crawl space and installing an impermeable floor seal.

MECHANICAL VENTILATION systems may be the best answer when most of the radon is released to the home from domestic water through showers and toilet flushing. These systems may also be needed in some homes to keep peak exposures to NO_2 and CO below existing health guidelines. Technical fixes available now to reduce indoor pollutant levels while minimizing heat losses are (1) electrostatic particle filters designed to remove specific toxic materials and (2) mechanical ventilation systems controlled by air quality sensors or equipped with heat-recovery devices (which remove heat from stale indoor air being channeled outside and transfer it to incoming fresh air from the outdoors).

Current ventilation standards are aimed at ensuring personal comfort, reducing odor buildup, and guaranteeing sufficient oxygen for room occupants. A national assessment of potential health impacts of indoor air pollution may stimulate development of new ventilation or other proper standards to protect human health.

Another pollutant of potential concern in the indoor environment is formaldehyde. Formaldehyde is a constituent of dozens of products found in the home—plywood, furniture and cabinetry made of particle board, carpet adhesive, draperies, and permanent-press clothing. It is also a combustion product present in cigarette smoke, wood smoke, and fumes from gas ovens. And this colorless gas with a pungent, irritating odor is a component of the urea-formaldehyde foam insulation found in about 2% of some 20 million insulated homes in the United States.

FORMALDEHYDE HAS BEEN IN THE LIMELIGHT because numerous residents, in complaints to the Consumer Product Safety Commission, have attributed their health problems to UF foam insulation. The reported symptoms included headaches, nausea, vomiting, diarrhea, chronic lethargy, and irritation of the eyes, mucous membranes, and respiratory system. Some of the symptoms, such as respiratory irritation, are also caused by NO_2, thus complicating the assessment of health effects of individual air pollutants inside buildings.

A basic feedstock of the chemical industry, formaldehyde is a highly toxic material that kills cells. This simple compound of hydrogen, carbon, and oxygen (H_2CO) has been used for many years by pathologists, histologists, and morticians as a tissue fixative. Recently, a study supported by the chemical industry found that formaldehyde causes cancer in rats exposed to levels an order of magnitude higher than the occupational exposure limit—2 ppm. (Most of the complaining consumers live in homes with formaldehyde levels ranging from 0.3 to 3 ppm.) In work performed with Paul Nettesheim of ORNL's Biology Division, Wally Dalbey found preliminary evidence that formaldehyde may act as a cocarcinogen under certain experimental conditions—that is, it may enhance the cancer-producing ability of a known carcinogen such as nitrosamine. After they injected hamsters with diethylnitrosamine following exposure to formaldehyde concentrations of 30 ppm in air, they found that the exposed hamsters had more tumors in their respiratory tracts than did the control animals injected with nitrosamines but allowed to breathe normal air.

Massachusetts banned the sale of UF foam insulation last November, and a proposed national ban on UF foam insulation may have broad-based support because of the public's fear of cancer. But Walsh believes that banning is not a good health protection philosophy. "Only 0.5% of all formaldehyde produced in the United States is present in UF foam. You cannot eliminate the formaldehyde problem in the home by banning this insulation. The policy of trying to achieve zero risk is impractical."

Excessive formaldehyde emissions from UF foam

Alan Hawthorne and Tom Matthews of the Health and Safety Research Division check out a dosimeter they developed that is capable of indicating levels of formaldehyde in the home. The chemicals in this device react to form a colored product, whose coloration intensity is proportional to the amount of formaldehyde in the air.

insulation are thought to occur primarily from use of outdated or wrong resins or from their improper mixing with other ingredients as they are pumped into wall cavities. The industry maintains that there is little or no problem if the foam is properly manufactured and installed. Walsh believes that a government certification program to ensure qualified installers for this important retrofit insulation is preferable to a ban on UF foam. Consumers can help keep formaldehyde levels down by applying formaldehyde-absorbent paint on foam-insulated walls, installing a vapor barrier facing the living space, and improving ventilation.

THE CPSC HAS BEEN ASKED to issue a safety standard limiting the allowable concentration of formaldehyde vapor in homes. (Several European countries have recommended a limit of 0.1 ppm for formaldehyde in indoor air.) To determine whether a home insulated with UF foam meets such a standard, a resident or installer could measure vapor levels with the government-approved, chromotropic acid method developed for occupational measurements. The problem with this chemical test is that it uses two acids, both of which are hazardous corrosive substances that require special protective measures. Thus, CPSC has contracted the Monitoring Technology and Instrumentation Group of ORNL's Health and Safety Research Division to examine and develop simpler and safer chemical coloration tests.

Alan Hawthorne, Tom Matthews, and group leader Dick Gammage have developed a dosimeter with chemicals that react in the presence of formaldehyde to form a colored product; the intensity of the coloration is proportional to the amount of formaldehyde. By comparing the dosimeter's coloration with a color chart, it is hoped that the user can determine whether vapor levels in a home conform with the health guideline and whether a more precise measurement of formaldehyde emissions is needed. The ORNL group is also developing passive collecting devices to trap enough formaldehyde to produce a definitive color response. In addition, the group is evaluating or developing a variety of spectrometers that can record over time the actual fluctuations in formaldehyde emissions and other indoor air pollutants.

"It is important to assess the impacts of indoor air pollution early," says Walsh, "in order to avoid some potential pitfall in the path to energy independence. We really don't know what the potential magnitude of the indoor pollution problem is. Thus far, the federal government does not appear to have recognized the significance of indoor air quality as a potential health problem. But we believe a national program is needed to determine levels of indoor air pollutants in representative building types. Then we can design epidemiological studies for following human health effects in populations selected by levels of exposures.

"Energy conservation measures can lead to large benefits," Walsh concludes. "But it is extremely important to recognize any potential risks early in the application of this technology so that remedies may be implemented."—C.K.

BOOKS

Communication: The Essence of Science, *by William D. Garvey. Pergamon Press, Inc. (1979), 332 pages, softcover $17.60, hardcover $35.20. Reviewed by W. S. Lyon, Analytical Chemistry Division.*

Scientists live in two worlds—a scientific world with its special norms and rigorous communication structure and a separate 'outside' world," William Garvey notes. Garvey is the Magellan of this scientific world, circumnavigating and exploring its boundaries. Unlike Magellan, however, he has returned safely to prepare his own maps and write his own account of the exploration.

Communication: The Essence of Science is the product of over a decade of research at the Johns Hopkins University. The author is a psychologist, but he does not limit his study to that field nor does he parade a stream of psychological jargon across his pages. Garvey is an investigative scientist and an excellent writer. Seldom does one find a quotable sentence in a modern book; Garvey's treatise sparkles with them. This review could be constructed by merely plucking sample sentences from the book's pages, but to do so would deprive the reader of the intellectual stimulation that comes from savoring them within the complete body of the text. Even so, I am not able to resist the temptation to quote now and then. So I shall.

Communication addresses a group the author calls librarians, but who are perhaps better designated as information specialists, whom Garvey considers "science's most important future partner." But the practicing scientist—physical or social—will find the book equally useful to him. Almost 60% of the content is made up of ten appendices, which are original papers published mainly in the late 1960s and early 1970s. The author has extracted the salient points from these research accounts, and the key ideas are discussed in the five chapters that make up the first 40% of the book. The titles of these chapters, "The Role of Scientific Communication in the Conduct of Research and the Creation of Scientific Knowledge," "Prepublication Dissemination of the Main Content of Journal Articles," "The Scientific Journal Article," "Postpublication Processing of Scientific Information," and "The Librarian's Role as a Social Scientist," give only a hint of the rich material that lies within them, even as the Portuguese and Spanish explorer's maps only faintly outlined the glories of the New World.

Garvey subdivides his world of science into an informal and a formal domain. "In science the journal article, with its elaborate structure of experts monitoring its contents and certifying its scientific quality and originality, marks the boundary between the informal and formal domain." But it is to the informal domain that Garvey (and this reviewer) is increasingly attracted. Garvey's studies, the most exhaustive of which include samplings from the physical, social, and engineering sciences, show that 90% of the material in journal articles has previously appeared in the informal domain. This domain

includes theses, informal tables, colloquia, preprints, and, most important of all, national meetings of professional societies. The main purpose of the formal domain—those formal publications such as abstracts, reviews, and books—is to consolidate the literature for new researchers entering a field and to provide a reputation for the researcher who publishes. The journal article itself establishes priority for its author, and the entire reviewing, editing, and publishing procedure authenticates and formalizes the work. Garvey believes that the research front is in the informal domain. Those who believe a front exists in the formal domain must live with the fact that their literature and citations are probably five years behind the informal domain. Rather than call the formal domain a research front, Garvey terms it a "citation front." Knowing that, the reader needs little acuity to discern that Garvey is not enamored of citation counts as a measure of a paper's importance. In one of his many experiments he compared evaluations of papers by experts with citation counts and showed rather conclusively that little correlation existed between the merit of the paper and the number of citations. The entire issue of citation counting is reviewed in Chap. 4.

Garvey's study of the informal domain demonstrates clearly that communication *is* the essence of science. Researchers use the oral presentation (or its equivalent, the preprint) as a sounding board. From the questions, comments, criticism, and discussion, these preliminary revelations provoke authors to rethink and rework their research ideas. Often the presented material stimulates members of the audience to try similar experiments or to redirect some of their own work; thus, as Garvey points out, the scientist is both producer and consumer. Running through the book is the theme that "science is a social system in which interactive communication is the salient feature."

A long series of studies on communication in science covered the full spectrum of communication media and was structured so that data from one study could be related to that from another. These studies were conducted in real time and were inclusive for nine different disciplines. From them a fascinating picture-schedule of scientific research emerges. In a study of conference attendance, for example, Garvey found that conference speakers are usually young Ph.D.'s from one of a select number of schools and that about two-thirds of conference attendees are non-Ph.D.'s, of whom only one-third have bothered to read the abstracts prior to hearing the talks. About 80% of these talks will eventually appear in the literature. Garvey paints the scientific audience thusly: "Most of the audience of any presentation are initially curious about, and not especially interested in, the author's presentation." They are at the session primarily on the basis of the title! Doesn't that open an interesting area for a scientific public relations expert!

Information is included on reports and preprints and on how data are refined and reworked through the informal domain. These data are presented so entertainingly that neither the casual reader nor the interested scholar will be bored. Some very deeply ingrained beliefs about the value of journals are questioned in the pages of *Communication*, but do not think that Garvey is thumping the tub for a radical departure from the current journal literature system, for in his final pages he argues very convincingly against change. In fact he examines one suggested innovation, the delayed integrative journal (in which no single piecemeal research could be reported, only integrated completed works or reviews), and concludes it could not succeed. He recognizes the indispensible archival, priority-setting, and certifying functions of the current journal system. What he suggests instead is the institution of an abstract journal with minimum peer review so that the formal domain can more quickly be brought into juxtaposition with ongoing research. After all, Garvey's observed median time of five years from completion of research to citation by others is long even by the time scale of information processing in Magellan's day.

Magellan's sailors circumnavigated the globe in 31 months; Garvey and his associates have explored the scientific world for considerably longer than that. But each group accomplished its task in its own way. To Juan Sebastián de Elcano, who succeeded Magellan upon his death, the king of Spain gave an addition to his coat of arms, a globe, and the motto *primus circumdedisti me*. Garvey, too, has achieved a first, and no one interested in science, communication, and the interaction of the two should fail to read the account of his explorations. oml

Hank Shugart joined the staff of the Environmental Sciences Division in 1971, the year he received his doctorate in zoology from the University of Georgia. Originally an ornithologist, he has broadened his interests to include terrestrial ecosystems and is now in his division's section on terrestrial ecology. In 1978–79, he spent a year at the Australian National University in Canberra, where he developed two forest-stand models for use in comparing ecosystem dynamics in Australian forests with those in North America. He gives us a brief account of this here.

ANOTHER CORNER OF THE PLANET

By HANK SHUGART

On the order of perhaps 200 million years ago, on a large southern continent we now call Gondwanaland, a very successful group of plants, the angiosperms, originated. These plants have evolved to the point that today they constitute virtually everything that the layman would consider a plant (with notable exceptions, such as pine trees, moss, and seaweeds). For example, when one looks at a landscape in East Tennessee from an airplane or automobile, at least 95% of the vegetation is some sort of angiosperm. Gondwanaland, the ancestral home of the angiosperms, broke apart some 100 million years ago, and one of the fragments is now called Australia.

Because Australia has been separated from the rest of the biological world for such a long time, the plants and animals have followed a separate evolutionary path from that with which we are familiar. Indeed, because of the relatively recent glacier movement over North America, ecosystems in Australia are considerably older, with more complete adaptation of the myriad species to their environments. My 11-month stay

A strangler fig begins its life as an epiphyte. The small tree growing from the large clump of ferns high in the forest canopy is a small strangler growing from a seed deposited by a bird.

in Australia was an extraordinary experience for me as an ecologist. Even though I had academic training that told me what to expect, the experience of actually seeing animals that I had known only from photographs and drawings is hard to describe. It is one thing to know that in Australia there is a fiery red parrot with blue wings and tail that is called a Crimson Rosella; it is quite another when 40 of these jewels drop from the sky into your backyard as you are having breakfast.

In the bush, the 1.5-m goanna, a varanid lizard, was a common sight. These animals run as long as 3 m in the outlying islands and are carnivores that feed on smaller lizards and mammals. They move fairly fast for their bulk, humping along in a strange loose-jointed action, with elbows flying and feet flapping.

Emus, flightless ostrichlike birds taller than a man, are timid in the bush, being often hunted for dog food by the graziers, but in the parks they are quite bold and would occasionally try to raid our picnic tables during family outings.

Black swans are very prevalent, seen frequently in almost every inland body of water, and even occasionally in the surf. Wombats, burrowing heavy animals that look like a cross between a bear and a pig, are killed by the hundreds by cars. Wombats are marsupials, as are most indigenous mammals on the continent. Bandicoots, nocturnal, insect-eating creatures (named for, but of no relation to, the bandicoot of Asia, which is a rat), have no counterparts in our hemisphere, with the possible exception of the coatimundi. Varying in size from that of a hamster to a house cat, bandicoots have long noses that taper from thin faces.

The black and yellow bowerbirds, who build enormous, towering nests within which the males perform their mating displays; the dragon lizards, descriptively named; arboreal mammals called "gliders," which range from mouse-size to a meter in length—all of the native fauna are reminders that Australia has been untouched in its evolutionary chain for the more than 50 million years since it broke away from Antarctica. The result is that it has very specialized animals. The koalas, for instance, can subsist only on the leaves of 11 of the some 700 species of eucalypts on the continent. This is the main reason that they are not seen more often in zoos. For that matter, koalas have been virtually extirpated by the glove trade; they are no longer seen in the wild, although there are attempts to bring them back in reserves.

But Australia is more than a place full of weird animals and strange plants. In the eyes of an ecologist, it's almost like another planet; it represents a test case for theories that have been developed about ecological systems in North America and Europe. At times during my stay at the Australian National University in Canberra, I was awed by the very concept of doing research in such a venerable and ecologically important landscape. At other times—when I found myself trying to learn two different computer systems, when I found myself removing the leeches that attack warm-blooded animals in the rain forest, when mail and telephone strikes caused all communication to grind to a halt—this grand perspective seemed very far away.

The purpose of my assignment to the ANU was to formulate, implement, and validate one (or, if possible, more) computer model of the long-term dynamics of Australian forest ecosystems. The research was funded by the National Science Foundation's systems ecology project in the ORNL Environmental Sciences Division, with additional funds from ANU's Department of Environmental Biology, Research School of Biological Sciences. The Commonwealth Scientific and Industrial Research Organization also provided travel, computer time, and research facilities.

The fundamental purpose of the trip was to meet several research objectives. First, for the past several years, staff members of the Environmental Sciences Division have been working to develop a center for modeling the long-term dynamics of natural ecosystems. This has been done by developing a

As the strangler grows, its vinelike roots grow down the trunk of the host tree.

Eventually the fig strangles its host and begins to close its roots around the dead tree. Here the strangler fig has almost completely encased its victim.

repertory of highly detailed succession models and by applying these models to topical problems. The current research was designed to test the generality of our modeling approach by working in forest systems on a different continent. Second, the forest systems of Australia are known to be considerably different in their structure, even at the most superficial level, from those in North America. Most of the forest systems in the southeastern United States have four to ten tree species, with continental distributions of their dominant species. This tends to make a forest in Tennessee resemble one in Maryland or Arkansas and allows the extrapolation of results from studies in one locale in eastern U.S. forests to those in another locale. In Australia, almost none of the trees have continental distributions, and the important tree species in a plant community can change dramatically over a short distance. By collecting analogous data for comparing Australian and North American forest ecosystems, we might be able to relate the structure of forest ecosystems to their function. Third, Australian forest eco-

As the strangler continues to grow, it is frequently one of the trees that towers over the rest to become a "canopy emergent" tree, typical of rain forests.

systems tend to be either quite depauperate, that is, limited in number of species, with only one or two dominants in many eucalyptus forests, or extremely diverse, as in the case of the rain forests. Since the Australian systems straddle the American systems in terms of their diversity, the study of Australian forest ecosystems provides test cases for extending our knowledge of the relationships among diversity, dominance, and function in ecological systems. Fourth, because of the advanced state of ecological science in Australia, many basic studies and surveys needed to implement complex ecosystem models have been completed and published. Fifth, an internationally recognized group of scientists at Canberra is developing new theories and sets of information on the behavior of perturbed ecosystems. An increased contact between these scientists, both at ANU and CSIRO, and our group at ORNL was thought to be mutually beneficial.

During this assignment, two ecological succession models were developed and a third was initiated and may be developed through later collaboration. I worked on both the completed models while in Australia, but I will report on their development separately for greater clarity.

The BRIND

This model was developed in collaboration with Dr. I. R. Noble in the Department of Environmental Biology, ANU. The model functions by keeping count of the birth, growth, and death of each individual tree in a simulated 0.08-ha forest stand. The general modeling approach (and that of the KIAMBRAM model described below) is derived from one that has been used in the ORNL Environmental Sciences Division to develop models of several forest ecosystems. In brief, it uses equations for growth, shape, photosynthesis, and shading to compute the growth of each tree for each year on a simulated forest stand. Birth and death of trees occur each year according to sets of probabilistic equations. The models are highly detailed in the amount of realism included in the formulation, so they require a large fund of information for each species of tree considered. Because the models draw from a broad base of information to obtain parameter estimates, they have been quite successful in providing detailed predictions of ecosystem responses to altered conditions, which in some cases have been supported by independent experiments.

The initial problem in the development of the BRIND was to select the forest ecosystem to model. I decided to use the entire upper elevation of the nearby Brindabella Range in the Australian Alps, naming it the BRIND model after the first syllable in Brindabella. There were several reasons for modeling this ecosystem; among them, the Brindabellas were near Canberra, so there was ready access. Mr. John Banks of the ANU Forestry Department gave me locations of several hundred reference plots in the mountains and allowed me the use of an unpublished survey of a catchment (that supplies most of Canberra's water supply) in the Brindabellas. Several individuals with both ANU and CSIRO were familiar with aspects of the Brindabella ecology and willing to provide information. The ecosystems in the mountains are ravaged by intense wildfires (the most extensive was in 1939) that are biologically interesting in the sense of ecological adaptation. Most important, in my opinion, is the fact that the climatic range in the Brindabellas is equivalent to the difference in temperature between Florida and Maine. This wide range of climatic conditions produces montane zones with different types of vegetation that involve about 18 major tree species, most of which are of the genus *Eucalyptus*.

The model was developed over about a six-month period. I was able to report preliminary model results at the 49th Australian and New Zealand Association for the Advancement of Science meeting in Auckland, New Zealand, where I hoped to obtain feedback from

In some cases, stranglers can spread over several trees and become immense. This wall of roots, encasing one of three trunks, each over 3 m in diameter, belongs to a single strangler fig in the shape of a giant tripod over 50 m tall.

scientists familiar with the ecosystems. Following the meeting, I prepared a draft manuscript documenting the model and put it into review in the Environmental Sciences Division. The next two months were spent preparing validation experiments for the model. The detailed model output agreed well with what was known about vegetation dynamics in the Brindabella Range, and predictions of changes in vegetations (and in their locations) were possible. The BRIND model also produced the successional patterns that were expected for alpine ash (*Eucalyptus delegatensis*) forests. In late February, unpublished data collected by A. Lindsay in 1939 became available, providing an independent set of information. The model passed the test by predicting this new information. A manuscript has been submitted to the *Australian Journal of Ecology*, and an ORNL/TM documenting

the model is in press.

The KIAMBRAM

The KIAMBRAM model was developed to simulate a subtropical humid rain forest such as might be found near the New South Wales and Queensland border. *Kiambram* is an aboriginal word indicating rain forest. The BRIND model was developed to simulate relatively depauperate forest ecosystems over a continental climatic range, whereas the KIAMBRAM model was designed to simulate a forest system with what a North American might consider continental diversity (125 species), but in a restricted climatic condition. The KIAMBRAM model was developed through collaboration with M. Hopkins of CSIRO's Land Use Research Division and I. P. Burgess of CSIRO's Forestry Division. The New South Wales Forestry Commission supplied data from 15 years of studies in the Wiangaree State Forest. The forest type for this model was selected in large measure because of the general interest in rain forests, both because of their role as a major repository of the earth's organic carbon and because of the current level of exploitation to which rain forests are being subjected. Further, Dr. Burgess had 15 years of individual tree growth data (from some 10,000 trees remeasured each year) that he made available for the study. In addition, Dr. Hopkins made available to me his three years of detailed observations on phenology and successional patterns from a forest of the same type.

Sets of data like these are unusual for any forest ecosystem, particularly rain forests, and to have access to two such sources was a stroke of good fortune. The model was developed along the same pattern previously discussed for the BRIND model, and a draft manuscript documenting the model structure was placed into Environmental Sciences Division publication review once it was determined that the model behavior seemed appropriate to the subtropical rain forest. It was then decided to use the KIAMBRAM model in an assessment of the current forest management program in New South Wales. The New South Wales Forestry Commission made available an outline of the actual practice of "timber-getters" (Aussie for lumberjack) in the Tweed Range, and a computer subroutine that removed trees by species and size according to this practice was developed. The results of this study were drafted into a manuscript that has been submitted to the *Journal of Environmental Management*. Also, the model has been documented in an ORNL/TM.

Other Tangible Results

During the last months of my assignment, I outlined the information that would be needed and developed a scheme to construct a model for the arid woodlands of Australia. This model would simulate the grass-shrub-tree mixtures that occur from Alice Springs, Northern Territory, to within a few hundred kilometers of the coast (e.g., Dubbo, New South Wales, or Talwood, Queensland). The model would include grazing and fire effects on this vegetation and use water relations models in an extremely unpredictable and harsh climate. This work may be continued as a collaborative project over the next year or more.

As my research assignment progressed, I decided to write a review of the different approaches that have been used to develop models of various forest ecosystems. This review was not a direct result of the offsite assignment, but, as I found myself being forced to consider alternative modeling approaches that might be used on the Australian forests, the framework of such a review came to mind. The document has been submitted as an invited paper to *BioScience*.

Evaluation

Up to this point, I have emphasized the concrete results of my research assignment. No less important, but somewhat less tangible, is the utility of these results. The models were developed to aid a basic research program funded by the National Science Foundation to analyze ecological systems and to determine the relationships between the attributes that are associated with major species in an ecosystem and the dynamic behavior of the ecosystem. Since the models have been implemented, validated, and applied to problems, and since the manuscripts regarding this work have been drafted for publication in the scientific literature, the next step of using the models will be to compare and contrast different ecosystems.

ORNL enjoys a reputation as an international center for ecosystems analysis and computer modeling of forest ecosystems. With the addition of the BRIND and KIAMBRAM models, which consider a total of 142 species of trees, the Laboratory will have seven detailed succession models, treating some 250 tree species, that are running and documented. This is more than twice the capability of any other research or academic institution. ornl

Take A Number.....

BY V. R. R. UPPULURI

Evenness Again

Take a sequence of four integers (a, b, c, d) and a random permutation of this sequence, such as (b, d, a, c). Find the total of the absolute differences $|a - b| + |b - d| + |c - a| + |d - c|$. It is interesting to note that this total is always even for all permutations of the original set. For instance, if $a = 16$, $b = 9$, $c = 17$, and $d = 1$, and (9, 1, 16, 17) is a random permutation, then the total of the absolute differences is equal to $|16 - 9| + |9 - 1| + |17 - 16| + |17 - 1| = 7 + 8 + 1 + 16 = 32$, which is even.

This result is true for any sequence of two, three, four, five, or any number of integers.

A Puzzle Game

Take five pieces of paper with the numbers 1, 2, 3, 4, and 5 marked on them.

Two players alternate turns in this game. The first player places a coin on one of the numbers and counts the number as his or her score; say this score is 4. The second player moves the coin to another slip of paper, say number 5, and announces his or her score to be 4 + 5 = 9. The first player now moves the coin to another slip of paper, say number 2, and announces the score to be 9 + 2 = 11. The players continue to alternate turns and keep score. The game continues until one player wins by either scoring 37 or making his opponent score above 37. What is the winning strategy?

Bear in mind that the coin must be moved to a different piece of paper at each play. It will be seen that the winning numbers during the play are 4, 11, 17, 24, 30, and 37.

Before coming to ORNL's Chemical Technology Division last year, Eli Greenbaum was a Union Carbide research scientist and an adjunct associate professor at the Rockefeller University in New York in the same field of research that he describes here. His three degrees are in physics, the doctorate from Columbia. He is shown here measuring the simultaneous production of hydrogen and oxygen in a specially designed and constructed flow apparatus which continuously purges the reaction cell of photosynthetically produced gases.

I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. There is, therefore, nothing to fear.... and there will be no want of either light or heat as long as the productions of the plant, mineral or animal kingdoms do not fail us. I believe, then, that when the deposits of coal are exhausted we shall heat and warm ourselves with water. Water will be the coal of the future.

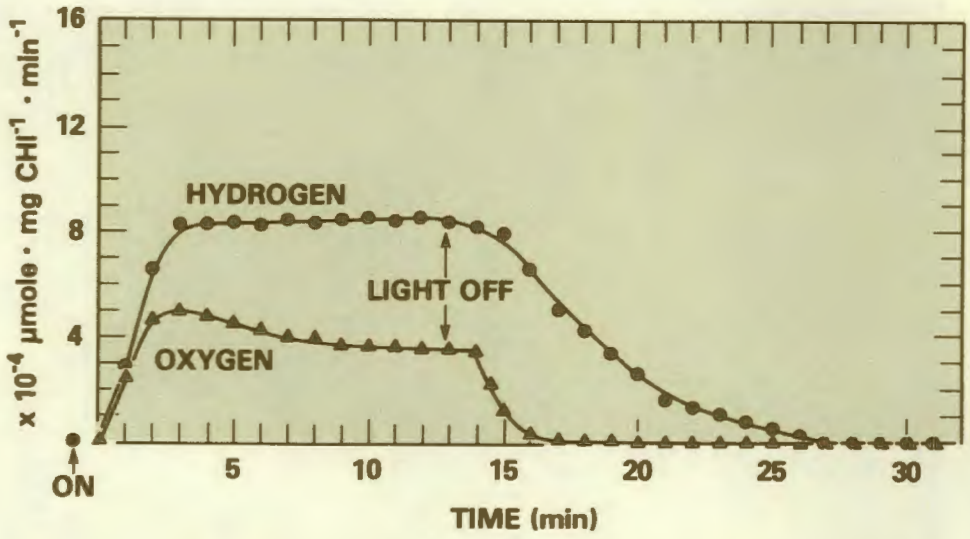
Jules Verne, ca. 1870
The Mysterious Island

Biosolar Hydrogen Production

By ELIAS GREENBAUM

A serious and challenging problem facing the nations of the world is how to replace dwindling sources of fossil energy and chemical feedstocks that historically have been available at low to moderate prices. One possible replacement source is a technological concept based on green plant photosynthesis. Photosynthesis is a logical choice because it is the basic biological process upon which all of life is totally dependent: it generated the earth's entire biosphere, it has provided us with all our fossil sources of energy, and it is the only source of food. However, it took many years for plant material to be converted into fossil fuel. Is it possible to use the photosynthetic process to produce usable energy in a shorter length of time? There is reason to believe that the answer is yes. One approach that we feel is especially promising is the photosynthetic production of

The first experimental data on simultaneous photoproduction of hydrogen and oxygen to be shown in the chloroplast-ferredoxin-hydrogenase system. This supports the conclusion that the system is capable of performing true photosynthetic water splitting.



hydrogen for fuel and chemicals.

The idea of using hydrogen as an energy carrier has been around for a fairly long time. Hydrogen, in addition to being a valuable chemical feedstock, is a clean-burning fuel which can be stored and transported. But only molecular hydrogen represents storable, transportable energy; hydrogen tied up in a molecule of water, which is the principal combustion product of hydrogen, must be liberated by splitting the molecule into free hydrogen and oxygen. These ideas can be summed up in the simple equation

$$2H_2O + \text{Energy} \rightarrow 2H_2 + O_2 \ .$$

When hydrogen is burned as a fuel the reverse process takes place:

$$2H_2 + O_2 \rightarrow 2H_2O + \text{Energy} \ .$$

We see that to split water into hydrogen and oxygen, energy must be provided. One attractive form for this purpose is solar energy. In photosynthesis, the pigment chlorophyll has the primary responsibility for capturing and converting the sun's energy into stable energy-rich molecules, such as carbohydrates.

Uses of Hydrogen

Among the solar energy conversion strategies, photobiological and photochemical conversions are unique in that the immediate product represents energy-rich molecules, such as hydrogen, that can be stored and transported. As an energy carrier, hydrogen would be compatible with the natural-gas pipe distribution, or a modification of that system. Hydrogen is also a valuable chemical feedstock used in petroleum refining, methanol production, and the synthesis of anhydrous ammonia for fertilizers. Furthermore, hydrogen trapped as a metal hydride could be used as a transportation fuel (e.g., when coupled with a fuel cell and used in an automobile).

Hydrogen is often thought to be very dangerous. The source of this impression may be the Hindenburg disaster of 1936, in which a hydrogen-filled dirigible ignited while attempting to land at Lakehurst, New Jersey. It is important, however, to keep in mind that the modern-day safety record of hydrogen is excellent; for example, hydrogen fueled all of the Apollo spacecraft which journeyed to the moon in the 1960s and early 1970s. Moreover, the United States has produced 85 billion cubic meters (3 trillion cubic feet) of hydrogen annually from fossil fuels without a significant accident.

Biosolar production of hydrogen refers to the photolysis (light-induced decomposition) of water using living plant organisms or material derived from plants. Currently, only three biological methods of splitting water into hydrogen and oxygen are known: (1) green algae, (2) blue-green algae, and (3) a system composed of isolated chloroplasts, electron carriers, and catalysts. The first two methods are based on living organisms, while the last is based on a nonliving system derived from living plant matter.

All these methods of photobiological hydrogen production have one important feature in common: they absorb photons and use the excitation energy to drive an energetically uphill reaction. The pigment molecules of photosynthesis absorb light in the visible portion of the electromagnetic spectrum, which corresponds to the wavelength range of about 400 to 700 nm. In the physical mechanism of the primary process of photosynthesis, the absorption of one quantum in a photosynthetic reaction center produces a charge separation pair of one plus and one minus charge across a photosynthetic membrane about 7 nm (70 Å) thick. This electrostatic potential energy is subsequently conserved by means of a series of biochemical reactions which can proceed in the absence of light.

Perry Eubanks prepares hydrogenase for the chloroplast-ferredoxin-hydrogenase system by means of ultrasonic disruption of bacterial cells.

Green Algae as a Hydrogen Source

The original discovery of hydrogen production by photosynthesis was made in 1942, using single-celled green algae, by Hans Gaffron and Jack Rubin of the University of Chicago. These algae are the prototypes of higher plant photosynthesis; even though they are composed of only one cell, they perform essentially all of the photosynthetic functions of higher plants. The fact that green algae can produce hydrogen at all is a biological mystery since there is no obvious metabolic benefit for the organism.

In the photosynthesis that accompanies normal plant growth, the molecular oxygen produced is released to the atmosphere. Molecular hydrogen, however, is not; it is chemically bound to atmospheric carbon dioxide in the plant. The path by which carbon dioxide is transformed into plant matter was first demonstrated by a team led by Melvin Calvin at Berkeley; for this work, Calvin was awarded the Nobel Prize in chemistry in 1961. Hydrogen chemically bound to carbon dioxide forms carbohydrates, the basic building block for the growth of new plant matter, which is an undesirable occurrence in the biosolar production of hydrogen and oxygen.

New algal growth, or carbon dioxide fixation, can be prevented by placing the algae in an atmosphere free of carbon dioxide. Moreover, atmospheric oxygen must be excluded from the algae in order for production of molecular hydrogen to take place. For the green algae to liberate molecular hydrogen, which would otherwise be trapped in chemical combination with carbon dioxide, they must synthesize hydrogenase, a biological catalyst, or enzyme. In a 20% oxygen atmosphere (air), hydrogenase can neither be synthesized nor function. Therefore, biosolar production of hydrogen is carried out in an anaerobic atmosphere, that is, one that is initially free of oxygen. But in water splitting, oxygen is produced as a by-product along with the hydrogen. Therefore, to maintain a functional hydrogenase, a method must be devised to prevent too large a buildup of photosynthetically produced oxygen.

ORNL's Algae Study

In ORNL's Chemical Technology Division, we have used an inert carrier gas which purges the reaction vessel of photosynthetically produced hydrogen and oxygen. The logical candidate for sweeping out these gases is nitrogen, since it constitutes about 79% of the earth's

atmosphere. By appropriate control of the flow rate, the absolute concentration of hydrogen and oxygen can be kept below the combustion point, so there should be no danger of explosion prior to separation, which can be done either by membrane filtration or chemical techniques.

One of the great advantages of working with living systems is that they are self-propagating. For example, biosolar panels could be seeded with an inoculum of algae and then allowed to self-propagate until the growth met our needs. It is important to note that algae do *not* have to be supplied with energy-rich media in order to multiply; they need only sunlight, water, atmospheric carbon dioxide, and inorganic mineral salts. When the algal cultures are sufficiently mature, air can be purged from the biosolar panels with nitrogen and the algae placed in the hydrogen and oxygen production mode.

We have shown that anaerobically adapted green algae will simultaneously produce hydrogen and oxygen for over 16 h when illuminated with visible light. At the end of the 16-h period the algae are still viable and can be rejuvenated by exposure to a cycle of normal aerobic photosynthesis. Then another period of hydrogen and oxygen production can follow, and the system can be recycled. The main limitation that we have encountered thus far is the rate of hydrogen production, which is still too low to be practical. Although this limitation applies to all systems that are currently under investigation, we feel that this problem can be overcome by further research and that a practical system will emerge.

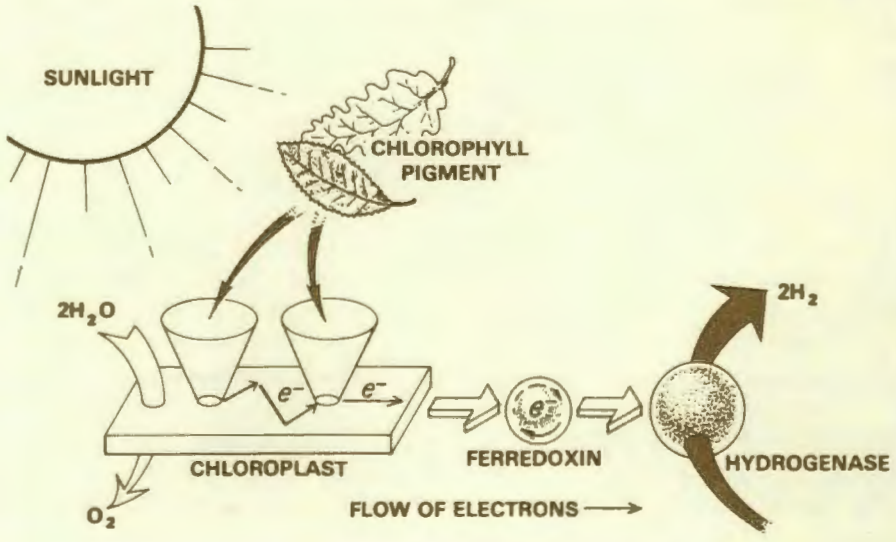
One reason for our optimism is that we have used these green algae to perform the first measurements of the photosynthetic unit size and the turnover time of hydrogen production. These results were obtained with experimental equipment of original design which can measure the absolute amount of hydrogen produced from a sample of algae illuminated with a single-turnover saturating flash of light. For these experiments we used xenon flash lamps or pulsed tunable dye lasers. The hydrogen photosynthetic unit size measurements suggest that the electrons for hydrogen production are derived from the mainstream of the electron transport chain of photosynthesis. The measurements of turnover time for hydrogen production suggest that the hydrogen photoapparatus is capable of a relatively fast intrinsic kinetic rate; it can keep pace with the rate of incident light quanta, even in full sunlight. These experiments were inspired by and are consistent with the pioneering experiments of William Arnold, of ORNL's Biology Division, who, in collaboration with Robert Emerson at Cal Tech in 1932, performed oxygen measurements which eventually led to the modern concept of the photosynthetic unit. The classic Emerson and Arnold experiments were the first studies of photosynthesis in flashing light.

Blue-green Algae as a Hydrogen Source

The second method of biosolar hydrogen production based on

BIOLOGICAL SOLAR ENERGY CONVERSION

In this method of biological solar energy conversion, water is split into hydrogen and oxygen. The driving force for this reaction is sunlight, which is captured by the chlorophyll pigment and funneled to the reaction centers of photosynthesis. Oxygen is produced in the chloroplasts. The hydrogenase enzyme is the final acceptor of the flow of electrons and produces hydrogen. Ferredoxin is a molecular shuttle which transports electrons from the chloroplasts to the hydrogenase.



living, intact algae was first demonstrated by John Benemann and his coworkers and uses blue-green algae. The difference between green and blue-green algae is much greater than a shade of green. Although green algae are closely related to higher plants, blue-green algae are more closely related to bacteria. In fact, they are also called cyanobacteria ("cyano" refers to the special pigmentation that gives them their blue-green color).

It is believed that one hydrogen-production method of blue-green algae is very different from that of green algae. Certain hydrogen-producing blue-green algae are multicellular filamentous organisms, and most of the cells perform photosynthesis and carbon fixation. However, a few of these cells are quite different in size and biochemical function. These larger cells, called heterocysts, normally fix atmospheric nitrogen. Consequently, the inert atmosphere must be something other than nitrogen, such as argon. In low concentrations of nitrogen, hydrogen can be produced in the heterocysts and oxygen can be produced in photosynthesizing cells, so blue-green algae are capable of simultaneous photoproduction of hydrogen and oxygen.

Water Splitting by a Nonliving System

We now come to the third method of photosynthetic water splitting. This method is a nonliving system whose components are extracted from plants and bacteria. The principal components of this system are chloroplasts, hydrogenase, and ferredoxin. Chloroplasts are the photochemical factories of photosynthesis present in all higher plants, such as spinach, and can be isolated from the leaves of plants by special biophysical and biochemical procedures. Reproduction is not possible in this isolated state, but the chloroplasts do retain many of their original properties.

As mentioned before, hydrogenase is the special enzyme needed for the liberation of gaseous hydrogen. Unlike unicellular algae, multicellular plants cannot synthesize their own hydrogenase, but hydrogenase can be added from an external source and appears to function in much the same way as internally synthesized hydrogenase. Here we see one of the special advantages of working with a nonliving, or cell-free, system: its composition can be controlled by the experimenter.

In the cell-free system composed of isolated chloroplasts, hydrogenase, and ferredoxin, the chloroplasts liberate oxygen, hydrogenase catalyzes the liberation of hydrogen, and ferredoxin is the molecular shuttle which connects the chloroplasts and hydrogenase. Hydrogen production by the chloroplast-ferredoxin-hydrogenase system was first demonstrated in 1961 by Daniel I. Arnon and his coworkers at the University of California at Berkeley. In 1973, John Benemann and his coworkers and Lester Krampitz began studying this system from the point of view of solar energy conversion.

ORNL Produces Gases with a Nonliving System

Research at ORNL on the chloroplast-ferredoxin-hydrogenase system was initiated by Zane Egan and Chuck Scott, whose work defined preparation procedures and parameters for hydrogen production. Recently, Perry Eubanks and I were able to show that, just as with intact algal systems, we could purge the system of photosynthetically produced hydrogen and oxygen and measure the production of both gases. These results were obtained with a specially designed and constructed flow apparatus using sensitive oxygen and hydrogen sensors. We are enthusiastic about these results because they support the hypothesis that the chloroplast-ferredoxin-hydrogenase system is capable of performing true photosynthetic water splitting, so that chemical oxygen traps may not be necessary in the design of a practical system. Also, this approach might provide an economic credit for the oxygen by-product. It is interesting to note that all three of the only known direct photobiological water-splitting systems—green algae; blue-green algae; and chloroplasts, ferredoxin, and hydrogenase—have now been shown to be capable of simultaneous photoproduction of hydrogen and oxygen.

It is appropriate at this point to ask, "Where are we? And where are we going?" The present status of the field is encouraging because there is no doubt that the concept is technically sound. However, the rate of hydrogen and oxygen production in continuous-wave light must improve significantly before practical developments can proceed. We feel that the key ingredient for learning how to improve the rates is fundamental research in photosynthesis, with particular emphasis on the chemistry and physics of hydrogen and oxygen evolution. With sufficient knowledge of how these light-activated reactions take place, photobiological hydrogen production may be able to take its place among the new energy sources that have been and will be developed when fossil fuels become too expensive or unavailable. ornl

information meeting highlights

Environmental Sciences Division
April 8–9, 1980

Technetium in the Environment

Radioecologist Chuck Garten reported on research being conducted on the biogeochemical behavior of technetium, a radioelement whose long-lived isotope ^{99}Tc (210,000-year half-life) is of interest in the management of the recycling and final storage of spent nuclear fuels. This research began at ORNL in 1978 with a seed money grant and is now sponsored by the Department of Energy and the Environmental Protection Agency. Incentive for this research was provided by published values of soil-to-vegetation transfer factors, called concentration ratios, that were two to three orders of magnitude larger than the generic value used in regulatory assessment models. A recent paper in *Health Physics* by J. E. Till, F. O. Hoffman, and D. E. Dunning, Jr., of the Health and Safety Research Division, demonstrated that if a new CR value representative of these published data were adopted in radiological assessment models, calculated doses from a release of 3.7×10^{10} Bq/year (1 Ci/year) of ^{99}Tc to the atmosphere could approach, and even exceed, present EPA uranium fuel cycle standards. A release of 3.7×10^{10} Bq/year approximates current releases of ^{99}Tc from gaseous diffusion plants processing recycled fuels. The source of the published data on soil-to-vegetation CR values for technetium, however, is entirely from potted plant experiments conducted under laboratory conditions at Pacific Northwest Laboratory and the University of Minnesota. The relevance of these data to actual field conditions is unknown.

Recognizing the potential shortcomings of these potted plant experiments, Garten, along with F. O. Hoffman, D. M. Lucas, and J. W. Huckabee, teamed with T. G. Scott of the Analytical Chemistry Division to perform the first known field investigations on technetium in soil and vegetation.

Two approaches were taken. One was the sampling of soil and vegetation near operating gaseous diffusion plants, which required the refinement of radiochemical techniques and the development of an isotope dilution mass-spectrometric capability to enable a reliable determination of low concentrations of ^{99}Tc in soil and vegetation. The other approach involved a single application of the gamma-emitting isotope ^{95m}Tc (61-day half-life) as a tracer in order to observe the time-dependent behavior of technetium in soil and vegetation. The ^{95m}Tc tracer was applied to field plots within the 0800 area of the ORNL reservation.

Results from both approaches indicate that field CR values are one to two orders of magnitude less than CR values obtained from laboratory experiments. In addition, concentrations in soil and vegetation exposed to a single application of technetium decreased with time, implying a reduction of biological availability in soil and a physical removal of technetium from both soil and vegetation. Such behavior should preclude a long-term accumulation of technetium in food chains.

The calculated dose to people from a release of ^{99}Tc to the atmosphere would be even less than the simple differences observed between laboratory and field CR values if radiological assessment models were to incorporate the observed dynamics of technetium in soil and vegetation. The calculated dose estimated using CR values from potted plant experiments would be reduced by a factor of about 200 or more when data on the dynamics of technetium in soils and vegetation are considered.

Garten mentioned that weathering processes, including leaching by precipitation, may account for the removal of technetium from the vegetation under field conditions. This process would probably not obtain under laboratory conditions. Work to resolve the large discrepancy between laboratory and field observations of technetium in soil and vegetation is continuing.

Wally Koehler has been engaged in neutron scattering research at ORNL since 1949. When the newly formed National Center for Small-Angle Scattering Research was established at Oak Ridge, it was primarily because of his expertise and that of metallurgist Bob Hendricks, whose small-angle x-ray camera is described in the Winter '78 issue of the *Review*. The two scientists and the equipment they have designed add up to a formidable and unique research facility. Koehler, a Union Carbide Corporate Research Fellow, is shown here receiving the congratulations of Dr. G. Cau, president of the Scientific and Medical University of Grenoble, which awarded Koehler the honorary title of Docteur Honoris Causa in ceremonies held last year.

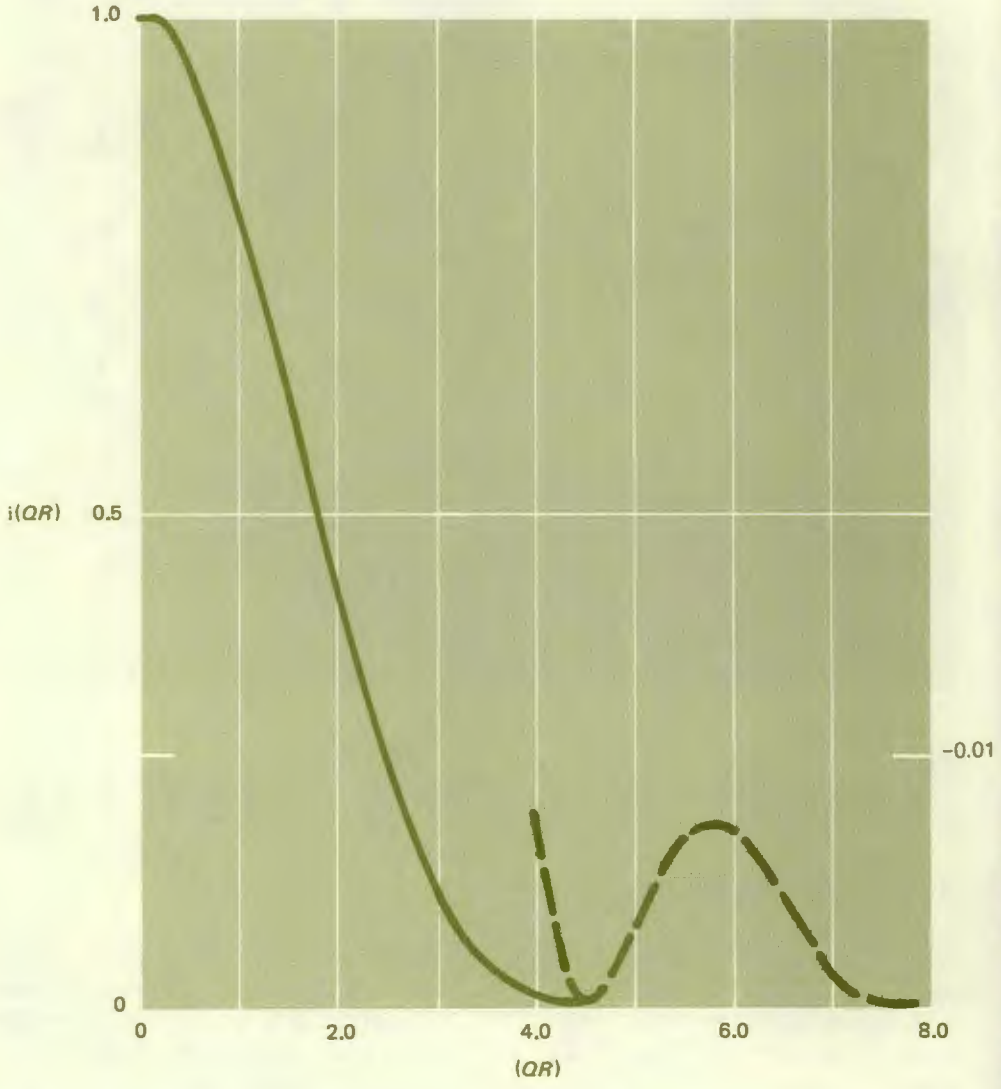
Small-Angle Scattering Research

By WALLY KOEHLER

Early in 1977, Bob Hendricks and I, with the help of our colleagues in the neutron scattering program of the Solid State Division, submitted a proposal to the National Science Foundation for the construction and operation of a national user-oriented small-angle neutron scattering facility at the High Flux Isotope Reactor. After consultations with ORNL and DOE management, we amended the proposal and extended its scope to include part-time use of existing small-angle x-ray and neutron scattering equipment, with the intention of creating a National Center for Small-Angle Scattering Research at ORNL. After the necessary reviews and site visits, our proposal was accepted and the Laboratory received funding amounting to $1.4 million for a three-year period beginning January 1, 1978. The Center is now into its third year of operation, and it seems appropriate to review what happened during the first two years of its existence.

First of all, one may ask, why spend so much time and money to study small deflections of a beam of radiation? The answer to this question is simply that one can obtain structural information from such measurements that cannot be obtained otherwise. The structures that lend themselves most readily to investigation by small-angle scattering methods fall for the most part into two general classes: (1) periodic structures with large lattice spacings and (2) nonperiodic extended, or global, structures with dimensions ranging from several tens to several thousands of angstroms (1 Å = 10^{-10} m = 0.1 nm).

It is well known that crystalline solids act as three-dimensional diffraction gratings for x-ray or neutron radiation. Such radiation, incident upon the atoms in a crystal, will be scattered into a series of intensity maxima or diffraction peaks because of interferences in the beams from the several atoms. The angular positions of these maxima, often called Bragg reflections (after the British pioneers who exploited x-radiation in the determination of crystal structures), are governed by Bragg's law, $\lambda = 2d \sin \theta$. In this relation, λ is the wavelength of the incident radiation; d is the spacing of a set of planes of atoms in the crystal; and θ, the Bragg angle, is one-half the angle of scattering, that is, one-half the angle between the direction of the incident beam and that of the Bragg reflection. In any crystal, there are many possible interplanar



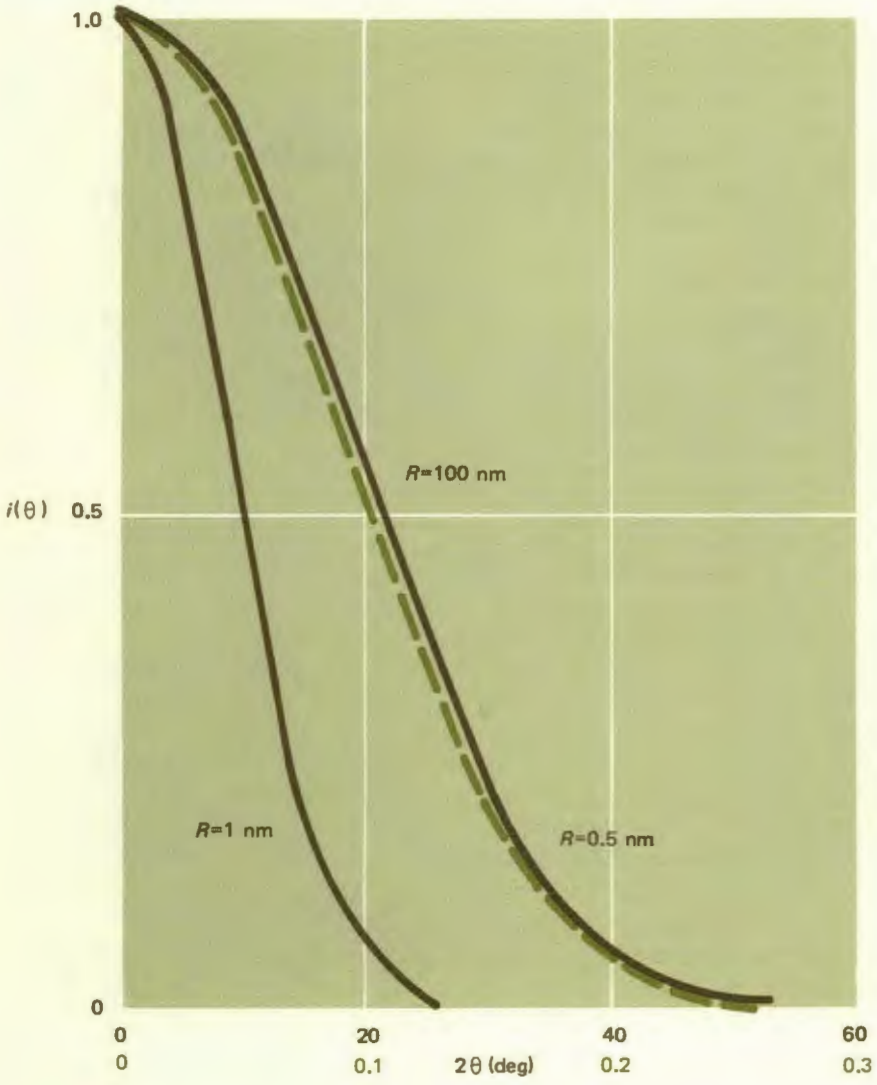
The normalized intensity of scattering of radiation from a uniformly filled sphere of radius R. The first zero of the function i(QR) *occurs at* QR = *4.49. The first secondary maximum, shown in dotted lines and to the scale on the right of the figure, is found at* QR = *5.76. The magnitude of this maximum is* 7.45×10^{-3} *that of the maximum at* QR = *0. Subsequent maxima are even weaker.*

spacings—hence many Bragg reflections in a diffraction pattern. It is important for our purposes here to notice that the Bragg angle varies inversely with the separation of the scattering planes. For most crystals the interplanar spacings d are of the same order of magnitude as the x-ray or neutron wavelengths generally used, and the scattering angles 2θ are quite large. In many cases of interest—certain minerals, crystalline polymers, proteins, or fluxoid lattices*—it is necessary to detect large lattice spacings, on the order of tens to thousands of interatomic spacings. In such cases the diffraction patterns must be extended to small angles. For example, for Cu Kα x-radiation (λ = 0.154 nm) the Bragg angle is 0.45° for a 10-nm spacing and 0.045° for 100 nm. For neutrons it is possible to use longer wavelengths, typically 0.45, 0.6, or 1 nm, but even with 1-nm neutrons the Bragg angle for a 100-nm spacing occurs at 0.28°. Nevertheless, with modern instrumentation it is possible to measure a sufficiently large number of intensities of Bragg reflections in the systems mentioned above to obtain crystallographic or magnetic structure information. The theory used to interpret the diffraction patterns is quite similar to that used in systems with spacings comparable to the wavelength.

Typical of problems in the global structures studied by small-angle scattering are the shape and arrangement of large molecules in solution and in the solid (biological macromolecules, polymers, and liquid crystals), precipitates and voids in metals and alloys, magnetization distributions, and so on. The scattering from structures of this type is characterized not by a series of strong intensity maxima, but rather by a single intensity maximum centered at zero scattering angle and falling off to zero more or less rapidly with increasing angle.

In describing the scattering from such structures it is often convenient to introduce the quantity $4\pi \sin \theta/\lambda$, sometimes designated by K and sometimes by Q, which is the magnitude of the scattering vector. In this, as before, λ is the wavelength of the radiation and θ is one-half the angle of scattering. A very simple example is the scattering of x rays or neutrons by a sphere of radius R and constant scattering density.

In certain types of superconductors, magnetic flux penetration occurs in the form of periodically arranged filaments. The interfilamentary separation is typically 80 to 100 nm. The filaments are called fluxoids; hence the name fluxoid lattice.



The normalized intensity of scattering of radiation from spheres of several different radii as a function of scattering angle. The curve for R = 100 nm, indicated here by a broken green line, refers to the lower scale. The entire scattering curve is inside 0.27°. For R = 1 nm and R = 0.5 nm, upper scale, the intensity is nonzero to 23 and 46°, respectively.

The intensity of scattering from such a system falls to zero first at a value of the dimensionless product QR of about 4.5. There are several very weak secondary maxima, the first of which has a magnitude of 7.5×10^{-3} relative to 1.0 for $QR = 0$. For a sphere whose radius is comparable to the wavelength of the radiation, the scattering curve will have a nonzero value out to fairly large angles, but when the particle is large compared to the wavelength, the nonzero scattering is restricted to very small angles.

For a specimen consisting of N such spheres, the total intensity is simply related to N times the scattering from a single sphere. It is, of course, rare to find perfectly spherical particles with well-defined constant radii (some standard polymer scatterers do approximate this condition, however), and in real specimens there will usually be a distribution of sizes and shapes. New theoretical treatments for the interpretation of scattering data from global specimens had to be, and are continuing to be, developed. Nevertheless, the general reciprocity relations I have indicated for the ideal case are valid for physical systems as well.

At this point it is pertinent to ask, why *neutron* small-angle scattering? The answer to this question is related to the nature of the interaction of neutrons with atoms. Except for the special case of magnetic scattering of neutrons, which I shall not consider now, neutrons interact with nuclei through a short-range nuclear force interaction. The strength of the interaction is measured by a coherent scattering amplitude, and the intensity of scattering is measured by the square of the amplitude, or cross section. Generally the nuclear scattering cross sections of nuclei are comparable in magnitude, whereas x-ray scattering cross sections are proportional to the square of the atomic number of the atom (e.g., 1^2 for hydrogen and 92^2 for uranium). In addition, different isotopes of the same element may have different neutron cross sections, and in important cases such as hydrogen and deuterium, the sign of the amplitude may be different (negative for hydrogen and positive for deuterium). For x rays, the scattering of which is by the atomic electrons, these conditions do not apply.

The signal that one observes in small-angle scattering experiments depends on the contrast in scattering density between the structural entities being investigated and the matrix in which they are embedded. (If the spheres mentioned above were dispersed in a medium with the same scattering cross section, it would not be possible to detect

them.) It is possible to modify this contrast for neutron scattering by appropriate isotopic substitution. For example, substitution of deuterium for hydrogen in polymers and biological systems produces the extremely powerful contrast variation technique for "seeing" individual molecules. Neutron sources, even those as intense as the HFIR, are much weaker than modern x-ray sources. However, because of the strong absorption of most materials for x rays, small-angle x-ray scattering specimens are necessarily very small. For most materials, the absorption of neutrons is relatively weak and much larger specimens can be used. This means that truly bulk properties can be investigated in addition to making up some of the intensity loss due to the low source strength. Frequently neither x-ray scattering nor neutron scattering techniques alone are sufficient; they are complementary and, taken together, produce a formidable probe of global structure.

Finally, a SANS facility that is truly user oriented is needed by the American scientific community. Small-angle neutron scattering cameras exist, of course, in the United States (two at ORNL, one at Brookhaven, and one at the National Bureau of Standards, for example), but for the most part they are used in programmatic research and are not always available for general use.

It may be of interest to note that by far the greatest number of research proposals submitted to the Institute Laue-Langevin in Grenoble, France, are intended for one of the two SANS facilities in operation there (D-11 and D-17). Indeed, these instruments are so oversubscribed that the Institute directors have proposed that a third be constructed during the next five-year operating period. Those of us involved with the SANS project at ORNL are convinced that our device will be saturated within a year of its opening to routine operation.

Organization of the Center

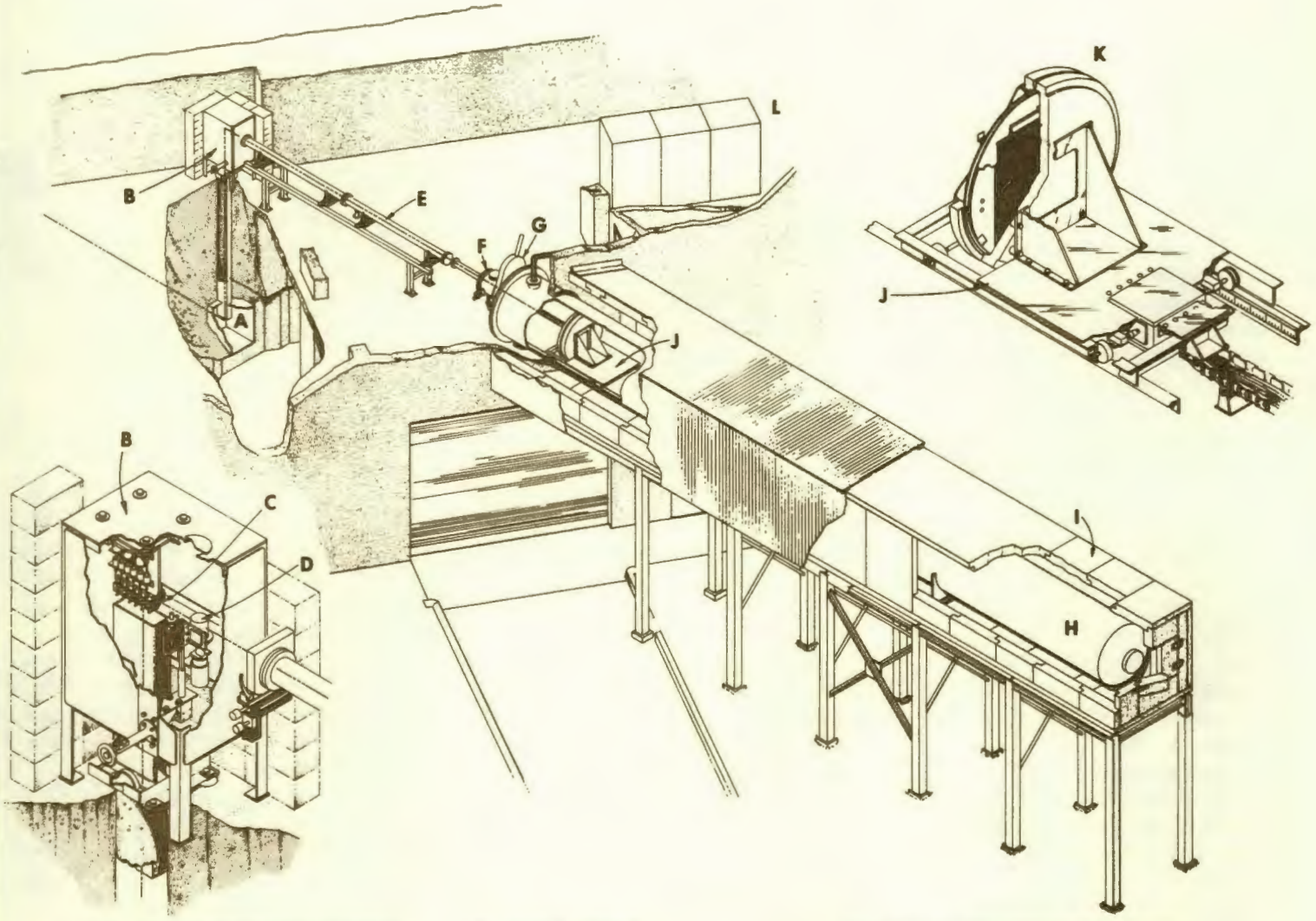
The NCSASR is jointly responsible to DOE through ORNL management and to several divisions of NSF (Materials Science, Biology, and Chemistry). A policy committee, with functions similar to those of divisional advisory committees, serves as an interface between NSF and ORNL and the directorate of the NCSASR. This policy committee consists of six experts in the areas of materials science, chemistry, polymer science, metallurgy, and x-ray and neutron scattering. The Center is administered by Bob Hendricks and me. Our staff currently consists of the two of us, providing experience and expertise in metallurgy and solid state physics, respectively, plus experts in polymer science (George Wignall) and physical chemistry (J. S. Lin). Mary Gillespie serves as secretary. Soon, we hope to add to the staff a biologist with experience in small-angle scattering methods. The Center reports to Alex Zucker, Associate Laboratory Director for the Physical Sciences, through Mike Wilkinson, Director of the Solid State Division.

The Center is, as indicated earlier, a national user-oriented facility. Beam time is, or will be, assigned on the basis of the scientific merit of the research proposed. All proposals, with exceptions noted below, are submitted to two members of a program committee who judge the merit of the research and determine whether the facilities of the Center are required for the research. In many cases equipment satisfactory for the successful completion of the project may be found in the investigator's home laboratory. Currently nine scientists, again representing biology, chemistry, materials science, polymer science, and metallurgy, serve on this committee. When an affirmative reply from the program committee is received in the office of the Center, beam time is assigned according to the best judgment of the staff and an in-house contact is designated. Usually, this contact is a staff member who has some interest in the problem; his task is to interact with the outside investigator. The research may be done by the proposer, if he or she is sufficiently experienced, or it may be done in collaboration with a member of the NCSASR staff.

Three exceptions currently exist for the review process: proprietary research, applied research, and in-house research by the Center's staff. The intention of the Center, ORNL, and NSF is to encourage participation by scientists in American industrial laboratories, and provision has been made, on a limited basis, to permit scientists to carry out proprietary research. Proprietary research proposals are not reviewed, and the data obtained from the research are closely guarded.

Beam time may be granted, at the discretion of one of the directors of the Center, with the advice of the policy committee, for work which would probably not be accepted for publication in a scientific journal but which would nevertheless provide valuable data for developmental or engineering projects. Such research, which we might designate as applied research, will similarly not be reviewed.

Very early in the formation of the Center, Hendricks and I insisted



(A) LOWER MONOCHROMATOR HOUSING
(B) UPPER MONOCHROMATOR HOUSING
(C) GRAPHITE MONOCHROMATING CRYSTALS
(D) COLD BERYLLIUM FILTER
(E) COLLIMATOR AND NEUTRON BEAM GUIDE
(F) SAMPLE CHAMBER
(G) 56-cm GATE VALVE
(H) 20-m X 152 cm diam VACUUM FLIGHT PATH
(I) 28-cm WOOD SHIELDING
(J) DETECTOR CARRIAGE
(K) 112-cm diam TWO-DIMENSIONAL POSITION-SENSITIVE DETECTOR (64 X 64 cm ACTIVE AREA)
(L) DATA ACQUISITION SYSTEM

30-m SMALL-ANGLE NEUTRON SCATTERING FACILITY

that a small fraction of the beam time be made available to the Center staff for their own research. We felt that the purposes of the Center would be best served if a small but active in-house research program were carried out. Naturally, except for this particular staff time, all other proposals from ORNL are subject to the usual review processes. This condition is fully supported by ORNL and NSF management and by the policy committee.

In addition to the program and policy committees, a user's group has recently been organized, headed by an executive committee chaired by J. S. King. This group, which consists of all actual and potential users of the Center, will (1) serve in an advisory capacity and communicate general users' concerns to the NCSASR and the policy committee, (2) assist in the use of NCSASR equipment, (3) provide information to interested scientists on the use of small-angle scattering facilities and encourage the organization of special seminars and conferences, and (4) maintain contact with small-angle scattering centers and user organizations in the United States and abroad. The first meeting of this group was held in November 1979 during the first NCSASR Workshop, at which some 150 members were

present.

The construction of ORNL's new SANS facility, which we call the 30-m machine, and its operation are funded by NSF. The ordinary costs of doing an experiment there are borne by NSF through the Center. Special equipment, long computing times, machine shop time, and, in general, all extraordinary expenses must be paid for by the user. Exceptions to free beam time are made only for proprietary users who pay for time on a full cost-recovery basis.

The same operating practices apply to the other small-angle scattering facilities at the Laboratory for that fraction of the time that they are operated as part of the NCSASR. These machines, two SAXS and two SANS facilities, were all built by DOE and have been made available, on a part-time basis, to outside users as part of a general trend toward establishing user-group modes of operation for many of the research facilities of the Laboratory. The move toward this type of operation for neutron scattering facilities reflects the recognition by DOE and ORNL management that research reactors and their associated scattering equipment are truly national resources that need to be made available to qualified scientists in the nation as a whole.

The 30-m SANS Instrument

It may be evident from some of the foregoing discussion that one important attribute of a SANS facility is a relatively long neutron wavelength. A second desirable feature is a low neutron background. In some of the European instruments the monoenergetic beam is produced by a mechanical velocity selector, essentially a set of rotating slotted disks, with typical wavelengths of 0.6 to 1 nm. Before monochromatization, the beam is usually transported from the reactor to a low-background experimental hall by total reflection from the highly polished walls of a neutron beam guide.

In the NSF-ORNL system, located at the HFIR, the monochromatization and beam transport are carried out by Bragg reflection from two sets of pyrolytic graphite crystals. High-quality pyrolytic graphite monochromators, produced solely by Union Carbide Corporation, are made by a hot-pressing process which, to near perfection, makes parallel the hexagonal layers of the graphite structure. The orientation of the hexagonal planes about their common normal is random, but this random orientation is unimportant for neutron scattering applications. At a scattering angle of 90°, crystal set at 45° to the beam, Bragg scattering from the hexagonal layers is restricted to neutrons of approximately 0.475 nm. (Again, look at the Bragg relation, $\lambda = 2d \sin \theta$, where now d and θ are fixed and allow a spectrum of neutron wavelengths to fall on the crystal. To satisfy Bragg's law, the neutron must have a wavelength of 0.475 nm). After Bragg reflection, the beam, now nearly monoenergetic, moves through an evacuated vertical flight path to an identical and parallel crystal on the engineering facility level above the beam room. At the reactor wall, the engineering facility level is shielded from the floor below by some 3 m of heavy concrete and is therefore a low-background region. The second crystal, acting in the same way as its partner below, redirects the beam parallel to its original direction. To repeat, the beam is now monoenergetic and displaced from the high neutron background of the beam room.

For a number of technical reasons, we require the highest-quality pyrolytic graphite we can get, but this means that the wavelength spread of the beam off the crystal is much smaller than necessary, $\Delta\lambda/\lambda \approx 0.01$, the high wavelength resolution resulting in an undesirable loss of intensity. To improve this situation we have installed six such pairs of crystals, each one slightly misoriented from its neighbor, so as to extract a different wavelength from the spectrum. At these long wavelengths, the graphite crystals are nearly totally reflecting for the Bragg-scattered wavelength and nearly totally transmitting for all other wavelengths. Each crystal in the lower monochromator group selects its wavelength and scatters it to its partner in the set above. The six beams are then all recombined with an overall $\Delta\lambda/\lambda \approx 0.06$, with approximately six times the intensity of a single pair.

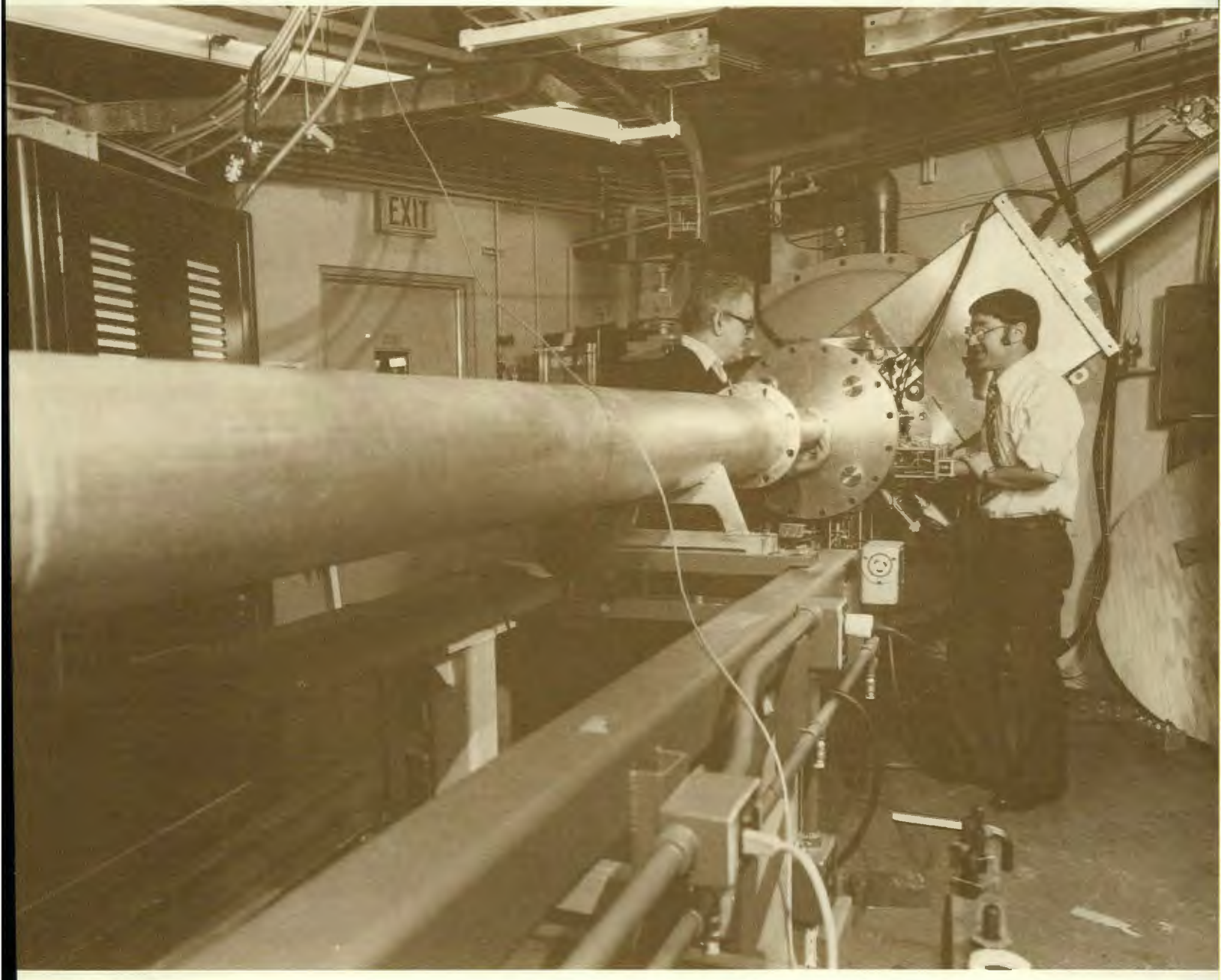
The situation is not quite as I have described it. Let us look again at Bragg's law, $\lambda = 2d \sin \theta$. For a given setting of the crystal, say $\theta = 45°$, a wavelength $\lambda_0 = 0.474$ nm will be scattered by the set of crystal planes with spacing $d_0 = 0.335$ nm, the separation between adjacent hexagonal planes. Note that Bragg's law can be satisfied for the same angular setting for a wavelength $\lambda_0/2 = 0.237$ nm and a set of planes with spacing $2d_0 = 0.670$ nm, with $\lambda = \lambda_0/3 = 0.158$ nm and $d = 3d_0 = 1$ nm and so on. All these other wavelengths are present to a greater or lesser degree in the beam incident upon the upper monochromator bank and again in the reconstituted beam leaving it. All of these, except the primary wavelength λ_0, can be eliminated by a filter, a cooled block of polycrystalline beryllium. It is sometimes useful to eliminate

all but the $\lambda_0/2$, for which purpose a tuned graphite filter is used.

The reconstituted beam is defined by an aperture at the exit of the upper monochromator housing and again by a collimating aperture just in front of the sample located 10 m away. The beam again passes through an evacuated flight path to eliminate scattering and absorption by air.

The sample chamber is a multipurpose evacuated box equipped with a motor-driven stage and a motor-driven collimator slit for remote positioning. Under the most frequently used experimental conditions, the only window in the presample flight path is at the monochromator end. All the rest of the system is evacuated.

The neutrons scattered by the sample are intercepted by a 64- by 64-cm position-sensitive area detector of the Borkowski-Kopp design, constructed by members of ORNL's Instrumentation and Controls Division. This detector is mounted on a motorized dolly that can be positioned anywhere from 1.4 to 19 m from the sample inside the 1.5-m-diam postsample flight path in the shape of a large evacuated cylinder. This tank



Koehler, l., and George Wignall face each other over the sample chamber of the 30-m small-angle neutron scattering facility. Wignall is the staff member charged with working with users whose interests lie in polymer science.

Small-Angle Scattering Applications

Superconductivity. For certain specialized problems, particularly those in which the scattering entities are long in one dimension, the double-perfect crystal technique is useful because of its high angular resolution. One such system is the two-dimensional flux-line lattice that results when a sufficiently large magnetic field is applied to certain types of superconductors.

High-resolution small-angle scattering has been used by D. Christen and his associates in studying the flux-line lattice properties in niobium. The spacings of the flux lines are on the order of 100 nm. For a neutron wavelength of 0.24 nm, the first Bragg peak from the fluxoid lattice occurs at a scattering angle of 1.45 mrad (300 s). Since the width of the incident beam is just 0.082 mrad (17 s), very high precision can be obtained.

The technique has been used to determine the symmetry of the flux-line lattice by measuring the angle of scattering of three successive lowest-order Bragg reflections. The area of the unit cell in a magnetic field region known as the intermediate mixed state is constant. This basic unit cell yields the equilibrium flux density B_o. Generally, the flux density is considered to be a macroscopic quantity; interestingly enough, small-angle scattering, a microscopic technique, can yield a highly precise measure of a macroscopic quantity. In a similar way, the lower critical field H_{c_1} of the material can be determined with great precision from SANS measurements of the sharp transition between the two field regimes known as the intermediate mixed state and the mixed state.

Conventional SANS measurements have been used, where the demands of resolution are not so great, to determine the flux density distribution in superconducting materials. It is expected that microscopic information on superconductors of the type produced by SANS experiments will ultimately aid in producing high-current, high-field, superconducting materials important in energy transmission systems.

Biology. Several important applications of neutron scattering methods to structures of biological interest may be found in the literature of the past ten years or so. A particularly pretty application of SANS has been developed by Engelman, Moore, and Schoenborn for studies of the structure of the ribosome. In this case the term structure means the distribution of matter on an intermediate, rather than on the atomic or molecular, scale.

The ribosome is a specialized part of a cell, an organelle, on which the final sequence of amino acids in a protein molecule is established (e.g., the form of the genetic code). It consists of a large subunit containing one each of 34 different protein molecules and 2 molecules of RNA, and of a small subunit with 21 proteins and 1 RNA molecule. Thus far, only the small subunit has been studied.

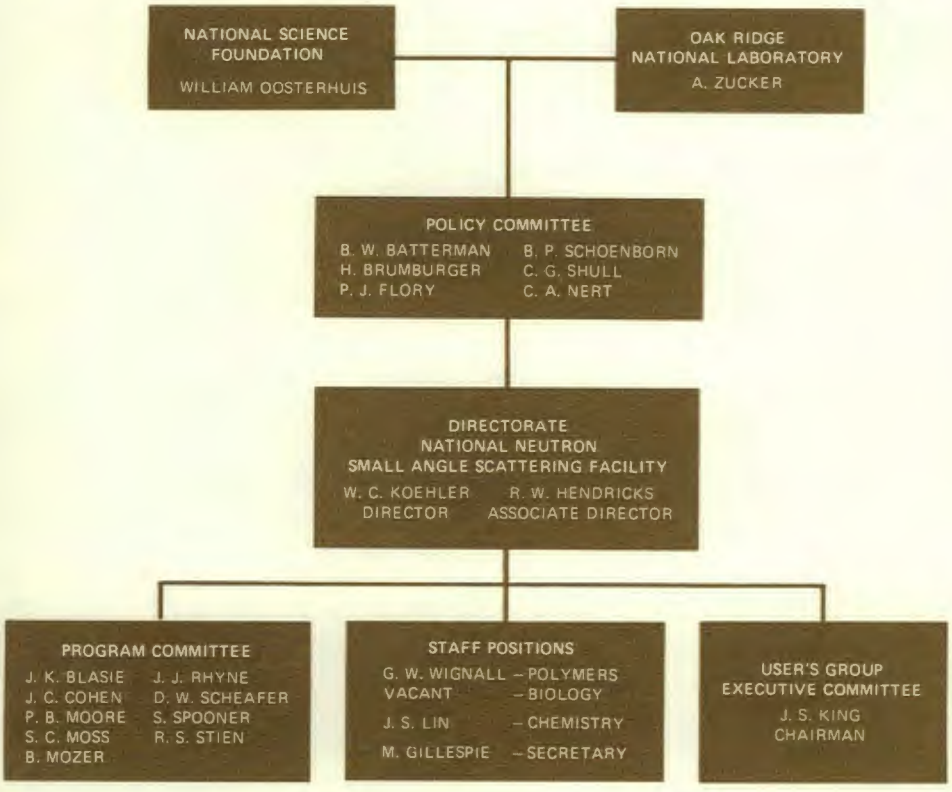
By means of some complex but well-understood biochemical analyses and syntheses, the investigators cited above were able to prepare specimens of the ribosome small subunits from *Escherichia coli* in which 2 of the 21 proteins were more or less completely deuterated. The state of the art of the chemistry is such that samples with many different deuterated pairs can be prepared. These tagged subunits scatter neutrons quite differently from the entities containing ordinary hydrogen because, as mentioned earlier, the scattering lengths of hydrogen and deuterium for neutrons differ in magnitude and, importantly, in sign.

The selectively deuterated specimens are placed in solution, and the solution is placed at the specimen position of a neutron scattering facility of the type that we will have at HFIR. In principle, the experiment is quite simple. The signal from the two tagged proteins can be enhanced, relative to the normal proteins, by the technique of contrast matching. One matches the average neutron scattering properties of the subunits to that of the solvent (water) by adjusting the H_2O to D_2O ratio. This means that the normal proteins in the subunits have little or no contrast with the solvent and that the marked proteins are the most conspicuous entities of the sample.

The scattering from the two tagged molecules shows an interference pattern. It is approximated by a damped sine wave, once the background scattering, which is measured in separate experiments, has been properly taken into account. From adjacent zeros, or minima, of the interference pattern, it is possible to infer the distance between centers of the two deuterated proteins.

After this procedure has been repeated several times, one may begin to map out the interprotein distances in the ribosome and therefore to determine the arrangement of the different proteins in the material. In addition to finding the relative positions of 21 proteins, such experiments can provide information on the general shape and orientation of each protein. Ultimately, it is hoped that such measurements will lead to a better understanding of one of the fundamental processes of life—the translation of the genetic code. As of January 1977, some nine protein pair distances in the small subunit had been determined, ranging from 3.5 nm between S5 and S8 (i.e., protein numbers 5 and 8 in the small subunit) to 11.5 nm between S3 and S7.

NATIONAL CENTER FOR SMALL-ANGLE SCATTERING RESEARCH



Organization of the National Center for Small-Angle Scattering Research, showing the composition of the Policy Committee, Program Committee, and staff.

extends out of the reactor building from the second level above ground and is supported on a steel framework. In May of 1980 a neutron shield, which will equalize the temperature of the top and bottom of the flight path in addition to its shielding function, will be built to enclose the flight tube.

The signals received by the detector are transmitted to a ModComp II minicomputer for processing and analysis by means of hardware and software identical to that developed by Bob Hendricks for his 10-m SAXS camera.

As of this writing all major components of the system as described have been built or purchased. A beam has been brought up, and its intensity and energy distribution have been measured at the position the sample will occupy. The measured neutron flux of 3.4×10^4 neutrons $cm^{-2}\ s^{-1}$ at 0.48 nm is within a factor of 2 of what was calculated. I am satisfied that this can be brought up to 10^5 neutrons $cm^{-2}s^{-1}$ with the replacement of some of the graphite crystals with more perfect material.

The detector has been given its final tests, preliminary experiments have been performed, and full user operation will begin in the fall. Some 20 proposals have now been received for the 30-m machine, and these are being queued for execution.

Undoubtedly, as the instrument becomes fully operative, many other experiments will be sent in for consideration.

Meanwhile, other facilities are available to users of the Center, including two SAXS and two SANS facilities. Over the past two years, about 40 experiments have been carried out in the NCSASR on one or another of those machines. A more complete description of those instruments can be found in a manual for users that has been prepared by NCSASR staff, in the technical literature, and in one case (the 10-m SAXS camera), in the 1978 winter edition of the *ORNL Review*.

It is not intended that this article include a comprehensive description of the 30-m SANS facility. Indeed, the full "machine paper" has not yet been written, for the final instrumental characteristics have yet to be measured. It is not inappropriate, however, for me to emphasize that much of the existing design for Bob Hendricks' x-ray machine was modified and enlarged for the 30-m neutron facility. We have saved an enormous amount of effort, time, and money in borrowing liberally from Hendricks' store of computer programs.

Finally, I wish to express my gratitude, and that of Bob Hendricks, to all the ORNL scientists, engineers, technicians, and craftsmen who, because of their interested, dedicated, and innovative participation, have brought this project along so far, so well, in so short a time. ornl

Of ORNL's small-angle scattering facilities available to users, the 10-m SAXS and the 5-m SANS (at the Oak Ridge Research Reactor) are available for up to one-third of the total beam time. The Kratky camera and the double crystal SANS instrument are relatively specialized and will probably not be used more than 10% of the total time. The 30-m machine is available for full user operation.

awards and appointments

Richard A. Griesemer has been appointed director of the Biology Division. He comes to his new position from the National Toxicology Program of the National Cancer Institute, where he served as associate director of the Carcinogenesis Testing Program.

Clifford Burchsted, Frank Neill, and **Roy Robertson** were among those awarded the Centennial Medal by the American Society of Mechanical Engineers, in observance of its 100th anniversary, for outstanding service to the society.

John Witherspoon has been appointed to the National Research Council's Committee on Federal Research on Biological and Health Effects of Ionizing Radiation. **Owen Hoffman** has been appointed as a reviewer for the same committee. Witherspoon and Hoffman have been appointed to a task group in Scientific Committee Number 64 of the National Council on Radiation Protection and Measurements. The task group's purpose is to identify and evaluate environmental models used to estimate the radiological dose to man from releases of radioactive materials.

Bob Gray was invited to join an 11-member delegation of the American Society for Metals that traveled to the People's Republic of China in August to visit the Chinese Society of Metals.

Ted Welton has won the Alexander von Humboldt Award, presented by the Federal Republic of Germany. Part of the award entails a year of research at the Institute for Theoretical Physics of the University of Frankfort.

Charles Scott has been elected a fellow of the American Institute of Chemical Engineers.

Carl Koch and **Harry Yakel** have been elected fellows in the American Association for the Advancement of Science.

Domenic Canonico was awarded the James F. Lincoln Gold Medal for 1980 for his paper "Significance of Reheat Cracks to the Integrity of Pressure Vessels for Light Water Reactors," delivered at this year's American Welding Society annual meeting in Los Angeles. At the same meeting, **David Braski, Stan David,** and **Gene Goodwin** received the McKay-Helm Award for their paper "Solidification Behavior of Austenitic Stainless Steel Filler Metals," published in the *Welding Journal*. Also, **Canonico** has been appointed to the Boiler and Pressure Vessel Main Committee of the American Society of Mechanical Engineers for a five-year term.

Ron Bradley has been elected a fellow of the American Ceramic Society. In the society's ceramographic contest at its annual meeting, **Peter Angelini, David Stinton, Jack Lackey, Charles DeVore, Thomas Henson, Larry Shrader,** and **Nobel Rouse** won first place in the category of unique techniques as well as Best of Show for their poster describing a method of identifying the partitioning of plutonium in Synroc.

Bob McClung has been named an Outstanding Engineering Alumnus by the University of Tennessee and received the Award of Merit from the American Society for Testing and Materials, which cited him for his contributions to the development of nondestructive testing techniques.

Harry Hoy has received the William H. Cameron Award for 1979–80 as a member of the Executive Committee of the National Safety Council.

Gene Hise and **John Moyers** received the Outstanding Engineering Award from the National Society of Professional Engineers for the Annual Cycle Energy System Demonstration House.

Clair Collins is the 1979 recipient of the Southern Chemist Award, given by the Memphis section of the American Chemical Society. The award consists of a medal and an honorarium.

Lew Keller has been appointed to the Board of Visitors of the University of Tennessee Chemistry Department.

Chris Bird has received the Academic Achievement Award for 1980 from the American Water Works Association for his thesis "The Effect of Bromide on Trihalomethane Formation." The award includes an honorarium.

Steve Kaye has been appointed reviewer for a subcommittee of the National Research Council's Committee on Federal Research on Biological and Health Effects of Ionizing Radiation.

Loucas Christophorou has been elected corresponding member of the Academy of Athens, Greece.

Chain Liu is the first to receive the Henry J. Albert Award from the International Precious Metals Institute. The award, which will become an annual event, was given him for his development of alloys for encapsulating plutonium to be used as fuel in space missions.

Five ORNL staff members have been included in the current edition of *Who's Who in America:* **Igor Alexeff, Don Gardiner, Abe Hsie, Manfred Krause,** and **Alex Zucker.** Hsie has also been selected to receive one of five Distinguished Alumni Service Awards given this year by Indiana University.

Tom Wilbanks has been named associate director of the Energy Division.

Ivan Sellin has been appointed chairman of the National Academy of Sciences Committee on Atomic and Molecular Science.

The American Nuclear Society has announced the following selections to the rank of fellow: **Al Boch, Bill Harms, Paul Kasten, Herman Postma,** and **Elliott Whitesides.** The society's Materials Science and Technology Division has awarded **K. R. Thoms** the American Nuclear Society Award for presentation of "An Irradiation Capsule Design Capable of Continuously Monitoring the Creepdown of Zircaloy Fuel Cladding," by Thoms, Th. van der Kaa, C. V. Dodd, and D. O. Hobson. **Helen Pfuderer** has been named vice chairman/chairman-elect of the ANS Environmental Sciences Division committee. **Betty Maskewitz** has been elected to the ANS Board of Directors. The society's Radiation Protection and Shielding Division has awarded **Francis J. Muckenthaler** its Award for Technical Achievement in recognition of his development of radiation detection systems and his radiation shielding experiments.

Nermin A. Uckan has been chosen to receive the Fusion Power Associates Certificate of Recognition.

Dick Snyder has been appointed a fellow in the American Society for Nondestructive Testing.

Len Fuller and **Therese Stovall** have received Certificates of Recognition from the National Aeronautics and Space Administration Lewis Research Center for their development of the computer program PRESTO.

letters

Editor:

Re: Crossword puzzle, p. 36, Winter 1980. For 111 Across, the middle name of Robert Neyland is called for. His middle name is Reece, or Reese, perhaps, not NEESE as shown in the answer on p. 74.

Other than that comment, which caused me some difficulty with some of the companion words, that was a very nice puzzle—quite challenging. Would like more.

R. Van Winkle
Engineering Division
K-25

Hume Craft answers:

The word is indeed REESE instead of NEESE as shown in the answer. Thank you for calling my attention to the error. I hope you will like the puzzles in future issues of the *Review.*

OAK RIDGE NATIONAL LABORATORY *REVIEW*

P.O. BOX X: OAK RIDGE, TENNESSEE 37830

U.S. Postage
PAID
BULK RATE
Oak Ridge, Tenn.
Permit No. 3

POSTMASTER: DO NOT FORWARD: IF ADDRESSEE HAS MOVED, RETURN TO SENDER IMMEDIATELY. RETURN POSTAGE GUARANTEED.

Bob Hendricks, left, and Wally Koehler, who together form the directorate of the National Small-Angle Scattering Research Center at ORNL, look at the heavily shielded monochromator housing in the small-angle neutron scattering instrument in the High Flux Isotope Reactor beam room.