'From the Outside World'

Feibelman Wins Major Prize in Surface Physics

Like a good wine, the work that Peter Feibelman (Solid State Theory Div. 1151) did in theoretical solid-state physics a few years ago has aged well. ''Bottled'' in papers published between the mid-70s and early 80s (he joined Sandia in 1974), it has brought him the 1989 Davisson-Germer Prize, awarded by the Council of the American Physical Society (APS).

The Prize Committee's citation says Peter is being recognized ''for his pioneering work in developing the theory of electromagnetic fields at surfaces.''

It's a prestigious prize — 1000 VP Venky Narayanamurti calls it *the* prize in surface physics — and it's the first APS prize for Sandia. Winning it is especially sweet because, unlike many of the other awards Sandians win, it did not start with a nomination by Sandia. The nomination came entirely from outside.

Named for two Bell Labs physicists whose landmark experiment in 1927 demonstrated the wave nature of electrons, the Davisson-Germer prize is awarded annually, but is given for surface physics only every other year. (In alternate years it's for atomic physics.)

To put it another way, if your specialty is surface physics, you have only five chances each decade for this prize. If you win it, you get $5000, a certificate, and — most important — public recognition for scientific achievement.

Better Picture

What Peter did was to provide a realistic theoretical model of electric fields and electron motion at the surface of materials (some details later). That model has proved valuable both in scientific understanding of surfaces and in interpretation of the data yielded by advanced diagnostic techniques used to study materials for practical applications.

Peter views the prize as validating his work and other basic research at Sandia: ''It's confirmation from the outside world that our basic research effort is world-class. Doing work for the long term is important, even when you can't quite see where you're going.''

The Prize Committee's chairman, Prof. David Langreth of Rutgers University, says, ''The nominations normally include letters of support from experts all over the world. That was certainly true in the case of Peter's nomination. The people on the committee — and obviously lots of people in the outside world — feel that his work was a major breakthrough in this field.''

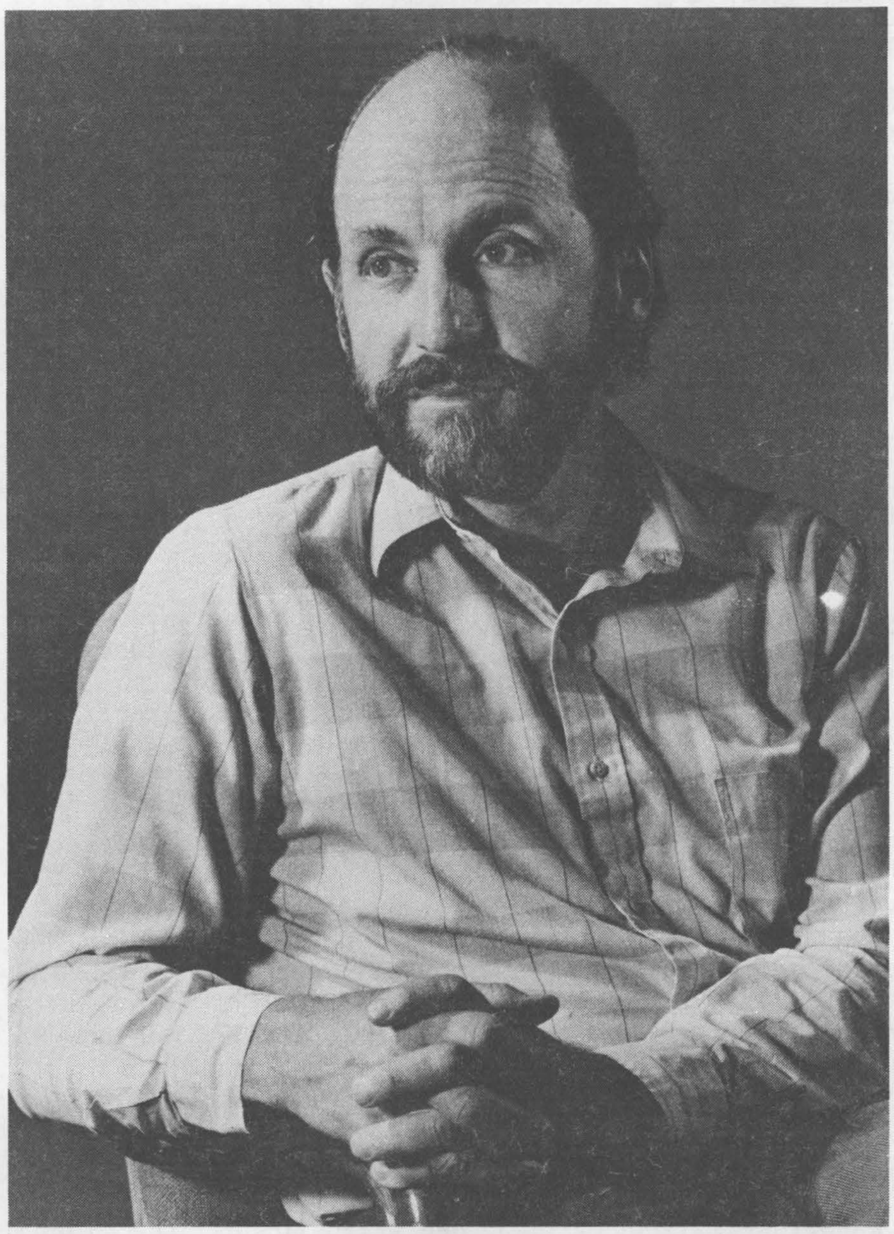
Peter's interest in surface electromagnetic fields was aroused by inadequacies in explanations of the photoelectric effect: ''In the early 70s, photoelectric emission came into wide use as a tool for learning about the possible states of motion of electrons near surfaces. What you do is shine light on a sample. Then you hope to learn about surface properties by interpreting the number, speed, and directions of the electrons that emerge.

''In those days, our understanding of the electric forces associated with a light wave near a surface was crude. We knew that some light would be reflected and some would be absorbed by the sample.

''But this knowledge did not bear on the important questions: How strong are the electric forces associated with the light wave in the immediate vicinity of a surface? In what directions do they push the electrons that are to be measured?

''I devised a scheme to predict these forces for a class of relatively simple materials, metals like aluminum, magnesium, sodium, and potassium. One of the most interesting predictions involved how the

(Continued on Page Four)



THEORY OF electromagnetic fields at surfaces has earned the Davisson-Germer Prize for Peter Feibelman (1151). Donated by AT&T Bell Labs, the prize will be officially awarded to Peter at the March 1989 meeting of the American Physical Society.

LAB NEWS

VOL. 40, NO. 23 SANDIA NATIONAL LABORATORIES NOVEMBER 18, 1988

SECRETARY OF DEFENSE MEDAL for Outstanding Public Service was recently presented to Stan Fraley (9241) by Bob Joseph, DoD's Deputy Assistant Secretary of Defense for Nuclear Forces and Arms Control Policy. The citation accompanying the award states that Stan's service as US chair of the US-USSR Inspection Protocol Working Group during the INF (Intermediate-range Nuclear Force) negotiations last year "was exceptional and was instrumental in the timely conclusion of the INF Treaty on terms that strengthened United States security and provided the effective means to verify Soviet compliance with the INF Treaty." During the award ceremony, AF Col. James Valdez read the entire citation on behalf of Defense Secretary Frank Carlucci.

Best-Ever ECP Participation

See Page Five

Antojitos

Behold Energy II! -- This issue -- at 32 pages the largest in LAB NEWS history -- features Sandia's solar programs (thermal, wind, and photovoltaic, plus the programs that aim to improve the storage batteries needed when the sun doesn't shine or the wind doesn't blow). Writers for today's installment are Donna Rix (3162), Will Keener, Nigel Hey, and Rod Geer (all 3161). Again, Rod served as project coordinator and Phyllis Wilson (3162) as copy editor.

Our final installment (probably our Dec. 23 issue) will include programs in coal, oil/gas, shale, geothermal, and magma.

* * *

Now It Can Be Told -- As the story below indicates, Tonopah Test Range headquarters has Air Force neighbors just down the hill who've been flying Stealth aircraft since 1981. The announcement is a kind of sanity check for us occasional visitors to TTR. Noticing a new string of hangars near the runway the DC-9 uses, we tended to ask TTRers questions like "What's that?" And they tended to reply, "You don't see anything." Stealth technology or no, it registers on eyeballs.

* * *

It Was a Dark and Stormy Night -- Well, late afternoon anyway. And Dick Houser (6222), Dan Alpert (6226), and Jay Holton (6222) had just finished showing off the power tower (aka solar tower, or, more precisely, the CRTF, for Central Receiver Test Facility; it's part of the STTF, or Solar Thermal Test Facility -- see why we non-purists call it the power tower?) to National Geographic photographer Chuck O'Rear, hosted by Will Keener (3161).

Sunset, a storm threatening, Jay, Chuck, and Will prepare to depart for Area I. Dedicated employees Dick and Dan go upstairs to the control room in Bldg. 9981 to check some new data. The time passes. The storm builds. They check the lightning early warning system -- "Pretty high," notes Dan. "We'd better get out of here," says Dick.

Off to the elevator. They're halfway down when KERWHACK! -- a lightning bolt kills the facility's electrical power. Dick and Dan are stuck in a hot (the fan stopped too, of course), dark, and stationary elevator. ("It's no place to be claustrophobic," says Dan later.)

Fortunately, building designers worry about things like this -- and install telephones (and lists of emergency numbers to call) in elevators. Unfortunately, they don't worry about how one is to read the numbers in total darkness. Well, not total. "We tried to read the list by the lights on the telephone dial and by the light from our electronic watches," says Dick. But to no avail.

Then Dick's habit of working late -- and thus needing to remember the Security phone number needed to dis-alarm some of Sandia's famed "alarmed" doors -- paid off. He dialed both 4-3214 and 4-1234 -- "It's one of those" -- and got Security. That's good. He was, however, just a bit rattled and told Security they were trapped in an elevator in "the solar tower." That's bad -- Security spent the next hour becoming exhaustively acquainted with the 400+ steps in the tower itself, not the control room tower where Dick and Dan were imprisoned.

And how did Dick and Dan spend the hour? Talking shop (told you they're dedicated employees).

"When the guards finally found us and pried open the doors, we leaped out -- luckily we'd been stuck near a floor -- and dashed off home without even thanking our rescuers," says Dan. "Hope they see this write-up and realize how grateful we were -- and are.

"Morals of story: (1) Work late often, so you'll have to memorize a phone number for Security, just in case;

(2) Or memorize the emergency phone number; it's 144 (or 12 dozen -- think of it as "totally gross!");

(3) Remember that the same Mother Nature who provides solar thermal power also provides lightning -- and, in a power struggle, bet on the lightning.

* * *

"What works is infinitely preferable to what doesn't work." --Ben Franklin (who had less respect for lightning than Houser and Alpert do -- now)

* * *

From the LAB NEWS Staff -- Happy Thanksgiving Day, Nov. 24; Happy FAT (Friday After T'giving) Day, Nov. 25; and Happy Chanukah, Dec. 4. •BH

LAB NEWS

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Congratulations!

Twelve Sandians received 1988 DOE Weapon Recognition for Excellence Awards from the Office of Military Application at ceremonies this week. Brig. Gen. Paul Kavanaugh, Deputy Assistant Secretary for Military Application, made the presentations.

The two Sandia Livermore award recipients were announced during Monday ceremonies there: Arnie Rivenes (8132) and Von Madsen (8317).

The ten Sandia Albuquerque award recipients, announced at the TTC on Tuesday, include: Jim Powell (1230), Mike Heck (2334), Bob Cover (DMTS, 5215), John Andersen (DMTS, 5161), John Portlock (7234), Paul Yarrington (1533), Bill Davey (1533), Archie Farnsworth (1533), Bob Courtney (7234), and Larry Harrah (ret).

The next issue of the LAB NEWS will include photographs and write-ups about these award winners.

Sympathy

To John Hunter (8364) on the death of his mother in Rusk, Tex., Oct. 1.

To Sandra Warner (8524) on the death of her grandmother in Clovis, Calif., Oct. 4.

To Quenton McKinnis (8451) on the death of his father in Las Cruces, N.M., Oct. 7.

To Julie Foster on the death of her father in Honolulu, Hawaii, Oct. 9.

To LaNeen Stewart (8522) on the death of her father in Walla Walla, Wash., Oct. 28.

To Renee Haynes (8531) on the death of her grandmother in Oakland, Nov. 1.

Sandia's Secret Nevada Neighbor

Stealth Fighter Based At TTR Airfield

The Air Force made a surprise announcement last week (Nov. 10) confirming the presence of a Stealth Fighter aircraft fleet, based next door to Sandia's Tonopah Test Range. The announcement was the first public acknowledgment by the government that the Stealth exists.

Officially designated the F-117A, the single-seat, dual-engine aircraft has long been rumored. The Air Force announcement stated that 52 of the advanced aircraft have been delivered to date and that seven more are still in production. They are built in California by Lockheed's Advanced Development Projects group, known as the "Skunk Works."

The Stealth Fighters are based at the Tonopah Test Range (TTR) Airfield, in desert country in the northwest corner of Nellis AFB in Nevada. Fifty-some Sandians operate the TTR, with a group of supporting contractors and security force. Most of the Sandians commute to the range from Las Vegas four days a week via a chartered DC-9 aircraft that lands at the same airfield.

Much information about the advanced fighter aircraft remains classified. However, the following additional information was made public in last week's Air Force announcement:

The F-117A is assigned to the Nellis AFB's 4450th Tactical Group, an operational tactical fighter organization that conducts normal activities for a tactical unit. Operational readiness inspections have been conducted.

The Stealth program began in 1978, with the first flight in June 1981. Initial operational capability was achieved in October 1983, and the last of the 59 Stealth Fighters is scheduled for delivery in FY90.

Task's Almost Impossible Experimentally

PASTA Learning to Predict Weld Quality

Although welding is a critical part of the fabrication of many weapon components, little was known in the past about the complex physical and mechanical interactions resulting from it. Lacking computer-aided predictive capabilities, component designers were often forced to use a ''trial-and-error'' approach to weld design.

''That approach can lead to problems,'' says John Brooks, supervisor of Joining and Physical Metallurgy Division 8312. ''For example, we might design and build a complicated component and, after welding it, find solidification defects, distortions, and variations in weld penetration. These problems are both complex and interrelated. We need computer models to give us a better understanding of what happens to create such problems and, ideally, the ability to predict the validity of a weld design.''

Sandia has, therefore, begun an interdisciplinary program to develop predictive capabilities in a generalized computer model of a weld. John and his division are interacting with several people from Applied Mechanics Dept. 8240 in an effort to develop a comprehensive weld-modeling capability.

The 8240 staff is developing computer and material models to simulate welding phenomena numerically; John's division is conducting experiments to provide data from which to determine the accuracy of the code predictions.

''There are a lot of things we don't understand about welds — we'd like a model that would help us predict such things as fusion-zone geometry, thermal history, metallurgical structure, and residual stress distributions,'' John says. ''That kind of understanding would allow us to better predict the long-term performance of welds in service.''

Gas-tungsten-arc (GTA) welding experiments have recently been simulated by a newly developed, fully coupled, thermomechanical finite element code called PASTA (Program for Application to Stress and Thermal Analysis) created by Bill Mason (8243) and Bill Winters (8245). One of their objectives was to evaluate the ability of the computer code to quantitatively predict the distribution of residual elastic strains in GTA welds.

Reduce Need for 'Trial-and-Error'

''With computer modeling, we hope to be able to reduce the need for 'trial-and-error' experimentation and, at the same time, improve our ability to evaluate parameters describing complex weld interactions. That kind of description is almost impossible to do experimentally,'' says Kim Mahin (8312), who led the welding and data-gathering experiments needed to validate PASTA.

In their initial experiment, a full-penetration weld was made on a fully confined plate of 304 stainless steel (see photo). The objective was to determine the actual residual elastic strains in the plate after welding. To accomplish that objective, Kim directed a series of neutron-diffraction measurements, conducted at Chalk River Nuclear Labs in Ontario, Canada, which has the facilities to do neutron-diffraction measurements compatible with the experiment.

At Sandia, the modeling work was complicated by the non-uniform, through-thickness thermal and stress distributions that occur during welding. These anomalies mean that a ''traveling'' GTA weld (one in which the arc is moved down a seam) is actually a 3-dimensional problem. However, using a thin-plate test specimen allowed the modelers to use a 2-dimensional analysis. Further limiting assumptions were avoided by considering modeling aspects during the design stage of the experiment.

The neutron-diffraction residual stresses measured on the experimental plate at Chalk River were then compared with the residual elastic strains calculated with the PASTA code. The comparison showed good quantitative agreement in regions where the material properties were isotropic (exhibiting the same values along the axes in all directions).

Second Generation Coming Up

''However, the PASTA predictions were not as good in certain areas of the weld plate, specifically in and around the fusion zone where the stress distribution and metallurgical structure are more complex,'' says Kim. The team is now planning a second generation of experiments to evaluate the discrepancies that showed up in the two sets of measurements.

''Even so, I'm pleased with the results of PASTA's first workout,'' says Bill Mason. ''We've found out a lot with this first pass. We just need some additional experimental results to verify the accuracy of the code.''

Mike Kanouff (8244) explains why the results are so important: ''For the geometry of the fusion zone, fluid mechanics is what it's all about. What we see in real welding is variation in weld penetration and in the weld shape.'' Mike has a separate code that evaluates fluid-flow effects. This code, when combined with the thermomechanical analysis used in PASTA, is expected to give a more realistic picture of all key factors that influence weld quality.

Others involved in the effort include Beth Fuchs (8243), who is working on thermal diagnostics; John Krafcik (8312), who collaborates with Kim on welding design and fabrication; Mike Baskes (8341), who is working with John Brooks on solidification models; and Doug Bammann (8243), who is working on materials models.

''As this effort shows, our research emphasizes important applications, using an interdisciplinary approach that demands close coordination between the modelers and the experimenters,'' says Peter Mattern, Director of Combustion and Applied Research 8300. ''Complementing that approach is the tremendous capability of our Cray supercomputers, which do the number-crunching that helps the researchers accomplish what was once an impossibly complex problem.''

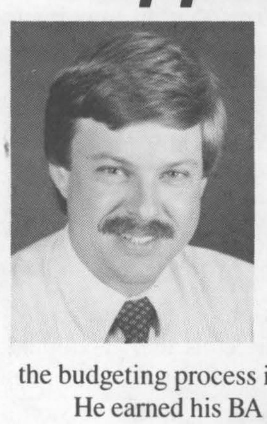
LOOKING OVER the stainless-steel welded plate used in the initial PASTA experiment are (from left) John Brooks, Kim Mahin (both 8312), Bill Mason (8243), and Mike Kanouff (8244). Behind them is one of the Cray computers used in the code calculations.

SANDIA LIVERMORE NEWS

VOL. 40, NO. 23 SANDIA NATIONAL LABORATORIES NOVEMBER 18, 1988

SECRETARIAL SEMINAR committee members gather around John Crawford (8000), kickoff speaker for the annual briefing for Sandia Livermore secretaries, held recently at the Pleasanton Hotel. Other speakers were Wilma Salisbury (3523), whose topic was "Working with Difficult People"; Gail Brajkovich, who discussed the advantages of American Business Women's Association membership; Jan Geddes, who talked on "Your Professional Image"; Bob Johnsen (8511), who reported on future site plans; and a panel of psychologists, who discussed "Superwoman: Tapping the Power Within." Planning committee members around John are (from left) Peggy Hatcher (8154), Beth Coleman (8312), Jan Allen (8532), Ellen Law (8431), and Sue Weber (8284).

Supervisory Appointment



RANDY CHRISTMAN to supervisor of Budget and Finance Division 8523, effective Nov. 1.

Randy joined Sandia at Livermore in July 1980, and worked for four years as a contracting representative in Purchasing. For the last four years, he's been involved in the budgeting process in the division he now heads.

He earned his BA in business at California State University at Fullerton and his MBA at UCLA.

He and his wife Deborah and their two children live in San Ramon. His outside interests include wine-tasting and gardening.

Without a Lab

So What Does a Theoretical Physicist Really Do?

Theoretical physicists are the butt of a class of jokes told by experimentalists and engineers. For example, one theorist, consulted on maximizing egg production, supposedly began, "We assume that chickens are spherical." Or another, asked to describe a bicycle: "If we first take a polycycle of z wheels, and for generality let z be a complex number . . . ."

What *does* a physicist do without a lab? Peter Feibelman (1151), 1989 winner of the American Physical Society's Davisson-Germer prize in surface physics, has some answers.

"There is a tendency in surface science to think of phenomena on a case-by-case basis," Peter says. "One of the most important functions of surface theorists is to act against this tendency. We try to focus attention on broader ideas and concepts — to put the properties of this molecule stuck to that surface into a useful *general* context."

Up till now, Peter says, surface science has gone through two major phases. "In the late 60s and early 70s, when no one had much knowledge of crystal-surface properties, we aimed mainly at understanding what the various experimental techniques actually measure, and at helping to derive a knowledge of surface structure from the data. My work on surface electromagnetic fields was in this mold.

"Nowadays it's different. We know the surface atom arrangements of many materials, and we can begin to test our ideas about what happens on them dynamically, say during a surface chemical reaction. Of course we still try to help in data interpretation as well as in the selection of experiments that might be particularly revealing. But we are also trying to *predict* fundamental dynamical phenomena using a variety of theoretical tools, from 'first-principles' calculations to semi-empirical models."

One pleasure of working at Sandia, notes Peter, is that basic surface-science experimental research is carried on by a sizable group of excellent people: "I've been here 14 years, and it seems there's always been at least one person working in an area where I think I can make a contribution. This level of interaction is one thing that makes it satisfying to be a theorist."

Traditionally, the theoretical physicist's essential tool was the pencil. Budgeters liked theorists, it is said, because they didn't need lab space.

Now, theorists often turn to the computer. "There's a certain snobbism afoot in theoretical physics," notes Peter, "that says, 'If it's important, you ought to be able to work it out analytically.' But this kind of attitude has not been helpful in surface physics.

"Computer simulations have often contradicted my preconceptions, and others have had the same experience. In some cases, computations have pointed to completely unexpected phenomena. My work on surface electromagnetic fields provides examples. No one ever realized that power absorption at a surface can lead to enhanced field strength in the same region. This result just came out of computations. And eventually I was able to understand it."

The availability of computers at Sandia is one thing Peter values greatly. "Sometimes I think I hold the Cray chair of surface science."

(Continued from Page One)

Feibelman

number of electrons knocked out of a metal should change as the light's frequency — or its color, if it's visible light — is varied."

Four years later, in 1979, experiments confirmed this prediction. Says Peter, "The agreement of experiments with the theoretical prediction gave my methods credibility."

The prediction scheme is only a part of the work being honored. It's hard to summarize the whole thing — Peter's 1982 review article on the subject runs to 121 pages of words, figures, and equations.

Experimenters Still Call

Peter contrasts the present interest in the field with that of a few years ago: "When I was doing this work, nobody paid a whole lot of attention. There was nobody competing with me in theory. And the methods were for simple metals, so most experimentalists didn't pay much attention either. Now there are more theorists — I can think of maybe half a dozen."

Although Peter doesn't play the role of a formerly neglected genius, he points out that "the work seems to have an increasing impact with time. I'm not working much in this area now, but every now and then experimentalists call up. I help them interpret their data, and then we publish. I've published several papers that way."

Experimental verification of another of Peter's theoretical predictions came only recently, some 14 years after Peter made it. In this case, he had predicted that the frequency of long-wavelength "surface-plasma oscillations" would diminish as their wavelength diminishes.

Although Peter emphasizes that an important part of his work was to interpret known data, Fred Vook (1100) is most impressed by the accurate theoretical predictions: "What is remarkable to me is that Peter had predictions that were really predictions. They weren't 'postdictions.' He had his theory before the experiments were done."

Dissatisfied with 'Textbook'

To arrive at his predictions, Peter started by trying to improve on what he calls the "textbook version" of the interface between two materials, or between a material and a vacuum. In this version, there's a perfectly flat surface where properties change sharply.

This "textbook model" is sufficient for many purposes. It's fine if you want to know what happens inside the material or well outside it. But it doesn't work at the surface, because the surface it describes isn't real.

That "textbook surface" is a mathematical artifice, says Peter. "If you're interested in what's going on around the atoms at the surface, you need more than the old model. And the surface is where the chemistry is."

So he worked out a way to explain, on the microscopic level, the motions of electrons at the surface when a light wave arrives. This knowledge is valuable in itself. But, as Peter's reference to chemistry suggests, there are also practical implications.

"Surfaces are important because where materials are in contact, they can interact chemically," he explains. "For example, noxious gases from auto exhaust decompose on certain metals and recombine as tolerable ones. Corrosion occurs on many surfaces, but can be inhibited with proper treatment. Surfaces of semiconductor materials have important electronic properties, and learning to control them is the key to building new, faster, and more efficient semiconductor devices."

Plenty Still to Do

Though pleased with the success of his theory and describing himself as "excited" by the prize, Peter does not claim to have had the last word — or written the last equation — on the subject. Working in a complex area, he made important progress in describing the surface physics of simple metals.

And he worked out his chosen problem to a logical conclusion: "I was like a dog with a toy. I growled and pulled at it until there was nothing left to chew on."

But, he points out, "For chemical applications, the simple metals aren't the materials that people are interested in working with. They need to know about the transition metals, such as platinum, palladium, rhodium. If they're interested in electronics applications, they need to study the semiconductors. In other words, my work needs to be generalized. That won't be easy. I improved on the old-fashioned theory, but there's lots more to be done.

"Before my work, there was only a crude theory of surface fields, totally inadequate for surface-science applications. Now we have a realistic theory for simple materials. It remains to be seen how usefully that theory can be applied to more complex ones."

Moving On

Although Peter has not tried to make major refinements in his theory for several years, he has remained involved in surface science. "In the past, Peter was looking at perfect infinite surfaces," says Fred. "Now he's looking at surface defects. This is much more difficult, but important. Properties of specific defects control catalytic properties, chemical properties — they can't be studied by the techniques that have been developed for perfect infinite layers.

"Peter has also worked on strained-metal overlayers, with Jack Houston [DMTS, 1134] and Charles Peden [1846]. Together with Mike Knotek [formerly 1134, now at Brookhaven National Laboratory], he

(Continued on Next Page)

Underlying Relationships

Probing a Surface

Every day, researchers at Sandia and throughout the world probe materials with light or electrons. The techniques include low-energy electron loss; ultraviolet photoemission, Raman, and surface-reflection spectroscopies; and others. When a researcher needs to know what such techniques reveal about the motion of electrons at the surface, the starting point is Peter Feibelman's (1151) work.

Before Peter's theoretical studies, many of the techniques for probing surfaces appeared unrelated. But through a "surface-response function" that describes how electrons at the surface interact with electric fields (such as those associated with a light wave), Peter showed the underlying relations among the surface probes.

He gives an example: "One measurement done to study surface properties is to monitor small changes in the amount of light reflected by a sample when small quantities of material are deposited smoothly on it. This kind of experiment is important, for example, when a sample is immersed in a liquid — perhaps the electrolyte of a battery — and you can't measure the speeds and directions of electrons that come out into the liquid.

"People had a crude understanding of how to interpret the results of such work. But my analysis made it much clearer just what properties of a surface are measured in a reflection-change experiment. Later work showed that, although no one had realized it, the same properties are measured in several other kinds of experiments, such as those involving energy exchange between particles and nearby surfaces.

"In other words, I proved that seemingly unrelated techniques were actually measuring the same quantities."

Executive Comments

I was simply delighted when I heard of Peter's winning the Davisson-Germer Prize. There are very few prizes for basic physics research, especially in solid-state science. This recognition by the American Physical Society is an important confirmation of the excellence of the kind of basic research Sandia is involved in. It will help us in maintaining and strengthening key contacts with the outside world of science, which is critical to our long-term health.

— Venky Narayanamurti, Vice-President of Research 1000

We have had a long history of supporting basic research in surface science here at Sandia because of the many materials applications in weapons and energy. It is now gratifying to also have this outside recognition of the high quality of our research. I look forward to other such awards in the future.

— Fred Vook, Director of Solid State Sciences 1100

(Continued from Preceding Page)

Feibelman

developed an understanding of stimulated desorption of ions from ionic solids.''

Discussing past and present work, Peter and Fred return to the topic of basic research. They agree that research without an immediate product in view is vital to labs like Sandia.

''You have to have an activity large enough that there are enough interactions among people to pay off,'' Peter says. ''You need a 'critical mass,' in other words. And for important things to happen, you need to be in contact with the rest of the basic-research world. It's also important to recognize that individual initiative is the key to success.'' •CS

'88 ECP Wrap-Up

Sandians Break ECP Participation Record

MEET SOME PEOPLE behind the numbers. Members of Facility Systems Engineering Div. 5245 made it the largest-ever 100-percent Fair Share division: (from left) Tim Cooley, Tony Roybal, Vickie Kurtz, Steve Williams, Debbie Faculjak, Dan Christoffersen, Gilbert Quintana, Larry Ritter, Belinda Garcia, and Chris Frazer. Not pictured: Ivan Waddoups, Carl Clark, Chris Hoover, Bill Paulus, Mark Snell, Art Trujillo, and Al Winblad.

Sandians responded to community needs this year with a record-breaking $1,282,665 pledged to the Employee Contribution Plan (ECP), 6.9 percent greater than the goal of $1,200,000.

Employee generosity was evident in the preliminary results of the 1988 ECP campaign. Total employee participation is at 89.7 percent — the highest ECP participation figure on record, according to ECP executive secretary Joe Laval. Participation's 2.5 percent greater than at the campaign start and 1.3 percent greater than 1987. Fair Share participation is at 47.3 percent, 3 percent greater than at the campaign start and 2.3 percent greater than 1987.

''It's people pulling together that makes this kind of effort work,'' says ECP Chairman Dennis Miyoshi (5240). ''The directorate reps came up with imaginative ways to campaign. They got their ECP messages across to employees.''

Twenty-seven divisions showed increased ECP participation; 27 divisions also showed increased Fair Share participation.

Everyone in Org. 400 (100 percent) participates in ECP; 96.5 percent of Org. 3300 and 95.5 percent of Org. 2100 employees participate in ECP. Organizations with levels of participation greater than last year include 3300, up 8.4 percent; 7800, up 7 percent; 1400, up 4.8 percent; 400, up 4.2 percent; 2100, up 4.1 percent; 3100, up 4.5 percent; 6200, up 4.4 percent; and 7400, up 4.3 percent.

Eighty-five percent of ECP contributions are Fair Share dollars. Org. 400 contributions are 82.6 percent Fair Share, 61.2 percent in Org. 5200, and 60.7 percent in Org. 2100. There was a 10.9 percent increase in Fair Share giving in Org. 7800, 8.8 percent in Org. 2100, and 7.3 percent in Org. 5200.

Divisions that donate 100 percent Fair Share include 1145, 1421, 2175, 3142, 5245, 5246, and 6213.

United Way of Greater Albuquerque

302 Eighth St. NW, P.O. Box 1767, Albuquerque, N.M. 87103 (505) 247-3671

November 10, 1988

Dennis Miyoshi, Chair
1988 Employees Contribution Plan
Sandia National Laboratories
P. O. Box 5800
Albuquerque, New Mexico 87185

Dear Dennis:

The continued leadership shown by Sandians in the United Way Campaign is very much appreciated in the greater Albuquerque community and provides an excellent standard for many others. The $1,282,665 pledged this fall to the campaign is a very important part of the funds that will be used to support the 44 local health and human services programs in our community.

During the campaign, many of the Directorate Representatives had the opportunity to visit a number of the agencies and numerous presentations by agency representatives provided information about the vital nature of the services provided. You can be assured that undesignated funds will be distributed to agencies through our citizen review process to respond to priority needs.

You make a tremendous difference. Thank you for your generosity and commitment to help those in need.

Sincerely,

Joyce Godwin
JOYCE GODWIN
1988 Campaign Chair

Allan J. Hisey
Allan J. Hisey, Chair
Board of Directors

KEY ROLE OF SANDIA EMPLOYEES in United Way is recognized in this letter from campaign heads.

Sympathy

To Roxana Corley (1112) on the death of her father-in-law in Belen, Oct. 19.

To Clorinda Berryman (3426) on the death of her mother in Albuquerque, Oct. 23.

To Renee Foster (3163) on the death of her mother in Albuquerque, Oct. 24.

To Hazlet Edmonds (3431) on the death of her father in Kansas City, Mo., Oct. 28.

To Joseph Melograne (3426) on the death of his brother in Albuquerque, Nov. 4.

'High-Quality People'

Fifteen Apprentices Achieve Tradesman Status

ELECTRONICS TRADESMEN (from left) Tony Montoya, Mark Aguilar, and Clarence Marquez (all 7412-2) use equipment shown here to obtain computerized layouts of printed wiring boards.

The offer: Sign up for a what's nominally billed as a five-year program. Be prepared for some 10,000 hours of (sometimes) grueling classroom work and on-the-job training.

Who in the world would go for *that* kind of "opportunity?" Plenty of folks, it turns out. When Sandia advertises openings for its apprenticeship program, it's not uncommon for a couple of thousand people to apply for a very few slots — sometimes as few as four.

"Our apprenticeship program is the lifeblood of our process-development operation," says Jim King, Director of Materials Process Engineering and Fabrication 7400. "Virtually all of our tradesmen are graduates."

Recently, 15 people in the "Class of 88" graduated to tradesman status. Representing three different specialties (electronics, machining, and materials), they were recognized at a graduation lunch earlier this month.

Electronics graduates are Mark Aguilar, Clarence Marquez, Anthony Montoya (all 7412-2), Anthony Micelli, Mabel Pecos, and Karl Sultemeier (all 7412-1). New machinist tradesmen are Henry Apodaca (7481-5) and Gregg Jones (7482-2). Rounding out the list are materials specialists Lorraine Herrera, David Jones, Frank Lucero (all 7411-1), Juan Romero, Charles Walker (both 7471-2), Howard Anderson, and Thomas Davis (both 7472-2).

Completion in Record Time

"Our 1988 graduates completed their tradesman requirements in record time," says Phil Gallegos (7412), who coordinates the electronics and materials apprenticeship programs. "Though we allow five years for program completion, they averaged 47.4 months — just less than four years. That's truly outstanding, in view of the number of classroom hours and on-the-job training time required."

Another eye-opening statistic from the apprenticeship program, given its rigorous requirements, is the completion rate: 98 to 99 percent. "We don't have many wash-outs," notes Jim King. "The primary reason, I think, is that we're very selective when we screen people who've applied for the program.

"The ones who are finally accepted are well qualified and strongly motivated to succeed."

Openings for Labs apprentices are advertised on a state-wide basis. As noted, there's always a large response. Screening procedures include an initial interview by Personnel, a written entrance exam (to determine general background knowledge), and an individual interview by the Joint Apprenticeship Committee (JAC).

The JAC, comprised of three supervisory (section and division) people appointed by Jim King and three people elected by the Metal Trades Union, looks for high interest and motivation levels, hobbies and outside interests that relate to program requirements, and good hand/mind coordination. After selecting finalists, the JAC makes its recommendations to Jim, who makes the final selection.

Non-Stop Regimen

Once in the program, apprentices face a non-stop regimen of both in-hours and out-of-hours classroom instruction, combined with hands-on training — not just in the specialty they've selected, but also in other areas that relate to their chosen field. "For instance," says Phil Gallegos, "someone in electronics would receive — along with a heavy dose of electronics-fabrication instruction — on-the-job training in areas such as machining, printed-circuit component assembly and layout, sheet-metal and plastics

(Continued on Next Page)

7400 Director's Award

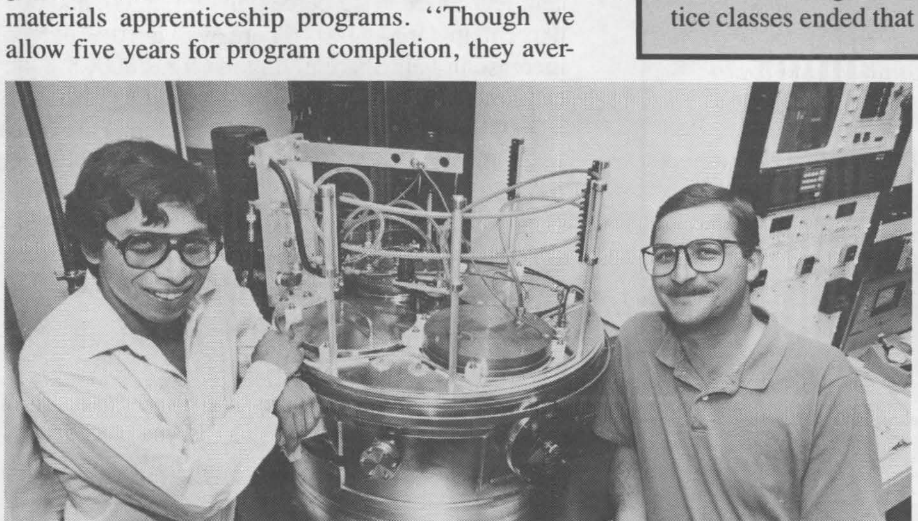
Another honoree at the apprentice-graduation lunch (see main story) was Ben Gardiner, supervisor of Hybrid Microcircuits Section 7411-1. Ben received the 7400 Director's Award for his major contributions to the apprenticeship program. The award, instituted in 1985, is a way of giving tangible recognition to otherwise "unsung heroes," according to its founder, Jim King (7400).

'Father-Confessor'

"Ben has been a combination father-confessor/mother-hen for people in the program," says Jim, "and he's been a central influence on the form and substance of its classroom-instruction aspects. He's been associated with the program in some way for the past 20 years."

Ben is the third recipient of the award. Previous winners are Wayne Trump and Ed Gullick (both 3521) in 1985 and 1986, respectively, for their classroom-instruction coordination efforts. (No award was given in 1987, because no apprentice classes ended that year.)

BEN GARDINER (7411-1) displays 7400 Director's Award — large and small versions. (The smaller one stays with the recipient permanently; the larger "travels" among recipients.)



TANTALUM NITRIDE SPUTTERING SYSTEM between materials tradesmen Frank Lucero (left) and Dave Jones (both 7411-1) is used for metal deposition on substrates.

MACHINISTS Henry Apodaca (7481-5, left) and Gregg Jones (7482-2) use a numerically controlled wire-cut electrical discharge machine to cut work pieces.

ELECTRONICS SPECIALISTS Karl Sultemeier (left) and Anthony Micelli (both 7412-1) stand in front of one of their projects: an asynchronous data-interface cabinet that's part of a PBX system to be used in the Tech Control Center (2648).

(Continued from Preceding Page)

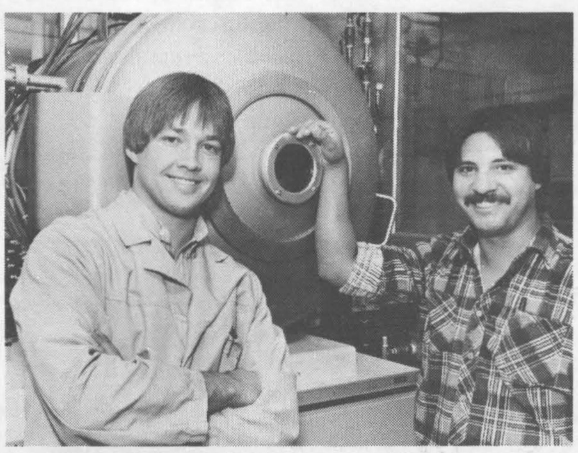
Tradesmen

work, and instrument repair and calibration."

"Training in a broad range of skills is essential," adds Jim. "That's because a lot is expected from our tradesmen. They have a challenging job: building prototypes of never-before-built devices designed by Sandia's ingenious engineers."

Phil says there's a side benefit of the hands-on training for Sandia: "After about a year in the program, apprentices do really productive work during their on-the-job training," he says. "They're not just 'practicing' anymore; they're contributing in a useful way to our mission."

Jim regards Sandia's apprenticeship program as "one of the finest training programs in the country." And, he adds, "we're proud of the high-quality people it produces." •PW



BEHIND MATERIALS TRADESMEN Chuck Walker (left) and Juan Romero (both 7471-2) is an electron-beam evaporator used for thin-film metallization.

Fun & Games

Bowling — SANDOE Bowling Assn. member Tomas Archuleta (7485) and Cecil Salazar (guest) rolled a first-place win at the 4-Game No Tap Tournament at Holiday Bowl on Oct. 15-16 with a combined 1529 handicap series. Second place went to Nita (155) and Phil Wilson with a 1507 combined handicap series.

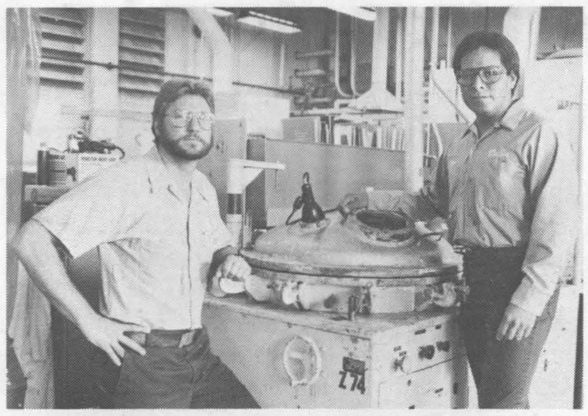
September Bowlers-of-the-Month included: Scratch — Fred Gunckel (2543), 672; and Mildred Smith (2831), 549; Handicap — Milt Stomp (6222), 655 and 682; and Suzan Baldonado (SERP), 496 and 649.

* * *

Fun Run — Dash away, dash away, dash away all — to the Jingle Bell Jog on Dec. 3 at 10 a.m. on the grounds of Heights Cumberland Presbyterian Church (8600 Academy NE). Events include a fun run and TAC-sanctioned races (10K, 5K, and walking). Registration fees ($8 pre-race, $10 race day) go to benefit Designs for Learning Differences School, a non-profit school for children with learning disabilities and other handicaps. Lew Suber (5252) and John Ashworth (5234) are on the board of directors. Santa Claus will present prizes for competitive events and for best costume with a holiday or race theme. Preregister at Gil's Runners Shoe World. For more information, contact Evelyn Kennerly on 296-2135.

* * *

Flying — Kirtland Aero Club is offering free initiation (normally $50) to all new members throughout November. The club offers all levels of flight instruction, and planes are available for business as well as pleasure flights. Call 4-0884 for more information.



IN THE PLASTICS SHOP, materials tradesmen Howard Anderson (left) and Thomas Davis (both 7472-2) display apparatus used to encapsulate electronic components.

Events Calendar

Nov. 18 — Exhibit opening, "Lava Pets," seven basalt sculptures of New Mexico animals by Taos sculptor Eduardo Rael; 9 a.m.-5 p.m., New Mexico Museum of Natural History, 841-8837.

Nov. 18-19 — "On the Verge," comedy about three intrepid Victorian women during the age of exploration; 8 p.m., Rodey Theatre, 277-4402.

Nov. 18-19 — Concert, "Happy 70th Mr. Bernstein," New Mexico Symphony Orchestra conducted by Neal Stulberg plays Bernstein, Beethoven, and Chavez; featuring piano soloist James Tocco performing Bernstein's Symphony No. 2, "The Age of Anxiety"; 8:15 p.m., Popejoy Hall, 842-8565.

Nov. 18-Dec. 22 — "A Poetic Vision: Spanish Colonial Painting," exhibition of religious paintings from the 17th-19th centuries, on loan from the Institute of Iberian Colonial Art; 9 a.m.-4 p.m. Tues.-Fri., 5-9 p.m. Tues.; UNM Art Museum, 277-4001.

Nov. 19 — Holiday Arts and Crafts Bazaar, 9 a.m.-4 p.m., Cleveland Middle School (6910 Natalie NE), 884-8567 or 881-0050.

Nov. 19 — "Boxes," Martha Heard's play about modern-day relationships between women and men; 8 p.m., First Unitarian Church (3701 Carlisle NE), 873-4338.

Nov. 19-30 — Exhibit, "Oasis in the Desert: Charles Fletcher Lummis' Photographs from Isleta Pueblo," 30 cyanotype UNM archive photos; 9 a.m.-4 p.m. Tues.-Fri., 5-9 p.m. Tues. evening (gallery talks on Nov. 22 by curator Joseph Traugott and Nov. 29 by Ted Jojola, director of Native American Studies at UNM); UNM Art Museum, 277-4001.

Nov. 20 — Crafts for Christmas, benefit for the American Heart Assn.; crafts by NM artisans, baked goods; 10 a.m.-4 p.m., Ramada Classic Hotel.

Nov. 20 — "Mud," Maria Irene Fornes' play about a woman's struggles for an education and a better life, presented by the Tapestry Players; 2 p.m., First Unitarian Church (3701 Carlisle NE), 873-4338.

Nov. 22-Jan. 20 — Exhibit, "Alexander Masley: Calculated Abstractions"; 9 a.m.-4 p.m. Tues.-Fri., 5-9 p.m. Tues. evenings (5:30 p.m. Dec. 6 interview and birthday reception with Alexander Masley); Jonson Gallery, 277-4967.

Nov. 25-27 — "Nutcracker Ballet," annual performance featuring the Southwest Ballet Co. and New Mexico Symphony Orchestra; 2 & 7 p.m. Fri. & Sat., 2 p.m. Sun.; Popejoy Hall, 842-8565.

Dec. 3 — Magic show, Peter Samelson combines illusion with philosophy, mime, and mental exercises; 8 p.m., KiMo Theatre, 848-1374.

Dec. 3-4 — Sinfonietta/Choral Series: Handel's "Messiah" performed by the New Mexico Symphony Orchestra and Chorus; 7:30 p.m. Sat., 3 p.m. Sun.; Central United Methodist Church (1615 Copper Ave NE), 842-8565.

Take Note

Mary Ann Sweeney (1265) was recently elected national chairman of the IEEE Plasma Science and Applications Society. Mary Ann has been active in IEEE for several years, progressing through various Society positions including secretary and vice-president of the Administrative Committee of the Nuclear and Plasma Sciences Society.

* * *

Frank Ortiz (123) and Hank Willis (ret.) were recently selected Centennial Outstanding Alumni by the College of Business Administration and Economics at New Mexico State University.

* * *

Allison Davis (1813) directs "The Maderati," a comedy playing at the Vortex Theatre tonight through Dec. 11. Allison sums up this play as "the invasion of the guerrilla socialites." Curtain times are 8 p.m. Friday and Saturday, and 6 p.m. Sunday. For reservations and tickets, call 247-8600.

* * *

All Faiths Receiving Home (United Way agency), a temporary crisis shelter for abused, abandoned, and neglected children, is hosting an Open House on Sunday, Dec. 4, from 2 to 4 p.m. Everyone is welcome. Those wanting to attend should call the Home on 345-8938 for directions.

* * *

"Survivorship: Gaining Momentum" is the theme of the third national assembly of the Albuquerque-headquartered National Coalition for Cancer Survivorship (NCCS) on Nov. 18-20 at the Clarion Four Seasons. National leaders in the survivorship movement will make presentations. Actor/survivor Joe Kogel will give a dramatic presentation Friday at 7:30 p.m. Tickets for the performance will be available at the door for $10. For more information, contact Tim Hagaman on 764-9956.

* * *

CanTree, the annual city-wide food drive sponsored by the Albuquerque Board of Realtors, is scheduled for Dec. 2 to 7. Donations of canned goods and non-perishable foods will be accepted from 9 a.m. to 9 p.m. at the CanTree site in Coronado Center. A Christmas tree will be built (12 ft. to 14 ft. tall) from canned goods donated by city residents during the drive. The goal this year is to collect 50 tons of food, which will be distributed by the Salvation Army to needy people in the community. Realtors will also go door-to-door Dec. 3 and 4 to collect food. For more information, call 842-1433.

* * *

The Christmas Wizard will be at the South Plaza Christmas Arts and Crafts Fair (Southern Blvd. & 20th St., Rio Rancho) on Nov. 26-27. Activities include live music, bicycle rodeos, hot-air balloons, McGruff the Crime Dog, clowns, Santa's workshop, and the Twinkle Light Parade at 4 p.m. Saturday. The Fair is a benefit for Meals on Wheels, Lifeline, All Faiths Receiving Home, and the Center for Victims of Domestic Violence. For information and schedules, call Mary Alice Thomas on 892-4000.

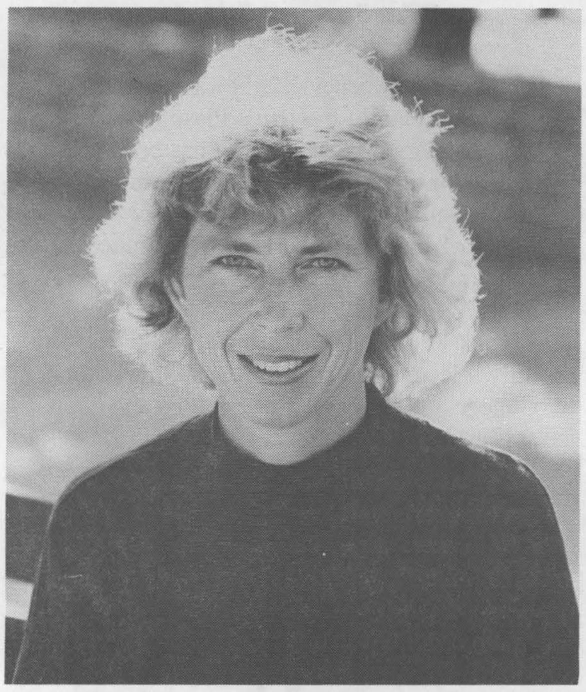
* * *

Some of the best bakers in Albuquerque, including professional chefs and bakers from the American Culinary Federation, are baking gingerbread houses for competition and silent auction at "Holiday Houses for HomeCare & Hospice" at the RECA/Better Homes & Gardens office (Ameriwest Bldg. at Eubank & Academy) on Nov. 20 at 2 p.m. Categories for the competition include traditional, country, fantasy, local landmark, Southwestern, and Victorian. Proceeds from the auction benefit Hospital HomeCare and Hospice.

* * *

MWR — Sandians may now charge KAFB MWR (Morale, Welfare, and Recreation) card fees to their Visa or MasterCard. Facilities such as the Arts and Crafts Center, Kirtland Lanes, Tijeras Arroyo Golf Course, Que Pasa Recreation Center, the enlisted and officers clubs, and the Aero Club now accept Visa or MasterCard.

Supervisory Appointments

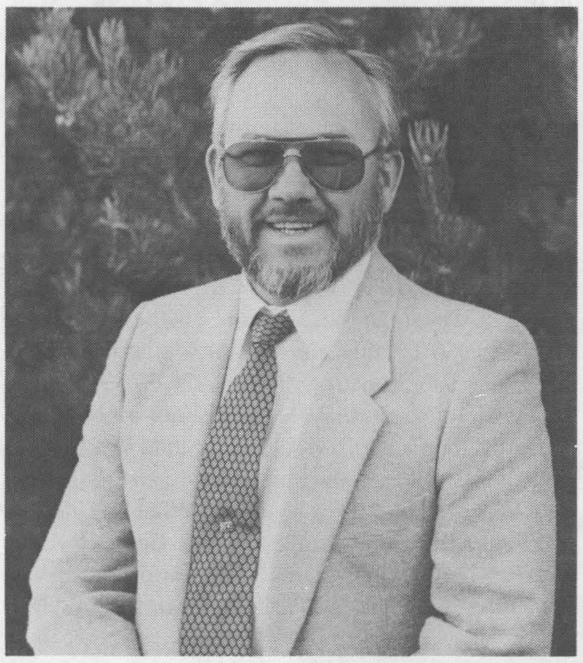


MELISSA SMARTT to supervisor of Digital Subsystems Software Div. 2315, effective Aug. 16.

Melissa joined Sandia in June 1983 as a member of the Adversary Analysis Division, where she analyzed command and control software, work that she continued when she moved to the Safety Assessment Technology Division. In January 1985, she transferred to the Advanced Electrical Systems Division. She joined Digital Subsystems Division II in May 1986, where she was project leader for CAMP, (Crypto-Algorithm-Message Processor) which provides initialization capabilities for CAP-equipped (Code-Activated Processor) weapons.

She attended New Mexico State University, where she earned a BS in independent studies and an MS and PhD in computer science. She is a member of the Association for Computing Machinery (ACM) and IEEE.

In her spare time, Melissa enjoys fishing and playing soccer. She lives with three teenagers (two daughters and an exchange student from Denmark) in Cedar Crest.



BILL CHILDERS to manager of Systems Research Department 9110, effective Sept. 16.

Bill joined the Labs in March 1961, working first as a staff assistant in an explosive test lab, then in the Air Drop Readiness Program as an arming, fuzing, and firing systems designer. In 1968, he transferred to the Reliability Division in Livermore. Bill returned to Albuquerque in October 1982 as supervisor of the Phase I and Phase II Division. He transferred to the Advanced Systems Development Division III in 1984, where he helped develop the first all-solid-state safing and arming device for conventional weapons.

He has an associate degree in EE from Georgia Technical Institute, a bachelor's in mathematics from California State University, and a master's in EE from the University of California/Davis.

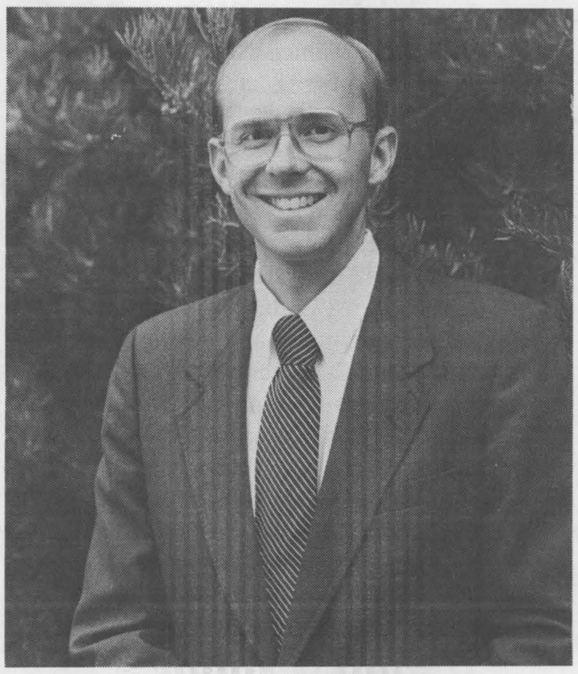
Bill's spare-time activities include fishing, boating, and camping. He and his wife Pat (9000) live in the North Valley. They have four grown children.

CLINTON (ANDY) BOYE to supervisor of Satellite Sensor Systems Div. III 9225, effective Sept. 16.

Andy came to the Labs in April 1984 after 10 years with the Air Force — five years as an enlisted man working on electronic countermeasure systems, and five years at KAFB's Air Force Weapons Lab (AFWL) working on high-energy laser weapons systems. Andy was a member of Sandia's Systems Research Division until his promotion. He studied the atmospheric propagation of directed-energy laser weapons systems and investigated the optical and near-infrared spectrum of lightning.

He has a BS in physics from the Georgia Institute of Technology and an MS in EE from UNM. He's a member of the Society of Photo-optical Instrumentation Engineers (SPIE) and the International Neural Network Society.

Andy's spare-time activities include personal computing and international cooking. He and his wife Lydia (9114) have one child and live in Sandia Heights.



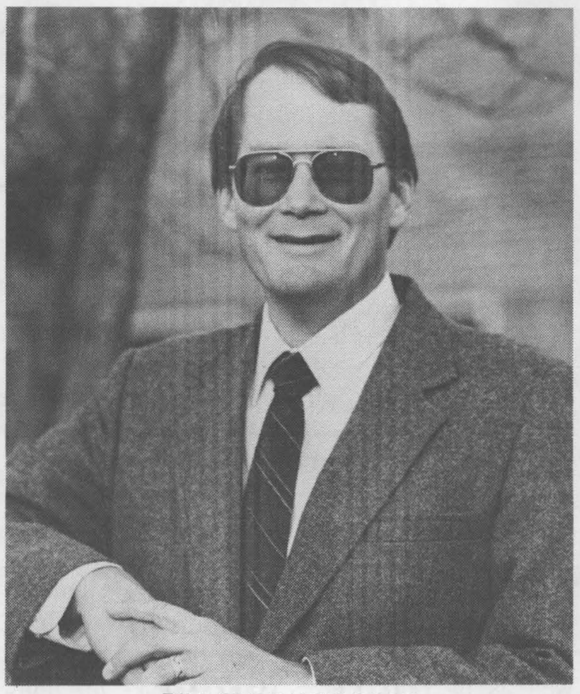
ANDY BOYE (9225)

WILLIAM SLOSARIK to supervisor of Satellite Data Systems Div. III 9226, effective Sept. 16.

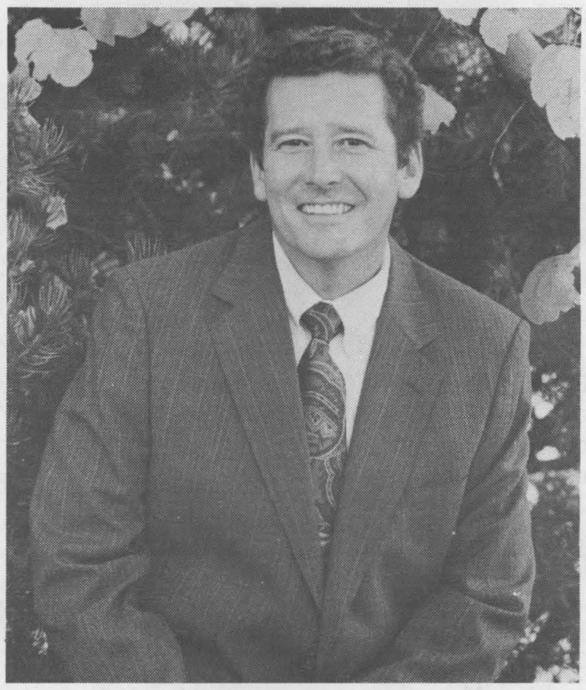
Bill joined Sandia in October 1981 and was a member of the Satellite Data Division until his promotion. He was a software engineer, and later project leader on ground systems being developed for the Air Force.

Before joining the Labs, he provided software support for Sandia through the Dikewood Corp., and did simulation work on missile systems for Raytheon in Boston. He has a BS in computer science from the State University of New York at Buffalo, and an MS in the same field from UNM.

In his spare time, Bill enjoys white-water rafting, cross-country skiing, and playing volleyball and softball. He and his wife Rise Pappas have one child. They live in Sandia Heights.



BILL SLOSARIK (9226)



JAMES KELSEY to manager of Advanced Systems Dept. 5260, effective Oct. 1.

James joined the Labs in August 1968 as a member of the Aerodynamics Department, where he performed aerodynamic and flight-mechanics analyses in support of exploratory development programs. In 1976, he joined a systems analysis group conducting utility and feasibility studies for advanced weapon systems. He transferred to the Drilling Technology Division in 1979, and was named supervisor of that division in February 1981. In March 1986, James joined the Advanced Technology Division, where he was project manager for a number of robotic systems, including Fire Ant.

He has a BS and MS in aerospace engineering from the University of Texas, and under Sandia's Educational Assistance Program, he received an MS and PhD in EE from UNM. He is a member of IEEE and is a registered engineer with the New Mexico Society of Professional Engineers.

James enjoys running, carpentry, landscaping, and traveling with his wife Suzanne. They live in Four Hills.

MARY ANN DEW to supervisor of Legal Administration Section 4000-1, effective Oct. 1.

Although Mary Ann joined Sandia in July 1980 as a secretarial trainee in the Quality Assurance Division, she has been a member of the Legal Organization since 1981, when she became department secretary in the Legal Department. She was promoted to staff secretary in 1982, and to legal assistant in October 1984.

Before joining the Labs, Mary Ann was a personnel supervisor at the law firm of Rodey, Dickason, Sloan, Akin, and Robb. She earned a bachelor's degree in business administration from the College of Santa Fe through Sandia's Educational Assistance Program. She is president-elect of the Duke City Business and Professional Women's organization.

Mary Ann enjoys RV traveling, singing, reading, and walking. She has two children and lives in the NE Heights.

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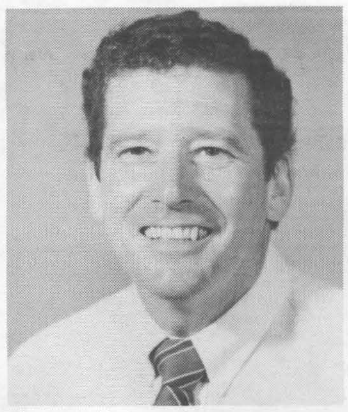
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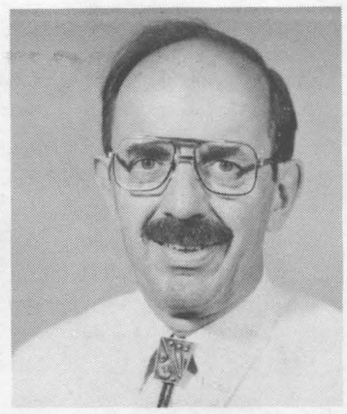
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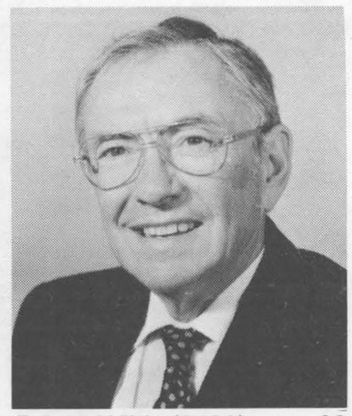
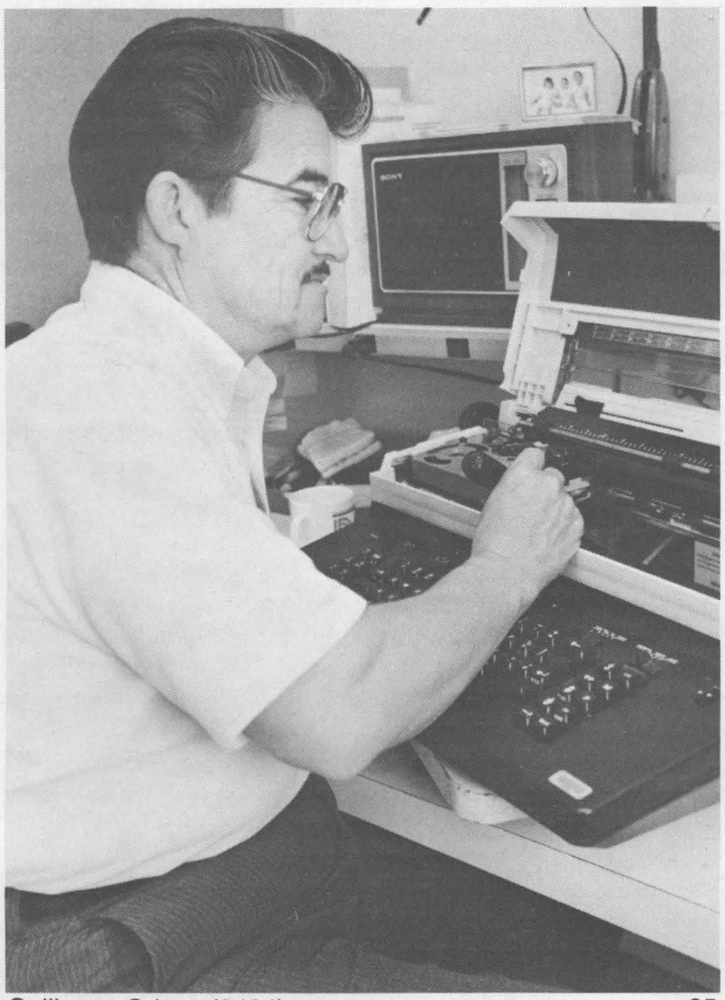

Robert Wilde (3430) 30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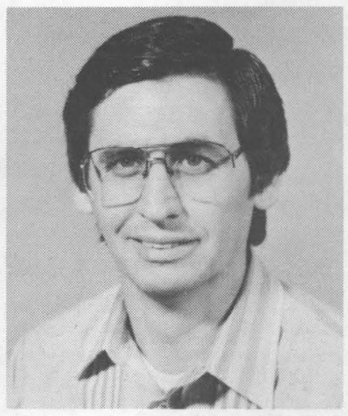
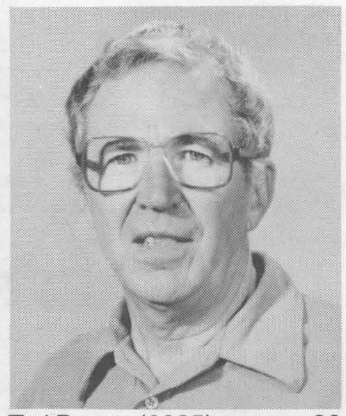

Mel Salazar (7243) 20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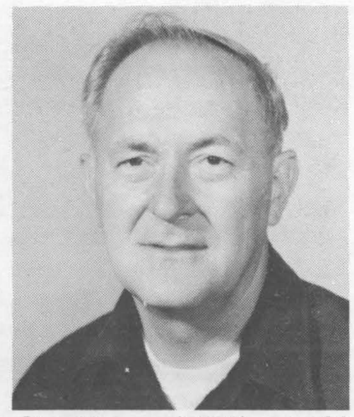
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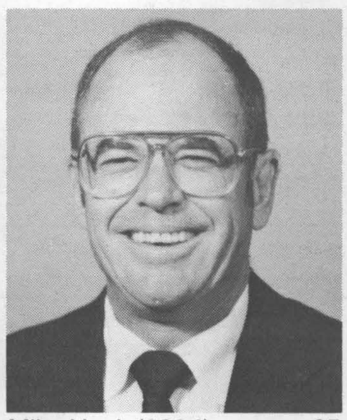
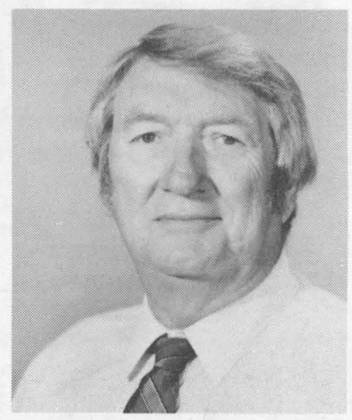

Mike Heck (2334) 25


John Portlock (7234) 25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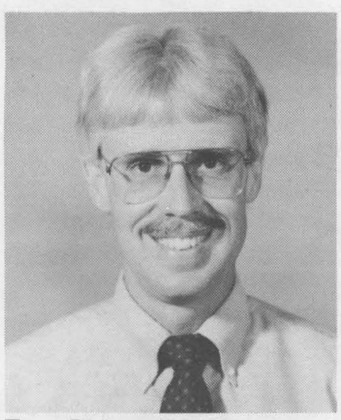
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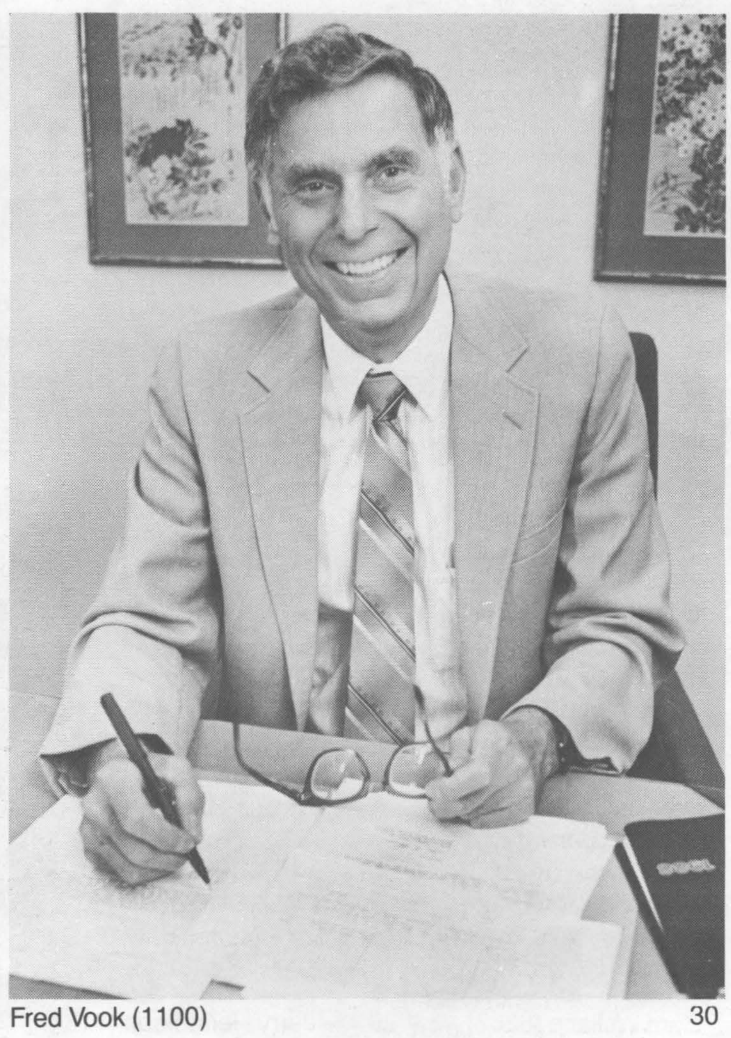
Jack Burkhardt (9122) 30


Jim Robinson (2561) 35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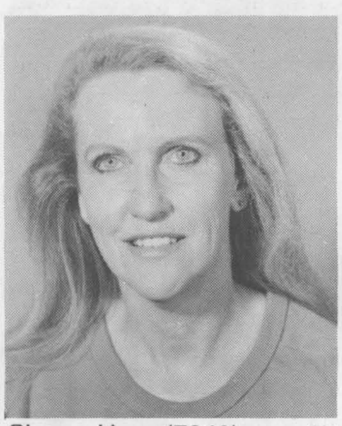
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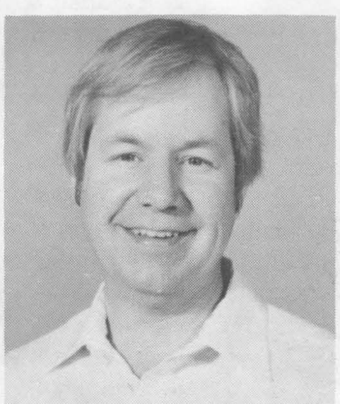
Ron Glaser (5256) 20


Bob Hughes (7556) 30

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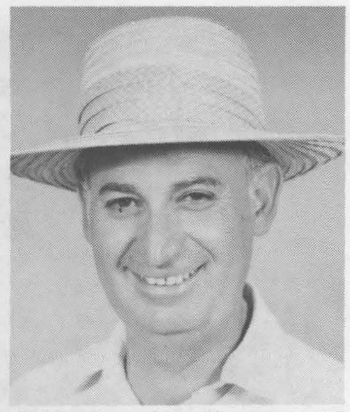
Bob Parks (2811) 20


Gladys Pettiford (3154) 15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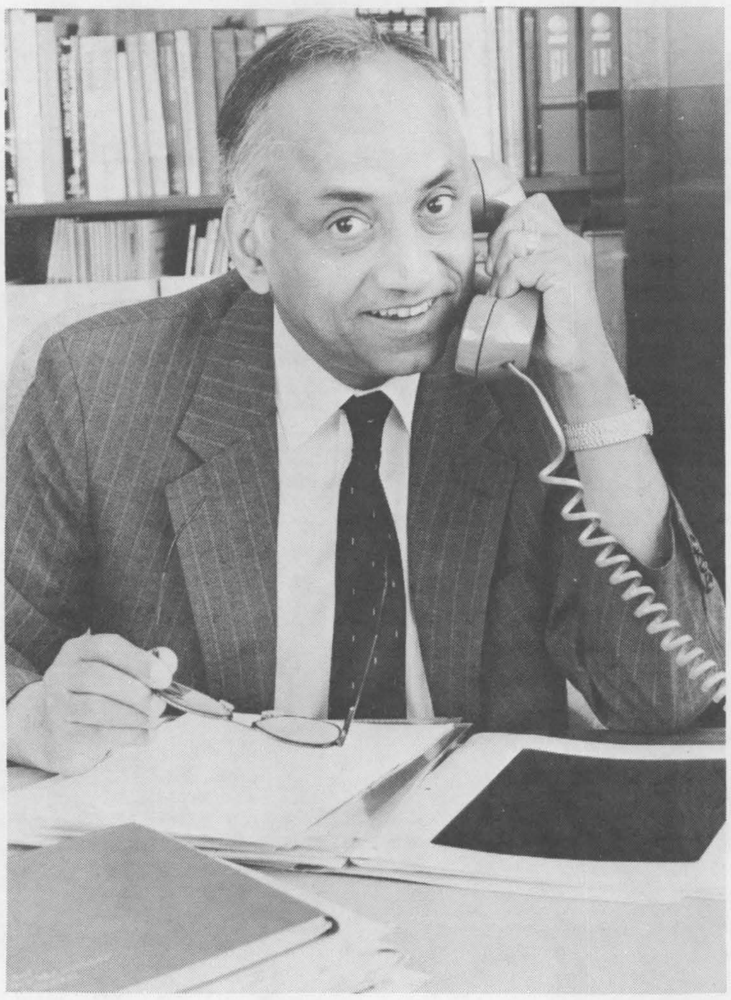
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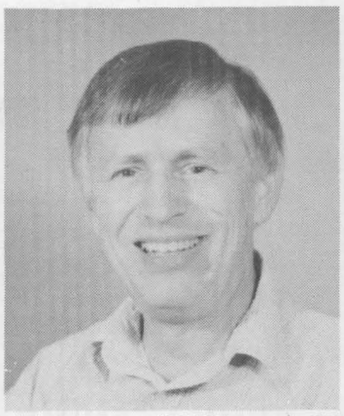
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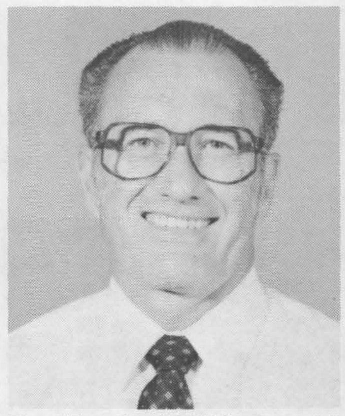
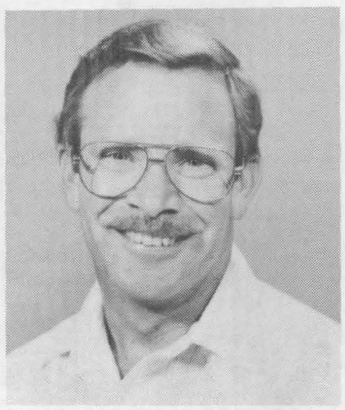
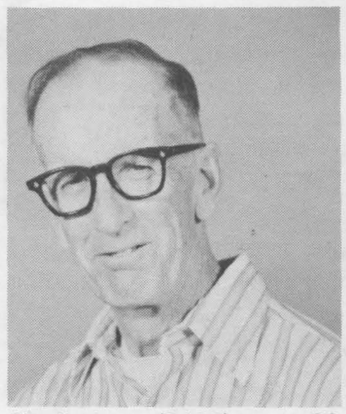
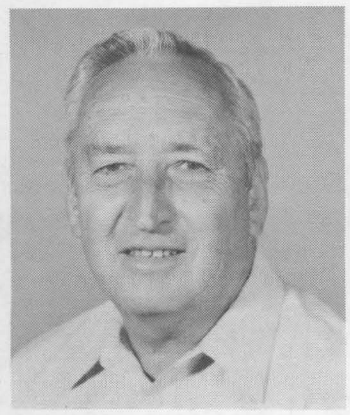
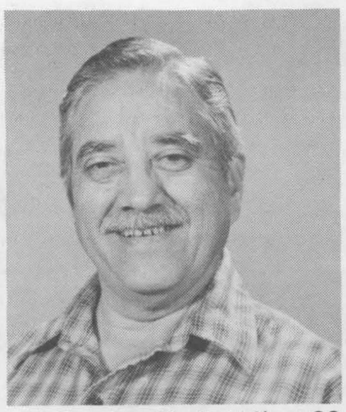

Dan Murphy (2533) 30


Nancy Nelson (2854) 30

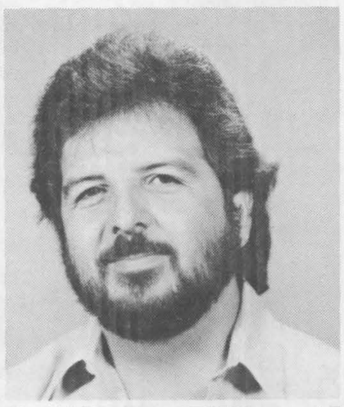

Tom Hobart (7481) 25


Jim Jackson (3426) 30


Bobby Little (2313) 30

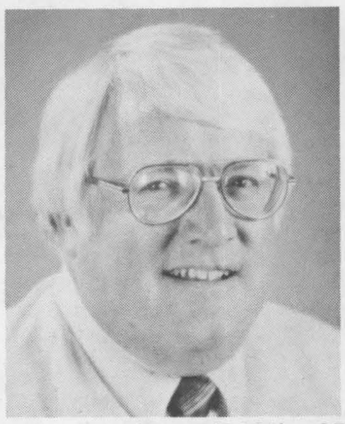

Fidelino Carrillo (7412) 30

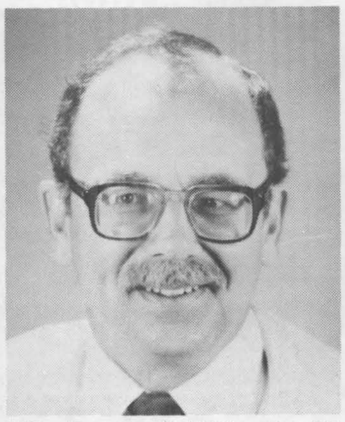

John Williams (9213) 30


David Zamora (7472) 15


Tony Chavez (3428) 40


Sam Wallace (6257) 20


Jerry Henderson (8131) 25


Mike Rogers (8432) 25

Welcome

Albuquerque
Karen Melgaard (7262)
Arizona
Zane Miller (2532)
California
Susan Nestor (144)
Georgia
John Young (9144)
Indiana
Blain Powers (5238)
Maryland
William Burcham (5128)
Massachusetts
William Suderman (7556)
Nebraska
Martin Rost (7222)
New Jersey
Tom Klitsner (1134)
New Mexico
Adolfo Bachicha (3726)
Sandra Knight (1845)
New York
Patrick Griffin (6452)
Ronald Weagley (1812)
Virginia
Courtenay Vaughan (1424)

UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS • UNCLASSIFIED ADVERTISEMENTS

Deadline: Friday noon before week of publication unless changed by holiday. Mail to Div. 3162.

Ad Rules

1. Limit 20 words, including last name and home phone.
2. Include organization and full name with each ad submission.
3. Submit each ad in writing. No phone-ins.
4. Use 8½ by 11-inch paper.
5. Use separate sheet for each ad category.
6. Type or print ads legibly; use only accepted abbreviations.
7. One ad per category per issue.
8. No more than two insertions of same "for sale" or "wanted" item.
9. No "For Rent" ads except for employees on temporary assignment.
10. No commercial ads.
11. For active and retired Sandians and DOE employees.
12. Housing listed for sale is available for occupancy without regard to race, creed, color, or national origin.

MISCELLANEOUS

ARMCHAIR, rosewood Dante-style, curule-legged, fitted yellow silk cushion, $185 (1968 appraisal). Caller, 296-9331.

BABY SWING/BASSINET COMBO, $20; changing table, $15; food dehydrator, $25; 3M copy machine, $15. Burchard, 298-8344.

COMMODORE C128, 1571 drive, SG-10 printer/GPI interface, Composite-RGB monitor, spreadsheet, database, word processing, $1300. Remschneider, 294-9932.

SKIS: Olin Mark IV, 190cm, Salomon demo bindings, $30. Meyer-Hagen, 293-7339.

FANCY PARAKEETS w/$60 cage, all extras, $35 OBO. Schaub, 265-0004.

BICYCLING HELMET, Bell Ovation, 9 oz., new in box, size S/M, catalog price $59.95, sell for $39. Kelly, 281-9774.

SQUARE-DANCE DRESSES, 8s and 10s. Hill, 275-7415.

LOBO BASKETBALL TICKETS, Dec. 3 Prairie View, Dec. 8 Oklahoma, 2 tickets per game, $7/ticket. Odinek, 892-5822.

HAMMOND ORGAN, upper and lower keyboards w/base pedals, cherry-wood finish, $400. Hole, 255-1444.

POMERANIAN, AKC-registered, male, 2-1/2 yrs. old, all shots, $150; red chow, male, 2 yrs. old, $50; firm prices. Gray, 281-4172.

KENMORE WASHER AND DRYER, $200; couch and loveseat, $100; 2 provincial chairs, $50; Sylvania stereo console, $50. Pitts, 294-2054.

SOUTHWEST AIRLINE TICKETS: Albuq.-El Paso, Nov. 25; El Paso-Albuq., Dec. 11; $15/ea. Mora, 281-9815.

STORM DOOR, $35; glass fireplace screen, $48; snow/mud tires, mounted on 15" wheels, $45. Pilat, 292-4727.

SMITH & WESSON Model 57, .41-magnum, Bianchi holster, 100 rounds ammo, $350. Cumiford, 877-6498.

ASOLO EXTREME PRO TELEMARK BOOTS, size 9-1/2, single-buckle, new, never used, $175; wet suit, man's medium size, $45. Blake, 881-1663.

'87 PALAMINO COLT TENT TRAILER, sleeps 5, $2300. Sanchez, 292-1982.

MAGNAVOX 19" COLOR TV, w/stand, $95; console stereo, w/tapes, $45; telephone table, $35; woman's white-gold ring, w/stone, $45. Thompson, 255-2678.

DRILL PRESS, floor model, 5-spd., w/1/2-hp motor, $75. Wayland, 299-2587.

KENMORE PORTABLE ELECTRIC DRYER, 110V, $50. Aubert, 296-4173.

COLLIES, AKC-registered, sable & white, 5 males, 3 females, available Dec. 3; parts for '67 Mustang and Cougar. Rhoden, 293-5301.

BALDWIN ENCORE ORGAN, model 130 series, w/Real Rhythm and Phantom Fingers, $1100. Roberts, 881-2815.

SKIL CHAINSAW, 2-hp; B&D radial arm saw; Ruger Blackhawk, 44-mag.; Ruger 10/22 carbine; VCR, w/remote control. Tolman, 296-8239.

RAINBIRD SPRINKLER HEADS, hose, fittings, removed from above-ground system, $15/all. Woods, 884-4224.

PAINTING COLLECTION, 100 originals by L'Henry, Silversmith, Garrett, Reuscher, Johnson, Ashcraft, for sale as a package. Conklin, 1-864-0207.

AUTO SHOP-MANUALS for '55 Chev., '59 Pontiac, and '68 Pontiac. Giddings, 281-3582.

THREE SOUTHWEST AIRLINE TICKETS, go anywhere Southwest flies, $125/ea. Cook, 255-7396.

DINING ROOM SET: solid brass and glass, formal contemporary, new, never used, $600 firm. Goodson, 294-8179.

SQUASH-BLOSSOM NECKLACE, silver and turquoise, $500. Hunter, 294-2877.

Deadline Notice

Because of the Thanksgiving holiday, the next issue of the LAB NEWS will be published on Dec. 9. Deadline for ads and other items is noon Dec. 2.

GARAGE SALE: baby clothes and items, maternity clothes, Tupperware, household items, Nov. 19, 8 a.m.-4 p.m., 10908 Elvin NE (Menaul/ Juan Tabo area). Morrison, 299-4757.

COMMODORE DISK DRIVE, model 1541, $120 OBO. Hansche, 281-5623.

FIFTH-WHEEL CAMPER, 30', $3500. Campbell, 888-3135.

MINIATURE DACHSHUND PUPPIES, AKC-registered, ready Christmas, black/tan, $225; refrigerated air conditioner, 8600-Btu, $135. Puccini, 255-0568 or 281-3438.

WATER-BED MATTRESS, waveless, w/liner & heater, no frame, $50 OBO. Suber, 275-1933.

CHAIN SAW, 3.7 McCulloch ProMac 610, w/case, $195; step-side chrome bumper to fit Chev. truck, $65. Snelling, 294-6161.

WATER BED, Hollywood king, foundation, frame, padded rails, heater, $75; duplex (trundle) bed, $150. Werkema, 293-4700.

PING "LOOK-ALIKE" GOLF CLUBS, 3-PW, $65; golf balls, $4/doz.; leopard coat, size 10, $50. Campbell, 889-0961.

ROUND-TRIP AIRLINE TICKET, Albuq. to Dallas, Delta, leave at 4:55 p.m. on Dec. 23 and return New Year's Day. Hill, 275-7415.

SEARS HEAT RECOVERY SYSTEM for forced-air furnace, $150. Guttman, 888-5114.

MAXI-TAXI STROLLER, canopy, footrest, $35; jogging trampoline, 6 legs, 38", $15; circular tip-resistant baby walker, $8; wrought-iron lamp set, $35. Vigil, 821-8059.

SHOES, 3 pairs: navy, beige, and white Deliso pumps, 1-1/2" heels, simulated alligator, 8-1/2 AAA, never worn, $22/pr. Slutts, 255-3693.

COMPUTER BOOKS: "123 The Complete Reference," "Using 123," "123 Tips, Tricks, & Traps," $20/all. Skogmo, 294-0133.

BEARFINDER 2x2 RADAR DETECTOR, new, never used, $50. Eckles, 1316 Lobo NE.

BABY-CRIB MATTRESS, $15; Cosco booster car seat, $13; stroller, $20; B&W TV, $20. Martinez, 294-5692.

PORTABLE COPIER, $250; kitchen table & chairs, $75; king-size water bed, $125; unfinished cedar chest, $125; misc. tables & lamps. Craft, 296-9499.

ETAGERE, $10; Sears electric typewriter, $75; TI computer, w/extra software and TV monitor, $50.; '65 VW parts: sliding metal window screens, $10; air conditioner parts, $20. Sabisch, 298-8350.

TWO ARBORVITAE EVERGREENS, 12' tall, free, you dig; cottonwood, mostly trunk, yours for the cutting. Zirzow, 294-7296.

BARBIE DREAM HOUSE w/furniture, car, misc., $75. Jackson, 836-1013.

TELEPHOTO LENS, 135mm, Super-Takumar for original Pentax Spotmatic, f3.5, screw mount, w/case, caps, and hood, $100. Mauldin, 293-3763.

TWO ROUND-TRIP TICKETS to San Francisco, leave Dec. 26 and return Jan. 2, $274/total. Davis, 294-0139.

AUTOMOBILE MAGAZINES, 25 to 30 years of "Hot Rod," "Motor Trend," "Car and Driver," etc. Hawk, 265-2228.

WASHER AND DRYER, J. C. Penney apt.-size, harvest gold, $170/set. Morrow, 281-9607.

CONN CORNET, w/case, $35. Miller, 298-5699.

POOL TABLE, 4' x 8', needs new fabric, w/balls, cues, cue rack, etc., $50; table-tennis top, 5/8", $15. Anderson, 294-8451.

PRINTER, dot-matrix, C.ITOH model 8510A Prowriter, w/manual, cost $565, sell for $180 OBO. Church, 299-2175.

TRANSPORTATION

'84 YAMAHA MOTORCYCLE, 650cc, 4.5K miles, $1000 OBO plus take over last 9 payments of $124/mo. LeBlanc, 888-1914.

'67 OLDS. TORONADO, tilt/telescope, PS, PW, power seat, climate control, AM/FM cassette, $2900. Kiekel, 294-6547.

'76 CHEV. IMPALA, V-8, AT, PS, AC, 4-dr., AM/FM cassette, $1000 OBO. Berg, 831-3269 or 299-8173.

'78 OLDS. TORONADO BROUGHAM, fully equipped, new transmission, recent engine overhaul, service records available, $1795 OBO. Martin, 883-7236.

'85 AUDI 5000S, AT, AM/FM cassette, AC, silver/blue exterior, dark blue interior, new tires, PW, power locks, $9100. Jaramillo, 898-3168.

'82 GMC SUBURBAN HIGH SIERRA, 6.2L diesel, 27K miles, cruise, AC, AT, AM/FM cassette, trailing package, $7500. Widdows, 298-7153.

'87 HONEY RV, 34', fully equipped, twin beds, cruise, Chev. chassis, AC, refrigerator, furnace. Spatz, 299-0410.

'69 DODGE MONACO, 318, 4-dr., PS, PB, AT, AC, radio, 67K miles, $1295. Ostensen, 296-4227.

'88 PONTIAC FIREBIRD, AT, PS, AC, AM/FM stereo tape, $10,500. Dalby, 299-2811.

'87 HARLEY-DAVIDSON XLH-1100, candy bronze paint, pull-back handlebars, spoke wheels, $5000. Nelson, 292-0742.

'48 OLDS. Model 76, 4-dr., $2500. Surran, 256-7344.

SCHWINN BICYCLE. Pilat, 292-4727.

'78 PONTIAC CATALINA, 49K miles, $2250. Smith, 291-8379 days, 299-4842 after 5:30.

'72 FORD F-100 PICKUP, SWB, 302, 4-spd., $1795. Eisenberger, 877-7041.

'76 OLDS. TORONADO, 80K miles. Forrest, 275-3797.

'64 CORVETTE, white w/red interior, completely refurbished, $12,500. Riley, 293-5868.

'81 HONDA CB650 MOTORCYCLE, $500. Conklin, 1-864-0207.

'87 YUGO, 29K miles, AC, AM/FM, FWD, some rear-end damage, best offer. Lang, 291-0650.

'82 OLDS. CUTLASS SUPREME, diesel, $1200. Childers, 344-9281.

MAN'S SCHWINN BICYCLES: World Sport 12-spd., w/extras, $160; 3-spd., $60. Owens, 296-3781.

DIAMONDBACK VIPER BICYCLE, w/mags, 20", $75 OBO. Richards, 281-9471.

'87 MAZDA B2200 PICKUP, AT, 22K miles, one owner, $5200 firm. Chavez, 891-8456.

'56 CHEV. PICKUP, $950. Narma, 296-5941.

'82 FORD ESCORT, 5-spd., new paint, needs clutch, $550. Carson, 892-9895.

'82 VW RABBIT, 4-dr., gas-powered, $1000 OBO. Campbell, 889-0961.

TAKARA 10-SPD. BICYCLE, $70 OBO. Owen, 299-3487.

'77 OLDS. CUTLASS S, 2-dr., $595. Windle, 881-6299.

'79 HONDA HATCHBACK, 30-mpg, FWD, steel radial tires, Diehard battery, no dents, $200 below blue book. Lagasse, 293-0385.

BICYCLE, Schwinn 20" high-rise, $45. Werkema, 293-4700.

'84 BUICK CENTURY LTD, 3.0L V-6, 4-dr., power windows, locks, seats, and antenna, $6200. Gomez, 293-8267.

'80 TOYOTA CELICA, AT, AC, PB, PS, 60K miles, $2600 OBO. Patterson, 822-1196 after 6.

'85 DODGE COLT PREMIER, 5-spd., AC, AM/FM stereo cassette, 22K miles, $5800. Oppel, 821-7675.

'77 DATSUN B210, AC, AM/FM, 5-spd., $295. Pierce, 293-2380.

BMX BIKE, $50. Jackson, 836-1013.

'86 PLYMOUTH VOYAGER, AT, AC, PS, AM/FM, cruise, luggage rack, tinted windows, 7-passenger, 49K miles, $9900. Wilcox, 899-8356.

'75 CHEV. MALIBU, 87K miles, one owner, 350 V-8, $900 OBO. Kelly, 293-2475.

'66 Mustang, 289, $2500; '66 Mustang, 200, $700; '65 Mustang, 200, parts only, $500; all for $3500. Wilde, 243-4209.

'78 CARRIAGE TRAVEL TRAILER, 31', Shea model, w/'76 1-ton Ford van, all amenities, $8000/both. Kerschion, 281-1671.

'84 JEEP GRAND WAGONEER, 360 V-8, 4-WD, AT, PS, AC, w/extras, below blue book. Robischon, 298-3992.

MAN'S 12-SPD. PANASONIC BIKE, new tires, $125. Miller, 298-5699.

'84 NISSAN SENTRA SW, AC, PS, PB, FM cassette, desert beige, 72K miles, $3295. Neal, 299-4956.

'72 VW VAN, $595; '65 VW van, $1595; complete VW engine, 12V w/headers & new muffler, $250; '67 VW van transaxle, $200. Thorne, 884-4870.

REAL ESTATE

4-BDR. HOME, Candelaria/Louisiana area, fenced, landscaping, pool, rock FP, wet bar, 2-car garage, covered patio. Vivian, 884-7719.

2-BDR. BRICK HOUSE, garage, Franklin stove, assumable 8-1/2% loan. Long, 296-2590.

2-BDR. MOBILE HOME, '84 Detroiter, 14' x 70', 2 baths, set up in adult park, $19,000 OBO. Dunham, 293-6971.

2-STORY ADOBE HOUSE, 2100 sq. ft., corrals, shed, 2 wells, 1.5 acres, irrigated, fenced, sell below appraisal. Conklin, 1-864-0207.

FOUR-PLEX, near Louisiana and Kathryn SE, fully rented, $4000 down, assume FHA, split closing costs. Cook, 255-7396.

2-BDR. HOME, 1-3/4 baths, FP, vaulted ceilings, clerestories, skylights, tile roof, security bars, solar heat, on cul-de-sac, $87,000. Neidigk, 293-0286.

MOBILE HOME, '86 Lancer, 16' x 80', extras, below NADA book. McClenahan, 299-4266.

3-BDR. HOUSE, NE, 1-3/4 baths, pool, corner lot, cathedral ceilings, assumable 9% FHA, $93,000. Copus, 281-4483.

4-BDR. HOME, 2 baths, 1925 sq. ft., NE, assumable 9.5% FHA, no qualifying, $101,900, $15,235 cash to loan. Miller, 298-5699.

WANTED

'80-'87 VOLVO SEDAN, 4-dr. or 2-dr., Model GLT, GLE, or GL, 240, 740, or 760. Jaramillo, 898-3168.

CONCRETE FINISHING TOOLS: large bull float w/extension poles, hand bull floats, finishing trowels, etc. Snelling, 294-5751.

LEFT-HANDED CALLIGRAPHER to give one or two lessons. Hunter, 294-2877.

PORTABLE SINGER SEWING MACHINE, good working condition. Hill, 275-7415 or 298-1061.

BOY'S BICYCLE with or without training wheels, for 4-5 yr. old; single bed in good condition, with or without headboard, reasonable price. Field, 268-0025.

OLD PHOTOGRAPHIC EQUIPMENT and parts, especially view-camera equipment. Narma, 296-5941.

PICCOLO TRUMPET, good condition. Schaub, 265-0004.

HOUSEMATE, 2-bdr. townhouse behind Four Hills shopping center, 2 baths, nonsmoker, $275. Shambo, 294-8530 leave message.

UNM BASKETBALL TICKETS for Oklahoma game Dec. 8, televised by ESPN. Hendrick, 296-2163.

UNDER-DASH AUTO CASSETTE TAPE DRIVE w/auto-reverse, but no AM/FM radio, can be old bulky model. Spears, 266-9782.

ORIGINAL RADIO for '50 Chev. sedan, working or not. Romero, 831-1974.

HOUSEMATE, share 3-bdr. house near Juan Tabo/Constitution, 2 baths, piano, male nonsmoker, $300/mo. plus 1/2 utilities. Billups, 291-8123.

WORK WANTED

HOUSECLEANING JOBS, by college student, references available. Copus, 281-4483.

LOST AND FOUND

SET OF TWO GM CAR KEYS, attached to a Firebird key chain, lost on Oct. 31. Smiel, 865-9081.

Break Out the Bubbly — The Big Day Is Finally Here!

GIGANTIC-GALA REMINDER: This is it — the *big* day — a party to end all parties! If you don't yet have your tickets for the reopening celebration this evening, call the Club office; there may be some room left. Festivities start at 6 p.m. with a reception featuring wine-tasting and all kinds of scrumptious hors d'oeuvres. Next, it's delightful dining — with prime rib or shrimp scampi as the entree selections. Last, but certainly not least, dance the night away to the mellow music of the Roland DeRose orchestra.

CIRCLE NEXT WEDNESDAY (Nov. 23) on your calendar, because Chef Henry and his energetic kitchen crew are planning a lunchtime menu for which we can all give thanks. To get you in the mood for the long holiday weekend, food choices include turkey and some very special trimmings.

MEMBERSHIP HAS ITS PRIVILEGES, and here's some good solid evidence. On Nov. 30 — Membership Appreciation Night — card-carrying C-Club members receive a well drink on the house; just head for the lounge right after work. And, speaking of the lounge, don't forget Monday Night Football get-togethers. Fans, regardless of team preference (even if it's *Denver*), can fill up on 50-cent food and drink items: tacos, hot dogs, and draft beer. More lounge news: Corona Night on Thursday, Dec. 8, features guess-whats for just $1.25 from 4 to 9 p.m.

BONKERS FOR BINGO? If so, just remember that the number-callers are back in action Thursday night, Dec. 1, for the one-and-only bingo bash in December. Card sales start at 5:30 p.m., and Early-Bird gamers have an extra incentive: The winner takes home a spiffy 10-speed bike (soon on display in the lobby).

REMEMBER PEARL HARBOR — and Secretaries Night, because they're both on the same date. On Wednesday, Dec. 7, the Club honors some of its most important members. If you're a secretary, here's your chance; buzz on over to the lounge after work for a free well drink. A trip to the salad bar that night costs just $2.

HO! HO! HO! — T-Bird card sharks get a jump on the holiday season when they combine gaming with a Christmas party on Thursday, Dec. 8, starting at 10 a.m. Count on the usual shuffle session, plus special goodies and door prizes. The big question: Will head dealer Jim McCutcheon replace his green eyeshade with a furry red hat? Show up and find out.

31st Annual Drive

Shoes for Kids Kicks Off

Stacked in their boxes, 2850 pairs of shoes would reach all the way to the top of the pile.

That's the number of pairs that members and friends of Systems Evaluation Directorate 7200 have bought for needy children through its Shoes for Kids campaign over the last 30 years.

The underlying theory is that Sandians might spend $20, the price of a (discounted) pair of shoes, on Christmas cards for other Sandians. "We say, 'Wish your friends on the job a happy holiday in person, and donate that $20 to our campaign,' " says Don Rohr (7212), who has headed the campaign for the last few years.

All the money donated goes to buy sturdy shoes for needy APS students identified by their teachers and school administrators. Kinney's Shoes in Coronado Center provides the shoes at a discount and personally fits the shoes to the recipients.

"It's a super Christmas tradition," says Don. "You realize that money can indeed buy happiness when you see the faces of the little ones light up as they get their very own pair of brand-new shoes."

"We're inviting all Sandians and retirees to join the campaign this year," says Linda Vigil-Lopez (7212). "Last year we raised enough money to buy 103 pairs, but that wasn't enough to go around."

Those who want to join the campaign should make out a check to "Shoes for Kids" and send it to Don or Linda in Div. 7212 by Dec. 9.

GIANT SHOE held by Don Rohr and Linda Vigil-Lopez (both 7212) is a "thank you" from students of Lowell and La Mesa Elementary schools for the new shoes they received through last year's Shoes for Kids campaign. Don and Linda invite all Sandians and retirees to put a warm shoe on a cold foot this Christmas; see the story.

EDWARD TELLER, Associate Director Emeritus of Lawrence Livermore National Lab, spoke recently to Sandians in the Technology Transfer Center. Teller discussed his views on low-yield nuclear weapons, the Strategic Defense Initiative, and topics introduced by the audience.

August 1988 Earnings Factors

	Earnings Factors
Savings Plan for Salaried Employees (SPSE)	
AT&T Shares	.9353
Government Obligations	.9981
Equity Portfolio	.9607
Guaranteed Interest Fund	1.0073
South Africa Restricted Fund	1.0061
Diversified Telephone Portfolio	
Unrealized Appreciation	.9616
Realized Appreciation	.0000*
Savings and Security Plan — Non-Salaried Employees (SSP)	
AT&T Shares	.9348
Guaranteed Interest Fund	1.0073
South Africa Restricted Fund	1.0071
Diversified Telephone Portfolio	
Unrealized Appreciation	.9619
Realized Appreciation	.0000*

September 1988 Earnings Factors

	Earnings Factors
Savings Plan for Salaried Employees (SPSE)	
AT&T Shares	1.0570
Government Obligations	1.0086
Equity Portfolio	1.0462
Guaranteed Interest Fund	1.0070
South Africa Restricted Fund	1.0061
Diversified Telephone Portfolio	
Unrealized Appreciation	1.0517
Realized Appreciation	.0079*
Savings and Security Plan — Non-Salaried Employees (SSP)	
AT&T Shares	1.0565
Guaranteed Interest Fund	1.0071
South Africa Restricted Fund	1.0055
Diversified Telephone Portfolio	
Unrealized Appreciation	1.0515
Realized Appreciation	.0080*

* The 1 has been removed from the earnings factor. Current month's DTP earnings may be calculated directly: Earnings Factor x DTP Current Worth = Current Month's Earnings.

Energy at Sandia

LAB NEWS

VOL. 40, NO. 23 SANDIA NATIONAL LABORATORIES NOVEMBER 18, 1988

Solar Thermal Programs — Techniques, Options, Solid Achievements

When the oil embargo hit 15 years ago, this country lacked the technology and scientific understanding necessary to harness solar energy in modern, efficient ways to produce heat and electricity.

Today, thanks largely to Sandia, it has that technology — and much of it is available to users of energy, ranging from utility companies to individual consumers.

This is perhaps the single most important contribution Sandians have made in their decade-and-a half of work in the field of solar thermal technology.

Their achievements in central receiver and distributed receiver systems have proved an important, verified-in-the-field fact: Solar thermal technology works and can, with other alternative energy sources, help serve as a cap on oil and gas prices. That's a critical thing to know, given the fact that the nation is once again becoming increasingly dependent on foreign oil.

''Solar thermal certainly isn't always economic,'' says John Holmes, supervisor of Central Receiver Technology Div. 6226. ''But we know that present component and integrated systems work effectively. We can generate 10 MW of electricity, but it's about two times too expensive for general use right now.''

Although solar energy funding is down about 85 percent since the early 80s, those who have worked on the program can look back with pride at a string of accomplishments, point out ongoing highlights, and see a bright, even sunny, future for projects that are just getting started.

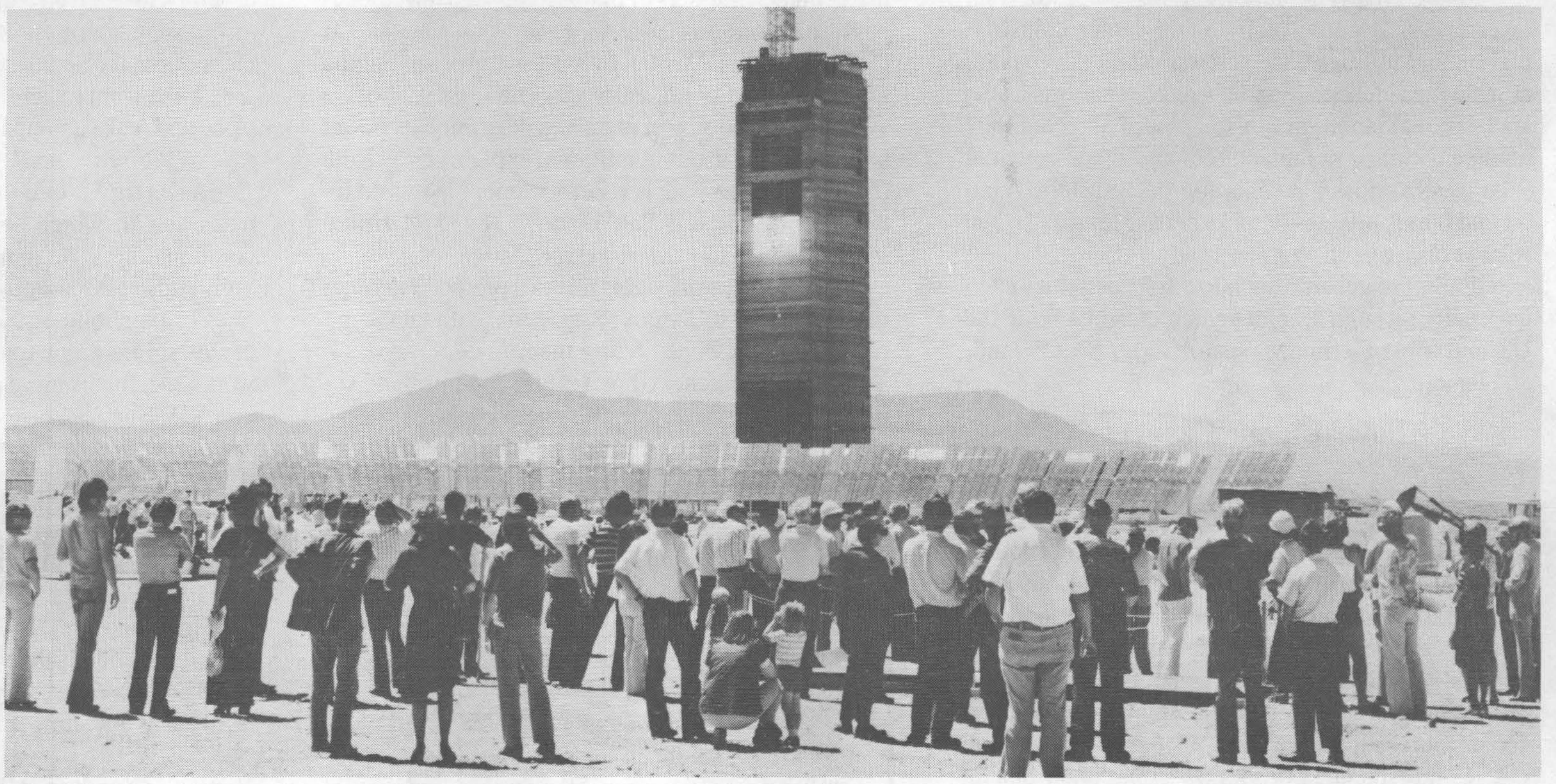
Central Receivers, Distributed Receivers

Solar thermal systems typically use mirrors, reflective parabolic dishes, or troughs to focus sunlight on a receiver, so that useful high-temperature (thermal) energy is produced. This technology has broad applications. There are the proven uses, such as commercial process heat and electricity generation. There are the potential uses under development — breaking down hazardous waste, for example.

Solar thermal is usually divided into technologies requiring a tower-mounted central receiver and a field of sun-tracking mirrors (heliostats) that reflect concentrated sunlight onto the receiver, and those with a receiver for each reflective dish or trough solar collector (or group of collectors), called distributed receiver systems (see ''Central Receiver Technologies Advancing'' and ''Hardware Becomes Key to Distributed Receiver Systems'').

In the case of central receivers, Sandia was instrumental in planning, construction, start-up, and operation of Solar One near Barstow, Calif., which provided enough electrical power for 3000 to 5000 typical homes (see ''Solar One — It Taught Us Many Things''). Although the Central Receiver Test Facil-

(Continued on Page Two)



SINCE THE "POWER TOWER" BEGAN OPERATION in 1977, hundreds of people from all over the world have visited the site. Shown here is part of the crowd at "Sun Day," May 23, 1977 — the occasion for the tower's first focusing demonstration.

A Look at Labs VAWT Work

Is the Answer Blowing in the Wind?

For the past 15 years, Sandia has been coaxing one of mankind's most venerable power sources — the windmill — out from the wraps of archaic technology and into the space age.

If it looks like an easy job, the impression is patently wrong. Modern machines are a far cry from the quaint and creaking monsters of Don Quixote's day. But even high-tech windmills are noisy, prone to metal fatigue (cracking that results from constant exposure to vibrations), and more than a wee bit tetchy when it comes to aerodynamics.

Sandia's involvement with windmills (more correctly wind *turbines,* since they don't mill anything) started in 1973, when Randy Maydew (400), Ben Blackwell (1553), Lou Feltz (9113), and Jack Reed (7111) were responding to AEC Chair Dixie Lee Ray's plea for new ideas on alternative energy sources.

The team, more familiar at the time with aerodynamics of weapon shapes and parachutes, now had the opportunity to turn professionally from swords to plowshares. Nevertheless, the name of the game was still interaction of airflows with surfaces, and the challenge was still to convert this interaction into something useful.

Randy and company were aware that Canadian scientists, working with National Research Council (NRC) funds, were investigating a vertical-axis wind turbine (VAWT). To the Sandians' surprise, the Canadian scientists were re-examining the work of a Parisian inventor, G.J.M. Darrieus. The design, patented in 1925, was characteristically Gallic. It was creative and iconoclastic, like no other windmill anyone had seen before. It was shaped like an eggbeater.

Sandians looked at the data on the Darrieus design and were impressed. Blades, shaped as airfoils like an airplane wing, provided aerodynamic ''lift'' and permitted rotation regardless of wind direction. The vertical axis would contribute to more efficient mechanical linkages than the more familiar horizontal-axis turbines. Further, in the words of a 1974 report, ''these data indicate that horizontal-axis systems weigh 4 to 10 times as much as the NRC vertical-axis system. Since total weight is a good indicator of cost, the vertical-axis wind turbine (VAWT) has great potential for cost savings.''

By that time, Sandia was already well into a project designed to demonstrate that wind power was economically competitive with other sources of power. Small scale models were built, computer simulation programs were being written and applied, and wind tunnel studies were conducted. Several prototypes, each roughly onion-shaped in profile, were built and evaluated.

When Dick Braasch (9122) joined the wind program in 1974, the focus on optimizing aerodynamic efficiency was giving way to pressures to create a durable, inexpensive machine for manufacture. ''We emphasized structural dynamics and how to use aerodynamics to make an inexpensive machine,'' Dick says. ''We worked toward increasing fatigue-life [basically, resistance to metal fatigue] of the machine and toward controlling power generation. The test machine now at Bushland, Tex., demonstrates this design approach.''

(Continued on Page Eight)

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Solar Thermal

ity (CRTF), or power tower, is at Albuquerque, Sandia Livermore actually planned, managed, and conducted the Labs' central receiver program from 1974 until 1986.

To date, Labs work in distributed receiver technology has proven itself with a number of efforts — the Modular Industrial Solar Retrofit (MISR) Project, Luz International's Solar Electric Generating Stations (SEGS), the Solar Total Energy Project (STEP) in Shenandoah, Ga., and many process heat systems.

Mature Technology

Line-focus or trough-shaped solar collectors for distributed systems were the first solar thermal technologies to mature, explains Jim Leonard (now 400). DOE and Sandia played key roles in the initial development of trough technology and in accumulation of operating experience.

Because they were considered nearly economic from a technical standpoint as long ago as 1980, linear concentrators were able to get into what Jim calls "the chicken-and-egg cycle." It's a paradoxical cycle of production, improvement, cost reduction, and more production, he says. "The market will be attracted to alternative energy when it is inexpensive. But it won't be competitively priced until it can be mass-produced."

Today, with so much research still to do and small budgets with which to do it, the situation calls for added creativity among Labs solar thermal researchers. Because many of the larger industrial players and utilities once active in solar thermal are now on the sidelines, Sandia's ongoing efforts as the lead national laboratory in solar thermal technology involve as many manufacturers and other potential solar users as possible. This approach sustains interest and builds private-sector expertise for a day when solar is once again "hot."

Labs researchers also follow solar activities internationally through several agreements involving the US and West Germany, Spain, Italy, Switzerland, and Israel.

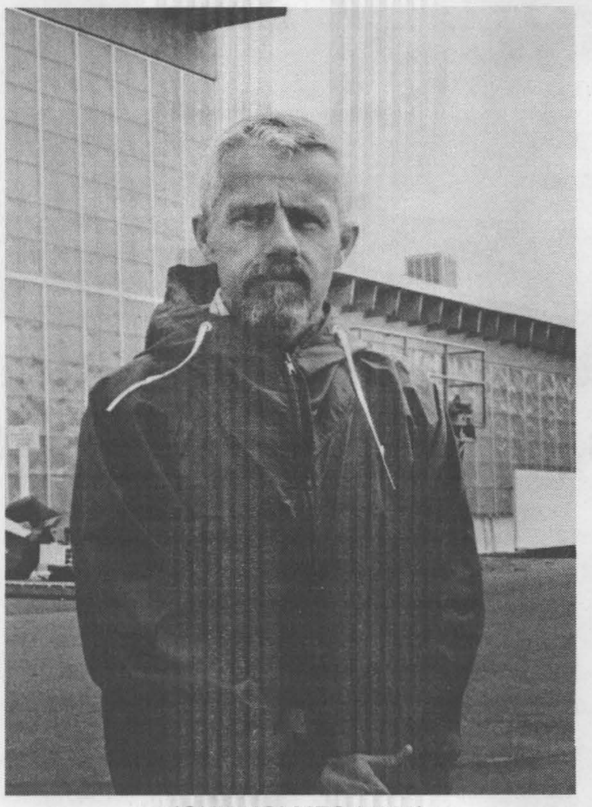
Solar-Unique Elements

While not vast in scope, solar thermal projects are important to the total energy picture. With only 6 percent of the global population, the US accounts for about 30 percent of the world's energy consumption. Of that amount, 38 percent is directed to industrial process heat and domestic heating. Another 35 percent is for electric power generation. Solar thermal techniques could replace substantial oil, gas, and coal resources for these uses.

Complementary work now going on at Sandia and elsewhere could also result in transportable fuels and chemicals from solar thermal technology (see "Chemical Transport of Solar Energy — It Does Work"). For example, one catalytic receiver being developed at Sandia could eventually convert natural gas to liquid fuels for use in transportation.

To achieve these goals, Sandia investigations have gone from the shotgun approach to the rifle shot. "We're taking the solar-unique points of systems and working intensely on them," says John Holmes. For central receiver technology, this means heliostats and receivers. For distributed systems, it means a shift from line focus or parabolic trough systems — thought to be well developed — to beefed-up work on a dish-Stirling engine solar power module system of producing electricity.

The dish-Stirling concept links a parabolic dish reflector with the externally heated Stirling engine (see "The Dish-Stirling Engine Combo"). But working with technologies like solar dish-Stirling engine systems that are not on the front burner in terms of imminent commercial impact requires a no-nonsense "what-do-we-need-to-reach-these-goals?" approach, says Jane Diggs (6227), who conducts systems analyses for distributed solar thermal systems. "We're looking at basic thermodynamics and physics, and whether we can get to commercialization," she says.



JOHN HOLMES (6226)

For distributed receiver systems, present system analyses are a combination of simple models and detailed questions about the day-to-day performance of components. The models will be refined as components arrive for testing at the Labs.

In central receiver technology, more complete mathematical models of plants have been developed, based on operating experience at Solar One and at the power tower. Written by staff members at Sandia Livermore and continually modified, these models simulate operation of a plant and determine its power output under various conditions, explains Greg Kolb (6226). Another widely used document in this country and in Europe is Pat Falcone's (8435) *A Handbook for Solar Central Receiver Design.*

"Systems work helps utilities predict outcomes using different subsytem components without the initial expense of constructing them," Greg says. "It also helps researchers direct efforts at improving key design areas to meet overall system goals."

Much different than the modeling work of the systems analysts, but contributing to it, are the hands-on efforts of Solar Thermal Test Facility (STTF) Div. 6222, where work on both central and distributed receiver technology occurs.

In the case of central receiver work, the power of the CRTF's 222-heliostat field — up to 5 MW of thermal energy — can be directed at test receivers. Ongoing CRTF projects revolve around reliability and maintainability of advanced heliostat designs and work on advanced receiver designs.

Testing for distributed receiver technology has been an important 1988 activity at the STTF. A privately developed Stirling engine is undergoing evaluation, and work continues on some dish concepts — including testing of an innovative faceted-membrane concentrator from the LaJet Co. (Abilene, Tex.). Following bench-scale testing of the engine, it will be integrated with a concentrator at Sandia's test facility for on-sun system testing.

Downward funding trends may make it appear that solar thermal isn't being weighted equally with other energy technologies. But several utilities, the ultimate commercial users for much of the technology, continue to be interested and to monitor progress. Each utility has a different financial situation, customer-need profile, and energy-resource mix, explains Cheryl Ghanbari (6222 contractor employee, Technadyne Engineering Consultants). "Some are only monitoring what we do now, but others are actively participating with us," Cheryl says.

And, as Tom Mancini (6227) — one of the many enthusiastic solar thermal boosters at the Labs — often points out, research can't wait until the need develops for a given technology. Tom's involvement in the solar thermal effort centers around development of parabolic dish collectors.

"We want to get this technology to the marketplace and make an impact for the energy users," Tom says. "We see a need for it." He and others envision an energy future in which no one fuel predominates and in which solar plays a part in the total combination. "We're not trying to build a Ferrari," Tom adds. "Although some might see the smooth lines of parabolic dish designs as the racing models of this solar-energy era, we want to build a reliable workhorse that is more plain vanilla. Maybe a Chevy or a VW Bug." •WK

A Look Back

Birth of Sandia's Solar Work

Sandia's present responsibility as lead solar laboratory for DOE grew from simultaneous efforts in the early 70s at the Labs' Albuquerque and Livermore facilities.

For most of the Labs' solar history, Sandia Livermore has been the lead lab in central receiver technology, with Albuquerque leading distributed receiver technology and photovoltaics. Two years ago, the programs were combined at Albuquerque.

A 1972 memo by Sandia Livermore's Tom Brumleve (ret.) cited reasons for the Labs to become involved in solar research. "The problems to be solved are both technically challenging and well matched to Sandia's capabilities," he wrote. Convinced that solar energy could substantially reduce the severe energy shortage projected at that time and sparked by the ideas of Aden Meinel and Marjorie Meinel (two University of Arizona professors), Tom cited a number of areas of Sandia expertise:

- Applied research into radiant-to-thermal conversion and heat exchange;
- Engineering to develop practical and economical components, rooted in Sandia materials research; and
- Systems studies to determine the best methods for operating a solar power installation and for meshing it with power distribution networks.

"Sandia is probably the best qualified among the three weapon laboratories," Tom concluded, mentioning both Albuquerque and Nevada Test Site as "well suited for solar experimentation."

Independent of Tom's work, Bob Stromberg, now supervisor of Technology Transfer Div. 4031, was pursuing solar projects from Albuquerque in 1972; he helped to secure the Labs' first solar funding. His work, also sparked in part by the enthusiasm of the Meinels, succeeded in involving the Labs in a community-level solar feasibility study for the National Science Foundation in 1973.

From that $100,000 project, Sandia moved to a $400,000 solar budget from AEC for the following year.

In 1975, the Energy Research and Development Administration (ERDA) replaced AEC and took charge of federal solar activities; both Sandia Albuquerque and Livermore became heavily involved. The Labs' solar budget that year ballooned to $15.5 million.

Later, when DOE was created, and it began to administer solar operations, work was well under way on Solar One (at Livermore) and other projects (in Albuquerque).

Albuquerque's original solar activities centered near Bldg. 832. In 1976, the Labs began a project to provide solar thermal heating, cooling, and power to the building for a year. Several name changes and reorganizations later, the Photovoltaic Technology Div. 6221 assumed operations in the original area (see photovoltaics articles in this issue), while solar thermal activities moved to CRTF's present location.

The Key: New Concepts

Central Receiver Technologies Advancing

In the case of central receiver solar technology, Sandia staffers aren't resting in the shade. They are hard at work making sure that no one asks, "What have you done for us lately?"

The intense effort that culminated in Solar One — the nation's first commercial solar electrical generation plant — is still pointed to as the crowning achievement of Sandia's central receiver effort (see "Solar One").

But research and development on the central receiver concept and transfer of resulting technology have come a long way.

Still, it may be years before recent efforts can all be put together in a new-generation plant. "It takes a lot of capital to build this kind of facility," explains John Holmes, supervisor of Central Receiver Technology Div. 6226. DOE spent $150 million on solar thermal technology in 1980 as construction of Solar One (near Barstow, Calif.) peaked, he notes. "But capital is not readily available in the economic environment right now," he admits.

John Holmes and John Otts, supervisor of Solar Thermal Test Facility (STTF) Div. 6222, now direct Sandia's central receiver program, although the work was directed for years from Sandia Livermore (see "Birth of Sandia's Solar Work"). Div. 6226 approaches the technology from an engineering design and development viewpoint; Div. 6222 handles testing efforts at the Central Receiver Test Facility (CRTF), or power tower.

Central receiver systems use a field of tracking mirrors (heliostats) to redirect and concentrate solar energy on a receiver atop a tower. The receiver, a kind of boiler, generates steam to drive an electrical generator. Central receiver systems also can provide process heat.

Another key central receiver component is a thermal storage system that must be used if the plant is to operate when the sun isn't shining. "A cloud," John Holmes says, "can stop steam generation and shut down the turbine, stopping electricity output. We need continuous electrical output, and to do that, we have to store heat and use it to drive the turbine."

Building on Early Work

"We learned a lot from Solar One," he adds. "It was based on very early technology. The receiver was a simple boiler with steam driving a turbine at the ground.

"Now we're working on solar-unique points in the central receiver system, receivers, and heliostats, to lower the cost and to increase the efficiency," he explains.

With design and engineering work continuing at Sandia, central receiver technology is moving toward the day when it will be ready for electric utility use. "The technology for the next plant promises to produce electricity competitively," John Holmes says.

"A group of southwest utility companies is studying central receiver technology now as a hedge against high fuel prices or power availability problems in the future," he adds.

One of those utilities, Arizona Public Service Company, designed a second-generation plant, which it hopes to build when economic conditions are more favorable. Greg Kolb (6226) studied the design, using special systems-analysis tools developed by Sandia. With a molten salt receiver, which stores heat very well, and other improved features, the second-generation design would improve annual efficiency from the 6 percent achieved at Solar One to 15 percent, which is necessary to achieve economic viability, Greg estimates.

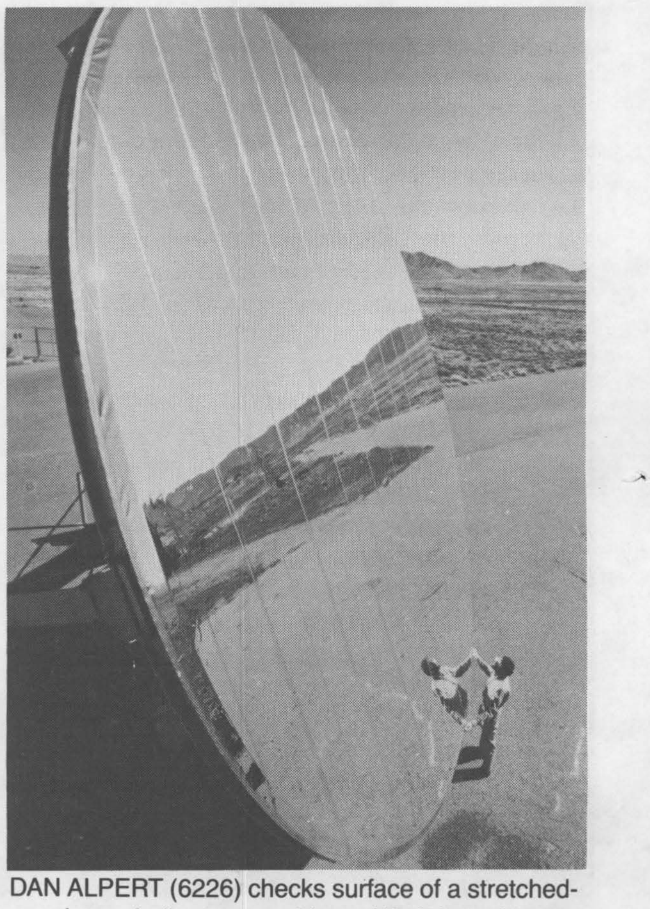
Even though Solar One converted only six percent of available sunlight to electricity on a long-term basis, the plant was very successful, Greg notes. "You have to get to first base on these projects," he explains.

"For example," says Duncan Tanner (8274), "concerns we had about the receiver at the beginning of the project didn't turn out to be problems." Also, heliostats were available 98 percent of the time, despite a small operations crew.

The Efficiency Robbers

Greg (who evaluated Solar One from actual experimental data, CRTF tests, and various analytical models) identifies system availability, receiver efficiency, and parasitics as crucial to achieving a truly economic central receiver generating plant. "We need to determine what causes failures, and how to quickly fix or even eliminate them," Greg says.

TOM BRUMLEVE (RET.)



DAN ALPERT (6226) checks surface of a stretched-membrane heliostat tested here. Work is under way on design of a new stretched-membrane heliostat, using lessons learned from testing this and other prototypes.

Receiver efficiency is the rate of conversion of light energy into the system to heat energy. In analysis of a molten salt design, receiver efficiency is predicted to be 80 percent; however, work is under way on a new receiver concept to achieve 90 percent efficiency.

"Parasitics" refers to the amount of electricity generated by a plant that is, in turn, consumed by the plant to run its own equipment. Careful component design in a full-scale plant may reduce parasitics from the 30 percent experienced with Solar One to 5 to 10 percent of generated electricity, Greg says.

While other central receiver components have met or exceeded efficiency goals, Sandians are dedicated to making the components even more efficient and less costly.

Receiver Design

This year has been one of overlapping projects for receiver designers at Sandia. Workers dismantled a five-megawatt molten salt tube receiver last spring, following extensive testing at the CRTF. At the same time, work was already under way on the next concept, a direct absorption receiver (DAR), scheduled for testing next summer.

The dismantled receiver, used in the Molten Salt Subsystem Component Test Experiment (MSS/CTE), was state-of-the-art when built as a scale model, explains Craig Tyner (6226). Molten salt, heated as it circulated through receiver tubes, was pumped through a heat-exchange system to create superheated steam for electrical generation.

"The idea was to build a scaled-down version of something that could be built on a commercial scale," explains Jim Chavez (6222), who worked with Craig. MSS/CTE and an earlier Molten Salt Electric Experiment reconfirmed the thermal storage properties of salt and the ability of a molten salt and steam heat transport system to generate electricity.

Labs solar thermal researchers are now gearing up to test the advanced DAR concept.

The idea, Craig explains, is to flow salt in a thin film over the outside of a smooth, tin-can-shaped receiver. The film would directly absorb the sun's radiant heat and reduce many limitations created by flowing salt through tubes.

(Continued on Page Four)

CRAIG TYNER (LEFT, 6226) and Jim Chavez (6227) stand about 20 feet up a life-size steel "erector set" that will become the 50-ft.-tall direct absorption receiver (DAR). It's due for testing atop CRTF starting next summer. Concentrated sunlight will heat DAR's molten salt to 500°C.

Solar One — It Taught Us Many Things

The product of a Russian idea, an American program to find peaceful uses for nuclear explosives, and an international energy crisis, Solar One will go down in history as an example of what can be done with industry and government cooperation.

Located in the Mojave Desert, it was the world's first pilot-scale central receiver electricity-generating power plant. Its field of 1818 heliostats, with a reflecting area of 71,083 square metres, surrounded a 300-ft.-tall tower that supported an almost-50-ft.-tall receiver.

After supplying its own power needs, Solar One could produce at least 10 MWe for Southern California Edison's grid for eight hours on the "best design day" — summer solstice.

Probably more than anything else, Solar One demonstrated to all that solar central receivers can provide reliable, useful electricity.

"We worked with industry and utilities," says Al Skinrood, supervisor of Project Engineering Div. III 8133. "It was a team, and an excellent example of cooperation between Sandia, Southern California Edison, the Los Angeles Department of Water and Power, and DOE."

You Name It, Livermore Did It

Al and many colleagues at Sandia Livermore were deeply involved in just about all phases of Solar One's design, analysis, construction, and testing. Sandia selected the design concepts and assisted the DOE in managing plant construction with Martin Marietta (heliostats), Rockwell Inc. (thermal storage and receiver), McDonnell Douglas (control systems), and Townsend & Bottum (construction).

But Solar One's roots really can be traced back to 1972, when Al and Tom Brumleve (ret.) were involved in Project Plowshare, which aimed at finding peaceful uses for atomic energy. In the course of studying US energy supplies, they concluded that severe energy shortages would soon occur, and that solar energy technology could make up some of the shortfall.

"The total US solar program budget in 1971 was $1 million," Al recalls. In 1972 it doubled. It doubled again in 1973. In 1974, it quadrupled. "Interest was growing," he says.

AL SKINROOD (8133)

Authorization for Solar One came in 1975, based on Sandia's recommendation. "We were technical managers of the program throughout its life," Al says.

The first central receiver concepts were published by three Russian authors in the 50s. Al actually discussed the idea with one of them before the Russians dropped the project. (They revived it in the 70s.) In this country, it was actually the University of Houston that got people thinking about central receivers.

Sandia Livermore managed $23 million in contracts with industry to develop competing designs and working models of hardware for Solar One. Some leaders of the effort at Sandia Livermore included Alvin Baker (8151), receiver system; Scott Faas (8131), storage system; Clay Mavis (DMTS, 8165), heliostats; and Duncan Tanner (8274), control system.

CRTF Served as Solar One Test Bed

The Labs evaluated working models, most of which were tested at the CRTF. It was DOE's predecessor, the Energy Research and Development Administration (ERDA), that had decided on a national facility to test hardware. Originally, it planned to build the facility at China Lake, Calif. Sandia, however, convinced ERDA to move the site to Albuquerque. Although many of Solar One's components were selected before the CRTF became operational, the facility did test a working model of the receiver eventually used atop Solar One.

Sandia handled specifications-writing for Solar One while John Otts (6222), Edward English (8442), Chuck Pignolet (DMTS, 8432), and Bill Morehouse (ret.) were on loan to ERDA and DOE to offer advice in awarding construction contracts. Actual plant design began in 1978, and the plant became operational four years later.

Sandia's involvement continued during the performance- and power-testing phases of plant evaluation. Duncan Tanner and James Bartel (8441) served as on-site managers during Solar One's testing phase.

Although Solar One ceased operation on Sept. 30 of this year, and is now being mothballed (so that components may see future use of some kind), it provided valuable lessons and insights into the technology of a central receiver electrical generating plant — lessons likely to be applied to next-generation central receiver technologies.

The plant ceased operation "with a bang, not a whimper," reports Greg Kolb (6226). "In its final year of operation, it recorded a 96 percent plant availability rate, which means the plant produced electricity 96 percent of the time there was enough sun to operate," Greg says. "Ninety percent is considered a goal for most renewable energy technologies. Solar One beat that easily."

(Continued from Page Three)

Central Receiver

Before DAR fabrication could begin, Jim and Craig had to address difficulties presented by the concept. Using a 10-metre-tall steel receiver mock-up, dubbed "the silver bullet," and other test panels, they looked at possible flow problems the salt may encounter as it streams down the receiver surface. Water tests (in place of salt) showed that waves form in the flow, causing whitecapping or spray near the bottom of the receiver. Loss of salt would likely result.

"We learned to control the waves, without complicating the simple design of the receiver too much," says Jim. DAR shakedown tests should begin early next year, with actual solar testing set to start next summer.

In another development, Sandia is working with a European consortium on a hot-air receiver, in which metal or ceramic fibers, heated by concentrated sunlight, transfer energy to air flowing over their surface. Sandia has built components for experiments at Almeria, Spain. Jim Chavez will monitor the experiments, scheduled for January 1989.

Heliostat Design

Computer-assisted tracking mirrors, modern-day analogs to the polished metal shields used by the soldiers of Archimedes to set fire to the sails of invading Roman ships, continue to be the most expensive and critical component in a central receiver system. About half the cost of a central receiver generating plant involves reflectors, pedestals, and sun-tracking hardware.

Thousands of mirrors, mounted on rotating frames and controlled by computers and electric motors to keep them pointed toward the sun, are needed in a commercial-sized plant.

Thanks largely to Sandia technical direction, evaluation, analysis, and testing, the cost of those heliostats has dropped dramatically in recent years — bringing the reality of a commercial-scale plant closer. Glass heliostats built for the CRTF in the mid-70s cost about $900 per square metre of glass surface. Later, heliostats for Solar One cost about half as much as increased heliostat size and improved mirror-manufacturing techniques cut costs.

'Stretched Membranes'

Costs of glass heliostats continue to come down, but to make further savings, materials lighter than glass are now being studied, explains Dan Alpert (6226).

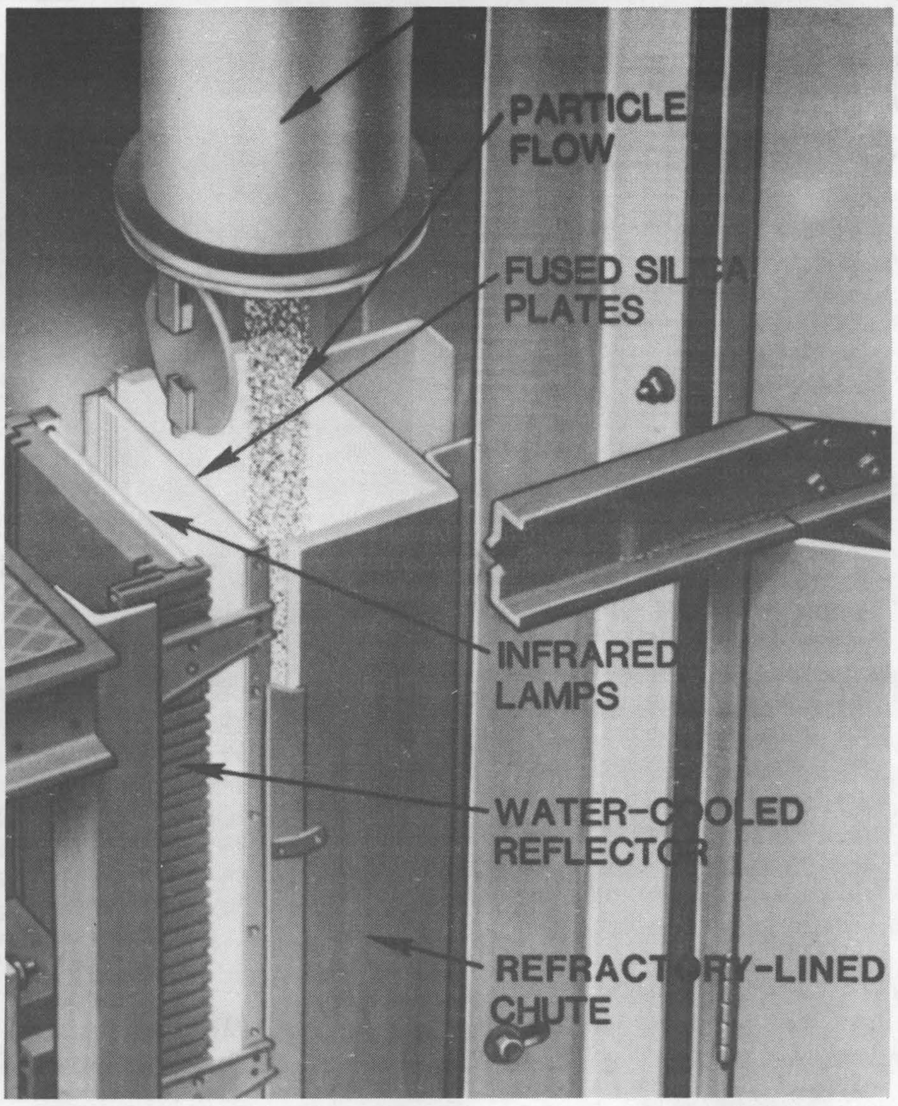
"First designs tend to be conservative. But now we've developed an understanding of the heliostat, and that will let us design closer to the structure's tolerances and limits," he says.

Sandia is now working with the Solar Energy Research Institute (SERI) at Golden, Colo., on the "stretched-membrane" heliostat — a thin metal membrane stretched drum-tight over both sides of a large, metal ring. A silvered polymer film goes on the reflective side. The membrane — a few thousandths of an inch thick — and hoop weigh only about 2.2 pounds per square foot, compared to about 7.2 pounds per square foot for glass mirror assemblies. This reduces the weight — and cost — of support structures.

An airtight space between the front and back membrane is evacuated with a fan or pump, drawing the centers of the front and back membranes together and producing a tightly focused beam.

Most of the Labs' planning and design work on the stretched-membrane heliostats occurred at Sandia Livermore. Tom Brumleve (ret.) developed many ideas used in the first working models. (He also made significant contributions to the DAR.) Clay Mavis (DMTS, 8165) was project leader on the stretched-membrane mirrors before oversight responsibilities moved to Albuquerque in 1987. SERI contributed analytical work on required membrane thickness and materials and built laboratory models.

Dan Alpert led testing and evaluation for the first two prototype stretched-membrane heliostats, which arrived at the CRTF in 1986, and for a second generation that arrived several months ago. These models are tested for their reflective qualities and ruggedness in wind, hailstorms, and other foul weather conditions. Science Applications International Corp. (San Diego) and Solar Kinetics Inc. (Dallas) have made test heliostats in the program.



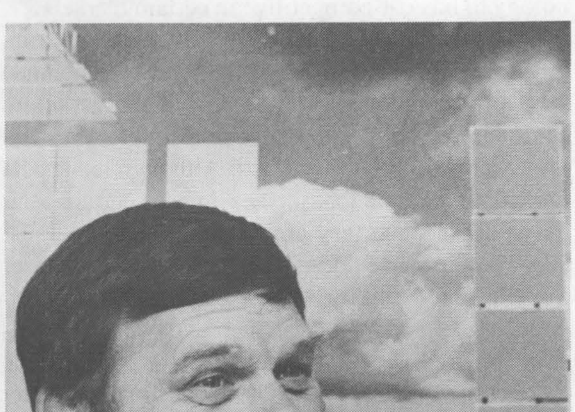
SANDIA LIVERMORE SOLAR RESEARCHERS determined that it's technically feasible to use sand-sized ceramic particles as heat-transfer medium for high-temperature solar central receiver plants. Tested during the mid-80s at the Radiant Heat Facility in Albuquerque, the concept called for refractory particles to be solar-heated while falling through a central receiver. After thermal energy was extracted in a ground-level heat exchanger, cooled particles would cycle back to the receiver for reheating by the sun. Test apparatus included 10-metre-long chute through which particle stream fell into a catch bin. A bank of high-energy infrared lamps simulated the radiant intensity of 500 suns.

Hardware Becomes Key To Distributed Receiver Systems

Hardware — that necessary commodity that links theory (predictably or unpredictably) with fact — is coming to Sandia's solar distributed receiver program with a vengeance.

After an extended effort to make some choices about the primary path the program should take, work is now shifting to evaluation of working models at the Distributed Receiver Test Facility (DRTF), a part of Sandia's Solar Thermal Test Facility (STTF). Next come component refinement and experiments to link them into a system.

The idea behind solar thermal distributed receiver systems: an energy receiver for each reflecting surface, be it a parabolic dish or trough. In dish technology, a receiver may be connected directly to a heat engine, or heat from several receivers may be transported to a central engine. One key value: Units can stand singly or be grouped to provide the needed energy level.



JOHN OTTS (6222)

Distributed receiver technology is responsible for some major Sandia solar successes to date:

- Sandia managed DOE's successful Modular Industrial Solar Retrofit (MISR) project, which assisted industry in producing low-cost, high-reliability solar trough collector and steam-production systems. The prefabricated systems were designed to augment oil- and gas-powered steam boilers for a variety of industrial uses. As a spin-off, a privately financed trough system that provides process steam was constructed for a Chandler, Ariz., company.
- Luz International, an Israel-based company with a California engineering subsidiary, used Sandia's line-focus trough concentrating technology to construct its Solar Electric Generating Stations (SEGS); each produces an estimated 140 MW, enough to supply the needs of as many as 70,000 homes. And Luz has scheduled an additional 500 MW of power generation for California in the future.
- Working with Georgia Power Co. and DOE, Sandia contributed design and management for a parabolic dish solar energy system, completed on a cost-sharing basis in Shenandoah, Ga. This Solar Total Energy Project (STEP) uses a field of dishes to provide a privately owned knitwear factory with electricity, industrial process heat, and air conditioning.

The combination single parabolic dish reflector/Stirling engine electricity-generating system now being pursued at the Labs offers exciting possibilities, researchers believe. It just may be the hardware that molds theory into fact.

A concave dish focuses sunlight into a receiver/Stirling engine mounted at its focal point. Heated working fluid in the receiver powers the engine. Each reflector/engine unit can function independently or as part of a group, producing many megawatts of electricity (see "The Dish-Stirling Engine Combo").

'Weight Equals Cost'

In the vernacular of Tom Mancini (6227), who's working to perfect the dish collector, "weight equals cost." Since the earliest days of dish testing, collectors have become considerably lighter. "But we

(Continued on Page Six)

Solar Irrigation

Using a parabolic trough solar energy collection system — then the most mature solar-to-electric arrangement — a Sandia team helped develop technology in the late 70s that provided farmers with a solar alternative to the high costs of electricity for irrigation.

Then, more than 35 million US acres were being irrigated at an annual cost of $500 million. And the figure was climbing. Sensing an opportunity for a large application niche for solar energy, DOE enthusiastically embraced the relatively new concept of solar irrigation.

The basic plan: Parabolic trough solar collectors focus sunlight onto receiver tubes along the axes of the collectors to heat fluid flowing through the tubes. The hot fluid is pumped to thermal storage tanks and then to a heat exchanger. In the exchanger, heat vaporizes a low-boiling-point fluid that drives a heat engine to pump water during the irrigating season, or to power an electric generator during the off-season.

Sandia already had some demonstrated expertise in solar parabolic troughs. So, not surprisingly, it became involved in three projects: one near Willard, N.M., and the others at Coolidge and Gila Bend, Ariz. Bob Alvis (now DMTS, 5153) was project engineer on the Willard and Coolidge programs; Sandia simply monitored activities at the 50-kilowatt Gila Bend project.

In the process of working out details of irrigation projects and getting them under way, Sandia engineers proved solar energy could be practically applied to irrigation and to other agricultural projects. "We developed automatic control systems to eliminate the need for an operator," recalls Jim Leonard (now 400), who worked on solar irrigation with Earl Rush (6227), Leroy Torkelson (dec.), and others.

Back on the Shelf for Now

"We also developed better solar collectors and hardware," Jim adds. "But the pure marketplace economics weren't yet there. So, even though solar irrigation has plenty of environmental and energy-security benefits, right now the technology is just on the shelf."

At Willard, a Sandia-designed, 25-hp, direct-drive pump system operated continuously during the irrigation seasons of 78, 79, and 80. The first solar-powered, deep-well-pumped irrigation system, the Willard project pumped enough water to irrigate 100 acres of mixed crops.

Coolidge, which became operational in November 1979, was a 150-kilowatt facility that operated — when weather permitted — all day, seven days a week, for three years. The largest trough experiment in the US at the time, Coolidge included 23,000 sq. ft. of Acurex trough concentrators and a 30,000-gallon thermal oil storage tank. The University of Arizona worked with Sandia to conduct experiments on each Coolidge subsystem and to measure and evaluate plant performance. The local electrical cooperative allowed use of its power lines for distribution of power to pumps. In its first 16 months, under the direction of Prof. Dennis Larson, the Coolidge project generated more than 140,000 kwh of electricity and operated 90 percent of the time when adequate sunlight was available.

In the second half of the project's three-year operating phase, an automated control system was installed, "and reliability increased to 97 percent," says Jim. "This evidence of reliability and long-term durability is essential to establish the technical credibility of solar or any new technology."

Chemical Transport of Solar Energy — It Does Work

Efficient transportation of thermal energy over long distances is an ambitious goal. But a device that uses a complex reversible chemical reaction to convert solar thermal energy into chemical energy (thus allowing long-distance transport) has been field-tested with some success.

The device, a combination solar receiver/chemical reactor, was designed and built by Sandia. It was tested late last year in a solar furnace at the Weizmann Institute of Science in Rohovot, Israel, as part of a US/Israel bilateral agreement.

Typically, thermal energy in the 600°C (1100°F) range — the range needed to provide industrial process heat or to make steam for a turboelectric generator — flows through pipelines as a heated fluid. But the entire pipeline operates at elevated temperatures, and must be insulated. Even then, a significant amount of heat is lost.

To stem these losses during transportation, Jim Muir, Jim Fish, and Rich Diver (all 6227) are proposing a better answer through chemistry. Specifically, they're interested in thermochemical energy transport, using a thermally driven reaction between methane and carbon dioxide to form hydrogen and carbon monoxide.

In this concept, a room-temperature gas, rather than a hot fluid, is piped over long distances. At its destination, the gas would be converted back into a hot fluid to heat industrial facilities or generate electricity.

US and Israeli Interests

Using reversible chemical reactions to transport solar thermal energy efficiently is a long-term objective of both DOE's Solar Thermal Program and the Israeli government's Solar Energy Program.

Goal of the US program is cost-effective transport of solar energy from a distributed parabolic dish solar collector field to a central site, possibly many miles away. Israeli researchers are interested in transport of solar energy — collected by large central receiver systems — from their deserts in the south to industrial regions in the rest of the country, and for energy storage. They envision transporting the solar energy from 100 to 200 miles.

The Sandia-Israel solar receiver/reactor was specially designed for these cooperative tests, and its size was tailored to the capacity of the Weizmann solar furnace, about 20 kilowatts of solar thermal energy.

The reactor's core consisted of vertical tubes filled with granules of a catalyst through which a mixture of methane and carbon dioxide could flow. A heat transfer fluid — sodium — surrounded the tubes, and the entire core was enclosed by a receiver/absorber wall.

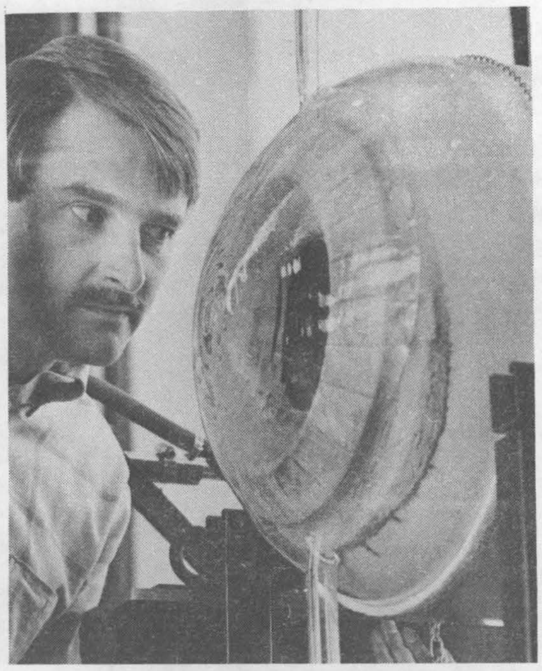
Solar radiation directed onto the wall evaporated the sodium, which condensed on the tubes and heated methane and carbon dioxide inside. These gases reacted to form carbon monoxide and hydrogen. Such an endothermic reaction absorbs heat, thus storing energy for transport.

In a full thermochemical energy transport system, the carbon monoxide/hydrogen mix would be piped to its destination and then converted back into methane and carbon dioxide in an exothermic reactor to release heat.

Sun As Catalyst

Sandia is now involved in another international thermochemical energy transport project in which sunlight acts directly on a catalyst. Through the International Energy Agency's (IEA) Small Solar Power Systems Project, the US, West Germany, and Spain are planning joint experiments on such a receiver.

Sandia is designing and fabricating a catalyst for the *ca*talytically *e*nhanced *s*olar *a*bsorption *r*eceiver (CAESAR). "The object is to demonstrate the direct-catalyst concept — the direct heating of the catalyst rather than transferring heat through hot tubes," Jim Fish says.



DIRECT CATALYTIC ABSORPTION RECEIVER, designed by Rich Diver (6227), uses concentrated solar energy to destroy hazardous wastes such as those created during microelectronics fabrication. During optimum sunlight, receiver of this size could chemically transform about two litres of waste every hour.

Sandia's solar furnace is being used for catalyst testing, with full-scale receiver tests in the IEA program scheduled for next year in Lampoldshausen, West Germany.

The chemical reaction associated with CAESAR is the same as the one used in the reactor tested in Israel — methane and carbon dioxide into carbon monoxide and hydrogen. Production of hydrogen is of particular interest to the West German researchers, who would like to use that gas to produce liquid fuels, such as methanol, from natural gas purchased from Saudi Arabia. Hydrogen also could be used in making fertilizers and in gasifying coal.

Another spin-off of the catalytic absorption receiver is its potential for destroying hazardous waste — a use that may open the door to a new class of solar chemical applications, Rich predicts.

From Weapons to Solar to Weapons

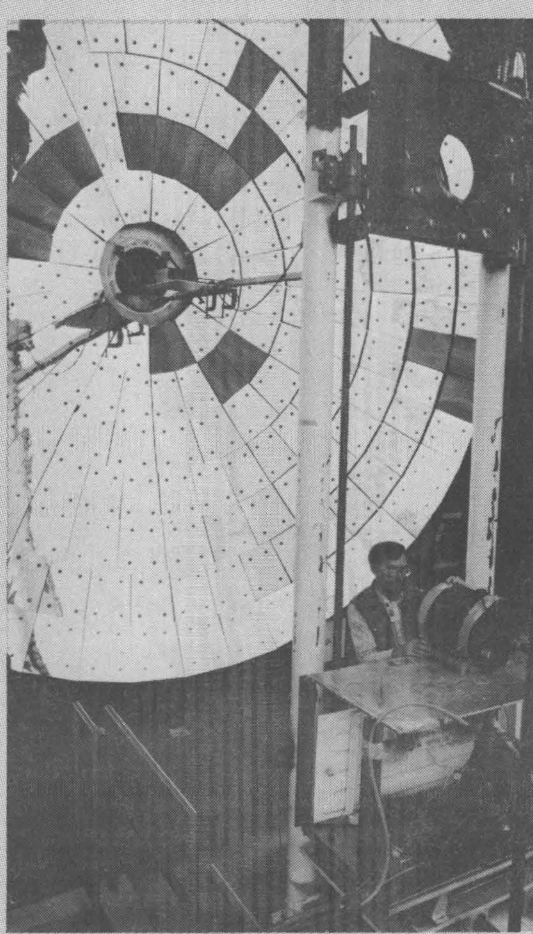
One useful spin-off from Sandia's role in solar thermal loops back to its "well-suited" roots in weapons research.

Because of the high-heat environments created by the reflected sun, test facilities — such as the power tower and a solar furnace also at the STTF — can simulate useful environments. This has resulted in a number of reimbursable test programs for other government groups and private companies.

At the power tower, a number of materials samples have been tested for survivability from the thermal effects of a nuclear blast. Signal-broadcasting rocket nose cones, called radomes, have been tested for friction effects of reentry into the atmosphere, and more tests are scheduled. Other missile aerodynamic surfaces have also been tested.

Now work is under way to simulate flight conditions even more closely, adding a pressurized air stream to the solar-provided heat. Interest has been high in this program; an advanced system, which could generate even more reimbursable testing, is expected to be in place by next spring.

The solar furnace has been the scene of numerous hazardous-waste disposal tests. The furnace focuses the power of 2500 to 2700 suns into a beam about a half inch in diameter at its highest intensity. Past work includes testing paint samples and radome materials, attempting to fuse powders to metal surfaces, and conducting critical sensor-calibration work.



BOB EDGAR (6222) adjusts calorimeter before calibration test at Sandia's solar furnace. Test object is placed at focal point of furnace's 22-ft.-diam. parabolic dish behind Bob.

(Continued from Page Five)

Hardware

must further reduce weight and cost, maintain high performance, and get the technology to the marketplace," Tom explains. "We know it's possible because other projects have shown solar thermal technology to be cost-competitive in certain markets."

In general, dish concepts received a boost from the proliferation of dish-shaped microwave antennae used in communications. Some felt this structure could simply be adapted to solar technology by fixing mirrors to the dish surface. Although the task is more difficult than that, dishes do have certain solar advantages, since they are curved along two axes. Also, performance doesn't degrade as sizes increase.

From the first use of expensive and very heavy cellular glass mirror facets, such as those in Sandia's two Test Bed Concentrators (used for test work at the DRTF), work has moved toward finding lighter reflective materials and testing single-surface dishes. While glass mirrors offer highly accurate optical properties, they also require rigid, relatively heavy support structures. And weight equals cost.

Dishes used at Shenandoah's STEP were made lighter by using aluminized reflective film over a metal substrate.

More recent dish developments at the Labs:

- Structurally integrated sheet-metal collectors;
- Stretched-membrane dishes, analogous to stretched-membrane heliostats used in central receiver technology;

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Hardware

- Sol-gel glasses and other reflective film surfaces for sheet metal and stretched-membrane collectors.

While the sheet-metal approach, developed from the STEP design, probably is closer to commercialization than the stretched-membrane dish, both will benefit from Sandia research on high-performance reflective films. Silver and silicon-oxide films are applied after a sol-gel dielectric layer, which helps smooth metal substrates. Silver and silicon-oxide films can then be covered with protective sol-gel layers.

''We're getting very high performance now — 95 percent reflectance for a small sol-gel sample,'' Tom says. ''A typical household mirror, by comparison, has 80 percent reflectance.''

Recent work done by Rod Mahoney (1824), Carol Ashley (1846), and Scott Reed (7471-1) shows the sol-gel process on a stainless-steel substrate significantly reduces surface scattering of sunlight.

Work on sol-gel and other aspects of dish technology closely parallels work other Sandians are doing with heliostats for central receiver solar technology. ''There's a lot of synergism between the small dish and heliostats,'' says Tom. ''We work back and forth a lot. There are similar problems in developing the performance limits and design parameters.''

Innovative Concentrator

Tom's present work in the concentrator project involves test and evaluation of a scale-model stretched-membrane dish constructed by Solar Kinetics, Inc. After about two years of evaluation, Sandia will participate in the contracting process for a full-size collector. Another project involves a new generation of a distinctive LaJet Energy Co. collector.

Sandia also is looking at a reimbursable program with NASA to test a concentrator designed for the manned space station program. ''The unit isn't even designed to carry its own weight, since it will be used in space,'' Tom says. ''Testing it in gravity, under wind load and with other environmental effects, presents some interesting problems.'' Tom and Chris Cameron (6222) are involved in that project.

Jane Diggs (6227), involved in analysis work for distributed receiver systems, sees 1988 as the year when much of her modeling work from past years has been converted to more detailed studies. ''Now we're finding out how components are going to operate day in and day out,'' she says. Also, questions of how components interact are being resolved. ''We're going to find out effects between components we didn't think of.''

JIM LEONARD (400)

Or, From Scotland to Albuquerque

The Dish-Stirling Engine Combo

The Stirling engine is not generally the subject of widespread conversation. But researchers at Sandia and elsewhere have been giving it high marks recently as a possible mate for the solar parabolic dish and as a way to efficiently use the sun to generate electricity.

This sterling performance began in 1982 with Project Vanguard at Rancho Mirage, Calif. Operated by Advanco Corp., the program used an Advanco solar dish to focus sunlight on a receiver coupled to a Stirling engine, a relatively small, highly efficient, externally heated machine invented in 1816 by a Scottish minister.

The Project Vanguard test engine provided conditioned power to the adjacent Southern California Edison electric grid. As a result of its performance, the Stirling engine is now receiving serious consideration for solar and other applications.

For Project Vanguard, a 1500-lb., 4-cyl. Stirling engine and accessories were mounted at the focal point of a 33-ft.-diam. parabolic dish. Hydrogen, the engine's working fluid, was heated as it passed through tubes located at the point of concentrated sunlight. Hot hydrogen flowed to cylinders, where it expanded against pistons that turned a crankshaft connected to a generator (also located on the focal-point assembly). Transmission lines carried the resulting electricity to the utility's power grid.

Although it has since been dismantled, Project Vanguard established a record for net solar-to-electric generating efficiency of 29.4 percent. ''That efficiency indicates that dish/engine arrangements may have the highest potential of any solar system,'' suggests Jim Leonard (longtime supervisor of Solar Distributed Receiver Div. 6227, who recently began an assignment with 400). ''It's also a level of efficiency rivaling conventional-power-plant capabilities.''

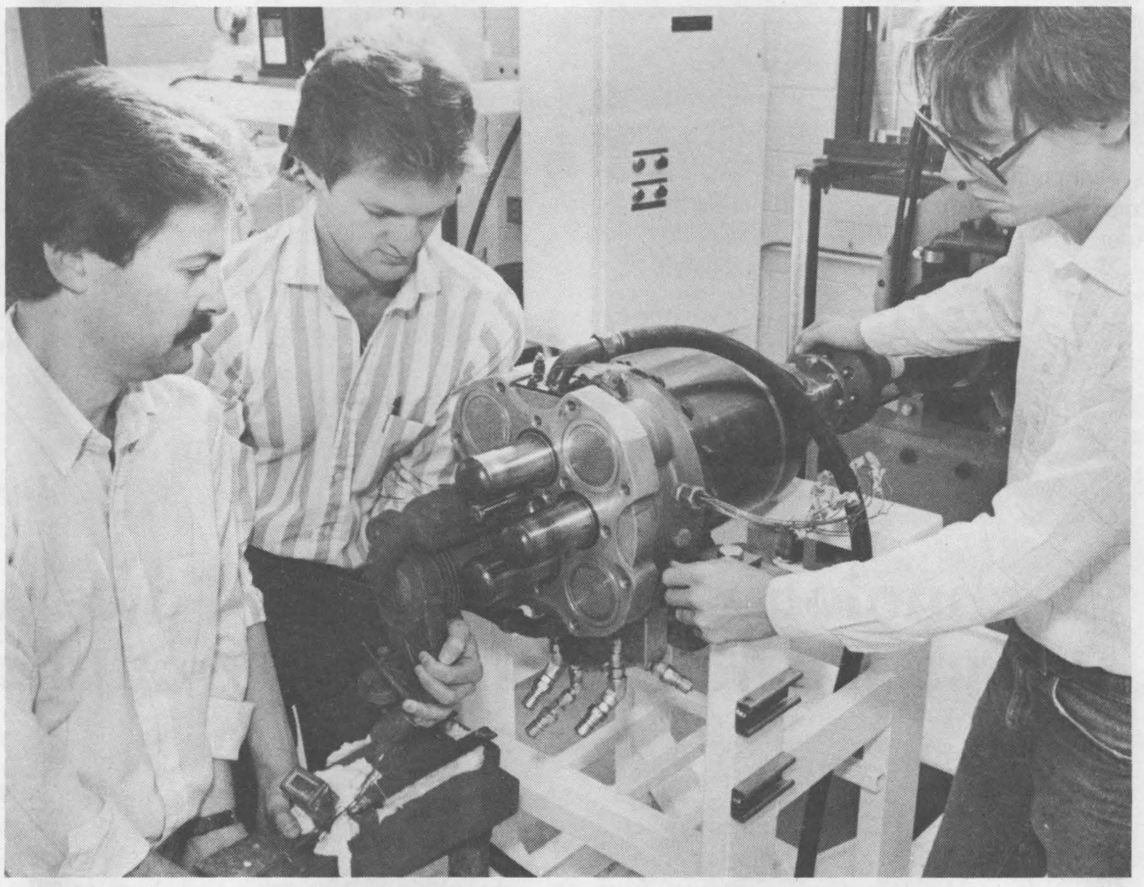
The DOE-funded Project Vanguard originally was managed by Jet Propulsion Laboratory (Pasadena, Calif.), which proposed the concept for prototype testing. But a transfer of responsibilities in 1984 brought it under Sandia management. The dish-Stirling idea also was highly regarded by McDonnell Douglas Corp., which built six modules before a corporate belt-tightening decision forced the St. Louis-based company to withdraw from solar development.

The challenge for Kevin Linker, Doug Adkins (both 6227), Scott Rawlinson (6222) and others involved in engine development for solar dish-electric systems has been to convert sunlight focused on a solar receiver into as much electricity as possible.

Other conventional engine technologies — the organic Rankine cycle, similar to central power stations, and the Brayton cycle, similar to jet aircraft engines — had been previously scrutinized, but they didn't offer performance needed for distributed solar receiver systems.

However, Project Vanguard illustrated the Stirling engine's potential. It offers thermal conversion efficiencies approaching 45 percent, quiet operation, and the ability to operate with heat sources ranging from solar energy to conventional fuels.

Project Vanguard's engine was originally an automotive Stirling engine modified and integrated with a solar receiver, Kevin explains. Because automotive engines typically have a 3500-hr. life — far short of the ideal 50,000-hr. life demanded of a solar engine — more development was needed.



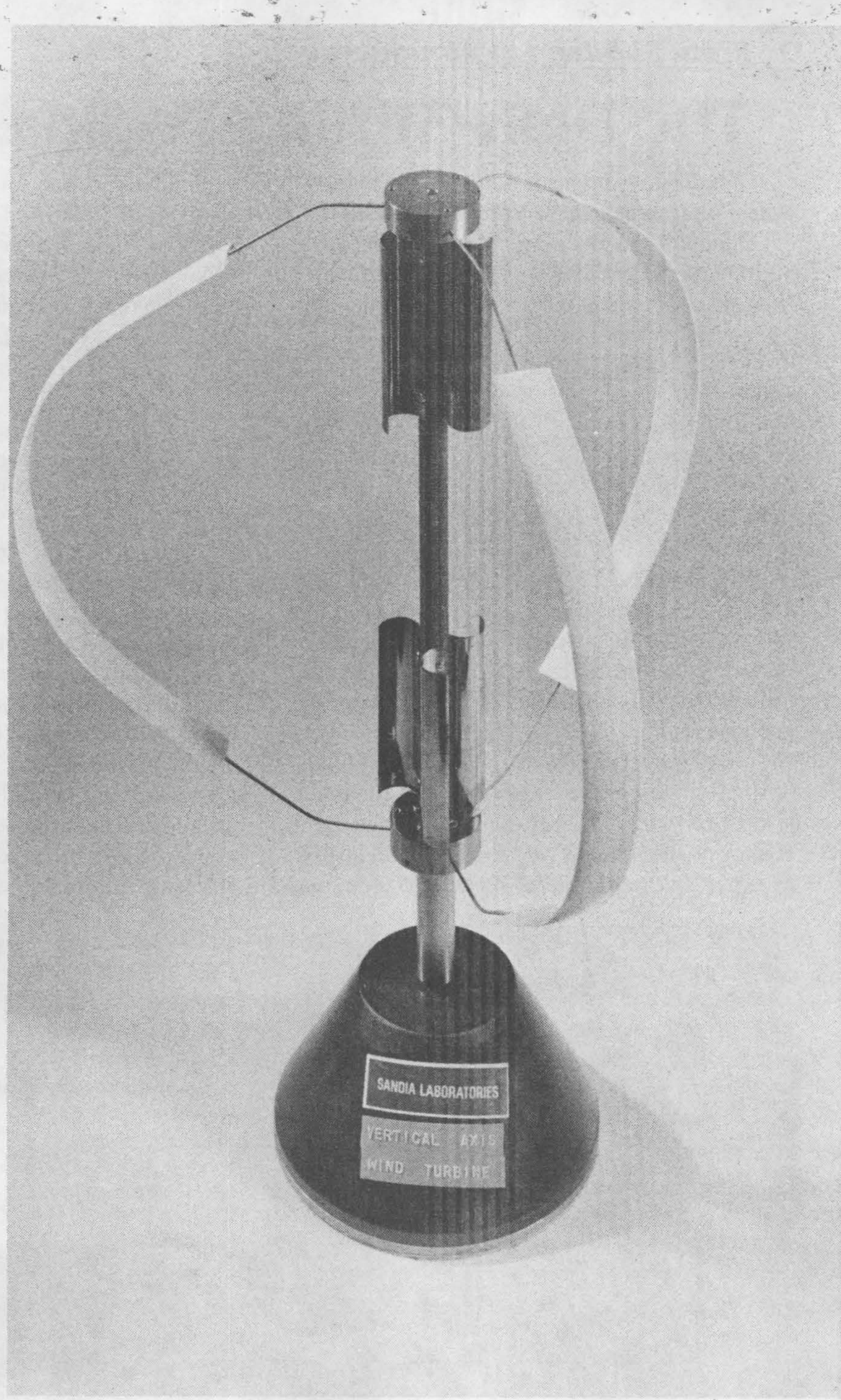
KEVIN LINKER (left, 6227), Scott Rawlinson (6222), and Doug Adkins (6227) attach a heat pipe to one of the four cylinder-head heaters of the new STM Stirling engine to be tested soon at Sandia.

So, with input from Kevin and others, Stirling Thermal Motors (STM), Inc. (Ann Arbor, Mich.) produced a new engine that arrived at Sandia earlier this month for tests during the coming year.

It's a 25-kilowatt kinematic Stirling engine (STM4-120), specifically designed to meet solar power generation demands.

Tests are planned for Sandia's Engine Test Facility (ETF) at the Distributed Receiver Test Facility (DRTF). Initial shakedown tests will lead to on-sun testing with a solar receiver mounted on a Test Bed Concentrator at the DRTF.

Down the road, Kevin says, is a free-piston-version Stirling engine. Since only two parts move — displacer and power piston — it shows promise for long life and high reliability, similar to that of a refrigerator compressor. Sandia is currently developing this engine through a DOE interagency agreement with the National Aeronautics and Space Administration.



HUMBLE-LOOKING BUT IMPORTANT, this desktop model of 1974-vintage Sandia-designed VAWT was a pretty important piece of hardware, recalls Randy Maydew (400). "We built six of these 25-cm-diam. models and used them with blower fans to demonstrate the VAWT concept to nonbelievers. At the time, our management was pretty skeptical. They couldn't conceive of a device that was driven by aerodynamic lift rather than aerodynamic drag, but that's what causes the VAWT to work. I even remember having to take a model and fan up to my boss's office back then." This VAWT design eventually received a patent in the names of Randy, Ben Blackwell (1553), and Lou Feltz (9113). Note backward-S-shaped starter rotors at each end of the model's shaft. Although they worked, researchers eventually dropped the rotors in favor of an electric starter.

(Continued from Page One)

Blowing in Wind

Dick — in his 11-year wind tenure — and his staff brought the VAWT from test model to its installation in power-generating wind farms in California and elsewhere. Project leader Emil Kadlec (DMTS, 9122), Bill Sullivan (2542), Don Lobitz (1522), Paul Veers (6225), Dale Berg (6225), and Jim Banas (dec.) were among key structural-concept specialists during that time. Also involved were Bob Grover (dec.), Mat Mattison (dec.), Tim Leonard (9122), Tom Ashwill (6225), Bob Nellums (9122), Paul Klimas (6227), and former Sandian Bob Akins.

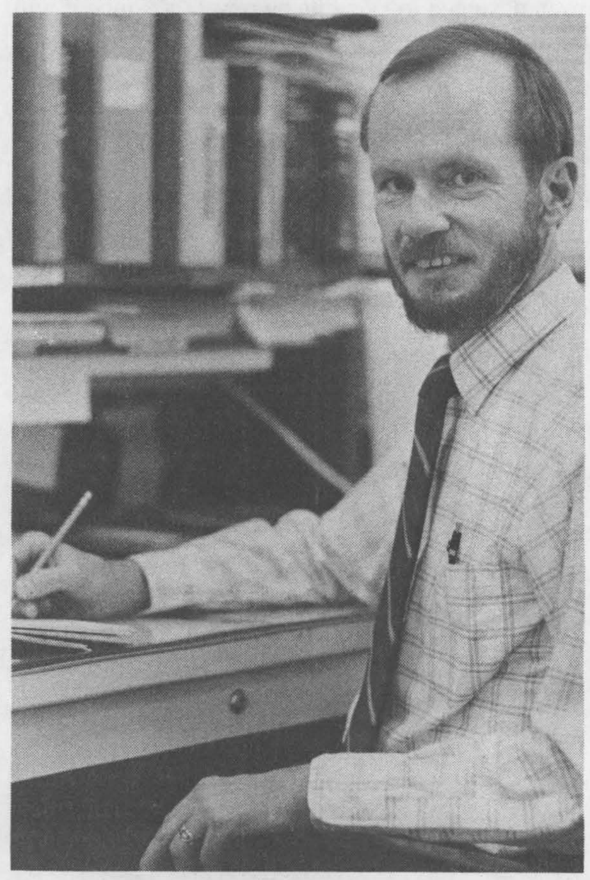
Because of damage wrought on a wind machine by vibration, Dick and staff worked to achieve a design in which machine vibration levels were minimized during operation. "It sounds easy, but in practice, it's quite difficult," Dick explains.

Interest from private industry — Alcoa, VAWTpower, and FloWind Industries — brought pressure to design a low-cost, reliable machine. Industry, in turn, provided Sandia engineers with insight into manufacturing processes and the realities of what could be accomplished. Industry also supported continued funding for the VAWT program at the Labs — funding that at times was in doubt, Dick recalls.

Today's Wind Team

Today, the project has a staff of 12, supervised by Henry Dodd (6225). Their work is augmented greatly, says Henry, through assistance from Engineering Analysis Dept. 1520, Aerodynamics Dept. 1550, Metallurgy Dept. 1830, and Experimental Mechanics Dept. 7540.

VAWT design also has gone through a metamorphosis, including a change from that slightly tubby outline to a slim pair of parentheses athwart a spinning mast. With the help of governmental incentives, eggbeater windmills have been installed from Canada's Gaspe Peninsula to California — including a whole army of them near Sandia Livermore at Altamont Pass.



HENRY DODD (6225)

Fired by the zeal of post-oil-embargo research on alternative energy sources, the VAWT spun Sandia a new image, that of international expert in wind power. But while the expertise remains with Sandia, commercial leadership no longer resides with the US. "What started off as world dominance has become, and I'm speaking conservatively, considerably eroded," says Henry, who joined Sandia's energy programs in 1976 and has been specializing in wind power since March 1985. "In fact, it may be irretrievably damaged. The task now is for the US to develop a technology — whether it be in

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Technology Transfer: Wind-Power Program's Most Important Product

What's the most important product to come out of Sandia's wind-power program?

For Henry Dodd (6225), it's neither a material nor a device. It's not even a manufacturing process. He says, "It's technology transfer, derived from system-engineering expertise, followed by successful commercialization in the late 70s.

"The vertical-axis wind turbine (VAWT) machines in California are direct spin-offs of the 17-metre low-cost design that Sandia originally contracted out to Alcoa," says Henry.

This early design was the first attempt to commercialize a VAWT. Performance criteria, including aerodynamics and structural analyses in addition to operating procedures, were worked out at Sandia. Alcoa did additional work on extrusion, assembly, and other necessities of the new technology — plus an economic study — that was funded by DOE and described in a publicly available report.

With the aid of this technical base, VAWTpower, Inc. (Albuquerque) and FloWind Corp. (Pleasanton, Calif.) commercialized the VAWT concept and, as Henry says, "That's why we have more than 500 of those machines out in California."

When larger VAWT blades were needed for a new research test bed, Sandia turned to Consolidated Aluminum Corp. (CONALCO) of Madison, Ill. CONALCO successfully produced the largest multi-void aluminum extrusions ever — a VAWT blade — in the fall of 1986. (A Swiss-owned company, CONALCO was bought by US interests recently and renamed Spectrulite.)

Henry explains that multi-void extrusions look solid outside but contain more than one empty cell inside. This makes for a strong, lightweight structure. "The manufacturing process is very proprietary," he says. "They wouldn't let me take a picture of the back of the extrusion machine, only the front of it."

The extrusion machine is a curiosity — a product of the engineering genius that was harnessed by Germany before and during World War II, and which has migrated into US high technology. Three of the machines were built by the Germans; at the close of the war, two of them went to the US and one went to the Soviet Union. They remain three-of-a-kind.

The big extrusions are being used in the latest of Sandia's Natural Laminar Flow (NLF) series of airfoils — the kind of airfoil, Henry says, "that you would never, ever use on an airplane." These are designed to "stall-regulate." As wind increases, it reaches a point where the flow over the blade is spoiled (stalled). Thus, the blade continues to produce power, but the power remains virtually constant as wind velocity increases. The secret lies in the shape of the blade, and the result is measured in greatly enhanced economy — there's no need to pitch blades or use some other complex mechanical system to operate in high winds.

"To non-aerodynamicists like I am, one airfoil looks like another," says Emil Kadlec (DMTS, 9122). "It looks like a wing. But, in fact, a lot of subtle things happen when you make minor changes to the cross section."

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PART OF FLOWIND'S Altamont Hills wind farm about 5 miles east of Sandia Livermore. Electricity produced by the 150-VAWT farm flows into Pacific Gas & Electric grid that services Bay Area.

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Blowing in Wind

horizontal- or vertical-axis wind turbines, or both — to get back into the competition.''

Perhaps surprisingly, competition for wind-turbine sales has not come from Canada, France, or even Japan, but Denmark. ''The Danes have really impacted the market,'' says Henry. ''Three-quarters of the wind turbines installed recently in California have been Danish machines.''

The reason for Danish success isn't entirely technological, Henry explains. The Danish government has supported its wind-machine manufacturers with tax breaks and by lining up financing and insurance packages.

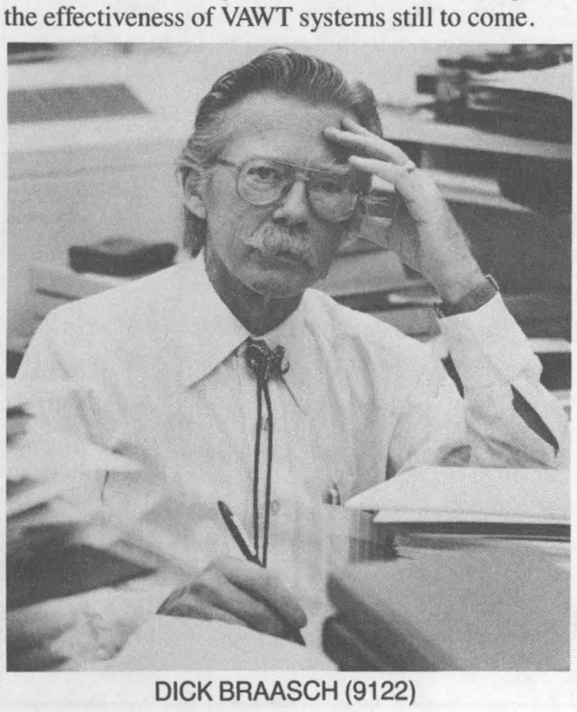
King of the VAWTs

Hopes for getting ahead of international competitors depend largely on the ''king of the VAWTs'' at Bushland, Tex., which, Henry says, provides ''a tool to evaluate the next generation of VAWT concepts and thus develop what we call a world-class machine, fully competitive in the world market.''

It towers above the windswept Panhandle plain west of Amarillo at a US Agricultural Research Service station. Its graceful aluminum blades are each 183 feet long, the two curving outward to a maximum 110 feet (34 metres).

Dedicated in May (LAB NEWS, May 20, 1988) the test bed is in its preliminary resonance-testing phase and has operated to its maximum rotational speed of 40 rpm in winds up to 25 mph.

In a 28-mph wind, the Bushland VAWT should generate half a megawatt of power, equal to 60 percent of the local community's normal power load. This sounds impressive enough, but in a sense, it's incidental. More important, the big machine is a test bed, designed to generate *information*. This includes information on aerodynamics, structural characteristics, and control systems — vital data to improve the effectiveness of VAWT systems still to come.



DICK BRAASCH (9122)

''Bushland was never intended to be a prototype,'' Henry stresses. ''I like to draw the analogy beween NASA's having large-scale wind tunnels at Langley and Ames for aircraft research, and Sandia's having this test bed near Amarillo for wind turbine research.''

A lot of new technology has gone into Bushland's giant eggbeater, hence the need for careful measurement and analysis that will allow project engineers to decide whether the innovations are worth retaining for future VAWT designs, and to ensure that they will not cause new and unanticipated problems.

For example, as an aid to their work, research engineers can change blade sections of the Bushland machine in order to test new shapes; the blade sections at the generator's ''equator'' can be unbolted and replaced with slightly different sections for testing when desired. Commercial machines would not have this feature.

The original VAWT test site in Albuquerque also has been refurbished and the 17-metre VAWT is operating again. As Henry says, ''It's easier and less expensive to check out some aspects of technical improvements on a smaller machine before applying them to the Bushland VAWT.''

Are there more ''windmills'' in our future? Henry thinks so, and he has plenty of economic data to illustrate his contention that VAWTs, properly placed, are incontrovertibly efficient (see ''Free as the Breeze''). ''By the early 90s, we should have demonstrated the technical improvements that will make VAWTs truly competitive in the eyes of a public power utility,'' he says. ''The thing we see ahead is a machine that would be rated at 500 to 1000 kilowatts — that's the scale of the Bushland machine.'' •NH

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Tech Transfer

Several experimental NLF airfoils were designed with the help of Jerry Gregorek of Ohio State University, where a wind tunnel was modified to perform dynamic airfoil testing. Paul Klimas (6227) began testing them about five years ago. ''Obviously, the contour differs from aircraft airfoils,'' says Paul. ''That's because the operating environment for VAWT cross sections is very different. There's a constantly changing angle of attack and a constantly changing wind speed.''

Emil explains the basic principle of stalling by talking about aircraft wings. The secret of imparting lift to aircraft lies in shaping the wings so that air flows farther over the upper surface than the lower surface — causing a relative vacuum that draws the wings upward. ''But when a pilot intentionally stalls, the nose goes up, and the wing is given a high angle of attack against the oncoming air,'' he says. ''The airflow separates from the top side of the wing, and you lose lift.

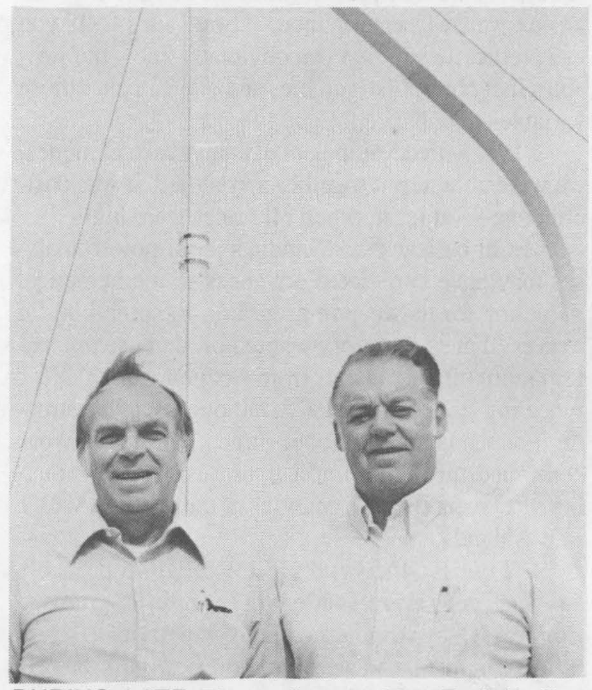
''In the Darrieus [named after the inventor of the VAWT], as the wind velocity increases, the angle of attack goes up, and at some point you will go into a stall. In a wind turbine, you want this to occur early so that the power is regulated at a reasonable wind speed.''

''You like a gentle stall if you're a pilot or a passenger,'' adds Paul. ''We like a sharp stall because we want control. To do this, we give the airfoil a sharper leading edge.''

Keeping Tabs on Sandia Technology

Have the Sandia airfoils made their mark? ''Right now, anybody who's building VAWTs watches us,'' says Paul. ''The 34-metre machine at Bushland is of great interest.

''The FloWind people and the Indal Technologies, Inc., people [of Canada] have already shown they can operate 25 to 50 percent more cost-effectively by using Sandia airfoils, depending on where they operate. That's in comparison with the late 70s technology used in the 17- and 19-metre VAWTs.



DURING LATE 70s and early 80s, Emil Kadlec (DMTS) and Jack Cyrus (both 9122) were seldom seen far from a VAWT, as they explained the developing technology to visitors from throughout the world.

''VAWTs are ready to move, but tax initiatives are gone and, at least for the moment, fossil fuels are cheap.''

While the team's work on airfoil design has not been recognized by the US Patent Office, Sandia has been ''fairly closed'' on releasing performance data, Paul adds. ''We want to preserve the North American edge on the technology.''

To make the airfoils, Sandia used existing extrudable materials, which are relatively inexpensive. However, with encouragement from the Labs, a supplier has made materials that are much more resistant to metal fatigue than the aluminum used in the first VAWTs.

''The early designs had 20 to 20,000 psi yield strengths, and it wasn't good enough,'' says Paul. ''So we told CONALCO that we'd like a stronger material, because the blades were falling apart. So they sat down with their metallurgists and, as a result, said, 'We'll design you a new alloy with a higher ultimate strength.' They altered the formula and put a special heat treatment on the extruded material. As a result, we have materials with 34,000 psi yield strengths on the 34-metre machine.''

Herb Sutherland (6225) heads up Sandia's investigation of materials properties of wind turbine blades, with the backing of Jim Van Den Avyle (1832). They centered their initial work on metal fatigue, which in California is reckoned to be the wind energy business's single biggest technical problem. (Fatigue also plagues horizontal-axis wind turbines, which usually have fiberglass composite blades.)

While refinements in basic VAWT design continue, Henry Dodd believes the concept has already proved its mettle. ''We developed a wind energy *sys-*

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Tech Transfer

tem, using the engineering-systems approach,'' he says. ''We've used structural dynamics, aerodynamics, and the Labs' control expertise. Sandia's power-systems people have helped out, as well.''

Priming the Pump for Structural Analysis

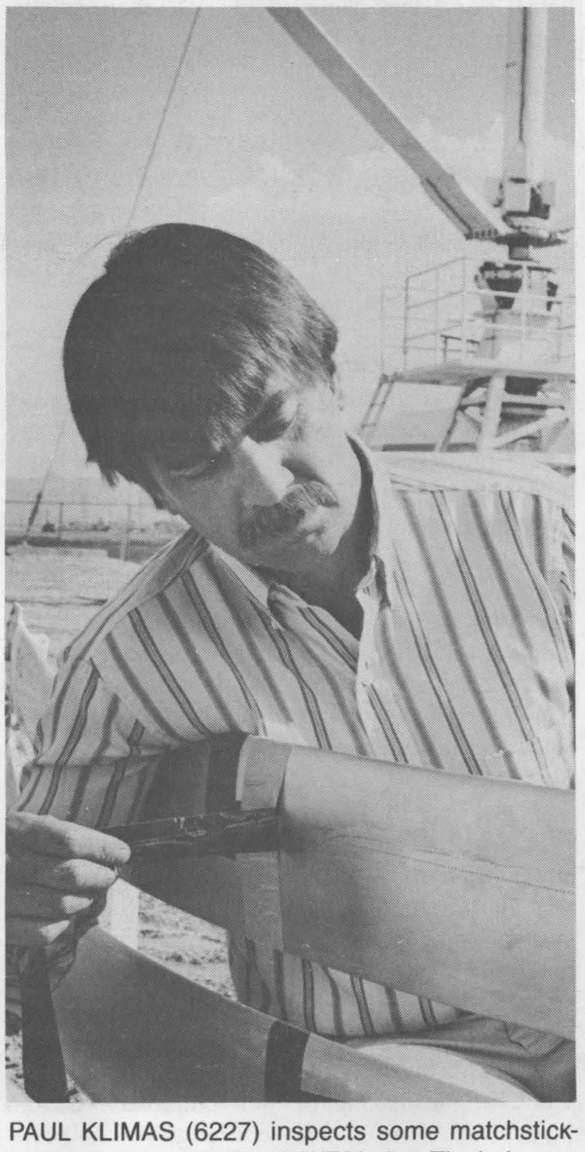
To get the wind-turbine program off to a firm start, Sandia relied on one of its strengths from weapon R&D — system analysis and integration — to determine what makes turbines tick. ''This meant we could really understand loads that went into the wind turbine, and turbine responses,'' says Emil Kadlec. ''These are crucial, not only in determining how well it performs, but also in determining how long it will perform in terms of fatigue life.

''This took a dedicated analytic effort by several Labs organizations, but we did it, and, as a consequence, we can predict what the fatigue life will be, as well as performance,'' Emil adds. ''If you can predict these, then you obviously know the variables that control fatigue life, and you can alter those variables to enhance fatigue life.

''So, with development of analytical techniques, we were able to put together a system that was cost-effective — at least, when oil prices were high.''

Emil believes that Sandia's wind-power analyses may have stimulated advances in mathematical modeling for its weapon programs — something of a reversal at a laboratory where non-defense innovation more often spins off from weapon work. VAWT modeling started about 1975, although detailed structural analysis started about three years later. Work continued through a number of designs, culminating most recently with analyses of the test-bed VAWT in Bushland.

''I believe the wind turbine program probably has benefited several non-energy Sandia programs,'' Emil says, ''by stimulating analytic activity in structural dynamics and aerodynamics. That's largely because the wind effort required analysis that could handle dynamic response.''



PAUL KLIMAS (6227) inspects some matchstick-diameter holes drilled in VAWT blades. The holes are key to a patented spoiler system that allows VAWTs to operate more efficiently in extremely high winds. Spoiler, patented in names of Paul, Emil Kadlec (DMTS, 9122), and Jack Cyrus (9122), limits torque produced by whirling blades during peak winds.

Emil says another achievement has been in popularizing use of induction generators with VAWTs. The best known generator, the synchronous variety that one might use in a recreation vehicle, is a stand-alone system that provides power as soon as the shaft starts spinning. An induction generator, by comparison, needs a kind of electrical priming — excitation. It works only when connected to a power line, and then it takes on the line's frequency characteristics, which control turbine speed. ''If the turbine tries to speed up, the increased load on the generator will tend to slow it down again,'' Emil explains.

The big advantage of using the induction generator with VAWTs is that it will tolerate surges that occur with wind variations. It's also much less expensive than the synchronous generator, and so are its controls.

High-Tech Centrifugal Blowpipe?

Yet another way of controlling the speed and power output of a VAWT came from Emil, Paul Klimas, and Jack Cyrus (9122). Patented by the DOE and called the pump spoiler, it prevents a VAWT from self-destructing in a runaway condition, and it helps achieve properly regulated power output.

Paul explains: ''If you take a hollow VAWT blade, put small holes in it near the equator, and leave the blade open at the ends, centrifugal force will pull the air in from the ends. This air, in turn, will be expelled from the center hole, spoiling the aerodynamics and slowing the turbine. The pumping action would be controlled with small valves.''

''An operating system would naturally include some computer-type logic that opens valves and spoils the aerodynamics when wind reaches a critical speed,'' Emil explains.

The pump spoiler is intended to help make wind turbines cheaper without sacrificing efficiency. ''Normally, you have to size turbine, gearbox, and generator to accept the maximum amount of power that will ever be seen at a given location,'' says Paul.

''But maximum winds occur only part of the time. Say I want to operate at from 15 to 35 mph; the pump spoiler could permit me to design the machine so it simply will not accept winds over that velocity,'' he explains.

Pump spoiling has not been incorporated into commercial wind turbines, but was the subject of experiments that Paul conducted with the help of Prof. Joe Sladky of the University of Washington.

Looking Toward the Future

''Many elements of the VAWT program are significant advances, and they're still going on,'' sums up Henry Dodd. ''In all, I repeat that our single greatest achievement has been technology transfer, which led to successful commercialization.''

''I think,'' Paul adds, ''the future looks very good for wind power, especially in the Great Plains, the Caribbean, and other places where winds average 13 to 14 mph.''

''Nevertheless, considerable problems remain. Problems with the first generation have made people gun-shy. Typically, those problems resulted when people ignored fatigue effects and the wind variability effects that just shake the hell out of these things. Easing these problems will require both improved design and improved materials.

''The Holy Grail of the moment, as always, is to reduce the cost of generating energy with wind turbines. Specially designed airfoils are going to go a long way to increasing energy production. We're also reducing operating and maintenance costs. On the other hand, the industry is not overcapitalized, and it's operating in an economically hostile environment — and will do so as long as fossil fuels stay cheap,'' Paul concludes.

Not There Yet, but Trying

Free as the Breeze

The poet James Montgomery made the simile ''free as the breeze'' famous, but the term ''cheap as the wind'' seems more appropriate for Sandia engineer Henry Dodd (6225).

Henry's division has as its primary task the challenge to make good the claim that wind power — specifically that from a vertical-axis wind turbine (VAWT) — may be the cheapest of all alternative energy concepts.

And they, with lots of help from others at the Labs, are doing pretty well. They've shown that current-technology machines (those based on the 17-metre design) can annually capture about 800 kwh per square metre of swept area (the area outlined by VAWT blades) at a good California site. Improved technologies resulting from Sandia R&D could double the annual energy capture at the California site, or make less windy areas, like the Great Plains, more economically attractive.

When the folks in 6225 speak of ''capturing the wind,'' they quite naturally do so in engineering terms. Efficiencies of wind-capture exceeding 45 percent are expected, they proclaim.

''When we're talking of wind-energy capture, we're considering how much — out of all the energy that's in a chunk of wind — is captured by the turbine,'' explains Henry. ''When you say the machine is 45 percent efficient, you're relating efficiency to useful shaft power.''

Notwithstanding, the landscape is hardly humming with eggbeater wind machines, and a number of VAWT enterprises have either failed or changed course in recent years. On the other hand, horizontal-axis wind turbines (HAWTs) have been around for centuries. Bearing this in mind, it's remarkable that 16 or 17 percent of the US-manufactured wind turbine capacity in California is represented by VAWTs.

Now that federal and state energy tax credits have been done away with, is the idea of wind power generation still a viable proposition?

''Obviously, if it were truly economic [as compared with the current cost of energy from other sources], wind-turbine power generation would be more popular,'' says Henry. ''But consider that there were about 13,000 turbines installed in California at the end of 1985, and there are now more than 16,500. That's more than 3000 installed machines and almost 400 megawatts of installed power *since* federal tax credits went away.''

The VAWT will truly make its mark when it is able to invade the wide open spaces of the Great Plains, Henry believes. But to do this, it will have to operate efficiently at wind speeds a tad lower than is currently the case.

''A good wind site in California has an average wind speed of 16 mph,'' he explains. ''The goal of the program now is to make wind turbines commercially attractive in 13-to-14-mph wind sites. This may not seem like much of a difference, but there is 50 percent more available energy at a 16-mph site, because power in the wind is proportional to velocity cubed. A more efficient turbine would make wind power economic for the Great Plains, including the panhandles of Oklahoma and Texas, as well as western Kansas.

''In terms of national impact, you have to open up areas like the Great Plains.''

Henry doesn't see wind energy and solar-thermal energy as necessarily being in competition — good solar sites are often not good wind sites, and vice versa. ''But,'' he says, '' the economics look good in those areas suited for wind energy. For example, we've seen wind machines installed for $600 to $800 per kilowatt, a very attractive figure for developing energy technologies.''

Research Goal: Less Expensive, Lighter Unit

Recharged Interest in Secondary Batteries

Nearly 200 years after discovery of principles used in the first voltaic pile, chemical technology required to make better batteries is constantly being pushed to new levels at Sandia.

That's because people hunting a safe and secure energy future know that improved secondary, or rechargeable, batteries are a must — that is, if electric vehicles, solar-energy storage systems, remotely located energy storage, and public utility load-leveling are ever to become commonplace, or even viable.

But cost-effective, highly efficient, rechargeable batteries like those being developed and analyzed at Sandia as part of a national battery-research program could become almost like gold in the event of another fossil-fuel energy crisis as severe as the one experienced in the early 70s. So it's no wonder Sandia's rechargeable-battery work attracts keen industry interest in the US and abroad.

Like other secondary batteries — the kind used in automobiles, for example — those of interest to Sandia rely on reversible electrochemical reactions so they can be charged and discharged repeatedly for long-term use (see "Inside a Rechargeable Battery"). Primary batteries, like those typically used in flashlights, lose charge during use and cannot be recharged.

Automobile batteries are fine for their purpose. They're relatively simple, inexpensive, and based on well-developed lead-acid technology. However, the car battery's main drawback is weight — it's very heavy for the amount of energy it stores, which severely limits its use for other applications.

New and developmental rechargeable batteries that interest Sandia are a breed apart from conventional rechargeable batteries that sit under car hoods. They have to be unusually long-lived, high-performance systems that will operate with high reliability and at low cost.

Good and Bad News

Since Sandia's advanced rechargeable-battery program began in 1981, technical progress has been encouraging. But the lack of markets, which could flip-flop almost overnight, and the low-cost requirement, which researchers have so far been unable to satisfy (though they're optimistic), remain big stumbling blocks for now. So, at least for the time being, advanced rechargeables are expensive compared to conventional lead-acid batteries.

In the US, various advanced rechargeable-battery technologies are being identified, nurtured, and demonstrated (and sometimes eliminated from further consideration) under the aegis of the Exploratory Battery Technology Development and Testing (ETD) Project (sponsored by DOE's Energy Storage and Distribution Office).

Typically, ETD approaches development by placing DOE-funded contracts with private industry. As ETD's lead lab, Sandia provides technical supervision, guides industry's work, tests industry's prototypes, and generally fills the gap between basic electrochemical system R&D (under Lawrence Berkeley Laboratory's Technology Base Project) and industry's product engineering capabilities. Additionally, Sandia undertakes specific studies to resolve intractable problems that appear during development.

The Labs also receives funding from DOE's Office of Transportation Systems (OTS) to support battery development for specific electric vehicle applications.

Sandia Albuquerque, one of DOE's "public-site operators" since 1983, has collected data on 7 to 11 electric vehicles assigned to routine transportation tasks around the Labs. "Our fleet has covered about 63,000 miles and consumed about 50,000 kilowatt-hours of energy," says Dick Bassett (2565), who heads the program for Sandia. "But lead-acid batteries give us a range of only 35 miles per charge. We certainly see the need for better batteries, ones that could at least double or triple that range."

Nick Magnani, manager of Power Sources Dept. 2520, directs ETD's lead-center activities. Project manager Ron Diegle, supervisor of Storage Batteries Div. 2525, is assisted by a complement of staff members, including those who have managed discrete elements of the program — Ken Grothaus (technology development), Paul Butler (technology evaluation), Jeff Braithwaite (technology improvement), and Kevin Murphy (budget and analysis, until his recent transfer to 2100).

Battery science and technology is something of a tradition at Sandia, because of the nuclear weapon program's critical need for energy supplies that will "turn on" decades after they've been put into stockpile. But the small, super-reliable calcium- or lithium-based thermal energy sources typically used in weapons are reserve-primary batteries — they're good for just one shot.

An initial ETD goal is to develop battery modules capable of storing about 50 kwh of electrical energy, or enough to provide electrical needs of a typical Southwestern US home for about four days.

Building Blocks for Load-Levelers

These modules are building blocks for batteries with up to 100-MWh storage capacities that would be useful for electrical utility load-leveling. Load-leveling involves storing excess energy at low-consumption periods so it is available during high-consumption periods when electrical generation shortfalls could occur.

Although the popularity of electric vehicles goes up and down with gasoline prices, rechargeable batteries obviously could be (and sometimes already are) used to power electric vehicles. That's an additional ETD interest.

A primary reason for the Labs' ETD connection is its interest in solar photovoltaic (PV) energy systems. When PV arrays can't be hooked to a utility grid, they must be connected to batteries that store energy for nighttime use. In fact, Sandia's initial involvement with rechargeable batteries was for solar energy storage. "These are stand-alone PV systems that are not connected to the power grid," Nick explains. "They primarily address Third World-type applications."

Before recently becoming 2100's administrative assistant, Kevin Murphy performed basic system analyses for ETD. He looked at rechargeable-battery systems, matched them with end-use applications, and finished up with the economics.

"A substantial load-leveling market may exist by the mid-90s," he says. "Several US studies indicate there could be an electrical generation shortfall by then. Because of this, we intend to have a technically viable, commercially available system ready by that time.

"Between now and the middle of the next decade, I think utility companies are going to change a lot," Kevin continues. "They'll be under lots of pressure, because projected generating demand looks like it's going to pick up — although this is very sensitive to economic growth in general. Also, utilities may not be bringing on new capacity as fast as old facilities must be retired. For example, many nuclear plants are old and will have to be decommissioned," Kevin says.

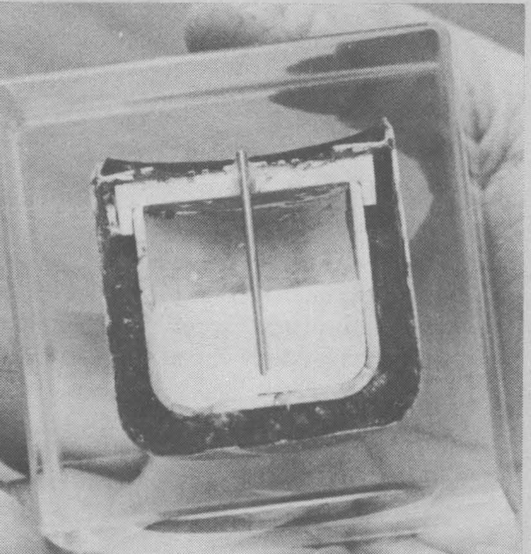
(Continued on Page Twelve)

Inside a Rechargeable Battery

A rechargeable battery is an electrochemical energy-storage device that operates by means of reversible oxidation-reduction reactions.

On discharge, chemical energy contained in the cell's active materials that are oxidized and reduced is converted into electrical energy. A power supply, used to charge the battery, restores the active materials to their original condition.

In many rechargeable batteries, electrode materials are solid and the electrolyte is liquid. However, the sodium/sulfur type (which researchers generally agree holds tremendous potential) and some other high-temperature batteries reverse the relationship.



CUTAWAY of a typical sodium/sulfur rechargeable battery imbedded in plastic. Dark U-shaped section is sulfur electrode; white material in center is sodium electrode that surrounds metallic rod terminal. Thin gray "U" between electrodes is beta-alumina electrolyte/separator.

Whether they have liquid or solid electrodes, rechargeable batteries have many common components. The major parts of a typical sodium/sulfur cell include:

- A negative electrode (sodium) that is oxidized during discharge, and an inert conductor that ends in a terminal (metal rod);
- A positive electrode (sulfur) that is reduced during discharge, and a current collector (the metal case and compressed carbon felt within the sulfur);
- A ceramic beta-alumina electrolyte that facilitates charge transfer between the positive and negative electrodes through ion conduction;
- A separator, or membrane, to physically separate electrodes (electrolyte can also serve as the separator); and
- A case that maintains proper mechanical alignment of cell components and allows safe handling.

During discharge, sodium oxidized at the beta-alumina interface forms positive sodium ions that travel through the electrolyte and combine with the reduced sulfur in the positive electrode to form sodium polysulfides. Carbon felt makes the sulfur electrode conductive.

There are other notable characteristics of rechargeable batteries. Electrodes can be pure materials, alloys, or composites. In some rechargeable battery systems (zinc/bromine, for example), two different aqueous electrolytes are used: one optimized for the positive electrode, and one for the negative electrode.

In cells containing solid electrodes and a single liquid electrolyte, a separator improves mechanical stability of the cell and prevents shorting out caused by the growth of metal dendrites. With liquid electrodes and two electrolytes, the separator also prevents undesirable mixing of liquids. •RG

(Continued from Page Eleven)

Batteries

ETD is a technology-transfer natural. It's designed to provide technical program management of private-sector contractors, under cost-sharing contracts that encourage commercialization.

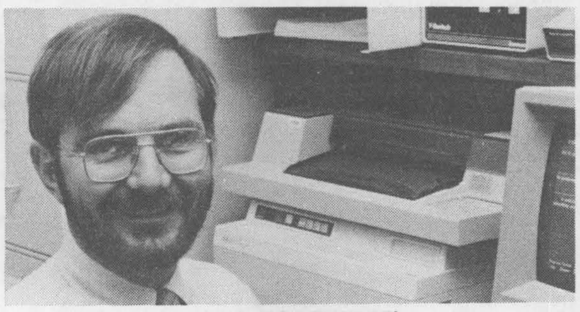
Rechargeable battery technologies that have been and still are of interest to Sandia and ETD include:

Sodium/Sulfur — This system has a molten sodium anode and a molten sulfur cathode, separated by a solid ceramic beta-alumina electrolyte. Cells are connected in series-parallel arrays. Operating temperature is 300-350°C.

In 1985, Ford Aerospace and Communications Corp. (FACC) completed 32 months of operating a 75-kwh stationary sodium/sulfur load-leveling module. Sodium/sulfur systems can potentially store three to four times more energy per unit of weight than conventional lead-acid batteries. In 1986, Chloride Silent Power Ltd. (CSPL) took over the work from FACC. CSPL hopes to produce a 50-kwh module of advanced design as a building block for a 500-kwh system, which, in turn, would guide development of batteries with capacities as large as 100 MWh. That's enough electricity to power 8000 typical Southwestern US homes for one day.

Recent technical achievements involve manufacture of an improved beta-alumina (composed primarily of aluminum oxide and sodium oxide) electrolyte and production of large quantities of reliable cells (see "Battery Advances Clearly Occurring").

Zinc/Bromine — This is a flowing-electrolyte system that promises good performance at a projected capital cost as low as $75/kwh of installed capacity. Most of the active materials are stored externally in



RON DIEGLE (2525)

liquid electrolyte and then pumped into the power-conversion stack as needed. This system, like all flowing-electrolyte batteries, easily dissipates heat generated by electrochemical reactions. Also, electrolyte is easily renewed, and the system suffers virtually no capacity loss with increasing cycle life. However, flow batteries like the zinc/bromine models are mechanically complex and generally less energy-efficient than other technologies.

Zinc/bromine technology is being developed and transferred through contracts for electric-vehicle use with Johnson Controls, Inc. (JCI) and for stationary use with Energy Research Corp. (ERC). Performance of a flow-through electrode developed by ERC has been improved, and bigger battery stacks using very large electrodes are being designed. The JCI effort is a continuation of the zinc/bromine electric-vehicle program, initiated with Exxon.

(Sodium/sulfur and zinc/bromine batteries are currently being designed for use in an experimental Ford Aerostar electric van.)

Nickel/Hydrogen — These batteries, usually configured as single, hermetically sealed, maintenance-free cells, have particularly strong staying power. Also, compared to other batteries, the nickel/hydrogen system performs very well at low temperatures. Tests have shown that, at -40°C, capacity was about 75 percent of room-temperature capacity. Discharge voltage decreases at the low temperature, but there is no loss of capacity.

Already, an aerospace version has been charged and discharged 7000 times without maintenance, simulating 20 years of operation. Now ETD has turned to private industry — COMSAT Laboratories and JCI — to solve a problem. The aerospace nickel/hydrogen system is one of the most expensive rechargeable-battery technologies, about $25,000 per kilowatt-hour of installed capacity. Nick reports that COMSAT and JCI now have a terrestrial design that is one-twelfth as expensive as the aerospace version. By using a number of cells in a single pressure vessel, costs could be further reduced by 75 percent.

An ongoing Sandia experiment involves what is believed to be the world's largest terrestrial-use nickel/hydrogen battery. Made by JCI, it's rated at 7 kwh. Since January, the battery (located in Bldg. 833) has been alternately charged by a PV array just east of Bldg. 833 and drained to simulate nighttime use. During 1989, the experiment will change somewhat. The battery, still charged by the solar cells, will power a portable refrigerator.

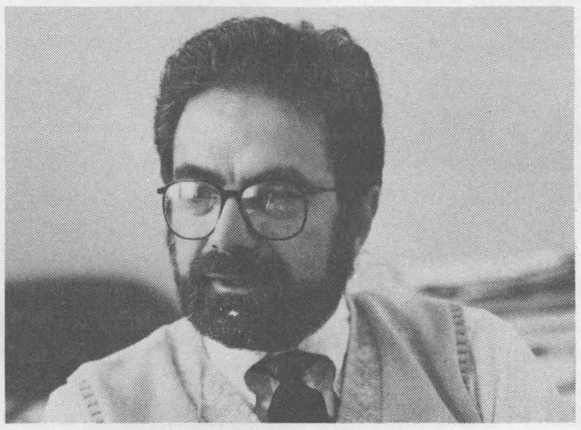
"Our tests are convincing us that this battery is ideal for remote solar-energy applications, such as powering a refrigerator used to store medical supplies in areas with no other sources of electricity," says Don Bush (2525).

"Unlike conventional lead-acid batteries connected to photovoltaic arrays," Don says, "this solar cell-nickel/hydrogen battery combo does not require a controller to disconnect the two components when the battery is fully charged."

The advanced secondary battery research list doesn't stop here. One promising new entrant is the aluminum/air system, which features a long-lived air cathode. ETD contracted with ELTECH, Cleveland, for development of a low-cost, long-life, mechanically rechargeable aluminum/air system for electric vehicle applications. Major remaining obstacles include identifying the best aluminum alloy to use as an electrode and designing the system for better efficiency.

Sandia has completed work on a sealed, maintenance-free, lead-acid rechargeable designed to store energy collected by PV cells (see "A Solid Case of Technology Transfer"), and on an iron/chromium system — called a REDOX (reduction/oxidation) battery — which was under development at the National Aeronautics and Space Administration's (NASA) Lewis Research Center for 10 years. Sandia also supported, albeit to a lesser degree, development of zinc/ferricyanide battery technology, at Lockheed (see "Just Call it Smart Plastic"). Additionally, the Labs keeps abreast of developments in other storage systems, ranging from fuel cells to those using lithium/metal sulfides or sodium/metal chlorides.

"There's still no clear winner in the secondary battery stakes," Ron Diegle says. "Each system has attributes and areas that need improvement. Substan-



NICK MAGNANI (2520)

tial progress has been achieved, but R&D is needed to bring technologies to the marketplace."

Nevertheless, Nick, Ron, and colleagues are convinced that, somewhere out there in the future, there's a battery that will power an electric car from zero to 55 mph in 20 seconds, another that will discharge 10 MW of off-peak surplus electrical power for up to five hours, and yet another for solar application that will store up to 40 kwh of electrical energy for as much as 30 days at a stretch.

Advanced rechargeable batteries are still waiting for their time, but, as Nick points out, "You could have something happen in the Persian Gulf that would change that situation very quickly, and batteries of this type would be in immediate demand.

"If something happens like that, it would be a real shock to the American public. Europeans and Japanese are making substantial progress in their secondary battery programs. It's important that the US maintain a competitive position in these technologies. If this country's secondary battery efforts don't produce results, we could end up buying from Japan or West Germany," Nick says.

"So, in a sense, ETD development work at Sandia and elsewhere on rechargeable batteries is insurance. We want to have these activities under way, so that we will have a chance when an energy crunch comes." •NH

Just Call It Smart Plastic

It's called sulfonated polysulfone.

It looks like cellophane, but in chemical terms it's a "smart plastic." No one figured out quite how useful it could be in electrochemical systems until Sandia arrived on the scene.

For some time, the most serious drawback to a promising idea for a new kind of rechargeable battery was its high projected cost. Then Charlie Arnold (DMTS, 1811) and Roger Assink (1812) recognized that sulfonated polysulfone might help get the expensive battery off the shelf and into action.

These inexpensive, flimsy-looking plastic sheets have some remarkable properties. They're highly conductive. They're corrosion-resistant. And, perhaps most important of all, they act as a traffic cop to ions.

Semipermeable Membranes

In other words, they're semipermeable membranes. This means that they can be used to separate battery electrodes, allowing positively charged ions to flow from one side of the cell to the other, while shutting out deleterious negative ions.

This job could be done before, but only with a material that costs about $70 a square foot. The same amount of sulfonated polysulfone costs about $5.

The bad news, if it can be called such, is that the battery system for which sulfonated polysulfone was developed — zinc/ferricyanide — has been shelved by the DOE-funded Exploratory Battery Technology Development and Testing (ETD) Project. Its main competitor, zinc/bromine, was too far ahead in technical development to keep both projects running. The good news is that sulfonated polysulfone, or a similar material, might prove useful for the promising zinc/bromine system.

"This inexpensive membrane has a real potential impact there," says Jeff Braithwaite (2525). "But we haven't yet determined if it really can be used for extended time periods."

Why is a membrane needed in the first place?

In a conventional electrochemical cell, two plates (one positive, one negative) are submerged in a liquid electrolyte. An electrochemical reaction causes a potential, so that when a load — a car's ignition system, for instance — is connected between the two plates, electrical energy will flow through the resulting circuit. At this point, positive or negative ions (depending on the battery type) flow through the electrolyte.

By contrast, there are two electrolytes in some advanced rechargeable batteries. Hence the need for a separator of some kind — for instance, a membrane in the zinc/bromine battery that will allow passage of positive zinc ions, while flagging down negative bromine ions.

Meanwhile, Charlie and Roger still are searching for exactly the right kind of "smart cellophane." As Charlie says, "The preliminary results are encouraging, but we're not quite there yet."

Despite Different Research Approaches

Battery Advances Clearly Occurring

Because of philosophical differences in R&D approaches that exist between US and foreign researchers, progress in development of advanced rechargeable batteries has become a matter of perspective.

The bottom line worldwide, however, is positive because advances are clearly being made in marketability, on the one hand, and in pure technical understanding of these complex and very important devices, on the other hand, reports Jeff Braithwaite (2525).

While Western European and Japanese companies continue to vigorously pursue applied research with an eye toward early successful commercialization — electric vehicles in Europe and electric utility load-leveling in Japan — US government funding agencies, businesses, and researchers are looking with a more critical eye at the inner workings of advanced rechargeable batteries.

Before technologies like rechargeable batteries can ever be expected to reduce the transportation sector's dependence on the internal combustion engine, the public and researchers must come to grips with a vital question: When will we want it and when will we need it? That's according to Jeff, who manages the technology-improvement component of this country's Exploratory Battery Technology Development and Testing (ETD) Project, DOE. "And frankly, right now electric vehicles are not economically competitive with gas-powered units, and they don't have the performance people want," he says. "Those facts seem to be driving US R&D along a logical path for the time being — developing detailed technical understanding and conducting solid baseline research of rechargeable batteries."

Historical Perspective

On the other hand, many foreign researchers, like those at the Swiss electrical giant Asea, Brown, Boveri (ABB), have moved with the times to keep advanced engineering development on the front burner. "That explains why European companies probably will create the first viable markets for electric cars," predicts Jeff, who adds a little historical perspective:

"Back in 1985, ABB had a staff of about 100 dedicated to the basic development of single sodium/sulfur cells," he recalls. "But, now that ABB has greatly improved cell performance and production capabilities, it concentrates on development and design of full-size electric vehicle batteries."

Additionally, the company recently switched its sales pitch on rechargeable batteries from one of economy to the stance that electric vehicles don't pollute the urban environment. "Back in the early 80s, they were looking at electric vehicles because of oil prices, but now it's pollution. Later on, as oil becomes more expensive, economics will come back into the picture," Jeff explains.

ETD work on sodium/sulfur battery development also is proceeding, but the approach clearly is different from that found in Western Europe and Japan. Both Sandia and subcontractor Chloride Silent Power Ltd. (CSPL) report progress on more basic development issues that they believe must be resolved before rechargeable batteries will ever be widely used worldwide.

CSPL points to impressive improvements in cycle life for both cells and battery modules (a collection of cells). As recently as three years ago, the sodium/sulfur industry was having trouble reliably achieving enough charge/discharge cycles to make extended lifetimes feasible. Now, lifetimes are exceeding 1000 cycles, which means that a typical rechargeable battery system in a commercial delivery van could operate reliably for several years.

During the past five years, Sandia has been contributing its strong engineering and system analysis skills to ETD projects.

Beta-Alumina, A Name to Remember

For example, a Labs evaluation showed that a breaching of ceramic-to-metal seals on the top of sodium/sulfur cells always kills cells. As a result, the seal was redesigned.

Another problem Sandia is still investigating is premature cell failure due to thermal cycling. Researchers identified the culprit-component to be its ceramic beta-alumina electrolyte. This brittle material can fracture following thermal cycling. As a result, the liquid sodium and sulfur mix, destroying the cell.

To understand the cause of this mysterious death following thermal cycling, Sandia designed and built several laboratory sodium/sulfur cells. Researchers were then able to look more closely at stresses that occur when reactants alternate from 25°C (77°F) solids (when the battery is dormant) to 350°C liquids (when it is in use).

During the coming year, an important part of Sandia's ETD work will be to use its research findings of the past several years to refine the thermomechanical model of sodium/sulfur batteries. With that updating, the model can then be used with confidence to redesign reliable commercial cells.

Different Types for Different Uses

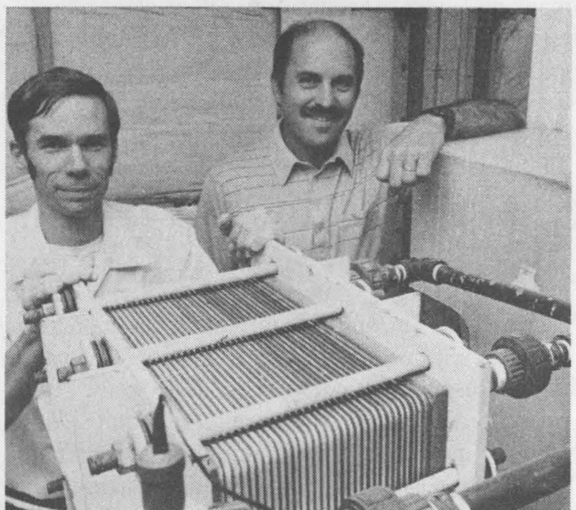
"Although the sodium/sulfur secondary battery system appears to have some nice performance characteristics, and is unquestionably a better performer than zinc/bromine when it comes to automotive use, zinc/bromine might yet be the technology of choice for large-scale utility load-leveling," says Nick Magnani, manager of Power Sources Dept. 2520.

"However, zinc/bromine is a complex system with flowing electrolytes, pumps, and a very dynamic chemistry. But if you start visualizing a very large battery system, zinc/bromine might be the most cost-effective choice, even though durability and energy efficiency will need improvement.

"A big battery plant capable of providing several hundred megawatt-hours of electrical power is a very complicated system," Nick continues. "But refining petroleum products requires a very complex system, too. Energy Research Corp., which has a large zinc/bromine development contract, already is looking into this type of system."

"By the end of next year," says Jeff, "we will have a prototype module of a load-leveling plant — small, compared with what will eventually be needed — that will allow us to analyze its effectiveness. If justified, we will then proceed with a significant scale-up program.

"Basically, we would like to see a customer — a domestic utility, in this case — become actively involved, to keep technology development alive," Jeff adds. "We probably can't continue with just government support for the six to seven years that are needed for final development. We need to identify an entry or niche market to entice industry to take over. This is probably the most favorable way to proceed."



BLDG. 833 IS HOME for a prototype zinc/bromine load-leveling battery, which has 30 cells and a 125-amp-hr. capacity. Paul Butler (left) and Jeff Braithwaite (both 2525) stand behind the battery, which requires external tanks to hold liquid electrolyte that flows through cells during operation. Paul is next to cell array; Jeff leans against one of two electrolyte storage tanks.

Solid Case of Technology Transfer

The lead-acid battery, because of its wide commercial availability, has been a baseline against which advanced rechargeable batteries are compared. However, required maintenance of this relatively old design generally makes it unacceptable for applications other than cranking car engines.

But in 1980, Sandia and Gould Laboratories got together to start changing that.

Direct descendants of prototypes that resulted from the Sandia/Gould research, development, and testing collaboration are now available from GNB Batteries, a corporate spin-off from Gould.

They are sealed, maintenance-free, lead-acid batteries that have performance characteristics not considered possible earlier.

Generally only slightly larger than auto batteries, they are capable of deep-discharge cycling, eight-hour nominal recharge, and operation and storage in a less-than-fully-charged condition.

They boast a five-to-seven-year life, based on daily deep discharge; a weekly self-discharge rate of one percent or less at temperatures between 25°C (77°F) and 50°C; operation over a temperature range of -17°C to 50°C; and ability to survive an open circuit stand (no load) in fully discharged condition at 50°C for a month.

"Because of these unique performance characteristics, they are particularly well suited for photovoltaic applications," says Don Bush (2525), who evaluated prototype batteries as Sandia/Gould development proceeded.

"A typical use would be in conjunction with an array of photovoltaic cells located in remote areas," Don continues. "During sunny days, the array converts sunlight directly into electricity, providing power and charging the batteries. At night or during cloudy periods, the batteries would be discharged to provide electricity."

Cells of these advanced lead-acid batteries resemble those of a car battery — positive and negative electrode plates with separators between them to prevent shorting — but they have very different electrolyte systems.

A car battery uses a flooded electrolyte with electrodes and separators submerged in liquid sulfuric acid electrolyte. The new batteries use an immobilized "starved electrolyte" that's key to its maintenance-free character and long life.

In "starved" systems, the amount and concentration of electrolyte are carefully controlled during fabrication so that sufficient acid is available to achieve the desired capacity without completely saturating the porous separator between electrodes.

All available acid is immobilized by absorption in the highly porous separator, leaving no free electrolyte and enabling the batteries to be operated in any position.

Void space in the separator allows passage of oxygen from the positive to negative electrode, where the gas is quickly reduced to water. Oxygen buildup is therefore prevented. At the same time, the negative active material oxidizes, keeping the negative electrode partially discharged and preventing hydrogen gas generation. This "oxygen cycle" virtually eliminates water loss from the battery. •RG

Cost Goals Within Sight

Photovoltaics Gaining Place in Sun

There really should be another word for photovoltaics — it's hard to pronounce, and defies precise definition.

But perhaps the same was said of the word *petroleum*, 50 years ago before it evolved to mean oil and gasoline and heavy industry — in short, before it became synonymous with *energy*.

The folks in Solar Energy Department 6220 — some of whom began researching photovoltaics even before *petroleum* also became synonymous with *energy crisis* — avoid the tongue-tangling problem by using the acronym, PV.

They would like to see PV evolve to mean a special kind of energy — a safe, dependable, nonpolluting energy based on a free, inexhaustible fuel that is immune to trade embargo and is unaffected by cycles of supply and demand.

The fuel is simple sunlight. Photovoltaics is the technology that converts sunlight directly to electricity by means of noiseless, lightweight solar cells (see "SOLAR CELLS" drawing, page 16).

The technology isn't new — solar cells have been providing electricity for satellites for almost thirty years now. And, as a result of work by Sandia and other researchers, photovoltaic-generated power has been chilling vaccines, pumping water, and powering electric lights in some Third World countries for several years. For even more years, PV has been powering railroad-crossing lights, harbour buoys, and isolated monitoring equipment — as well as consumer gadgets such as watches and calculators, now being produced in the millions each year.

What *is* new is that the technology is now approaching the stage at which million-watt plants can ultimately be built to produce electricity that is economically competitive with that produced by fossil fuels and nuclear energy, perhaps as soon as the mid-90s.

Breaking Barriers

This progress stems from recent breakthroughs in the efficiencies at which solar cells convert sunlight into electricity — and from other developments that have reduced the cost of photovoltaic-generated electricity.

One of the more impressive improvements is the 31-percent-efficient multijunction concentrator cell demonstrated recently by Photovoltaic Cell Research Div. 6224 (LAB NEWS, Aug. 26, 1988).

This is the latest of a number of achievements in the drive to bring down the cost of photovoltaic power to DOE's long-term goal of 6 cents per kilowatt-hour — the cost at which photovoltaic-generated power will be fully competitive with the cost of conventional forms of power.

"Breaking the 30-percent-efficiency barrier in the laboratory with highly advanced experimental cells gives us a glimpse of the exciting possibilities for the future of PV," says Don Schueler, manager of Solar Energy Dept. 6220.

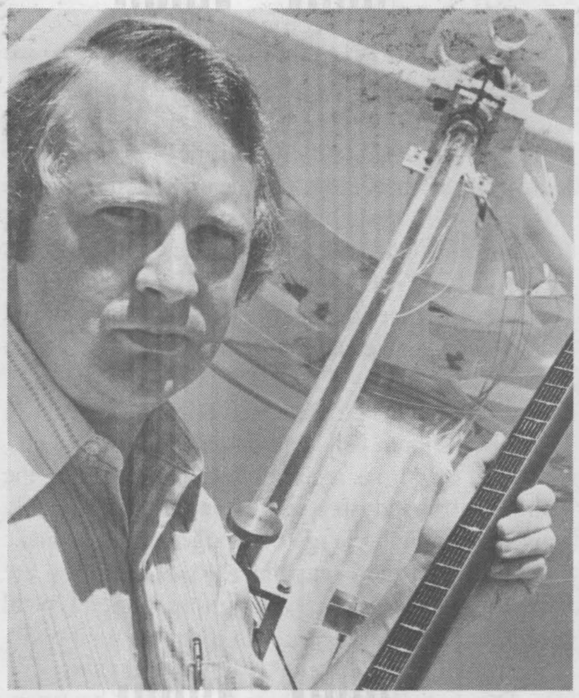
"In the meantime, steady progress is being made on more conventional cells and modules that will play a major role — in the near term — in the development of photovoltaics for the large-scale generation of economically competitive electricity."

"The efficiencies demonstrated recently by a number of conventional silicon cells put us squarely within the range needed to achieve module efficiencies of 20 percent — that's the module efficiency we need to meet DOE's *intermediate* goal of 12 cents per kilowatt-hour," says Dan Arvizu, supervisor of Photovoltaic Cell Research Div. 6224.

Twelve cents per kilowatt-hour — the value of electricity during peak-demand periods for many utilities — represents a reasonable market entry point for PV, says Dan.

Still Some Challenges

But photovoltaic power plants aren't going to be springing up overnight.



DURING EARLY DAYS of solar R&D, Don Schueler (6220) and others were interested in determining feasibility of integrated solar collectors to produce both electricity and heat. Here, Don holds equipment for such a system — a special receiver tube with silicon solar cells mounted on its surface.

"It's important to distinguish between experimental cells and 'module-ready' cells," says Eldon Boes, supervisor of Photovoltaic Technology Division 6221. "Sometimes it's a long step from achieving an efficiency with an experimental cell to achieving a comparable efficiency in one that's module-ready — ready to be connected to other cells and installed in a module.

"Module-ready cells generally need to be considerably larger in area than experimental cells, and they need to be fabricated in a way that makes them readily mountable into assembly packages — without losing the high efficiencies. And cell manufacturers have to be able to duplicate laboratory results in the mass-production setting."

That's no small step. The 28 percent efficiencies achieved in the laboratory more than two years ago have not yet been achieved in module-ready cells: "Module-ready silicon concentrator cells with efficiencies above 23 percent are still not commercially available to module manufacturers," says Eldon, "but that figure — 23 percent — is important because, after optical and electrical losses, it still permits module efficiencies of 20 percent.

"Of course," he notes, "the higher the efficiencies you get in the cells, the higher the efficiencies, proportionally, you're going to get in the modules."

Bringing Down Costs

Closely related to efficiency is cost — the single factor that has delayed the advent of large-scale generating plants based on photovoltaic power.

In 1975, when Sandia received its first funding under DOE's National Photovoltaic Program, the cost of electricity produced by photovoltaic systems was approximately $3 per kilowatt-hour; the cost of electricity generated by fossil fuels and nuclear energy was from 2 to 10 cents per kilowatt-hour (see "Photovoltaics: From Space to Earth").

This sharp difference spurred a tremendous research and development effort by industry, universities, and DOE's National Photovoltaics Program. Today's costs range from 25 to 35 cents per kilowatt-hour — a more than 10-fold decrease since 1975.

Lower costs permit photovoltaics to be used economically for a wide range of applications in remote regions not readily serviced by a utility grid — in the US and around the world. For now, sales of remote-site photovoltaic systems are "paying the rent" — providing the technical and financial base necessary to support continued advances in the technology.

"But," says Don, "if photovoltaic electricity is to be a truly viable energy-supply option in the 90s, its cost will have to be on a par with other utility-supplied electricity."

One-Sun Cells

From the start, Sandia's photovoltaic research program has been working toward this goal by developing specially designed high-efficiency cells to be used with low-cost optics to concentrate the sunlight. The recent breakthroughs into higher conversion rates have been achieved with concentrator cells.

But advances are also being made with the workhorses of photovoltaic systems — non-concentrating, or one-sun cells — which have been reliably cranking out power since the mid 70s.

Their efficiencies are lower because they don't use concentrators — but their costs are also lower.

"And sometimes lower efficiencies combined with lower costs can be as viable as higher efficiencies combined with higher costs," says Dan.

A recent consolidation of DOE's Photovoltaic Research Program has given Sandia a larger role in the continuing research and development of one-sun cells, as well as the opportunity to review the progress of research in one-sun cells.

Dan cites the outstanding progress made in DOE/Sandia sponsored work at the University of New South Wales (Kensington, Australia). Researchers there have developed a larger-area (45 cm^2) one-sun silicon cell that achieved 19.6 percent efficiency — and a batch of them, fabricated for assembly into a prototype module, demonstrated an average encapsulated efficiency of 19.2 percent.

"Preliminary measurements on a mini-module using these cells indicate that the total-area efficiency will clearly establish a new module efficiency record, perhaps exceeding 16 percent, for a module using one-sun silicon cells," says Dan.

"This would put one-sun cells in the running for achieving the near-term goal of photovoltaic-generated electricity at 12 cents per kilowatt-hour. But I believe that to get the higher efficiencies and lower costs required to meet the long-term goal of 6 cents per kilowatt-hour, we'll have to turn to concentrator technology."

Concentrating on Concentrators

The big advantage of concentrator systems is that less silicon, which is expensive, can be used. Instead of letting "one sun" fall on a silicon surface, multiple suns are focused on much smaller cells, but net output from the array remains the same. Energy conversion efficiency also improves with intensity.

Concentrating cells are therefore more efficient than one-sun cells, so the entire light-gathering system — the so-called aperture area — can be smaller for a given power rating. Costs are lower because inexpensive concentrators — usually plastic Fresnel lenses — cost less than the additional silicon required for one-sun cells.

But considerations of efficiency are not entirely clear-cut. Concentrating cells, for example, also operate with high currents, so electric resistance losses become more important. Designing around these characteristics means that concentrator cells are more complex and costly per unit area than one-sun cells.

"Despite their complexity," says Dan, "high-intensity solar cells for concentrator systems do not increase in cost in proportion to their concentration ratios — you can double the concentration ratio without doubling the cost — so the cost of the cells accounts for a smaller fraction of the total cost of the module. Concentrating cells account for less than a third of the total cost of the module, one-sun cells for about half."

Today's typical commercial concentrator systems use silicon cells that were first demonstrated in the laboratory in 1980. Typical efficiencies of the

(Continued on Next Page)

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Place in Sun

cells are approximately 20 percent at a concentration of 100 suns.

But research, either fully or partly funded by Sandia, is brightening the outlook for higher efficiencies and lowering the costs of silicon-based concentrator systems, Dan believes.

For example:

- Researchers at Stanford have demonstrated an experimental silicon concentrator cell that is 28.2 percent efficient at 140 suns.
- Stanford has also produced a prototype module-ready silicon cell with 27.2 percent efficiency at 100 suns.
- Researchers at the University of New South Wales have demonstrated a module-ready cell that is 25.2 percent efficient at 125 suns.

"A couple of percentage points difference may not sound like a lot," says Dan, "but an increase of just two percentage points can lower the allowable cost of a module by 25 percent. The near-term goal is to achieve silicon cells that are nearly 30 percent efficient."

Advanced High-Efficiency Cells

Dan is also optimistic about the future of so-called advanced high-efficiency solar cells — cells made of III-V materials (compounds from Group III and Group V in the Periodic Table of Elements) — such as gallium arsenide.

"Concentrator modules developed for silicon cells can be readily adapted to use these cells," he says. "Today gallium arsenide is roughly ten times more expensive than the most highly refined silicon, but gallium arsenide cells have potentially higher efficiencies than silicon cells and can be operated at higher light concentrations. As progress continues, these features will be evaluated on a cost vs. performance basis against silicon.

"We don't really expect research on III-V cells to pay off in the short term, but long term is something else."

Varian Associates (Palo Alto, Calif.), for example, recently fabricated a gallium arsenide concentrator cell with an efficiency of 28 percent, later increased to 29 percent by use of a special optical prism cover that diverts light that would otherwise fall on the metal grid onto the cell.

"That's a new record for a single-junction cell," says Dan. "Gallium arsenide cells offer great potential, especially for multijunction cells."

Multijunction cells achieve higher total conversion efficiency by making better use of the solar spectrum. For example, Sandia's record-breaking, 31-percent-efficient cell is described by principal investigator James Gee (6224) as "a mechanically stacked, multijunction solar cell." His team achieved the high efficiency by stacking a gallium arsenide cell developed by Varian atop a silicon cell developed by Stanford. (Sandia was involved in both developments.)

Another fabrication technique consists of *growing* a high-band-gap material (a material that absorbs light from the high-energy part of the light spectrum) on a material with a lower band gap.

"Our analysis indicates that two-junction stacked cells can achieve efficiencies up to 40 percent," says Dan. "We plan to keep pushing for higher efficiencies because we believe these high-efficiency cells will be to tomorrow's high-performance concentrator systems what 1980-vintage cells are to today's concentrator systems."

Concentrator Module Research

Module development, especially those modules using one-sun cells, is a major responsibility of the photovoltaic industry. But research on concentrator modules is inherently more complex (requiring the integration of lenses, cells, cell assemblies, and interconnects), so Sandia is working closely with industry to design and develop these advanced modules.

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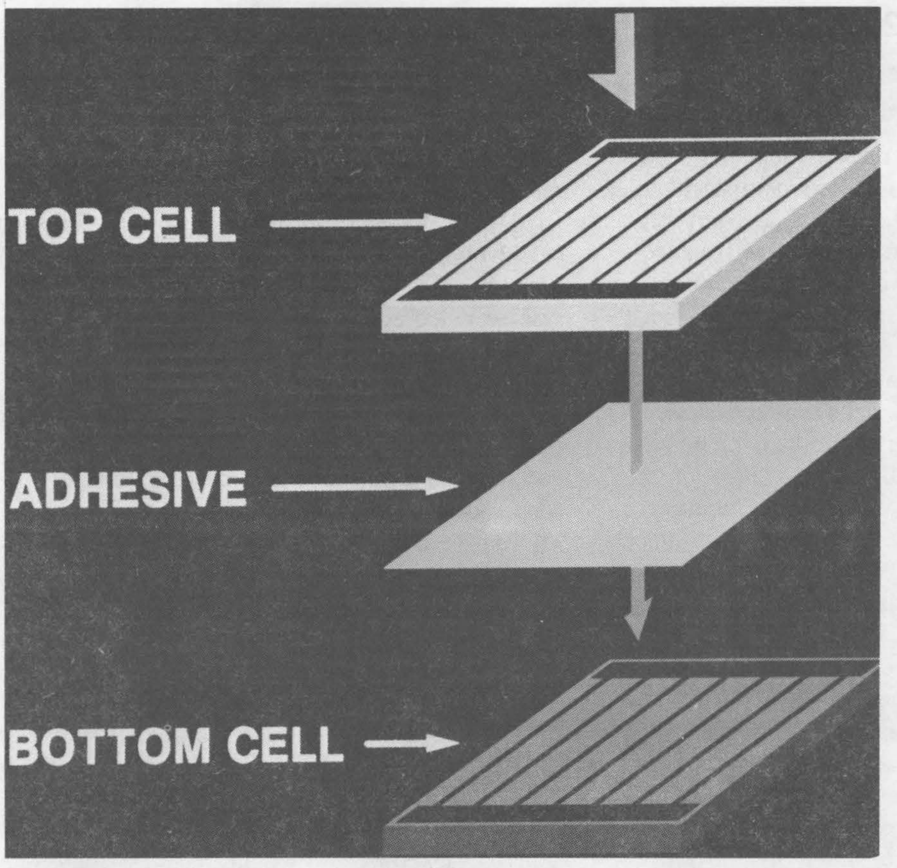


MECHANICALLY STACKED SOLAR CELL, shown in this diagram, is the result of work begun at Sandia in 1984. The top cell (gallium arsenide) captures solar energy from the high-energy (blue) part of the spectrum, while the bottom cell (silicon) absorbs energy from the low-energy (red) portion. The new composite cell has attained the highest-ever PV conversion efficiency — 31 percent — in lab tests.

Unique Mission

PV Research Labs at Sandia

Two special laboratories will soon be supporting Sandia solar cell research programs — one is not so new, the other is brand-new.

The not-so-new Photovoltaic Device Measurement Laboratory (PDML) in the basement of Bldg. 823 is a world-class facility for measuring and characterizing photovoltaic cells to identify their performance and limiting mechanisms.

"The instrumentation for this lab has been assembled over the past ten years," says Dan Arvizu, supervisor of Photovoltaic Cell Research Div. 6224. "And many people over the years have developed the test procedures."

The PDML can perform measurements such as light current-voltage curves with up to 1000 suns illumination, dark current-voltage curves with a variable ramp to avoid cell heating at high currents, spectral response, hemispherical reflectance, capacitance-voltage, transient response to electrical or optical excitation for determining recombination parameters, and scanned laser-beam-induced current. These measurements are all useful in determining the performance and loss mechanisms of solar cells.

New Lab

The brand new Photovoltaic Device Fabrication Laboratory (PDFL) in Bldg. 883 should be in full operation by spring. Tests to certify the lab as a class-100 clean room are under way, and the equipment installation and check-out phase has begun.

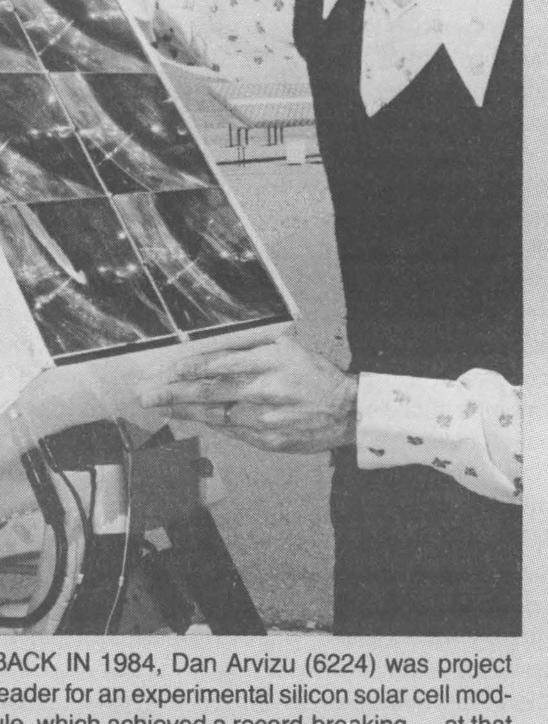
The PDFL's unique goal: to provide a precisely controlled processing environment in which one-sun solar cells can be routinely fabricated from high-quality semiconductor materials at efficiencies exceeding 20 percent.

"In the past, our solar cell processing has been supported through our radiation-hardened microelectronics processing facilities," says Dan, "but with Sandia's expanded role in DOE's Photovoltaic Research Program and with recent advances in high-performance cell designs for concentrators and one-sun cells, we needed a facility designed specifically for photovoltaics.

"Our primary purpose is to transfer to industry what we learn in the lab so that industry will be able to avoid production processes that adversely affect the performance of finished cells — and obtain the efficiencies in their own commercially produced cells that, until now, have been obtained only in research labs.

"Once the PDFL is in full operation, and we have demonstrated the ability to sustain a precisely controlled production environment for the routine production of high-quality cells, we'll investigate ways to better understand how production processes affect the performance of cells."

Researchers from universities and industry will be encouraged to participate as visiting scientists. A key feature of the program is that scientists will be able to use the PDFL to develop and better understand proprietary processes.



BACK IN 1984, Dan Arvizu (6224) was project leader for an experimental silicon solar cell module, which achieved a record-breaking — at that time — conversion rate of 17 percent.

Terrestrial Translation of Space Technology

Photovoltaics: From Space to Earth

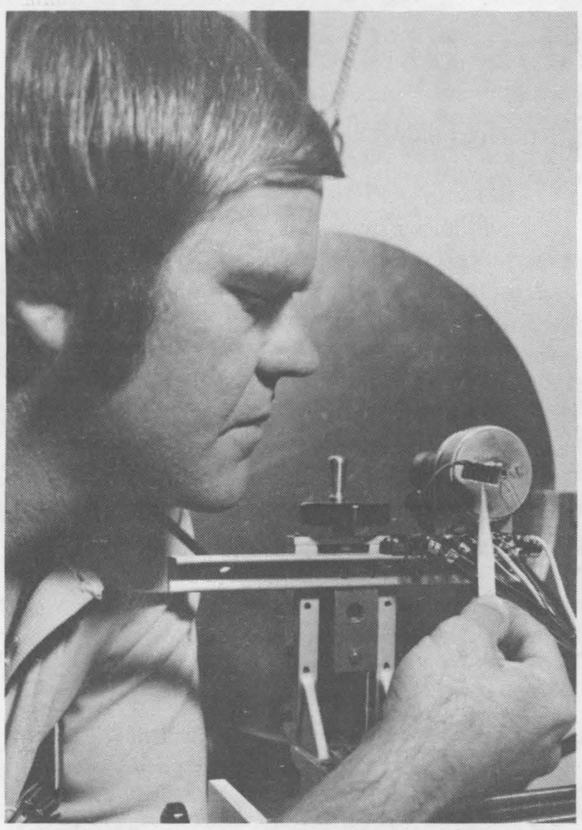
In the pre-oil-embargo days of the early 70s, when Don Schueler, manager of Solar Energy Department 6220, Ed Burgess (400), and Jerry Fossum (EE Dept., Univ. of Florida) first began studying the behavior of solar cells under concentrated sunlight, the future of solar cells was still up in the air — or, rather, still out in space.

Solar cells had been powering on-board instrumentation in satellites since the cells had been allowed — albeit reluctantly — to serve as a back-up power source on the first Vanguard launched in 1958.

Back then, solar cells were thought by everyone — except a few innovative engineers with the US Army Signal Corps who championed their use — to be too novel and unreliable to be part of the basic design of the satellite.

But the cells surprised even their most ardent advocates.

Three weeks after Vanguard's launch, when the life of the primary batteries had expired as expected, the cells continued to power the satellite's back-up transmitter — for which no shut-off mechanism had been provided. With no way to shut it off, the transmitter continued to operate for six years, effectively cluttering a radio band until 1964.



MID-70s-VINTAGE solar cell being readied for high-artificial-illumination tests aimed at reducing solar cell size. That's Ed Burgess (now 400), one of Sandia's early-day solar researchers.

After two more solar-powered satellites were launched in 1958, photovoltaic (PV) power systems — and shut-off mechanisms — became standard equipment on anything leaving earth for outer space.

By the early 70s, satellites carrying photovoltaic systems capable of producing many kilowatts of electricity were being launched routinely.

But back on earth, the use of photovoltaic power systems was negligible.

Not that their potential wasn't recognized — some enthusiasts even envisioned huge orbiting photovoltaic array fields that would microwave limitless amounts of cheap, clean energy back to earth in the near future.

Don (then supervisor of the Solid State Electronics Division), Ed (then Solid State Materials Division), Jerry (then Semiconductor Circuits Division), and a few others were also excited about the possibility of using solar cells to obtain electricity directly from the sun. But as scientists, they took a less sanguine view of just how — and how soon — the solar technology developed for space systems could be translated into terrestrial uses.

They knew that between even extraordinary results in the laboratory and the practical application of a technology may lie many years of arduous research and development.

"It really wasn't a question of *whether* solar cells would work — the space program had already proved they would work," recalls Don. "But solar cells were incredibly expensive."

And thus, so was the electricity they produced.

In the early 70s, the cost of solar-produced electricity was reported to be $500 per watt of peak power (watts produced at solar noon on a clear day). This cost dropped to $50 per watt of peak power in 1974 — $3 per kilowatt-hour, compared to 2 to 10 cents per kilowatt-hour for electricity generated by fossil or fission power plants.

"The big question," continues Don, "was whether we could find ways of reducing that cost. We knew that one way to economize was to squeeze more energy out of solar cells by focusing more light on them. With concentrated sunlight focused on them, a few cells could produce the same amount of electricity produced by many ordinary cells."

For example, concentrating the sunlight tenfold — "ten suns" — would mean that only one-tenth the number of expensive cells would be needed. (One sun is the energy — about 1 kilowatt per square metre — of sunlight striking the earth's surface.)

Unfortunately, concentrated sunlight produces heat, and high heat poses a problem for conventional solar cells. At high operating temperatures, they lose efficiency — convert a smaller percentage of the available sunlight into electricity.

"We began trying to find out just how silicon cells behaved at high illumination levels — 40-100 suns — and at the high temperatures associated with those levels of illumination," says Don. "And we wanted to explore ways of modifying the cells to improve their performance at high illumination levels."

Computer Code Used

For their studies, Jerry adapted a computer code developed originally for analyzing radiation effects on integrated circuits.

"The use of computer codes for analyzing radiation damage in integrated circuits was nothing new to the weapon program," notes Jerry. "But this was the first time a numerical computer code had been used to analyze solar cells. Today no one designs solar cells without computer codes, but back then we were breaking new ground."

"Jerry's computer code allowed us to evaluate many design iterations without actually having to build the cells," recalls Ed. "And we were able to identify where and how the designs could be modified for the best operation at different illumination levels."

By late 1974, they had learned enough to present a paper at the 1975 IEEE Photovoltaics Specialists Conference describing Sandia-designed and fabricated cells capable — at 40-suns concentration — of converting 12 percent of available sunlight to electricity. The paper was one of the earliest papers on terrestrial uses of photovoltaics.

Due partly to the work reported in this early paper, Sandia was selected by the newly formed Energy Research and Development Administration (ERDA) for a major role in the National Photovoltaic Conversion Program.

"Things began to happen pretty fast," recalls Don. "Early in 1975, I went to Washington for six months to help set up the National Photovoltaic Program and transfer existing activities from the National Science Foundation to ERDA.

"When I returned to Sandia later in the year, my group became the Photovoltaic Systems Definition Project Division and moved to the Advanced Energy Projects Department (now 6200). We received our first funding from ERDA and were able to turn our cell studies into a full-fledged photovoltaics project with seventeen people assigned to it.

"Our specific mission was to reduce the cost of solar energy systems by developing alternatives to the one-sun cells and flat-plate arrays commonly used in the space program." (Flat-plate arrays are usually fixed in place to face the sun — they neither track the sun nor use lenses or other devices to concentrate the sunlight.)

First Concentrating Photovoltaic Array

Within the year Don's group had completed its first major project: construction of the first photovoltaic concentrating array.

"Compared with today's sophisticated technology," says Don, "that first array was pretty crude. The cells were made here in our semiconductor device labs [now the Center for Radiation-hardened Microelectronics], and achieved an unprecedented 14 percent conversion rate — they converted 14 percent of available sunlight to electricity. But we had to scrounge for the rest of the array.

"For a tracking mechanism, we used an old US Army surplus searchlight mount. And Ed located a company that made Fresnel lenses for overhead pro-

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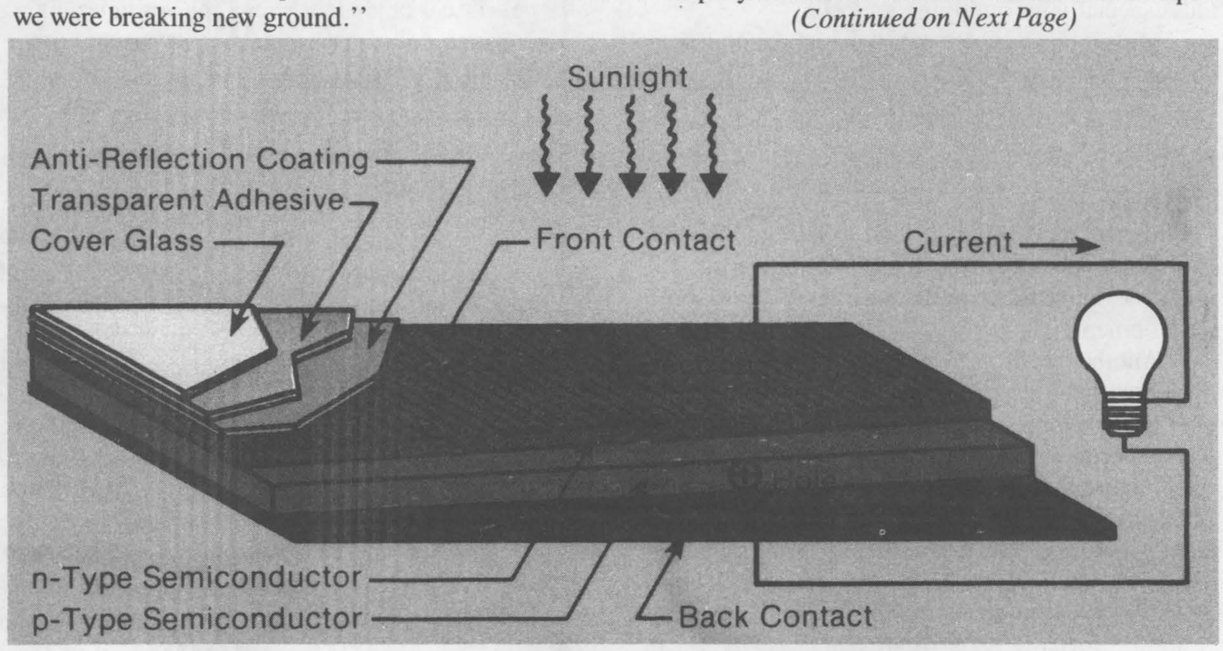
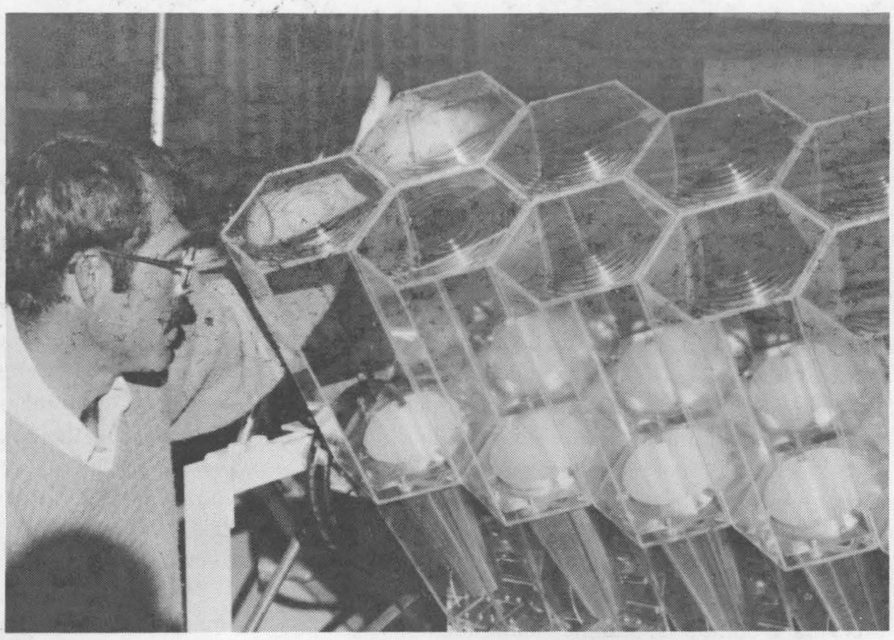


SOLAR CELLS are the basic power elements in photovoltaic systems. At the heart of the typical solar cell are two layers of oppositely charged semiconductor materials — a p-type (for positive) that tends to collect "holes" or positively charged particles and an n-type (for negative) made in a different way to collect negatively charged electrons. On top of these are a conducting grid, an anti-reflective coating, and a protective cover-glass. As light shines on the cell, an internal barrier — an electrical field — pushes an increasing number of electrons to the top of the cell and holes to the bottom. When the layers of the cell are connected by means of an external electrical circuit, excess electrons trapped in the n-type layer will readily flow through it. This flow of electrons constitutes a useful electric current. If the circuit is connected to a load (such as a light bulb), electrons from the n-type layer will flow through the load, performing useful work (such as heating the light bulb's filament to incandescence). Once their work is done, they flow back into the cell through a return wire, completing the circuit and recombining with holes in the bottom p-type layer. Electricity will flow continuously, as direct current, for as long as the cell is exposed to light.



BACK IN 1981, Eldon Boes (6221) inspected a module representing one of the earliest attempts to increase conversion efficiencies by splitting the sun's spectrum. This module first split the spectrum optically and then directed different portions of it to different cells.

(Continued from Preceding Page)

Space to Earth

jectors and worked with its staff to design a special lens for 60-sun concentration.''

''It was sort of the square-hole, round-peg problem,'' recalls Ed. ''Our cells were round — the necessary shape for the most efficient use of the silicon material — but our lenses were square. Hexagonally shaped lenses would have been better, but the square shape allowed us to simplify the support structure. The trick was to get the square lens to project a circular image onto a round cell.

''We did it by varying the focal length in the corners of the lens so that light hitting those areas was intercepted and projected toward the center of the cell.

''It was a clever idea, and probably patentable — the technique is used routinely now — but we were so busy trying to get the array built in time to report on it at the next Photovoltaic Specialists Conference that we didn't bother with a patent.''

With help from Mike Edenburn (now 6511), who tackled the problem of diverting heat away from the cells, and Gene Hammons (now 1144) who invented — and later patented — an inexpensive tracking device for keeping the array pointed toward the sun, the array was finished in time for Mike and Ed to report on it at the 1976 conference.

''The array produced one kilowatt of electricity, a tremendous amount in those days, though we speak in terms of megawatts now,'' recalls Don. ''Our basic design concept — Fresnel lenses in a matrix up front to concentrate the sunlight and cells mounted on a back plane to spread out the heat — has withstood the test of time. Both cells and lenses have undergone vast improvements, of course, but our basic design is still being used in today's concentrator systems.''

Early Experimental Systems

''In fact,'' continues Don, ''our array was the model for several of the experimental utility-sized PV systems installed at different locations around the country in the early 80s.''

Ranging in size from 20 kw to more than 200 kw, the systems were the largest of their kind and represented all three major technologies in photovoltaics — fixed flat-plate, line-focus concentrator, and point-focus concentrator. They were designed to serve a local load (like a manufacturing plant) and were hooked into the utility grid.

The systems were installed, tested, and operated in the private sector with funding from DOE; Sandia provided technical support and project management.

''These systems — some are still in operation — worked surprisingly well, considering they represented the first attempts to build and operate PV concentrating systems,'' says Don.

They were designed especially to produce answers to questions about the technical feasibility of operating components and full-scale systems over a period of several years. These included questions about environmental effects, reliability of the systems, operating requirements and costs, comparisons in performance, and comparisons of actual and predicted performance.

To gather the data needed to answer these questions, Sandia's electronic subsystems group developed a monitoring program to assess how the new technology was performing.

The program eventually included a computerized data monitor designed to record detailed information about the performance of the system over a long period of time. Teams of engineers and technicians also visited the sites to talk to operators and to perform special tests on the systems to identify component failures.

Recently, PVFORM — a computer simulation model — was added to the monitoring program to help study system performance and to assist in designing new systems.

''We learned from the operation of the experimental systems that both concentrator and flat-plate systems are simple to build, that they can operate successfully in a variety of applications, and — most important — that they're reliable,'' says Don.

Technical Knowledge Base

''Just when it looked as though the PV industry was really taking off — even private industry was beginning to fund substantial development programs — the price of oil fell, and the country decided it really didn't have an energy crisis after all,'' recalls Don.

''We had to change our strategy — the economics of those first experimental systems was based on oil prices that were $40 a barrel, and going up. We redirected our efforts toward improving the technology further — making it more efficient and less expensive, and applying PV to high-value uses.''

At the same time, Sandia was gathering a technical knowledge base on all aspects of photovoltaics. Those first large systems, which continued to be monitored, yielded a considerable body of information based on actual operating experience. And subsequent studies and analyses of residential- and community-sized systems and of small stand-alone systems yielded even more information.

''We found ourselves sitting on the largest body of technical information on PV, probably, in the world,'' says Don.

It was from this huge technical knowledge base that the Design Assistance Center evolved.

''The Design Assistance Center,'' says Don, ''is able to take the knowledge — including information on design, economics, and applications of PV systems — and help other people learn how to use PV just as we were learning to use it in the early 80s. Most important, the Center provides the technical know-how for combining today's components into technically and efficiently integrated and fully functional systems [see ''DAC Promotes PV in US, Around World''].

The Future

''I'm frequently asked why we should continue to develop photovoltaics for large-scale utility use when utilities already have more generating capacity than they need,'' says Don.

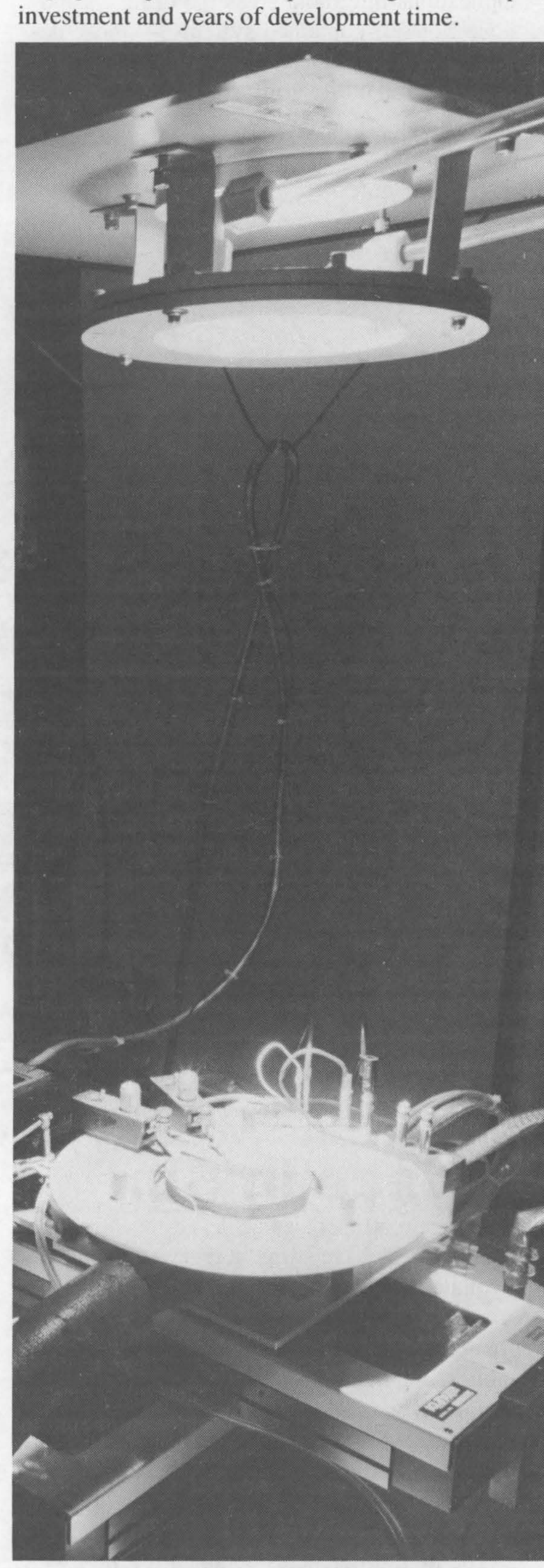
''But more and more people are taking a favorable view of photovoltaics because its environmental impact is practically zero. It has no belching smokestacks to cause acid rain, makes no contribution to the greenhouse effect, entails no nuclear waste, causes no oil spills, and doesn't consume non-replenishable fuels such as oil and coal.''

Aside from these advantages, utility power forecasters are currently predicting that significant new generation capacity will be required in the mid-90s. Best estimates are that more than 50,000 megawatts of new electrical generation capacity will be required by 1995.

''Even if we made a very conservative assumption,'' says Don, ''that 20 percent of this new generation capacity is for peaking power and that only a small fraction, say 10 percent, of that could best be supplied by photovoltaic systems, the potentially available market would be more than 1000 megawatts — 200 megawatts annually starting in 1990.

''Even this conservative estimate of the market potential is an order-of-magnitude increase in the total annual production of photovoltaics by all the current suppliers in the world.''

Planners also make it clear that whenever the time does come for adding new generating capacity, the utilities will use the technology that makes the best business sense for their needs. And, says Don, the modularity of PV systems — they can grow as requirements grow — may be preferable to building large power plants that require a large initial capital investment and years of development time.



LENS-CELL TESTER is used by Labs researchers to characterize lens/cell combinations for possible use in PV concentrator modules.

Appropriate Now for Some Uses

DAC Promotes PV Technology in US, Around World

At first glance, Tern Island, a tiny dot in the Pacific, appears to have nothing in common with the Hopi Indian Reservation in Arizona.

But both are isolated — by land or sea — far from population centers; both are trying to solve power-supply problems; and both are being helped by Sandia's Photovoltaic (PV) Design Assistance Center to solve those problems.

The Design Assistance Center (DAC), staffed and operated by Gary Jones' Photovoltaic Systems Research Div. 6223, works to accelerate the use of photovoltaic technology by making it easier for potential users to understand and use the technology.

''Research in systems technology — everything needed, including all hardware and the know-how to combine components into technically integrated and fully functional systems — has been under way since the first large experimental systems were installed in the early 80s,'' says Gary.

With most of the systems-related technical questions successfully resolved, photovoltaics is now an appropriate, economical power source for a wide variety of applications, especially applications in remote areas requiring ''stand-alone'' or self-contained systems — those designed to generate electricity with no assistance from a central utility grid.

''Transferring the technology data base built up by past research — and the know-how we've gained from actual operating experience — to users and industry has become one of the major emphases of systems research,'' says Gary. ''We look for any project where the use of photovoltaics would be cost-effective and make sense. Tern Island is a national wildlife refuge [operated by the US Fish and Wildlife Service] that has been operating on photovoltaic power for about a year now.''

The photovoltaic system installed there powers all the electrical loads on the refuge, including a water pump, lights, refrigerators, freezers, a computer, and the island's radio.

DAC first helped to determine the specifications for the system and then provided technical review of the proposals for it. In this case, PV was a cost-effective alternative to the high cost of purchasing and transporting diesel fuel to the island, but the DAC team also examined other alternatives.

''We go face-to-face with the people, look at their needs, and then give them the information they need — including information about PV, if it seems an appropriate option — so they can solve their power problems in the way that's best for them,'' says Mike Thomas (6223).

Similar DAC services may help the Hopi solve their power-supply problem. John Stevens and Hal Post (both 6223) met late this summer with Hopi Foundation officials to discuss a model project that could result in PV systems being installed at several hundred reservation homes that now rely on batteries or small gasoline generators — or do without electrical power.

''Here, cultural preferences may play as large a part in the final selection of a power source as price comparisons,'' says Hal. ''For cultural and religious reasons, village leaders refuse to allow power lines of Arizona Public Service to enter some villages.

''The idea of having the sun serve as their primary power source appeals to the Hopi. They've already found PV's competition — gasoline engines — to be too noisy and unreliable. PV, which operates quietly and draws its power from the sun, may prove to be the most attractive option for them.''

DAC also works with federal government agencies and international organizations to encourage the use of PV systems to meet the power needs of developing countries.

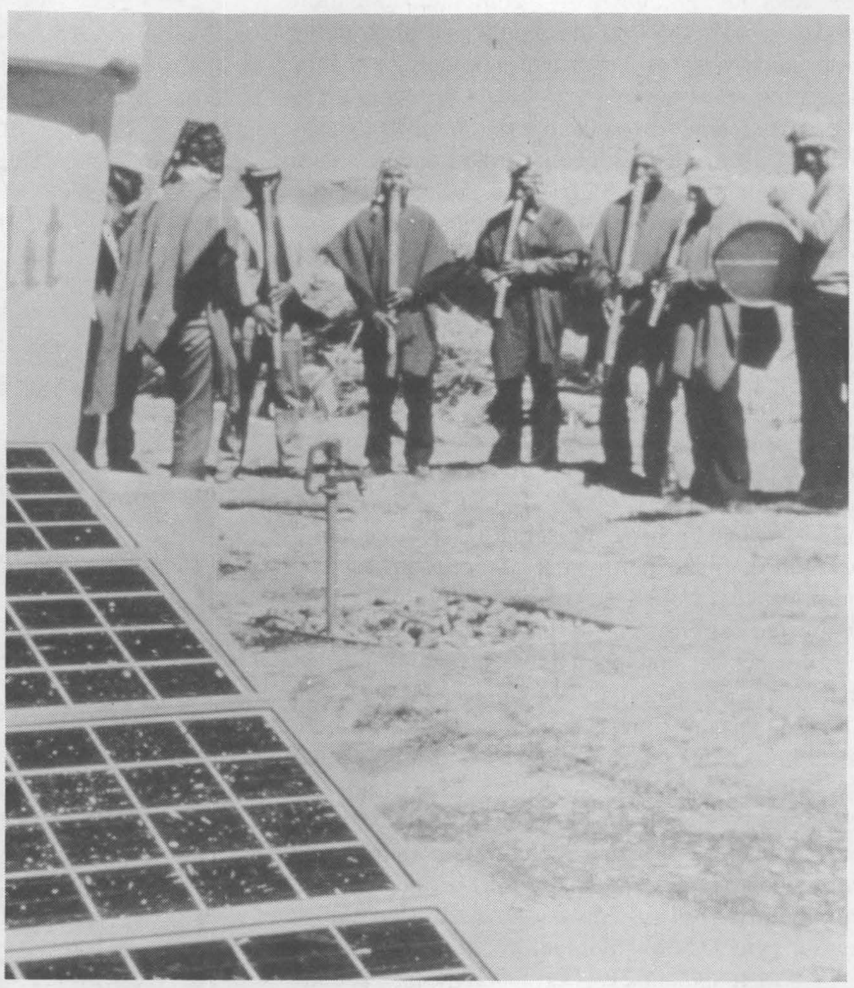
''Small, stand-alone PV systems are particularly appropriate for powering water pumps, medical refrigeration, and electric lights,'' says Gary. ''One small system can go far toward improving the health and quality of life for people living in remote areas.''

Two years ago, working with the Organization of American States, DAC managed the installation of low-maintenance, PV-powered vaccine refrigerators in Guatemala, Honduras, and El Salvador. Easy to use and with no fuel requirements, they keep medical vaccines fresh and available.

More recently, DAC managed the installation of three PV-powered water-pumping systems to provide water to residents of the Altiplano region in Bolivia. Installation of the three systems culminated a cooperative effort among DOE, the World Bank, and the Bolivian government. Initiated through a joint agreement between the World Bank and DOE's PV Energy Technology Division, the pilot systems demonstrated the potential benefits of using PV to power water pumps in developing countries.

Other organizations DAC continues to work with include several United Nations agencies, the Pan American Health Organization, and the South Pacific Institute for Renewable Energy.

DAC's role in developing PV systems overseas stems from the 1984 enactment of the Federal Renewable Energy Export Act. In conjunction with this act, the Committee on Renewable Energy Commerce and Trade (CORECT), a committee representing major federal agencies, provides information and advice to assist renewable energy activities in developing countries.



SOME OF THE LOCALS participated in the "dedication ceremony" for one of three PV water-pumping systems in the Altiplano region of Bolivia. Sandia's PV Design Assistance Center managed installation of the systems, a cooperative effort among DOE, the World Bank, and the Bolivian government.

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Place in Sun

''The new efficiencies achieved recently with concentrator cells have stirred a renewed interest in photovoltaic concentrator technology,'' says Eldon Boes.

In addition to in-house research on lenses, cell assemblies, and interconnects, Eldon's Photovoltaic Technology Div. 6221 develops prototype modules that incorporate the latest advances made in the cell and component programs and actively supports the development and fabrication of prototype modules by private companies.

''The high efficiencies obtained recently with silicon cells make obtaining module efficiencies exceeding 20 percent a very realistic goal, so development of concentrator modules in the private sector is really expanding; about ten firms are now developing concentrator module designs. We expect a number of them to achieve peak efficiencies of 19 percent, assuming 23-percent-efficient concentrator cells are used.''

'Hands-On' Tech Transfer

''We spend a good deal of time giving what might be called 'hands-on' support to module developers in the private sector,'' Eldon says.

''In a sense, we actively develop the technology from *within* the industry. For example, a company representative might tell us about a lens design the company is planning to develop. Using a computer code, we'll analyze the design and advise the company on ways it might be improved. We'll also measure the optical performance of the lens, once it's actually constructed.

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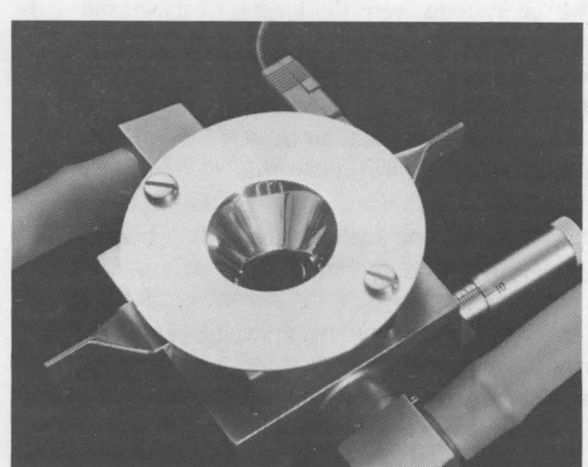

DETAIL OF PV SYSTEM developed in the early 80s, showing reflective brass cone mounted on solar cell housing. Cone's purpose is to help increase solar cell module efficiency.

Purifying, Crystallizing, Slicing, Doping

Why Solar Cells Are Expensive

It's the high cost of solar cells that drives the tremendous research effort aimed at increasing their conversion efficiencies. Cells are expensive because the semiconductor materials they're made of are expensive to refine and process.

By far the most popular semiconductor is single-crystal silicon — the most highly refined form of silicon. It was first used for its photovoltaic capabilities more than 30 years ago, when researchers at AT&T Bell Labs produced a solar cell that converted four percent of the incident sunlight to electricity.

Recent breakthroughs in conversion efficiencies of 28 percent have made silicon the material most likely, at least in the near term, to achieve the high efficiencies needed to make photovoltaic technology practical for generating electricity on a large scale.

Common As Sand

Despite these new efficiencies, single-crystal silicon and the cells made from it remain expensive. Not because silicon is scarce — it's the main ingredient of ordinary sand and is the earth's second most abundant chemical element (after oxygen).

But, unfortunately, silicon is *not* dirt cheap — it doesn't occur in nature in the highly pure, single-crystal form required for high-efficiency solar cells.

Rather, it exists as silica, which contains impurities that must be removed through expensive, time-consuming refining processes. Silicon used in high-efficiency solar cells must be 99.99999 percent pure. The refining process typically begins with quartzite, which can be almost 99 percent pure silica.

It is heated with carbon to break the silica into elemental silicon and carbon dioxide. A chemical vapor blown over the silicon reacts with most of the impurities, causing them to leave as part of the gas. The remaining impurities are removed by using hydrogen chloride and a copper catalyst to convert the silicon to a liquid — trichlorosilane.

Pure silicon is isolated from the trichlorosilane by a slow, energy-intensive chemical-vapor deposition method, in which silicon crystals are ''grown'' — built by accretion, much the way rock-candy sugar crystals are formed on a string.

From Ingots to Wafers

But the resulting silicon is polycrystalline and must be melted and grown into a single crystal using either of two techniques, both of which resemble candle dipping.

In the Czochralski crystal-pulling technique, a small single crystal of silicon placed at the end of a rod is lowered until it barely dips into a molten mass of purified silicon, then rotated and raised very slowly. As the crystal rises, the melt in contact with it solidifies, the atoms arranging themselves into the same orientation as those in the seed crystal.

In the second technique, an ingot of polycrystalline silicon is supported vertically above a seed crystal. Radio-frequency heating causes a molten zone at the interface of the seed crystal and the ingot. As the heat moves up the ingot, single-crystal silicon solidifies below the molten interface and perpetuates upward. The region of molten silicon is unsupported, maintaining itself only by surface tension — hence ''floating zone.''

The finished crystal is sliced with diamond-tipped saws into thin wafers, each of which will become an individual solar cell. Because the saw blade is about the same thickness as the wafers, as much as 50 percent of the costly purified silicon is wasted during slicing.

At this point, the wafers are poor conductors of electricity — the highly refined silicon behaves more like an insulator.

To obtain the electrical properties needed for solar cells, they must be ''doped'' with selected impurities — minute amounts of elements such as boron or phosphorus.

One Grain Salt to Bag of Sugar

Dopants are now most often added by a diffusion process so exact that it's been likened to adding a single grain of salt to a five-pound bag of sugar.

In this process, a rack of wafers is popped into a heated chamber. Typically, one side is exposed to ions of phosphorus, the other to ions of boron. As the dopant materials penetrate to the desired depth, different electrical charges are created on either side of the wafers.

The result is a solar cell capable of converting sunlight directly to electricity.

The finished cell is expensive because of the inherent waste of some of the production processes — and because *all* the processes call for the time and labor of skilled workers.

(Continued from Preceding Page)

Place in Sun

''Sometimes just taking the time to discuss a proposed component design — its pros and cons — can be helpful to a company. We have a huge knowledge base to draw on, and we can help a company see its proposed design in the context of what has — or hasn't — been tried in the past.''

Tech transfer is also the purpose for one of the division's prototype modules, the Sandia Baseline Module. ''We're developing it expressly for the purpose of demonstrating the newest techniques and design features that we feel can be incorporated into commercial modules now,'' says Eldon.

Special features of the module currently include new high-efficiency cells from the University of New South Wales, a special prism cover for the cell assemblies developed by Entech (Dallas/Ft. Worth, Tex.), and the use of an improved soldering technique developed in-house by the division. The technique allows a less expensive cell assembly design to be used in the module.

Through use of the technique, a cell can be soldered directly to a copper heat spreader, which in turn is isolated from the module housing with an inexpensive thermally conductive adhesive. The new technique eliminates the use of expensive ceramic.

''The trick was to overcome the large thermal expansion mismatch between silicon and copper,'' notes Eldon.

Looking Ahead

Testing of the module is still a month away, but it has already attracted the attention of several firms that are adopting many of its design features for use in their commercial modules.

''In the next year we hope to push the efficiencies of concentrator modules to more than 20 percent,'' says Eldon.

''We're also continually pushing the frontier of concentrator research by working with experimen-

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FIRST PV CONCENTRATOR ARRAY, designed and built by Sandia in the mid-70s, used 135 Fresnel lenses (right) to concentrate sunlight on an equal number of silicon solar cells (bright spots on left). The array's silicon cells achieved an unprecedented — for that era — 14 percent conversion rate, recalls Don Schueler (6220).

Sandia's Right There

Commercializing the Better Solar Cell

Widely respected photovoltaic (PV) demonstration projects, world-class testing facilities, and timely outside contacts have positioned Sandia as a major contributor to commercialization of the steadily improving solar cell.

Some recent examples:

• A cooperative agreement between Sandia and the University of New South Wales (Australia) is paving the way to lower-cost, one-sun PV modules, which use cells that receive solar energy directly, without lenses to multiply the sun's power (see "Photovoltaics Gaining Place in Sun").

Under contract with Sandia, the university developed a new processing technology, using laser machining, that makes 20 percent sunlight-to-electricity conversion efficiencies possible for one-sun cells. Previously, individual one-sun cell efficiency rarely exceeded 15 percent, with panels converting energy at 13 percent or less on average, Dave King (6224) reports.

The new cells are chemically etched, diffused lightly with phosphorous, and oxidized. A laser then machines deep, narrow grooves into the silicon. Grooves are filled with a copper conductor using a plating process.

"The resulting cell, for reasons we still don't fully understood, has better electrical properties than other silicon cells processed in more conventional ways," says Dave.

While Sandia and the university continue investigations, Midway Laboratories (Chicago) and ARCO Solar (Woodland Hills, Calif.) have their eyes on the technology.

No More Silicon Sawdust

• Ongoing Sandia studies of silicon crystal-growth technologies for one-sun cells also have industry watching because of the potential for reducing production costs.

In conventional cell manufacturing, large blocks of pure silicon crystals are grown, then sawed into thin slices. The saw damages the crystalline surface and wastes part of the crystal block, reducing it to silicon sawdust (see "Why Solar Cells Are Expensive").

Three innovative processes under investigation concentrate on thin sheet growth, rather than silicon crystalline blocks. One creates ribbons of thin silicon pulled out of a vat of molten material, similar to pulling a bubble out of a tub of soapy water between one's fingers. Another pulls molten silicon through a thin slot in a graphite mold, creating a polycrystalline thin sheet. In a third process, silicon is deposited in a thin layer on a ceramic substrate.

A number of firms are championing these methods, and Sandia is actively involved with the most promising approaches, says Paul Basore (6224). "In the case of technologies where there is no strong market yet developed — like these new processing methods — the Labs provides impetus [through contracts with solar energy-related businesses] for research to bring costs and efficiencies to the point where they may be useful to electric utilities," Paul says.

Fixing the Flux

• A Sandia-developed soldering apparatus, used to prevent degradation of solar cells and to increase their reliability, is now being used in a manufacturing process at Alpha Solarco Co. (Cincinnati).

The device is based on Doug Ruby's (6224) research on flux materials and soldering in a controlled, gaseous atmosphere. When gallium arsenide cells were first soldered into modules, they suffered damage that reduced operating efficiency. Normal liquid fluxes were damaging the solar cells, Doug explains.

He found an appropriate flux, hydrogen chloride gas, that removes oxide from metal and solder to permit a clean metal-to-metal connection and a stronger bond. Then he developed a system of soldering that incorporates this gaseous flux.

During the effort, Doug designed and supervised fabrication of a soldering station at Sandia. A similar station, modified to permit the station to operate in a mass production mode, is now being used by Alpha Solarco to build a 300-kilowatt PV array.

• Most firms currently developing modules are using a Sandia-developed soldering technique that has led to an improved cell assembly design. The technique was derived from reliability studies by Clement Chiang (6221). It allows silicon cells to be soldered directly to a copper heat spreader, eliminating the costly alumina cell-substrate and improving overall efficiency of the module.

And Two More

• Entech, Inc. (Dallas), with Sandia's assistance, developed and patented a cell cover (using prismatic patterns) that helps focus sunlight onto active parts of the cell after the light passes through a Fresnel lens. With development support at Sandia, this "secondary-optics" technique has helped improve concentrator efficiencies. At least two companies are now using prism cover designs.

• The team of Don Sharp (1841), Janda Panitz (1834), Len Beavis, and Beth Richards (both 6221) has identified an electrophoretic coating process that's key to producing an electrical-insulating but thermally conducting material that can be produced inexpensively for use on PV concentrator modules. (Electrophoresis basically seeks out and plugs electrical current.)

"Materials typically are both thermally and electrically conductive or are neither thermally nor electrically conductive," Beth says. "The exceptions, such as certain ceramics, are usually expensive."

In this case, the coating must conduct heat away from the cell to keep operations as cool as possible. But it must also insulate the housing from electrical current to prevent short circuits and shock hazards from merely touching the housing. Finally, it must not be too expensive or difficult to produce.

While testing and development continue at Sandia, the Labs team has begun working to transfer the promising new coating technology to an Albuquerque firm. •WK

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Place in Sun

tal 'laboratory' modules that use a few exotic cells and lenses to establish new module efficiency marks. This helps us define and understand where the technology should be going in the longer term — and to envision what concentrator modules will be like in, say, the year 2000."

"The outlook for PV is extremely encouraging," says Don Schueler.

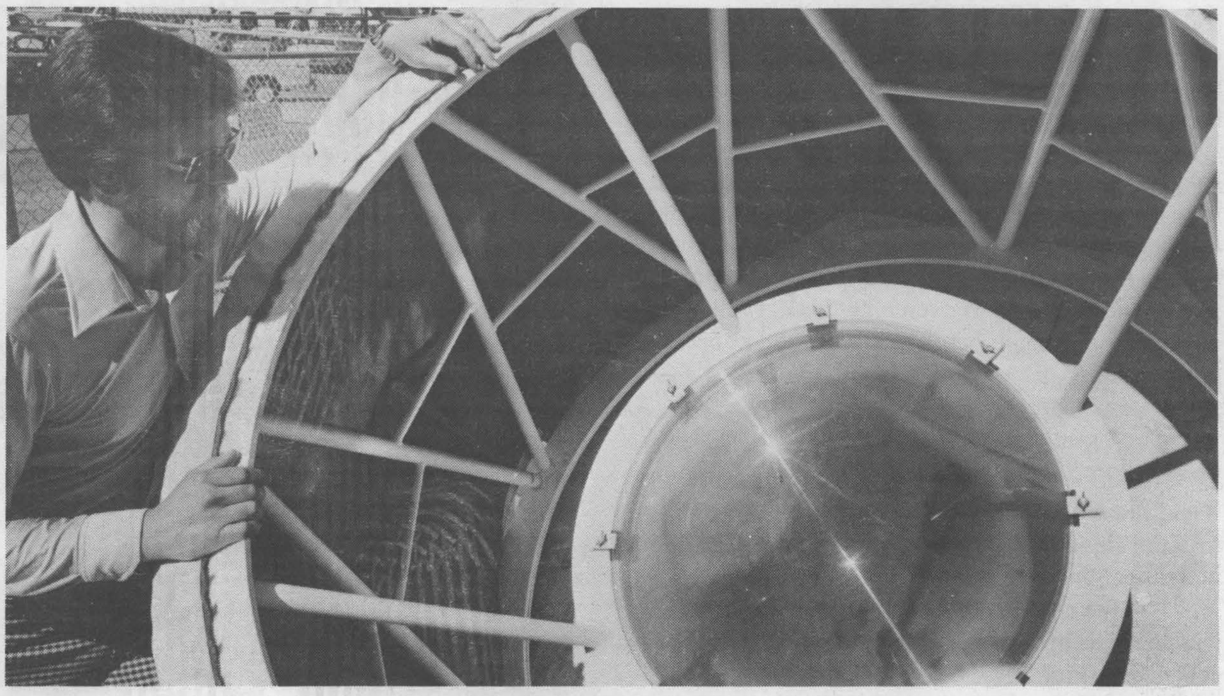
"There's no doubt that, as developing nations of the world expand their use of electricity, photovoltaics will play a significant role in supplying it. The inherent flexibility of PV — its ability to produce whatever amount of electricity is needed — on the same site where it will be used makes it particularly suitable for supplying electricity to Third World sites, whether that's a small village, a hospital, or a simple water pump. In areas without central power plants and utility grids already in place, PV systems often will be the best, most economical choice for supplying electricity.

"I also think that we will see large PV power systems begin generating electricity for US utility markets within the next decade or so, just as we saw wind-farm generating systems begin supplying electricity to the utility markets in the 80s.

"This may be a bold prediction for a conservative engineer to make — especially with the cost of PV power still about a factor of four above current electricity prices," says Don. "But it's already quite clear that the current cost of PV-generated electricity can be cut in half through a combination of the latest technological advances and the economies of scale that will come with larger-scale production levels. The remaining factor-of-two reduction will come through the fruits of current and future R&D.

"There is also growing concern over the environmental effects of using fossil fuels to generate electrical power — in particular, the greenhouse effect caused by increasing levels of atmospheric carbon dioxide and other gases. Environmental concerns are beginning to rival the concerns over oil imports, fluctuating prices, and uncertain supplies.

"Given these concerns — and the phenomenal success PV is having for all kinds of specialty applications — it's likely that our PV work at Sandia will, at the least, remain stable, and will probably see some growth." •DR



FRESNEL LENS on a two-axis tracking device developed in the mid-70's by Gene Hammons (1144) for measuring efficiency of solar cells. Gene received a patent for the tracker.