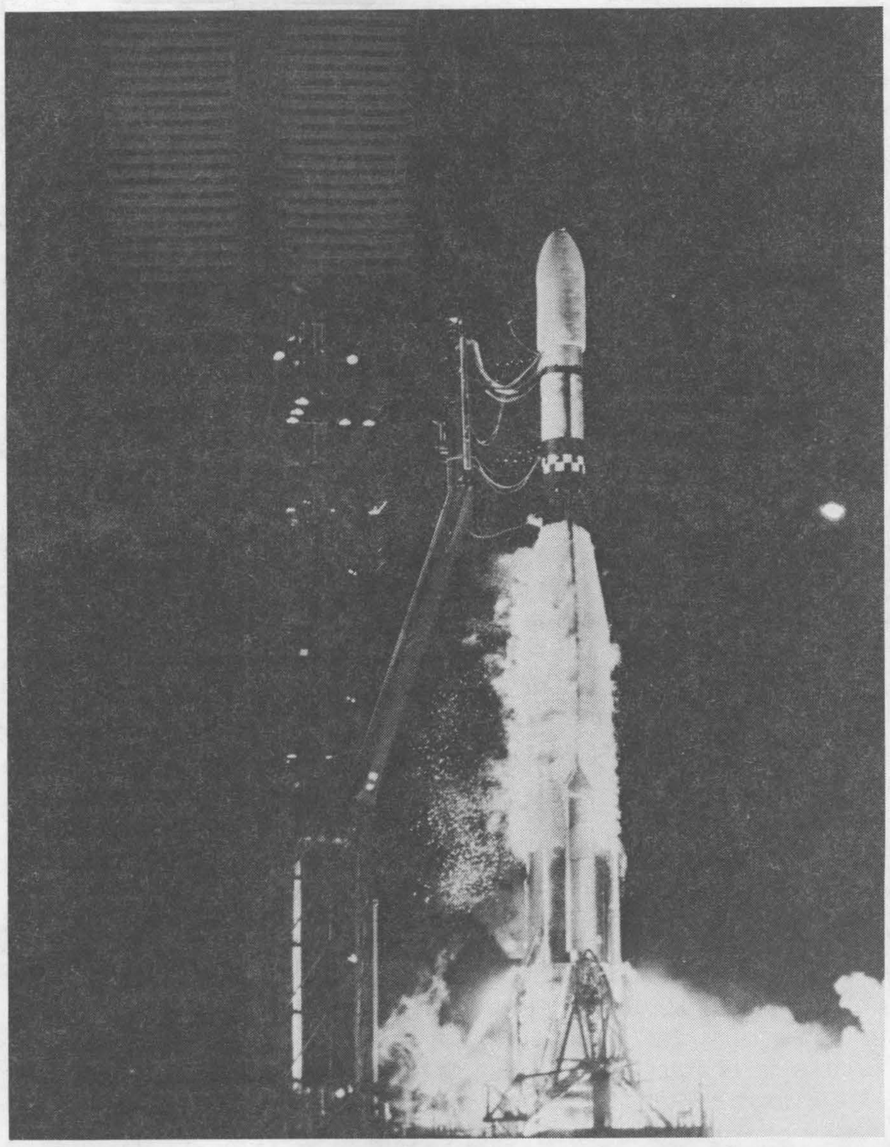
A Silver Bird!

First Vela Satellites Launched 25 Years Ago



FIRST TWO VELA satellites for detecting nuclear bursts in space lifted off 25 years ago from Cape Canaveral (then Cape Kennedy). Six Sandians who developed and tested Vela components witnessed the spectacular Oct. 16, 1963, night launch.

LAB NEWS

VOL. 40, NO. 21 SANDIA NATIONAL LABORATORIES OCTOBER 21, 1988

Twenty-five years ago — 1963 — a year filled with memorable events. Among them:

- President John F. Kennedy was assassinated.
- Martin Luther King made his ''I Have a Dream'' speech.
- The Limited Test Ban Treaty (LTBT) banning atmospheric, space, and underwater nuclear weapon tests went into effect.
- Gangster Joseph Valachi identified crime bosses and generally ''spilled his guts'' about organized crime before a Senate subcommittee.
- Polaroid introduced instant color film.
- The Beatles came on strong to dominate pop music for years.
- Sports greats Stan ''The Man'' Musial and Bob Cousy took off their (respective) cleats and sneakers and ''hung 'em up.''

That same year, the US ''hung up'' its first satellites for detecting nuclear weapon tests (explosions) in space. Last Sunday, Oct. 16, was the silver anniversary of that event — the launching of the first two Vela satellites. Sandia had a big hand in developing and testing those two — and the 10 more Velas launched during the next seven years.

The Vela (Spanish for watchfulness, or vigil) satellites were about five feet in diameter and weighed 500 to 730 pounds (newer ones included bigger, more sophisticated payloads). Each of the first pair was an icosahedron (20 sides of equal shape and size). Nineteen sides were solar power panels, and the 20th was the rocket motor exhaust area. Radiation sensors were placed at the corners of the icosahedron. This basic scheme was used in newer Velas, with only minor changes.

In use until 1984, the Velas were always launched in pairs and placed in circular orbits about 60,000 miles from earth. They were placed 180 degrees apart, on opposite sides of earth, thereby allowing two satellites to monitor all surrounding space.

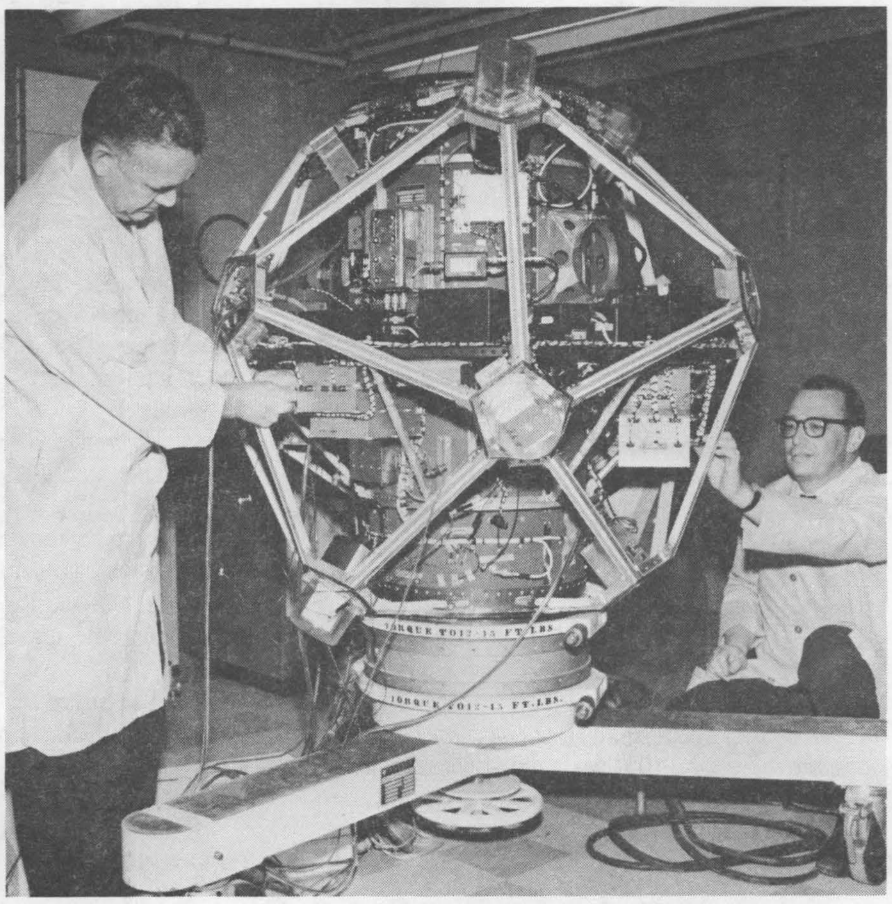
Sandia a Major Contributor

The Vela satellite program was a cooperative effort. In 1959, the Atomic Energy Commission (AEC, now DOE) and the DoD's Advanced Research Projects Agency (ARPA, now DARPA) had agreed that AEC would develop and provide satellite sensors and instruments for monitoring nuclear bursts in space and ARPA would provide the developmental satellites.

The Air Force Space Systems Division (now Air Force Space Divison) managed the satellite design, fabrication, and launch functions; TRW produced the satellites under contract. Los Alamos National Lab (LANL) provided sensors for detecting X-ray, gamma ray, and neutron radiation from space bursts and natural background radiation in space.

On the first three Vela pairs, Sandia provided the data-processing electronics and power-conditioning systems to support LANL's space nuclear-burst sensors.

On the last three pairs, Sandia also developed optical sensors and related instruments that were added to the payloads. The optical sensors detected extraordinary flashes of light and heat, allowing the new Velas to also monitor the lower atmosphere for nuclear bursts.



TEST, TEST, TEST. Before Vela satellites were launched, Sandia's automated test equipment was used to give them a thorough going-over — repeatedly. A new computerized test system developed by the Labs allowed the complete payload to be given almost continuous comprehensive testing. Now-retired Sandians Bob House (left) and Simon Steely are shown hooking up the first Vela payload for tests.

The Labs' interest in using satellites for detecting nuclear detonations began before the 1959 AEC/DoD agreement. There was growing worldwide concern in the mid-50s about the dangers of radioactive fallout from atmospheric nuclear tests. Public sentiment was also building against possible nuclear tests in space.

A National Academy of Sciences group (the Panofsky Panel) concluded that it was scientifically feasible to build and use surveillance satellites for detecting nuclear bursts. In the late 50s, working groups were formed at AEC's weapons labs (Sandia, LANL, and Lawrence Livermore National Lab) to define the nitty-gritty problems and to explore solutions.

Sandia's group, formed in August 1959, was called the Buzzer Committee. Says Gus Simmons (Senior Fellow, 200), one of the few remaining committee members still working at Sandia, ''Make sure you refer to us as 'old buzzers' and not 'old buzzards.' ''

'Mission Impossible'

The working groups generally agreed on two main points: (1) yes, satellite monitoring would be great and (2) it would be a mighty difficult — and

(Continued on Page Four)

Antojitos

Last Week's Scare Headlines made it sound as if Sandia were overrun with foreign agents blithely wandering unescorted through the Labs' labs and libraries, pocketing classified devices and skimming classified documents for fun and profit.

Such headlines catch the attention, but only the naive will believe that four decades of Sandia security consciousness could have evaporated overnight. Remember that, to much of the outside world, only the Tech Area fences separate the good guys from the bad, badgeless bunch.

In reality, of course, no Labs visitors from Communist-bloc nations were permitted inside the fence. And the fewer than 20 visitors from so-called "sensitive" countries who were allowed to come inside were escorted at all times. At no time did they have access to classified or sensitive information. In relation to classified information, we hardly need be reminded that the "need to know" applies to everyone, visitors as well as Sandians.

* * *

Some Pride -- and some trepidation -- goes along with this voluminous issue of LAB NEWS. Energy is an exciting topic with a rich past, a challenging present, and an important future; we're proud if we succeed in sharing that excitement with you.

Trepidation? It's like being the parent of 27 children -- it's tough to know what they're all doing to/for your reputation. Given the number of stories in today's issue and the number slated for two more issues, we've probably left out a few names, omitted some salient facts, or been guilty of what we're most commonly accused of -- the dreaded "oversimplification."

We're plunging ahead, ever mindful of the piteous disclaimer prefacing too many books: Its strengths are those of our sources; its weaknesses are ours alone.

We do want to thank those sources -- all of whom are named in the various stories. We especially want to thank Energy VP Dan Hartley and Directors Virg Dugan (6200) and Peter Mattern (8300). On the AEC/ERDA/DOE level, two of the dozens who helped Sandia succeed in getting our energy program off the ground (or down into it, as the case may be) were Ray Romatowski (later manager of DOE/AL) and Jim Kane (LLNLer assigned to ERDA at the time).

Writers for today's stories and those to follow (in reverse alpha order, for a change): Phyllis Wilson, Donna Rix, Larry Perrine (all 3162), Jim Mitchell (3160), Will Keener, Nigel Hey (both 3161), Bruce Hawkinson, (3162), Rod Geer, and Ken Frazier (both 3161). For the whole series, Rod is serving as "project coordinator," Phyl as copy editor.

* * *

Beware "Beware" Signs -- New signs on Tech Area fences read:

BEWARE
AREA UNDER
SECURITY SURVEILLANCE
VIOLATORS WILL
BE PROSECUTED

Fred Schkade (2614) asks, "What mortal dangers of said surveillance are we supposed to beware of? And what violation of said surveillance are we supposed to be prosecuted for?" I think what the sign means -- as opposed to what it says -- is that we won't want to do anything near a fence we wouldn't want to do on television. But I'm open to other opinions . . . •BH

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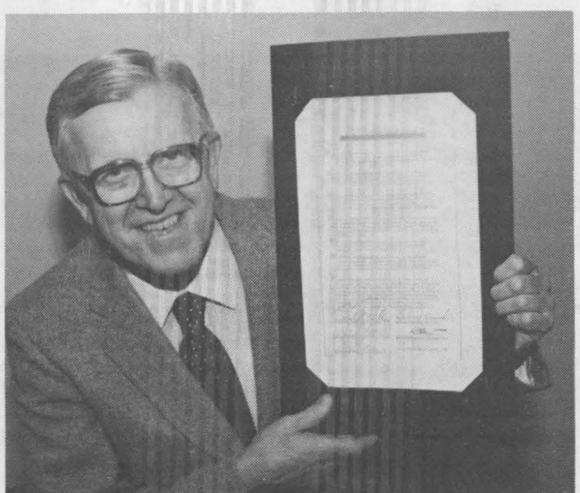
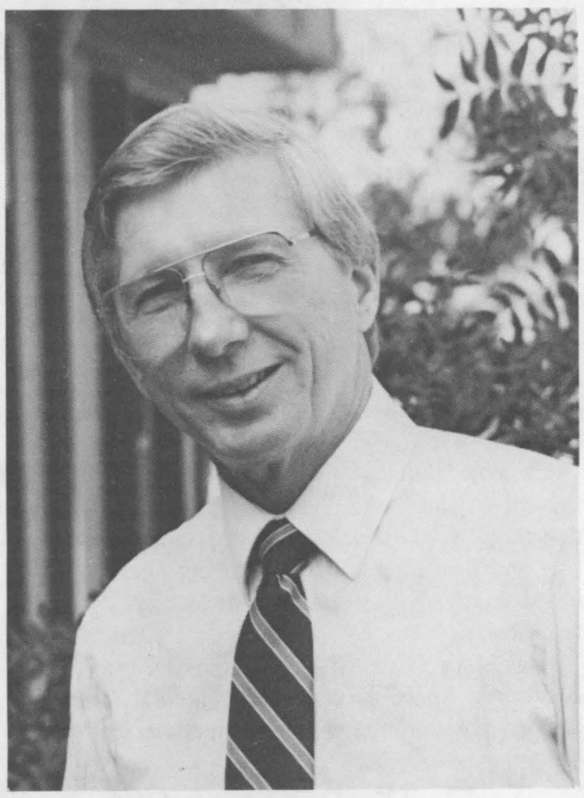


AL SKINROOD (8133) holds the resolution passed by the California Energy Commission commending Sandia, DOE, Southern California Edison Company, and the Los Angeles Department of Water & Power for the success of Solar One, the pilot solar central receiver plant experiment near Barstow. It shut down last month after six years of operation. Sandia was technical manager for Solar One, which contained 1818 heliostats and a central receiver tower that could generate more than 10 MWe of power for some 6000 residents in the Barstow-Daggett area. Al was supervisor of the Solar Central Receiver Div. during the life of the project.

A DOE QUALITY-IMPROVEMENT AWARD was presented to Jim Lang (left, 5253) on Oct. 14 by DOE/AL Assistant Manager Robert Hymer. Jim received the award for his efforts on the W88 X-ray shield, particularly his close coordination with the Y-12 production plant at Oak Ridge during the initial design and development of the shield. As a result, the award citation stated, quality was improved and projected program costs were reduced by $300,000.



Hickman Takes SNLL Post

Jack Hickman is transferring to Livermore to become manager of Advanced Systems Dept. 8170, effective Oct. 16. He comes from the Org. 400 staff, where he has served as congressional liaison in Washington since November 1986.

He joined Sandia in 1962 as an MTS in the Project Division. Later he worked in the Joint Test Assembly Division, Safety Studies Division, and Safety Assurance Division before becoming supervisor of the Safety Assessment Technologies Division in 1974.

In 1976 he transferred to the Nuclear Fuel Cycle System Safety Division and in 1983 was promoted to manager of the Reactor Systems Safety Department, where he stayed until joining the 400 staff in 1986.

Jack received his BS degree in Electrical Engineering from Oklahoma State and his MSEE from UNM. His son, Kirt, is a senior at UNM, and his daughter, Lin, is a junior at UNM.

His outside interests include flying and backpacking. He holds a private pilot's license.

LEAP Faire/Circus

Hundreds of Sandians flocked to the ''Big Top'' on Oct. 11 for LEAP Faire/Circus 88 — the kickoff of the annual Livermore Employees Assistance Plan campaign — aiming to raise $145,000 to assist some 30 charitable agencies and the United Way.

Despite cool and cloudy weather, the crowd warmed to the magical world of P.T. Barnum, and to the booths where Sandians tested their skills or visited with representatives of the various agencies receiving financial support through LEAP.

There were strolling clowns and sideshow attractions. There were center-ring acts featuring four directors performing ''great feats'' with the assistance of their secretaries.

And there was a 2000-metre fun run/walk that attracted more than 100 participants. (Results and winners' photos in next LAB NEWS.)

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SIGNING UP Fair Share donors at the LEAP Circus/Faire were (from left) Lorenna Petersen, Peg BonDurant, and Tracey Lamee (all 8523). That's LEAP treasurer Mel West (also 8523) in sunglasses.

HUMAN CANNONBALL Commander Kaboom (aka Paul Brewer, 8500) explains his misfire out of the big gun to LEAP Circus Ringmaster Cliff Yokomizo (8162).

MUSCLEBOUND Ronald Strongandbigger (aka Ron Detry, 8200) is assisted on stage by aerobics ballerina Joan Bersie (also 8200).

THE GREAT RICARDO (aka Rick Wayne, 8400) gets help in finding his tightrope from Arlene Harrell (also 8400).

GENO THE HORSE (played by Gene Ives, 8100, and Bob Dougherty, 8270) gets a pat for a good performance from its trainer, Karen Anderson (8100).

(Continued from Page One)

Vela

maybe impractical — thing to accomplish. Keep in mind the very first artificial satellite — the USSR's Sputnik I — had been launched less than two years before. And the US had launched its first relatively simple satellite communication experiment only months before (Project SCORE, December 18, 1958).

At the time, it must have seemed like a ''Mission Impossible'' assignment: ''Build a highly complex electronic system. It needs the capabilities of a room-sized IBM 704 computer. Even though computer components can fail in an office with a constant temperature, put the system atop a powerful rocket and blast it into space where it must work perfectly in extreme temperatures. It must distinguish natural radiation from nuclear-blast radiation, produce reliable data, reduce that data down to a meaningful package, and transmit it back to earth where it can be deciphered easily. The satellite can't weigh more than about 500 pounds or be more than five feet in diameter. And, by the way, it has to have an on-board, self-sustaining power system.''

Obviously, there were a lot of technical challenges ahead. But the weapon labs were undeterred. Their efforts were soon merged with similar work being done by ARPA, and the Vela program went into high gear in September 1959.

Glenn Fowler, retired Sandia Vice-President who was involved in the program, says the emergence of solid-state electronics was one of the key developments that made Velas possible and, eventually, so reliable.

''We were beginning to use solid-state devices in our nuclear field test instrumentation work and realized they should be used on space systems,'' Glenn says. ''Their low power consumption and ability to withstand cold temperatures in space made them ideal for Vela.''

Sandia Did Exhaustive Component Tests

As the R&D on the Vela program matured and hardware evolved, Sandia began exhaustive prelaunch tests of Vela components — all kinds of tests ranging from high-altitude balloon flight tests to new computerized tests. The computer equipment could perform 50,000 individual tests in seconds to check complete assemblies of the detectors and logic system.

''The automated test system that Sandia devised was a pioneering effort and among the very first computerized systems for simulating harsh environments and testing components repeatedly,'' says Dick Spalding, manager of Sensor Systems 9230. (Dick is one of only seven Sandians who began work on the Vela satellite program, stayed with it throughout its duration, and then stayed on in related programs without interruption; see ''Seven Sandians.'')

The US and USSR had both stopped atmospheric nuclear tests in 1958, but the USSR resumed testing in late summer 1961. The Limited Test Ban Treaty, signed originally by the US, USSR, and UK in the summer of 1963 (and soon thereafter by more than 100 nations), banned full-scale nuclear weapon tests everywhere except deep underground, where radioactive products could be contained safely. President Kennedy signed the treaty into US law on Oct. 7, making it effective on Oct. 10.

''Trust but verify'' — a translation of the Russian proverb, ''doveryai no proveryai'' — was the key precept, and on Oct. 16, 1963, only six days after the LTBT treaty went into effect in the US, the first two Velas were launched and soon monitoring the heavens for nuclear tests.

The close timing of the events is coincidental. The original plan called for a July 1963 launch of the first Vela pair — a plan made independently of test-ban treaty discussions and deliberations — but the launch date was slipped slightly because of minor technical problems.

Amazing Reliability Record

The 12 Velas proved to be the most reliable and long-lasting space systems ever deployed. The six pairs were launched and operated during a 21-year span. The last pair — launched in 1970 — was turned off Sept. 29, 1984, after about 14-1/2 years of continuous operation.

''That's pretty amazing, considering that Vela program planners originally hoped Velas would last three to six months,'' says H. M. (Brick) Dumas, manager of Space Systems Dept. 9210. ''Even though

(Continued on Page Five)

'First Branch on the Sandia Tree'

Sandia's component development and testing work for the Vela program — and treaty-monitoring R&D leading up to the program — set a couple of important precedents for the Labs:

For one, it was the birth of the weapons treaty verification technology program at Sandia, which develops and refines technology for verifying worldwide compliance with current and future weapons treaties. The program today involves about 300 employees, most in Exploratory Systems (Org. 9000), but includes others throughout the Labs.

Also, it was the first real ''branch on the Sandia tree'' — the first major project that didn't involve the weaponization of nuclear explosives. Although that remains Sandia's primary mission, there is diversity today — the energy program, advanced conventional munitions, treaty verification technology work, and more.

The Vela nuclear explosion test detection program had three major parts: space and high-altitude atmospheric nuclear test detection; lower atmospheric and surface; and underground. Sandia did considerable work in all three Vela areas and continues advanced work in these areas today.

Key to Vela Success May Be Key to Future Successes

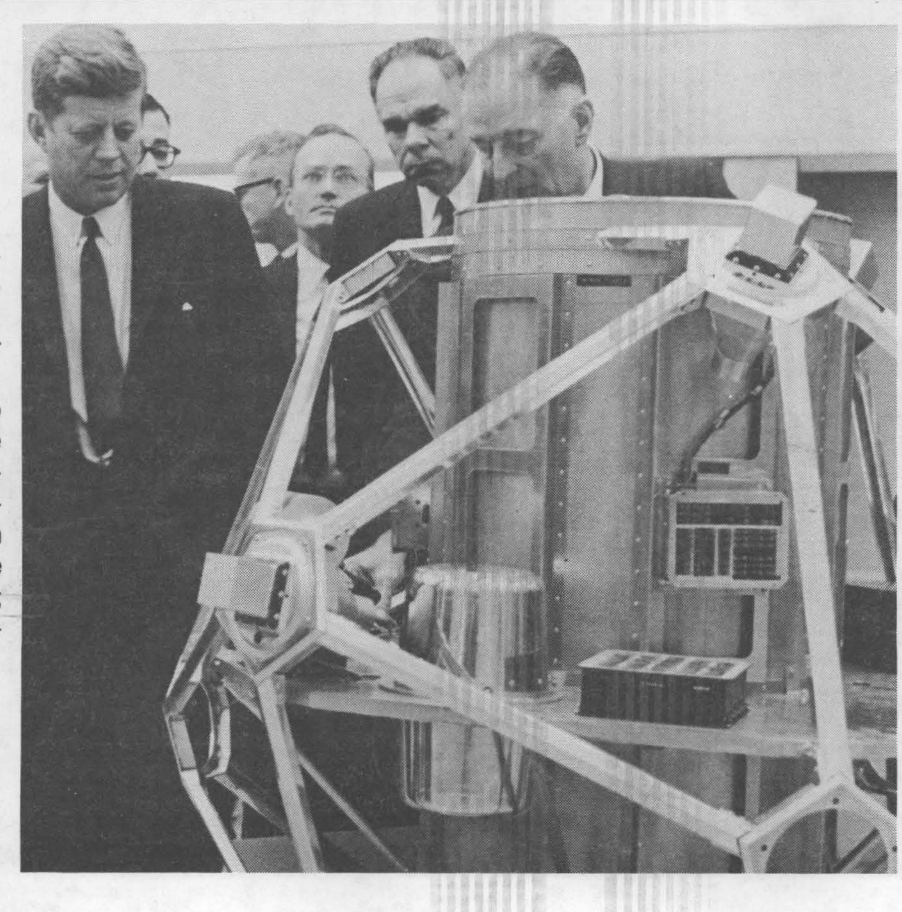
As several mid-80s failures in the US space program demonstrated, the technologies involved are difficult at best. Yet, beginning 25 years ago, 12 Vela satellites were launched without failure and operated almost flawlessly thereafter.

And these were complex systems — the Sandia-designed logics system alone on each of the first two Velas launched Oct. 16, 1963, contained more than 23,000 components. The last pair, launched in April 1970, operated in space for about 14-1/2 years.

Bill Myre, Monitoring Systems 9200 Director, believes the success of the Vela program resulted in part from a *healthy* fear of failure.

''For its day, Vela was by far the most complicated spacecraft this country had ever launched,'' says Bill. ''Frankly, we were all scared to death that it wouldn't work. I know many of us involved were thinking along the lines of, 'This thing probably won't work, but it sure won't be because the parts I'm working on fail.' ''

Executive Vice President Orval Jones (20) believes that type of thinking can continue to serve us well. ''A healthy fear of failure — coupled with resolve that 'our part' of the system certainly isn't going to be the downfall — may be a good formula for success, in space programs or anywhere else,'' says Orval.



PRESIDENT JOHN KENNEDY views an early Vela satellite during his Dec. 6, 1962, visit to Sandia. The first pair of Velas was launched Oct. 16 the following year. Next to the President (from left) are McGeorge Bundy, Special Assistant to the President for National Security Affairs; Glenn Seaborg, Chairman of the Atomic Energy Commission; and "Monk" Schwartz, Sandia President.

Seven Sandians: Satellite Savvy Since Sixties

The list of Sandians who made significant contributions to the Vela satellite program over the years and made it a tremendous technical success is long — too long to include everyone.

Perhaps more meaningful, says Bill Myre (9200 Director), is the list of Sandians who found this type of work so interesting and challenging that they stayed with it over the years. That's the case with seven employees — five active and two recently retired — who began work on the Vela program, stayed with it throughout its duration, and continued on in new monitoring programs with similar objectives and goals.

The seven Sandians who definitely know how to keep a job: Bill Goldrick (9233), Keith McCoy (9214), Jesse Rehberg (9214), Don Roelle (9234), Bill Rogers (ret.), Dick Spalding (9230), and F. E. (Tommy) Thompson (ret.).

(Continued from Page Four)

Vela

one satellite was a little difficult to keep oriented properly after it went into orbit, none of the 12 Velas ever really failed.

"Each pair was turned off in favor of newer, more sophisticated ones," Brick continues. "That includes the last pair [Vela V-B], which was still working when turned off after a new satellite monitoring system was in place."

And the Velas fully lived up to their name during their 21 years aloft. Because not all nations signed the LTBT, some did conduct atmospheric tests after Velas were launched.

These tests were detected. Sandia received its share of the credit for the success of the AEC (DOE)/DoD/ private industry partnership.

Following the launch of the fourth pair in 1967, AEC Chairman Jim Ramey expressed his appreciation in a letter to then-Sandia President John Hornbeck: "The Vela Satellite Program . . . is an unprecedented achievement in the field of space research and development. The sound design, high quality, and remarkable performance of the optical and electromagnetic pulse detectors and of the space-based data processing electronics for the Atomic Energy Commission's payload clearly demonstrate the technical skill, professional competence, and dedicated effort of personnel at your Laboratory."

Vela is now a "silver bird" — and a "soaring success!" •LP

Fun & Games

Horseshoes — Ringing in wins at the Sandia Labs Horseshoe Tournament at Los Altos Park on Oct. 1 were: Class A — Curly Saxton (ret.), 42.2 percent ringers; Class B — Jim Reed, 24.4 percent ringers; Class C — Jim Fisher, 20 percent ringers; Women's Div. — Carnella Towne, 17.5 percent ringers; Doubles Tournament — Tom Towne (5152) and J. McMullen; and Retirees Bracket — Curly Saxton.

* * *

Ski Swap — The 22nd Annual Ski Swap is scheduled for Oct. 28-30 at the Exhibit complex on the State Fairgrounds. The first snowfall won't be far behind, so it's time to haul out your equipment (downhill and cross-country) and see what you need to add, replace, trade, or sell.

Register equipment or clothes for sale on Friday between 11 a.m. and 7 p.m. The sale starts at 9 a.m. on Saturday and closes at 4 p.m. Pick up unsold items and checks for what you've sold at the Super Sunday Sale between 2 and 4 p.m.

The Ski Swap is the Sandia Peak Ski Patrol's source of funds for medical supplies and rescue equipment. The all-volunteer group has 60 patrollers as well as an auxiliary and junior adjunct. For more information, contact John Shunny (ret.) on 265-1620.

'Positive Outcome'

Ralph Bonner, Director of Personnel 3500, recently shared with LAB NEWS his thoughts on the new on-site resource and referral service:

"Our contract with Cariño to provide on-site resource and referral services to Sandia's working parents is the very positive outcome of many people's efforts. These include Dr. Merrie Rockwell's [3320] informal survey of 568 Sandians in 1986 and Margaret Harvey's [3510] recent management-requested study of child-care resources and employer options.

"Those efforts helped to identify the full range and variety of employee-parent needs and the appropriate role Sandia could play to help meet those needs.

"An on-site referral specialist will provide valuable assistance to working parents in their search for convenient, affordable, high-quality child care — without impinging on their right and responsibility to make their own selection of appropriate providers."

Help for Working Parents

Child-Care Resource and Referral Service Comes to Sandia

Working parents can now get help toward solving their child-care problems from Sandia's new resource and referral specialist, Dorothy Baird.

Dorothy, a contractor employee with Cariño Child-Care Resource and Referral (an agency funded by the city, state, and United Way), will be on-site at Sandia each day — 7:30-11:30 a.m. Monday through Thursday, and 1-4:30 p.m. Friday. She can be reached on 6-2258 during those hours.

She'll help parents locate, evaluate, and choose child-care services.

"No one is better qualified to choose appropriate care for a child than the parents themselves," says Dorothy. "They know the child's needs and those of the family best. But I can help by supplying a list of available child-care providers. And I can arm parents with information about what to look for and what kinds of questions to ask, so they can evaluate those providers before they select one."

Where to Look

Dorothy will maintain a data base of licensed child-care centers and family day-care homes — as well as information about other programs and options.

"Once parents have determined the *kind* of child care that would be best for their situation, we can search the data base for providers that offer that particular kind of care," she says.

"Some parents, for example, may prefer care offered by a child-care center to that offered in an individual family home. Or they may prefer child care in their own homes. They may feel that the child would be happier in a large group of children — or in a smaller group. And the child may have other special needs that must be accommodated."

What to Look For

"Once we've identified three or four providers that meet the basic requirements of the family, the next step is for the parent to visit the providers to evaluate them before finally selecting one. This is really the hard part.

"I advise parents to plan to stay long enough on a visit to get a feel for what it would be like to be a child there for 8 to 10 hours every day."

There are some key things they'll want to observe during their visit, too, Dorothy notes: "Cariño, of course, will already have checked the facility to see that it is free of safety hazards — unprotected electrical cords or cleaning supplies, for example — but parents will want to observe how adults caring for the children handle 'problems.' What happens when children fight, or when a child cries or is unhappy? Does the facility have areas for quiet times? For active times? Are there enough toys and play equipment?

"By arming themselves with a mental — or even an actual — checklist of things to look for, parents can feel more confident about the choices they make."

Questions to Ask

Dorothy is also prepared to suggest important questions for parents to ask when they are evaluating a child-care provider.

"One of the first questions to ask," she says, "is what the caregiver/child ratio is — how many adults are caring for how many children — and whether that ratio meets state regulations, or is better.

"It's important to remember that state regulations are really the *minimum* standards below which no child-care program should fall — good-quality programs should exceed them.

"And there are other important questions that parents can ask to help them make the right decision — questions about when and what kinds of meals or snacks are served, the duration and spacing of naps or rest periods, whether the child is given opportunities to make choices and decisions, the policy for disciplining children, and many, many more.

DOROTHY BAIRD

"A complete listing of things to look for, questions to ask, and other information will be compiled in the child-care handbook now being put together — it should be available by early December."

Networking Link

Dorothy will also serve as the link between Sandia parents who would like to exchange information about their experiences with various child-care providers.

"Parents may want to share or seek information about other child-care problems as well," notes Dorothy. "My office can serve as a sort of bulletin board or channel of communication for them.

"I'll be maintaining a library of materials that provide good information on the elements of high-quality care and other child-development issues."

Recruiting

When Dorothy *isn't* on-site consulting with parents, she'll be recruiting, training, and developing family care providers throughout the community.

"If, during my follow-up discussions with parents seeking child care, I find that many in a certain geographical area are having difficulty finding the kind of care they want, I'll go into the area to scout and recruit family care providers — people who care for children in their homes," Dorothy says.

"Once family care providers have been recruited, they will attend an orientation session sponsored by Cariño. They will also be required to provide letters of reference and evidence that the caregiver meets health standards. A referral specialist will visit the caregiver's home to ensure that safety standards are being met, and the Department of Human Services will do a background check on all adult members of the household."

Former Police Officer

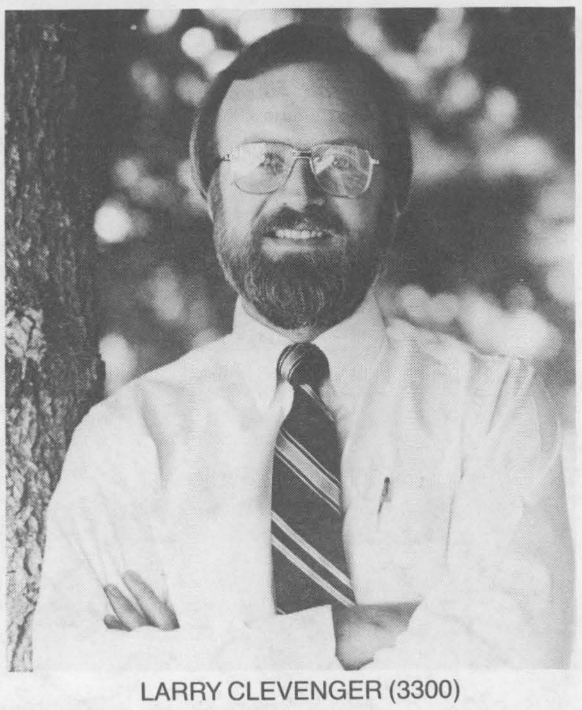
Dorothy's experience includes 20 years as a police officer with the Albuquerque Police Department. She was responsible for setting up the Child Abuse Unit in the early 80s and worked as an investigator in that unit. She's also worked as a detective in the Juvenile Unit and the Sex Crimes Unit, investigating crimes involving children. •DR

Orientation Sessions

To meet Dorothy Baird and learn more about available services, plan to attend either of two 30-minute orientation sessions in the TTC at 12 noon — one is today (Friday), the other is Tuesday, Oct. 25.

Dorothy is now on-site each day — 7:30-11:30 Monday through Thursday, and 1-4:30 Friday — in Bldg. 832, Rm. 80. She can be reached on 6-2258.

Supervisory Appointments



LARRY CLEVENGER (3300)

Clevenger Named Medical Director

LARRY CLEVENGER, MD, was named Medical Director 3300, effective Sept. 16.

Larry has been with Sandia's Medical organization since he joined the Labs as a staff physician in May 1979.

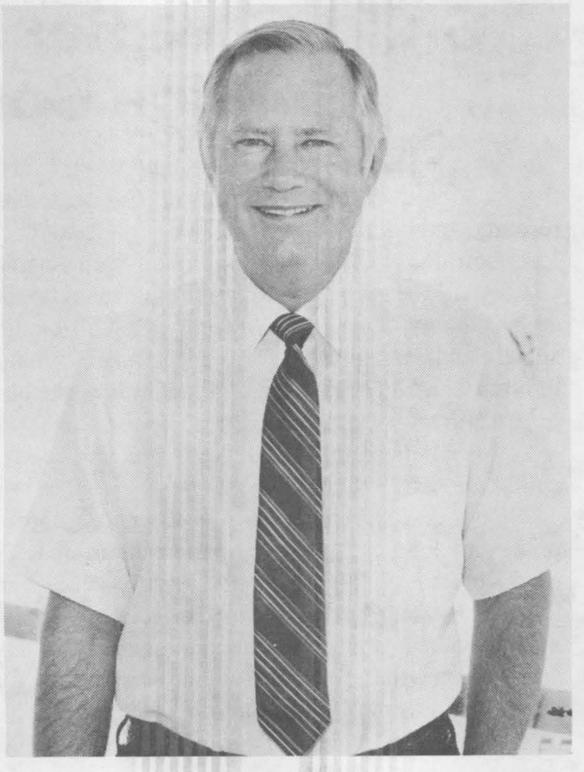
He became associate medical director in 1985, managing the Industrial Medicine and Medical Administration divisions.

Larry earned his MD at UNM, as well as a BA in psychology. He interned in family practice at San Bernadino County Medical Center in California. He also has a master's in public health from the University of Michigan, and is certified by the American Board of Preventive Medicine with a specialty in occupational medicine.

He's a member of the American Medical Assn., the Bernalillo County Medical Assn., the American Occupational Medicine Assn., and the NM Medicine/Business Coalition. He also serves on the board of directors for the NM Affiliate of the American Heart Assn. and on the HealthNet board of directors.

Larry enjoys family activities such as hiking, camping, backpacking, and fishing. He also is active in Cub Scout and Little League activities. His hobbies include woodworking and music.

He and his wife Lynne have three children. They live in the NE Heights.



ROBERT BEASLEY (DMTS) to supervisor of Test Measurement Div. 7171, effective Aug. 16.

Bob joined Sandia in 1959 as a member of the Field Operations Division at Salton Sea Test Base, where he worked with tracking cameras and other photographic instrumentation. In 1961, he transferred to the Photometrics Division in Albuquerque. He joined the DoD Range Operations Division in 1965, and was involved with coordinating Sandia test activities at remote locations. Bob transferred to the Test Instrumentation Division at Tonopah Test Range in 1970, where he was responsible for TTR telemetry activities and data communications systems.

He has a BS in physics from Idaho State College and an MS in the same field from the University of Illinois. He is a member of the Range Commanders Council Telemetry Group and the Telemetry Standards Coordination Committee.

Bob's spare-time activities include hunting and fishing. He and his wife Geneva have three children and live in Las Vegas.

* * *

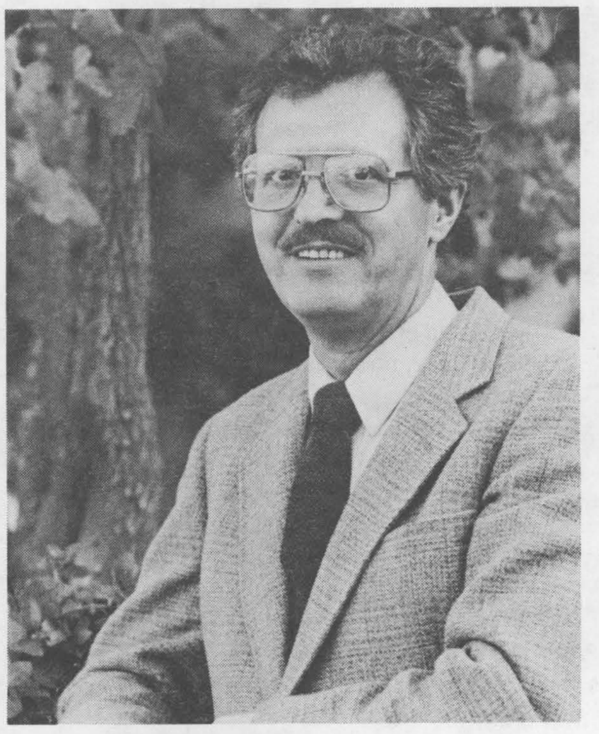
ERNEST NEVADA to supervisor of Maintenance Operations Planning Div. 7815, effective Oct. 1.

Ernie joined the Labs in 1970 as a mechanical apprentice. After completing the five-year program, he was assigned to Facilities' outside utilities group. He was a pipefitting instructor in the apprentice program from 1975 to 1978. In 1978, he became a standards analyst in Div. 7815. He was appointed supervisor of the Support Section in March 1981, where he was responsible for providing labor support. Ernie supervised the Painting, Sheet Metal, and Wood Shop Section from June 1982 until his promotion.

ERNIE NEVADA (7815)

Before joining Sandia, he served in the Navy in Vietnam in 1968 and 1969. He's currently working on a degree in business administration from the College of Santa Fe.

In his spare time, Ernie enjoys softball, camping, and hunting. He and his wife Theresa have three children and live in NW Albuquerque.



WILLIAM CAMP to manager of Mathematics and Computational Science Dept. 1420, effective Sept. 16.

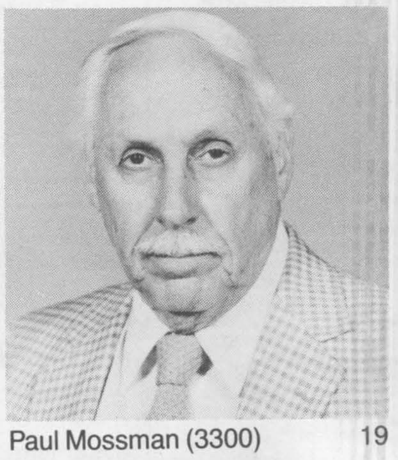
Bill came to Sandia in August 1970 and joined the Solid State Theory Department a year later, where he worked primarily on mathematical aspects of the theory of phase transitions. In February 1977, he was promoted to supervisor of the Reactor Theory and Analysis Division, where his work included analyzing reactor accident studies.

He has a BS in electrical and nuclear engineering from Manhattan College in New York City. His PhD project at Cornell was in mathematical physics. He is a member of the American Physical Society and the Society for Industrialized Applied Mathematics.

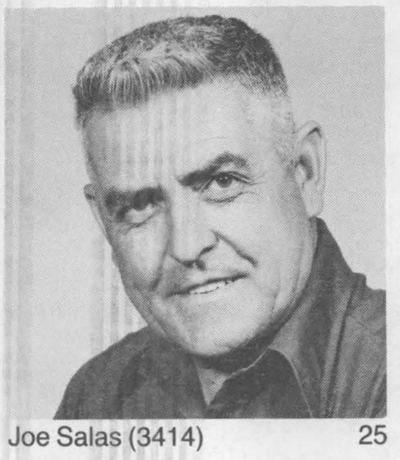
Bill spends his spare time in outdoor activities with his family, including hiking, backpacking, camping, skiing, and traveling. He's been an avid runner for 20 years, plays golf, and enjoys cooking French Canadian food. He's also active in church activities.

He and his wife Terry have two children and live in Cedar Crest.

Retiring



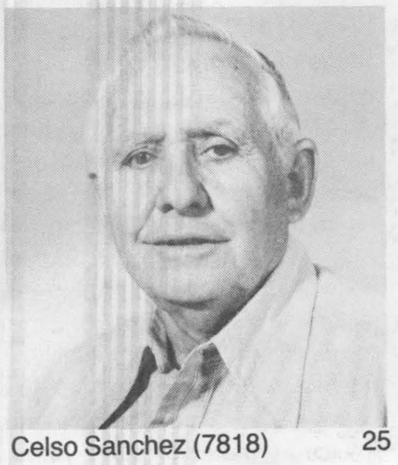
Paul Mossman (3300) 19



Joe Salas (3414) 25

Frank Chavez (7412) 40

John Sundberg (7213) 36



Celso Sanchez (7818) 25

Take Note

Instead of giving candy and apples to Halloween tricksters, consider tickets to the New Mexico Museum of Natural History. The Museum is again selling sets of admission tickets at $3 per dozen (admits children ages 3-11), available at the Museum (1801 Mountain Rd NW) now through 5 p.m. on Halloween. The tickets, which represent a 75-percent price reduction, are good for admission any time during November. For more information, contact the Museum on 841-8837.

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Get a head start on holiday gift-buying at a Discovery Toys fair on Oct. 22 from 9 a.m. to 3 p.m. at 1632 Moon NE. The toy sale is to benefit Designs for Learning Differences School, a nonprofit school in Albuquerque for children with learning disabilities and other handicaps. For more information about the fair, call Evelyn Kennerly on 296-2135.

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Retiring this month and not shown in LAB NEWS photos: Lois Amsden (2632), Jake Bernal (3428), Bill Buckalew (6447), George Dalphin (3144), Frank Fox (7818), Dixie Gochnauer (3437), Richard Griffith (2314), Ralph Hampy (2114), John Justus (3710), Evelyn Ratcliff (6000), Eleanor Slutts (400), Anthony Toya (3741), and Glen Brandvold (9190).

Retirement Seminar

Ben Bolden and David Senasack of Prudential Insurance Co. will present "Financial Success by Design" at 7:30 p.m. on Nov. 1 at the Prudential office (ABQ Bank bldg., 3rd floor, Suite 330, 6501 Americas Parkway NE). The seminar covers retirement topics such as social security, pensions, and loss of insurance as a result of retirement. Seating's by reservation only; phone your RSVP to Sandy Jenkins at 881-1111.

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

MISSION OAK BENCH, $350; antique recliner, $75; camel-back trunk, $40; moving boxes, 50¢ ea. Dingman, 292-6934.

GERMAN SHEPHERD PUPPIES, AKC-registered, 2 males, 4 females, police/German/champion bloodlines, dewclaws removed, $200. Gonzales, 898-8728.

KITCHEN TABLE, w/leaf & 4 chairs, $75; microwave, $60; bookshelves, $50; stereo, $50; all OBO. Myers, 299-6540.

BUILT-IN OVEN, GE, not self-cleaning, coppertone, $50 OBO. Payne, 299-5966.

SEARS CAR-TOP CARRIER. Miller, 292-5634.

UPRIGHT FREEZER, 20 cu. ft., $290; trash compactor, $125; kerosene heater, never used, $75. Marron, 345-4006.

HORSES, for experienced riders: bay (almost black) half-Arab mare; sorrel gelding, $800/ea. OBO. Hurt, 281-3675.

TRAILER HITCH and roof rack for VW Beetle, $15/ea. Stromberg, 299-8591.

FASTFOLD PAPER FOLDER, $150; Danish-styled light oak queen-size water bed w/matching nightstands, no mattress, $225. Spires, 275-3655.

FUR JACKET, Eddie Bauer, down-filled, woman's medium size, mouton lamb, wolverine trim/hood, never worn, $275. Powell, 268-8607.

RCA B&W TV, 12", $50. Miller, 255-7716.

BROWNING 12-GA. BPS, new in box, never fired, $350 firm; Winchester M-70, 270-cal., pre-'64, K-2.5 Weaver, Echo mount, $525 OBO. Zownir, 256-3753.

QUEEN-SIZE SOFA-SLEEPER, contemporary style, Southwestern design, blue, newly reupholstered, $300. Pompeo, 265-9182.

WOMAN'S SHOES, white, size 5-1/2, new; leather slippers, rubber soles, size 6, new. Gonzales, 243-1434.

SHOP MANUAL for '84 Ford Bronco II and '83 Ford Ranger, cost $50, sell for $20. Barr, 821-5870.

COLT 357-MAG.; S&W 44-mag., stainless; llama 9mm on .45 frame; misc. reloading equipment; Yashica Super-8 sound camera projector. Dobias, 822-0013.

MAGNAVOX COLOR TV, 19", no remote, $125. Duvall, 881-4406.

WOMAN'S ICE SKATES, size 6, $10. Marder, 291-8140.

H-P CARD READER, for H-P 41C, CV, or CX series calculators, includes 40 blank cards and instruction manuals, $120. Ross, 294-8788.

COUCH, blue/rust floral, $300. Tripp, 822-8580.

SKIS, K2 model 5500, 185cm, w/ Salomon 647 bindings, $130 OBO. Plummer, 296-4327.

SCUBA PACKAGE: 2 tanks, B.C. regulator, depth and pressure gages, weight belt. Barton, 268-7349.

TRS-80 COLOR COMPUTER, w/documentation, $40; moving boxes w/ packing paper, free. Smith, 256-0861.

UNM BASKETBALL SEASON TICKET, Section 6, Row 23 (chairback), $188 (UNM price). Ard, 299-0863.

FIFTH-WHEEL CAMPER, 30', $4500. Campbell, 888-3135.

THREE-STAGE CAR SEAT, $12; preschooler booster car seat, $13; wooden sandbox, $7; bicycle training wheels, $4. Follstaedt, 299-5941.

MOVING BOXES; complete B&W darkroom equipment, $20. Sleefe, 281-4103.

RIFLE: Winchester 30-06 w/scope & case, used once, cost $550, sell for $450; office desk, new, custom-made, $275. Luna, 877-3137.

MINK COAT, long, natural ranch, diagonal cut, fits woman about 5'7" tall, appraised at $4500, will consider reasonable offers. MacDougall, 884-9711.

IBM COMPUTER, System 2 w/20M hard disk, removable 3-1/2" disk, printer, monitor, $3300. Hahn, 822-1341.

KING-SIZE WATER BED, waveless, new heater and liner, bookshelf headboard, $175. Kelly, 255-7226 or 294-7084 leave message.

RADIO-CONTROLLED TOY TRUCK, new, 2x4, 4x4, extras, cost $120, sell for $60. Heider, 897-0752.

COUNTER-TOP ELECTRIC STOVE, Kenmore, coppertone, $35. Peterson, 256-7514.

ELECTRIC HEATER, thermostat variable to 1650W, $15; Svea stove w/Sigg nested boilers, $25. Rhoads, 298-6157.

BABY CRIB, Jenny Lind style, $40; baby walker, $10; baby swing, $10. Sturgeon, 281-2956.

DINETTE SET, 5-piece, wood, 42" round table (extends to 66"), 4 chairs (2 captain's), $250. Adam, 256-9105.

COLOR TV, Zenith 25", table model, Chromacolor II, $45. Trump, 299-5162.

FOUR ELECTRIC WALL HEATERS, 10', $25/ea. Cibicki, 877-7098.

KING-SIZE WATER BED, bag-type, heater, rustic wood frame and headboard, pads, complete, $75. Meyer-Hagen, 293-7339.

FIVE TRUCK TIRES, 8.75x16.5LT tubeless, usage varies from 7K to 17K miles, $45. McGee, 299-0661.

DINING ROOM SET, contemporary brass/glass; hockey gear; oak bedroom set; guitar; stereo; more. Goodson, 294-8179.

RECEIVER, turntable, speakers, tennis rackets, timing light, lamps, stoneware, drinking glasses, other household items. Clauss, 266-9319.

THREE END TABLES, enclosures w/ doors, $25/ea.; programmable police scanner, w/books and antenna, $100; 5 RV tires, 8x19.5, $25/ea. OBO; RV TV antenna, $50. Singleton, 299-1613.

SKIS, Head 140cm, w/Tyrolia bindings, $20; Munari size 7 DIN-certified ski boots, $15. Kerschen, 821-2848.

AMATEUR TRANSCEIVERS, Swan SSB400, mobile, fixed, tri-band antennas, VFOs, supplies, coax., $300; Swan 250, $200 or make offer. Arlowe, 298-1770.

SHOTGUN, Remington LT 20-ga. pump, $300; Winchester model 94, 22-mag., $150; Winchester model 94, 30/30, $160; 300-mag. Weatherby w/scope, $1200. Avila, 294-2020.

WATER BED, 12-drawer stand, headboard, padded side boards, 8-drawer chest of drawers, tri-fold mirror, nightstand, $800 OBO. Danneels, 292-1548.

WASHER AND ELECTRIC DRYER, almond, heavy-duty, less than 1 year old, $495. Hoffheins, 293-5221.

RELOADING EQUIPMENT, powder measure, $25; 44-mag. carbide die set, $25; rollaway bed, $30; rider toys, $5/ea. McFarland, 292-3129.

PRECOR ROWING MACHINE, 615e, $145; car ski rack, fits roof rack, used once, $50. Laguna, 881-9316.

CRIB MATTRESS, $10; baby carrier, $5; gate, $5; diaper bag, $3; bathtub, $3; B&W TV, $20. Martinez, 294-5692.

WATER-BED MATTRESS, queen-size, heater, etc., no frame, $110; electric typewriter, $35. Vanderburg, 836-1169.

N-GAUGE TRAIN SET, w/accessories, $100; 30-lb. re-curve bow, Shakespeare, $65; humidifier, 7-gal. console-type, $35. Bruneske, 897-4721.

STORM DOOR, brown, w/frame & hardware, latch & deadbolt locks, keys, opens L-R from outside, $40. Osburn, 298-0354.

FOUR TOYO TIRES, for 4-WD, 31", $120 OBO. Garcia, 293-2810.

LIVING-ROOM FURNITURE: 4-piece sectional, armchair w/ottoman, all deep burgundy/rust upholstery, $120. Lagasse, 293-0385.

LOBO BASKETBALL SEASON TICKETS, w/parking, chairback, mezzanine. Underhill, 294-5774.

HOT-AIR SOLAR PANELS, 39" x 11', complete w/new accessories, heats 800 sq. ft., $300; misc. solar equipment. Brantley, 294-1169.

TI99/4A COMPUTER, color monitor, printer, 2 disk drives, modem, speech synthesizer, word processing, spreadsheet, PASCAL, games, make offer. Shipley, 888-1666.

MOTORCYCLE HELMET, $20. Murphy, 881-1520.

TRANSPORTATION

'29 MODEL A FORD TUDOR, 90% restored, $6000. Dingman, 292-6934.

RECUMBENT BICYCLE, 25 lbs., chrome/moly frame, cost $1400, sell frame for $450 (complete bike $700, w/extras $850 OBO). Corwin, 298-0113.

'79 YAMAHA XS-1100, black, shaft drive, extras, $1400. Gonzales, 898-8728.

'79 PLYMOUTH VOLARE, 2-dr. hardtop, V-8, PS, PB, AT, AC, 59K miles, $1395. Rauch, 821-6992.

'82 YAMAHA 650 MAXIM, $900 firm. Brooks, 299-3464.

'81 SUBARU GLF, new tires, shocks, brakes, $1750; '79 Honda XL500, $550; '76 Honda TL250/350, $300 OBO. Freshour, 275-2206.

'73 CAMARO Z28, L82 350-cu.-in. engine, AT, $4500. Marrs, 281-9889.

'74 CORVETTE, 350 V-8, 4-spd., new paint, Goodyear Eagle tires, Enkei aluminum wheels, Alpine stereo, more, $7750 OBO. Marlman, 883-8660.

'84 VOLVO 240GL SW, pewter exterior, beige leather interior, tinted glass, $10,500 OBO. Broyles, 281-1917.

'87 MERCURY TOPAZ, 4x4, AT, AC, cruise, cassette stereo, below NADA book, $7700. Sleefe, 281-4103.

'87 HONDA HURRICANE 600R, white & red, $2995 OBO. Burke, 298-7896.

'80 HONDA ACCORD, 3-dr. hatchback, AC, new AT, $2200 OBO. Byars, 294-6676.

'86 SUNSTREAM MOTORHOME, 30', all extras, 6K miles. Jacobs, 821-2403.

'79 CHEV. CHEVETTE, 2-dr., $750; '75 Pontiac Trans Am, 400 CID, AT, honeycomb wheels, 77K miles, $3500. Perea, 296-2309 after 6.

'85 NISSAN PICKUP, 4-WD, chrome wheels, camper shell, stereo, 49K miles, $5900. Kemm, 294-3959.

'80 MONTE CARLO, blue, PS, PB, AM/FM cassette, $2500. Salisbury, 242-6299 or 266-4280.

'70 CHEV. BLAZER, 4-WD, 4-spd., AC, AM/FM, CB, 3 gas tanks, 84K miles, $2500. Seavey, 884-8215.

'77 BMW 5301, white, leather w/sheepskin covers, tinted windows, AM/FM cassette, AC, PW, power sunroof, $4500 OBO. Trump, 296-1984.

'84 FORD F150 PICKUP, PS, PB, AC, cruise, 6-cyl., 23K miles, $6500 OBO. Hassig, 292-3350.

'81 CITATION, 4-dr. hatchback, 4-cyl., AC, PS, PB, cruise, stereo, bucket seats, Michelins, 52K miles, 30 mpg. Stam, 299-3724.

'73 MERCURY MONTEGO, damaged fender, $400 firm; '76 Chrysler Newport, needs 2 windows, $400 firm. Butler, 821-7148.

'87 MAZDA 626LX, 4-dr., 5-spd., AC, cruise, AM/FM cassette, PW, PL. Craig, 888-2651.

'76 TOYOTA COROLLA SW, AT, AC, AM radio, 76K miles, one owner, $975. Schroll, 299-9142.

'81 FORD FAIRMONT, 6-cyl., new tires, rebuilt engine, AC, PB, PW, 4-dr., maroon. Carrillo, 292-7283 after 5.

'71 INTERNATIONAL TRAVELALL 1010, equipped for trailer towing, extras, $2350 OBO. Newton, 268-1961.

'82 FORD ESCORT, new clutch, 79K miles, AM/FM cassette, $1700. Zamora, 294-3737.

'53 FORD CUSTOMLINE, V-8, AT, new paint, interior, tires, $2600 OBO. Schaub, 821-7242.

'59 INTERNATIONAL PICKUP, new tires and brakes, $800 OBO. Foltz, 291-0051.

'78 DATSUN 280Z, 2x2, new radio, paint, and tires, $3500. Martinez, 293-4831.

'84 CHRYSLER LASER XE, turbo, auto diagnostics, AT, AM/FM cassette, power everything, $500 under blue book, $4975. Barr, 294-9034.

'70 VW BUG, $1250 OBO. Kitta, 296-4057.

'84 BRONCO II, 4-spd., AM/FM cassette, 40K miles. Eckley, 294-7650.

'56 CHEV. PICKUP, w/spare parts, $950. Narma, 296-5941.

'79 DOLPHIN MOTORHOME, 17-1/2', 32K miles, fully self-contained, utility trailer available, $6900 OBO. Castle, 293-8379.

'82 TOYOTA CELICA ST, 5-spd., AM/FM cassette, radials, tinted windows, serviced every 5000 miles, never wrecked, $2950. Brantley, 294-1169.

'80 DODGE MAXIVAN, PS, AT, V-8, finished interior, $1950. Pierce, 293-2380.

'84 PONTIAC FIERO SE, PW, PL, sunroof, new tires and brakes, red/gray interior. Atkins, 299-0810 leave message.

'84 RX-7 GSL-SE, silver, AC, PW, cruise, AM/FM cassette, tinted windows, new tires, leather seats, sunroof, 49K miles, $8500. Brooks, 298-3294.

REAL ESTATE

4-BDR. HOME, Nob Hill, 2-1/4 baths, office or den, pool, part basement, 2350 sq. ft., $109,000. O'Neill, 255-6355.

3-BDR. HOME, 1400 sq. ft., 6-year-old Wood Bros., 1-3/4 baths, finished 2-car garage, landscaping, near Spain & Juan Tabo, $99,900. Baldwin, 293-6730.

3-BDR. LOG-SIDED HOME, Cedar Crest, study, 2 baths, heated workshop, double garage, horse facilities, Hwy. 14 frontage, 2-1/2 acres, $149,900. Hurt, 281-3675.

4-BDR. HOME, Tramway/Lomas area, 2021 sq. ft., 2 baths, Jacuzzi, assumable ARM 10%, $117,900. Gonzales, 298-0190.

3-BDR. NEW CUSTOM HOME, off Tramway, brick front, pitched roof, close to park/schools, $94,900. Haynes, 296-0336 or 296-4690.

3-BDR. HOUSE, 1 bath, near Lomas/Morris, $2000/down, $64,900. Thomas, 293-0681.

2-BDR. MOBILE HOME, '87 Skyline, 14' x 52', 1 bath, $13,600 book value, sell for $9800, will consider trade. Cole, 281-9873.

4-BDR. HOME, located on 12th fairway of Rio Rancho golf course, views. Johnson, 892-4943.

WANTED

POWER LAWN MOWER, good condition, prefer rear-bagger. Miller, 292-5634.

LWB FOR '75 PICKUP, 3/4-ton. Chavez, 842-6374.

PROPANE STOVE, in good condition, type used in camping trailers. Martinez, 821-6096.

TRANSPORTATION for bedroom set and misc. to Irving, Tex., cost negotiable. Myers, 265-7293.

WASHER/DRYER, large apartment-size or portable, no more than 5 years old. Levan, 821-3707.

EXERCISE TREADMILL, will buy or trade Sears exercycle. Sorrell, 292-0874.

CHILD'S CAR SEAT, booster type; man's ski boots, size 14. Appel, 292-0463.

OAK, CHERRY, OR APPLE BRANCHES, dead/pruned, small or large. Cibicki, 877-7098.

USED CELLO, in good condition, have violin for possible trade. Meissner, 268-7952.

BMX BICYCLE, Diamondback or other high-quality make; 120cm, 150cm, 160cm, 170cm skis; size 2 ski boots. Kerschen, 821-2848.

COMMODORE VIC20 COMPUTER. Foltz, 291-0051.

Attention, C-Clubbers

As mentioned last issue, the fix-up crew is hard at work on renovations at the Coronado Club. Meantime, evening functions are on hold — but there's a light at the end of the tunnel. Circle the whole month of November on your calendar, because Manager Sal Salas tells us that C-Club activities will be back in full swing next month. That means you can look forward to those ever-popular Western Nights, Friday-night dinners, and Sunday brunches.

Next to Thanksgiving, the most important date to remember next month is the 18th; a pull-out-all-the-stops Grand Reopening Celebration includes a happy-hour band, drink specials, the usual Friday-evening dance band, and door prizes. More details next issue.

News note: Last month, C-Club tennis instructor Don Ansel was named US Professional Tennis Assn. (PTA) "professional of the week" by the cable network program, "Inside World Tennis." Don received the award at a PTA tournament in Palm Springs, Calif.

And now, today's riddle: What unretiring group will be the first one in the door in November? If you guessed those wily T-Bird card sharks, you're absolutely right. Trust the sharks to be first in line — every time. The wheeler-dealers go back into action on Thursday, Nov. 3, beginning at 10 a.m. As usual, it's good everything: conversation, cards, refreshments, and door prizes.

Medical Corner

'Drug-Free America Week': It's Oct. 24-30

Sandia is participating in "Drug-Free America Week" by reminding employees of its long-term (since 1972) Program for Alcoholism and Other Drug Abuse. (A booklet by that name was recently distributed to all employees; if you failed to receive one, call 6-2281.)

Through its ongoing program, Sandia is part of DOE's campaign to achieve a "drug-free workplace." If you would like further information, call Jim Kelly on 4-4154 or Steve Anderson on 4-3993.

Sympathy

To Ray Alls (2341) on the death of his son in Albuquerque, Sept. 27.

To Hermenes Baca (7818) on the death of his brother in Albuquerque, Oct. 2.

To Sue Stone (5112) on the death of her mother in Albuquerque, Oct. 5.

Congratulations

To Barbara and John (2346) Fuller, a son, Benjamin, Sept. 13.

To Linda and Russ (1512) Skocypec, a daughter, Valerie Rose, Sept. 30.

To Kerrie and Patrick (5221) Sena, a daughter, Emilee Lolita, Oct. 3.

Events Calendar

Oct. 21 — "Rainbow Serenade," benefit concert for Casa Esperanza, featuring the New Mexi-Chords Barbershop Chorus; 8 p.m., Hoffmantown Baptist Church (8800 Harper NE), 821-1305.

Oct. 21 — Bluegrass concert by the BCH Acoustic Group, 7:30 p.m., First United Methodist Church (4th & Lead SW), tickets available at Riedling, Pimentel & Sons, and Encore Music.

Oct. 21-22 — Classical Concert II: "Hymns to the Human Spirit," NM Symphony Orchestra and Chorus perform music by Mozart and Stravinsky; 8:15 p.m., Popejoy Hall, 842-8565.

Oct. 21-22 — Premiere performance of original works by Tim Wengard & Company, featuring modern dance and classical ballet pieces, including "Blue Mesa" performed by Tom McVeety; 8 p.m., KiMo Theatre, 265-1087 or 848-1374.

Oct. 21-31 — "Kingdom Come," by Nancy Gage, premiere drama of love and life on the Navajo Reservation; 8 p.m. Fri-Sat., 6 p.m. Sun.; Vortex Theatre, 247-8600.

Oct. 21-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.

Oct. 22-23 — "Chrysanthemums in Song," fall flower show; 2-5 p.m. Sat., noon-5 p.m. Sun.; Albuquerque Garden Center (10120 Lomas NE), free, 296-6020.

Oct. 23 — Danish Boys Choir, 30-member group of 9- to 14-year-old boys from Copenhagen; 4:15 p.m., New Mexico Museum of Natural History, 841-8837.

Oct. 23 — Concert, classical music by the Albuquerque Philharmonia Orchestra, guest conductor Ted Rush; 2 p.m., KiMo Theatre, 294-6866.

Oct. 23 — Keller Hall Performance: UNM Jazz Band; 3 p.m., Keller Hall, 277-4402.

Oct. 25 — The Slovak State Folk Festival: 60 acrobats, dancers, musicians, and singers from behind the Iron Curtain; 8:15 p.m., Popejoy Hall, 277-3121.

Oct. 25 — Nikolario Dance Company, multi-media dance performance; 8 p.m., KiMo Theatre, 848-1370.

Oct. 27-29 — "Dancescape," fall performance by UNM Dance Division, combining modern dance, jazz, ballet, and flamenco; 8 p.m., Rodey Theatre, 277-4402.

Oct. 28-29 — "Comedy with Music," Victor Borge conducts the New Mexico Symphony Orchestra, featuring a program of light classics and outrageous silliness; 8:15 p.m., Popejoy Hall, 842-8565.

Oct. 28-29 — "1000 Airplanes on the Roof," story of a man's encounter with unknown beings, music by Philip Glass; 8 p.m., KiMo Theatre, 848-1370.

Oct. 29 — Keller Hall Series: Seraphin Trio; 8:15 p.m., Keller Hall, 277-4402.

Oct. 29-30 — Albuquerque Doll, Old Toys, and Miniature Show; 10 a.m.-6 p.m. Sat., 10 a.m.-5 p.m. Sun.; Exhibit Hall, NM State Fairgrounds, 883-6986.

Oct. 29-31 — "Mud," Tapestry Players production of play by Maria Irene Fornes about a woman struggling for an education and a better way of life; 8 p.m., First Unitarian Church (3701 Carlisle NE), 843-4338.

Oct. 30 — Garfield Family Concert: Garfield the cat and his sidekick Odie join the New Mexico Symphony Orchestra; 2 p.m., Popejoy Hall, 843-7657.

Oct. 30 — Vienna Boys Choir: costumed operettas, sacred songs, and folk music; 4 p.m., First United Methodist Church (4th & Lead SW), 243-5646.

Take Note

Peter Chen (1533) has been appointed an associate editor of the *Journal of Wave-Material Interaction* for the term 1989-1991. The journal is edited by Prof. V. K. Varadan of the Research Center for the Engineering of Electronic and Acoustic Materials at Penn State.

* * *

The October meeting of the New Mexico Section of the American Society of Mechanical Engineers is scheduled for Oct. 25 at El Patron Restaurant (Wyoming Mall Shopping Center). Larry Teufel (6232) will speak on "*In Situ* Stress Measurements in the North Sea — Applications to Petroleum Production." Social hour begins at 6:30 p.m., dinner at 7:15, and the speech at 8. Cost is $11 per person. For reservations, call Jim Allen (1522) on 4-6764. For more information, contact Joe Koski (6514) on 6-0138.

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Attention, DeVry alumni: an alumni reception is set for Nov. 11 at the Albuquerque Radisson Inn (1901 University SE) from 5 to 7 p.m. Chairman of the Board Dennis Keller is the host and offers you an opportunity to catch up on DeVry activities and take a peek into the future. A buffet dinner and beverages will be served. To RSVP or ask any questions, contact Marcia Curtis at the DeVry Alumni Assn. on 1-800-225-8000, ext. 5384, by Nov. 4.

* * *

Lots of philatelic phun's to be had when the Albuquerque Philatelic Society presents "ALPEX '88," its annual stamp show, this weekend at the Holiday Inn Midtown (2020 Menaul NE). Hours: 12 noon-7:30 p.m. today, 10 a.m.-7 p.m. Saturday, and 10 a.m.-4 p.m. Sunday. The show features stamp exhibits, stamp dealers, special-cancellation envelopes, and sales of mint stamps at face cost by the US Postal Service. Admission is free.

Fun & Games

Fun Run — Runners, walkers, and their canines are invited to participate in the 8th Annual "Charlie Black Memorial Fun Run" on Nov. 6 at the intersection of Barstow and Paseo del Norte NE. Prizes will be awarded for first, second, and third places in each age and gender group, with a separate set of awards for top finishers in the "run with your dog" category. In addition to the four-mile run, there will be a two-mile noncompetitive walk. Registration is at 8 a.m., with the race starting promptly at 9. Entry fee is $8 before race day and $10 on race day. All fees go to support the animals at the Animal Humane Association of New Mexico (AHA). Entry blanks are available at Gil's Runners Shoe World and at AHA (615 Virginia SE). More information from Mike Rex (3521) on 4-2838.

(In 1969, two boys threw a mongrel pup from a downtown Albuquerque parking structure. AHA rescued him, named him Charlie Black, and kept him as a mascot until he died of old age.)

AN EXHIBIT of oriental-style watercolors by Faith Perry (3523) is on display in the Bldg. 802 lobby through Nov. 4. Here, she works on one of her latest creations. Faith, who's displayed her work at many shows and galleries, also teaches SERP classes that explore this unique art style; more info from SERP on 4-8486.

(Continued from Page Ten)

Combustors

tically enhanced drying system. They also have a patent disclosure for an injection system that promises to extend the range of firing rates over which a pulse combustor can operate.

Empty Lab — Once

Almost five years ago, the pulse combustion program started at the CRF with an empty lab. Now there's a highly interactive program, four Sandians working with five visiting researchers, close involvement with both Lennox Industries, Inc. (the leading US manufacturer of pulse combustion equipment) and the Gas Research Institute, labs full of equipment, and ten publications in reputable journals and conferences.

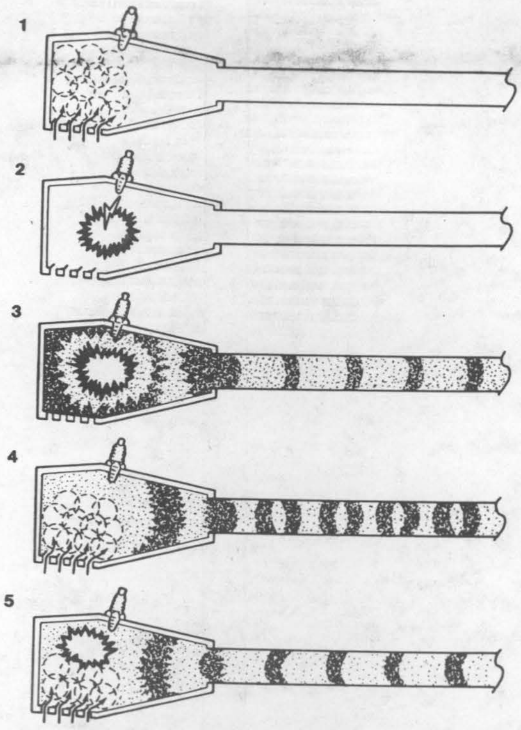
It all started as a result of several coincidental events. A Japanese researcher from Toshiba wanted to come to the CRF to learn laser diagnostics technology. As his share of the bargain, he offered to bring with him water-heater pulse combustion technology. It clearly had enormous promise.

At the same time, the Gas Research Institute and the American Gas Association had seen the advantage of this technology and had been working collaboratively with Lennox to develop the first-generation domestic space heater. Lennox now markets this as its pulse furnace. It has been highly successful.

All this combined with encouragement from Marvin Gunn, the CRF's program manager at DOE Conservation's Energy Conversion and Utilization Technologies Program in Washington. He had been managing the engine program and wanted the CRF to take on a continuous combustion program (for furnaces and the like) as well.

'A Clean Sheet of Paper'

''Pulse combustion has such tremendous potential,'' says Mike Dyer. ''The staff member from Toshiba came, we hired a fresh PhD researcher out of Berkeley, Jay Keller, and we put these two guys in that empty lab back in 1984. We had the opportunity with a clean sheet of paper to design a program just the way we wanted it. Out of that, without exaggerating, has come probably the most technically sophisticated, innovative research group in this area in the world.''



PULSE COMBUSTOR OPERATION begins (1) when fuel enters a combustion chamber through flapper valves. Fuel/air mix is ignited by a spark plug (2), causing the first pulse. This closes flapper valves (3), forcing combustion products out of the tailpipe. Negative pressure created in the chamber allows flapper valves to open again (4), and another charge of fuel and air enters the chamber. When the reflective wave re-enters the chamber (5), the new mix ignites without the use of the spark plug, causing the next pulse.

One example: A graduate student from the University of Michigan, John Dec (now a 6427 staff member), worked collaboratively with Jay and other members of the team for three years as part of his PhD thesis to determine the basic controlling process that governs the enhanced heat transfer.

Says Mike: ''They've used time- and space-resolved laser velocimetry to map the momentum boundary layer. They've developed a new laser diagnostic to measure real-time temperature that maps the thermal boundary layer evolution. And they've applied wall heat transfer gauges. All these together have developed a complete picture of the nature of the process.''

Some people, he says, ''think pulse combustors are designed by art. But, really, by understanding the fundamentals of the processes, you can vary parameters and know what to expect. We've reached a certain level of understanding in incorporating these principles, proving them in an actual apparatus. That's been just a tremendous breakthrough.''

The CRF's Pam Barr (8363) has developed a computer-based model of pulse combustion and has done a parametric computer design study in collaboration with Lennox. The Lennox people are now back developing prototype hardware on their own for their next-generation pulse burner. (They see the need for an advanced system to remain competitive in the international marketplace.) They have fabricated several prototype combustors based on the results of this interaction. Lennox is planning to participate in a more extensive collaborative program at Sandia under DOE's Industrial Fellow program. Pam has also developed a model of a twin-tailpipe pulse combustion system being developed by Forbes Energy Engineering Company.

Key to the research is the intimate coupling of experiment and theory, incorporating the new information gained into improved computer models.

''A lot of this technology is transferred through these models that incorporate all the new understanding,'' says Mike. ''We use these models as libraries of knowledge. As you learn something, you incorporate it into the model, and the model keeps track of what controls the processes.

''It also keeps track of all the things that are difficult for us to synthesize, all the complex coupled relationships. You have transient fluid flow, transient combustion, transient acoustic wave motion. You vary something at this end, and it has effects all the way up at the other end.

''This team has been able to sort these interactions out, and I think it really provides a new analysis tool that can accelerate the design and implementation of this technology.''

Mundane, Prosaic — and Needed

Coal Research Goes High Tech

It's mundane. It's prosaic. It's coal.

In fact, these ignoble chunks of carbonaceous conglomerations challenge our science and technology and shape our energy future.

Coal may be ancient in both origin and use. But for better or worse, energy requirements, especially here in the US, are wedded to the continuing, and increasing, combustion of coal.

No wonder. It's not glamorous, but it is abundant.

The US has 30 percent of the world's coal reserves. This amounts to something like 400 billion metric tons. At current US production rates (around 750 million metric tons a year), that would be enough to last four or five centuries.

So, as US dependence on oil continually intertwines in global geopolitical concerns, coal at least offers the comfort of ample domestic supplies — along with all the pressing environmental problems it poses.

Getting to the Fundamentals

At Sandia's Combustion Research Facility (CRF), researchers seek to move the science and technology of coal combustion toward the 21st century.

Doing it means getting down to fundamentals.

That isn't easy in a fragmented industry mired in tradition. Take the boilers that burn coal in power plants.

''Designs that exist today are extrapolations of practice that is essentially 60 years old,'' says Don Hardesty, supervisor of Combustion Research Div. 8361.

''Designers of coal-fired power plants make little use of high-technology capabilities that have evolved in the past 20 years in the areas of coal-combustion science and computational fluid mechanics.''

These are exactly the high-tech areas the CRF has been pioneering.

Don, who manages the CRF's coal program in Bill McLean's Combustion Technology Dept. 8360, was one of the few early CRF members with an academic background in combustion science. He came out of Princeton to Sandia Albuquerque with a degree in mechanical engineering with emphasis in combustion. ''Back then we were flying to the moon,'' he recalls. ''The real thrust was propellant combustion. We needed to learn how to burn liquid in large rocket motors.''

But, when the CRF was being created in Livermore, his combustion expertise made him a natural to transfer to that lab. He was soon at work on low-pressure flame combustion. (Low-pressure reactors allow slower burning, thicker flames, and, therefore, better resolution and easier measurements.)

In the mid-70s, he became interested in coal and received a go-ahead to work on that subject as well. The needs, then great, still are.

''We require industry to generate electric power in a clean, environmentally acceptable manner,'' notes Don. ''Imposition of these constraints, coupled with a more practical engineering problem of being flexible about our fuel sources, means that our present approach to designing coal combustors is too inflexible, costly, and polluting.

More Basic Understanding Still Needed

''We need the proper predictive and design tools — computational codes for coal combustion, like those that already exist for the automotive and gas turbine industries — in order to do a much better job of designing boilers and

(Continued on Next Page)

A KEY COMPONENT of CRF's Coal Char Combustion Lab is the laminar flow reactor that Don Hardesty (left) and Reginald Mitchell (both 8361) are watching. It burns pulverized coal in environments like those found in utility company boilers.

(Continued from Preceding Page)

Coal Research

furnaces to satisfy environmental constraints and to be fuel-flexible.''

Developing these codes requires considerable improvement in understanding how coal burns and how pollutants are produced.

Under the sponsorship of DOE's Office of Fossil Energy, Sandia's CRF developed a broad program of fundamental and applied coal-science research. Fundamental studies emphasize experiment. Applied research involves laser-based optical and physical sampling techniques to monitor combustor flames and flow streams.

Where might the greatest impact come? Improving the ''quality'' of coal, or ''coal beneficiation,'' can have a big impact. But it's also now known that careful control of mixing rates of fuel, air, and output of pulverized coal combustion systems can bring about reduced emissions, increased fuel flexibility, and increased efficiency. The key lies in better understanding of details, particularly in quantifying behavior of combustion processes, including details that govern changes in temperature and composition of fuel particles as reactions proceed. This new knowledge will serve as the critical input to new predictive codes for boiler design.

''There's optimism among engineers like myself,'' says Don. ''Virtually anything we've done in an intelligent fashion to improve ways to burn gasoline or coal has worked. For example, we realized that by carefully mixing fuel and air, we eliminate temperature peaks and reduce nitric oxide formation. Combustion process details *are* important.''

To get those details, CRF's coal program has an impressive arsenal of research tools.

There's the laminar-flow reactor in Reginald Mitchell's (8361) lab. Reginald, a chemical engineer from MIT, designed the lab to simulate coal boiler combustion conditions. Coal particles are injected in a single stream on the reactor's centerline, and combustion processes are directly observed and monitored.

A CRF-developed coded-aperture imaging diagnostic system measures size, temperature, and velocity of individual coal particles as they react.

Fool's Gold Causes Problems

''We use these data to determine how pulverized coal burns, how local temperatures and local oxygen concentrations influence burning rates, how nitrogen and sulfur are evolved, and how all this relates to the way in which mineral matter evolves,'' says Reginald.

Mineral matter is a special problem. About 15 percent of the weight of North American coals is mineral matter — silica, alumina, iron pyrite, and so on. ''It's a list as long as your arm,'' says Don.

''For instance, there's fool's gold [iron pyrite]. It's the source of at least 50 percent of the sulfur in high-sulfur coals. About half of the sulfur in these coals can be mechanically removed,'' Don says. ''The other half is tied up in organic molecules that make up the hydrocarbon matrix.''

Minerals cause most of the coal's problems — sulfur and other unwanted gases, particulates (fly ash). Minerals also cause corrosion, erosion, and deposits on equipment.

''During the next two or three years we'll be developing a sound research program to address mineral matter,'' says Don. ''We want to know how mineral matter evolves, how it transforms, and how it deposits. In a sense, it will be the cradle-to-grave of mineral matter.''

To attack the mineral-matter problem, Larry Baxter (8361) joined Don in developing the newest tool in the CRF's coal research program, the Multifuel Combustor. Larry, a chemical engineer from BYU, uses it to measure gas and material properties in coal combustion flows littered with mineral and fly-ash particles.

A mobile, laser-based system makes precise measurements of the size and flux of these particles in a variety of research and simulated industrial conditions. A Fourier-transform infrared spectrometer will be applied to measure both gas and surface properties under simulated fly-ash deposition conditions.

Must Be Multidisciplinary

Scientific challenges addressing coal problems clearly require multidisciplinary research, which, says Don, ''is one reason why so little really good research has been done.''

Not many organizations have the means. ''You need materials scientists, chemists, spectroscopists, and chemical engineers working hand-in-hand,'' Don continues. ''Our program has those types of people plus physical chemists, inorganic chemists, electron optics experts, and mechanical engineers. All are needed.

''Often, we also draw on the resources of our academic visitors to provide an additional perspective.''

A good example is the team formed by Tom Fletcher (8361) to unravel the early reaction history — the pyrolysis — of coal particles. Tom heads a group that includes University of Utah professors Ron Pugmire and Dave Gant, and Alan Kerstein (8363). ''The professors provide strong organic chemistry input with an interpretation of coal chemical structure based on their nuclear magnetic resonance spectroscopy studies of coals,'' Don says. ''Alan uses percolation statistics to interpret coal pyrolysis based on these data, and Tom uses a CRF flow reactor to determine coal particle temperature, rates of reaction, and yields of tar, gases, and char during pyrolysis.''

Team members are pooling their information to develop a predictive model of the process for industry.

Expect Technology Transfer Too

Some CRF-designed coal research tools — especially the optical diagnostics — may end up being used directly by industry. ''We like to think that some of these tools will ultimately find their way into the power-generation industry as control monitors,'' says Don. Already, representatives from a big lumber company and a manufacturer of coal-combustion equipment have visited and taken optical diagnostic technology back with them.

In addition, the Electric Power Research Institute (EPRI) has contracted with CRF, on behalf of the electrical power industry, to do exploratory research in coal combustion.

And some individual companies are beginning to take the high-tech route.

''Ten years ago there was virtually no one among the equipment manufacturers even thinking about using big codes and big computers to do detailed modeling of coal-combustion processes,'' says Don.

Now that may be changing. ''Babcock & Wilcox [a large manufacturer of coal-burning equipment] has been the most aggressive, forming a team to develop a computational fluid mechanics and combustion capability.

''I'm a believer that we could do a much better job of burning coal more cleanly,'' says Don. ''We have shown over and over again in the combustion business that if you control and manage the details in the right way, you can vastly improve the process.

''We're beginning to do some of that in the coal business.''

Getting Rid of Belching Smoke

Real-World Problems With Real Diesel Engines

"On the hill" at Sandia Livermore, in an island building surrounded by the tech area, a gleaming diesel engine from Cummins Engine Company has been installed and put through early test operations.

It is the start of a test program that embodies all that is special about Sandia's Combustion Research Facility (CRF) and its unique approach in working directly with industry to help solve crucial combustion-related energy problems.

Cummins' contribution doesn't end with the engine. The company also sent two of its own PhD researchers, Axel zur Loye and Henry Ng. Axel, a recent Princeton graduate, will be working full-time through 1989 at the CRF as a DOE Industrial Fellow.

He's collaborating with Sandia researcher Dennis Siebers (8362) to learn exactly where and how soot forms and evolves inside a working diesel engine. The goal — reduce it.

"It's one of our most exciting collaborations," says Mike Dyer, who oversees all the CRF engine programs as supervisor of Combustion Applications Div. 8362. The engine program has been under continuous support for the past dozen years by DOE Conservation's Energy Conversion and Utilization Technologies (ECUT) Program.

"The diesel particulate issue is of timely importance to our country," Mike continues. "There is a synergistic blend of talents. And the project challenges every aspect of our capabilities — large engine testing, in-cylinder imaging diagnostics, and combustion science."

(The Cummins engine is in the same lab where Dennis Siebers earlier demonstrated the feasibility of Bob Perry's RAPRENOx NOx-reduction process, a discovery also important to the diesel industry; Dennis continues research on RAPRENOx technology, using the same Sandia test engine, while also working with the Cummins engine.)

Sophisticated Approaches

Almost from the beginning, the CRF has focused on sophisticated approaches to real-world problems in combustion. What's new this time is a real-world engine. No simple, idealized, bench-top laboratory engine.

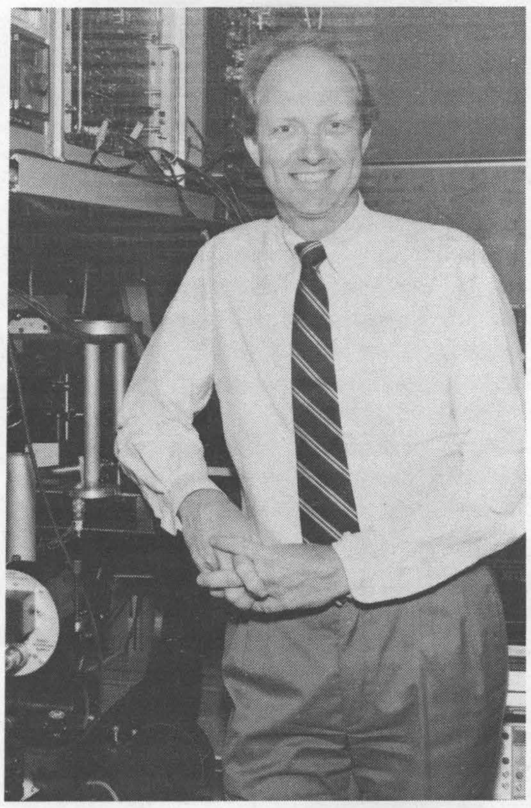
Says Mike: "Our peer reviewers and industry groups were telling us that our diagnostics were good and the problems we were working on were good. But how do they apply to a real engine? What happens in a real engine, when you look at realistic combustion-chamber shapes and realistic operating conditions?"

Actually the largest engine from industry to operate at the CRF is not the Cummins diesel, but a mammoth 750-horsepower rotary engine brought in by John Deere. Although gone now, it filled most of a sound-insulated laboratory room. Mike Dyer called it "the beast."

The Deere rotary, a direct-injection stratified charge engine, was modified only by addition of several small windows to allow the laser diagnostic measurements.

For three months during the latter part of 1987, Philip Dimpelfeld of Deere's rotary engine division worked, as a DOE Industrial Fellow, with the CRF's Pete Witze (DMTS, 8362). They took laser Doppler velocimetry measurements of flows inside the engine. The goal? To validate a computer model that's being developed at John Deere in collaboration with Princeton. "It's all a big collaborative network," Mike notes.

The diesel project with Cummins is bigger yet. The heavy-duty diesel engine industry has a problem. New Environmental Protection Agency



OVERSEEING ENGINE RESEARCH and DOE's Industrial Technology Fellowship Program at CRF is Mike Dyer (8362).

(EPA) standards restricting the amount of smoke particulate and NOx that can be released from all new large truck and bus diesel engines take effect in 1991 and become even stricter in 1994. It's a dilemma for the industry. It's considered the most pressing issue facing the diesel engine development industry today. "They're working like crazy," says Mike.

The stringent regulations are forcing the diesel industry, like the gasoline-engine industry a decade earlier, to look at new research approaches. Many in industry now realize that a scientific approach to understanding the fundamental processes rapidly forming and destroying soot inside the engine is essential for further improvements.

Cummins and Sandia have, as a result, begun an aggressive collaborative program to investigate the processes controlling particulate formation in a realistic heavy-duty diesel engine. The engine is the Cummins NH Series, incorporated into many tractor-trailer trucks now on the highways.

Cummins brought a one-cylinder version to Sandia, but it's still good-sized. For vibration isolation, the four-ton block of concrete it sits on is separated from the rest of the building's floor. Laser diagnostics crisscross its exterior.

"They sent us a single-cylinder version of the engine with some optical windows and, to boot, a staff member challenged with understanding where, when, and why particulates form inside the cylinder," says Mike.

The immediate goal is to help meet the EPA-mandated emissions. But, notes Mike, "1991 is amazingly soon." They're really looking five years down the line toward the 1994 standards.

The program is taking advantage of Cummins' expertise in diesel engine design, development, and testing and its knowledge of the trade-offs between emission of particulates and of oxides of nitrogen. The research will also make full use of Sandia's unique in-cylinder laser-imaging diagnostic capability and the CRF's staff expertise in processes of soot formation and oxidation.

"The outlook's very positive," says Mike. "We are confident the companies that embrace these new approaches will be positioned to develop products that provide the best compromise between performance, emission control, and fuel economy."

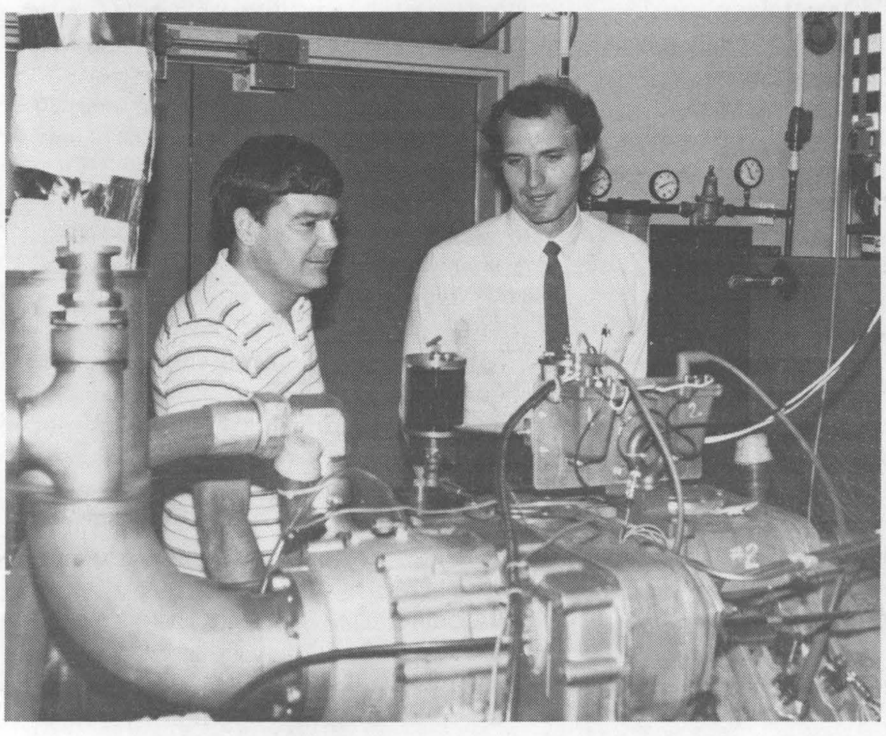
Pushing the Limits

"This project pushes our limits," Mike continues. "It taxes our diagnostics." The laser-imaging equipment will be taking a quarter of a million data points on particulate locations during every engine-firing cycle.

The investigators are starting by taking laser velocimetry measurements of the in-cylinder flows during intake and compression. These data will be compared with multidimensional calculations being performed at Cummins using a DOE-developed computer model from Los Alamos. Then the Sandia-Cummins team will begin what are termed "the high-risk, high-payoff" in-cylinder particulate imaging measurements. This will be followed by engine modifications to reduce the emission levels.

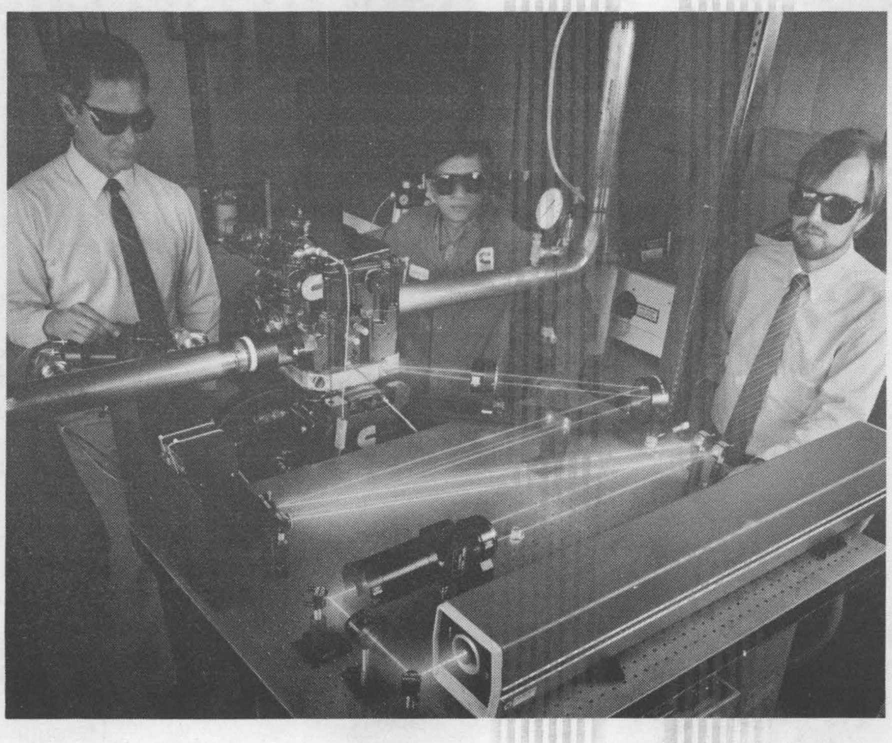
"My job here is very easy," says Mike Dyer. "I find I don't have to work to motivate people. People see the problem, the EPA demands on industry, and the commitment these industry people are making to this program. The enthusiasm is remarkable." He tells of a contract electrician working to help get the diesel engine project up and running. "He positively bubbles. He says, 'I've never worked on anything as exciting as this. We're going to keep these things from belching smoke all over the highways.' "

Concludes Mike: "It really is gratifying."



JOHN DEERE's prototype 750-horsepower rotary engine (foreground) got a workout while at CRF last year. Pete Witze (DMTS, 8362, left) and Philip Dimpelfeld (DOE Industrial Fellow from John Deere's Rotary Engine Division) ran the large Wankel-type rotary engine through its paces, measuring in-cylinder air velocities and turbulence to verify a John Deere multidimensional computer model.

Visiting Scientists? Postdocs? Industry? This Is Sandia?



LEARNING MORE ABOUT particulate formation and destruction processes of diesel engines is one goal of a cooperative program under way between CRF and Cummins Engine Co. Key participants include (from left) Dennis Siebers (8362), Henry Ng, and Axel zur Loye (both Cummins). Axel will be working through 1989 with an optically accessible diesel research engine (shown here) developed at Cummins and loaned to Sandia.

The ubiquitous state-of-the-art laser diagnostics, computers, and research engines at Sandia Livermore's Combustion Research Facility (CRF) shouldn't obscure a key ingredient of the CRF formula for success: an aggressive program of collaboration with industry and university researchers.

No ivory tower research center this. To solve real energy problems in the real world, the CRF seeks out and encourages joint programs with, and visits from, outside combustion research groups.

Probably no other Sandia organization works so closely and so regularly with outside scientists and engineers. With its postdoctoral students and visiting resident scientists, not to mention industrial fellows and just the regular stream of scientific visitors, the CRF seems like an international crossroads in combustion science.

One of these continuing interactions, with General Motors, has been going on now for more than 12 years. Ford and Chrysler have also long been industry partners with the CRF.

Other companies work with the CRF as well: Cummins, Navistar, Exxon, Unocal, United Technologies, General Electric, and Lennox.

So do universities: Princeton, Stanford, Berkeley, MIT, Penn State, Wisconsin, Purdue, Yale, and a host of others. As do the other DOE national weapon labs, Los Alamos and Lawrence Livermore.

A Two-Way Street

''We have worked diligently over the past decade to interact with industry in a truly two-way relationship,'' says Peter Mattern, who heads the CRF as part of his duties as Director of Combustion and Applied Research 8300. ''We learn from them and they learn from us. It's a two-way street.''

One of the main mechanisms for these collaborations are ''working groups.'' With representatives from one or more companies, universities, other national labs, and Sandia, the groups identify key issues, guide research toward solutions, and assure that the results are quickly made available to industry. DOE, through its Energy Conservation and Utilization Technologies (ECUT) program, sponsors the work. The companies pay their participants' costs.

Mike Dyer (8362), whose engine program is at the core of this collaboration, has enormous respect for the industry researchers: ''Without their skepticism, without their challenging us to follow through on our promises, without their willingness to come to meetings and educate us about issues they know like the backs of their hands, we would have never gained the constituency we needed to keep this program in the public light.''

Dan Hartley (6000), former director of combustion at SNLL, calls it a model program. ''It keeps being referred to as *the* model program for university-national laboratory-industry interaction,'' he says.

But the working groups aren't the only kind of industrial interaction. The DOE Industrial Fellowship Program sends industrial researchers to places like the CRF. Fellows' salaries are paid by their own companies, but DOE underwrites their other expenses. The diesel and pulse combustor programs have DOE Fellows in residence at Sandia.

Visiting Scientist Program

''We operate the CRF as a user facility,'' says Steve Binkley (8350), who, in addition to heading up the CRF's Combustion Sciences Dept., manages the CRF's visiting scientist program.

Steve, Bill McLean (8360), and Peter Mattern all proudly point out that the CRF hosts more than 1000 scientists a year as part of the visiting scientist program. And that's just short-term visitors, those who stay a few days.

Long-term visitors are those who come to the CRF for more than five days (some for up to two years) and engage in technical work. The number of these long-term visiting scientists has been rising every year, from 11 in 1982 to 34 in 1986. In 1987 there were 69. The total this year could reach 80. ''It's pretty clear that the growth curve simply can't continue for much longer,'' says Peter. ''We simply don't have the resources.''

The nearly 70 long-term visitors in 1987 contrasts with the CRF professional staff of only 40. The visiting scientists require space, staff time, and support-people time, notes Peter.

''On the other hand, we are delighted that they come. It's a way for us to interact with the outside world, to keep current.''

How well does it work?

''We have found, somewhat to our surprise, that carefully worked out joint experiments with visiting scientists turn out to be productive for the visitor and productive for the home team — almost without exception,'' says Peter. ''Nearly all of our interactions are viewed as positive by our visitors and by our staff. They get more work done.''

He points to the ''wonderful assortment of resources out there in the laboratory'' that the visiting scientists can draw upon. With that support from DOE comes an obligation to use those resources effectively, he says. ''The fact that we bring visitors in and share the work with them and write joint papers is really making better use of the resources. It seems to work out very well.''

One measure of that success: About half of the CRF's publications in 1986 resulted from joint CRF-university collaborations through the visiting scientist program.

Perhaps even more novel, for Sandia, is the postdoctoral program. It is a way of extending the depth of interaction with universities. CRF's postdoc scientist program started in 1985 with four postdocs engaged in research. Last year, the number was allowed to grow, and by the end of 1987 the CRF had nine postdocs on the staff. By the end of this year, the total is expected to reach about 15.

''Our experience with postdoc students has been very good,'' says Steve Binkley. ''We have found that we are able to attract postdoc students who, in my estimation, are at the same level of maturity and same scientific depth and breadth as staff members we would hire.

''What's more, when they leave the CRF they have absolutely no difficulty at all getting either academic or industrial jobs. We're proud of that. They're extremely productive when they're here.''

People-Issues

Nevertheless, all these interactions provide some interesting challenges in human relations. ''These interactions are not easy,'' says Mike Dyer. ''We always have to keep addressing the people-issues.''

At the CRF a premium is put on the ability to collaborate, both with colleagues and visitors. For one thing, the very nature of combustion research is interdisciplinary, involving many subfields in science — physics, laser spectroscopy, fluid mechanics, chemistry — not to mention advanced engineering.

''It's a team approach,'' says Peter Mattern. ''We work hard at that interface. If there's a new understanding developed on the science side, we want to see that it finds its way rapidly over to the technology side.

''Having the people, the laboratories, the facilities, and the opportunities to interact — all at the same place — is something that's probably unique in the combustion field,'' he adds. ''Having all that stuff in one place and the right cultural climate for it allows fruitful collaborations to happen.''

Mike Dyer reiterates the point: ''The ability to collaborate is one of the things we get judged on here at the CRF.''

Says Peter, ''When we recruit combustion people I tell somebody who's interviewing, 'If you're the kind who likes to sit in your office with the door closed, don't come here. You're not going to be happy.' You see people in and out of each others' offices constantly, talking about technical matters, working to solve problems.''

One of the ''people'' challenges that occupies Mike Dyer's attention is to make sure the industry collaborators get due credit. It can be a problem. The Sandians and the university scientists who work at the CRF publish their results in the open scientific literature. Industry scientists, doing the same kind of research, often cannot. Their companies consider the work proprietary. It is much harder for industry scientists, of equal competency, to establish professional reputations among their scientific peers.

What they *do* want, Mike notes, is acknowledgement of their contributions. ''We have got to acknowledge the essential contributions that industry makes to guiding this research. It has to be. We need input from industry professionals to keep the work relevant to their needs.''

'Biggest Improvement in Past 10 Years'

PDC: Star of the Drill Bit Show

It scarcely need be said that rock is hard.

But man has been beating on it, breaking it, chipping it, crushing it, blasting it for a long time.

By now, you'd think, he'd have rock-busting down to an exact science.

Not so.

It's particularly not so when it comes to breaking rock down at the bottom of a borehole.

Boreholes — or drill holes as they are called — are the means for reaching oil, gas, and other minerals located below the earth's surface.

The basic borehole, for extraction of oil or gas, is some eight to twelve inches in diameter and can extend up to six miles (30,000+ feet) or so into the earth.

The means of drilling such holes *economically* is surprisingly limited.

When Col. Edwin Drake drilled the first oil well at Titusville, Pa., in 1859, striking oil at 69-1/2 feet on Aug. 27 of that year, he used a percussion drill.

A percussion drill, also known as a cable tool rig and still used to drill water wells and other assorted holes, is not nearly as exotic as its name suggests. Basically, it's a simple machine that repeatedly drops a heavy chisel-shaped bit into a hole from a cable, gradually deepening the hole as blows from the bit's sharpened edge break the rock.

Such a drill works okay in relatively shallow holes — a couple of thousand feet deep, at most — and when drilling in "soft" rock such as shales. It won't drill economically through really hard rock — granite, for instance.

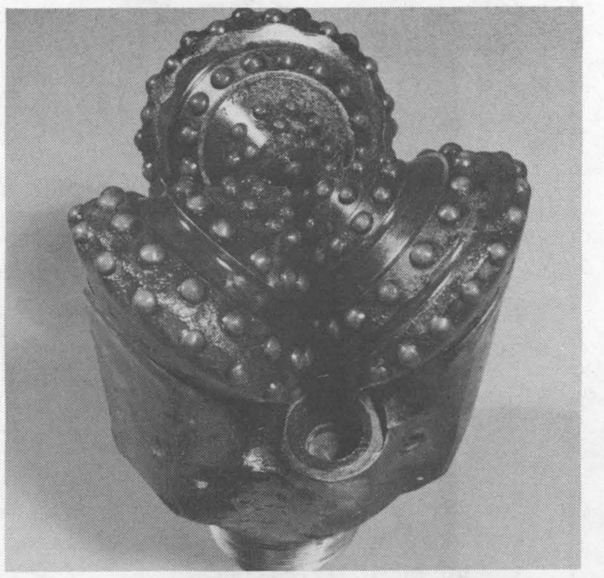
For some 50 years after Col. Drake struck oil at Titusville, no one was able to figure out a better, more economical means than percussion drilling for breaking rock in a borehole.

From Percussion to Rotary

Then, in 1908, the Howard Hughes Tool company introduced the rotary drill bit, using a steel-toothed bit to sink an oil well at Goose Creek, Tex.

This bit, which features two or three toothed cones that revolve as the bit is rotated, crunches easily through rock. For really tough drilling, the cones contain rounded tungsten carbide inserts rather than teeth.

This bit, invented by Howard Hughes, Sr. (not the Junior of movie lot and Spruce Goose fame), is one of the great inventions of all time. It is still in wide use today. When folks look back to 1908, they point to the epic invention of that year as Henry Ford's Model T, forgetting that Howard Hughes' invention did much to provide the fuel that's kept the "T" and all its successors on the road for 80 years.



TYPICAL ROLLERCONE drill bit, basically unchanged since its invention in 1908 by Howard Hughes, Sr. Cones with tungsten inserts revolve as bit head rotates.

The bit's a great invention, but it does have limitations. It gets dull; bearings fail. If the rock is particularly hard and/or abrasive, the bit can wear out after only a few feet of drilling. In softer rock, it may last a thousand feet or more.

Ultimately the bit has to be pulled out of the hole and replaced. Because the bit is attached to the bottom of a string of pipe — the drill string — pulling it may be no simple matter.

The drill string typically consists of 30-foot sections of pipe screwed together. So pulling the pipe, section by section, from a 20,000-ft. hole and then putting it back again can take a couple of eight-hour shifts. A good rule of thumb is that pulling the pipe out and putting it back in takes an hour per 1000 feet of pipe.

This often means that the bit is on the way into or out of a hole a good part of the time, depending on how often the bit becomes dull or loses a bearing. In the meantime, rig costs go on — to the tune of $5000 to $10,000 an hour in such tough drilling locations as the North Sea.

When Sandia began tackling energy problems after the Arab oil embargo in 1973, drill bit improvements looked like a good place to start — a good match for the Labs' weapon R&D capabilities in materials sciences, in systems analysis, and in components and systems design.

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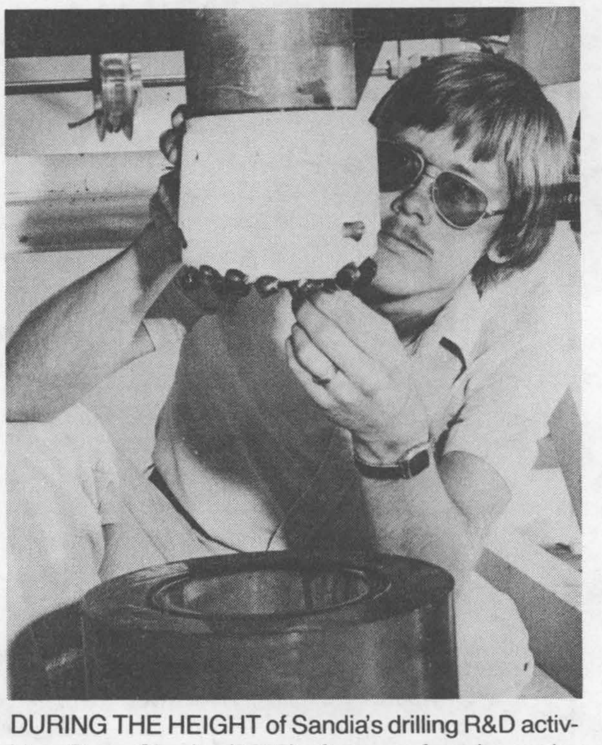


DURING THE HEIGHT of Sandia's drilling R&D activities, Dave Glowka (6252) often was found examining drag bits before testing in the Bit Hydraulics Facility. During testing, the rotating bit was situated inside a transparent plastic hole that simulated a borehole.

Spark of Life for Spark Drill

The spark drill lives!

Or at least Sam Varnado sees a spark of life in this innovative borehole drilling technique that stirred enthusiasm among Sandia energy researchers in the mid-70s.

The spark drill, conceived by Russian technologists, is truly a Buck Rogers way of drilling a hole — nothing nearly so mundane as scraping rock with tungsten, steel, or diamonds.

The drill never made it to Sandia field tests — the project was snuffed late in 1978 — but a laboratory version once fired away atop blocks of rock and concrete in a water-filled tank in a drilling lab in Bldg. 851.

The drilling process basically involved the generation of high-voltage sparks between electrode gaps on the bottom surface of a bit. As the electrodes were energized in quick succession, bright blue sparks lit the water around the bottom of the bit, the floor shook, and the room was filled with a sound not unlike the rapid, not-so-distant firing of a shotgun.

And that was only a low-energy model.

Each spark broke rocks by creating a high-pressure shock wave in the drilling fluid (water, in this case) around the bit. This wave was followed by formation and collapse of a bubble, which supplemented the rock-breaking action of the shock wave.

40 Pulses a Second

A downhole electrical pulse generator discharged about 40 pulses a second, achieving drilling rates up to 30 feet per hour. Spark energies of 100 to 200 joules — only 1.5 to 3 horsepower — and shock pressures of 2000 to 10,000 times atmospheric pressure were produced.

It was figured that a 150-hp model might drill more than 100 feet per hour. And yet the drill ultimately didn't seem worth commercializing for a variety of reasons.

"It wasn't compatible with existing drill rigs," says Max Newsom (now 9120), first supervisor of the Drilling Technology Div. "It would have required a sizable redesign of rigs at a time when every drilling contractor in the country had all the work he could handle. The drill just wasn't economically competitive. There were better options."

The drill also suffered because it was difficult to get a lot of electrical power downhole easily, and because the spark-producing electrodes didn't last long.

Despite these negatives, technology advances of the past decade or so are making drilling researchers take another look at the spark drill, says Sam (a former Sandian, now general manager of Titan Corporation's Albuquerque operations).

No revival is currently in sight for three other drilling technologies conceived or developed at Sandia. The terra drill, which used Sandia's capabilities in earth penetration — terradynamics — was halted early-on. It involved firing projectiles through a rollercone bit to make the rock ahead easier to drill. "A wellbore was not a friendly place to operate a machine gun," says Max, "although Bob Alvis [DMTS, 5153] and I received a patent on a terra drill concept in June 1977."

Mack Truck Needed

Suffering one of the earliest demises in Sandia's search for a long-life bit was the downhole changeable bit. This system rotated a new rollercone bit into place while the system was still at the bottom of the hole. Both new bits and dulled bits were stored in a magazine several feet above the bottom of the hole and were pulled into and out of cutting position by a chain.

Sliding the new bit and the dulled bit past each other within the confines of a seven-inch-diameter pipe required some neat engineering — principally by Dick Ashmore (ret.). The biggest problem was that the smaller rollercones, necessitated by the tight fit in the borehole, wore faster than those in standard bits. "We needed a Mack truck downhole, and we had a Jaguar," says Bob Fox (ret.). "We quit early."

The chain bit, invented by Bob and Neil Botsford (DMTS, 5221) — and worked on by Dick, Henry Togami (ret.) and Jack St. Clair, now back at TTR (7173) after some time in the oil patch — also cycled new cutting surfaces into place without removing the bit from the hole. A prototype bit, which consisted of diamond-studded cutting links mounted on a continuous chain, used six cutting surfaces (more could have been added) to drill 250 feet in granite in one test.

The 'Guru'

He Gets the Most From PDC Bits

A combination of two of the hardest materials known, diamond and tungsten carbide, a good polycrystalline diamond compact (PDC) drill bit costs $15,000 to $20,000.

Run the bit too fast with too much weight on it in rock that's too hard and it will burn up. You lose $15 to $20 Gs, plus the really big bucks — the $50,000 or more that it can cost to pull the pipe from a wellbore to replace the bit.

Yet, running the bit below its optimum rate can cost a lot of money too when you stop to consider that operating a drill rig in some high-cost areas, the North Sea, for instance, can cost upwards of $10,000 an hour.

A properly operated PDC bit on such a rig can lop several hundred thousand dollars off the cost of completing some wells.

As the driller weighs his options in such expensive operations, he is often relying, albeit remotely and indirectly (and in most cases unknowingly), on the insights of a Sandian, usually found these days in a Bldg. T-35 office or nearby lab.

'Guru of PDC Bit Technology'

"He's the guru of PDC bit technology," says James Kelsey (now 5260), supervisor of the Drilling Technology Div. from 1981 to 1986.

"He's provided the basis for industry to do the engineering design of PDC bits," says former Sandian Sam Varnado, who supervised the same division from 1978 to 1980. "Really pioneering work."

The object of these compliments, Dave Glowka (6252), views the results of his PDC research over the course of nine years more modestly:

"It's a more or less complete body of work in terms of taking an emerging technology, recognizing that it had wider applications, and doing the testing, applied research, and design work to establish its basic parameters."

He also points out that two other Sandians, Al Ortega, now a University of Arizona mechanical engineering professor, and Mike Stone (1521), made major contributions to the work, and that the three built on the very early findings of Charlie Huff (now at Los Alamos National Laboratory), John Finger (6252), and other Sandians. Basically, Dave's work identifies heating above 350°C as the most significant cause of PDC damage downhole, explains how the damage mechanism works, and suggests ways of mitigating this damage — both in designing the bits and using them in the field.

Dave came directly to the drilling division in October 1978 after finishing his MS in mechanical engineering at the University of Texas.

For 7-1/2 years, until he transferred to 6314 in May 1986, Dave worked almost exclusively on PDC bit problems. He finished that PDC work last fall with publication of a report, "Development of a Method for Predicting the Performance and Wear of PDC Drill Bits," that constitutes one of his most important contributions to the technology.

The report describes a new method for predicting cutter forces, temperatures, and wear on PDC bits, plus such performance parameters as weight-on-bit (WOB), drilling torque, and bit imbalance.

A computer code, called PDCWEAR, has been developed by Dave to make the new method readily available as a tool for general bit design and analysis.

Computer Code: Designer Tool

"The code is a tool the bit designer can use without a lot of work — he can try out variations of his design on the computer without going back into theory," says Dave.

"It's best for comparing bit types. It gives very reasonable predictions for weight-on-bit, torque, rock type, cutter placement, and bit life.

"All the major bit manufacturers have a copy and reaction generally has been favorable," Dave says of the code, which is available from the National Energy Software Center at Argonne National Lab.

The new method of predicting wear began with experiments with a single PDC cutter and then moved to the interaction of multiple cutters mounted on a milling machine.

"The cutters don't share the load equally," says Dave, "so we developed a theory — a numerical model — to account for the overlap of cutters and proved it out experimentally.

"This was the first time cutter overlap had been considered in estimating bit forces. Heretofore, everyone had just assumed that each cutter bears an equal fraction of the load," explains Dave, who has returned to a drilling assignment after a year-and-a-half Geotechnical Design Div. 6314 stint. While there, he investigated methods of drilling into tuff, a rock type being considered for disposal of high level radioactive waste and spent fuel from nuclear power plants. He also worked on the design of waste emplacement and retrieval equipment for a tuff disposal site.

With cutter interaction effects accounted for, the user of the new wear code can employ single cutter data, simply inputting the angle of the cutter, rock type, etc., to determine how a complete bit would respond.

Dave's earliest work at Sandia was on bit hydraulics — the flow through and around the bit of the drilling mud used to cool the bit and to flush rock cuttings from the hole.

This work led to a paper (authored with Al Ortega) on frictional heating of PDC cutters during rock drilling, and later to establishment of a bit hydraulics facility in Bldg. 851.

This facility consisted essentially of a length of drill pipe inserted in a transparent plastic base that simulated a borehole. The pipe, with bit attached, could be rotated at up to 900 rpm.

During a test, water flowed through the drill pipe, out the nozzles (ports) in the bit, and up the boreholes as in a typical field operation. Tracers — 3mm-diam. plastic spheres — could be injected through a single nozzle in the bit or through all nozzles simultaneously. High-speed photos recorded movement of the tracers, providing data about fluid velocity — or lack of it — across the face of the bit.

Key Part of Experiments

A key part of the experiments — one that has provided data for Dave's subsequent work — was the attachment of thin-film resistors on PDC cutters across a bit. The resistors were heated electrically, creating temperature differentials between cutter surfaces and drilling fluid. Measurement of the power required to maintain these differentials provided additional data about flow across each cutter and the distribution of flow across the face of the bit.

Work in the bit hydraulics facility had practical consequences for PDC bit designers.

"We learned that a bit needs multiple 'junk slots,' " says Dave, "or else stagnant flow regions develop and some of the cutters get excessively hot. Most bits today have multiple slots."

Located around the periphery of the bit, the slots facilitate the flushing of chips from the bottom of the hole.

"We also learned to reduce the number of nozzles in the bit," says Dave. "With too many nozzles, velocity is reduced and you don't get the cooling the cutters need. This idea has caught on with most bit manufacturers."

Another idea that caught on with industry is the bit hydraulics facility concept itself. Two have been built by commercial bit manufacturers. The one here was mothballed after three years, as Dave moved to analytical approaches to understanding bit heating and its effect on bit life.

In the two-year period from April 1984 to June 1986, Dave published four papers dealing directly with either frictional heating or thermal responses relative to PDC bits. One was a joint effort with Al Ortega, who left Sandia at the end of 1987, and two were with Mike Stone, an expert in finite-element analysis.

A paper by Dave and Mike, "Effects of Thermal and Mechanical Loading on PDC Bit Life," drew a rave review from Executive Editor Keith Millheim of Amoco Production Co., when it appeared as "pick of the issue" in the June 1986 edition of *SPE Drilling Engineering*.

"This paper is long," Millheim wrote, "[but] when you've completed your study, I promise you'll know how thermal effects and loading contribute to PDC bit wear . . . . Reading this paper is work, but like the great philosopher and ex-coach John Madden said, 'No pain, no gain.' "

Effects of Thermal Stress

While the recent publication of the PDCWEAR code is important to bit designers, Dave feels his chief contribution to PDC technology is the understanding he and Mike developed concerning the effects of thermal stress on cutter life.

"We've found that, at about 350°C, cutter wear begins to increase by an order of magnitude," says Dave. "This is the result of a combination of tensile and compressive stresses created by heat and weight at the bottom of the boreholes.

"There is compressive yielding of metals, leading to microvoids in the grain structure, which act as microcrack initiators and lead to increased wear. In addition, the coefficient of expansion between the PDC and the tungsten carbide to which it is bonded is sufficiently different to produce tensile stresses that lead to microcracks — and subsequent wear — on the surface of the diamond layer.

"There is also a synergistic effect between temperature and abrasivity of the rocks that results in the pulling out of the cobalt binder material between the diamond crystals."

This knowledge about thermal stresses has an imminently practical application in the field (beyond need to keep the cutters cooled below 350°C): Drillers who yank the PDC bit off the bottom immediately after the drill stops risk damage to cutters because compressional forces are diminished, while opposing tensile forces remain high. Dave says drillers should reduce weight on the bit slowly — over a period of perhaps 30 seconds so the bit can cool and tensile stress abate.

How does Dave see the future for PDC bits?

In the short term, drillers need to accept the materials limitations of the bits, while designers strive for improved performance through better placement of cutters and await arrival of cutters that are stable at higher temperatures.

Dave also sees greater use of cutters that are two to three inches in diameter rather than the one-half-inch models currently used. "I think our Society of Professional Engineers paper of last year will probably stimulate use of the larger cutters, which are more efficient at removing rock than are smaller ones," says Dave.

Drill-String Dynamics

It was 1980.

The Middle East was unpredictable. Oil prices were high. Fears of shortages seemed real.

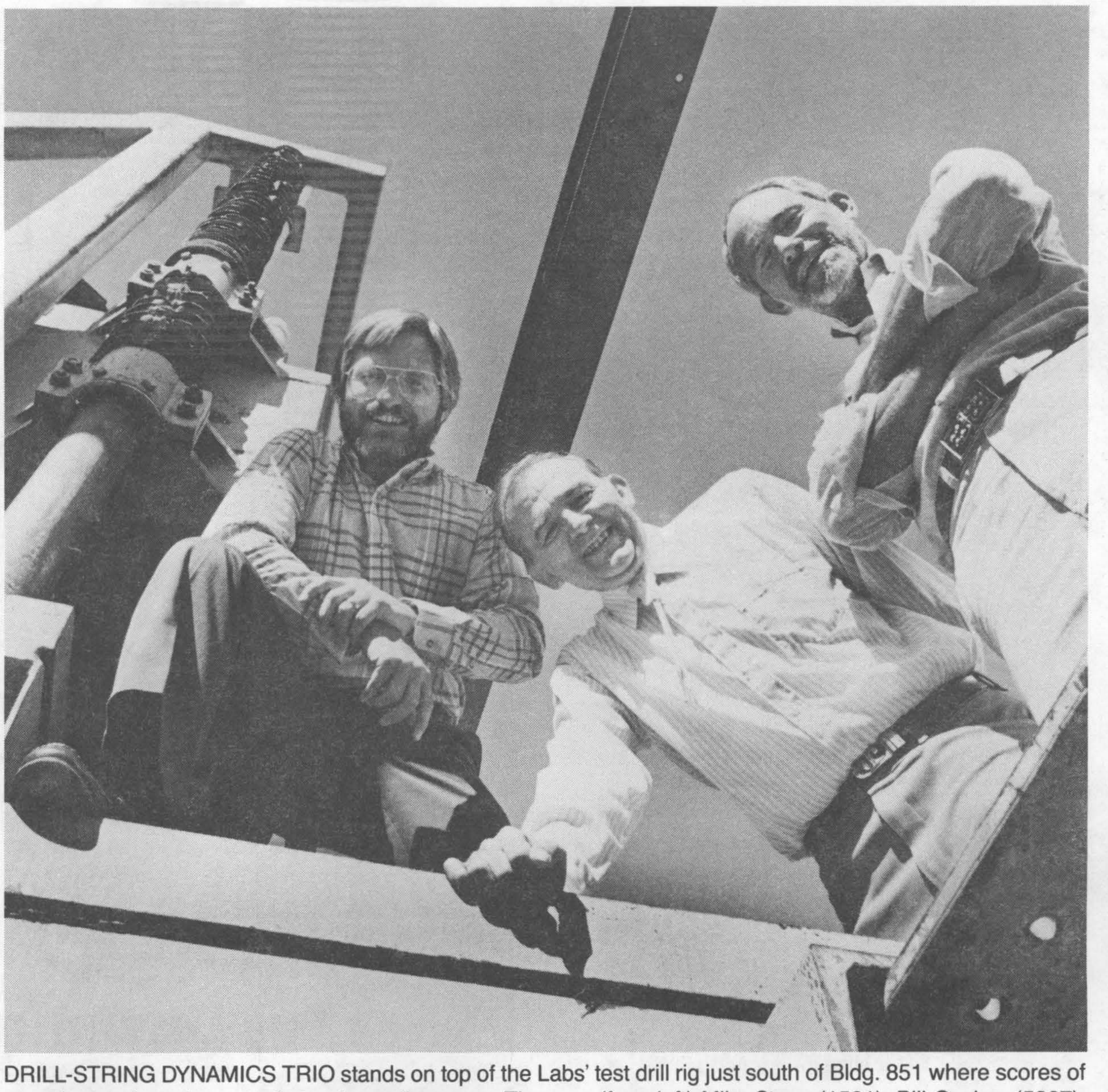
Energy companies were looking for ways to most effectively use the new polycrystalline diamond compact (PDC) drag bits to drill into harsh underground environments that had been ignored a few years earlier.

Developing more geothermal energy fields also was on the minds of engineers and researchers interested in searching for and developing ways to use more thermal energy. But successfully locating and then tapping geothermal fields were severely testing the drilling experts and their equipment.

They needed a better understanding of drill-string dynamic behavior — how vibrations, impacts, and lateral motions anywhere along a drill string's length affect the overall drilling operation.

From the bottom, a drill string consists of the drill bit, the drill collars (thick-walled pipe onto which the bit attaches), and stabilizers (or centralizers) that keep collars and bit in the center of the hole. These form the bottom-hole assembly (BHA), which can be almost 1000 feet long.

Next come thousands of feet of drill pipe — the length depending on depth of the target. For a typical 12-in.-diam. hole, steel drill pipe usually is six inches in diameter. Steel joints couple 30-ft.-long segments together.



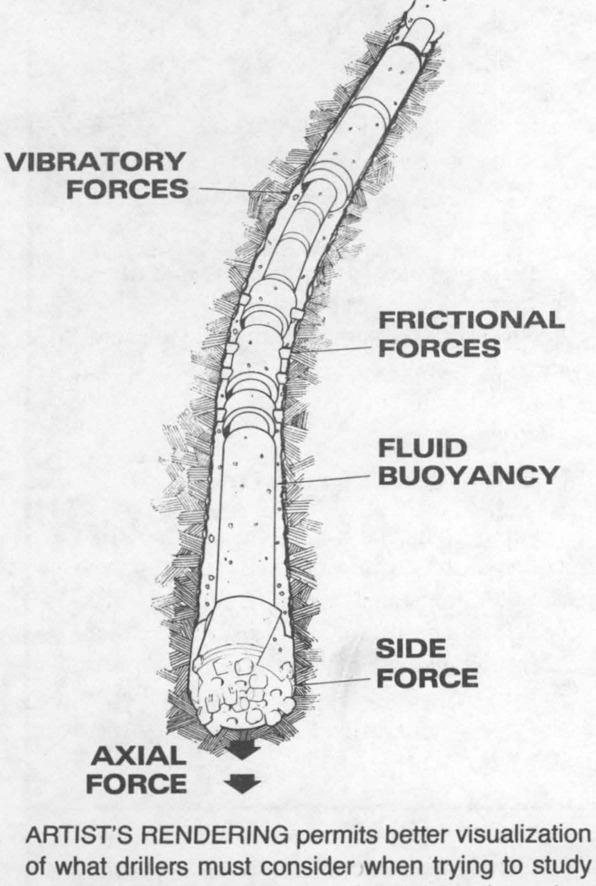
DRILL-STRING DYNAMICS TRIO stands on top of the Labs' test drill rig just south of Bldg. 851 where scores of experiments have been performed over the years. They are (from left) Mike Stone (1521), Bill Caskey (5267), and John Finger (6252). Their work helped to bring about the most complex and complete computer code ever designed to describe how vibrations, impacts, and lateral motions along a drill string affect a drilling operation.

Aboveground Components

The drill string also includes two aboveground components. They are the kelly that twists what's downhole, and above that, the swivel — a plumbing fitting that supports the drill-string weight and permits drilling fluid (mud) to flow down the drill pipe to the bit.

With PDC bits, it's extremely important to maintain a constant weight-on-bit (WOB) to prevent premature bit wear and overheating. (WOB is essentially the weight of the drill-string components, minus the amount that the string is being "held back" by its rigging.)

Additionally, it's vital to ensure that the drill pipe is never in compression — that can lead to increased fatigue at the joints and expensive pipe failures — but instead is in tension like a guitar string. A compressed drill pipe is also more likely to cause the bit to stray out of its intended drilling path.



ARTIST'S RENDERING permits better visualization of what drillers must consider when trying to study and understand complexities of drill-string dynamics.

Sandia's drilling organization began working on drill-string dynamics early in the 80s. Over the years, the program it initiated has received support from DOE, NL Industries (an oil service company), and four oil companies — ARCO, Conoco, Mobil, and BP-America (formerly Sohio).

Today, as the research concludes, the program has given birth to the most complex and complete computer code ever designed to define how an understanding of drill-string dynamics can be used to minimize drill-pipe fatigue, to determine a bit's drilling direction, and to optimize a bit's rate of penetration and useful lifetime.

The GEODYN 2 code, developed by Sandia contractor Jordan, Apostal, Ritter & Associates (JAR), has been made available to the four supporting oil companies so they can adapt the code to their own needs. It also is available from the National Energy Software Center, and requests for it come from around the world.

Controlling Forces, Vibrations

"When we approached oil companies about participating in an effort to understand and model PDC drill-string dynamics," recalls Bill Caskey (now 5267), "they were most cooperative. They saw it as an opportunity to — finally — be able to control, in a systematic and scientific way, the forces, vibrations, and displacements at the bit and bottom-hole assembly that influence drilling direction.

"They knew that forces on a bit are strong indicators of a bit's tendency to deviate from its path — to produce doglegs when a straight hole is desirable or to defeat a directional drilling program when one is attempted.

"But they also wanted to be able to control those influences and, thus, the drilling direction," Bill emphasizes.

Although not widely recognized outside the industry, it isn't all that easy to drill a hole in a desired direction or to a predetermined spot. Along with WOB and other drill-string influences, there's the earth itself to consider. Many formations are not homogeneous. Their "bedding planes" may tilt and consist of different rock types. Forcing a drill bit to cross these boundaries and continue to do exactly what's called for can be a challenge.

In establishing the drill-string dynamics project, Sandia's drilling researchers had a broader agenda than did their oil company colleagues.

"Reliable directional drilling was important, but we also wanted to determine the feasibility of an advanced drilling system," recalls John Finger (6252), "that would be capable of automatically changing its own drilling conditions — bit RPM, weight on bit, and the like — based on output from downhole diagnostic tools.

Such tools would have to be extremely rugged to operate reliably in the face of continuous vibrations and pounding. "Obviously, an understanding of drill-string dynamics was needed," John adds.

"The drill-string dynamics code that has emerged [from the Sandia- initiated and directed project] could help reduce drilling costs even before we get to the field," explains Mike Stone (1521). Mike has been with the program since it began and has been primarily responsible for laboratory-scale and field tests designed to verify the drill-string dynamics code. "When the code is used properly, it gives us and the oil companies the ability to address problems and to investigate potential solutions without resorting to expensive full-scale drilling system field tests," Mike says.

"We can, in effect, design a drill string and simulate its operation, on the computer. That lets us see problem areas and provides us the

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Dynamics

opportunity to make changes in bit rpm, BHA [bottom-hole assembly] design, or WOB before the system ever goes to the field,'' Mike adds.

PDC bits, for example, do their best work with a fairly constant WOB — about 30,000 pounds for an 8-1/2-in.-diam. PDC bit. But drill-pipe oscillations often cause the bit to have twice the intended WOB crushing down on it — and then no weight at all, because the bit is bouncing off the bottom of the borehole. This action, if not minimized by controlling drilling parameters, can break off tungsten carbide studs tipped with diamond cutters. Also, if the bit is lifted off the bottom and suddenly cooled, the thermal stresses could degrade it.

Weapon Program Spin-Off

Development and verification of JAR's complex code has been a deliberate and careful process. In response to a Sandia query, JAR first performed a feasibility study and determined that existing technology could be used to produce a code. As JAR wrote the code, Sandia used its systems analysis expertise, developed and matured during years of application in weapon R&D, to ensure that the code was addressing the concerns of the Labs and industry participants.

''Sandia also needed to ensure that the numerical concepts used in the code were based on good engineering mechanics principles, another weapon R&D-related forte,'' Mike recalls.

So as each finite-element model of bit-rock-BHA interaction was developed and written, Sandia verified it experimentally in labs located in Bldgs. 851 and 860.

Tom Carne, Arlo Nord (both 7544), and Mark Tucker (now 5246) designed and conducted those tests. ''Basically, the experiments used relatively short segments of drill string instrumented with accelerometers and other devices to measure the string's natural frequency and the displacement and vibration that occurred when the string was 'excited' by striking it with an instrumented hammer,'' Tom explains.

The first series used a freely suspended drill string. Then Tom and Mark progressed to a rotating drill string in a rig, a rotating drill string with force applied to the bit, and finally to a drill string that actually drilled rock. Agreement between code calculations and the test measurements was consistently good.

Then, in December of 1986, Sandia participated in a full-scale field test with ARCO at the oil company's research drill field about 25 miles east of Dallas. ''The test involved drilling a 1000-ft.-deep hole and collecting data from a special near-bit instrument package that made stress and acceleration measurements as drilling progressed,'' Tom explains.

Analysis of field data and comparison of those data with projections made by the code is still under way; however, it's clear that the code accurately mimics wellbore and downhole physics — and that it shows, for the first time, the interaction of drill strings and the rocks surrounding them.

''It's too bad, but the actual value of the code may be muted for the time being, thanks to low energy prices,'' John Finger says. ''There's been such a large cutback in R&D budgets in the drilling industry that people just haven't had the dollars or the need to take advantage of the code.''

But, even in these times of relatively little immediate concern about oil and gas supplies, and as this project winds down, a new branch seems to be sprouting. ''There's a growing interest in adapting the code for conventional roller-cone bits,'' Mike Stone says. •RG

THIS DRILLING R&D relic being examined by Dave Shirey (5267) is the prototype cornering water-jet drill designed for use in coal mines. It died when funding for the Labs' fossil energy drilling program became a victim of budget cuts.

Pressure Coring Vital For Downhole Assessment

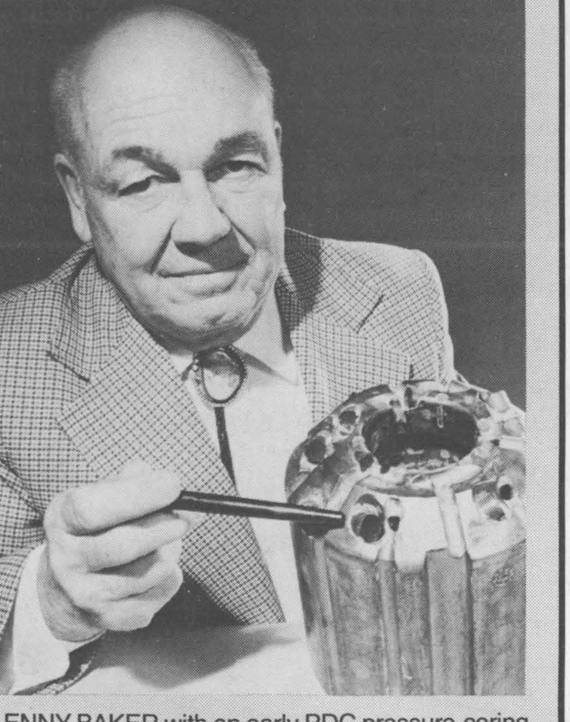
During those days more than a decade ago when Sandia's drilling experts were dissecting the PDC (polycrystalline diamond compact) drag bit to improve its performance and useful life, they also were asking a question: How else can we use the PDC bit?

Two specific drilling ideas sprouted and matured into equipment designed for very different uses — a PDC pressure coring bit and a PDC bit for drilling roof bolt holes in coal mines to improve stability.

Lenny Baker (ret.) developed the advanced pressure coring system that used a PDC-equipped bit and a special fluid that blocked invasions of the core by drilling mud.

He did such a good job that Pressure Coring, Inc., a Midland, Tex., energy-boom company in business then, invited him to come and make advanced PDC pressure coring systems for them. He liked the offer, took early Sandia retirement, and moved to Midland.

Today, as the ''essentially retired'' co-owner of Syntech Bit Co. in Midland, Lenny's still doing bits. ''We just finished a PDC coring bit for Texas A & M's ocean drilling program,'' he says.



LENNY BAKER with an early PDC pressure-coring bit that he designed while at Sandia.

Characterizes Core's Composition

Pressure coring is a way to gather samples of oil- or gas-bearing strata in their downhole condition so that precise measurements of the core's composition can be made. Such data are vital in assessing the commercial feasibility of many oil recovery operations.

Before Lenny's work, pressure coring systems drilled at such slow rates that drilling fluids washed away many of the core's ingredients, making it very difficult to piece together an accurate recipe of what the core contained — residual fluids, oil, salt water, natural gas, for instance — in its bottom-hole condition.

With oil and gas prices down, the demand for pressure coring also is down. Only Eastman Christensen Co. (Salt Lake City) still routinely uses PDC pressure coring systems that derive from Lenny Baker's Sandia work.

However, that should change when energy prices move up enough to prompt widespread tertiary and enhanced oil and gas recovery operations.

Didn't Catch On

Although a good idea technically, the PDC-tipped coal mine roof bolt drill didn't proceed past successful Sandia field tests. While it drilled very effectively, it turned out to be too expensive to compete with conventional tungsten carbide roof bolt hold bits,'' says Joe Tillerson (6314), who supervised the group that worked on the bits. •RG

(Continued from Page Fifteen)

PDC

"Our approach was that something was needed that would keep the drill on the bottom of the hole, not going to and from the bottom to change dull bits," says Max Newsom (9120), the first supervisor of the Drilling Technology Div.

"We did a lot of brainstorming — with folks like Dick Ashmore [ret.], Bob Fox [ret.], Neil Botsford [DMTS, 5221], Charlie Huff [now at Los Alamos National Laboratory], Jack St. Clair [7173], and Lenny Baker [retired from Sandia, and now co-owner of Syntech Bit Co., Midland, Tex.]," says Max. Five drilling concepts, employing an assortment of Sandia expertises, emerged: the terra and spark drills, a continuous chain bit, a downhole replaceable bit, and a drag bit using synthetic polycrystalline diamond compact (PDC) cutters.

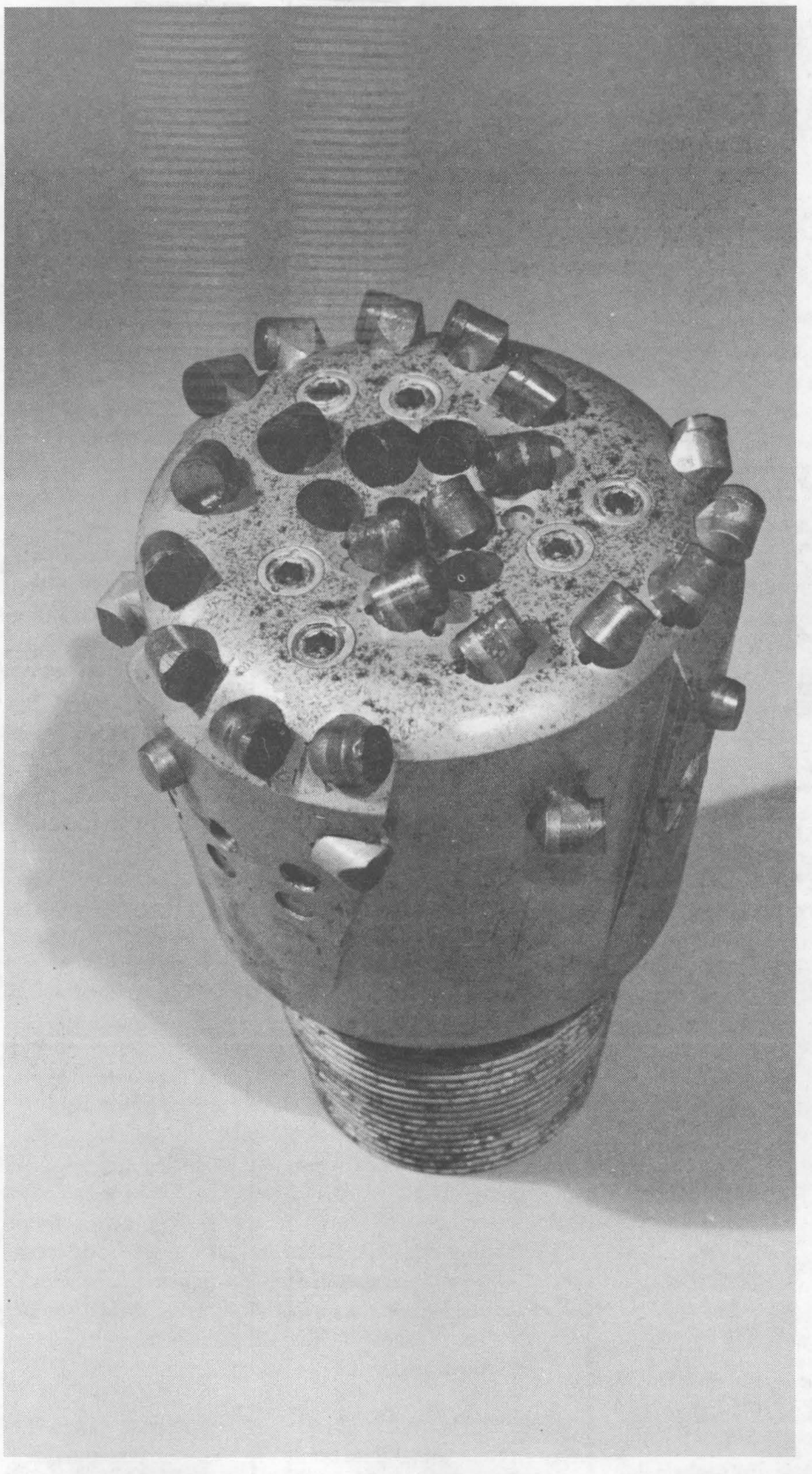
The latter bit, unlike rollercone bits, has no moving parts — the wafer-shaped diamonds, typically mounted on tungsten carbide substrates and bonded to tungsten carbide studs located across the bottom of the bit, simply scrape away rock at the bottom of the hole as the drill stem rotates.

All the new concepts except the PDC bit ultimately fell by the wayside although Sam Varnado, a former Sandian who headed the Drilling Technology Div. from January 1978 until December 1980 when he went to work for NL Industries, still entertains hopes for the spark drill (see "Spark of Life"). By and large, the new drills and bits were simply the victims of economics — other designs proved to be more competitive.

"In the end, economics drives the drill," says Max.

And economics is well on the way to making the PDC bit a billion dollar bit.

Today PDC bits are used to drill 25 to 30 percent of the footage put down annually to extract and explore for oil and natural gas. In some high cost areas where the rock formation is well-suited for PDC use — the North Sea or the Gulf of Mexico, for example — PDC bits are used to drill more than half the footage.



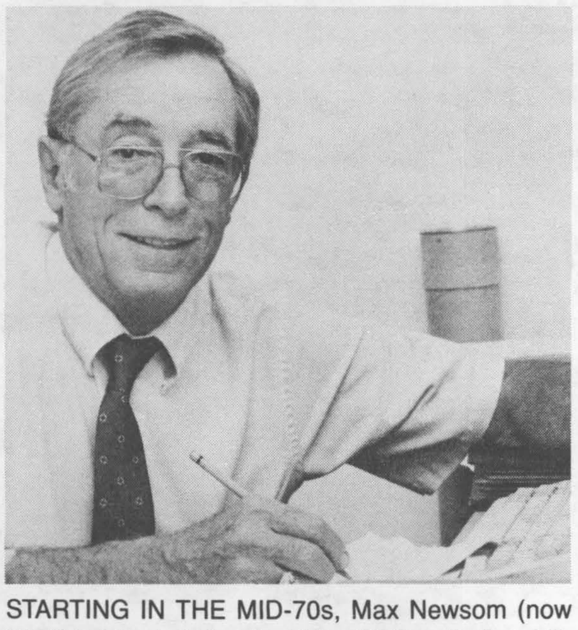
ONE OF MANY PDC drag bits available today that incorporate Sandia design concepts.

PDC Worth Extra Costs

"PDC bits can reduce costs by 25 to 30 percent in such wells — a lesser amount in other areas," says Sam, "even though a PDC bit usually costs in the neighborhood of $15,000 — about ten times the cost of a rollercone bit."

General Electric is proud of its PDC bits, which it markets as Stratapax:

> **In the northern North Sea, bits featuring Stratapax blanks on turbodrill have become the conventional practice for the 12-1/4" bit drilling of the Cretaceous section of claystones and mudstones with oil-based fluid. Stratapax blank bits on turbine typically drill over 3000 feet at greater than 50 ft./hr. here, in comparison to average rollercone bit performance of about 300 feet at 18 ft./hr. Use of Stratapax blank bits in turbodrill versus rollercone bits on rotary in this application has saved operators up to $700,000 per well, with three Stratapax blank bits replacing thirteen rollercone bits and saving the operator nine days drilling time per well.**



STARTING IN THE MID-70s, Max Newsom (now 9120) led the Labs' early drilling R&D as its first drilling division supervisor.

Given that a 12,000-ft. gulf well costs between $4 and $5 million to drill and a North Sea well several times that much, cost savings of 25 to 30 percent amount to big bucks.

Sam thinks that PDC bits will some day — when very-high-speed drilling with higher-temperature PDCs is fully implemented — be used to drill perhaps 70 percent of all oil and gas footage (see "Drilling — the Future").

That's an opinion not to be taken lightly — Sam, now general manager of Titan Corporation's Albuquerque operations, recently wound up his second stint as chairman of the Society of Petroleum Engineers' Drilling Technology Committee.

Sandia: Midwife and Parent

Sandia's contributions to PDC bit technology are complicated, and credit for them is a shade confused — a not unusual situation, given a role that has included both midwifery and parenting, but not conception.

Sandia didn't invent the PDC bit. The PDC cutters are an outgrowth of General Electric's development of synthetic diamonds, announced in 1955, and originally used for grinding, sawing, and polishing very hard metals. The company introduced its Stratapax PDC cutter blanks for drill bits in 1976.

But the button-shaped diamonds wouldn't stay attached to the bits. "They were shucking downhole like corn off a cob," says Max Newsom, "but it was clear they had a lot of potential."

Funded by DOE's Geothermal Technologies Division, the Drilling Technology Div. was looking for ways of economically drilling in the very hard rocks, such as andesite, found in geothermal reservoirs. Such rocks can wear out rollercone bits rapidly.

Work quickly began to determine why the PDC wafers were coming loose from their mounting studs.

James Kelsey (5260), who headed the drilling division from January 1981 to March 1986, gives credit to Ed Hoover (9133) and Charlie Huff for eventually pinpointing the reason that the PDCs were detaching.

"They did the early testing on bond integrity using ultrasonics, and pointed out that the bonds weren't good."

"GE was working with us under contract," says Sam Varnado, "and when we showed them the test results, they were — of course — very interested."

First Workable Solution

Both Sandia and GE worked on the bonding problem. Jim Jellison, supervisor of Process Metallurgy Div. 1833, was the first to come up with a workable solution — diffusion bonding. The first paper on the technique was published in September 1977.

The process involved coating the Stratapax element and the tungsten carbide mounting stud with nickel, locking them together, and placing them in

(Continued on Next Page)

Drilling — The Future

The incorporation of PDC (polycrystalline diamond compact) bits into the mainstream of oil and gas drilling is an evolution.

The revolution in drilling technology — using robots and artificial intelligence — is yet to come. But it must, says Sam Varnado, former Sandian and former chairman of the Society of Petroleum Engineers' Drilling Technology Committee.

The revolution, which Sam sees coming in the next 10 years, is necessary because the nation needs more economical ways of reaching the copious reserves of gas that exist in this country at 15,000 to 25,000 feet. "We've found the 'easy' oil in this country," he says. "But with improved drilling techniques we could build our energy policy around deep natural gas for the next 50 to 60 years.

"Drilling is going to get deeper and hotter. Some of the early Sandia work on downhole motors and high-temperature seals is going to be important. We were ahead of our time on those."

PDC bits have led — or are leading — to changes in drilling equipment. "In a sense, PDCs can now out-drill the rigs," says Sam. "We're having to go to bigger mud pumps — up to 5000 psi — to keep the bits cool and to clear the hole. And to keep up with the more rapid rates of penetration made possible by PDCs — and better rollercone bits as well — we're now seeing drilling in 90-ft. lengths of drill stem (rather than the standard 30 feet) with top drives rather than present ground-level drives. The higher pressures and rotary speeds are also requiring more frequent inspection of pipe."

Evolution Continues

But these are part of the evolution. The revolution Sam sees will include robot rigs to handle pipe, lightweight rigs drilling at high rotary speeds, drilling decisions based on artificial intelligence rather than educated hunch, and quick relay of data back to a central base for processing evaluation.

"To do all this, we badly need a National Center for Drilling Research — at Sandia or someplace else," says Sam.

Before this revolution comes, both Sam and Dave Glowka (6252) agree that another evolutionary change — water-jet drilling — holds a lot of promise. Dave makes a strong case in his last PDC report for the use of moderate-pressure water jets to extend the application of PDC cutters by breaking up rock in front of the cutters.

Sandia supported considerable research through the years on water-jet drilling, principally by contractors; Marv Timmerman (9141) also did early work on the technique at Sandia. High-pressure mud pumps on present-day drill rigs can routinely produce the 4500 psi that Sam and Dave believe can do useful work when combined with PDCs and other cutters. A big problem, however, is that downhole space constraints currently won't allow each PDC cutter to be assisted by its own water jet.

But even that doesn't necessarily block application of water jets, as Dave notes in his last report: "Water-jet assistance can significantly increase bit life and reduce weight-on-bit (WOB) and drilling torque requirements. Greater than 20 percent improvements in bit life and 19 to 36 percent reductions in WOB and drilling torque are predicted for a design utilizing only *four* nozzles operating at 4500 psi."

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PDC

a thin-walled steel can filled with a pressure transfer medium such as graphite.

The can was then evacuated, sealed, placed in an autoclave, and subjected to pressures of 30,000 psi at 650°C for four hours. Under these conditions, the metal layers flow, creating high-quality welds with shear strengths of 60,000 to 80,000 psi.

This was sufficient to keep the PDCs attached during hard-rock drilling, as a handful of Sandians shortly began to prove in a series of pioneering design and drilling activities.

Charlie Huff, Dick Ashmore, and J. W. Miller (ret.) reported on this early PDC work in a 1978 report. And Charlie, Alan McFall (now at Baker Exlog, Houston), and Jack St. Clair followed with a paper presented to the Society of Professional Engineers meeting in Houston in October 1978.

Charlie, who left the Labs in 1980 to work on PDC bits at Petroleum Concepts, Inc., Midland, Tex., noted at the time that the new cutters "performed very well in an overstressed condition — bit weights up to 30,000 pounds."

Such tests, in both field and laboratory, helped not only to prove that the bits would stand up under actual severe drilling conditions, but established such vital characteristics as rake angles — the angle at which the cutting edge intersects the rock — and optimum placement of cutters across the bit surface.

(Twenty to 40 of the half-inch-diameter cutters, positioned to cut slightly overlapping channels in the rock, are located across the bit surface. The number depends on tool design and size. They extend about one-quarter-inch above the bit surface, "machining" the rock much like a lathe as the drill turns.)

PDC bits of a variety of shapes and sizes were designed and tested — a 6-1/2-in. PDC bit, a hybrid rollercone/PDC bit, and a PDC core bit. A more fracture-resistant mounting stud also was developed.

Field tests of the most promising designs followed. Sam Varnado was soon saying that, "If these tests are successful, we will place increased emphasis on transferring this technology to private industry."

The tests continued to demonstrate that in the right formation — ironically, in softer, less-fractured rocks than the very hard geothermal reservoirs of particular interest to DOE program sponsors — the bits drilled faster and longer than rollercone bits.

Meanwhile, GE scientists, working in parallel with development of the gas diffusion bonding technique at the Labs, perfected the lower-cost brazing technology used today to affix PDC cutters to the tungsten studs on the bits.

"We showed what the problem [with the bits] was, demonstrated a solution, and proved that such a bit could be an economical performer," says Sam. "GE responded with a superior manufacturing technique."

Improved Understanding Via Codes

Having helped prove that the bits were a practical success, Labs engineers since about 1980 have strived for better designs and longer operational life, based on improved understanding of how the bits cut and how they fail (see "Drill-String Dynamics").

A key contribution, following earlier Sandia work on cutter placement and orientation by Charlie Huff, Sam Varnado, Paul Yarrington (1533) and others, was the "Stratapax Computer Program" developed in 1982 by Eugene Aronson (DMTS, 2542), Kathleen McCaughey (2543) and Lee Walton (2614).

This program has been widely used in commercial bit design, and is the immediate predecessor to the latest (and probably last) major Sandia contribution to PDC bit development, Dave Glowka's (6252) PDCWEAR code. Dave, the acknowledged "guru" of latter-day bit analysis and design, finished his final report on the code last fall (see "PDC Pioneer").

Dave himself points to the basic research of Dave Zeuch (6232), John Finger (6252), and several others as "important contributions to the understanding of rock breakage" with PDC bits.

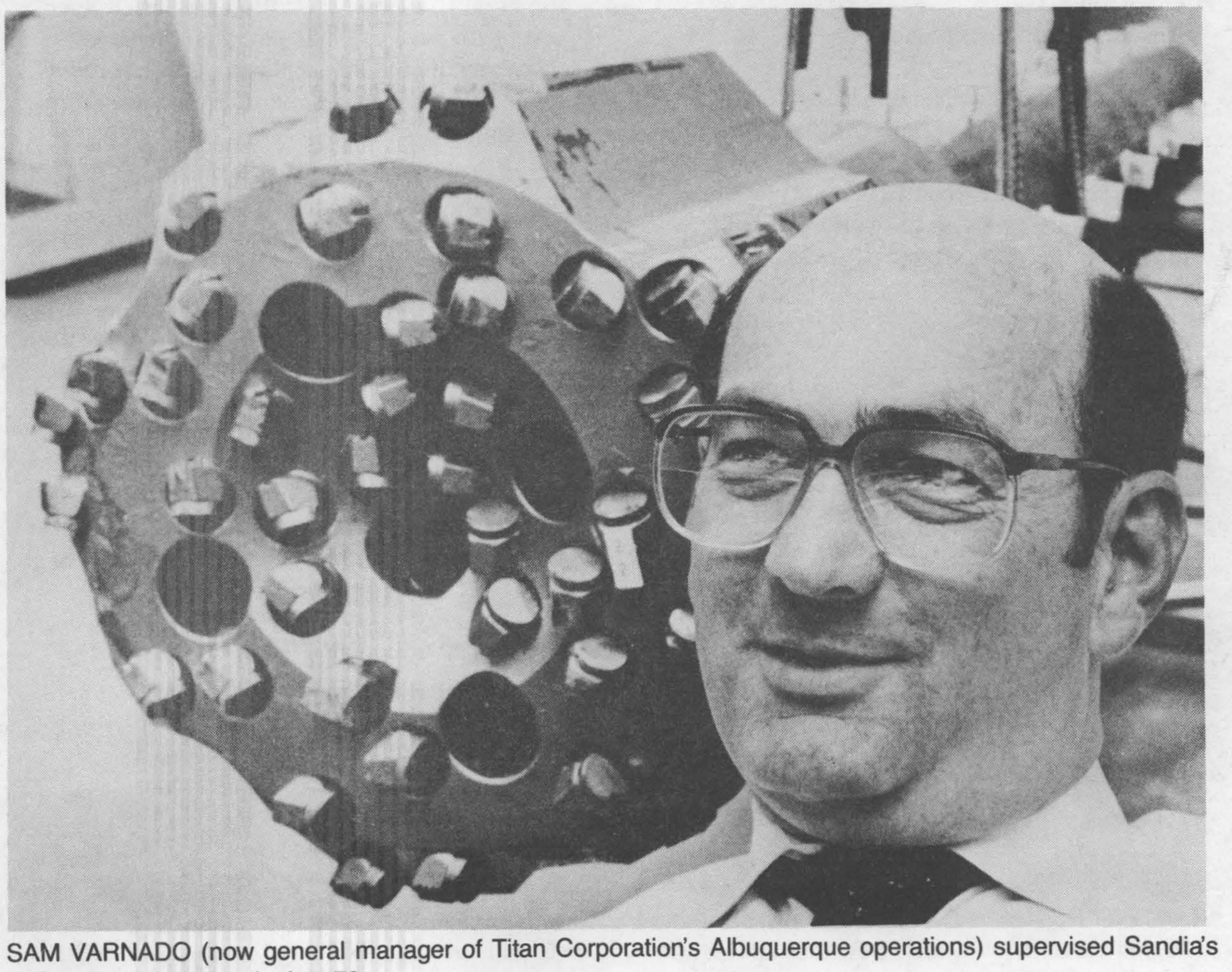
While work remains to be done in several areas, Sam Varnado nevertheless pronounces PDC bit development "the biggest improvement in drilling technology in the past 10 years.

"I saw a PDC bit come out of a Gulf of Mexico hole after drilling 6000 feet," he says. "It looked like new. It was put back down and drilled another 6000 feet." Rollercone bits used in the Gulf typically wear out after drilling 1200 to 1300 feet.

"There are other improvements coming in PDC development — bits that can operate at higher speeds and temperatures — but we're getting to the point where bit wear is not the limiting factor in drilling operations; you have to come out of the hole for some other reason.

"It's clear," Sam concludes, "that this part of the drilling industry wouldn't be where it is today without the work done in the past 10 years at Sandia."

•JM



SAM VARNADO (now general manager of Titan Corporation's Albuquerque operations) supervised Sandia's drilling division during the late 70s.

Energy at Sandia

LAB NEWS

VOL. 40, NO. 21 — SANDIA NATIONAL LABORATORIES — OCTOBER 21, 1988

Sandia's Energy Program: An Overview

Superficially, Sandia's energy program is much more *un*like its weapon program than like it. What, for example, does a new nuclear warhead for the Trident II missile have in common with a new technique for determining the optimum locations of the drill holes in an oilfield?

The answer: "Plenty," or "Far more than the casual observer would guess."

Certainly, there are differences between the weapon and energy programs. Sandia's energy program has a much briefer history — some 15 years versus more than 40 years. Its span is wider — pulse combustion technology is much less like a vertical-axis wind turbine than the old B53 bomb is like a modern W84 ground-launched cruise missile. Its visibility is, generally, higher — more Americans heard about Sandia's development of the RAPRENOx antipollutant process than ever heard about its development of the laydown bomb.

But the similarities between the two programs far outweigh their differences.

First, and most important, the bedrock on which both programs are built is national security, Sandia's "reason for being." Just as no nation can ensure its security without a means to defend itself, so no nation can survive without an adequate supply of safe, assured, affordable, and (given the need for long-term survival) environmentally sound forms of energy — energy for heat, light, food, transportation, and communications. And for national defense itself — no modern defense force can function without energy.

Another similarity: Just as Sandia's weapon program is coherent — it focuses on a vital and particular niche in the weapon cycle (the R&D needed to convert a nuclear device into a credible deterrent) — so the energy program is coherent. It focuses on those energy technologies related more-or-less closely to its long-lived and successful weapon program (see sidebar on Shuster and origins).

And another: Both programs depend on Sandia's tech base — its basic and applied research and its across-the-board development capabilities, both in things (facilities and equipment) and in people (their talent, their energy, their creativity, and their dedication). Certain tech-base areas developed for the weapon program have been vital to the energy program — Sandia's capabilities in materials sciences, geosciences, thermal sciences, fluids and aerodynamics, and instrumentation.

The Role of the Labs

For an overview of Sandia's energy program (more commonly, program*s*, plural), LAB NEWS visited Virgil Dugan, Director of Advanced Energy Technology 6200. He's worked in one SNLA program or another since the early 70s.

Virg sees the energy role of Sandia (and that of the other national labs) as complementary to the role of industry, on the one hand, and the role of government, on the other. "The primary motivator for industry is, at least traditionally, to improve the rate of return on its investment," he explains. "The function of government that concerns us here is its obligation to ensure that industry (and the rest of us) is provided with long-term sources of energy, that energy resources are used efficiently, and that the nation's environmental safety and health is protected."

So what's the function of the national labs when it comes to energy? Says Virg, "If you think of industry's role as a hand of a clock pointing at 12 and government's role as a hand pointed at 3 — at right angles, in other words, not opposed, not at 180 degrees from each other — then the labs' role is represented by a hand halfway between 1 and 2.

"Less figuratively, their role is to further *both* industry's and the government's roles — to improve the nation's security by making it more self-sufficient and less dependent on foreign energy sources, to improve industry's efficiency and its ability to compete on the world market, to promote, in other words, the objectives of both industry and government.

"We [Sandia] feel we're in a unique position to help both industry and government from our '1:30' position.

"That view ties in with the view of the national labs as representing the government's technological thrust," Virg continues. "Other agencies and entities represent, for example, its military, its social, its economic, its law-enforcement thrusts. Sandia and

(Continued on Next Page)

Guide to This Special Issue (and Two More)

Energy: Past, Present, Future

This and two future LAB NEWS issues will feature Sandia's major energy programs — past, present, and most likely future. (The exceptions: fusion and fission — its inertial confinement and magnetic fusion programs and its current-generation and next-generation nuclear reactor programs. We'll cover those separately later.)

LAB NEWS invites its readers to save this special energy section and combine it with the next two installments. The result will be, we hope, a useful reference source for those interested in what Sandia has accomplished in 15 or so years of energy R&D.

This issue: combustion, drilling technologies, and several general features; next issue: solar, wind, and batteries; final issue: oil/gas, shale, coal, magma/geothermal.

Origins of Sandia's Energy Program

Until late 1973, most Americans took their energy sources for granted. Whatever the source — oil (and gasoline), natural gas, coal, electricity — they expected it plentiful, and they expected it cheap.

Then came the OPEC (Organization of Petroleum-Exporting Countries) embargo on oil. It brought sharp increases in prices, lines at those service stations that had gasoline available at all, and a belated realization that the nation was all too dependent on foreign sources for cheap energy.

The "energy crisis," as it was widely called, generated shock waves that affected the nation's economic, political, and social structures. And, naturally, a cry went up — "Why are the national labs not working on this overwhelming problem?"

Sandia's answer was, "We are. And we have been."

For Sandia not only had seen the "crisis" coming — Congressional committees, think tanks, and other labs had seen that too — but Sandia also had some programs in place that showed promise of reducing the nation's dependence on foreign oil, at least over the long term.

Why was Sandia already involved in energy? Although the reduction in force of 1972-73 is

(Continued on Page Five)

DON SHUSTER (ret.), in 1973, examining a solar collector tapped for use as the basic energy collecting element in the "Solar Community," one of several proposals presented to AEC for funding during the Labs' early energy R&D days.

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Overview

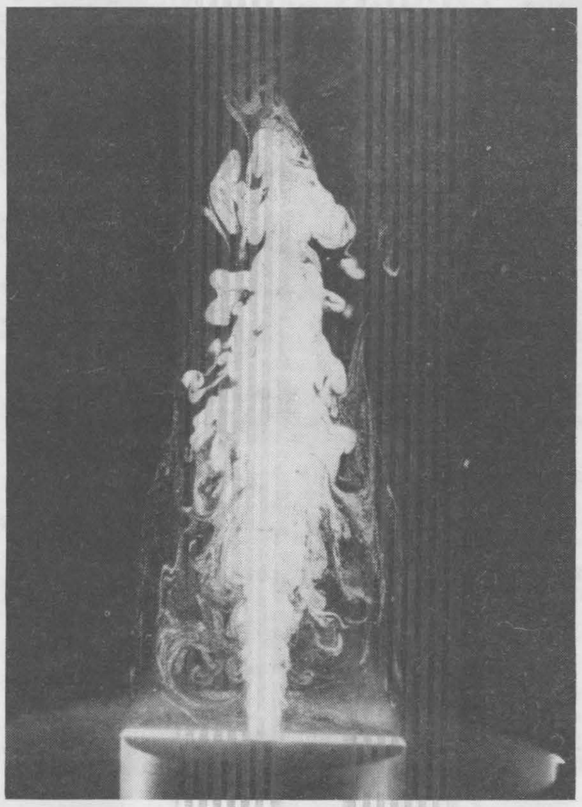
the other labs represent the government's duty to provide the technology that's a vital part of the foundation of a modern society."

"Within the structure Virg describes, we [Sandia] have the latitude to pursue a wide range of energy goals," adds President Irwin Welber. "Some of those goals are suggested by Sandia itself, some by Congress and DOE, and — increasingly more often, I'm proud to say — some by industry. Other than, of course, funding, our only real constraint is that we must not compete with industry — we must not do what industry can and will do for itself.

"Given the tight economic conditions for US industry in the world market, however, it's not difficult for Sandia to avoid competing with industry while making significant contributions to the nation's energy welfare."

Sandia's Major Energy Programs

So much for prologue. Let's continue this overview by taking a broad look at the sources of energy upon which Sandia programs are built. One of those sources is coal. It's at once the most abundant and the most obstinate of the nation's energy sources. It is, as everyone knows, a pollutant. Burning it leads to particulate matter, the source of widespread visual pollution. And coal-burning is the prime suspect in an even more insidious form of pollution, acid rain. Lately, the concern over the increase in atmospheric carbon dioxide, and the resulting "greenhouse effect," has become significant.



1/2-MILLIMETRE-THICK SHEET of laser light illuminates tiny nonburning alumina particles suspended in a flame. This helps CRF scientists learn more about gas flow in turbulent flames.

Sandia has sought to overcome, or at least to minimize, these side effects. One way is to burn coal underground, thus getting the benefit of its energy but minimizing pollution. Another is to liquefy it, thus contributing to the nation's dwindling supply of fuels usable in "rolling stock" — cars, trucks, buses, trains — and airplanes. Still another is to pulverize it and develop more efficient, less polluting ways to burn it. To provide understanding for each application area, Sandia is exploring the structure and reactivity of coal under a variety of use conditions.

Oil/Gas

Like coal, oil and gas are polluters when they're burned — additional contributors to the "greenhouse effect." But, unlike the case with coal, industry has already exhausted most of the easy-to-extract oil and gas deposits. So Sandia has worked toward efficient exploitation of those resources that remain.

To that end, Sandia has developed new techniques and instruments (acoustic, electric, and electromagnetic) for locating deposits, for logging exploratory wells to determine their production potential (new downhole instrumentation), and for optimizing the location of the boreholes needed for access to the deposits.

Sandians have sought better ways to locate and extract gas from "tight" sands and oil from "heavy deposits" (by providing new understandings of the geological formations involved and by developing new devices for heating the oil so it's easier to pump to the surface, for example). Working closely with US industry, Sandia pioneered the development of the "modified *in-situ*" approach to the retorting of oil shale.

In an early and highly successful program, Sandia helped to develop longer-lived drill bits, which means less time wasted "pulling the string" (removing, a segment at a time, a drill stem hundreds or

(Continued on Page Four)

People, Equipment, Experience — We Had Them

Energy Programs Tap Weapon Expertise

"We see a problem as a set of equations — a mathematical expression," says Mike Stone (1521), reaching into his desk drawer for a small object about the size and outward shape of the cap on a large bottle of ketchup.

"We don't necessarily care about application," he says, fingering the weapon component, a capacitor that has a slight, yet-to-be-explained bulge created during its manufacture.

"Our analysis methods and techniques are not directed toward any specific application. We can respond to both [kinds of problems] — weapons or energy."

That quote from Mike, an expert in finite-element analysis, explains a great deal about the Labs' ability to respond to the energy crisis and the successes that often followed this rapid reaction.

Almost always the response and subsequent advances were anchored deep in the Labs' existing weapons R&D capability, whether it be materials, component design, analytical technique, or a dozen other resources.

Making Big Problems Smaller

Finite-element analysis is a good example of this on-tap capability. A numerical technique for analyzing a problem by dividing it into small, solvable subsets and then reconnecting them to reach an overall solution, it has been honed through the years to a fine edge at the Labs on applications such as stress analysis of glass-to-metal seals and dozens of other weapon and weapon-component problems.

It works just as well in looking at the stresses produced in thousands of feet of drill stem (see "Drill-String Dynamics") or diamond cutters in a drill bit (see "PDC Pioneer") as it does in analyzing those in millimetre-size parts of arming, fuzing, and firing systems. Mike and other colleagues in applied mechanics have worked on a variety of such problems.

Sandia successes haven't been limited just to such "finite" problems. Some of the Labs' largest programs, such as combustion research at Livermore, can be traced to an ability — again anchored in weapons expertise — to respond to a technical challenge almost overnight.

A proposal written in a single day by Dan Hartley (now 6000) and colleagues at Livermore and carried to Washington that evening was a key factor in establishment of the Combustion Research Facility (see "CRF Origins"). That proposal was based on the Labs' lead in laser diagnostics, used to measure the mixing of gases in weapon components.

Today, almost a decade and a half later, laser diagnostics remains one of the indispensable tools of the internationally acclaimed CRF.

From diffusion bonding of diamond cutters to drill bits to preparing oil and gas fields for enhanced recovery operations to development of new or improved materials for solar collectors, the Labs' long-established capability in materials and processes has been used throughout the energy program.

Weapon R&D and Black Chrome

Dick Pettit (now 7243 but then in Thermophysical Properties Div. 1824) led the group that developed an improved black chrome, used to coat the receiver tubes that run along the axis of parabolic solar collectors. Concentrated sunlight is reflected onto these tubes, filled with a heat-transfer fluid.

Absorbance characteristics of the original chrome degraded significantly after several hundred hours of operation at 300°C. Today, the chrome developed in 1981 by Pettit and crew lasts for years.

"It's now the standard for low-to-medium-temperature collectors," says Dick.

The weapons connection: "I was studying model metallic systems," says Dick, "looking at them at their 'critical points,' the kind of thing of interest when you're investigating materials that can withstand the temperature created by reentry or a high flux of radiation."

Another weapons connection: "There were many variables that controlled the production of a better black chrome," says Dick. "The statistical design capabilities of Dick Prairie's old group — 7223 — simplified the problem. "His people were able to tell us what variables were important to the process and to sift through them quickly so we could concentrate on those that made a difference."

Quick Responses: A Trademark

Bob Fox, now-retired supervisor of the Advanced Component Development Div., cites another case of quick response by Sandians from the weapons side of the house.

"Max Newsom [now 9120] called one afternoon in 1973 and asked if I could come by his office for a brainstorming session on drill bits," Bob recalls. "Neil Botsford [DMTS, 5221] and I went over, and in the course of the session, the idea for the chain drill bit sort of evolved as Max outlined the need for a bit that wouldn't need to be pulled from the hole so often.

"I remember we looked at the beaded chain on a light switch, holding up the end so that a loop formed," says Bob. "We noted that if you had a closed chain (like a necklace), put cutters on it, and advanced it so that sharp cutters were always on the bottom, you might have a bit that could stay downhole a long time.

"We went back to the lab and sketched it out," he adds. While the chain bit made it into the field for tests, but never to the market, it nevertheless demonstrates the rapidity with which weapons expertise could be brought to bear on energy problems.

"Max needed the help of a component development group," says Bob. "We were one.

"He needed mechanical designers. In Fred Duimstra, Henry Togami, Dick Ashmore [all ret.], Lou Crop [6511], and others, we *had* them."

Yes, we had them — people, equipment, experience — the principal reason that Sandia, with years of weapons work behind it, was able to respond quickly and successfully to the nation's needs in the energy arena. •JM

Then and Now — Energy Numbers

In 1973, according to DOE's Energy Information Administration (EIA), the United States imported 14.7 quads (quadrillion BTUs) of energy, mostly oil from the Middle East. We paid about 35 cents a gallon to gas up our cars, and some of us paid our monthly winter heating statements with a $20 bill and got some change.

That year, Arab producers jolted us out of our energy complacency by imposing an oil embargo on the US and some other nations they considered politically unfriendly. Although some US energy analysts had warned about our increasing dependence on cheap imported oil, most Americans didn't see the danger and were shocked and irritated by the gasoline shortages and the waiting lines at gas stations that soon followed.

Since then, national energy moods and priorities have gone through numerous phases. From inconvenience and displeasure, we went through a period of indignation toward OPEC (in particular, its Arab members); remember even the calls to "go over there and get 'our' oil" militarily? This was followed by some national handwringing, then by some thoughtful concern and planning (albeit somewhat faulty, in that it was sometimes based on flawed figures and assumptions).

Next came national resolve for energy independence through conservation (some encouraged, some forced), increased domestic oil and gas production (encouraged by higher prices), establishment of the Strategic Petroleum Reserve, and R&D on every conceivable alternative energy source — synfuels from shale and coal, solar, wind, geothermal, biomass, and so on.

Can It Last?

Now, about 15 years after the Arab oil embargo began, we again have a seemingly abundant supply of easy-to-get/easy-to-use energy at affordable, if not bargain, prices. But can it last? And how have we done in our resolve for energy independence? A look at some other EIA numbers (compiled from 1973 onward):

• PRODUCTION — Domestic production from all major energy sources went from 62.1 quads in 1973 to 64.5 quads in 1987. Our production bottomed out at 59.9 quads in 1975 and peaked at 65.8 quads in 1984.

• CONSUMPTION — We consumed slightly more energy in 1987 than we did in 1973 — 76 quads and 74.3 quads, respectively. Consumption was at its highest in 1979 at 78.9 quads and was lowest in 1983 at 70.5.

• IMPORTS — In 1987 we imported 15.4 quads of energy (mostly oil) — about 0.7 quad less than in 1973. However, our net imports were lower — 11.5 quads compared to 12.7 in 1973, primarily because we produce and export more coal now. Gross and net energy imports both peaked in 1977, when we imported 20.1 quads, net 18. Net imports bottomed out at 7.5 quads in 1982.

Consumption and production figures for some traditional energy sources and facilities (production and consumption figures quoted in quads rather than barrels, cubic feet, etc., to allow direct comparisons):

• OIL — In 1987 we consumed 32.6 quads of petroleum, down from 34.8 quads in 1973. Petroleum consumption peaked in 1978 at nearly 38 quads and was at its lowest in 1983 at 30.1. Domestic production of crude oil has remained relatively steady. In 1973, the US produced petroleum energy equivalent to 19.5 quads. In 1987, production was nearly 17.6 quads. Production bottomed out at 17.3 quads in 1976.

• NATURAL GAS — In 1987, we consumed 17.2 quads of energy from natural gas, down from the high of 22.5 in 1973 (figures include supplemental gaseous fuels). The decline in our use of natural gas has been gradual and fairly steady during that period (attributable in large part to the switch by electric utilities from natural gas to coal). The US has basically been able to produce what it needs; domestic production has tracked consumption closely.

• COAL — US coal consumption has gone up fairly steadily since 1973, when we used nearly 13 quads, to 18 quads in 1987. Domestic coal production has also climbed steadily, from almost 14 quads in 1973 to 20.1 quads in 1987. Most of our coal is used to fire power plants that produce electricity.

• NUCLEAR — Electric power consumption and production from US nuclear plants has climbed steadily since 1973. In 1987, we produced 4.9 quads of electrical energy from nuclear, up from 0.9 quads in 1973, and we consume all we produce. Prospects for maintaining this rate of increase are nil because some of our plants are aging, and, after several more plants under construction come on line, no additional plants are planned for the near future.

• HYDROELECTRIC — Consumption and production of electricity from hydroelectric facilities have been fairly steady. In 1973, we consumed 3 quads, and in 1987, not quite 3.1 quads. We produced nearly 2.9 quads in 1973 and 2.6 quads in 1987. The differences in production and consumption figures come from net electricity imports from bordering nations.

• OTHERS — Since 1973, we have produced the equivalent of between 2.1 and 2.6 quads annually from natural gas plant liquids. All other sources, including electricity from geothermal, wind, photovoltaic, and solar thermal, accounted for only about 0.25 quads in 1987, less than four-tenths of 1 percent of our total energy production. •LP

View From the Top

VP Hartley on Energy Program

Historically, Sandia's energy programs were tailored to respond to the nation's push toward energy independence. But that was the 70s, early 80s.

"Today, we are moving beyond national concerns," says Dan Hartley, VP of Energy Programs 6000. "We're looking at the global impact of energy — the climatic changes energy use is causing, the toxic and hazardous waste energy produces, and the economic effects related to energy supply and demand.

"And Sandia is in a unique position to deal with each of these problems. We have a broad, synergistic energy program staffed by knowledgeable people, technical experts in each of the sources that effect climatic change and create waste-management problems. In other words, we have both expertise, experience, and perspective.

"It's true we don't have, say, economists and energy policy experts on our staff, but we're forming alliances with institutions that do — we're working with MIT, for example, to develop a new cooperative program called 'Responding to Global Change.'

"We do, on the other hand, have the largest energy program of any of the national labs," Dan continues. "Some other labs do get more BES [Basic Energy Sciences] funding from DOE, but many of those BES dollars don't go into energy research *per se*.

"And we're not the largest because we've done a better job of 'selling' our program; it's because our services are sought — and because our programs are strong enough that they weren't cut."

Cuts and Culls

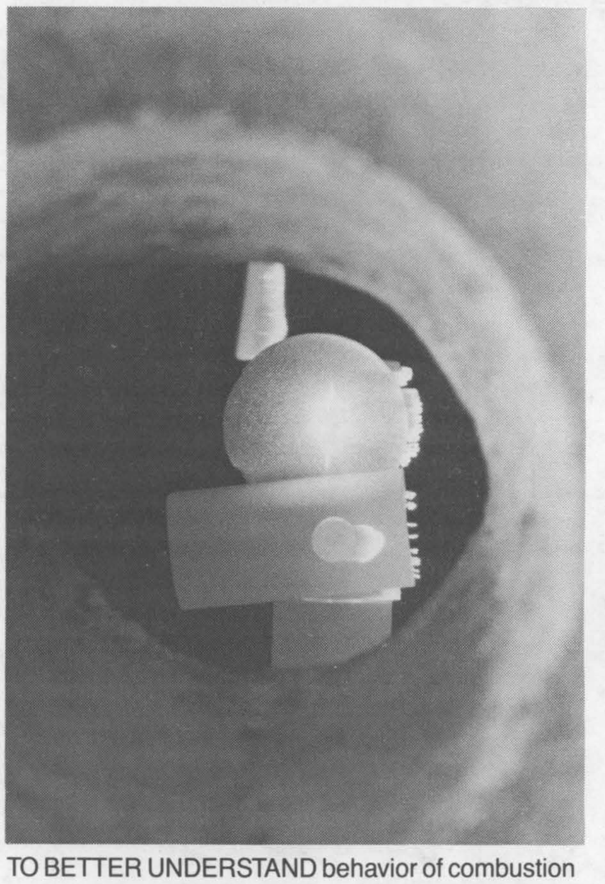
Cut? From 1980 to 1987, federal funding for energy decreased by 80 percent. Sandia's energy funding dropped by only 50 percent. "The effect was to cull out all the DOE programs that didn't show promise of being useful," says Dan. "What was left was extremely solid — and much of what was left was right here at Sandia. We have a good solid base to build on for the future — plus those global challenges.

"I believe that we're not only the biggest but the best — the lab known for its high-quality product. That sounds parochial and self-serving, and maybe it is. But the experts in the energy field have complimented our work often enough that I've come to believe they're right.

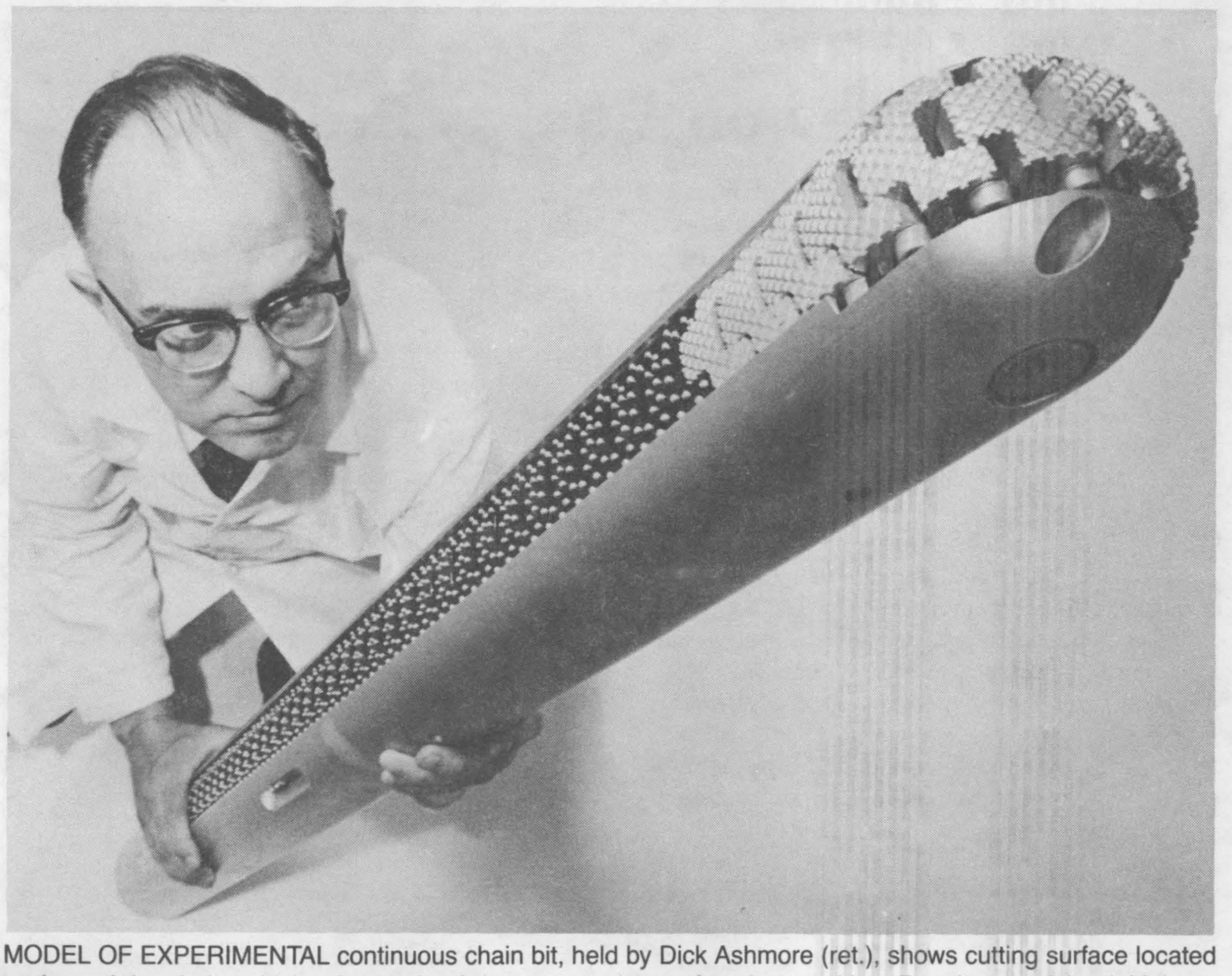
"If so, it's a tribute to Sandia's strong recruiting skills — we end up with top-notch people — and to AT&T's management philosophies, and to the ethos of the Labs in general, not just the energy side."

So, from the point of view of Dan and other leaders of the energy program at both Sandia Albuquerque and Livermore, the future appears positive. Dan puts it this way: "Either the price of oil will remain low, and energy *per se* will not get the kind of support from Congress that the *impact* of energy will get — that is, the problems surrounding energy use will demand attention. Or oil prices will rise, compounding the issue by adding the problem of scarce or expensive resources to the impact problem. Either way, the future is challenging and exciting."

Just as Sandia's focus has shifted from national to international concerns, so there's been a shift in Sandia's relationship with industry and others. "We've moved beyond developing technologies that we hope industry will use to creating working alliances with industry — and with academia and with other national labs," says Dan. "And we're getting tremendous cooperation from both Los Alamos and Lawrence Livermore."



TO BETTER UNDERSTAND behavior of combustion materials in harsh environments, CRF scientists study properties during interaction with a surrounding stream of hot, highly reactive gases, such as those found in combustion exhausts. Raman spectroscopy is invaluable for determining structural phase and chemical composition under such conditions. Here is a quarter-sized zirconia ceramic disk, a possible coating material for turbine blades. A stream of 950°C exhaust gases that contains fly ash flows by it at six metres a second. (Fly ash buildup is the brilliant fringe on the right edge of the circular sample.)



MODEL OF EXPERIMENTAL continuous chain bit, held by Dick Ashmore (ret.), shows cutting surface located on face of the chain, which advanced to bring new cutting surface into position. Despite promising initial test results, advanced development and testing were dropped.

(Continued from Page Two)

Overview

thousands of feet long to allow replacement of the drill bit at the bottom).

Geothermal Energy

Sandia has developed new kinds of drilling muds and new ''hardened'' versions of logging devices that can survive the rigorous geothermal environments. In a related scientific area, Sandia is responsible for the Drilling Project Office of the Continental Scientific Drilling Program, which aims to provide new knowledge of the structures underlying the North American continent.

Solar Thermal

Sandia has played a key role in developing concentrated solar technologies for commercial powerplant use — technologies that involve focusing solar energy onto a pipe running through a trough-shaped collector, into a receiver at the focus of a dish, or, by way of heliostats (sun-tracking mirrors), onto a receiver atop a tower. The goal in each case is to heat a fluid (water, air, or molten salt, for example) and use that energy for driving a generator and/or for space-heating or other industrial purposes.

BY THE EARLY 80s, some energy organizations were regularly publishing SAND documents that discussed their approach to technology transfer and recent successes. In 1983, Virgil Dugan (6200, left) and Dick Traeger (6250) posed with some then-recent technology advances transferred to energy-related industries. At the front of the table is the combustion section of a downhole steam generator used in enhanced oil recovery. Virgil's hand rests on the electronic package of the Seafloor Earthquake Measurement System, a PDC drag bit sits on the table, and Dick holds a well-logging tool developed for operation in harsh geothermal environments.

Sandia Livermore assisted in the engineering development of the nation's biggest electricity-producing solar plant, Solar One, near Barstow, Calif. (which was recently shut down after six-plus years of operation). The DOE's Solar Thermal Test Facilities are in Sandia Albuquerque.

Sandia has established baseline data on the performance of both traditional and innovative line concentrators (parabolic troughs), point concentrators (parabolic dishes), and heliostats for concentrating sunlight on receivers (solar-heated boilers). It has also had responsibility for the materials-science work and computer codes that make these advanced designs possible.

Photovoltaics

Sandia has been heavily involved in the effort to develop ''solar cells'' (photovoltaic chips) that demonstrate significantly higher conversion efficiency. Recently, a multijunction cell was demonstrated that converts a record 31 percent of the solar energy hitting the cell into electricity.

In addition to research on the cells themselves, Sandia has pioneered the use of sunlight concentrators (primarily Fresnel lenses) to increase the amount of solar energy that falls on a solar cell, and the Labs has done pioneering work in the systems technology underlying all types of photovoltaic devices.

Wind Energy

A major Sandia contribution in converting wind energy into electrical energy is a modern version of the eggbeater-shaped VAWT (vertical-axis wind turbine) invented by G. J. M. Darrieus in the 1920s. The improvement was made possible by Sandia's years of experience with sophisticated aerodynamics (a VAWT blade is a kind of airfoil), with advanced materials (VAWT blades are subject to metal fatigue), and with complex computer codes (needed to simulate the behavior of a variety of blade sizes and shapes in a wide range of wind speeds).

Currently, the 165-ft.-tall VAWT near Bushland, Tex., is the nation's largest such wind machine. But it's more than tall; it's a test bed — designed to generate information as well as electricity.

Rechargeable Batteries

Sandia is the lead lab in DOE's Exploratory Battery Technology Development and Testing project. Much of Sandia's work involves new materials, ones that show promise of being able to store large amounts of energy, discharge that energy, and repeat the cycle again and again — and not cost much to manufacture.

Currently, Sandia is investigating sodium/sulfur, nickel/hydrogen, zinc/bromine, and other even more exotic battery materials. Each has its own advantages and disadvantages — more appropriately, its own positives and negatives.

Combustion

Researchers at Sandia Livermore's Combustion Research Facility (CRF) are using high-tech devices (coherent anti-Stokes Raman spectroscopy, for example) to gain new insights into the complex nature of an old-tech chemical reaction — combustion.

Along the way they've aided in the nation's struggle to reduce the amount of pollution that comes from burning gasoline, coal, and other fuels. The most famous example of success here is RAPRENOx, a process that almost eliminates nitrogen oxides, which cause smog, from internal combustion engine exhausts.

Still another CRF achievement is that scores of scientists from both academia and industry (coal-furnace manufacturers to automobile-engine designers) have spent months or years in residence at the CRF exchanging information with Sandia researchers. That experience promises to be a useful model in other energy-related programs.

Finally . . .

More detail on each of these programs will be found in this special section or in the two to follow; the beginnings of Sandia's energy program are described in the related ''Origins'' story. •BH

(Continued from Page One)

Origins

sometimes assumed to have forced Sandia to diversify its programs, the RIF simply hastened a diversification that began much earlier — well before both RIF and "energy crisis," some especially perceptive Sandia executives had felt that a single-mission lab was a mistake.

One who held that view, and who was in a position to do something about it, was Glenn Fowler, then the VP to whom the Special Projects directorate reported. He had pushed for (or at least quietly found funding for) such non-weapon programs as Vela (a space-based system to verify the ban on atmospheric and surface nuclear testing), nuclear reactor safety studies, and planetary quarantine (designed to avoid contaminating other planets during exploratory missions from earth).

Meet GAFCO

"Back about 1968, we had a sort of informal group that got together to discuss possible new programs, programs that would build on the tech base developed to support the weapon program," says Don Shuster (ret.), then Director of Exploratory Systems Development. "We called the group GAFCO — G. A. Fowler & Company — and it was Glenn who urged us to brainstorm, to at least consider some 'way-out' (to use his term) directions.

"In a sense, we took him at his word — several of us, including Bob Stromberg [now 4031], became convinced that we ought to go way out to the sun: We ought to start a program to exploit the 'solar community,' or 'total energy,' concept, which is a little like what's now known as 'co-generation.'

"That is, a solar community involves building homes around a centralized solar collector," Don continues. "From the collector, the homes would get their hot water and their electricity, via a solar-heated steam generator. The waste heat would be used for space heating and — using the model of the old Servel gas refrigerators — cooling too.

"What we had to do was to quietly nurture the idea long enough to demonstrate some feasibility. That's true at Sandia, and I suspect it's true at most R&D labs, including [AT&T] Bell Labs.

"Let me tell you a little story: Mervin Kelly [Bell Labs president from 1951 to 1959] was convinced that coaxial cables and microwaves were the only ways to transmit long-distance telephone signals, so he issued an edict prohibiting work on satellite transmission systems. When he retired, a host of plans based on satellites suddenly and miraculously emerged. Telstar was operating by July 1962.

"In the late 60s, that was the solar community project."

Don Goes to Dixie

"Dixie Lee Ray was chairman of the AEC in the early 70s, and some of her advisors were convinced there would be energy problems in the future," Don continues. "President Nixon put her in charge of a panel to study ways to reduce America's dependence on foreign oil. In the summer of 1972, I think it was, I served on her panel. So when the oil embargo arrived in late '73, the panel had some broad-brush recommendations as to where government R&D funds should be spent."

Even before the embargo, in early '73, Small Staff (headed by President Morgan Sparks) created in Glen Brandvold's (ret.) department a division headed by Bob Stromberg to explore the feasibility of the solar community concept. Another division under Max Newsom (now 9120) in Morgan Kramm's (now 5230) department began to investigate advanced drilling and logging techniques. A division in the Aerodynamics Research Dept. began concentrating on the VAWT (vertical-axis wind turbine) concept. And several researchers in the Solid State Sciences Directorate generated significant interest in "solar cell," or photovoltaic, technology.

At this point then, because of the recent RIF, most Sandians realized the need to diversify. And the oil embargo and the report issued by Ray's panel (which confirmed the need for the kind of work already in progress at Sandia) both made the direction in which to diversify unmistakable — energy.

"President Sparks told DMA [the AEC's Division of Military Application, then Sandia's sole funding source] that Sandia needed to seek some funding for energy programs," recalls Don. "DMA gave that request a tacit approval, at least, and Morgan found some seed money somewhere in the AEC. Small Staff then had to decide which of the fledgling GAFCO programs should share that seed money — but maybe there were some other good ideas that could build on Sandia's weapon-development expertise."

So, after the oil embargo got the attention of all Sandians, Small Staff wanted to get them involved in the search for creative sources of energy. It created a committee, headed by Jim Scott (ret., then Director of Exploratory Projects) and Don (then Director of Advanced Planning and Analysis). Committee membership included, among others, Orval Jones (now 20), and Arlyn Blackwell (then a Sandia-Livermore department manager, now 400); it was coordinated at the Small-Staff level by Al Narath (now VP, Government Systems, at AT&T Bell Labs). The committee used flyers, forms, and a LAB NEWS article or two to solicit energy ideas from all around the Labs.

One of the projects that came out of this period aimed at well-logging, that is, improved ways to collect and analyze the data from boreholes — oil and gas boreholes, coal deposits, geothermal resources, etc.

Other projects, in addition to the ongoing solar ("solar community," VAWT, and photovoltaics) and drilling projects, included better ways to get the oil out of oil shale, and the Enhanced Oil Recovery project (specifically, a downhole steam generator to soften heavy oil), new storage batteries (growing out of Sandia's long-term experience in thermal batteries for weapons), and combustion (which aimed to increase the efficiency of combustion by analyzing the phenomenon with laser diagnostic and other advanced techniques).

Not Every Bandwagon

"It's important to note that Sandia didn't jump onto every bandwagon labeled 'energy,' " says Don. "Our rationale for accepting a project was based on positive answers to three questions: One, is the proposed program matched to Sandia's capabilities, equipment, and people? In other words, did it exploit the technologies and talents we'd amassed over our years in weapon development?

"Two, is it innovative, ahead of the pack? The new chain drill and spark drill were obvious examples here. And three, does it have significant potential payoff? Will it really decrease the nation's dependence on foreign oil?"

How did (and do) all these projects relate to the above rationale? "We could do heat-resistant electronics for geothermal logging because we had hardened electronics against *all* severe environments, not just the high pressures and temperatures electronic devices see during an underground nuclear test," says Don. "And our overall instrumentation capability was well developed.

"We had the talent and the tools to put a science and engineering component into then-current drilling technologies. We had field-test capabilities to add as well.

"And we weren't afraid to ask questions and go out to the oil patch to find answers," Don continues. "A couple of examples among many — Max Newsom went over to Pecos [Tex.] where a crew was drilling a 30,000-ft.-deep hole. The temperatures were so high that the engineers couldn't log them; they could only measure the pressures.

"Then Max went to a Siberian oil field and saw a turbine-powered bit [drilling 'mud' pumped downhole rotated the bit]. But the Soviets didn't have the high-strength-steel drill string needed to take advantage of the bit. These kinds of experiences helped Sandia focus on real-world energy problems.

"We got into hard-rock drilling because we wanted to be able to tap into magma deposits, and magma typically lies under hard rock.

"And we got into solar because it was basically a materials problem — how cheap can you make efficient and durable heliostats, collectors, solar cells. And solar cells, of course, built on Sandia's expertise in optics and hardened microelectronics as well as materials science."

Early in the solar program, Sandia Albuquerque began specializing in photovoltaics and the "solar community" concept, Sandia Livermore in large focused-collector arrays. Both labs had difficulty in reducing the cost of collectors — "The problem is that we've got aerospace companies building collectors," asserts Don. "We should be using automobile manufacturers.

"Look at VAWT," he continues. "Our early mistake was adapting exotic materials used for helicopter blades for our turbine blades — very expensive. Now we use extruded aluminum, which costs far less."

(Don, incidentally, tried to talk Sandia management into putting a VAWT atop Sandia Crest, "the only consistently windy enough place around Albuquerque. I think Small Staff thought I couldn't be serious.")

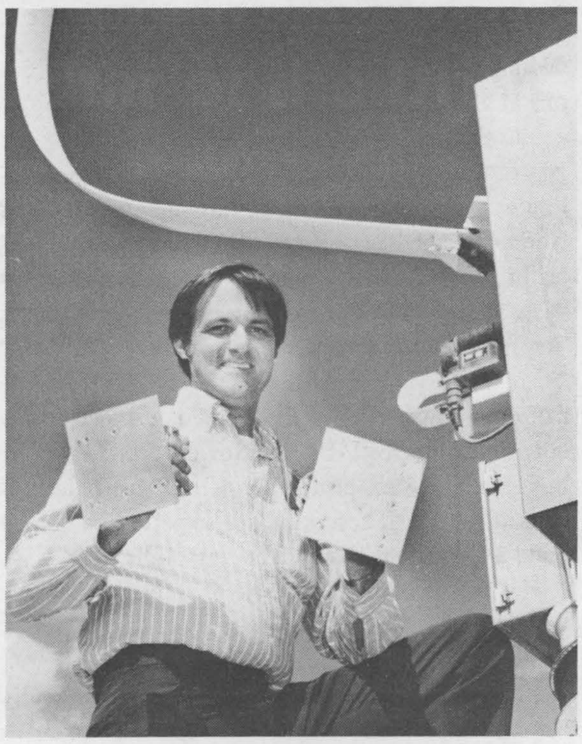
Nearly all of Sandia's energy programs tapped the Labs' extensive ability, again from the weapon program, to develop mathematical models of complex phenomena. What the weapon program couldn't provide was enough geologists — "We had a few people who knew geology from our cratering work [connected with underground nuclear tests], but we needed many more," recalls Don. "So the mid-70s saw us develop an active recruiting program aimed at good geologists."

'Origins' Phase Ends

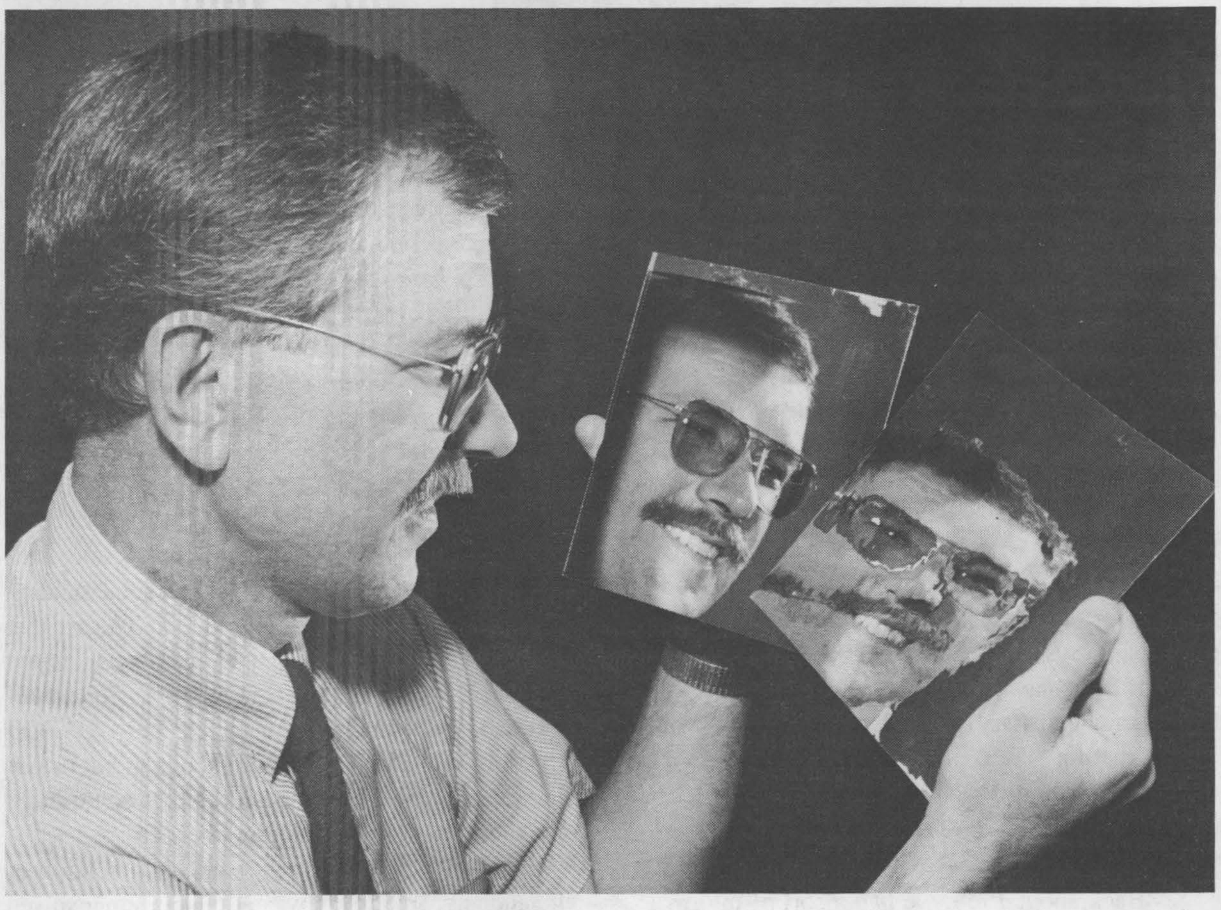
The "origins" phase of Sandia's energy program ended when its role as a key player in the energy drama was accepted externally and internally.

The external acceptance is suggested by the fact that two Sandians (Jim Leonard, now 400, and Billy Marshall, now 6210) spent the last part of 1974 in Washington helping ERDA establish the Project Independence Blueprint, which was a plan to promote "renewable" sources of energy. (The AEC, along with some other government entities, became ERDA, or Energy Research and Development Administration, on Oct. 11, 1974.) Other Sandians — including Jim, Don Schueler (6220), Bill McCulloch (6511), Al Baker (8151), and Ralph Richards (ret.) — assisted in setting up ERDA's Solar Photovoltaic and Solar Thermal programs in 1975.

Formal internal acceptance came late that year when Small Staff created, in Al Narath's vice-presidency, an Energy Projects and Systems Analysis Directorate under Jim Scott. It included an Advanced Energy Projects (mostly solar) Dept. under Glen Brandvold, a Geoenergy Technology Dept. under Hap Stoller, and a Systems Analysis Dept. under Virg Dugan. •BH



BILL SULLIVAN (now 2542) holds movable panels that automatically brake a vertical axis wind turbine (VAWT) in high winds. His patented "wind spoiler" moves on roller system from base of VAWT blade to equatorial center. Scale versions were proof-tested on Sandia's 5-metre VAWT.



DICK PETTIT (now 7243) holds two versions of acrylic reflective films made by 3-M. Despite its unacceptable light-scattering tendency, the original 1974 version (right) appealed to Dick for use on early solar parabolic troughs. Following a Sandia/3-M collaboration, the company came up with a new film (left) that could be used on troughs, while Dick developed equipment to precisely characterize performance of reflective films.

Energy Transfers Begin Early

Technology Transfer: A Matter of Push and Pull

In 1974, Dick Pettit (now 7243) wanted to find the best reflective material for solar parabolic troughs that Sandia had recently begun to study.

But to do that, he first needed some new equipment that precisely characterized just how much light reflected off the materials that interested him.

So, using primarily off-the-shelf parts, he designed a reflective characterization instrument.

Next, he started using the new technology to test candidate materials. He tried silvered glass, but it was too heavy and it didn't bend gracefully. He also auditioned polished aluminum, but shied away from it because polishing actually caused light scattering.

The product that he really liked was a thin aluminized acrylic reflective film made by 3-M, then used primarily for decorative applications, such as on lighting fixtures.

Unfortunately, the film's sticky backing created a rippling, orange-peel texture that significantly degraded its solar reflective and focusing characteristics.

Two Important Properties

But Dick still liked the film. It had two important properties — it was lightweight and it bent easily.

He contacted 3-M researchers responsible for the film and told them how he wanted to use their product and about his problem. They hadn't been aware that their product was of interest in this area of solar energy research.

In a matter of weeks, the Labs had struck up a relationship with 3-M. The company agreed to investigate process and manufacturing changes that could improve the film's reflectance. Sandia, in turn, offered its facilities and equipment — including the characterization instrument developed by Dick — to define the performance of prototype aluminized reflective films that 3-M designed for solar applications.

Ultimately, 3-M was able to market a new solar reflective aluminized film. And 3-M and solar energy researchers routinely use solar reflective characterization instruments that evolved from Sandia's original design.

That's an early and almost-too-good-to-be-true example of technology transfer from Sandia's energy research effort. Things went smoothly, there was early industry involvement, a marketable product — the film — resulted, as did Dick's new piece of scientific equipment that has become an industry standard.

Although hardly any of Sandia's technology transfer actions follow such a smooth path, the Pettit/3-M tale does illustrate something very important:

Long before the 1980 Stevenson-Wydler Act mandated that government-funded organizations devote part of their resources to technology transfer, some significant technologies were emerging from the Labs' early energy research, and on their way to the private sector.

There were:

- Vertical axis wind turbines (VAWTs);
- Solar parabolic troughs;
- Well logging tools able to operate at 275°C, almost 100°C higher than existing equipment;
- Lubricating muds for high-temperature, deep drilling operations;
- A portable viscometer to measure flow characteristics of drilling muds designed for harsh environments;
- Polycrystalline diamond compact (PDC) drill bit design advances to improve bit life and drilling speed;
- A black chrome plating process for solar collector tubes (Dick Pettit also was involved in this work); and
- A highly precise method of breaking up underground rock to free gas for recovery.

Additionally, by the mid-70s, technical working groups composed of Sandia Livermore combustion experts and representatives of engine manufacturers such as Ford, General Motors, Chrysler, and Cummins had been established.

"Most weapon-related transfers occur due to technology push," says Glenn Kuswa, manager of Technology Transfer and Management Dept. 4030. "Basically, we push the technology out the door toward the potential user.

"However, with energy programs that have technology transfer built into their program plans, we often experience technology pull — industries and businesses approaching us because of our developments and expertise," Glenn says. "When pull operates, we recognize needs in the civilian sector and direct our activity to satisfy those needs."

In fact, during Sandia's energy R&D boom-days from the mid-70s to the early 80s, the Labs was so widely known for its energy research that a national magazine once referred to "Sandia Solar Labs." Back then, it didn't surprise the Labs' public relations officers to have visiting reporters ask whether Sandia was involved in any projects other than solar and wind.

Sandia Livermore's Combustion Research Facility epitomizes technology interchange, another means of transferring the Labs' technologies. "We've learned," says Peter Mattern (8300), "that bringing visiting researchers to the CRF is our most effective means of technology interchange, and that our cooperative working groups are an effective model for industry-government-academia interaction."

But It Takes Work

Despite the documented successes, CRF's technology interchanges, and the helping hand of technology pull, technology transfer takes a lot of work. Seldom is it as automatic as saying to industry, "Here's the development. Take it, make it, sell it." Often much additional labor, capital, and time are required to make knowledge developed at the Labs and transferred to industry ready for the marketplace.

"You can see why patience and persistence are such virtues in this endeavor," explains Virgil Dugan, Director of Advanced Energy Technology 6200. "New technologies and understanding can emerge ripe for transfer, only to find no widespread demand for them in the marketplace."

That clearly is the case right now with some of our fossil fuel contributions. For example, Sandia was a major contributor in the 70s when the study of synthetic fuels to replace expensive oil and gas was in vogue. Results of mid-70s Sandia research helped convince industry and DOE to shift their efforts from true *in situ* oil shale retorting (leaving all oil shale underground for processing) to modified *in situ* retorting (mining just enough rock to create void space sufficient to support underground combustion, which true *in situ* techniques could not do reliably).

"Unfortunately, the oil shale business is essentially inactive now because of relatively low oil and gas prices, so our contributions are sitting on the shelf until interest in synthetic fuels reappears," says Paul Hommert, supervisor of Advanced Technology Div. 6258.

Glenn believes the Labs could present an even more impressive technology transfer scorecard if it

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Tech Transfer

beefed up its efforts to keep in touch with technologies after their initial transfer.

"We tend to speak up when a technology is first transferred," he says. "But we must not close the book on a particular technology just because a company wants to begin selling a product that we developed or to incorporate some of our suggestions into new designs of its existing products. We're finding that technologies that initially seem to offer a fairly narrow industrial impact can actually have much broader applications.

"Many of our publics miss that point, I believe."

One prime example of such a broadening technology is Larry Teufel's (6232) work on understanding underground stresses and how to measure them. *In situ* stress measurements were originally used to improve placement of oil and gas recovery wells in hard-to-tap reservoirs. "But now, it turns out," Virg Dugan says, "that the oil and gas application represents just the tip of the iceberg."

The technique is now being used to better understand *in situ* stresses found in Yucca Mountain (Nev.) tuffs that are being studied as the potential host-rock for high-level radioactive waste. In fact, the underground stress measurement technique actually seems applicable to the study of any kind of deep reservoir.

Expanded Applications

Other technology examples whose applications expanded with time include:

- Sandia's airfoil theory that led to improved VAWT blade designs has more recently provided valuable insight to horizontal axis wind machine manufacturers. Helicopter blade and other airfoil designers are interested in Sandia's work, as well.
- Sandia Livermore's pulse combustor program started as a basic study of flame dynamics, but it has broadened so that the Combustion Research Facility has contributed to the formulation of computerized design criteria for commercial pulse combustors.
- The Labs' initial transfer of basic process descriptions for fabricating highly efficient crystalline silicon solar cells was followed by development and eventual transfer of computer programs that permit solar cell manufacturers to understand the relationships between device performance and processing specifics.

Transfers of scientific or technical concepts, rather than hardware, posed challenges. The underground stress measurement technique is an example. "Here the initial transfer," says Virg, "was new technical understanding of stress relaxation in cores after they were brought to the surface. That was complemented by a patented diagnostic tool [invented by David Holcomb and Mike McNamee, both 6232] that let the science go to the field. But the real transfer involved only an understanding."

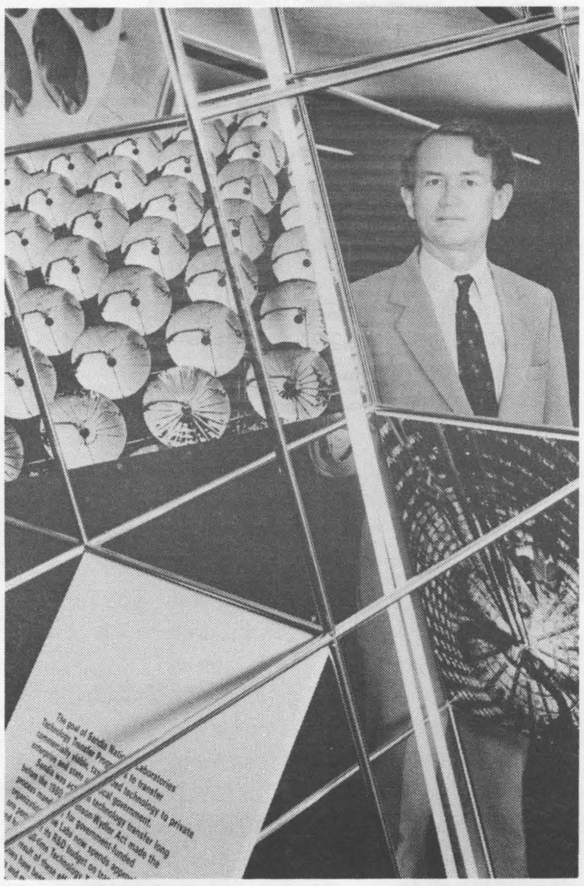
Other significant non-hardware transfers are:

- A unique understanding, based on Combustion Research Facility lab tests, of engine knock — the loud "pinging" noise caused by abnormal fuel ignition;
- A computer model (GEOTEMP) that predicts temperatures of drilling fluids, cements, and casing strings in geothermal wells; and
- A standardized technique for characterizing the properties of reflective materials used on solar collectors.

The Labs has experienced steadily increasing interest in its technology during the past eight years, and Virg sees "a strong, positive upswing" in energy-related developments despite a general lack of concern from the public about energy prices and about dwindling supplies of certain fuels.

"There's also a new mood within industry to work more closely with national labs and to depend more on their capabilities and expertise," Virg says.

Glenn Kuswa lists other reasons that should mean a healthy technology transfer future, particularly for energy-related programs.



GLENN KUSWA oversees Sandia's growing technology transfer activities as manager of Dept. 4030, which uses scientific and administrative staff. Since 1982, about 250 Labs technologies, many energy-related, have been transferred to some 900 recipients.

"Sandia's limited consulting policy is helping," he explains. "On a case-by-case basis, it permits employees to work on their own time with an interested company to transfer technologies that were developed here. Our employees negotiate compensation with the companies for whom they consult."

Design Assistance Center

The Design Assistance Center (DAC), basically Gary Jones' Photovoltaic Systems Research Div. 6223, has been an energy technology transfer all-star since its inception about four years ago. It should continue to play a major role in future activity. "We're here to accelerate the acceptance of cost-effective photovoltaic [PV] technology beyond the normally expected market infusion rate," Gary says.

DAC works with private industry, state and federal government agencies, and foreign concerns that are considering the use of PV in an upcoming project. "It helps them become familiar enough with the technology, including system design and operation, and subsystem selection, that they have confidence in it," explains Mike Thomas (6223), DAC task leader.

"We also provide non-PV technical assistance — systems integration expertise, for instance — to solar cell firms," adds Hal Post, systems research project leader in 6223.

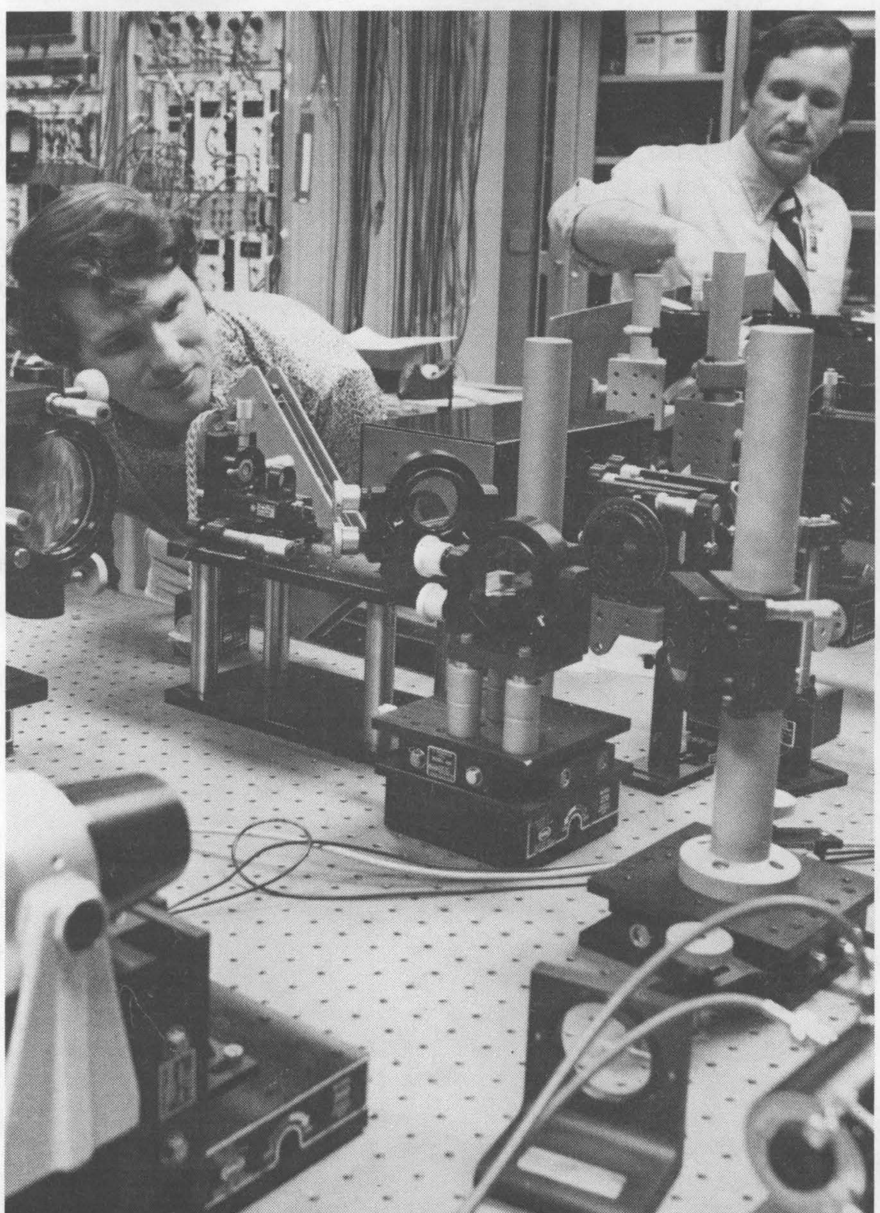
Some DAC accomplishments:

In the Tonto National Forest (Ariz.), it is helping with a conceptual design and feasibility study to provide solar power at a remote 350-unit Roosevelt Lake campground. In Phoenix, it assisted a housing developer in the conceptual design, procurement, and evaluation of a PV electric system for a 24-home community. At the request of the Pan American Health Organization, it demonstrated how commercially available solar cell panels could economically power stand-alone water disinfectors in remote areas that do not have a ready supply of safe drinking water or electricity.

DAC also has produced three booklets for users considering a PV project. One evaluates some existing PV projects. Another provides a step-by-step approach for identifying military applications of PV and procuring appropriate systems. The third offers a simplified approach to sizing systems and discusses hardware selection, installation, and maintenance.

Predicting technology transfer successes is tricky. "We've had our 'can't-miss' items that did, and we've had some real sleepers like Larry Teufel's anelastic strain recovery technique," Virg recalls.

"Right now I'm enthusiastic about two solar efforts headed by Jim Fish [6227]. One uses concentrated sunlight to drive a catalytic absorption reactor that decomposes hazardous wastes such as chlorinated organic solvents. For the other, we're working on a way to put solar energy, methane, and carbon dioxide into a reactor at the focal point of a solar concentrator dish and get liquid methanol out." •RG



RETURN TO THE EARLY DAYS of CRF — vintage 1979 — with Larry Rahn (DMTS, 8354) and Peter Mattern (8300) in a coherent anti-Stokes Raman spectroscopy (CARS) lab. Their work of about a decade ago led to techniques that significantly increased the detection capability of CARS, which remains a primary combustion research tool today for determining flame temperatures and major species concentrations.

Modern Prometheans

The Fire Primeval: Challenge of Combustion

To our early human ancestors, fire was a life-warming, culture-transforming discovery. To the ancient Greeks, it was one of the four fundamental elements of nature.

No wonder. Like the sun itself, fire gives life, heat, comfort, and power — the power to move minds and mountains.

The scientists and engineers of Sandia Livermore's Combustion Research Facility could well be called modern Prometheans, although they would eschew so flamboyant a label. They are trying to tame fire by knowing it more intimately than the Greek philosophers could even have imagined.

To understand the primal secrets of combustion, their quest draws upon the most modern tools of science and technology. Laser diagnostic beams that can penetrate the heart of flames and peer into the combustion chambers of working engines. Specially made research engines and combustors that allow experimental measurements under carefully controlled conditions. World-class supercomputers and numerical codes that express all the newfound knowledge in models that can be mathematically manipulated and generalized.

The goal is not merely knowledge of the Promethean flame for knowledge's sake. They seek to learn practical ways to make the process of combustion more efficient and less polluting. To make our energy supplies go further and our air less despoiled.

It's a crucial need. Almost all our nation's energy relies upon combustion.

What's Driving the Problem

''Something like 90 percent of the country's energy comes from the combustion of fossil fuels in one way, shape, or form,'' says Steve Binkley, manager of Combustion Sciences Dept. 8350. ''This is really what is driving the whole problem.''

Peter Mattern, who heads the CRF as Director of Combustion and Applied Research 8300 at Sandia Livermore, takes a historical view:

''Until recently there has been only a very poor understanding of how things burn. Perhaps there wasn't any real need to know — there have been ample resources to burn.''

That's all changed now, he says. In the 70s, when the price of oil skyrocketed, we realized there is a finite limit to our fuel resources. And newfound concern about air pollution, reinforced by regulatory actions, concentrated attention on the deleterious products of combustion.

''Those two driving forces caused us to address two critical issues — how we can burn fuels more efficiently, and in a way that we don't pollute the environment.''

There is nothing simple about it.

''The fact is that combustion is a terribly challenging problem,'' says Peter. ''It couples highly complex and sophisticated chemistry with a facet of fluid mechanics that no one still knows how to deal with correctly — turbulence.'' He points out that every commercial combustor that burns fuel for practical purposes involves turbulent flow. The fuel and air are moving violently, turbulently, with respect to each other.

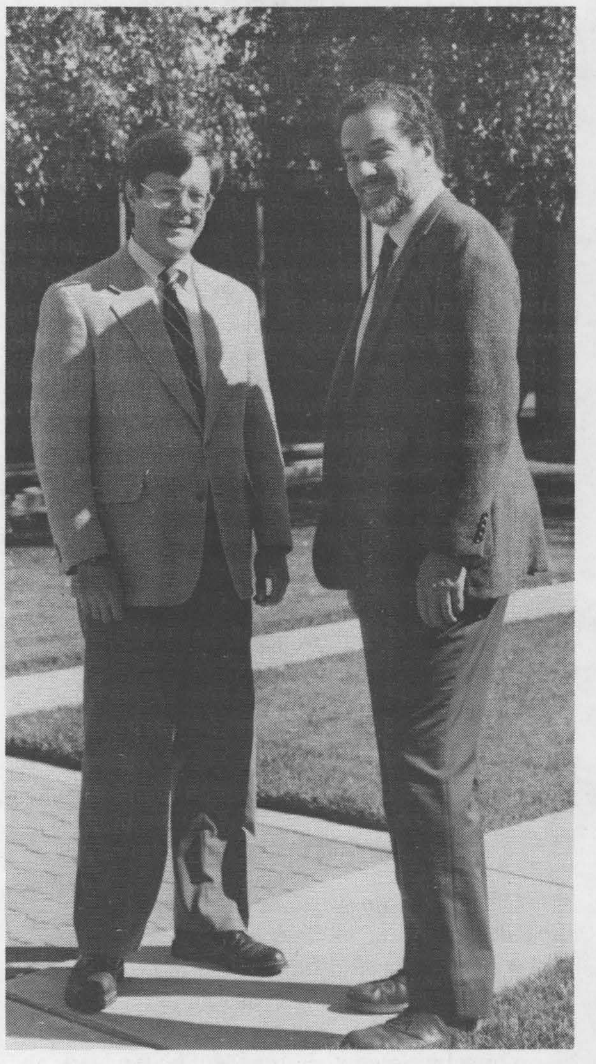
''Science does not know how to deal accurately with turbulence,'' Peter continues. ''It's a frontier area of research. So you're combining what amounts to state-of-the-art computational chemistry with a cutting-edge research problem in fluid mechanics.

''The field will remain a challenge for as long as it takes to learn how to make rather complete chemical descriptions of complex processes — like gasoline combustion — and as long as it takes to learn how to deal with turbulent motion of fluids.''

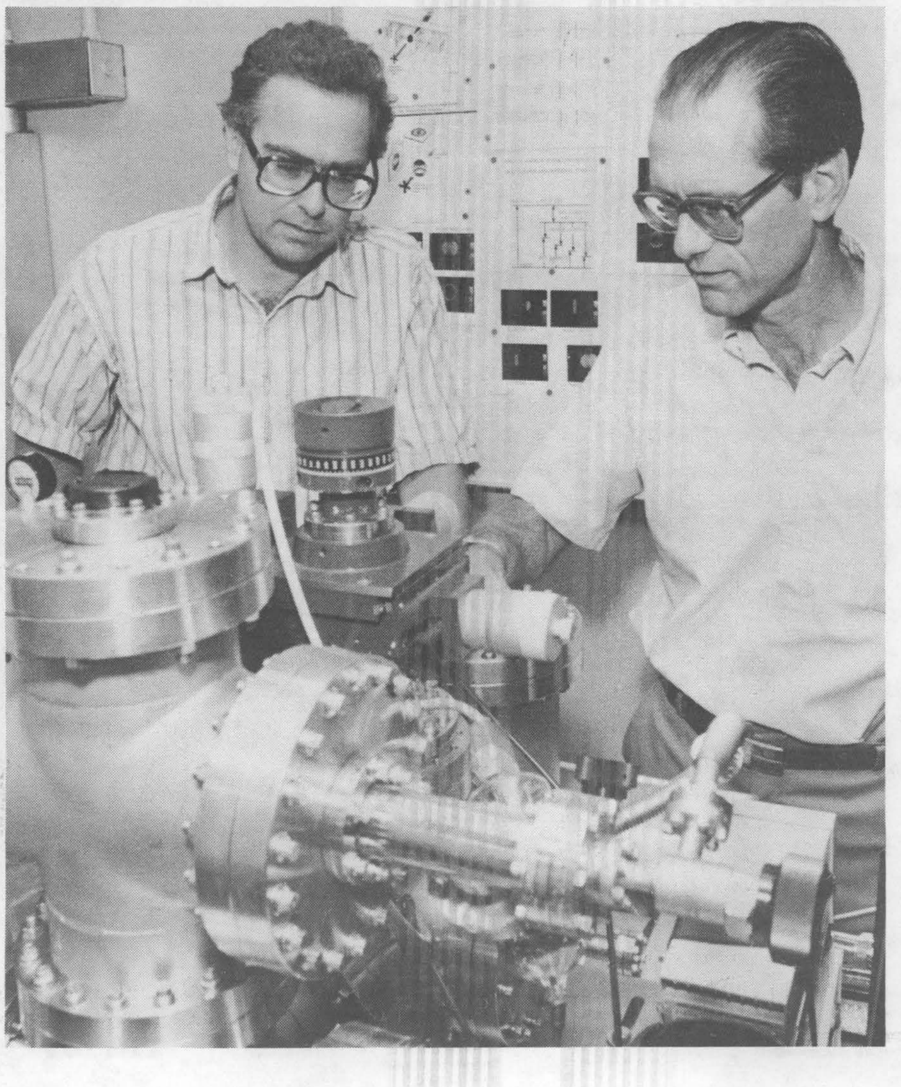
Advanced Techniques Needed

Steve Binkley, whose background is in computational chemistry, agrees with that overall perspective. ''Over the past 40 or 50 years, the seat-of-the-pants way of designing combustors has been pushed about as far as it can go. If we are going to make any real significant advances over the next couple of decades in addressing these critical energy problems, we are going to have to rely on more advanced scientific and engineering techniques.''

But the CRF has developed a knack for coming up with those advanced techniques. Just a few months ago, for example, it began using a spark plug fitted with fiber-optic ''eyes'' to probe combustion problems inside auto engines while they are running (LAB NEWS, Aug. 12, 1988). So impressive is the diagnostic tool, developed in a collaborative effort with the University of Toronto, that all of the ''Big 3'' US automakers may soon be using similar ones in their engine research programs.



STEVE BINKLEY (8350, left) manages CRF's fundamental and theoretical studies of combustion chemistry and laser-based diagnostics development, while Bill McLean (8360) manages its applied research efforts, which are aimed at larger-scale combustion processes.



FUNDAMENTAL STUDIES of microscopic molecular processes are one key responsibility of Combustion Chemistry Div. 8353. Here George Fisk (right) and Dave Chandler (both 8353) examine new 2-D ion-imaging apparatus in CRF's Chemical Dynamics Lab. Dave's recent studies with methyl iodide provide important new understanding about how molecules dissociate after they absorb light. "Similar studies contributed to our understanding of the RAPRENOx anti-pollutant process," says George, 8353 supervisor.

The Combustion Research Facility is dedicated, as Steve puts it, ''to pushing combustion science as far as it can go.'' The new scientific information is then put to ready use in Bill McLean's Combustion Technology Development Dept. 8360, where combustion processes associated with engines, furnaces, and power plants are being probed by lasers and computers.

Science at the CRF is directed toward two different scales of combustion phenomena. ''We look at the fundamental microscopic details of the chemical processes that go on in combustion,'' Steve says, ''and we look at macroscopic combustion phenomena — fluid mechanics and associated phenomena in turbulent reacting flows.''

The microscopic phenomena include chemical dynamics, chemical kinetics, and spectroscopy. Take chemical dynamics.

''The idea,'' says Steve, ''is to understand both the spatial and temporal resolution of chemical reactions. If molecule A is reacting with molecule B, you want to know where in space that's occurring, and you want to know — literally moment by moment — how that reaction is evolving.''

He refers to ''some absolutely beautiful experiments'' in this area by Dave Chandler and others in George Fisk's division (8353). ''The amount of information they've been able to get out of just one experiment is incredible.''

And chemical kinetics. ''We're very interested in something called state-to-state dynamics, which is looking at the actual time evolution of chemical reactions, molecule by molecule. We've developed a number of techniques that enable us to probe the chemistry, literally down to the molecule-by-molecule level. We try to understand how all these chemical reactions play together to make combustion.

''We combine the experimental studies with detailed theoretical calculations — quantum mechanical techniques as well as mechanical techniques —

(Continued on Page Ten)

'A Tremendous Concept'

The CRF — Its Origins

Sandia's Combustion Research Facility was born out of the oil crisis of late 1973. Dan Hartley, now Vice President for Energy Programs 6000, recalls the beginning:

"Right after the oil shortage hit us, there was some rumor that the AEC laboratories might get involved in trying to deal with energy. We knew something might happen. We were lined up at the gas stations for gas."

At that time he had a small division of people who were using lasers to measure fluid problems for weapons. Arlyn Blackwell (now 400) had recently been his boss, and Dan decided to propose something to him.

"I said we had something unique to offer because we were way ahead of everybody in laser diagnostics, and we could apply it to combustion problems, particularly in engines. That would be an area where Sandia could contribute to the energy initiative."

A short time later, while on vacation in Georgia, Dan got a phone call from Arlyn. Washington had asked if Sandia had any good ideas for energy research programs. They wanted them sent immediately.

"So I started thinking about a written proposal while on vacation. When I got back, we [Taz Bramlette, 8364, Bob Setchell, 5164, and Dan] had one day to write it up. Taz handcarried it to Washington that night. The proposal was funded."

Summer Breakthrough

"The real breakthrough came in the summer of '74," says Dan. The American Physical Society invited him to lead a study at Princeton called the Role of Physics in Combustion. "All the societies like APS were considering how their constituencies could contribute to the energy problem.

"During my summer at Princeton, I pulled together about 25 people from all over the country, including Don Hardesty [8361]. We asked, 'How can physics contribute to combustion?' By physics, we meant measurement and diagnostics and a basic understanding.

"Out of that, really, came the guiding document for everything that's happened since then. We concluded that we needed a research center where we could bring in people from the outside and work with them to develop diagnostics and computer models."

Then, he recalls, came a big hoopla about who would build the center and why Sandia, and why Sandia Livermore. "Tom Cook [retired EVP] got involved at that point. He was our vice president then. He really liked the idea and encouraged me to go for the whole thing — to be *the* Center for Combustion Research."

Dan and others had to answer endless questions. "Tom, Arlyn, and I had many memorable trips back to ERDA [Energy Research and Development Administration, predecessor to DOE] and to Congress. People in Congress were very receptive. Energy hadn't gotten politicized yet. We found it remarkably easy to sell this idea. In terms of big ideas, we were way ahead of other people.

"So we got ERDA's support." A key figure in that process, says Dan with undiminished appreciation, was Jim Kane, then on assignment at ERDA headquarters from Lawrence Labs. (He's now the liaison between the University of California President's office and LANL, LLNL, and Lawrence Berkeley Lab.) "He ended up being our champion, along with Ray Romatowski [retired manager of DOE's Albuquerque Operations Office]. Jim strongly supported the idea, and we got it all funded — the concept and the building."

Their timing was just right. "If it had waited a year, there'd have been 20 other people there asking, 'How about us?' "

Tom decided to keep the Sandia Livermore energy work tightly focused, on combustion and on solar. "What really helped is that we started with a core of 10 or 12 people who had expertise in laser diagnostics, the central theme of the CRF," says Dan. All stopped what they had been doing and turned to this new program.

'Hiring Real Stars'

The next step was to recruit more staff. "I knew the kind of people we needed to hire," says Dan. "We concentrated on hiring real stars. It worked. We were able to start with people such as Pete Witze [DMTS, 8362], Jim Miller [8353], Reginald Mitchell [8361], and Larry Rahn [DMTS, 8354] — all internationally known scientists at the CRF today."

Key guidance from Jim Kane continued. "He added a dimension to our proposal we hadn't included," Dan recalls. "We were going to do good science. That was our proposal. His proposal to me was two things. One, we build a facility half-supported by the Office of Basic Energy Sciences, which gives it a good science base, and half-supported by the applications side of ERDA — fossil, conservation, and so forth.

"We did that from the beginning, and it's still that way today. It turns out to have been a tremendous concept. It gets the science to the technology to industry, and it's all mixed together. Terrific. It was such a good suggestion.

"The other thing he said was that we should make it a user facility. We had no idea what that meant. We just wanted to do good science. But he said, 'No, you really need to encourage people from the outside to come work with you.'

"We've done that and it's been a very big plus."

Initially, the CRF was scattered. Staff was in a couple of trailers and then in an old explosive-test building up the hill in what is called Area 8 in Livermore.

'This Is Embarrassing'

"I was just a young supervisor," recalls Dan, "and Al Narath [then a Sandia vice-president and now Vice-President, Government Systems, AT&T Bell Laboratories] came to see what was going on. I can remember taking him up and trudging through this mess. I thought, this is embarrassing.

"But he was impressed. He said it was the only energy area where something was happening. He may have been fibbing to me. But it inspired us.

"So from the beginning, I had mixed feelings. On the one side, Al Narath and Tom Cook were a thousand percent behind us. It was recognized immediately that we had a unique capability in Livermore and we should run with it.

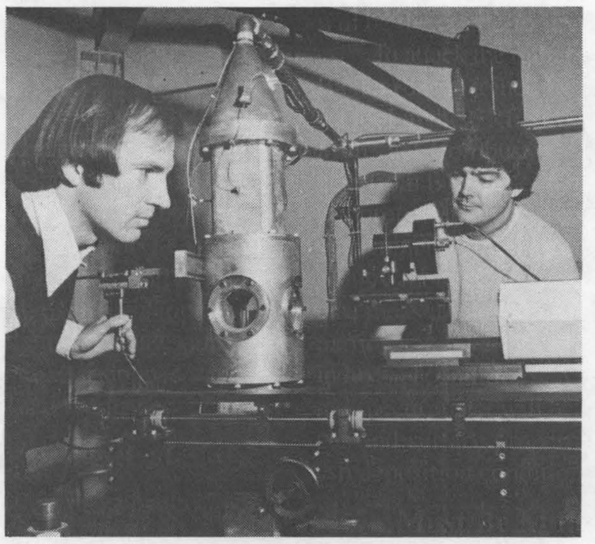
"The other part — I read someplace that the entrepreneur who succeeds is the guy who feels like his career depends upon his succeeding. I know now it didn't, but at the time I felt that this was my whole career, and if I didn't make this thing work I would have failed, my whole life.

"I remember a couple of times when CRF didn't make it in the budget, and I called the guys back at headquarters and talked to them and talked to them. I was so committed. I felt it was so important. So it eventually got back in.

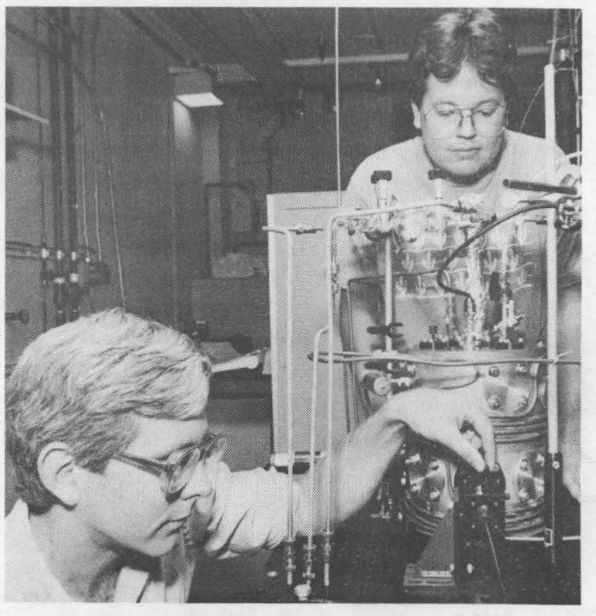
"It is so many little things like that."

Now that he's no longer responsible for the CRF, does Dan think it's fulfilled its promise?

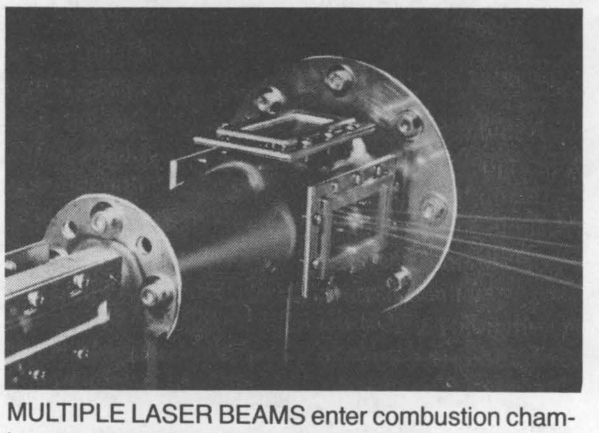
"I think our expectations were very high in the beginning. And I think it has significantly exceeded those expectations."



DAN HARTLEY (6000, left) and Pete Witze (DMTS, 8362) in 1975 setting up laser Doppler velocimeter on high pressure flame facility during early days of Sandia Livermore's combustion research.



WHILE GEORGE WILKERSON (8353, right) looks on, Joe Durant (8353) aligns the fiber-optic output coupler of a laser photolysis/laser-induced fluorescence apparatus in CRF's Chemical Kinetics Lab. This and other research tools help scientists learn more about elementary gas phase reactions important for thorough analysis of the combustion process.



MULTIPLE LASER BEAMS enter combustion chamber of a research pulse combustor at CRF. Such laser-velocimetry experiments permit scientists to learn more about fuel/air mixing in the chamber and how actual combustion progresses.

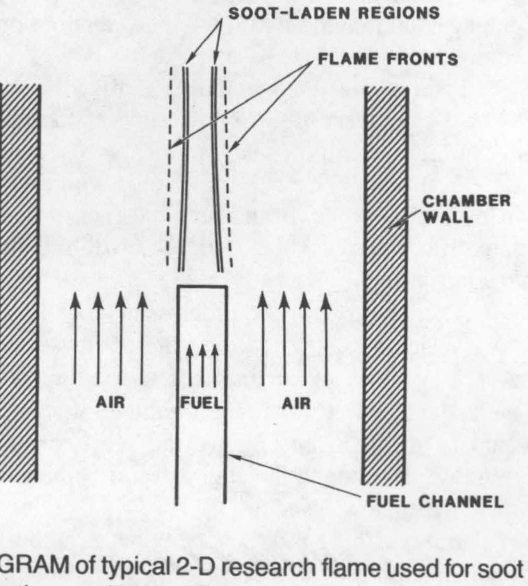


DIAGRAM of typical 2-D research flame used for soot and other studies at CRF.

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CRF Challenge

to develop models that integrate all this information together, both theory and experiment.'' The model should describe, as closely as possible, the physical reality of the combustion system.

Predictive Capabilities

And what makes a good computer model? ''The real thrust is to develop a model that has predictive capabilities,'' says Steve. ''You want something that not only explains all that you already know but also serves as basis of a predictive tool to help you go beyond where you're at today.''

The reacting-flows work, carried out in Bob Lucht's division (8351), applies laser diagnostics in clever ways to determine concentrations of chemical molecules and species anywhere in a flame. One experimental setup, for example, uses not quite co-planar mirrors to make the facility's central laser beam (piped in from next door) zigzag back and forth many times through a flame. That gives a two-dimensional slice of data. Then you can rotate the equipment, moving the flame gradually through a sheet of laser light and building up a three-dimensional representation of CH or OH, or methane, whatever you want. Says Steve: ''It's like a CAT scan of the flame.''

How has CRF's fundamental research helped contribute to energy solutions?

Peter Mattern points to the whole subject of nitrogen chemistry. Nitrogen is a special problem in combustion. It's in most fuels. And it's the largest constituent of air. So it's always involved in combustion, often in the form of environmentally harmful by-products. ''There have been payoffs in the understanding of nitrogen-based chemistry in a number of areas,'' says Peter.

The most visible and most publicized, of course, is Bob Perry's discovery of the RAPRENOx process (LAB NEWS, Dec. 19, 1986); Bob is now president of Technor, Inc. (Livermore) and a CRF visiting scientist.

The RAPRENOx process virtually eliminates smog-causing nitrogen oxides from test engines. It may provide the diesel industry a way to operate truck and stationary engines so that they can minimize outputs of both soot and nitrogen oxides. Until now, those were contradictory goals.

Other CRF Contributions

But that's not all. Says Peter, ''Our people have also contributed to a much better understanding of the source of fuel-bound nitrogen and have made what we feel is a direct contribution to understanding the thermal de-Nox process that Exxon has out on the market.''

De-Nox is a way to reduce the amount of nitrogen oxide in an exhaust stream by injecting ammonia into it at a particular temperature. It is used for industrial smokestack applications. ''Our people made a genuine and recognized contribution by identifying chemical pathways for the removal of NOx. These mechanisms were then embedded into Exxon's computer model. The Exxon people tell us this computer tool saves them considerable real dollars in pilot plant evaluation and tuning — they can do it on the computer instead.''

Peter recalls that when he was offered a chance to take part in combustion science at the CRF a decade ago, ''it took me about 2 microseconds to say, 'You bet.' '' He was a physicist with expertise in laser diagnostics. Both lasers and energy were hot scientific topics. ''I was delighted with the chance to contribute.''

There has been good progress in those 10 years. ''We've learned how to get at the combustion process as it takes place in 'real environments.' We understand how to use measurements in computer models to affect our engineering practices. And I think we understand the chemistry of combustion a lot better than we used to.''

But one thing is almost certain. ''Combustion-related science will remain a fruitful challenge.''

•KF

REASONS THAT PULSE COMBUSTORS are more efficient and less polluting than conventional combustion methods are becoming clearer due to research by Taz Bramlette (8364, left), Pam Barr (8363), and Jay Keller (8364). Jay adjusts photomultiplier tube used to reveal energy release in prototype Lennox pulse combustor hidden behind diagnostic equipment.

Pulse Combustors: Exciting New Heating Technology

It is an entirely new kind of home furnace heating technology, and the Combustion Research Facility (CRF) at Sandia Livermore is on the leading edge of technical advances. What's all the excitement about? Pulse combustors. They use acoustic effects — yes, acoustic, as in sound — to increase heating efficiency.

The advantages for home furnaces are already dramatic. Progress toward further advances is probable. Experiments and numerical modeling (on SNLL's Cray supercomputers) are intimately coupled. Ties to US industry are close. Implications extend to many industrial processes.

''I call this a canonical CRF program,'' says Mike Dyer, supervisor of Combustion Applications Div. 8362. ''It incorporates all the positive attributes of a CRF program into one.''

Acoustic Enhancement

Pulse combustion is an old technology — one of the first patents is a 1906 French patent, and the Germans used the technology on V-1 buzz bombs in World War II. But no one had ever really applied it to furnace technology for domestic heating.

Essentially, it involves using pulses of acoustic energy to enhance heat and mass transfer. Acoustic pulses are generated by repeatedly igniting a fuel-air mixture. The acoustic wave zings down to the end of the chamber, and reflects. In continuous operation, little packets of fuel and air enter and are automatically ignited because the gases inside are hot. The waves rush down and back, down and back, all in sequence.

The pressure-pulses push hot gases down the tube at high velocities, like surfers riding the crests of powerful waves. Even though the average velocity down the pipe is 10 to 20 metres per second, there are instantaneous velocities in the downstream direction of 100 metres per second and of the expansion wave in the other direction of 60 metres per second.

''So it's like blowing hot wind over something 100 metres per second in one direction and then 60 metres per second in the other,'' says Mike. These gases are hot, coming down the tail pipe, and they have to transfer their heat. They transfer it to the cooler wall. The high velocities greatly enhance the heat-transfer process.

It's analogous to making your cake bake faster by putting a fan in the oven to add turbulent fluid motion that causes the heat transfer to increase. Your cake bakes twice as fast. Here, the clever introduction of acoustic energy vastly speeds the hot air motion and dramatically boosts its heat-transfer efficiency.

Widespread Recognition

Mike says Sandia has been fortunate to be able to put considerable research staff into the pulse combustor program. This, combined with the CRF's multidisciplinary approach and all the research tools available to Sandia and industry scientists working there, has brought the research widespread recognition. ''It's gained a significant international reputation,'' says Mike.

''It's exciting because we are right on the leading edge of this tremendously promising technology.''

He lists the advantages: ''By operating with a condensing heat-exchange system, pulse combustors achieve a 90 to 95 percent thermal efficiency, compared to 60 to 70 percent with the furnace in your house right now. Factors-of-3-higher heat transfer rates. Factors-of-3-lower NOx emissions. Virtually no hydrocarbons and carbon monoxide.''

The advantages aren't limited to home furnaces, important as that use may be. Pulse combustors might be used in modern steel furnaces or in future coal-burning power plants. They aren't limited to natural gas. Liquid and solid fuels are fair game too.

''This technology can be generalized, we feel, to many processes that rely fundamentally on heat and mass transfer,'' says Taz Bramlette (8364), who is reponsible for building ties with industry. In fact, Taz and Jay Keller (also 8364) have just been granted a US patent for an acous-

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