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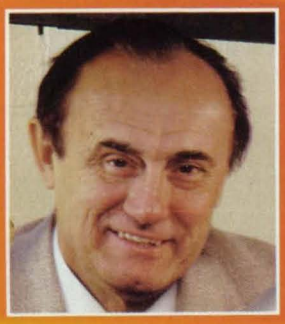

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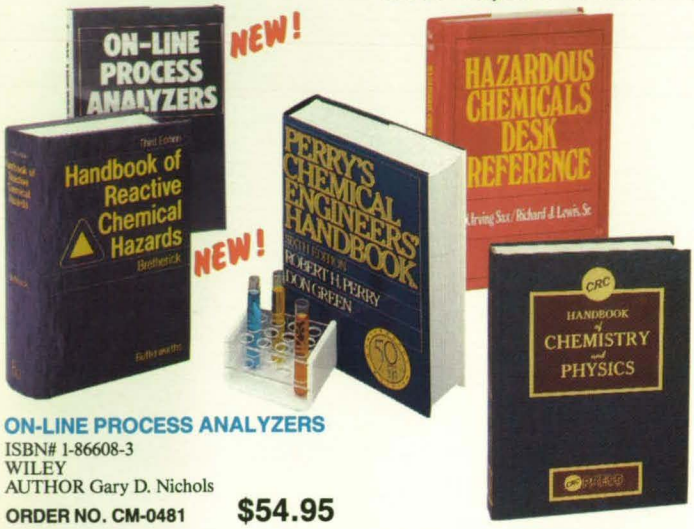

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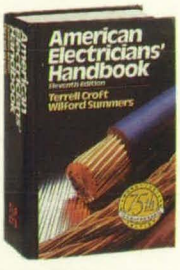

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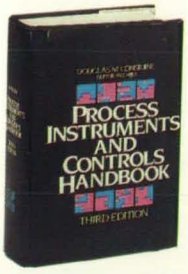

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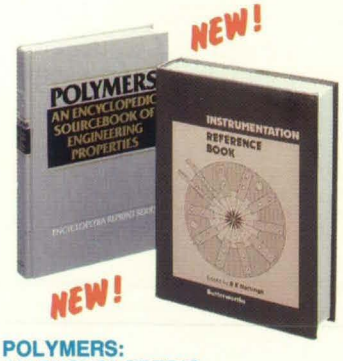

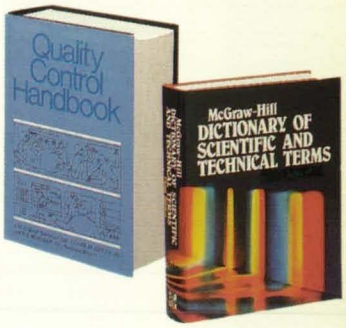

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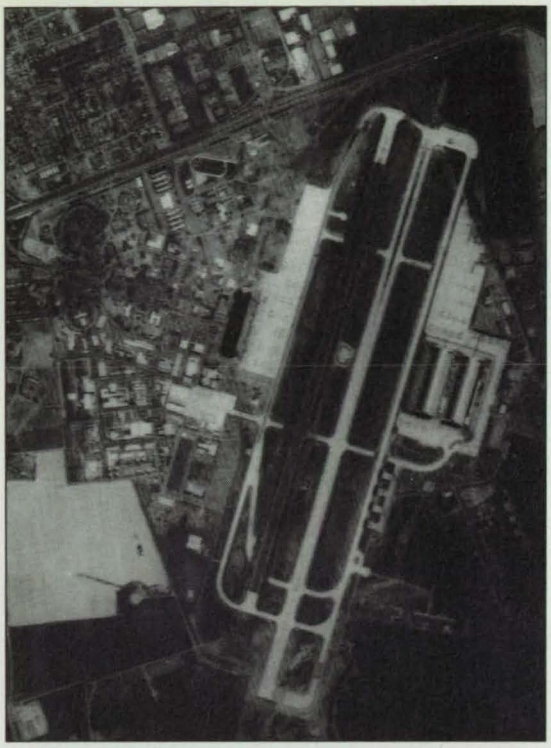

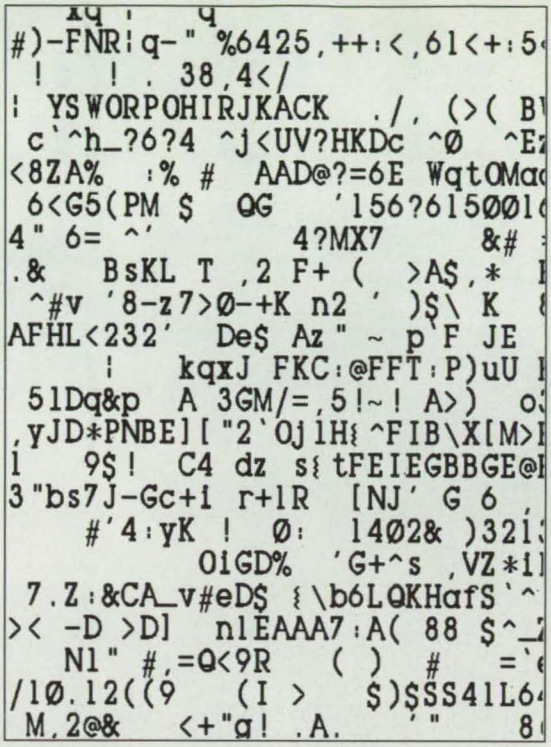

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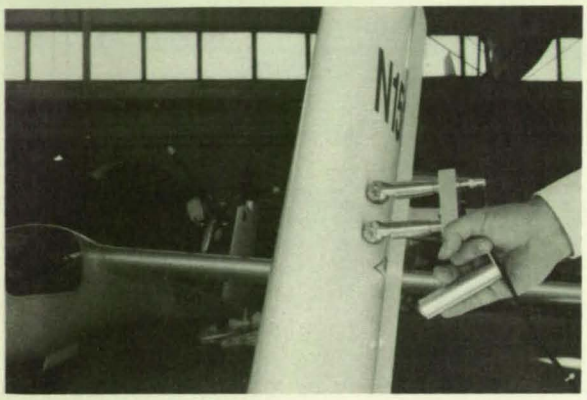

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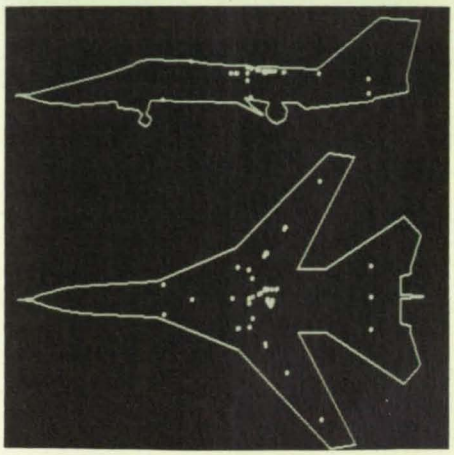

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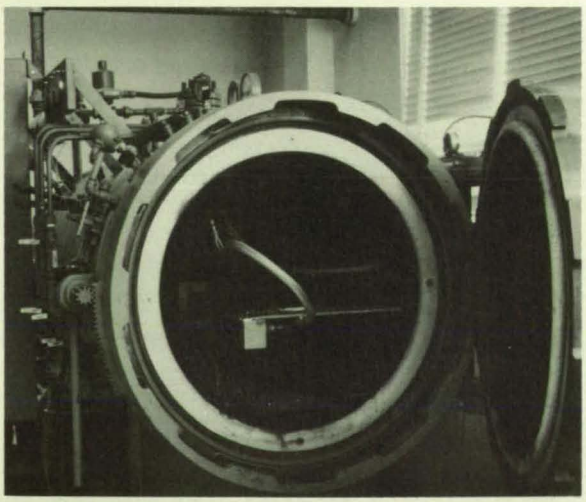

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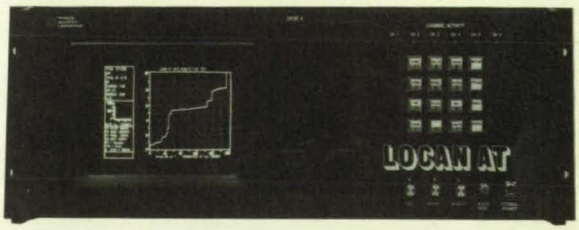

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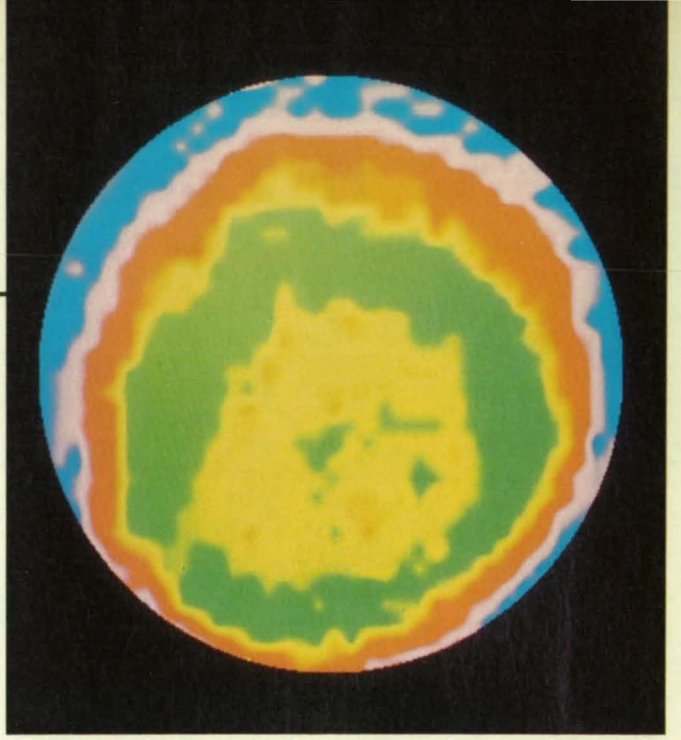
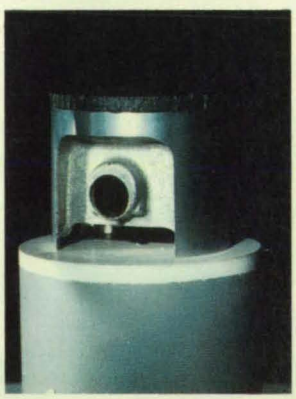


NASA engineers are using ultrasonic imaging to detect slight defects in ceramic materials. The image above reveals subtle variations in the porosity of a ceramic part. See page 60. *(Photo courtesy NASA)*

DEPARTMENTS

On The Cover: Veteran scientist Harold E. Sliney has been named NASA's Inventor of the Year for his work on a self-lubricating composite coating called PS200. The cover photo shows a PS200-coated bearing journal during high-temperature testing. Turn to page 10. *(Photos courtesy NASA)*



A composite engine piston developed at NASA's Langley Research Center could effect a $7 billion annual fuel savings in the U.S. See page 14. *(Photo courtesy NASA)*

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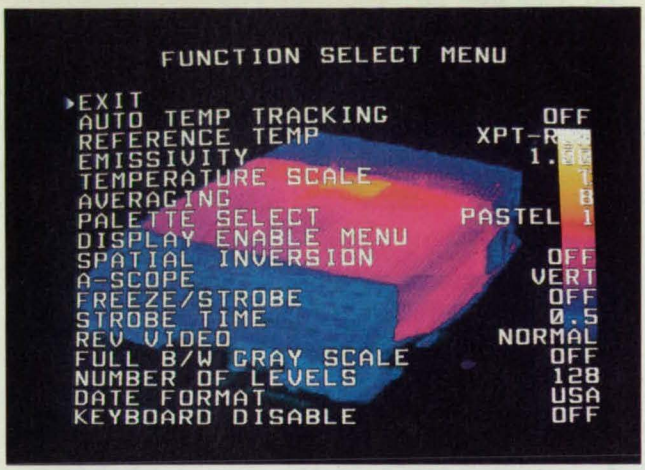

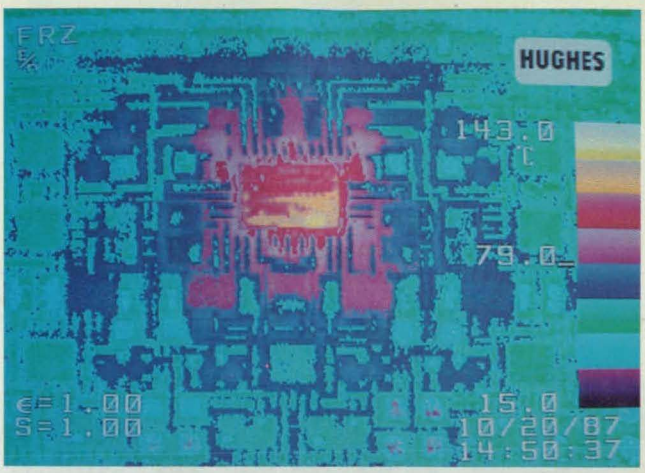

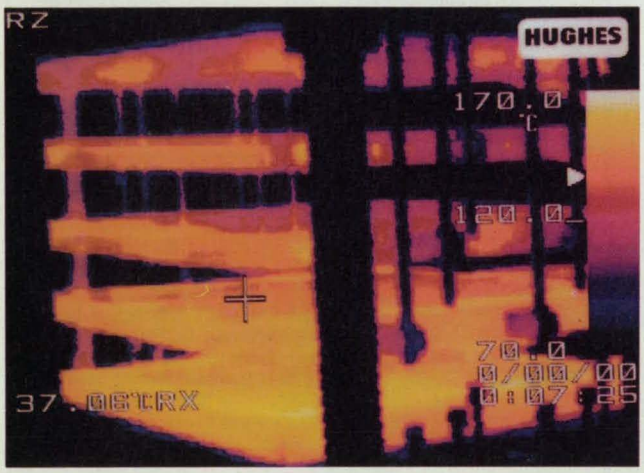

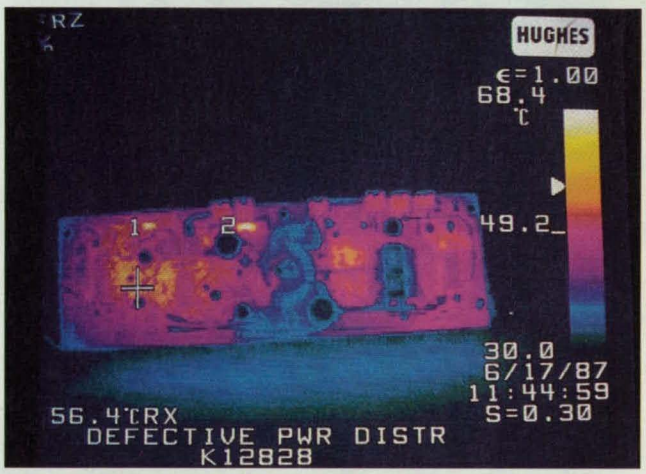

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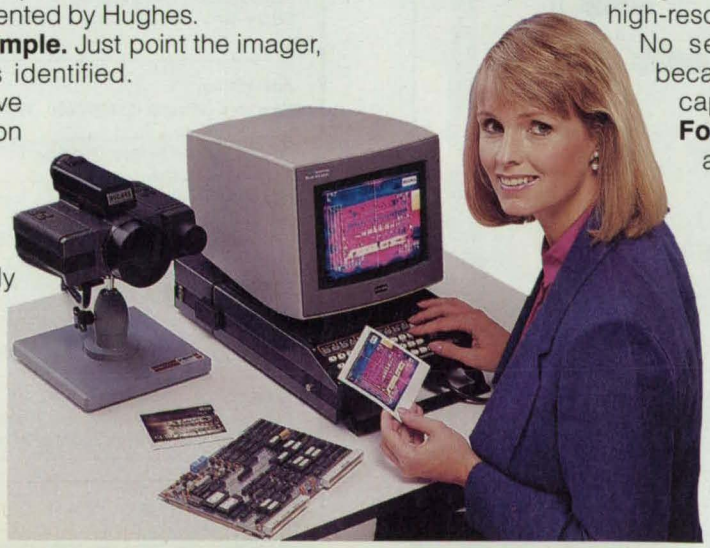

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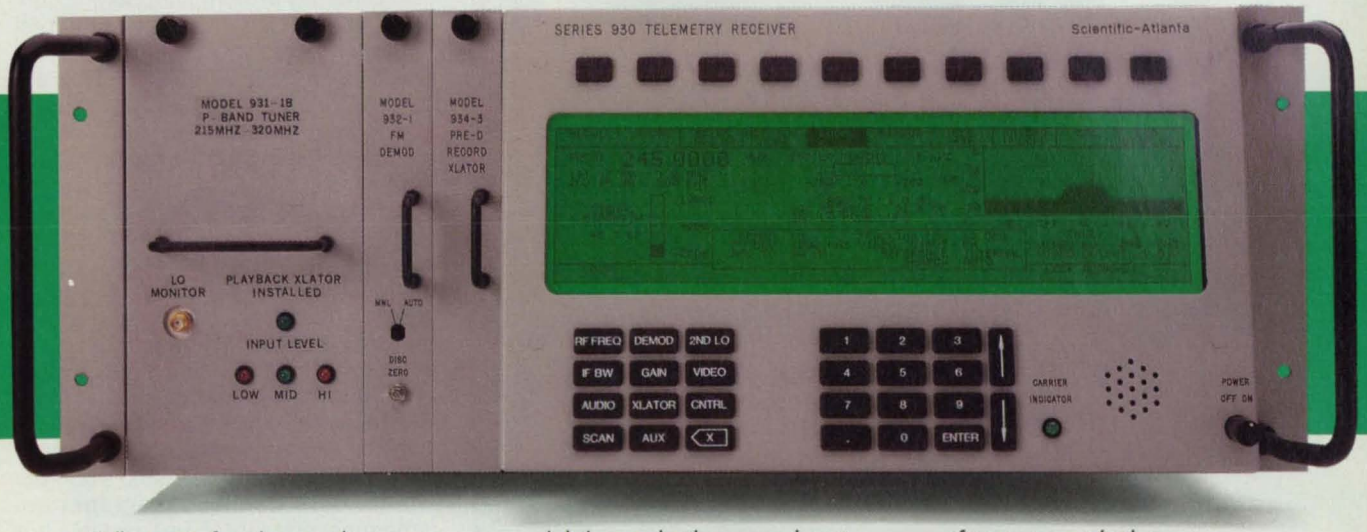

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Harold Sliney displays a Stirling engine cylinder coated with PS200.

A gas bearing journal coated with PS200 (left) and finished by diamond grinding (right).

A novel composite coating designed to boost the performance of advanced automobile and aircraft engines has earned veteran scientist Harold E. Sliney NASA's 1989 Inventor of the Year Award. Dubbed PS200, the self-lubricating coating enables the use of sliding contact bearings and seals with low friction and wear over a wide temperature spectrum up to 900°C. By comparison, conventional solid lubricants such as molybdenum disulfide and graphite are only effective to 500°C.

"Difficulty in lubricating sliding contacts at extreme temperatures has been a major obstacle to the development of more fuel efficient heat engines such as the adiabatic diesel and the Stirling engine," said Mr. Sliney, a Senior Scientist in the Surface Science Branch at NASA's Lewis Research Center. "No single solid lubricant will work from a cold start condition up to the maximum temperatures anticipated for these engines. This technology challenge drove me to create the PS200 series of composites."

Sliney's invention offers the versatility other solid lubricants lack; it is lubricative from room temperature or lower to 900°C over repeated temperature cycles. Furthermore, PS200's components have the necessary thermochemical stability to be used in a hot reducing atmosphere, as found in Stirling engines that contain hydrogen gas as the working fluid, or, conversely, in the oxidizing environment of diesel or gas turbine engines.

The patented composite consists of a nickel alloy-bonded chromium carbide matrix with dispersed particles of silver and calcium fluoride-barium fluoride eutectic. An extremely hard substance, chromium carbide provides outstanding wear resistance. Silver and the fluorides, on the other hand, are soft materials that act synergistically to reduce friction by forming low shear strength films on sliding surfaces. The ratio of carbide to lubricant additives can be tailored to the needs of the specific application, Sliney said.

Lewis' Karate Kid

Over the span of four decades, Harold Sliney has turned the challenging science of high-temperature lubrication into an art form. The Lewis scientist holds seven patents for innovative material mixtures, and has authored more than 70 articles and papers on solid lubrication. Sliney's creativity has earned him NASA's Exceptional Service Medal and a fellowship in the Society of Tribologists and Lubrication Engineers.

"Since I was a young boy I've been fascinated with both aviation and chemistry," he said. "I feel fortunate to have found a career that combines the two."

After graduating from John Carroll University in 1955 with an M.S. in Chemistry, Sliney joined the Lewis Center's Lubrication Research Branch (now called the Surface Science Branch) and began developing solid lubricants for propulsion systems. "My early days at Lewis were especially exciting because we were on the threshold of space exploration," recalled Sliney. "Our orientation was towards long-term research that would advance an entire body of knowledge, as opposed to today's climate where research is usually tied to a specific project with a set time frame."

Sliney said his greatest satisfaction comes from working with young scientists. "I believe we have to continually build for the future. That's why I've made it a part of my job to help young professionals learn the business and become able researchers. Over the years I've taken about 15 young men under my wing, and when they've gone on to become successful I've felt a kind of fatherly pride."

His role as an educator extends beyond tribology to the Martial Arts. A black belt in karate, Sliney teaches a weekly karate class at the Lewis Center for employees and their families. "I like karate because it's both physically and mentally challenging," he said, adding "I'm drawn to challenges, especially in my work. There's a constant challenge to improve upon existing technology."

Away from Lewis, Sliney is the quintessential family man. "My life primarily revolves around my wife, my five children, and my nine grandchildren," he explained. "I look forward to spending time with them, seeing their smiling faces. Compared with that, everything else in life finishes a distant second." □

The blended powders are plasma-sprayed onto the target surface and then diamond-ground to the desired coating thickness. "We've put a lot of effort into improving process control and finishing methods in order to achieve a reproducible product," the 61-year-old inventor stated. "For instance, we're using x-ray imaging to closely monitor and analyze the coating's chemical composition immediately after spraying."

PS200 can also be made into free-standing parts via powder metallurgy techniques such as sintering and hot pressing. Bushings and seals formed from the composite should enable the application of variable pitch stator vanes in the turbine section of gas turbine engines. "I'm confident PS200 has the high-temperature durability needed to survive turbine applications," Sliney said.

Up To The Test

Sliney's invention has been tested successfully as a backup lubricant for hot gas bearing in turbomachinery and as a cylinder liner coating in an external combustion Stirling engine. Foil bearings with PS200-coated journals have endured tests consisting of 10,000 starts and stops at bearing temperatures from 25 to 650°C.

As part of the NASA/Department of Energy Automotive Stirling Engine Project, a Stirling's cylinder walls were coated with PS200 and tested at an upper cylinder temperature of 760°C. "Our experiments with the Stirling have demonstrated that a piston engine can operate at high temperatures with absolutely no oil lubrication in its cylinders," Sliney said proudly.

In current Stirling designs, polymer piston rings are located in a cool area near the bottom of the pistons because they cannot handle the heat in the upper cylinder region. The extra protection provided by the Lewis coating will allow the rings to be moved to a hot zone on top of the pistons, which should improve engine performance by about seven percent, according to William Tomazic, Stirling Project Manager for the Lewis Center.

"A considerable amount of power is lost in the gap between the top and bottom of the piston," explained Mr. Tomazic. "By installing a ring near the top of each piston dome we can seal the gap and thereby boost engine power."

NASA also hopes to apply the composite coating to a Stirling "free piston" variant being developed to generate electricity aboard the Space Station Freedom.

Further, Sliney's invention could be employed as a lubricant for the sliding contacts in propulsion systems and airframes of supersonic and hypersonic aircraft. The Boeing Company plans to evaluate PS200-coated control surface seals, bearings, and engine inlet ramp seals for the National Aero-Space Plane.

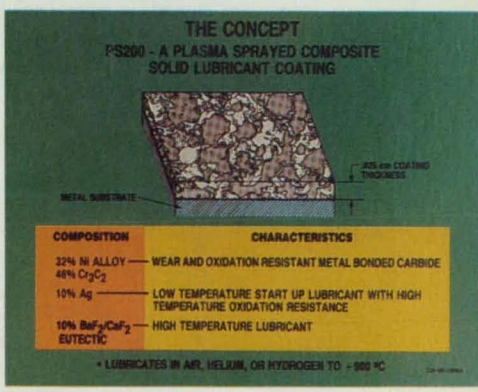
Second Generation

PS200 evolved from a group of composites Sliney developed during the 1970's, called the PS100 Series, which contains a nichrome matrix with silver and fluoride additives. "PS100 is a relatively soft material useful in situations where the sliding velocities are very low and the loads very light," explained Sliney. "But I wanted a lubricant with superior wear resistance, which meant finding a harder matrix material. I chose chromium carbide because its oxidation-resistance is better than that of other carbides such as tungsten and titanium, and because chromium is a readily available material."

Sliney's innovative coating blends chromium carbide for wear resistance, silver for lubrication up to 500°C, and calcium fluoride-barium fluoride eutectic for lubrication from 500-900°C.

Since the first research reports of PS200 were presented in 1986, more than 1,000 requests for information have been generated from a variety of industries worldwide. NASA is now negotiating with four metallizing companies interested in licensing the patent.

Mr. Sliney had previously received the NASA Space Act Award for his invention. NASA's Inventions and Contributions Board judged it to be a "significant accomplishment in aerospace technology." With this latest accolade, Sliney automatically qualifies as NASA's nominee to the National Inventor of the Year competition, sponsored by the Intellectual Property Owners, Inc., of Washington, D.C. The winner — to be selected from approximately 100 industry and government nominees nationwide — will be announced in April. □



10 NASA's BEST:

The '89 Inventor Of The Year Nominees

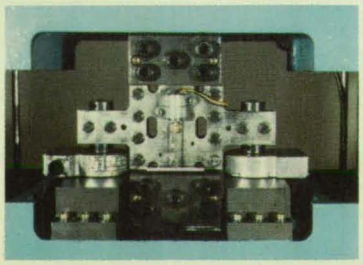
NASA's Office of General Counsel, sponsor of the agency's Inventor of the Year competition, selected Harold Sliney's composite coating from a field of ten nominee inventions, each patented and/or commercially available during 1988. The other finalists' innovative work — which spans such disciplines as avionics, microelectronics, materials science, test and measurement, and telecommunications — is described on the following pages.

Dr. John H. Crews
Aerospace Technologist
Langley Research Center

Dr. Crews' entry, the Bearing-Bypass Materials Testing System, will enable engineers to address a long-standing and serious design problem: the failure of mechanically fastened joints in composite structures due to complex loads and geometric discontinuities. Design and analysis of these joints are complicated by the uncertainty of the redundant load paths, the nonlinear load behavior, and by the heterogeneous nature of composite materials. To compensate for these uncertainties, engineers usually take a conservative design approach and heavily reinforce the laminates near the joints.

Dr. Crews' research, which has focused on investigating composite joint damage under the combined action of bolt/hole bearing loads and joint bypass loads, should lead to more efficient joint designs.

Within a structural joint, fastener holds can be subjected to the combined effects of bearing loads and loads that bypass the hole. The ratio of the bearing load to bypass load depends on the joint stiffness and form. As the joint is loaded, this ratio remains nearly constant until damage develops in the material. Dr. Crews' invention employs two hydraulic servo-control systems synchronized to apply proportional bearing and bypass loads to a laminate with a central hole. Unlike present bearing-bypass test methods, which either are limited to tensile loading or cannot maintain constant bearing-bypass load ratios throughout testing, the new invention works equally well in tension and compression while keeping a constant bearing-bypass ratio.



Dr. Crews' testing system will provide new insight into the mechanics of composite joints.

☆ ☆

Dr. Leonard A. Haslim
Program Manager,
Advanced Plans and Programs Office
Ames Research Center

Named last year's top inventor for his electro-expulsive aircraft deicer, Dr. Haslim has earned another nomination by creating an innovative seat cushion that offers a comfortable, lightweight, cost-efficient alternative to the polyurethane foam cushions now used in aircraft, automobiles, and many types of home furniture. These cushions support combustion and pose a toxic gas hazard when exposed to fire. Haslim's improved model uses a fire-blocking configuration of self-extinguishing materials that produce virtually no hazardous fumes.

The cushion contains a segmented tubular spring with an elliptical cross section. Formed from cured resin-impregnated fabric, the tube can be rapidly and economically produced by the pultrusion process. The spring assembly includes a group of parallel-arranged tubes with perpendicular slots that allow the tubes to nest within one another. An elastomeric material positioned between adjacent tubes provides shock absorption. Energy is dissipated when the elastomer is squeezed and pushed through holes in the tubes.

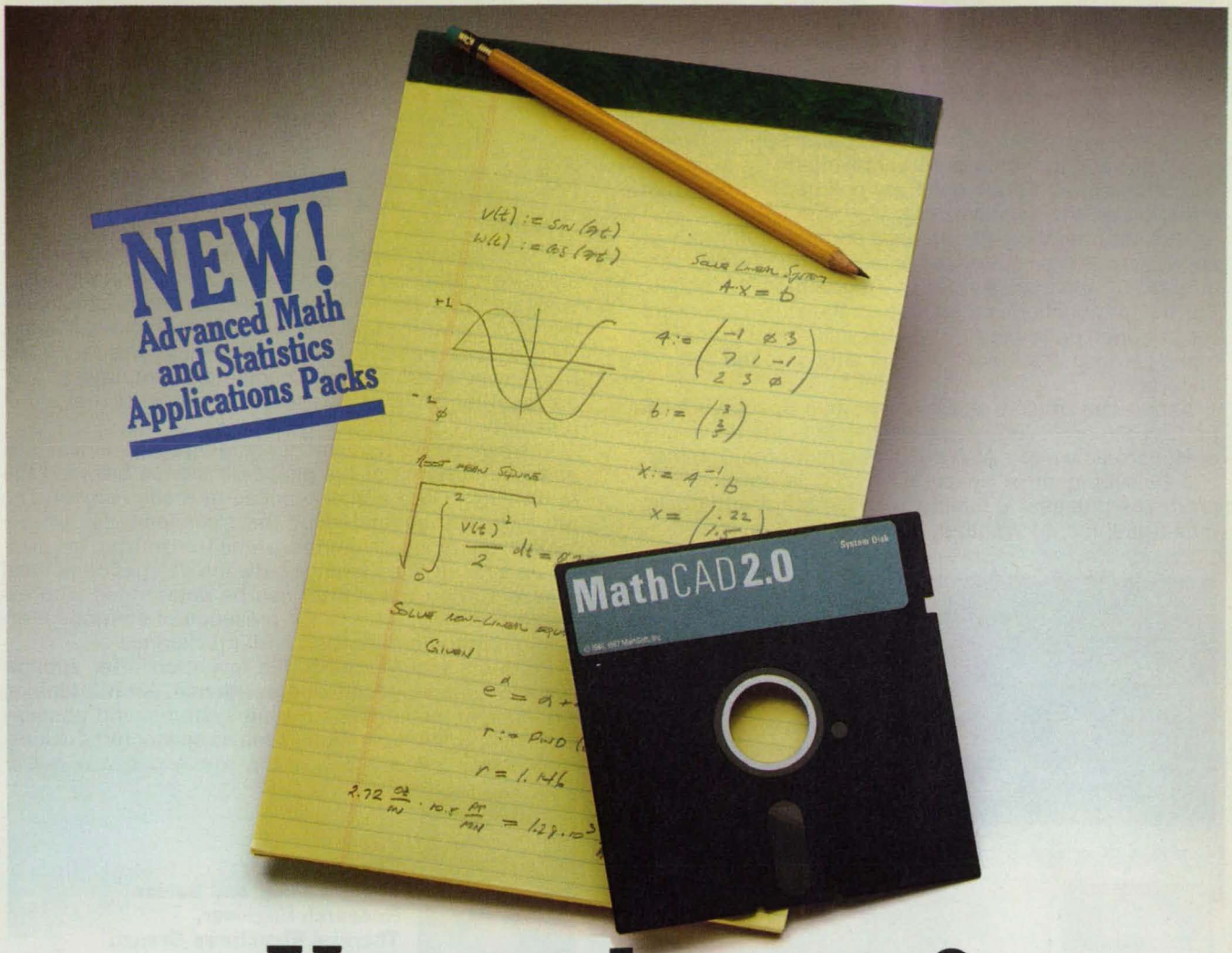
The cushion's "feel" can be adjusted by changing a tube's axial dimensions and thickness, or by altering the number and location of tube slots.

Haslim's latest innovation has been licensed to the trading company that owns Bridgestone Tires. The first cushions manufactured by Bridgestone are slated for use in Toyota cars. General Motors Corp., interested in Haslim's invention because it requires no metal parts, has asked NASA for a model demonstration.

☆ ☆

Dr. Robert J. Naumann
Chief of the Low-Gravity
Science Division
Marshall Space Flight Center

Dr. Naumann has designed a facility for processing materials in space under ultra-high vacuum conditions.



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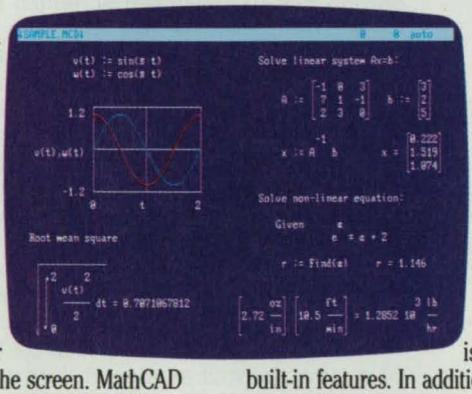

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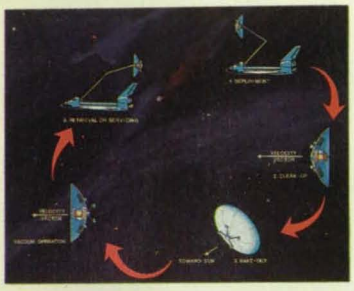
Useful for molecular beam epitaxy crystal growth and metals purification, the facility features a shell-shaped wake shield that would be attached to a robot arm and flown behind the Space Shuttle. The material to be processed is placed at the apex of the shield's convex side, facing the wake direction, while the power supplies, electronic support modules, control movement gyroscopes, and other support equipment are positioned in the ram direction on the concave side.

This configuration eliminates a perpendicular view of any surface that could cause contamination, and prevents outgassing molecules from drifting behind the shield. Further, atmospheric molecules on the shield's forward face cannot be re-emitted in the wake direction. This limits the backscatter of contaminants onto the subject materials.

As a result of Dr. Naumann's work, a Space Vacuum Epitaxy Center (SVEC) was established at the University of Houston. One of NASA's 16 Centers for the Commercial Development of Space, the SVEC is developing a prototype processing facility in conjunction with Space Industries, Inc. of Webster, TX.



In the wake of the convex shield, a void would be created where electronic materials could be produced in commercial quantities.

☆ ☆

Dr. Benjamin Seidenberg
Physicist/Aerospace Technologist
Goddard Space Flight Center

A major advance in the art of heat transfer is made possible by Dr. Seidenberg's invention, the Polymeric Heat Pipe Wick. The porous, cylinder-shaped wick serves as an inlet for the working fluid in a capillary pump loop (CPL) heat pipe system, which uses a vaporization process to efficiently transfer heat with little or no external power requirements. Heat is absorbed by the fluid as it evaporates, and then released when the vapor condenses.

The key factor affecting the system's efficiency is the selection of the working fluid. Although anhydrous ammonia and Freon are the best refrigerants, until now they could not be used in capillary loops because there were no wick materials that were physically and chemically compatible with these fluids. Dr. Seidenberg solved this problem by forming the wick from POREX™ UF, an open-cell, polyethylene, thermoplastic foam previously used in filters. Besides being compatible with ammonia and Freon, POREX UF is flexible, highly permeable, and temperature-resistant from −70°C to +116°C. The material's self-lubricating surface and ultra-high molecular weight make it easy to machine and insert into heat pipes.

The invention has commercial value in the chemical process industry, where high-power exothermic reactions take place and isothermal conditions are needed. Other potential applications include transformer cooling, electronic box cooling, and heat spreading.

☆ ☆

Paul W. Shores, Herbert S. Kobayashi, and Christopher L. Lichtenberg, Johnson Space Center

The Johnson Center's nominees jointly developed a distance measuring system that is highly accurate, easily scaleable to a variety of frequencies, and relatively immune to distortion and interference. It employs a small, inexpensive, passive transducer which needs no active power sources, local oscillators, amplifiers, mixers, or other complex electronic components that affect reliability.

The invention's transponder ranging system measures distance in terms of the phase difference between the return signal and a phase-locked reference signal. The return signal generated by the transponder is phase-locked, but at a sub-multiple of the transmitted frequency. As a result, the distance between a target object and a base station transmitter can be determined with extreme accuracy, even in the presence of spurious electronic harmonic distortion and interference.

Products incorporating this invention offer applications in surveying, collision avoidance, aircraft landing systems, shiplane maneuvering systems, and possibly space proximity operations such as spacecraft docking.

☆ ☆

Allan H. Taylor
Group Leader and Senior Research Engineer,
Thermal Structures Branch
Langley Research Center

Mr. Taylor has created a composite piston that promises to dramatically improve the performance and durability of automobile engines. The piston features an aluminum body cast around a cap made from carbon-carbon material. Current schemes to attach composite caps to metallic pistons use pins or bolts which can result in thermal stresses between the materials, leading to premature failure of the piston. Taylor's version is formed with conical faces, the extentions of which intersect a common vertex on the cylindrical axis of the body, enabling stress-free retention of the cap at all temperatures. When the piston assembly is heated or cooled, the metal expands or contracts radially from the coincident vertex. Where the metal makes contact with the cap, the snugly fitting conical faces slide without interference. Since the metal body is free to expand, no thermal stress is produced.

The Langley engineer chose carbon-carbon because of its low thermal expansion rate and high-temperature strength, which allow the piston-to-cylinder wall to be so narrow as to eliminate the need for piston rings. This cuts engine friction losses in half and results in a lighter, simpler, and less expensive piston.

The composite piston may be the enabling technology for an adiabatic engine, as its structure can endure sustained operating temperatures of 427°C without an oxidation-resistant coating. When a silicon carbide coating is applied to the piston, it can survive above the melting temperature of all metal engine parts.

Taylor's invention should improve the performance and fuel economy of internal combustion engines by about ten percent. If the composite piston were uniformly

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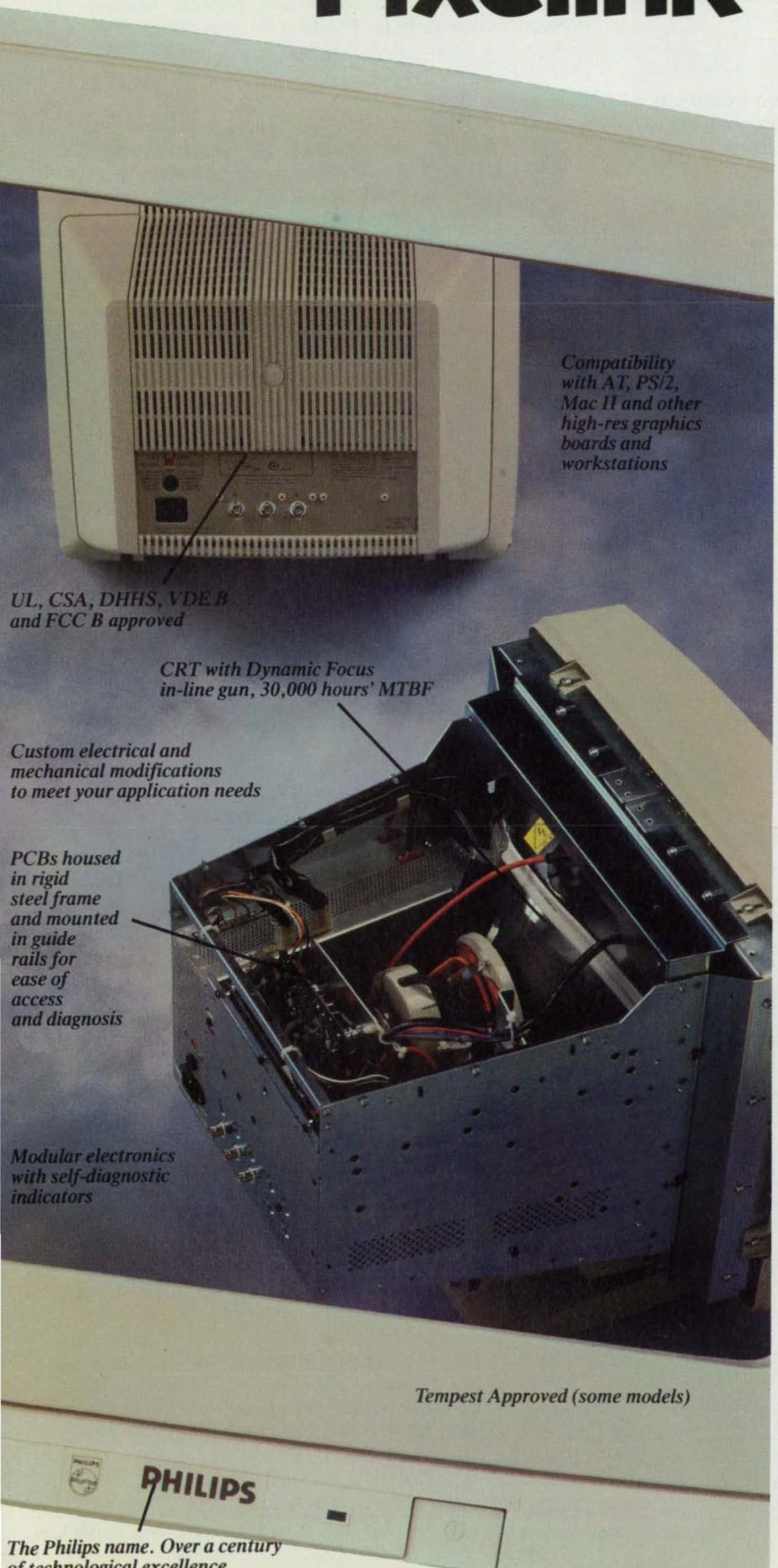

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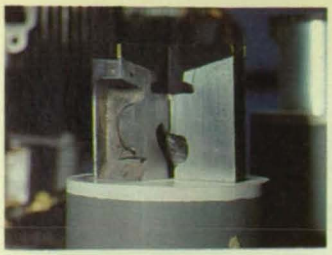


Taylor's composite piston, featuring a thermal-stress-free carbon-carbon crown, could effect a $7 billion annual fuel savings in the U.S. alone.

adopted in automobiles, this improvement would result in a worldwide fuel savings of $14 billion annually.

☆ ☆

Dr. Leonard M. Weinstein
Group Leader,
Turbulence Structure and Modeling Group
Langley Research Center

Dr. Weinstein has invented a device that detects and measures ice thickness on the outside of an aircraft during flight, allowing pilots to decide whether to heat the surface or change flight speed or elevation to remove the ice.

Current techniques provide only indirect evidence of ice build-up, cannot distinguish between ice and water, or only give ice content of the air, not surface thickness. Researchers are developing an ultrasonic approach that will measure actual ice thickness, but it is far more complex and expensive than Dr. Weinstein's invention.

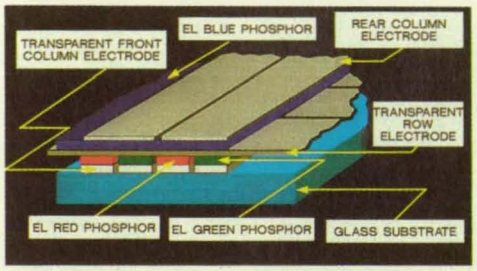
The new device, called a capacitive ice thickness detector, consists of three surface-mounted gauges. One detects the presence of water or ice, another determines whether the temperature is above or below freezing, and the third measures ice thickness. Presence and thickness of ice are sensed by changes in electrical signals between small conductors in the gauges. A layer of pure water or ice on an aircraft's surface wll result in a relatively stronger signal. Built-in circuits work in harmony to process the sensor data and provide accurate ice measurements in less than a millisecond.

☆ ☆

Dr. James B. Robertson
Senior Research Scientist,
Crew/Vehicle Interface Research Branch
Langley Research Center

Dr. Robertson's nomination stems from his work on a flat-panel, full-color, electroluminescent display with improved picture resolution, brightness, and contrast ratio over current commercial models.

Thin-film electroluminescent (TFEL) displays are rapidly gaining acceptance as computer screens and instrument displays in automobiles and aircraft cockpits. To compete with cathode ray tubes in more than limited ap-



An illustration of Dr. Robertson's unique two-layer TFEL display.

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plications, however, TFEL displays must be offered in full color. This requires the use and control of phosphors in the three primary colors: red, blue, and green. A major obstacle has been the dimness caused by the blue phosphor, weakest of the three colors.

Dr. Robertson's solution involves superimposing a phosphor layer of alternating red and green stripes over a layer composed solely of blue phosphors, with the two layers separated by insulating material and the row and column electrodes used to excite the phosphors. The size and shape of a picture element (pixel) in the one-color layer matches that of two side-by-side pixels in the red and green layers. This configuration not only increases brightness by doubling the blue phosphor's active area, but also improves contrast ratio over the stacked, three-layer designs of present flat-panel displays. It requires roughly one-third fewer interfaces and creates less unwanted capacitance than do three-layer models.

Robertson's display also offers twice the resolution of current coplanar (single-layer) designs, where the number of pixels per inch is limited by the minimum width of the electrodes.

NASA has licensed the invention to Planar Systems Inc., a leading manufacturer of TFEL displays in Beaverton, OR. The company plans to begin producing the two-layer version later this year.

☆ ☆

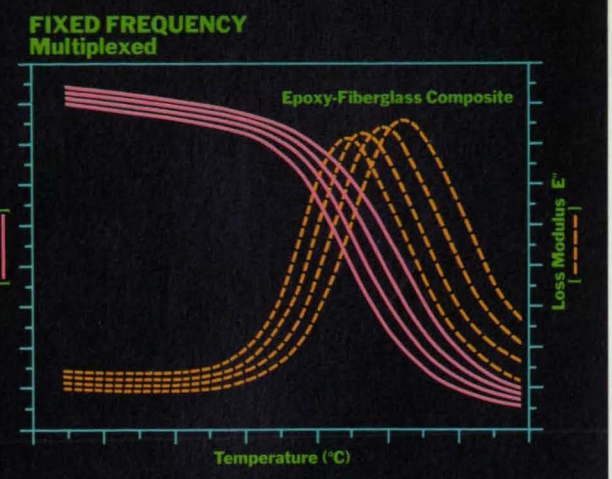
Paul E. Wren (Retired)
Formerly Ground System Manager, Search And Rescue Satellite Mission (SARSAT)
Goddard Space Flight Center

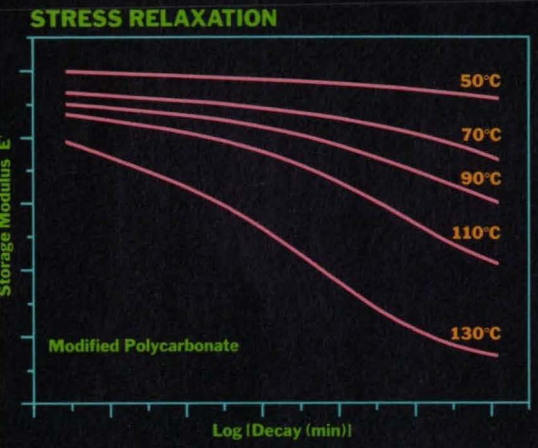
An emergency locating system developed by Mr. Wren will provide search and rescue forces with a means of detecting extremely weak radio frequency (RF) transmissions from ships and aircraft in distress. Presently, many SOS transmissions go unnoticed because of low signal strengths. Wren's new transmitter and receiver system, which offers a 24db increase in sensitivity over traditional audio detection methods, could solve this problem and save innumerable lives.

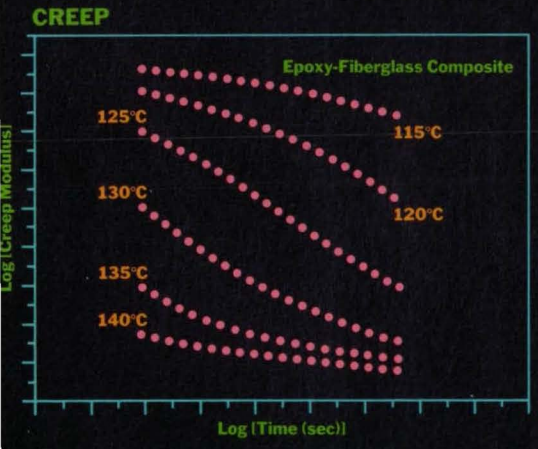
The invention detects distant or faint signals by transmitting a pure sineusoid and capturing the signal with a phase-locked loop receiver. Though the RF technique is over forty years old, this is the first time it has been applied to a distress locating system. The transmitter includes an RF oscillator whose carrier signal connects with a transmitter antenna through a gate and an RF amplifier. The signal has four variable parameters, with each set of parameters corresponding to a different piece of information that is automatically extracted and indicated by the receiver. A distress signal having two seconds of unmodulated carrier followed by eight seconds of the distress waveform may indicate that an aircraft is the source of transmission, while one second of unmodulated carrier with an ensuing waveform of five seconds, followed, in turn, by one second of the carrier signal modulated by a 100 Hz audio tone might mean that a ship is sending the SOS, and that the ship is an oil tanker.

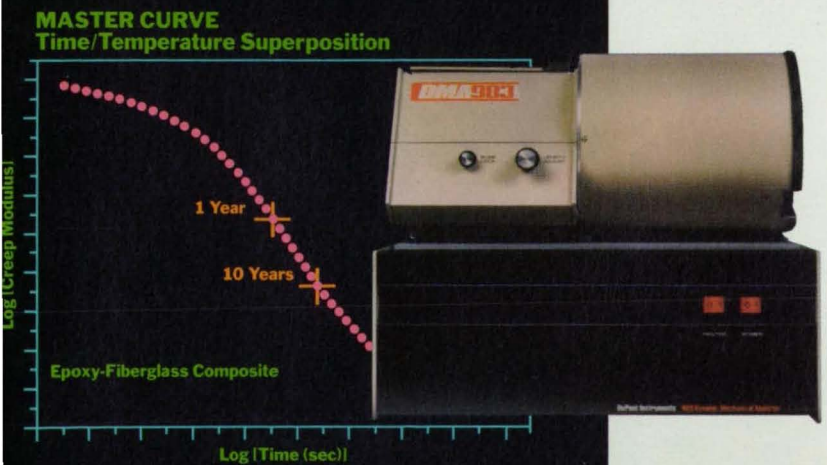
Previously, search and rescue forces had no advance knowledge of who or what they were looking for. This new capability will allow for better coordination among rescue operations.

For information on licensing any of these inventions, contact the patent counsel at the NASA field center that sponsored the research (See page 22).









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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 22). NASA's patent-licensing program to encourage commercial development is described on page 22.

Adaptive Control of Remote Manipulator

A robotic control system causes a remote manipulator to follow closely a reference trajectory in a Cartesian reference frame in the work space. The system is insensitive to changes in the robot and load parameters and requires less computation and memory than do other control systems of similar capability. (See page 38).

Self-Aligning Robotic End Effector and Receptacle

An industrial-robot hand and a mating receptacle are keyed to each other for positive automatic alignment. This arrangement simplifies accurate gripping and manipulation of objects. (See page 80).

Inspection in Overhead Spaces Containing Asbestos

A transparent glove bag promises to save time and effort during the inspection of overhead areas for asbestos. Health authorities may find this method just as safe but simpler and cheaper than extensive cleanup and costly respirators used by today's inspectors. (See page 73).

Current Regulator for Sodium-Vapor Lamps

A proposed regulating circuit would maintain a nearly-constant alternating current in a sodium-vapor lamp. For a lamp-voltage variation of 150 to 90 V, this circuit can maintain the lamp current within 1 percent of the desired value. (See page 26).

Protection Against Brief Interruptions of Power

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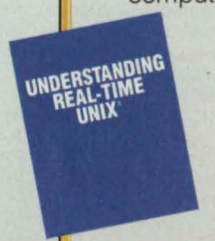

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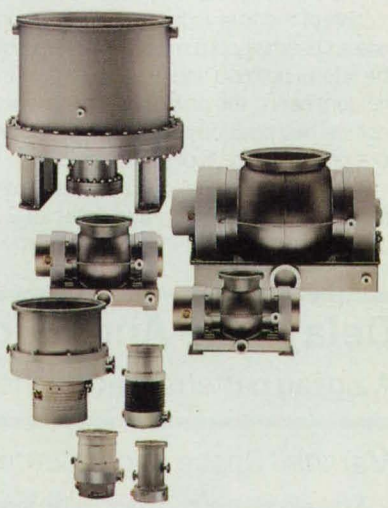

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Circle Reader Action No. 402

Electronic Components and Circuits

Position-and-Direction Sensor for Light Beams

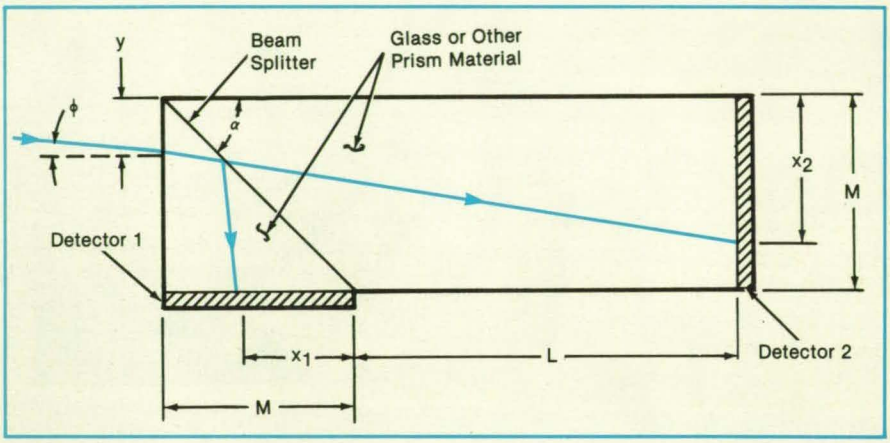
A beam from a spurious source could be detected.

Marshall Space Flight Center, Alabama

A proposed optoelectronic sensor would measure both the position and the direction of incidence of a laser beam or other narrow beam of light. A conventional sensor used to measure the direction of incidence contains one position-sensitive photodetector or a linear array of photodetectors. The measured position of incidence of the beam on the array, in combination with an assumption as to the point of origin, is used to infer the direction of incidence. However, when the assumption is incorrect (for example, when stray light strikes the detector), then the position of incidence is no longer a true measure of the direction of incidence.

The new sensor would be part of a robotic welding system in which a laser beam is reflected from the pool of molten metal and monitored by a lateral-position sensor. In this system, it is necessary to distinguish between the true reflected beam and spurious light and to measure the direction of the true reflected beam. To provide an unambiguous measurement of both the lateral position and the direction of the incident beam, the proposed sensor would include two position-sensitive photodetectors or linear arrays of photodetectors.

This incident beam of light would strike detector 1 at position x_1 and detector 2 at position x_2, as shown in the figure. Provided that the plane of incidence coincides with the plane of the figure, x_1 and x_2 can be expressed as slightly complicated functions of the angle of incidence (ϕ), the lateral position of incidence (y), the angle of the beam splitter (α), the length of the detectors (M), the longitudinal distance between the detectors (L), and the index of refraction (n) of the glass or other prism material.



The **Position-and-Direction Sensor** would split an incident beam of light into two beams and measure their positions of incidence x_1 and x_2. The position y and direction ϕ of the incident beam can be calculated from x_1 and x_2. The sensor could be made as a rigid unit that would be resistant to misalignment.

Because α, L, M, and n are fixed and known in advance, the equations can be solved for the desired quantities ϕ and y in terms of the measured positions of incidence x_1 and x_2. The position outputs of the photodetectors could be digitized and processed continuously to obtain real-time indications of the lateral position and direction of the beam of light.

This work was done by Matthew A. Smith of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 4 on the TSP Request Card.* *MFS-29275*

Delay-Line Anode for Microchannel-Plate Spectrometer

A zigzag pattern enables the location of incident pulses in two dimensions.

Marshall Space Flight Center, Alabama

A developmental photon-counting readout system for a microchannel-plate spectrometer includes a delay line and timing circuit to measure the wavelength coordinate and a wedge/wedge charge-division system to measure the orthogonal spatial coordinate. The charge-sensing element of this system is a planar anode made of strip-line material featuring a zigzag electrode pattern on the front face and a ground plane on the rear face. This system should prove advantageous for portable two-dimensional spectrometers that have large image planes and for which the design requirements include simplicity, reliability, low power consumption, and low mass.

The anode plane is placed near and parallel to the rear plane of the microchannel-plate detector. When a photon strikes the front plane of the detector, electrons are emitted from the rear plane, and they travel to the adjacent areas on the anode. Because the voltage and current pulses caused by the deposition of the electron charges travel along the zigzag anode strip line at known speed, the difference between the times of arrival of the pulses at the two ends of the line can be used to find the x coordinate of point of impingement.

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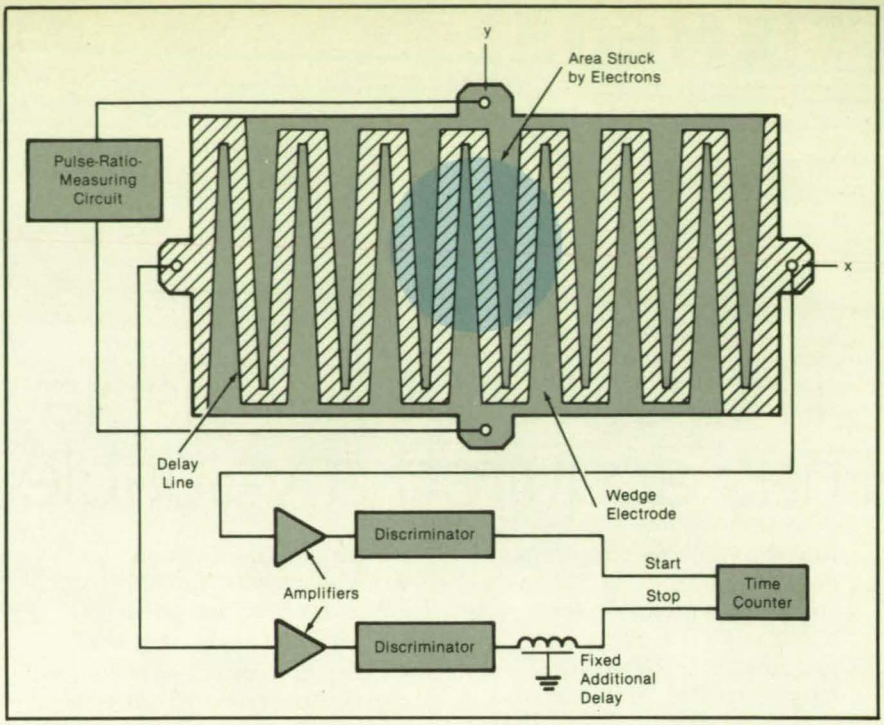
The difference in time is measured by a start/stop time counter.

The width of the bunch of electrons from one photon is several times the pitch of the zigzag. To ensure that about half the charge is deposited on the delay line, the width of the delay line is made one-quarter of the pitch of the zigzag. The remaining half of the charge falls on the interdigitating wedge electrodes; the portion that falls on each wedge depends on the width of the wedge at the point of impingement, which varies linearly with the *y* coordinate of the point of impingement. Thus, the *y* coordinate of the photon can be determined by circuits that measure the ratio between the charges deposited on the wedge electrodes.

When the system is fully developed, the time- and ratio-measuring circuits should be able to determine the *x,y* coordinates of the centroid of impinging charge with a spatial resolution much finer than the pitch of the zigzag. A design that achieves such performance will have to take into account such considerations as matching of stripline output impedances, attenuation and dispersion of pulses in the delay line, interactions between the delay line and the wedge electrodes, timing errors due to rise times of pulses, thermal noise, shot noise, and spurious signals at the fundamental frequency of the zigzag. In an experimental version that included a zigzag of 1-mm pitch, illumination with ultraviolet light through a 25-μm pinhole produced a Gaussian distribution in the *x* coordinate of detected photon events with 70 μm full width at half maximum.



The **Zigzag Delay-Line and Interdigitating Wedge Electrodes** are laid out together on an anode plane. Time- and charge-ratio-measuring circuits determine the location of an impinging bunch of electrons.

This work was done by M. Lampton of the University of California for **Marshall Space Flight Center**. *For further information, Circle 144 on the TSP Request Card.*
MFS-26073

Current Regulator for Sodium-Vapor Lamps

The operating current would be kept nearly constant as the lamp ages.

NASA's Jet Propulsion Laboratory, Pasadena, California

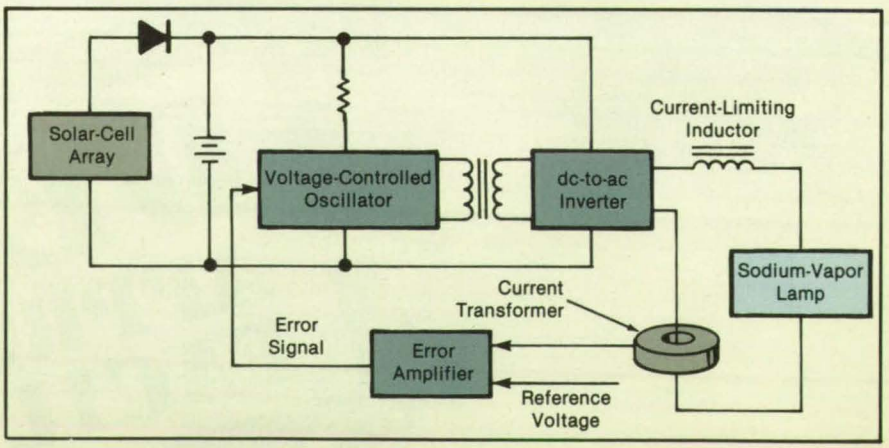
A proposed regulating circuit would maintain a nearly-constant alternating current in a sodium-vapor lamp. The regulator is necessary because, as the lamp ages, the potential drop across the lamp at the specified operating current decreases from about 150 to about 90 V. The regulator is part of a dc-to-ac inverter circuit that might be used to supply power to a street lamp from a battery charged by a solar-cell array.

As shown in the figure, power from a solar-cell array or battery is fed to a dc-to-ac inverter, the frequency of which is determined by a voltage-controlled oscillator. The inverter output is supplied to the lamp through a current-limiting inductor. Because the reactance of the inductor is proportional to the frequency, the lamp current can be increased or decreased by respectively decreasing or increasing the frequency.

The lamp current is sensed by a current transformer, the output of which is fed to one input of an error amplifier. The other input is a reference voltage corresponding to the specified lamp current. When the lamp current differs from the specified value, the current-transformer output differs from the reference voltage. The voltage comparator, therefore, emits a voltage proportional to the current error.

The error voltage is fed to the oscillator as a frequency-control signal, thereby changing the oscillator frequency and the lamp current by an amount that nearly cancels the current error. For a lamp-voltage variation of 150 to 90 V, this circuit can maintain the lamp current within 1 percent of the desired value.

This work was done by Colonel W. T. McLyman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 131 on the TSP Request Card.*
NPO-16702



The **Regulated Lamp Power Supply** would maintain a nearly-constant lamp current over a wide range of lamp voltage drops. The inverter frequency would be varied to control the current via the frequency dependence of the reactance of the current-limiting inductor.

TEAM WORK

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Inductively-Activated Short-Interval Timer

The absence of direct electrical contacts increases reliability.

NASA's Jet Propulsion Laboratory, Pasadena, California

A timing circuit in a pneumatically launched projectile triggers an explosive charge in the projectile at a specified delay after the launch. Both power and control signals are coupled inductively to the timer from the stationary launcher circuitry (see figure). This eliminates the need for direct electrical contacts, which are unreliable and which can generate sparks that trigger the explosive accidentally. Inductive coupling also provides higher reliability in field operation than contacts do. The underlying concept could be useful in such other safety-related applications as remotely or automatically controlling the flow of bottled flammable gas.

Initially, a driver in the launcher operates in a flyback-transformer mode at a repetition rate between 20 and 120 kHz to charge the main storage capacitor, C_1, to about 8 V. The smaller filter capacitor, C_2, is charged to about 5 V. The capacitors supply power to the signal-processing logic circuits through voltage and current regulators.

The energy to fire the explosive squib is taken from C_1. Power for the regulators is drawn from C_1 through the squib at a low current (less than the firing current), as a means of continually testing whether the current path through the squib remains intact. If it is not intact, C_1 is discharged to prevent accidental detonation in the event of subsequent unplanned reconnection.

The signals that control the delay are coded by the frequency of the pulses applied from the launcher. Under normal circumstances, only the reset and delay-setting frequencies need to be applied. Another frequency code orders a shutdown for safety, and the lack of frequency signifies the launch and the start of the delay. All frequencies and timings within the circuit are determined with reference to its 32.768-kHz crystal oscillator.

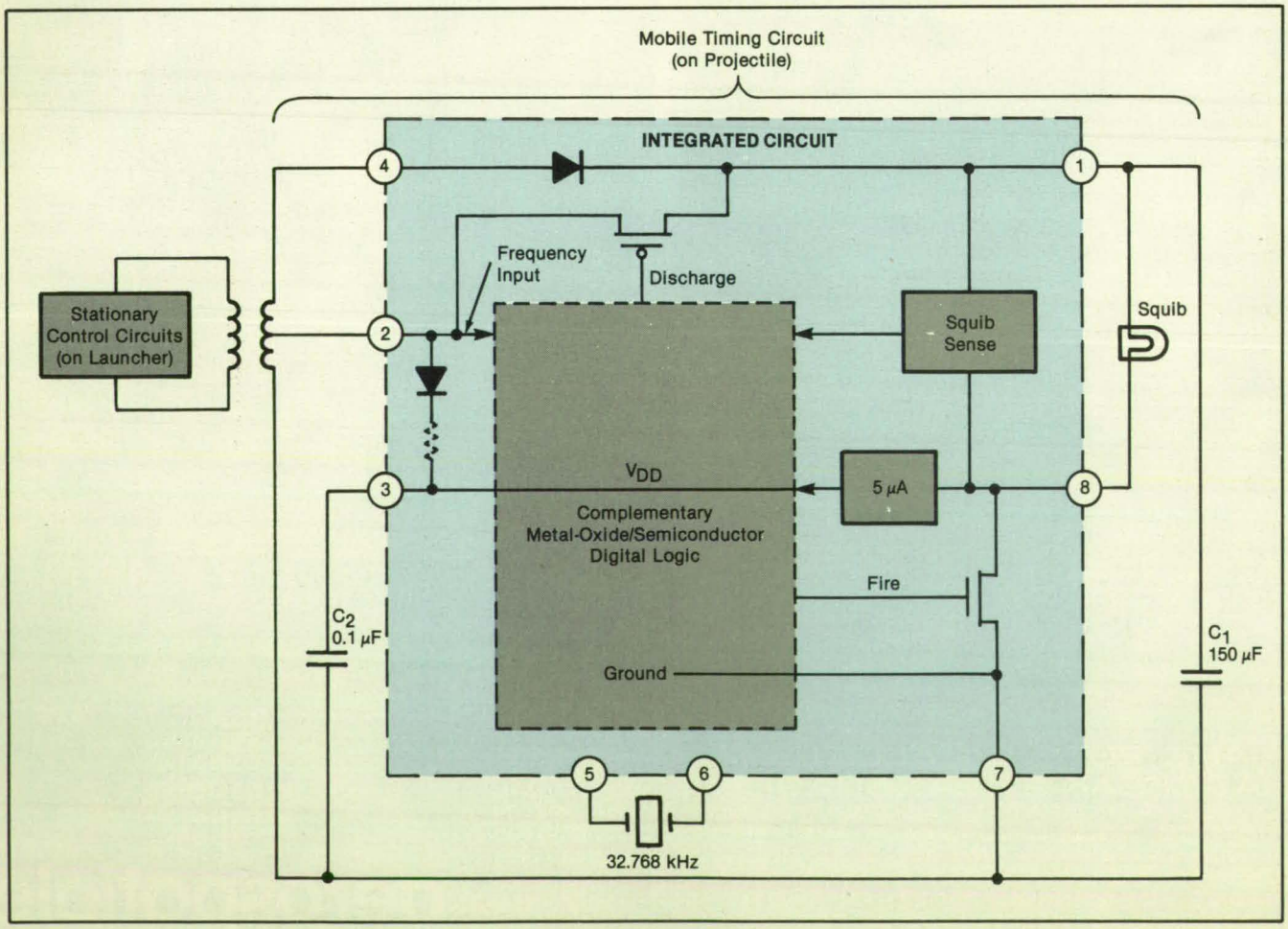
Initially, the reset code (120 kHz) is applied for a minimum of 0.5 s. Because this is the highest frequency used, it charges the storage capacitor at the maximum possible rate. It also provides time for the crystal oscillator to stabilize and turns the circuits on in a known reset state.

Next, the delay-setting frequency is applied for a minimum of 0.26 s and is maintained until shortly after the launch. The nominal frequency range for setting the delay is 32 to 99 kHz, corresponding to a delay of 24 to 8 s. Logic circuits in the timing section execute a formula for delay that decreases with increasing frequency.

The safe-shutdown frequency can range between 16 and 24 kHz and is nominally 20 kHz. This signal need be present for only 5 ms. Then the energy in C_1 is discharged through the same coil on the board that is used to receive the initial charging pulses so that the discharge can be detected for test purposes by inductive coupling back to the external driving coil.

This work was done by Gordon A. Wiker and George H. Wells, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 146 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 22]. Refer to NPO-16882.



Frequency-Coded Power and Control Signals are coupled inductively through the airgap between coils on the launcher and on the circuit board of the projectile.

TEAM WORK

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Low-Inductance Capacitor for Low Temperatures

A planar capacitor is made on an epoxy/fiberglass printed-circuit board.

Langley Research Center, Hampton, Virginia

A test at the National Transonic Facility (NTF) requiring the use of a shadowgraph system dictated that the light source be mounted on the wall of the test section within the cryogenic environment of the plenum of the tunnel. The light source of the shadowgraph, which includes a high-pressure, 75-W xenon arc lamp, was modified to allow all high-voltage triggering components to be mounted inside an aluminum lamp housing. When the entire assembly was tested in operation in an environmental chamber at temperatures down to −160 °C, the high-voltage capacitor in the assembly did not survive the extreme cold: differential contraction of the internal parts of the capacitor caused the unit to fail. Subsequent tests of replacement oil-filled and ceramic high-voltage capacitors yielded the same results, and a limited search for capacitors of similar voltage rating that could tolerate the extreme cold was unsuccessful.

It was decided to design, fabricate, and test a suitable capacitor at the facility. The desired properties included tolerance of a wide range of temperature, low inductance, high breakdown potential, low series equivalent resistance, and ease of manufacture. A planar design using G-10 (or equivalent) epoxy/fiberglass double-sided printed-circuit-board material was selected. The planar design and flat copper plates ensured low inductance and low series resistance. The planar construction minimized the effects of thermal contraction, and the epoxy/fiberglass substrate ensured a high breakdown voltage.

Tests indicated that a capacitor between 600 and 700 pF would be adequate to produce reliable starting of the lamp. A board 0.032 in. (0.81 mm) thick, 9.5 cm by 16.5 cm, was etched with 0.75-cm borders to yield a conductor area of 8 cm by 15 cm (see Figure 1), with a measured capacitance of 650 pF. With the dielectric strength of the epoxy/fiberglass material rated at 510 volts per mil (2×10^7 V/m) the board possesses a dielectric strength of over 16,000 V, which is more than adequate for this application.

The capacitor was mounted in the lamp housing (see Figure 2), and the complete unit was repeatedly cycled between room temperature and −160 °C. The lamp was started, and the operation was verified at each change in temperature of 20 °C. The complete shadowgraph system was installed in the plenum chamber of the NTF and functioned without failure.

The design is simple, and this type of capacitor should be easy for any printed-circuit-board facility to fabricate. The design is suitable for any small-capacitance, high-voltage capacitor, whether operating at low or high temperature.

This work was done by David B. Rhodes, Stephen B. Jones, and John M. Franke of **Langley Research Center**. *No further documentation is available.* *LAR-13714*

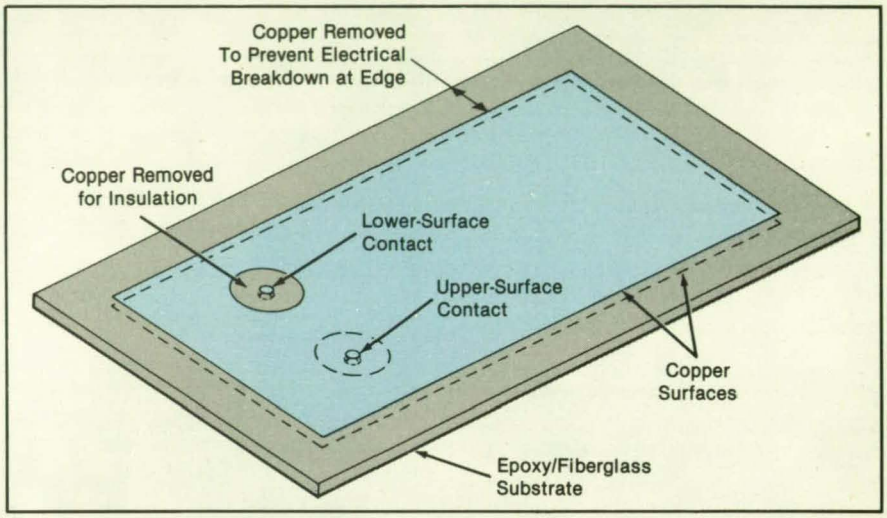

Figure 1. **Etched Circular Areas** insulate contacts on the planar capacitor fabricated from printed-circuit-board material.

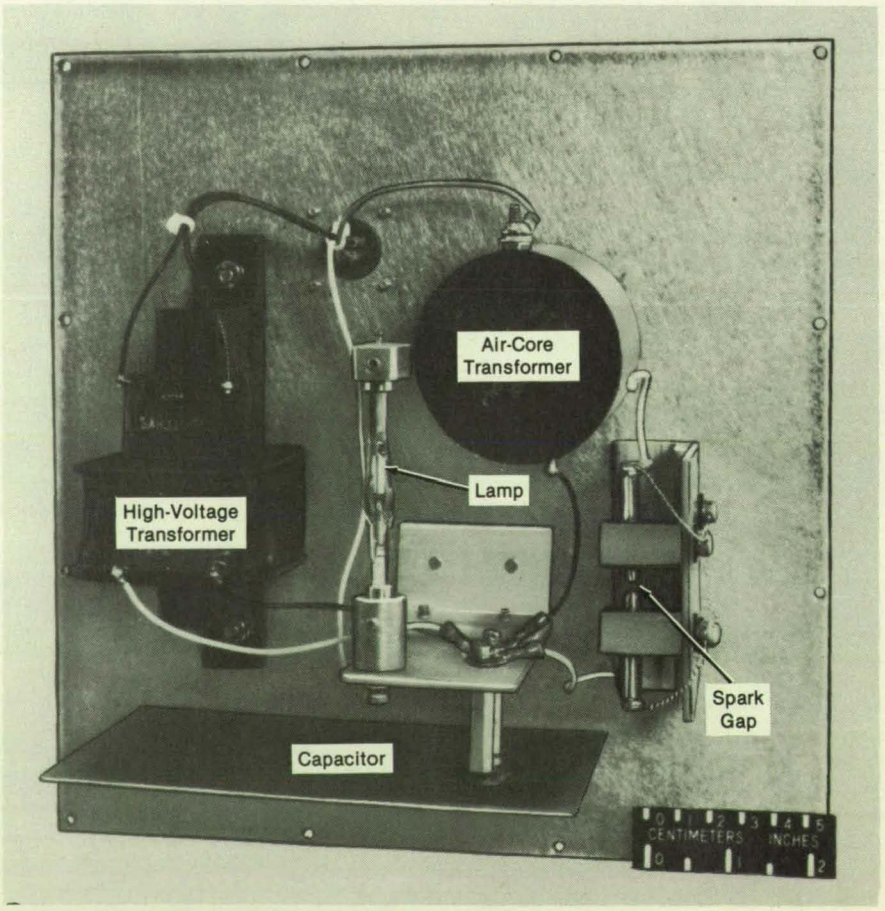

Figure 2. This **View From the Rear of the Lamp Housing** shows the placement of components, including the new capacitor.

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Integrated-Circuit Broadband Infrared Sources

Microscopic devices consume less power, run hotter, and are more reliable.

Goddard Space Flight Center, Greenbelt, Maryland

Simple, compact, lightweight, rapidly-responding reference sources of broadband infrared radiation have been made available by integrated-circuit technology. These devices are intended primarily for use in the calibration of remote-sensing infrared instruments. The new devices should eventually replace conventional infrared sources, which are relatively massive and complicated, dissipate excessive power, and respond too slowly. The new devices should also replace the present generation of miniature infrared sources, which are expensive and delicate and have both unduly-low maximum operating temperatures and reduced reliability when operating near those maximum temperatures.

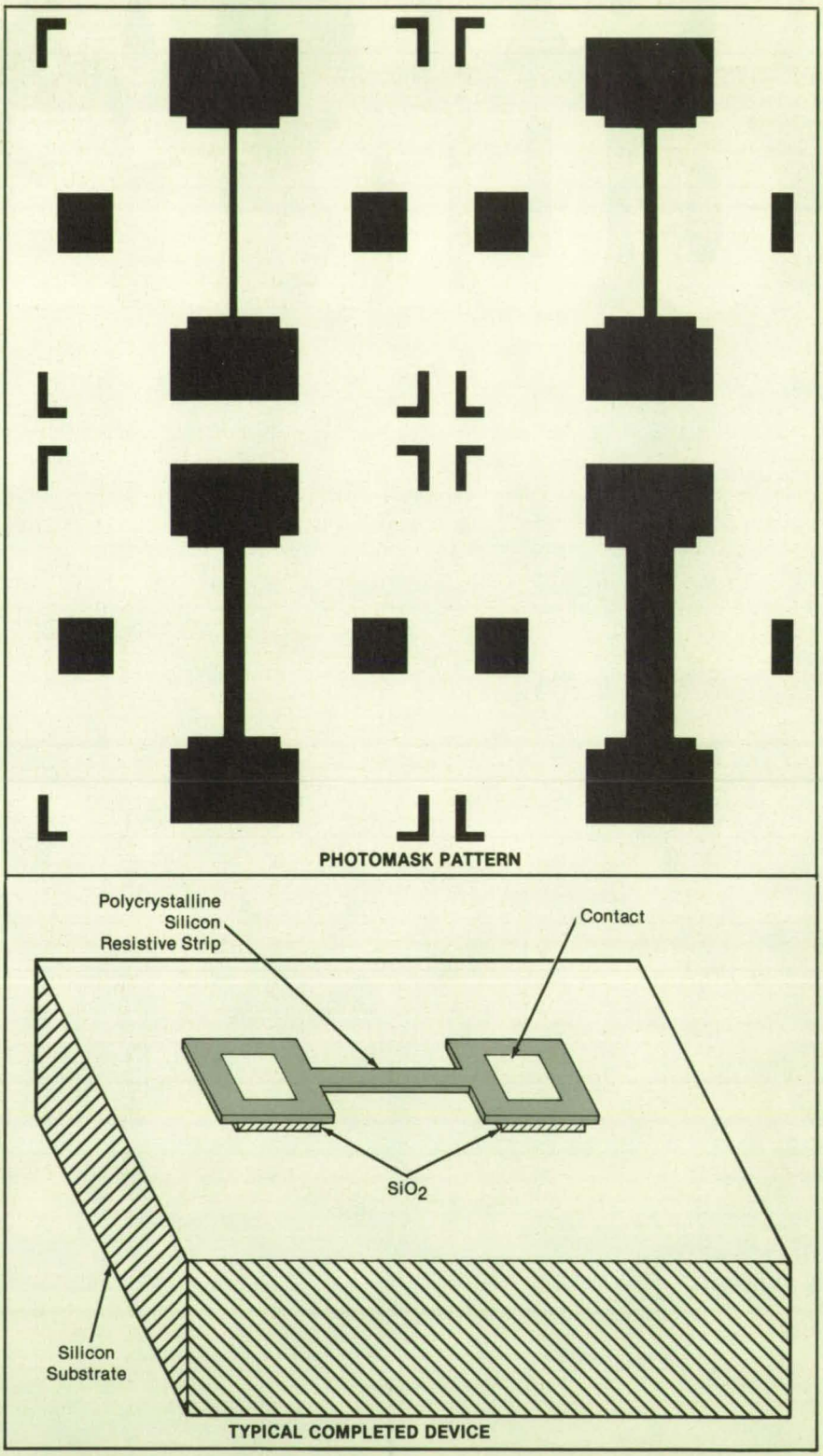
The new devices are essentially microscopic resistors that consist of beams of polycrystalline silicon. The resistors are heated by electrical current to make them glow in the desired range of wavelengths. They can operate in air or vacuum. The voltage applied to each resistor is adjusted to obtain the desired operating temperature, current, or power dissipation. (Measurements have shown that the current-vs.-voltage curve is fairly linear.)

A device can be made or used alone or as part of a flat-panel or complicated multielement array of reference sources. A device or array is fabricated as follows:

1. A silicon substrate is oxidized to a depth of 10,000 Å.
2. A film of polycrystalline silicon 8,000 to 10,000 Å thick is deposited on the oxide.
3. The polycrystalline silicon is doped with boron to obtain a resistance of 50 to 100 Ω/□.
4. The polycrystalline silicon is etched to form the pattern of resistor strips and contact areas (e.g., as shown in the upper part of the figure).
5. The oxide is stripped from the exposed areas of the wafer and from under the beam(s), leaving only the oxide under the contact areas.
6. A thin film of aluminum is evaporated onto the entire wafer.
7. The pattern of contact pads is masked, and the aluminum is etched to leave only the portion in the contact areas.
8. The aluminum is alloyed to form the contacts.

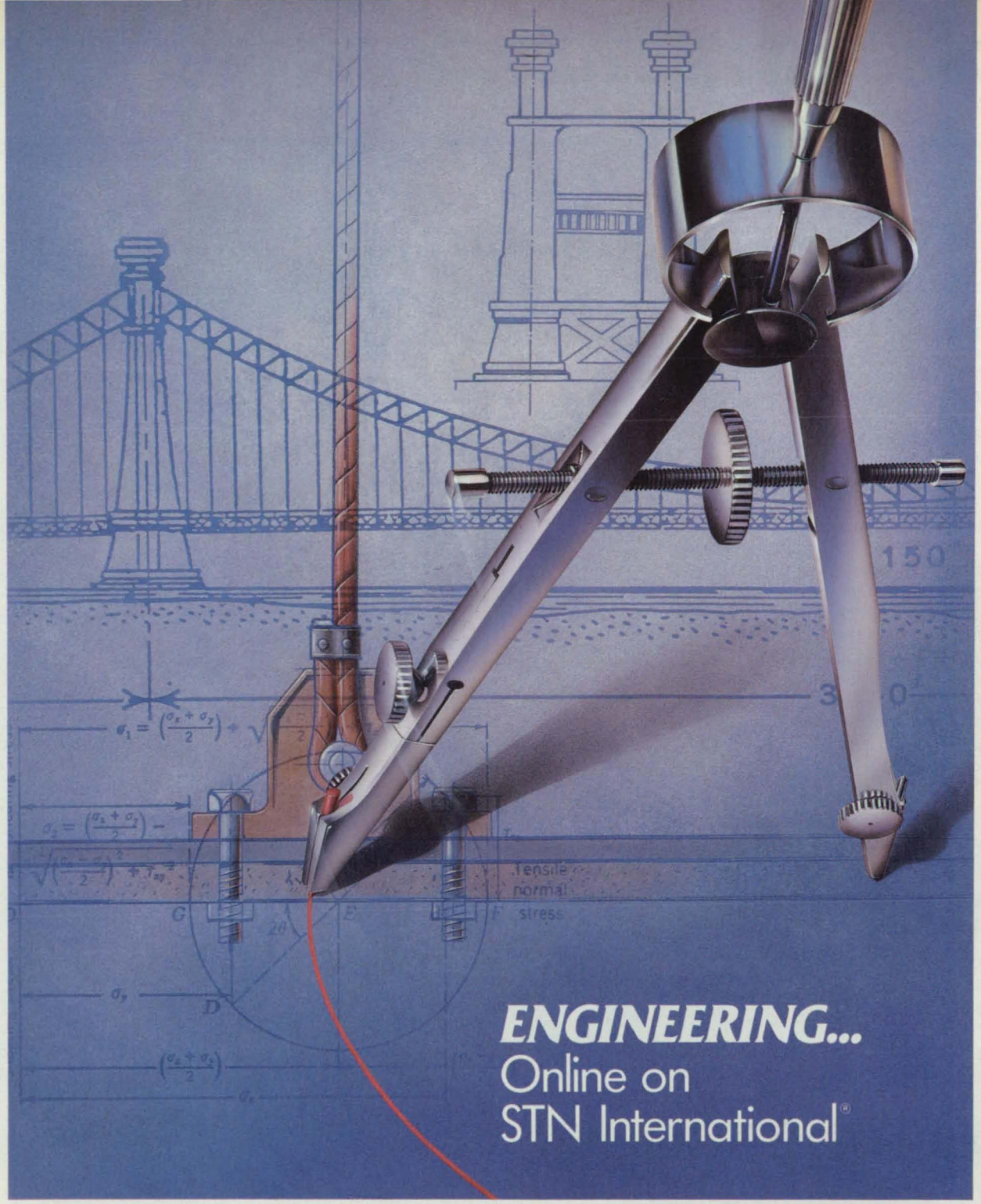
A typical completed device is shown in the lower part of the figure.

The self-passivating nature of the polycrystalline silicon adds to the reliability of the devices. The maximum operating temperature is over 1,000 K, as compared to the maximum of 600 K in prior devices. The power dissipation is only one-fourth that of the prior devices.



An **Integrated-Circuit Photomask Pattern** is used to make polycrystalline silicon strips of various widths and, therefore, of various electrical resistances and infrared characteristics. The strips are used as "glow-bar" resistors to calibrate infrared-sensing instruments.

This work was done by G. Lamb, M. Jhabvala, and A. Burgess of **Goddard Space Flight Center**. *For further information, Circle 114 on the TSP Request Card.*
GSC-13085



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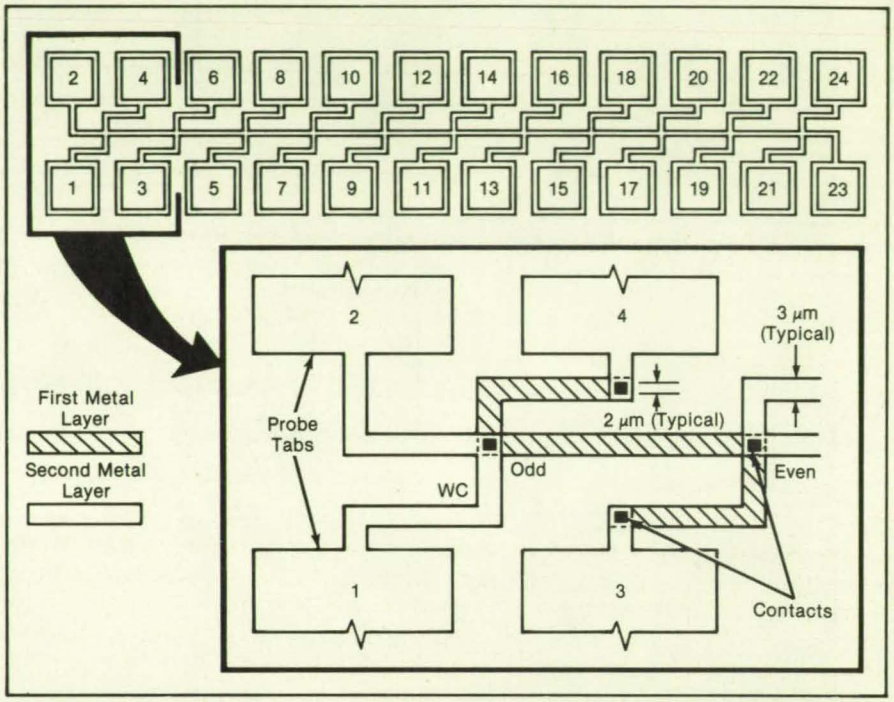
Chain of Test Contacts for Integrated Circuits

Microcircuit connections between probe pads yield data on the quality of fabrication.

NASA's Jet Propulsion Laboratory, Pasadena, California

A test structure that forms a chain of "cross" contacts can be fabricated together with large-scale integrated circuits. If necessary, a number of such chains can be incorporated at suitable locations in an integrated-circuit wafer for determination of the fabrication yield of the contacts.

The test structure (see figure) includes a first and a second layer of metal (or heavily doped semiconductor) arranged in thin, meandering strips ending in terminal pads for electrical probing. The strips overlap in cross-like intersections where contacts are made between the layers through "vias" in the intermediate insulating layer. Current is injected at the ends of the chain, i.e. through pads No. 2 and 23. Voltages are measured between pads No. 1 and 4, 3 and 5, etc., up to No. 21 and 24. The ratio of the voltages to the current is a good measure of the ("interfacial") contact resistance, although some parasitic resistance is added by the requirement that the strips must be wider than the contact to allow for misalignment. Progressing along the chain, the cross contacts are designated alter-



This **Chain of Cross Contacts** is fabricated as a test structure for contacts in a large-scale integrated circuit. Four-point resistances are measured to obtain statistical data on the quality of contact fabrication.

nately as "odd" and "even" for convenience in discerning the effects of misalignment on the resistances of the contacts.

In a conventional two-terminal contact chain, one can measure only the total resistance of all the contacts in the chain. If the number of contacts is large, measurements of a number of chains yield only limited statistical data about the quality of fabrication, and the measurement of one chain can be insensitive to unacceptably high resistance in one or a few contacts. However, in the new structure, the resistances of individual contacts can be determined: In addition to making it possible to identify local defects, it enables the generation of statistical distributions of contact resistances for the prediction of the "parametric" contact yield of the fabrication process.

Two prototype wafers contained 40 test structures like the one shown in the figure. The contact resistances of each wafer had bimodal distributions — one mode for the even contacts and another mode for the odd contacts. This bimodality was attributed to a misalignment of the odd contacts that was observed under a microscope. However, if one plots the contact conductance G (i.e., the inverse of the resistance) on normal probability paper, then both modes extrapolate to similar probabilities Y_0 at $G = 0$. The average Y_0 is a convenient measure of the parametric contact yield.

This work was done by Udo Lieneweg of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 82 on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 4,725,773). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 22]. Refer to NPO-16784.

Protection Against Brief Interruptions of Power

A rotating-machine system would bridge gaps of a few cycles in utility power.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed rotating standby power system would compensate for brief interruptions in the commercial power supply. The system would furnish a few cycles of alternating current from its stored rotational energy. It would protect equipment vulnerable to brief losses of power; for example, it would prevent computers from erroneously suppressing or adding bits to the data being handled at the moment of a power failure.

Although "uninterruptible" power supplies make up for low power-main voltages by employing synchronous inverters across the mains and provide power as long as their batteries hold out, they are expensive. The proposed rotary standby system may be more economical when interruptions last no more than a few cycles.

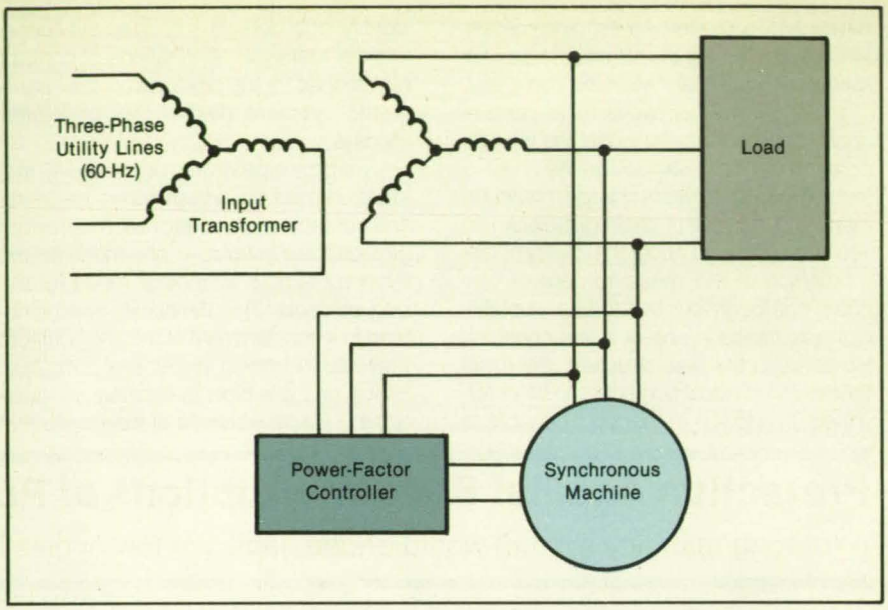
The standby system could include a synchronous motor, alternator, or condenser. It would operate in synchronism with the power-main voltage. It would run on energy furnished by the mains, which also supply the load composed of computers, air-conditioning, lighting, and other equipment.

The synchronous machine would have to be large enough to drive the load for the maximum expected duration of an interruption in power without slowing down appreciably. The proper size would be determined from the total energy needed by the load during the longest expected outage,

the energy stored in the rotating mass of the machine, and the speed-versus-voltage characteristics of the unpowered but loaded machine.

So that the entire system that includes the machine presents a favorable power factor to the utility lines, its phase angle would be adjusted by standard power-factor controllers. The adjustment would lower electricity bills by reducing — or even canceling — the reactive volt-amperes drawn by the load. However, the phase angle between the line and the machine should not be made so large that it produces a large phase shift when the line drops out and the machine takes over. Such a shift could disturb some types of power supplies, especially in single-phase applications.

To demonstrate the concept, tests were run on a 15-kW, 18.7-kVA generator connected as a synchronous condenser and standby power source. The unit was operated with and without a flywheel attached. The time in 60-Hz alternating-current cycles was measured from the instant the line power was interrupted until the generator voltage dropped to 422 V (88 percent of its rated output). With the flywheel, that time proved to be ample for brief outages, with a worst-case value of 2.2 cycles under full load at unity power factor.



A **Synchronous Machine Idles** on power from a three-phase utility line. If the utility power ceases, the synchronous machine supplies power to the load for a few cycles.

This work was done by Theodore A. Casad of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 56 on the TSP Request Card.*
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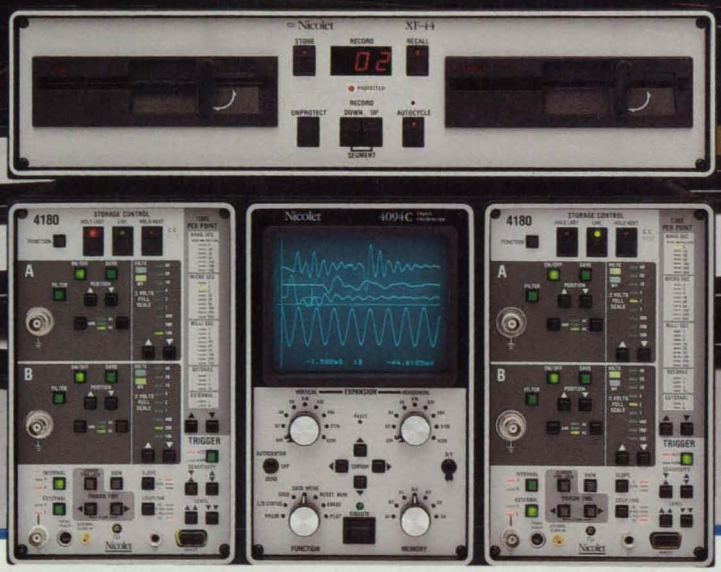

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Electronic Systems

Adaptive Control of Remote Manipulator

A reference trajectory is tracked without modeling robot dynamics.

NASA's Jet Propulsion Laboratory, Pasadena, California

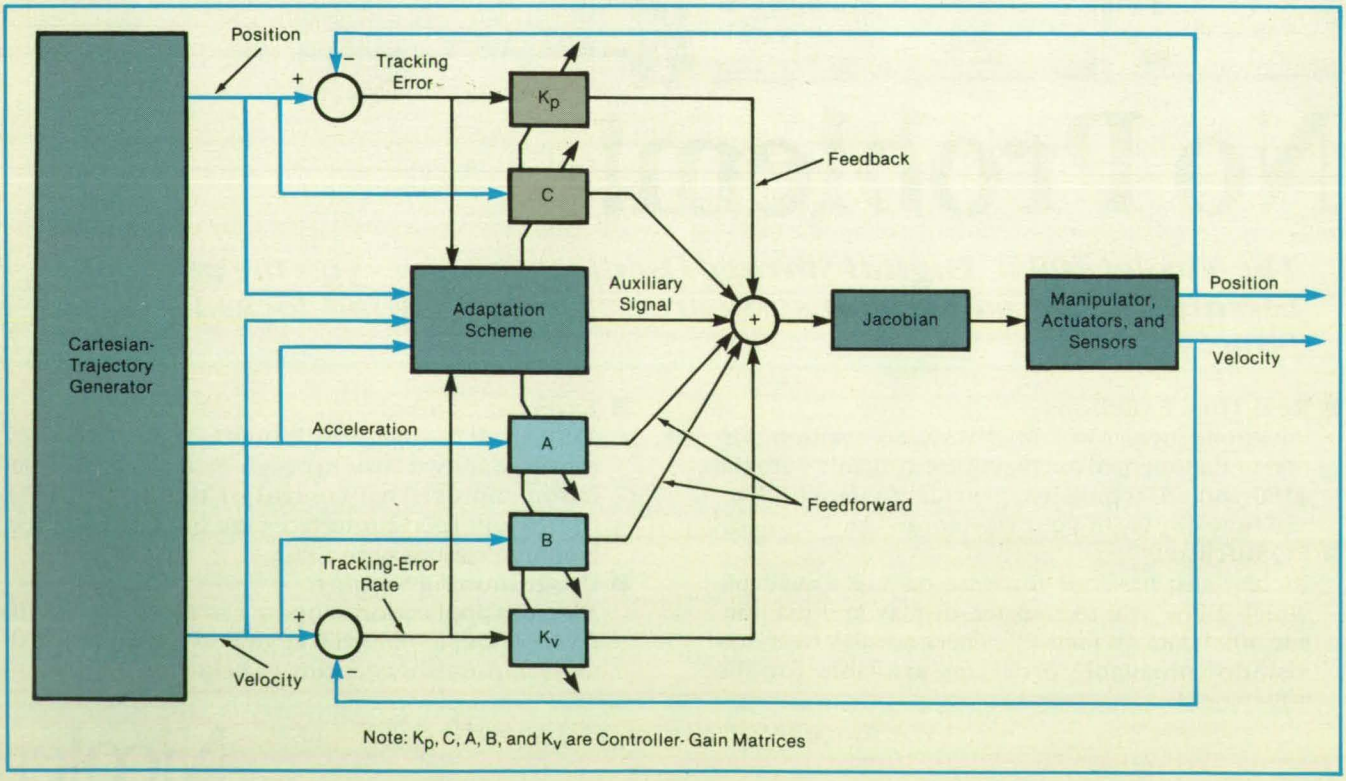
A robotic control system (see figure) causes a remote manipulator to follow closely a reference trajectory in a Cartesian reference frame in the work space, without resort to a computationally intensive mathematical model of robot dynamics and without knowledge of the robot and load parameters. The system, derived from linear multivariable theory, uses relatively simple feedforward and feedback controllers with model-reference adaptive control.

The system requires measurements of the position and velocity of the end effector of the manipulator. These can be obtained directly from optical sensors or by calculation using the known kinematic relationships between the measured manipulator-joint angles and the end-effector position.

In deriving the control equations, the coupled nonlinear differential equations of the robot dynamics and kinematics are first expressed in general form, then linearized by the calculation of perturbations about a specified operating point in the Cartesian coordinates of the end effector. The resulting mathematical model is a linear multivariable system of order 2n (where n = the number of independent spatial coordinates of the manipulator) that expresses the relationship between the increments of the n actuator control voltages (inputs) and the increments of the n coordinates of end-effector trajectory (outputs).

The problem then becomes one of making the end-effector trajectory increments track the reference-trajectory increments: this requires independent feedback and feedforward controllers. The feedback controller provides a stable closed-loop system with poles at desired locations in the Laplace-transform complex-frequency domain and ensures that initial tracking errors decrease asymptotically to zero with time. For this purpose, it suffices to apply position and velocity feedback through $n \times n$ position- and velocity-feedback gain matrices.

The feedforward controller causes the actual position to track the reference position. The incremental feedforward controller is chosen to be the minimal-order inverse of the end-effector transfer function. The total control law combines the trajec-



Note: K_p, C, A, B, and K_v are Controller-Gain Matrices

The **Adaptive Control System**, using feedforward of the desired trajectory and feedback of the actual manipulator position and velocity, causes the manipulator to track a reference trajectory. The system is insensitive to changes in the robot and load parameters and requires less computation and memory than do other control systems of similar capability.

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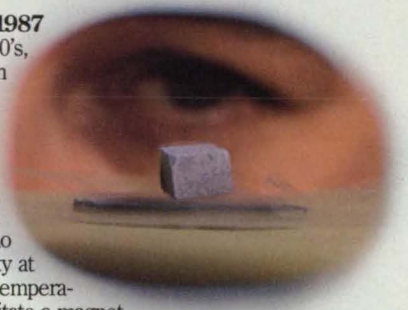
1986
Was it preposterous of us to try to reproduce the power of a room-sized laser in a smaller unit? No, we actually made our latest surface-emitting diode lasers smaller than the head of a pin. But what's really incredible are the opportunities they've opened for miniaturizing equipment in medicine, computing and satellite communications.

1982
Once world communications had been linked via satellite, further innovations seemed highly improbable. Then one of our multidisciplinary research teams developed the first solid state amplifier for use in orbit, which doubled the capacity of our early "birds," and extended their operating life.



1987
During the early 60's, we were a pioneer in superconductivity research, and the leader in developing commercial applications for superconducting wire which operated at extremely low temperatures. Modern superconductors have no resistance to electricity at twice the previous temperature and can levitate a magnet like the one shown here, but we're working on superconductive circuits that will operate at room temperature.

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tory and actuator-voltage increments with the values of the actuator voltages and positions at the nominal operating point.

The gains of the controllers and the operating-point term in the total control law are varied continuously to adapt to variations in the coefficients of the robot model due to changes in the operating point. The adaptation laws, derived by the Lyapunov method, do not require the knowledge of any robot parameters or of the payload and are based entirely on the reference trajectory and the tracking error, both of which are available. Thus, the adaptive controller treats the robot as a "black box."

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 147 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-16922, volume and number of this NASA Tech Briefs *issue, and the page number.*

Eight-Channel Spectrometer

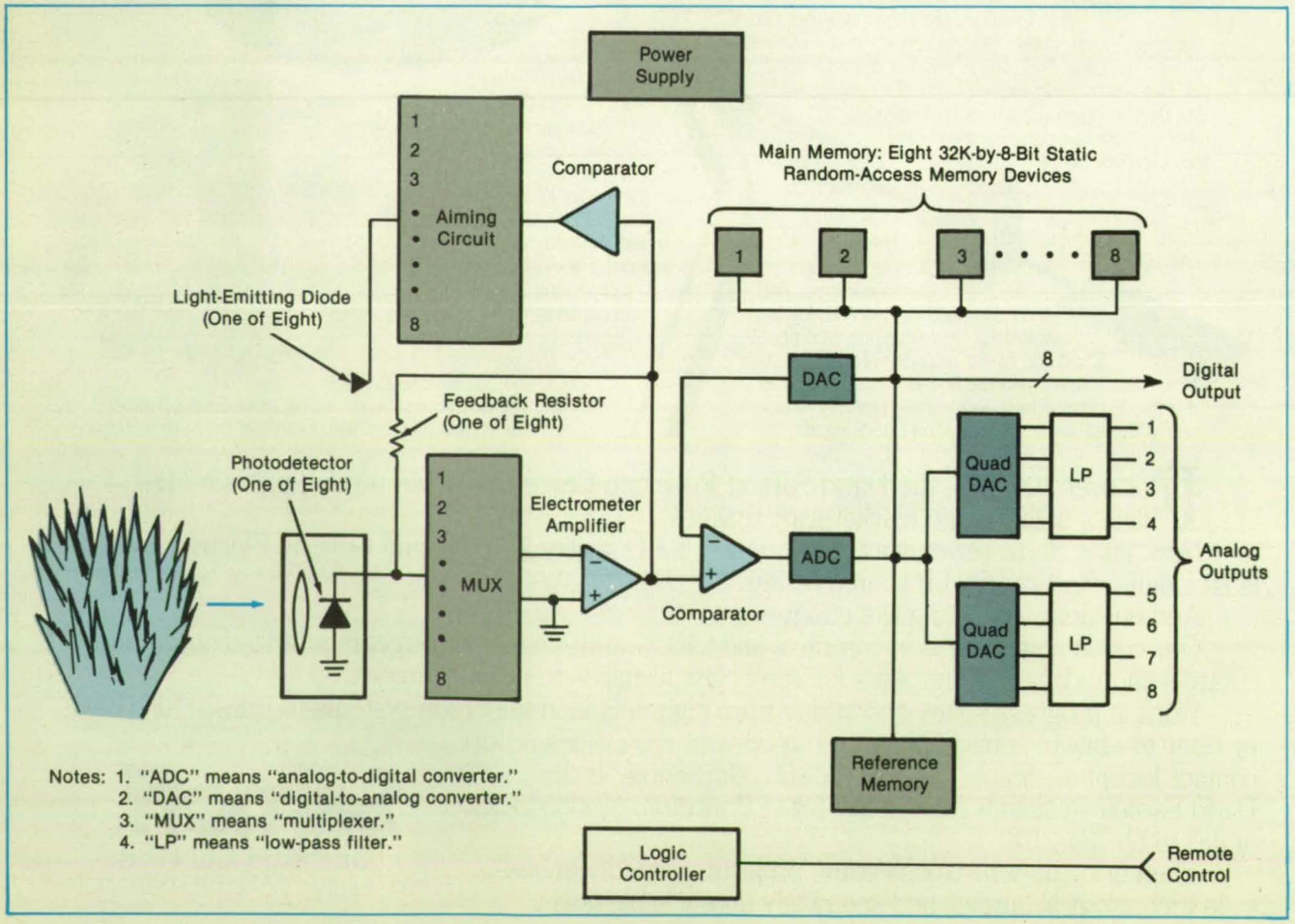
Photodetector signals are multiplexed for digitization and recording.

Marshall Space Flight Center, Alabama

An inexpensive, compact, battery-powered, eight-channel spectrometer (see figure) produces 8-bit digital data in each channel and records the data for subsequent reconstruction in analog form or for transmission to a computer for analysis. The unit is designed for use in the analysis of rocket-exhaust plumes. Modified versions of the spectrometer could be used to analyze combustion in boilers or gas turbines.

The photodetector for each channel is a silicon positive/intrinsic/negative diode operating in the photovoltaic mode. The wavelength range is 185 to 1,150 nm. A lens and a filter of ~10-nm bandwidth at the spectral line of interest are placed in front of each detector. The outputs of the detectors are fed through a multiplexer, which connects each one in turn (at a rate of 10 samples per second) to an electrometer operational amplifier. Each detector is also permanently connected to a feedback resistor and rolloff capacitors so that the output of each can be adjusted and scaled to obtain a nearly-flat spectral response over the wavelength range of interest, with maximum dynamic range.

To obtain net spectral data, the background spectrum is subtracted. Background readings taken previously in the absence of the plume or flame to be analyzed are reconstructed for each channel by a digital-to-analog converter and fed to the noninverting input terminal of a comparator, while the electrometer-amplifier output is fed to the inverting input terminal of the comparator. The output of the comparator, which is the net spectral reading in



The **Eight-Channel Spectrometer** digitizes and stores spectral readings during a test as long as 27 minutes. The recorded spectrum as a function of time can be read out digitally or "played back" in analog form.

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one channel, is digitized. The readings from each channel are stored in the main memory in a static random-access-memory device devoted to that channel. The memory holds 27 minutes' worth of spectral readings.

An aiming circuit is used to align the spectrometer with a lamp or other artificial source of light placed temporarily at the test position. This circuit converts the reading in each channel to the output of one of eight light-emitting diodes. When the spectrometer is aligned, these diodes light up with equal brightness.

For analog output or playback of data, the digital data from the main memory are fed through two quad digital-to-analog converters, each of which reconstructs the readings in four channels. The output in each channel can be used to drive a strip-chart recorder or other display or recording device.

This work was done by Steven W. Huston and Milton C. Hensley of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 99 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 22]. Refer to MFS-29421.

Liquid-Crystal Optical Correlator

A liquid-crystal television screen serves as a spatial light modulator.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optical correlator uses a commercially-available liquid-crystal television (LCTV) screen as a spatial light modulator. Correlations with this device can be done at video frame rates, making such operations as bar-code recognition possible at a reasonable cost. With further development, such a correlator may be useful in automation, robotic vision, and optical image processing. As higher resolution LCTV's are developed, the resolvability of such correlators will increase, the cost of this improvement being borne by the consumer television market.

The correlator is shown in the figure. An input video signal generated by a computer, video camera, or television receiver is sent to the LCTV screen. A collimated laser beam is incident upon the screen. Each LCTV picture element consists of two parallel polarizers with a polarizing liquid crystal in between that is oriented by an impressed electric field. The light transmission through each picture element ranges from about 0 to a maximum value depending on the bias applied.

Thus, the video modulation applied to each picture element determines the amount of laser light that passes through it. As a result, the collimated beam is spatially modulated so that a cross section of the beam looks like the television image.

The light transmitted through the screen passes through a lens focused on the Fourier-transform plane. A reference light beam, split off by a beam splitter after collimation, is focused by a long-focal-length correlation lens and reflected onto the correlation plane beyond the Fourier-transform plane. A Fresnel-zone plate of the pattern with which it is desired to correlate is formed at the Fourier-transform plane. In the initial experiments, the pattern was a computer-generated Ronchi ruling and was recorded at the Fourier-transform plane with a thermoplastic recording camera. In a more sophisticated version, spatial filtering was added to remove the grid patterns of the LCTV screen.

When an image is subsequently impressed on the screen, the light pattern on the correlation plane shows the correlation between the present image and the one represented on the zone plate. A detector array, photographic film, or other medium may be used to record the correlation pattern.

This work was done by Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 143 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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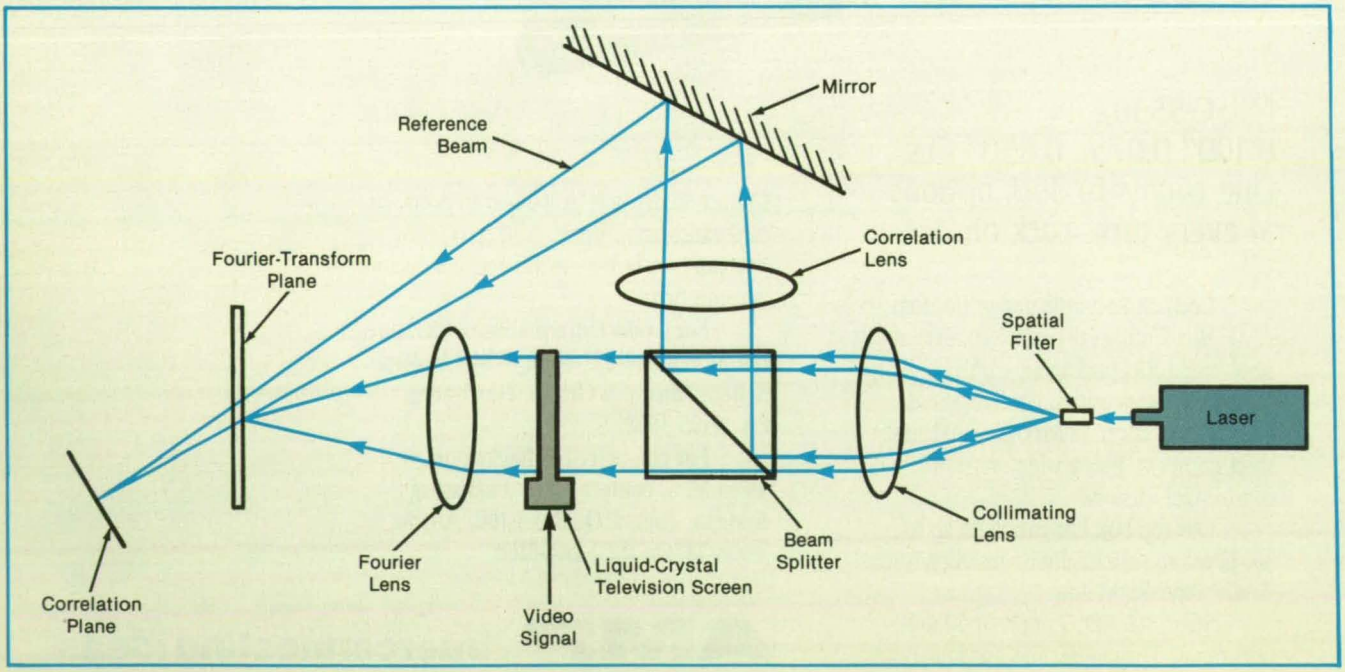
Refer to NPO-16750, volume and number of this NASA Tech Briefs *issue, and the page number.*



In the **Optical Correlator,** the liquid-crystal television screen serves as a transmitting spatial light modulator. The correlation between the pattern on the screen and the pattern represented on a zone plate at the Fourier-transform plane appears as a pattern on the correlation plane.

Optical Receivers With Rough Reflectors

A postdetection processor analyzes signals to reconstruct the transmitted message.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed receiver for optical communications would use a rough reflector instead of the diffraction-limited reflector customarily thought to be necessary for such systems. The rough reflector would collect and focus the optical signal. The other receiver components include a narrow-passband optical filter to reject out-of-band background radiation, a spatial filter to limit the receiver field of view, an optical-detector array (typically two concentric detectors), and a postdetection processor to reconstruct the transmitted message (see figure).

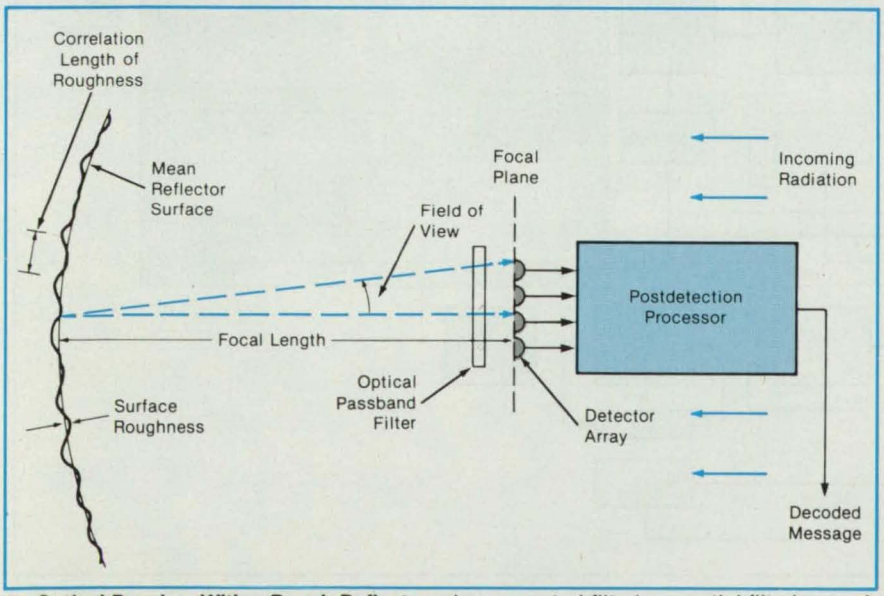
In price and performance, rough-reflector receivers are expected to be competitive with receivers using diffraction-limited optics, when large-aperture reflectors are required and background noise is not too high. A diffraction-limited reflector provides the greatest protection against background noise because the receiver field of view can be minimized. However, a large diffraction-limited reflector is difficult and costly to construct.

The error probabilities for a receiver employing a rough reflector depend on the average signal and background counts, which in turn depend on the reflector rms (root mean square) surface deviation (surface roughness), the average correlation length of the surface deviation, the reflector aperture, and the receiver field of view. The error probabilities must be optimized to achieve the best performance as the other parameters are changed. In the absence of background radiation, only one detector is required, and the only drawback in using a rough reflector is that the larger field of view required for a given performance level increases the chance that signal sources other than the intended one might enter the field of view.

The degradation, induced by noise, in the performance of a rough reflector can be viewed as a loss of effective collecting aperture. The effective diameter can be expressed as the diameter of a diffraction-limited reflector of equivalent performance. For a rough reflector having an aperture diameter of 20 m, a surface roughness of 2 μm, and a correlation length of 1.4 μm in a receiver operating at a symbol error probability of 10^{-5}, the effective aperture diameter decreases to 10 m as the background noise increases from 0 to 0.1 counts per picosteradian.

For a signal with a circularly-symmetric intensity distribution emanating from a pointlike source, the receiver can be optimized by partitioning the field of view into two concentric regions, each of which contains an independent detector. In addition to the background noise, one detector is designed to receive a significant portion of the signal in the central diffraction ring, while the other is included to receive a significant portion of the signal scattered out of the central diffraction ring. The output signal is computed using a decision function involving weighted sums of the two detector signals.

This work was done by Victor A. Vilnrotter of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 149 on the TSP Request Card. NPO-16664*



An **Optical Receiver With a Rough Reflector** rely on spectral filtering, spatial filtering, and postdetection signal processing to achieve performance nearly equivalent to that of a receiver with a diffraction-limited reflector.

Digital Controller for Acoustic Levitation

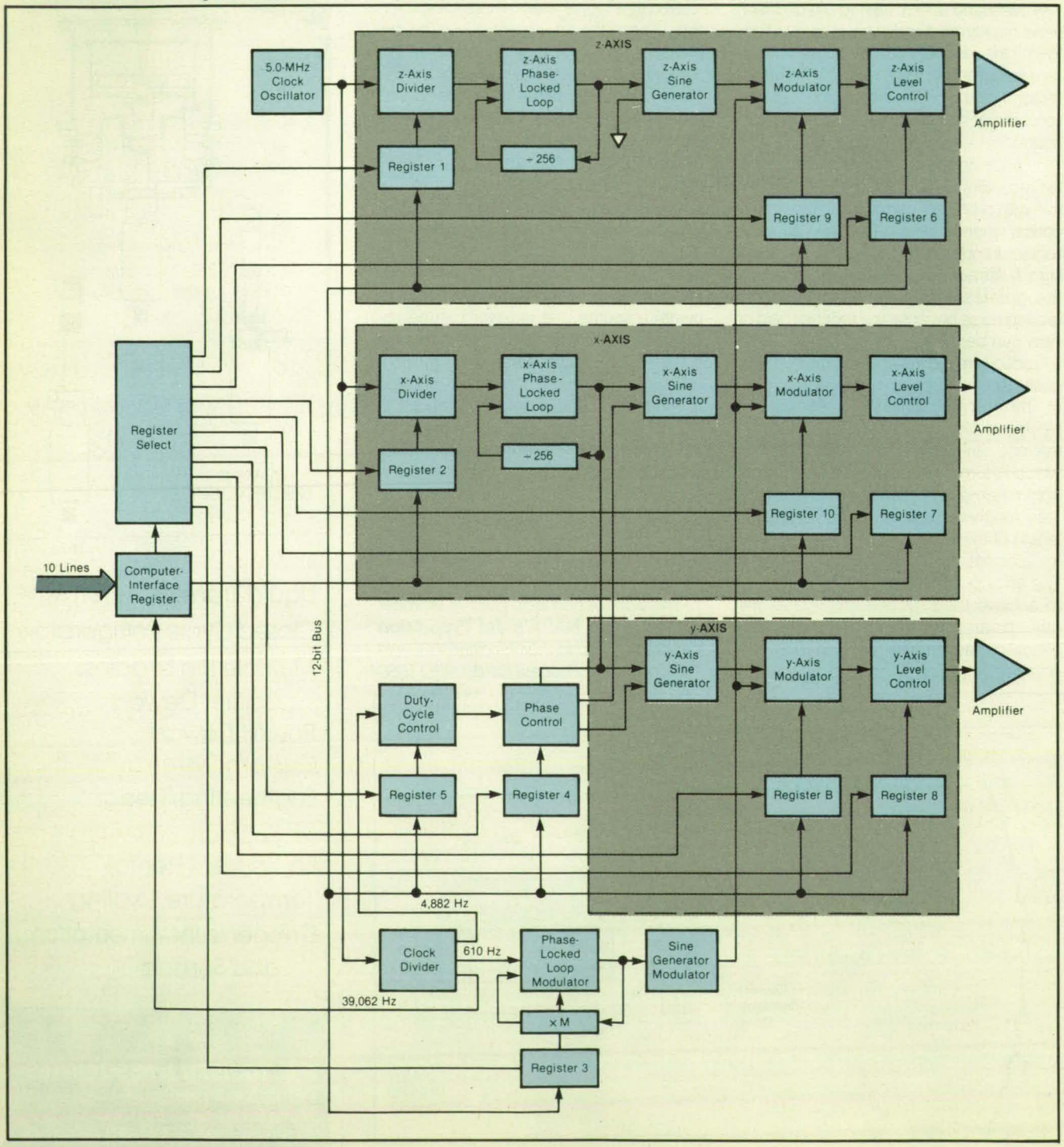
A computer controls sonic fields in three dimensions.

NASA's Jet Propulsion Laboratory, Pasadena, California

An acoustic driver digitally controls sound fields along three axes. It allows the computerized acoustic levitation and manipulation of small objects for such purposes as containerless processing and nuclear-fusion power experiments. It may also be used for controlling the motion of vibration-testing tables in three dimensions.

The driver produces three mutually orthogonal sine waves, maintaining precise relationships among their frequencies, phases, and amplitudes. The driver outputs are independently determined by digital signals from 11 function registers (see figure). The registers are parallel-input, parallel-output storage devices, connected to receive control signals from a twelfth register, the computer-interface register. A computer sends data to the computer-interface register over 10 input lines.

In the z-axis channel, register 1 controls a frequency divider that operates on the 5-MHz clock signal. In combination with a phase-locked loop and a sine-wave generator, the divider produces a carrier wave. Under control of register 9, the degree of modulation of the carrier wave is estab-



A **Computer Sends Instructions** to a computer-interface register, which distributes them to various registers in the acoustic controller. The channels for the z and x axes use three registers each, and the channel for the y axis uses two. The functions of three additional registers are shared by the channels.

lished. The modulated carrier is fed to a level controller, where the output level amplitude is set according to the data in register 6. After amplification, this audio signal is fed to the z-axis acoustic transducer.

In the x-axis channel, registers 2, 10, and 7 do the frequency, modulation, and amplitude control, respectively. In the y-axis channel, the output of the x-axis phase-locked loop is fed to the sine-wave generator. This ensures that the frequencies of the x and y axes are identical. The degree of modulation and amplitude are controlled just as in the z and x channels, by registers 11 and 8.

For all channels, the modulating frequency is controlled by the data in register 3. This register feeds the modulators in each of the channels synchronously. It can vary the modulating frequency from about 0.05 to 12 Hz and integral multiples thereof up to 1,000 Hz.

A phase-control circuit receives instructions from register 4. This circuit produces a pulse that starts the x and y sine-wave generators on their sine-wave cycles. It thus fixes the phase relationship of the x and y channels. The phase-control circuit receives its clock pulses from the x-axis phase-locked loop so that its function is synchronized with the x and y carriers.

When activated by register 5, a duty-cycle controller commands the phase-control circuit to reverse. This reverses the sine waves on the x and y axes.

The driver produces its outputs at frequencies ranging from 620 to 10,000 Hz, depending on the choice of equipment. The frequency of a given equipment selection can be varied over a 1-octave range by the computer software.

This work was done by D. Kent Tarver of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 134 on the TSP Request Card. NPO-16623*

Timing Sampler for Delay Measurements

One chip contains delay chains and associated testing circuits.

NASA's Jet Propulsion Laboratory, Pasadena, California

An integrated circuit called a timing sampler is used to measure delays in complementary metal oxide/silicon logic gates, as part of the system described in the preceding article. The circuit chip contains chains of inverters and metal traces having the minimum parasitic delays (delay chains), circuits to compare pulse timings, and an output multiplexer (see Figure 1). The timing sampler enables delay measurements for both positive and negative logic-level transitions by use of a variety of circuit geometries representing tentative practical designs.

There are 128 delay chains, eight of which are metal traces. Each of the remaining 120 chains is a series of 40 inverters. The chains differ in the sizes and shapes of the transistors in the inverters and in the inverter loadings: The n-channel (pulldown) transistors have widths of 3, 4.5, 6, 9, and 12 μm. The p-channel (pullup) re-

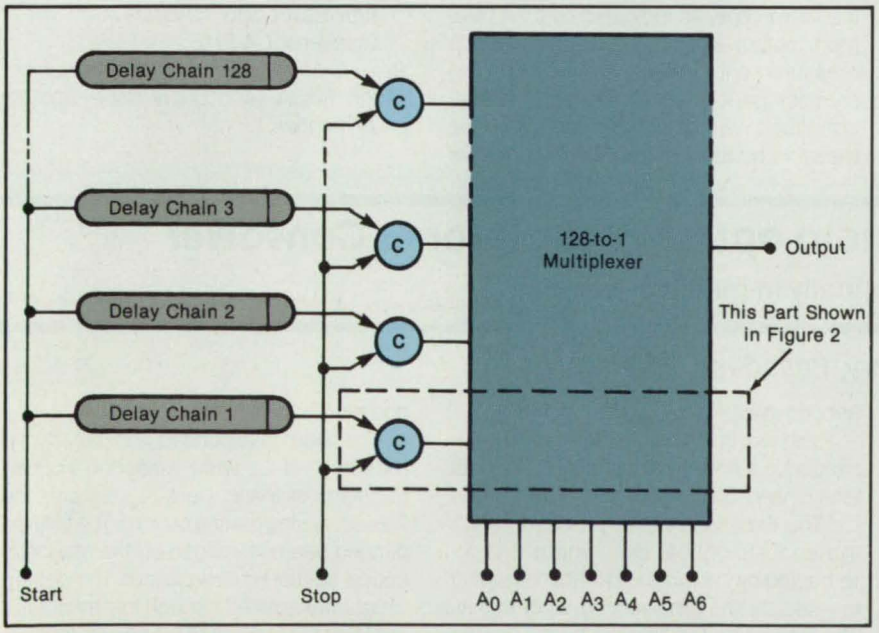


Figure 1. The **Timing Sampler** is an integrated circuit that includes metal traces and inverter chains to be tested for signal-propagation delays. The circuit chip also includes timing comparators (C-elements) and a computer-controlled multiplexer that connects the C-element outputs to the computer one at a time.

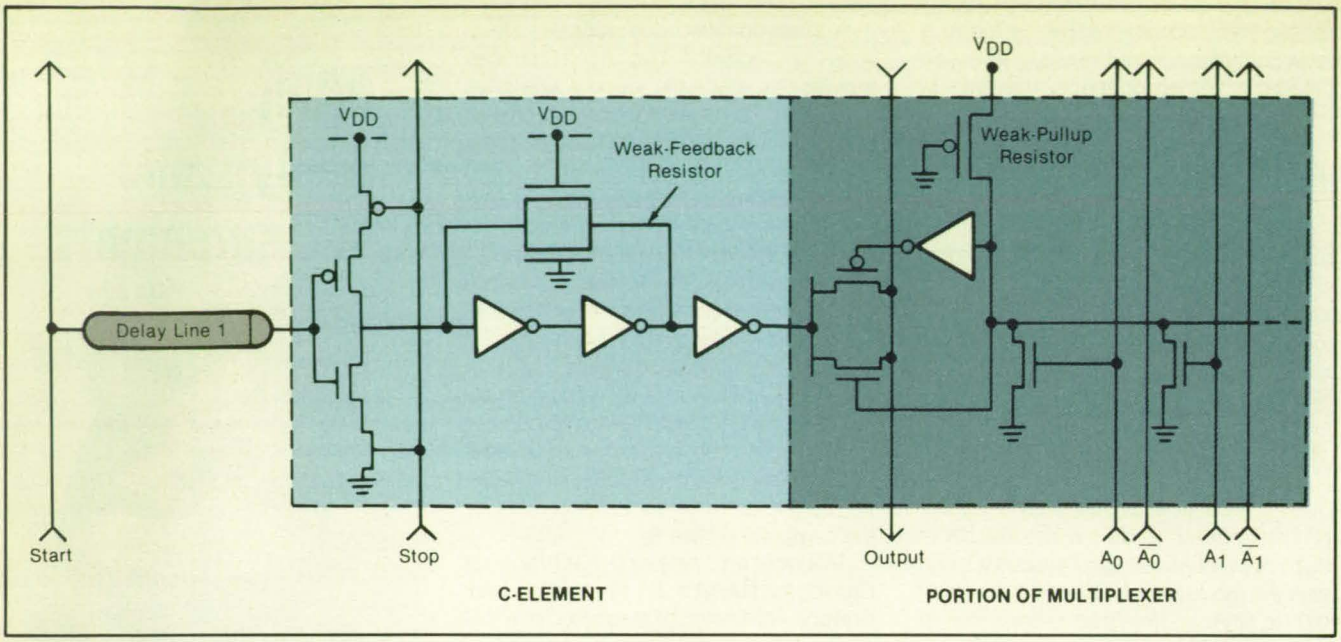


Figure 2. A **C-Element** is a bistable circuit with hysteresis. It is used as a timing comparator because its output depends on whether the "start" or the "stop" pulse arrives first.

sistors and the pulldown transistors have the same lengths, the values being 3, 6, 9, and 12 μm. The ratios of the widths of the pullup transistors to those of the pulldown transistors are 1, 1.5, and 2. In 60 of the delay chains, loads are connected to the output of every other inverter to simulate a fanout of two for each inverter pair. The input ends of all the delay chains are connected to a common input "start" line.

At the output end of each delay chain is a bistable circuit called a "C-element" (see Figure 2), which has two input terminals and one output. A C-element of this type is constructed with the output of a three-input majority circuit connected back to one input. One C-element input is connected to a common input "stop" line; the other input is connected to the output of the last inverter in the chain. The latter input is specially designed to provide the same load to the last inverter as that connected to the other inverters in the chain, so that the delay of the last inverter is the same as those of the preceding inverters. (Delay is a function of loading.)

The output of each C-element is connected to a 128-to-1 multiplexer, the output of which is the timing-sampler output. The C-element exhibits hysteresis: Its output logic state becomes zero when both inputs are zero, or one when both inputs are one; otherwise, the output remains in its previous state. The output transitions depend on which of the two input signals arrives first: the "stop" pulse or the "start" pulse, which has been delayed by propagation through the delay chain.

The timing sampler is used with other equipment that adjusts the interval between the "start" and "stop" pulses until both pulses arrive at the C-element input at the same time, as indicated by the C-element output signal. In a series of such measurements, an experimental timing sampler performed as expected. When correlated with the circuit geometries, the measurements showed that the inverter delay is inversely proportional to the transistor width.

This work was done by Brent R. Blaes and Martin G. Buehler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 140 on the TSP Request Card.*

Title to this invention, covered by U.S Patent No. 4,688,947 has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)]. Inquiries concerning licenses for its commercial development should be addressed to

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Refer to NPO-16645, volume and number of this NASA Tech Briefs *issue, and the page number.*

Acousto-optical /Magneto-optical Correlator or Convolver

Binary signals are processed optically in multiple channels.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental system has been built to demonstrate the optical processing of multiple channels of binary signals. One of the input channels contains a signal that varies with time and is applied to a one-dimensional acousto-optical cell. The other input channel contains a two-dimensional pattern that can be stationary or that can vary with time and is applied to a magneto-optical spatial light modulator. The output is the time-varying correlation or convolution of the first input with one of the rows in the second input.

As shown in Figure 1, a laser beam is expanded in a horizontal plane by cylindrical lens L_1 and collimated by cylindrical lens L_2. The expanded beam passes through the acousto-optical cell, where it is intercepted by the moving diffraction grating created by the time-varying input signal. The transmitted, diffracted beam passes through Fourier-transform cylindrical lens L_3, which enables a spatial filter to select the portion of the signal refracted to the positive first order.

The beam is expanded vertically by cylindrical lens L_5, while a second Fourier-transform cylindrical lens, L_4, restores the filtered moving grating pattern. The fully expanded beam is imaged on the magneto-optical spatial light modulator. The pattern of light transmitted through this modulator contains the product of the one-dimensional, moving input pattern, with each of the patterns stored on each row of this modulator.

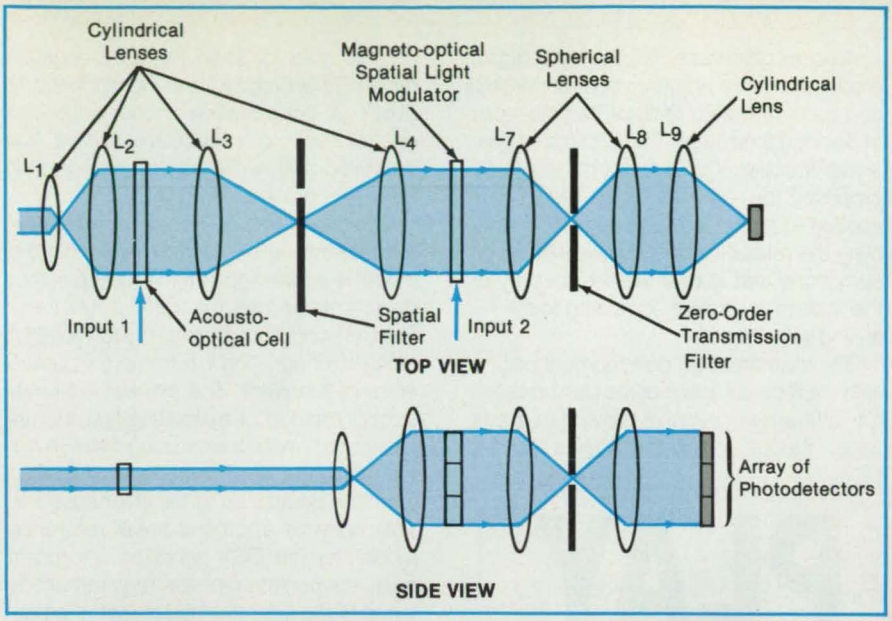


Figure 1. Using **Acousto- and Magneto-optical** spatial light modulators, this apparatus processes two streams of binary signals optically.

The convolution or correlation of the two patterns with each other is obtained via the Fourier transform of the product of the two input light-transmission patterns. (Whether the convolution or the correlation is obtained depends upon the order in which the information is stored in each row of the two-dimensional pattern.) Because the product of the two functions also contains the regular grid structure of the magneto-optical modulator, which would cause crosstalk between channels, the beam is Fourier-transformed by spherical lens L_7, passed through a zero-order transmission filter (which removes the grid), and retransformed by spherical lens L_8. The final cylindrical lens, L_9, focuses each convolution or correlation signal onto a series of photodetectors; the time-varying output of each photodetector is one of the designated correlation or convolution signals (see Figure 2).

This work was done by Hua-Kuang Liu of Caltech and Jeffrey A. Davis of San Diego State University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 138 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 22]. Refer to NPO-17178.

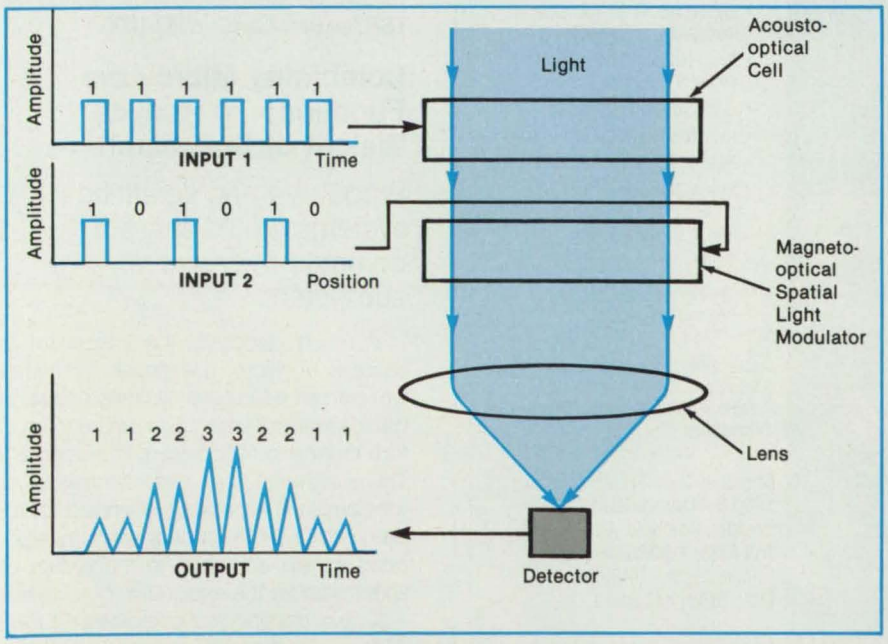


Figure 2. In this **Simplified Schematic Representation**, the convolution of the two inputs appears at the output of the photodetector as a signal that varies with time.

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Discrete-Time Model-Reference Adaptive Control

The command-generator tracker concept is exploited in the discrete-time setting.

A paper discusses the stability of digital model-reference adaptive control (MRAC) of a robotic system or plant that operates at discrete time steps. The command-generator tracker (CGT) concept, originally proposed for continuous-time systems, is applied in the discrete-time setting, enabling the relaxation of some restrictive assumptions that guarantee the stability of the system controlled according to the resulting algorithm.

The mathematical development begins with the representation of the plant in deterministic-autoregressive-moving-average form. The CGT condition on inputs and outputs is invoked. Then the error-equation dynamics are stated and incorporated to obtain a nonadaptive model-reference control law. Finally, the indirect MRAC law is derived, and the main theorem regarding stability is proved.

The use of the CGT concept is novel in discrete-time MRAC in that matching of the model is addressed in terms of the output signals rather than the transfer functions. The CGT condition enables the formulation of the error equation in terms of the parameters of the plant. The indirect adaptive-control method of estimating first the unknown parameters and using them in, for example, the pole-placement algorithm can then be applied to the error equation. This scheme affords a small reference model via the CGT condition and casts away the minimum-phase requirement by virtue of the adaptive placement of poles.

There is a price, however. If the CGT condition must hold for an arbitrary model input signal, then the plant is necessarily of minimum phase. If it is not of minimum phase, then the resulting control algorithm, in its present form, applies only to single-input/single-output finite-dimensional systems. The tradeoff between the class of model input signals and the class of systems that can be considered may be a practical and desirable one in many situations. Likely applications include systems in which sensors and actuators are not placed together.

This work was done by John T. Wen and Deirdre R. Meldrum of Caltech and Mark J. Balas of Rensselaer Polytechnic Institute for ***NASA's Jet Propulsion Laboratory****. To obtain a copy of the report, "Discrete Time Model Reference Adaptive Control Using CGT Concept," Circle 155 on the TSP Request Card. NPO-17062*

Combining Microwave Functions To Reduce Weight of Spacecraft

Propulsive and scientific systems would share a common microwave subsystem.

A report discusses the integration of sources of microwave power for microwave-arcjet propulsive systems and such microwave instruments as synthetic-aperture radar and radiometers in spacecraft. This integration is an essential feature of the Combined Microwave Science and Propulsion (COMAPP) concept, which incorporates a new approach to the design of spacecraft for the exploration of planets.

One of the principal objectives in COMAPP is to reduce the overall weight of a spacecraft and to maximize the portion of the weight devoted to scientific instrumen-

tation. The general approach involves (1) taking advantage of the inherent greater efficiency of microwave arcjet propulsion than of chemical propulsion in outer space and (2) the relative ease of generation of the large amounts of solar/electric power required by the scientific and propulsive systems.

A large fraction of the mass of a microwave-arcjet propulsive system is in the source of microwaves. Thus, a significant redundant mass can be eliminated by using the same source of microwaves for both science and propulsion. This also makes it possible to reduce mass further by eliminating redundant monitoring, power-supply, and heat-rejection equipment.

The source of microwaves would probably include one or more magnetrons, which offer a fairly-low mass-to-power ratio (typically 0.4 g/W), a high energy-conversion efficiency (about 72 percent in a kitchen microwave unit), a moderate anode operating temperature (about 250 °C), and suitability for use in phased-array antennas. The relatively-simple power-processing requirements of magnetrons enable the use of power supplies that have mass-to-power ratios of less than 3.5 g/W.

It may be possible to extend the integration beyond the microwave-source stage to the thrustor(s), which could also be used as microwave radiators when the flow of propellant gas is turned off. The propelling/radiating structure might consist of a large array of thrustor(s)/microwave radiators mounted near power converters and thermal radiators. Each thrustor(s)/microwave radiator could be driven by its own magnetron, and a low-power microwave distribution system could carry modulation and injection-lock the magnetrons. Of course, such integration of thrustor(s) and antennas may necessitate the reorientation of the spacecraft between thrusting and radiating modes.

The reduction in mass achievable by integration is roughly proportional to the microwave power required by the arcjet. A preliminary estimate shows that 100 kg of the magnetron mass can be achieved at a power of 1 MW. Furthermore, less propellant would be required because of the increased performance of the microwave-arcjet propulsion system. For a spacecraft having an initial mass of 50,000 kg undergoing an increase in velocity of 6 km/s during a transition from low orbit to synchronous orbit around the Earth, the saving in propellant mass is estimated to be 12,400 kg.

This work was done by Bryan A. Palaszewski and Richard M. Dickinson of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Microwave Arcjet Propulsion/Science Instrument Integration," Circle 27 on the TSP Request Card. NPO-16953*

Physical Sciences

Correlation Functions Aid Analyses of Spectra

Signals much weaker than noise are identified.

NASA's Jet Propulsion Laboratory, Pasadena, California

New uses have been found for correlation functions in analyses of spectra. In an approach that combines elements of both pattern-recognition and traditional spectral-analysis techniques, spectral lines can be identified in data that appear useless at first glance because they are dominated by noise. The new approach should be particularly useful in the measurement of concentrations of rare species of molecules in the atmosphere.

The cross-correlation function, $C(x)$, of two functions $f_1(x)$ and $f_2(x)$ is defined by

$$C(x) = \int_{-\infty}^{\infty} f_1(x' + x)\, f_2(x')\, dx'$$

Depending on its sign, x is called the "lead" or "lag." If f_1 and f_2 are identical, then $C(x)$ becomes the autocorrelation function $A(x)$. A new quantity called the "heteromorphic coefficient" (H) is defined to express the degree to which f_1 and f_2 match each other:

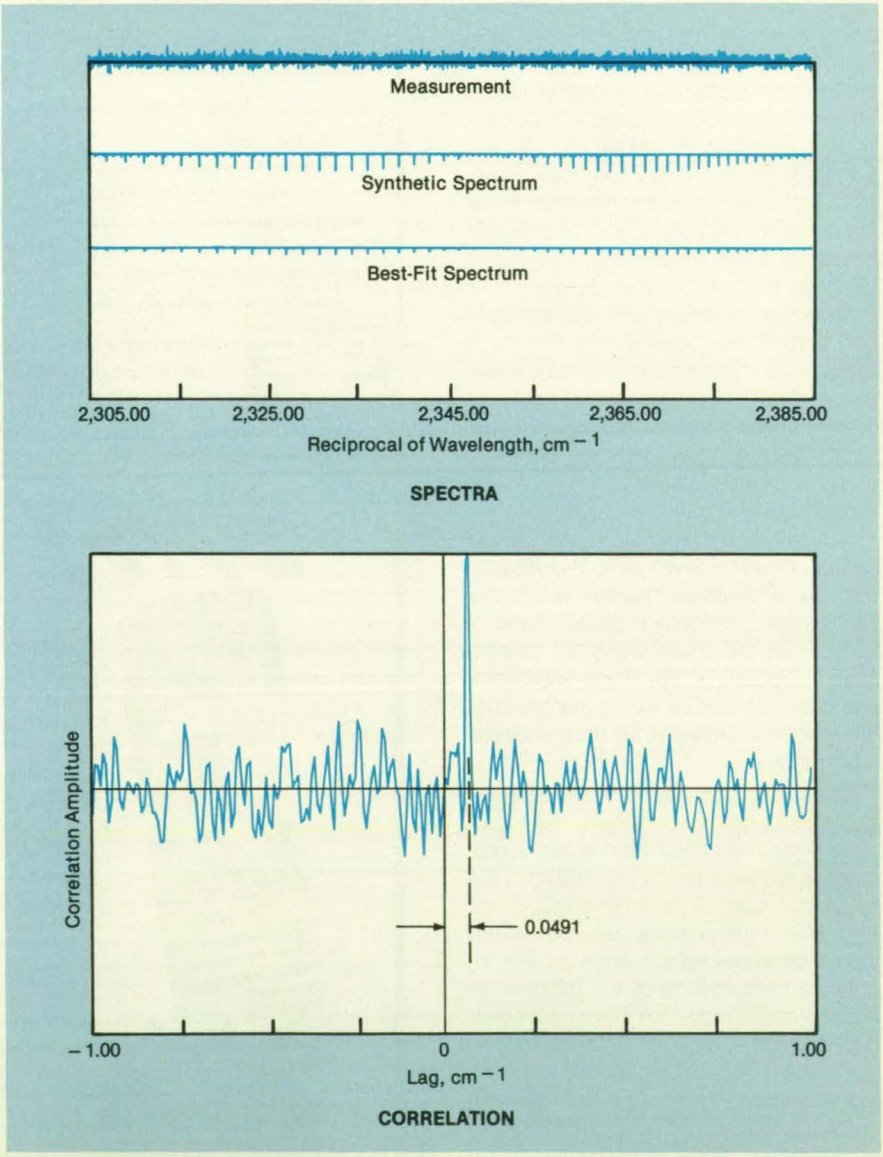
$$H = [A_1(0) - A_2(0)]/C_{max}$$

where C_{max} = the peak value of $C(x)$, usually (but not always) found at $x = 0$. H is 0 if f_1 and f_2 are identical and diverges toward infinity if f_1 and f_2 are uncorrelated.

Suppose that $f_1(x)$ represents an especially-noisy spectral intensity as a function of the reciprocal of wavelength and $f_2(x)$ represents a synthetic, laboratory, or theoretical spectrum for which one is searching in the noisy data. $C(x)$ is computed, and, if a correlation peak is found (see figure), then f_2 is adjusted in amplitude and wavelength until it gives the best fit as indicated by the approach of H to 0. Because of noise in the autocorrelation functions, H cannot necessarily reach precisely 0; and one can compute a limiting value of H toward which to strive, to avoid overfitting of data.

The lead or lag in the correlation peak also yields useful information. In the example of the figure, the lag of 0.049 cm^{-1} indicates a Doppler shift caused by a relative velocity of about 6.3 km/s between the spectrometer and the atmosphere.

Correlation analysis is much more effective than traditional spectral-analysis techniques in the extraction of weak signals that appear to be hopelessly "buried" in noise. Both visual inspection and least-squares analysis are point-by-point-comparison techniques that fail to identify signals lower than about 1 standard deviation of the noise. On the other hand, cross-correlation exerts a powerful averaging effect that suppresses the effect of noise because it considers an entire spectral inter-



A **Noisy Spectrum** was measured in the upper atmosphere in the search for the characteristic lines of CO_2. A correlation peak was found between a synthetic CO_2 spectrum and the noisy data, leading to a "best-fit" CO_2 spectrum extracted from the measurements.

val instead of the small interval around an individual spectral line.

Correlation analysis works best over large spectral intervals containing highly structured spectra with many lines. It is not expected to be useful in the search for broad, shallow spectral continua. When spectral lines of more than one molecule are sought, all have to be fitted concurrently to make H converge properly: the technique to do this will require further research. When a Doppler shift is present, the spectral interval must be restricted somewhat so that the dependence of the shift on frequency does not, itself, result in decorrelation. (However, a correction for this dependence could presumably be made in the synthetic spectrum.)

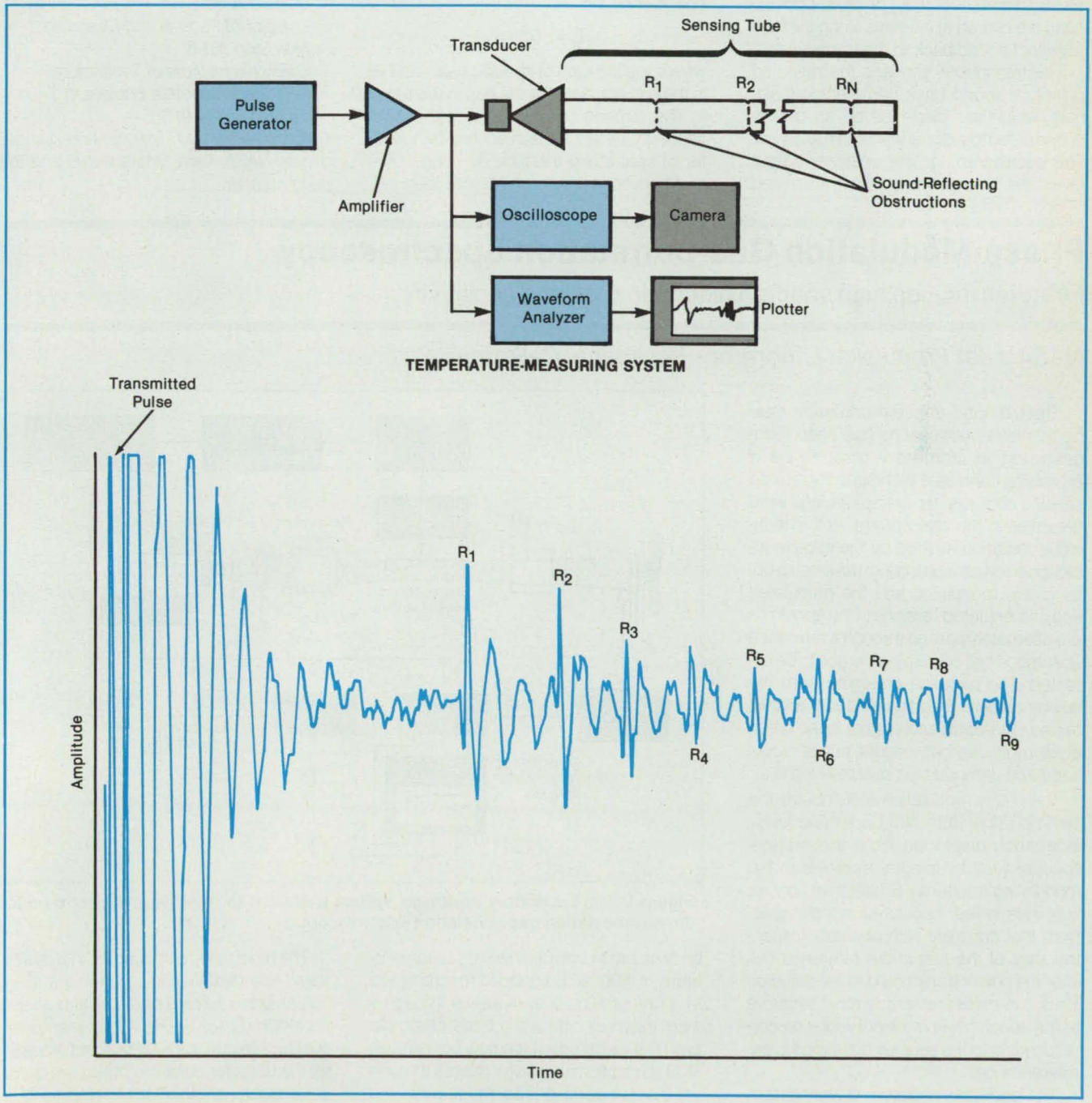
This work was done by Reinhard Beer and Robert H. Norton, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 156 on the TSP Request Card.*
NPO-17306

Acoustical Measurement of Furnace Temperatures

Simple probes withstand severe conditions, yet give spatially-resolved temperature readings.

NASA's Jet Propulsion Laboratory, Pasadena, California

A prototype acoustical system has been developed to measure temperatures from ambient to 1,800 °F (1,000 °C) in such structures as large industrial lime kilns and recovery-boiler furnaces. The acoustical temperature probes are simple, rugged



Pulses of Sound are reflected from obstructions in the sensing tube. The speed of sound and the temperature in each segment are deduced from the travel times of the pulses.

tubes of stainless steel, ceramic, or other suitable materials. The acoustical system gives spatially resolved measurements of temperature and replaces thermocouples, which are attacked by the corrosive atmospheres of the kilns and furnaces. Although pyrometers could be used in place of thermocouples, they cannot resolve spatial variations of temperature within their fields of view.

The system (see figure) is based on measurement of the travel times of pulses of sound. A loudspeaker or other suitable transducer at one end of the sensing tube acts as the transmitter and receiver. Signals from a pulse generator are converted by the transducer to pulses of sound, which travel along the sensing tube. Holes, diametrical rods, or other obstructions are placed at intervals along the tube to reflect sound back to the transducer.

The transducer converts the reflected pulses of sound back into electrical signals, which are displayed on an oscilloscope or fed to a digital waveform analyzer. The oscillogram or the analyzer output gives the time between the transmitted pulse and each of the received pulses. The speed of sound C_n in the segment of the tube between the $n-1$st and nth reflectors is given by

$$C_n = 2l_n/(t_n - t_{n-1})$$

where l_n is the distance along the tube between the two reflectors and t_n and t_{n-1} are the times of receipt of the nth and $n-1$st pulses, respectively.

The transducer end of the sensing tube can be left open to the atmosphere or, if the tube is sealed along its length, can be connected to a supply of a suitable gas at a known regulated pressure. In either case, the temperature T_n in the nth segment of the tube is deduced from the simple relationship between the temperature and the speed of sound:

$$T_n = C_n^2/\gamma R$$

where γ is the ratio of specific heats and R is the gas constant for the gas in the tube.

The dimensions and material of the sensing tube are chosen so that the transfer of heat along the tube by conduction and convection is much weaker than the radial transfer of heat through the wall of the tube. Thus, at a given location along the tube, temperature of the gas inside the tube is nearly the same as that of the gas just outside the tube, and the travel times of the pulses give good indications of the local temperatures in the gas just outside the segments of the tube.

This work was done by Shakkottai Parthasarathy and Shakkottai P. Venkateshan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 91 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-17007, volume and number of this NASA Tech Briefs *issue, and the page number.*

Phase-Modulation Gas-Correlation Spectroscopy

Features include high spectral discrimination and sensitivity.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electro-optic phase-modulation gas-correlation spectroscopy has been demonstrated in laboratory tests to be a promising candidate technique for remote sensing of gases, temperatures, and wind velocities in the atmosphere. In this technique radiation emitted by the sample atmosphere is passed through an electro-optic phase modulator, and the modulated and unmodulated versions of the spectrum are alternately passed through a reference absorption cell containing the gas to be detected. The radiation emerging from the reference cell is band-pass filtered and detected. The correlation signal is the difference in intensity between the phase-modulated and unmodulated detected signals.

The phase modulation redistributes the emission spectrum into upper and lower sidebands displaced from the original spectral lines by integral multiples of the modulating frequency. Emission or absorption lines in the modulated sample spectrum that correlate with absorption spectral lines of the gas in the reference cell alter the power transmitted to the detector. Thus, the measurement is most sensitive to the spectrum in the input radiation corresponding to the species contained in the reference cell.

The laboratory prototype system shown in Figure 1 has been used to measure part of the infrared spectrum of N_2O. Blackbody radiation from a glow bar at a temperature of 1,000 K is chopped mechanically at a rate of 500 Hz and passes through a 1-cm-thick cell containing the N_2O sample gas. The radiation, which now contains an N_2O absorption spectrum, passes through an electro-optic phase modulator and through a 1-cm-thick reference cell containing N_2O.

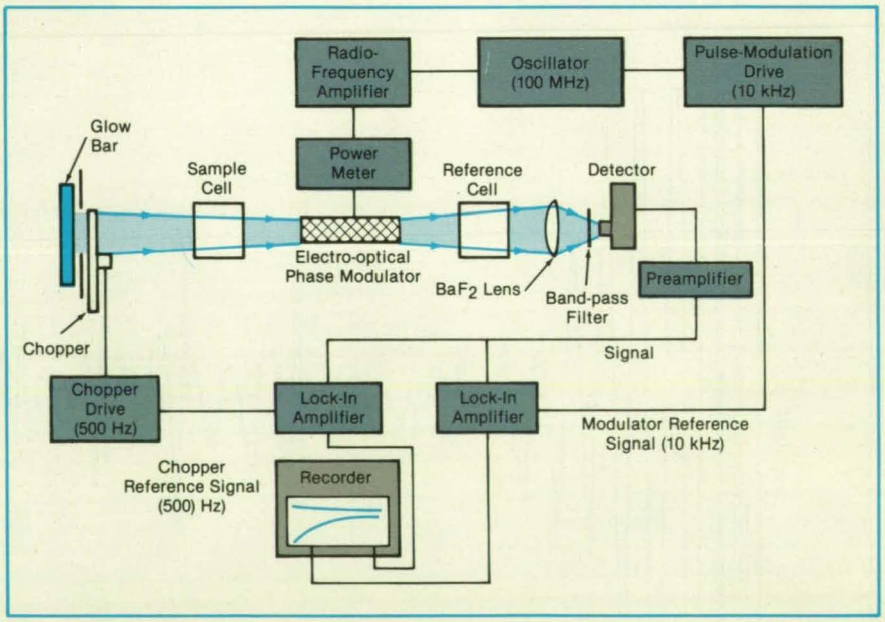

Figure 1. This **Laboratory Prototype System** was used to demonstrate electro-optical phase-modulation gas-correlation spectroscopy.

The modulator, a crystal of CdTe, is activated and deactivated by turning a 15-W, 100-MHz modulating signal on and off at a repetition rate of 10 kHz. A lock-in amplifier synchronized to the 10-kHz signal processes the detector output to obtain the correlation signal. Another lock-in amplifier synchronized to the mechanical chopper processes the detector output to obtain a

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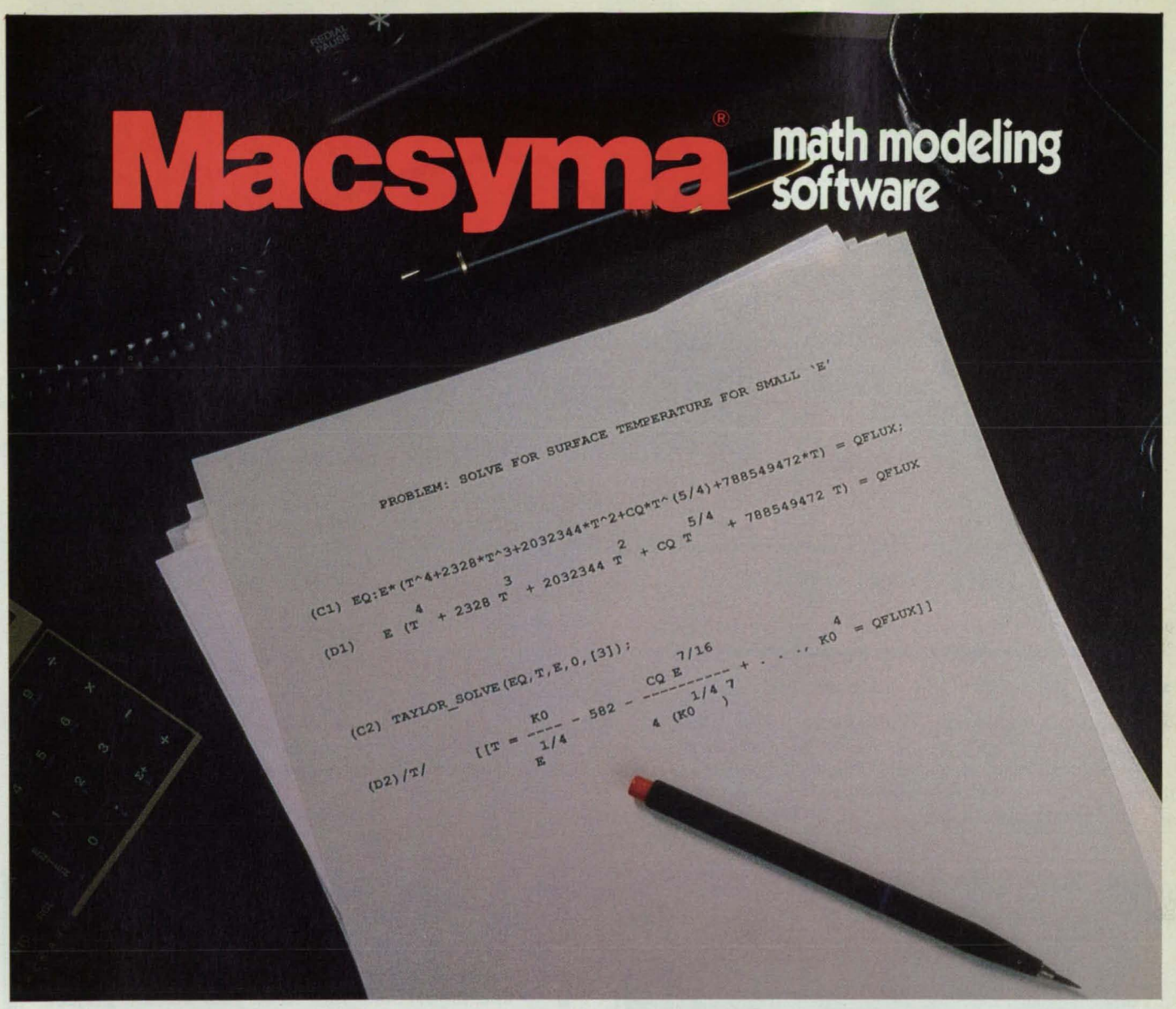

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measure of the total radiant energy transmitted through the system.

The system was tested at various pressures of N_2O in the sample and reference cells from 0 to 10 torr (0 to 1.3 kPa). The measurements showed that as the pressure in the sample cell rises (at a given fixed pressure in the reference cell), the correlation signal first increases, then levels off to a maximum, then decreases. The experimental and theoretical correlation curves were in excellent agreement (see Figure 2).

This work was done by David M. Rider, John T. Schofield, Jack S. Margolis, and Daniel J. McCleese of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 136 on the TSP Request Card.*

NPO-17013

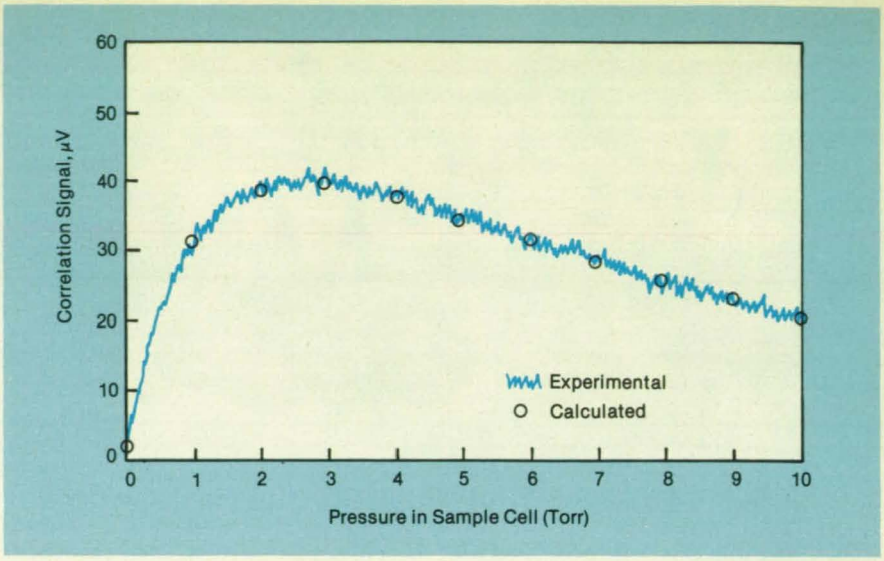


Figure 2. The **Correlation Signal** was measured and calculated as a function of the pressure of the N_2O gas in the sample cell of the system of Figure 1. For this set of data, the pressure in the reference cell was 1 torr (130 Pa).

Electrolytic Heat Switch

Thermal conduction is altered electrically.

Marshall Space Flight Center, Alabama

Experiments have demonstrated the feasibility of an electrolytic device of electrically-controllable thermal conductivity. The investigation continues in the effort to develop a thermal switch that will be lightweight, less than 1 cm thick, and easily integrable into existing heat-transfer systems, and that will consume minimal electric power while switching between the "off" state (low thermal conductance) and the "on" state (thermal conductance 10 times that of the "off" state).

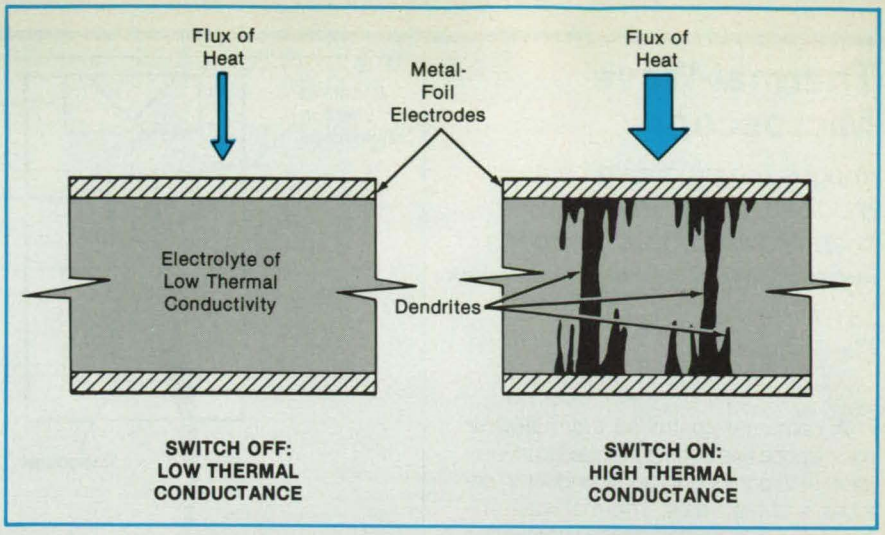
The device includes an inner ionomeric layer of low thermal conductivity sandwiched between two metal-foil electrodes (see figure). When the device is fully developed, the ionomeric layer will likely be a conductive polymer — perhaps polyaniline. In effect, the device will be a metal/conductive-polymer secondary electrical cell.

The electrical charging of this cell causes

metal dendrites to grow from the foils across the inner layer by the deposition of ions from the electrolyte. Because the thermal conductivity of the metal is much greater than that of the ionomer, the overall thermal conductance of the device decreases as the dendrites grow across the inner layer.

The useful lifetime and operating characteristics of the device depend on many factors that interact with each other. Of primary concern is that the metal deposits be dendritic rather than spongy or densely-packed, smooth layers of crystals. The properties of the metal deposits are affected by the temperature, current density, type and concentration of electrolyte, the type of ionomer, the type of filler material (if any) in the inner layer, and the sizes, shapes, and materials of the electrodes.

As experience was gained during the early experiments, the device evolved through several versions. Because the solid electrolyte was not sufficiently developed for thermal tests, the cells were made with liquid electrolytes filled with porous polymeric materials to reduce thermal conduction and to suppress convection in the electrolytes, which also contributes to the transport of heat. In addition, the anodes were covered by perfluorinated cationic membranes (of a type used as a separator in silver oxide batteries) to assure the reversibility of the electrochemical reactions by preventing the dendrites from penetrating to the anode and thereby causing electrical short circuits.



The **Flow of Heat** across the electrolytic heat switch is increased or decreased by the electrochemical deposition or dissolution, respectively, of highly-thermally-conductive metal dendrites across the thermally insulating layer of electrolyte.

The design selected for thermal tests included silver electrodes, an electrolyte of silver nitrate in water, and a filler of polypropylene felt. In the tests, the thermal conductivity of the device was increased 21 percent by the deposition of silver dendrites in the inner layer. There is hope for considerable improvement because, according to the projections of a mathematical model, silver dendrites occupying only 1 percent of the area of a cell should increase the thermal conductance by a factor of 10. Furthermore, using data from experiments in electrochemical jigs, it is estimated that the power necessary to operate a typical cell of 20 by 20 cm will be only 2.5 W.

This work was done by Myles Walsh, Gregory D'Andrea, Joseph Adelstein, Brian G. Dixon, and R. Scott Morris of Cape Cod Research for **Marshall Space Flight Center**. *For further information, Circle 118 on the TSP Request Card.*
MFS-26074

Thermal-Wave Microscope

Images are produced by a modified computer-controlled scanning electron microscope.

Lewis Research Center, Cleveland, Ohio

A computer-controlled thermal-wave microscope has been developed to investigate III-V compound semiconductor devices and materials. Thermal-wave microscopy is a nondestructive technique that can provide information on subsurface thermal features of solid samples. Furthermore, because this is a subsurface technique, three-dimensional imaging is also possible.

Thermal-wave imaging is performed with a modified scanning electron microscope (see Figure 1). An intensity-modulated electron beam generates thermal waves in the specimen. The modulation frequency is typically in the range of 0.1 to 10 MHz.

The thermal waves generated by the electron beam are critically damped, but they interact with thermal features in the specimen. The thermal waves are not detected directly. Instead, the acoustic waves generated by the thermal waves are detected by an acoustic transducer glued to the sample. The transducer signal is amplified and fed to a lock-in amplifier before undergoing analog-to-digital conversion. The image is built up point by point as the electron beam is indexed through a raster of points under the control of the computer. The software that controls the scanning electron microscope and handles the image data was written in FORTRAN 77.

Thermal-wave microscopy is limited by low signal levels, extremes in signal contrast, and poor edge definition. However, once the image data are in the computer, various digital techniques can be applied to enhance features of interest in the image. The resulting images can be fed back to the scanning electron microscope for display or can be stored on a magnetic disk.

Thermal-wave images of a stainless-steel specimen from a single image scan and from averages over 16 and 100 scans show the effectiveness of image averaging in reducing noise (see Figure 2). These images show a granular structure, whereas an ordinary secondary electron image of the same sample shows only the surface texture of the sample.

This work was done by Robert E. Jones, Ihor Kramarchuk, Wallace D. Williams, and John J. Pouch of **Lewis Research Center** *and Percy Gilbert of Purdue Uni-*

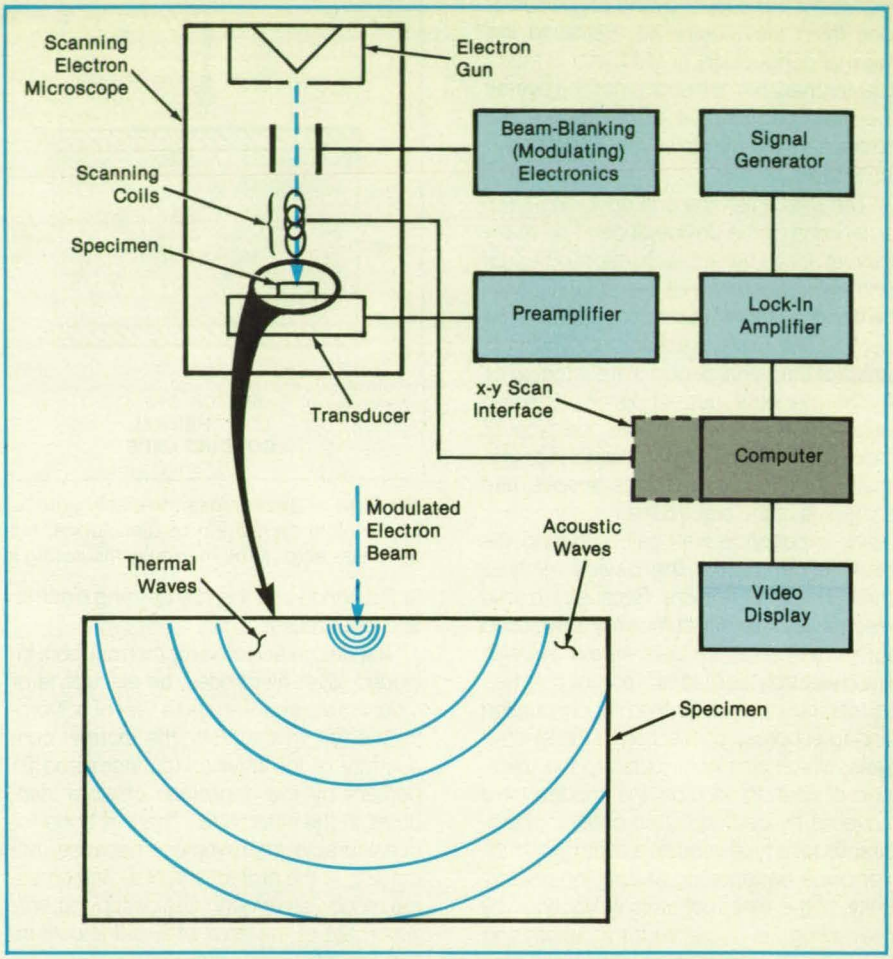


Figure 1. The **Thermal-Wave Microscope** uses an intensity-modulated electron beam of a modified scanning electron microscope to generate thermal waves in a sample. Acoustic waves generated by the thermal waves are received by a transducer and processed in a computer to form images that can be displayed on the video display of the microscope or recorded on a magnetic disk.

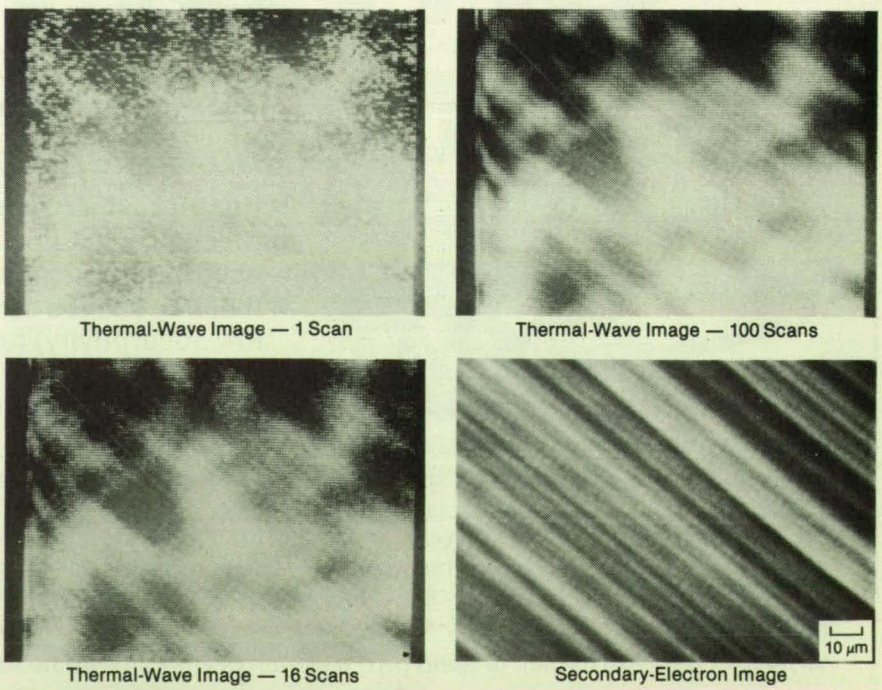


Figure 2. The **Noise in a Thermal-Wave Image** of subsurface grain structure of stainless steel is reduced by averaging over a number of scans. Also shown for comparison is a scanning electron micrograph, which shows the surface texture of the specimen but not the subsurface grain structure.

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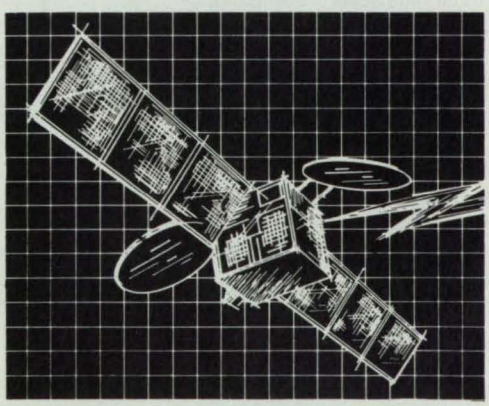

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versity. Further information may be found in NASA TM-100157 [N87-26278], "Computer Control of a Scanning Electron Microscope for Digital Image Processing of Thermal-Wave Images."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 87 on the TSP Request Card.
LEW-14740

Spectrograph Measures Contamination of Optical Elements

Reflectance and transmittance are measured over a range of wavelengths.

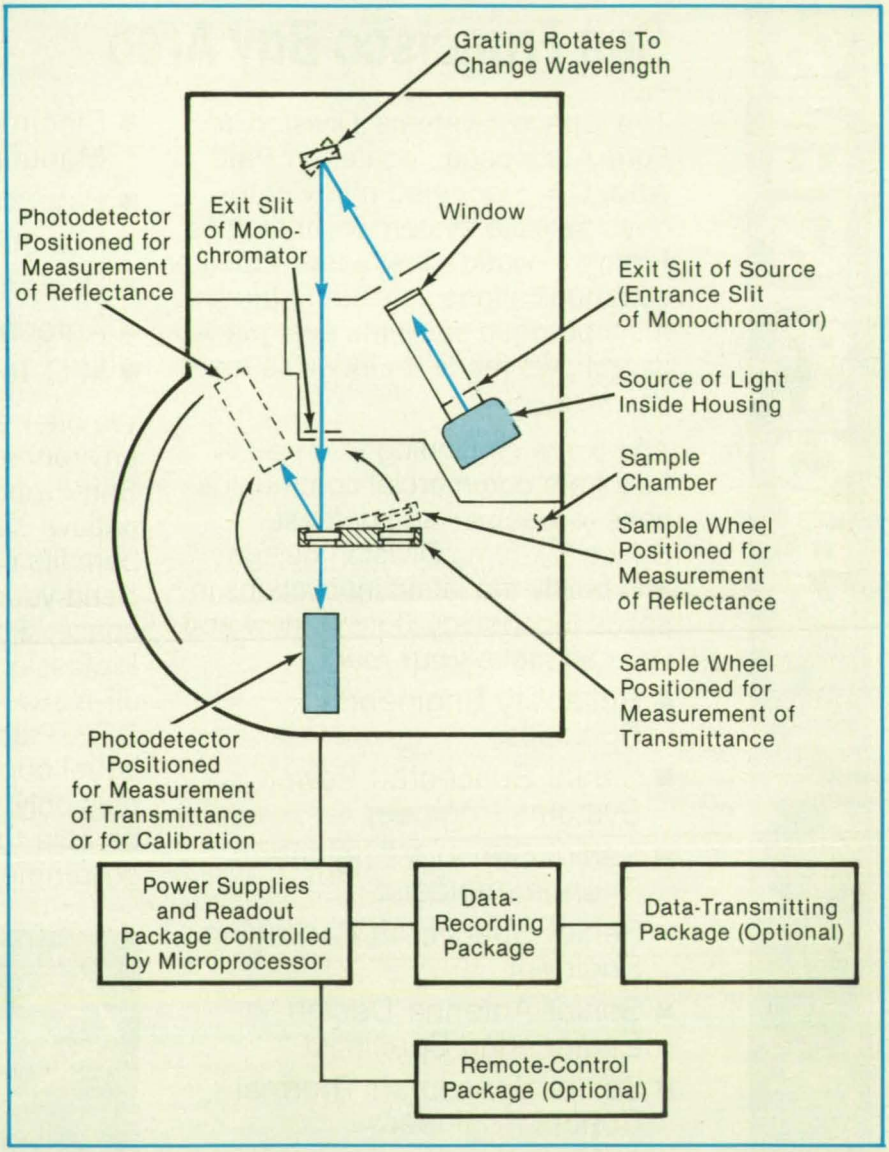
Marshall Space Flight Center, Alabama

A scanning-monochromator spectrograph has been designed to measure contamination on the surfaces of optical elements as a function of time. The spectrograph repeatedly exposes samples to the environment, then measures their transmittances or reflectances over a range of wavelengths. The spectrograph is intended for use at vacuum-ultraviolet wavelengths to evaluate the effects of outgassing, heating, and cooling on optical instruments. However, the principle of operation is also applicable to the spectral monitoring of time-dependent contamination at other wavelengths and in laboratory, industrial, or other settings.

The spectrograph (see figure) includes an intense source of light with an exit slit that serves as the entrance slit to the monochromator. For the vacuum-ultraviolet wavelength range, the source could be a deuterium lamp with a magnesium fluoride window. The slit is typically 1 mm wide. The ribbon-shaped beam of light emerging from the slit is dispersed in wavelength by a holographic grating, which is rotated to scan in wavelength or fixed in orientation to select a fixed wavelength that falls on the exit slit of the monochromator. A ribbon of light at the wavelength of interest emerges from the exit slit of the monochromator and travels toward the test position.

A wheel that holds several sample optical components rotates until the desired sample is at the test position. If the transmittance of the sample is to be measured, then the photodetector remains at the position shown in solid lines while the photodetector output is measured as a function of wavelength. For calibration, this measurement can be taken without any sample obstructing the light. If the reflectance of the sample is to be measured, the photodetector is rotated to the position shown by dashed lines, and the sample wheel is tilted to the position shown by dashed lines to reflect light toward the photodetector. When samples are not being tested, the sample wheel can be rotated to expose samples to the environment.

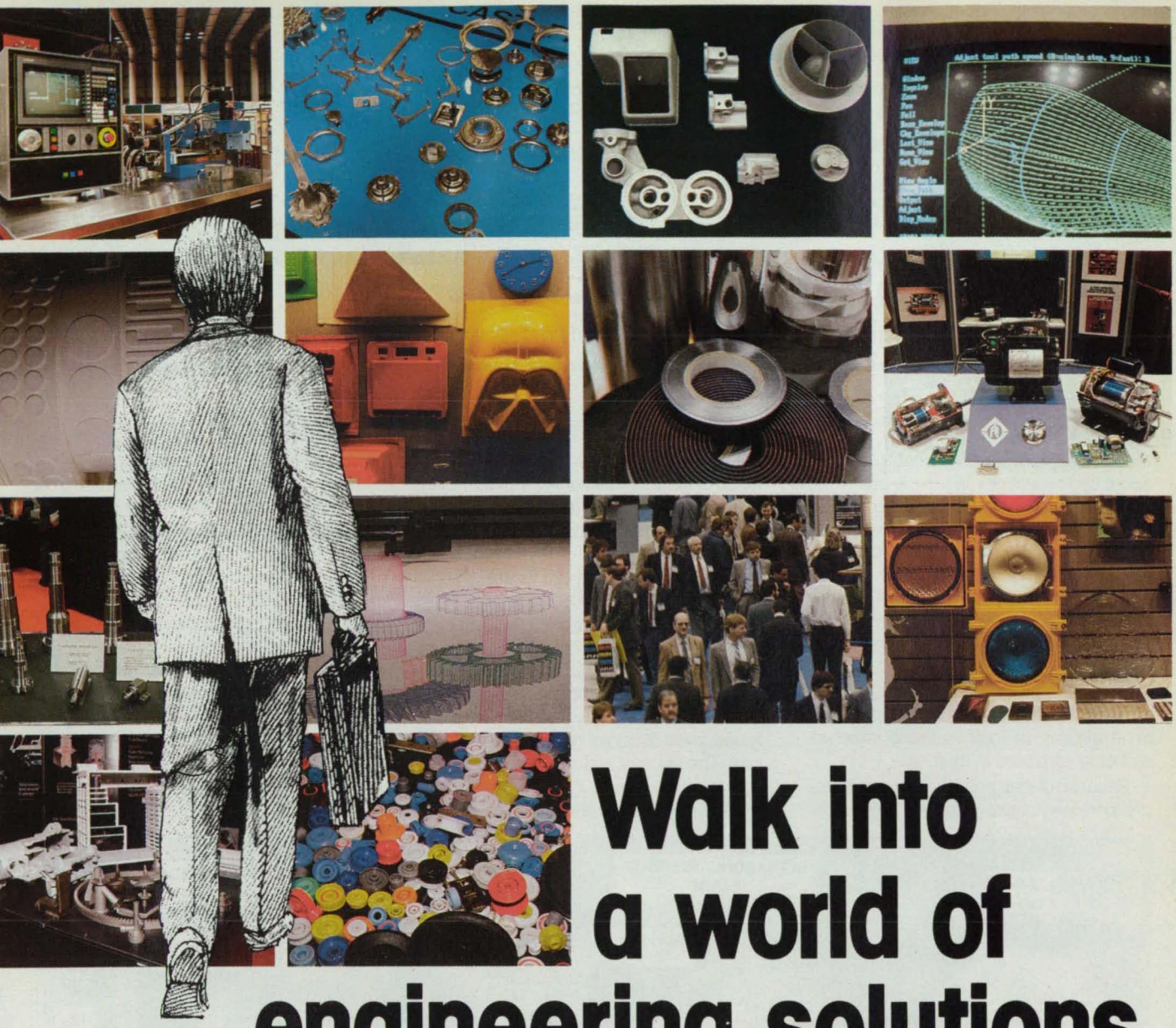
The grating, detector, and sample wheel are positioned by motors under the control of a microprocessor. The data on these positions and the photometer-output data are synchronized with time signals of the system and recorded together in an attached memory unit for subsequent processing. Alternatively, the spectrograph can be controlled remotely and/or the data can be transmitted to an external memory or processor.



The Contamination-Measuring Instrument contains a scanning-monochromator spectrometer that measures spectral reflectance or transmittance. This is one of several versions that differ with respect to the placement of samples, detectors, and/or auxiliary reflectors for the two kinds of measurements.

This work was done by Bruce K. Flint, Robert D. Fancy, and Robert V. Jarratt, Jr., of Acton Research Corp. for **Marshall Space Flight Center**. *For further information, Circle 20 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 22]. Refer to MFS-26076.



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Materials

Acoustical Imaging of Defects in Ceramics

Ultrasound is superior to x rays in the detection of microporosity.

Lewis Research Center, Cleveland, Ohio

To date, the strengths of sintered ceramics (e.g., SiC) vary significantly and are about two orders of magnitude below the theoretical strengths. Adding to the problem is the fact that the fracture strengths of identically-produced experimental samples differ as much as 35 percent. These discrepancies are attributed to voids, inclusions, agglomerates, and anomalously large grains. These defects, which cause premature failures, are introduced or formed during the ceramic-manufacturing process. Considerable work has been done already to remove these strength-reducing variations in materials.

Because of their brittle nature, ceramics are extremely sensitive to even slight variations in microstructure. Direct observations have shown the importance of the kinds of defects mentioned above by identifying them as the sites of localized failures. These sites cannot be determined a priori by optical and x-ray methods. It seems plausible that these failure-causing variations do not occur spontaneously in isolation but are the result of the history of variations in processing.

Color images obtained from precise acoustic measurements reveal subtle variations in the porosity fractions and the mean sizes of pores in ceramics (see figure). The velocity and attenuation of ultrasound have been found to be related directly to the density and mean size of the pores, respectively. These variations are unobservable in x-ray analysis.

This work was done by Edward R. Generazio, Don J. Roth, and George Y. Baaklini of **Lewis Research Center**. *Further information may be found in NASA TM-100129 [N88-15257], "Imaging Subtle Microstructural Variations in Ceramics with Precision Ultrasonic Velocity and Attenuation Measurements."*

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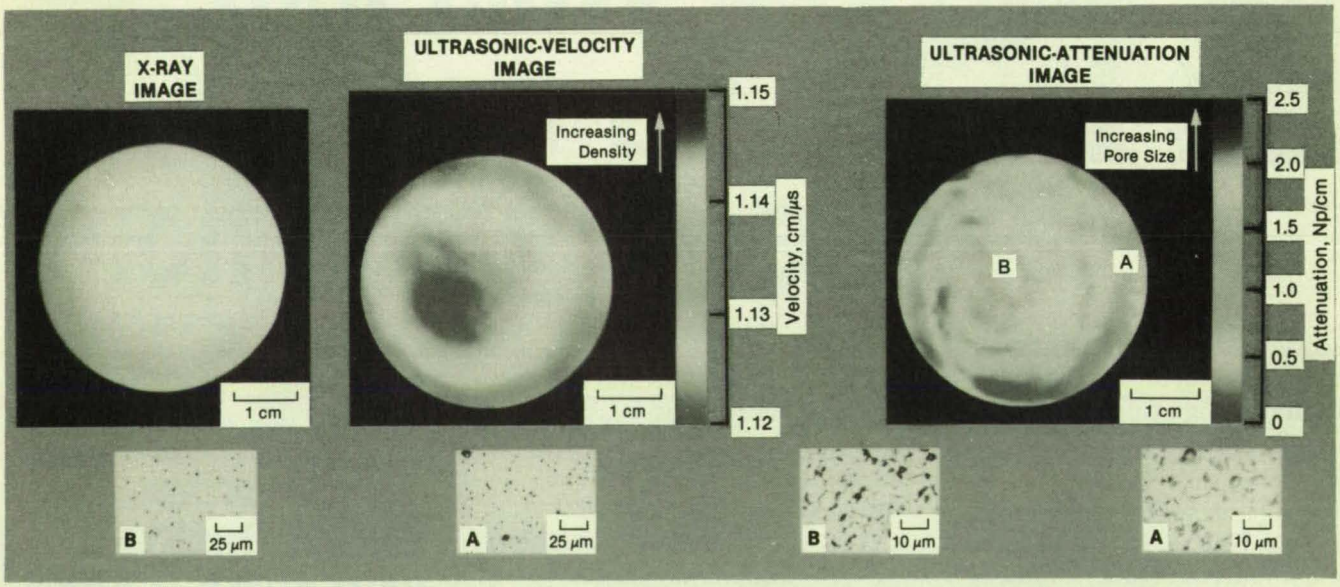
LEW-14747



Ultrasonic Imaging is more sensitive than x-ray imaging in the detection of subtle variations in the porosity of a specimen of ceramic.

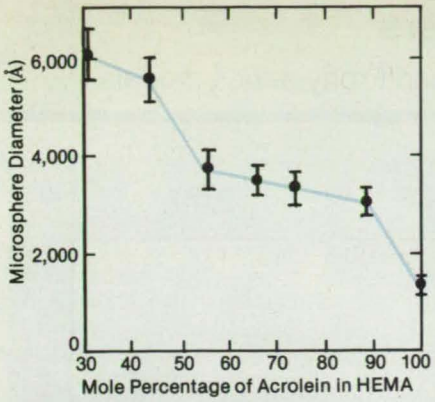
Nonaggregating Microspheres Containing Aldehyde Groups

Aggregation is avoided by irradiating hydrophilic monomers in the presence of acrolein.

NASA's Jet Propulsion Laboratory, Pasadena, California

Cobalt gamma irradiation of hydrophilic monomers in the presence of acrolein yields exceptionally-stable, nonaggregating microspheres. Previous microspheres containing aldehyde groups (such as polyglutaraldehyde microspheres) tended to aggregate during reaction with amines and proteins.

Mixtures of 2-hydroxyethyl methacrylate (HEMA) and acrolein form homogeneous solutions in distilled water containing 0.4 percent polyethylene oxide (PEO). After



Microsphere Diameter is an inverse function of HEMA/acrolein ratio, but the variation is slight in the range from about 60 to 90 percent acrolein. Therefore microspheres can be prepared with similar size but different hydrophobicity.

deaeration with nitrogen, the mixtures are irradiated at room temperature with gamma rays from a cobalt source; total exposure time is 4 hours, at a rate of 0.2 milliroentgen per hour. The reaction product is centrifuged three times for purification and is kept in distilled water.

The irradiation of pure acrolein in water containing PEO produces colloidal particles approximately 1,000 Å in diameter. Adding HEMA increases the diameter of the microspheres; but, as the figure shows, variation is slight in the middle range of monomer ratios. Therefore microspheres can be prepared with similar size but different degrees of hydrophobicity.

To produce cross-linked microspheres containing acid functions, N, N'-methylene-bis-acrylamide and methacrylic acid are added to the HEMA/acrolein polymerization mixture. The size characteristics of the cross-linked microspheres closely approximate those in the figure. Seven of these preparations were analyzed for the presence of aldehyde groups. The acrolein homopolymer was found to contain approximately 65 percent of the expected aldehyde groups.

This work was done by Alan Rembaum of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 95 on the TSP Request Card.*

Title to this invention, covered by U.S. Patent No. 4,413,070, has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)]. Inquiries concerning licenses for its commercial development should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125

Refer to NPO-15459, volume and number of this NASA Tech Briefs *issue, and the page number.*

Calculating Dynamic Shear Moduli of Polymers

A nonlinear mathematical model replaces oversimplified linear and Prony-series models.

Marshall Space Flight Center, Alabama

An improved nonlinear mathematical model has been developed to fit experimental data on the relaxation of stresses in viscoelastic materials. The model, which was developed specifically to study the shear moduli of rubbery solid rocket propellants, can also be used to characterize polymers in general, other viscoelastic materials, and composites of viscoelastic materials. It can facilitate and improve the accuracy of analysis and numerical simulation of the mechanical behavior of structural components (for example, tires) made of such materials.

Plots of the shear modulus as a function of time have been fitted by such models as piecewise-linear approximations, power laws, and Prony series. These models do not represent the data accurately over the full range of times (see figure) and do not account adequately for the effects of temperature, strain, and rate of strain. The new model provides the flexibility to fit a wide range of experimental data by expressing the shear modulus as a sum of terms, each of which is a product of other terms. One form of the model, which is likely to be used widely, is

$$G = G_{static} + G_{dynamic}$$

where G = the shear modulus.

In a typical case, the static term would be a constant, while the dynamic term would be given by

$$G(t,T,\varepsilon,\dot{\varepsilon})_{dynamic} = M(t)M(T)M(\varepsilon)M(\dot{\varepsilon})$$

where t = time, T = temperature, ε = strain, and $\dot{\varepsilon}$ = rate of strain. Each of the multiplicative terms could have either of two forms:

$$M(X) = C_1\beta_m(X) \text{ or}$$

$$M(X) = C_1\exp[C_2\beta_m(X)]$$

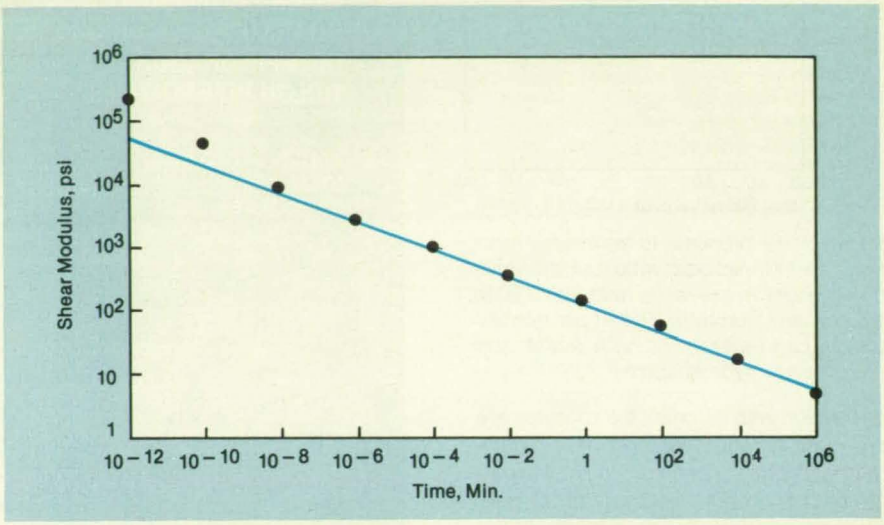
where

$$\beta_m(X) = \left\{\left[\sum_{i=0}^{m} C_{Ni}(X - X_R)^i\right] \Big/ \left[\sum_{j=0}^{m} C_{Dj}(X_o - X_R)^j\right]\right\}^{P_X}$$

where X_o may equal X or an original value of X; X_R is a reference value of X; and C_{Ni}, C_{Dj}, and P_X are constants. For example, the temperature multiplier might be given by

$$M(T) = C_1\exp\{C_2[-C_3(T-T_R)/(C_4+T-T_R)]^{P_T}\}$$

The further development and verification of the new model depend on detailed and consistent tests of specimens of the material in question.



These **Experimental Stress-Relaxation Data** can be fitted fairly well with a straight line at times greater than 10^{-6} min. However, the data diverge from the line at shorter times, necessitating the use of a different mathematical model.

This work was done by Carleton J. Moore of **Marshall Space Flight Center**. *For further information, Circle 135 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 22]. Refer to MFS-28340.

Multiple-Purpose Rigid Foam Insulation

Properties can be adapted to a variety of demanding applications.

Marshall Space Flight Center, Alabama

A plastic foam promises to serve as a multiple-purpose thermal insulation. On the Space Shuttle (for which it was developed), the material can replace every insulating material on the external fuel tank, ranging from general surface insulation to ablative insulation on small areas subject to high aerodynamic heating. It can also be used on closeouts, ramps, and repairs. The material costs less than those currently used, but offers higher thermal resistance, greater strength, and lower weight.

The material is a rigid, closed-cell, thermally stable foam of urethane-modified isocyanate. It is made by reacting a polyol mixture with a polymeric diphenyl methane diisocyanate in the presence of a catalyst and a fluorocarbon blowing agent. Its properties can be customized for a particular application by adjusting the proportions of the ingredients in the polyol mixture.

The polyol mixture consists of a reactive flameproofing agent (15 to 30 percent by weight of the polyol mixture), a nonreactive flameproofing agent (10 to 40 percent), a nonhydrolyzable silicone copolymer (10 to 40 percent), and an amine-initiated polyether resin (3 to 16 percent). The catalyst consists of any two of the following compounds: a tertiary amine, an alkali metal salt organotin, or a quaternary ammonium salt.

The density of the cured insulation ranges from 2.4 to 3.5 lb/ft^3 (38 to 56 kg/m^3). Its flatwise tensile strength is 65 to 85 lb/in.^{2} (0.45 to 0.59 MPa) at room temperature. Its bond strength is 50 to 70 lb/in.^{2} (0.34 to 0.48 MPa). The material performed well in simulated ascent and reentry heating environments.

This work was done by Matthew T. Liu of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 122 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to the Martin Marietta Corp. Inquiries concerning licenses for its commercial development should be addressed to

Patrick M. Hogan
Assistant General Counsel Patents
Martin Marietta Denver Aerospace
P.O. Box 179
Denver, CO 80201

Refer to MFS-28264, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Polymer Lubricants for Use in Vacuum

Both solid and film polyimides offer low friction and wear.

A report describes tests of the lubricating properties of 10 polymer-based materials — in particular, polyimides — in vacuum. Lubricant researchers previously noticed that the friction and wear of some polyimide films had dropped dramatically when the materials were heated in air. They postulated that the improvement was due to the thermal desorption of water vapor. Because water vapor would desorb in vacuum even at low temperature, polyimides might be good candidates for vacuum lubricants.

Commercially available materials, in the forms of solid bodies and films on metals, were tested on a pin-on-disk apparatus in a vacuum. Similar tests were also done in an air atmosphere at 50 percent relative humidity.

The following materials were evaluated:

1. A polyphenylene sulfide (PPS) disk reinforced with 40 percent of graphite fibers;
2. A poly(amide/imide) disk with polytetrafluoroethylene (PTFE) and graphite-powder additives;
3. A commercial polyimide with no additives;
4. A PMR-15 polyimide with 70 percent of PTFE powder added;
5. A polyimide made from the diamine 2,2-bis [4-(aminophenoxy)phenyl]-hexafluoropane (4-BDAF) and pyromellitic acid dianhydride (PMDA) (for short this polyimide is called "100 PMDA");
6. A copolyimide made from 4-BDAF and a combination of 80 mole percent of PMDA with 20 mole percent of benzophenonetetracarboxilic acid dianhydride (BTDA) (for short denoted as 80 PMDA/20 BTDA);
7. An 80 PMDA/20 BTDA polyimide reinforced with 50 percent of high-modulus graphite fibers;
8. A film of 100 PMDA polyimide;
9. A film of PI-4701 polyimide; and
10. A film of PI-4701 polyimide with 50 weight percent graphite fluoride, a solid lubricant.

All the polymer materials except the 80 PMDA/20 BTDA polyimide with 50 percent graphite fibers and the 100 PMDA solid and film produced lower coefficients of friction in vacuum than in air. Only the polyimides without solid-lubricant additives showed substantially-lower steady-state wear rates in vacuum than in air.

The best low-wear, low-friction material was the 80 PMDA/20 BTDA solid-body polyimide. The friction and wear properties of most of the polyimides were so good in vacuum that solid-lubricant additives were not necessary. In fact, powdered solid-lubricant additives tended to produce weak points where cracks and spallation could start under sliding contact.

Polymers containing graphite fibers did not wear well in vacuum. The fibers on the surface tended to crack and debond during sliding.

Although the 100 PMDA polyimide produced high friction in vacuum, its wear was low. It therefore may be suitable for traction drives in vacuums.

This work was done by Robert L. Fusaro of **Lewis Research Center**. *Further information may be found in NASA TM-88966 [N87-17906], "Tribological Properties of Polymer Films and Solid Bodies in a Vacuum Environment."*

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LEW-14661

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Physical Sciences

Transferring Lens Prescriptions Between Lens-Design Programs

Most data are transferred automatically, and the user is notified of those that are not.

The Optical Lens Prescription Data Formatter computer program enables the user to transfer complicated lens prescriptions quickly and easily from one major optical-design program to another and back again. Thus, one can take advantage of the inherent strength of either program. The programs are ACCOS V from Scientific Calculations, Inc., of Fishers, NY, and CODE V from Optical Research Associates of Pasadena, CA.

The translation program works quite well for most lens prescriptions. On all tested lenses, it correctly translates the radii, thicknesses, polynomial aspheric data, tilts, decenters, and aperture sizes of the lenses. Limitations occur for special types of surfaces and some data pickups because the design programs are not fully equivalent. In these cases, the translation program translates all the data it can and prints comments mentioning the rest. The user can then manually adjust the lens to model the system correctly.

This program is available in two machine versions: PRIME and DEC VAX. The PRIME version is written in FORTRAN and requires approximately 64K of 8-bit bytes. The VAX version is written in FORTRAN and requires 64K of 8-bit bytes but has been fully tested in only one direction — ACCOS V to CODE V. At some installations, differences in lens-data files may require modification of format statements. The program was released in 1987.

This program was written by John E. Stacy of Caltech, Laura Wooley of the University of Rochester, and Brian Carlin of Santa Barbara Research Center for **NASA's Jet Propulsion Laboratory**. *For further information on PRIME version, Circle 158 on the TSP Request Card.*
NPO-17092

For further information on VAX version, Circle 157 on the TSP Request Card.
NPO-17093

Isothermal-Gas-Transfer Program

One or two tanks with or without venting or consumption can be simulated.

The Isothermal Gas Transfer program (GASXFER) solves a variety of problems in which a gas or gas mixture is transferred between two containers. The model is general in nature, consisting of an upstream tank and a downstream tank. As many as three different feed gases may be combined in the upstream tank. Downstream flow may be defined either as constant, dependent on the size of the orifice, or variable in such a way that constant pressure is maintained in the upstream tank. The program assumes isothermal flow and isothermal conditions within the tank.

The program can simulate a single tank by setting the volume of the downstream tank either to zero (no vent flow) or to infinite volume, which simulates venting into an environment of constant pressure or a vacuum. In addition to adjusting the volume of the containers, the user may also adjust the feed. For example, the feed gas-

es can be used to simulate a purge of the upstream tank. In another combination, the feed gases may be used to simulate a life-support system in the cabin of a spacecraft. The three feed gases in this case would then consist of oxygen, nitrogen, and either carbon dioxide or water vapor, where the negative value of oxygen feed simulates consumption by the crew.

Special features of the program include its ease of entering data and ease of obtaining output. The program displays, prints, or graphs a complete pressure history of each gas as a function of time.

GASXFER was written in the Lotus Symphony macrolanguage as implemented on the IBM PC-series computers. It requires a fixed disk and at least 384K of random-access memory and Lotus Symphony 1.0 or greater. The program was released in 1988.

This program was written by Don I. Levine of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 11 on the TSP Request Card. MSC-21400*

Mechanics

Simulation of Satellite Trajectories and Navigation

Gravitational, radiational, and atmospheric effects are taken into account.

The Orbit Analysis and Simulation Software, OASIS, is a software system developed for covariance and simulation analyses of problems involving Earth satellites, especially the Global Positioning System (GPS). It provides a flexible, versatile, and efficient software tool for the analysis of accuracy in Earth-satellite navigation and GPS-based geodetic studies. To make future modifications and enhancements easy, the system is modular, with five major modules: PATH/VARY, REGRES, PMOD, FILTER/SMOOTHER, and OUTPUT PROCESSOR.

PATH/VARY generates trajectories of the satellites. Among the factors taken into consideration are the following: (1) the gravitational effects of the planets, Moon, and Sun; (2) the orientations and shapes of the space vehicles; (3) solar pressure; (4) solar radiation reflected from the surface of the Earth; (5) atmospheric drag; and (6) leaks of gas from the space vehicles. The REGRES module reads the user's input, then determines whether a measurement should be made based on geometry and time. PMOD modifies a previously-generated REGRES file to facilitate various analyses. FILTER/SMOOTHER is especially suited to a multisatellite precise determination of orbit and geodetic-type problems. It

can be used for any situation where parameters are simultaneously estimated from measurements and a priori information. Examples of nonspacecraft areas of potential application might be very-long-baseline interferometry geodesy and radio-source-catalog studies. OUTPUT PROCESSOR translates covariance analysis results generated by FILTER/SMOOTHER into easy-to-read quantities desired by the user, performs mapping of orbit covariances and simulated solutions, transforms results into different coordinate systems, and computes postfitted residuals.

The OASIS program was developed in 1986. It is designed to be implemented on a DEC VAX 11/780 computer using VAX VMS 3.7 or higher. It can also be implemented on a Micro VAX II, provided that sufficient disk space is available.

This program was written by Sien-Chong Wu, William I. Bertiger, James S. Border, Stephen M. Lichten, Richard F. Sunseri, Bobby G. Williams, Peter J. Wolff, and Jiun-tsong Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 139 on the TSP Request Card.* *NPO-17442*

Mathematics and Information Sciences

Monitoring the Execution of a VAX Image

The time spent in each subroutine is displayed.

The computer program PROCSCAN was developed to monitor the profile of an executable image during execution. The purpose is to identify the routines in which a program is spending most of its time. Thus, PROCSCAN can be a very useful first step in the optimization of a program.

PROCSCAN samples the program counter of the executing image and compares its value to a table of entry-point addresses to determine which subroutine is executing. The table of subroutines in the image is generated by the program SCANEXE (NPO-17298), which is included with this program, but is also available from COSMIC as a separate package. The output from PROCSCAN is a sorted histogram of subroutines versus time spent in each subroutine.

Because of the number of data collected, it is not possible to sample the program counter every time it changes, so the data represent a proportionate sampling of where the program is spending its time. During a few minutes of operation of a central processing unit, a fairly accurate picture can be formed. If a program has been linked with the /NOTRACEBACK qualifier, or it calls routines contained within a sharable library, then PROCSCAN will not function.

The program is written in C (77 percent), Assembler (13 percent), and FORTRAN 77 (10 percent) for execution on a VAX 11/780 computer operating under VMS 4.X with a central-memory requirement of 33,280 bytes. The program was developed in 1987.

This program was written by Peter J. Scott of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 59 on the TSP Request Card.*
NPO-17297

Building Mathematical Models of Solid Objects

Models are assemblies of primitive parts.

The Solid Modeling Program (SMP) version 2.0 provides the capability to model complex solid objects mathematically through the aggregation of geometric primitives (parts). The system provides the designer with a basic set of primitive parts and the capability to define new primitives.

Six primitives are included in the present version: boxes, cones, spheres, paraboloids, tori, and trusses. The user defines a primitive part by specifying the dimension and construction attributes required by a given type of part. By variation of the construction attributes for certain primitives, numerous additional shapes can be represented. For example, a cylinder is a special case of a frustum of a cone of which both radii are equal.

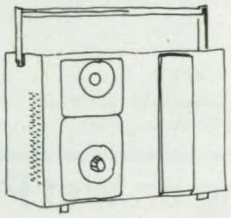
In addition to the construction of solid models, SMP has extensive facilities for the editing, display, and analysis of mathematical models. The geometric model produced by the software system can be put out in a format compatible with such existing analysis programs as PATRAN-G. SMP provides a facility for approximating the mass properties of the resulting solid model. Because of the association of SMP with the design of spacecraft, the calculations of mass properties are expanded to include approximations of projected areas.

SMP runs interactively on a VAX computer under VMS and is written in VAX/VMS FORTRAN 77. Several commercial libraries are required: LASSLIB & RIMLIB from Boeing's RIM library and the PLOT/10 Tektronix TCS library. A minimum available disk quota of about 15,000 blocks is required. The program was developed in 1986.

This program was written by Donald P. Randall, Kennie H. Jones, William H. von Ofenheim, Raymond L. Gates, and Christine G. Matthews of Computer Sciences Corp. for **Langley Research Center**. *For further information, Circle 161 on the TSP Request Card.*
LAR-13803

Two Leak Detectors for the Price of One!

Theirs



+

Theirs

= Ours

Until now, if you needed both fast general purpose and hydrocarbon-free leak detection, you had to buy two leak detectors: a reverse flow unit for fast cycle testing with high sensitivity at rough vacuum pressures, and a "conventional" unit for testing clean systems or parts.

The new HLT150 from Balzers is the first and only portable helium leak detector that does both. A new Turbo Reverse Flow™ dual inlet design (patent pending) gives you the versatility you want in a single compact, easy to use unit. Balzers has redefined the state of the art in leak detection to give you two leak detectors in one.

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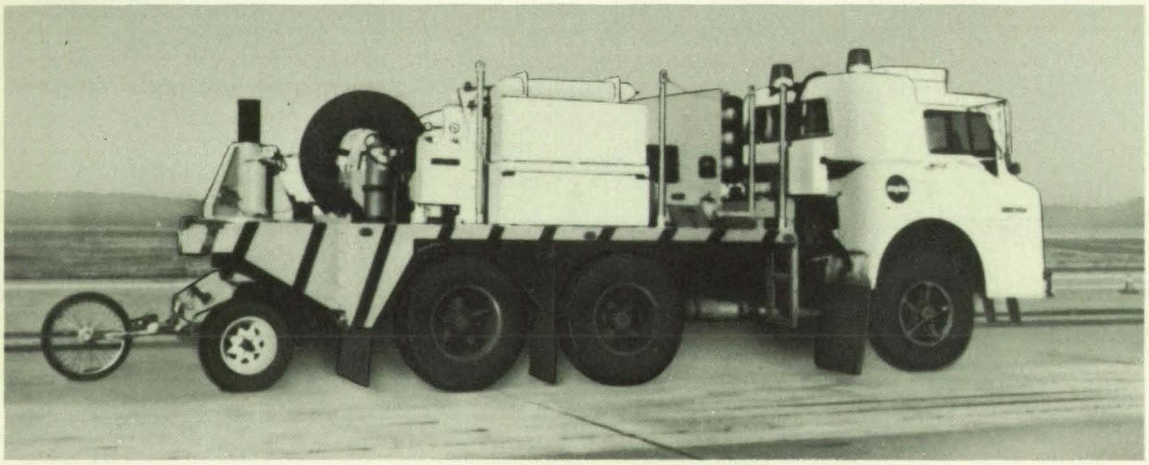
Mechanics

Tire Footprint Affects Hydroplaning on Wet Pavement

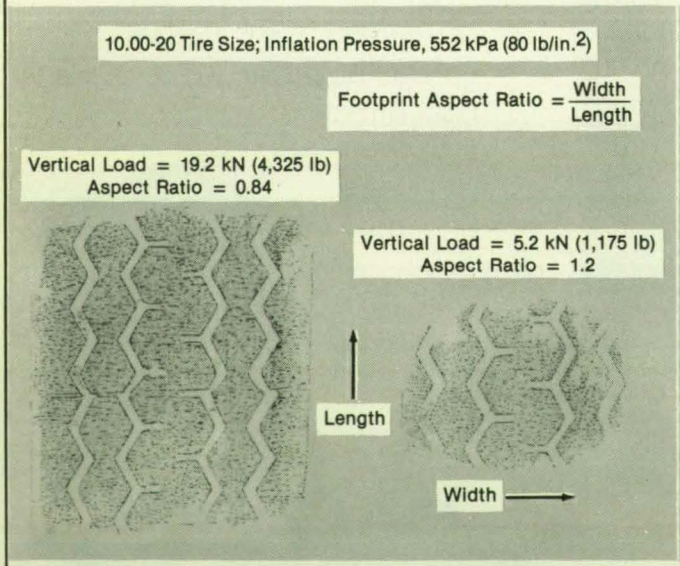
Higher aspect ratio of the tire footprint requires slower speed for safer driving on wet roads.

Langley Research Center, Hampton, Virginia

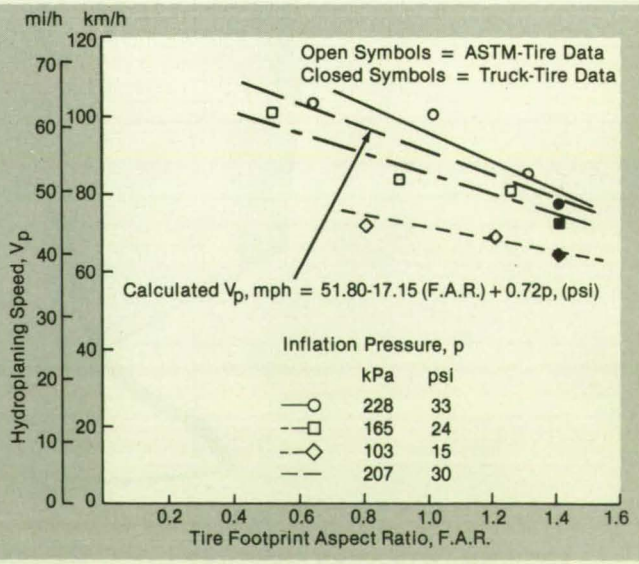
Recent investigations of tire hydroplaning at highway speeds reveal that, in addition to the inflation pressure, the tire-footprint aspect ratio (FAR), defined as the width divided by the length of the tire surface in contact with the pavement, significantly influences the speed at which dynamic hydroplaning begins. Various tire tests were conducted on flooded surfaces through a range of speeds, inflation pressures, and vertical loads using tires mounted on the instrumented tire-testing vehicle shown in the figure. Tests were conducted at constant speeds on ASTM E-501 grooved and E-524 smooth automotive tires. A com-



INSTRUMENTED TIRE-TESTING VEHICLE



TRUCK-TIRE FOOTPRINTS



VARIATION OF TIRE-HYDROPLANING SPEED WITH FOOTPRINT ASPECT RATIO

HIGHWAY-VEHICLE TIRE-HYDROPLANING-SPEED STUDY

Automotive-Tire-Footprint Aspect Ratio is a significant factor in the hydroplaning of the tire, as indicated by the results of tests on a highway vehicle.

bination of different tire-inflation pressures and vertical loads produced a large range of FAR's for evaluation under free and yawed rolling-test conditions. Tire speeds and forces developed during the tests of up to 65 mi/h (105 km/h) were monitored on the flooded test surface to identify the development of hydroplaning.

The study was focused on automotive tires because the FAR's of automotive tires vary more than those of aircraft tires. Although footprint widths of automotive tires remain nearly constant, their lengths, and therefore the FAR's, vary significantly under different loading conditions — the greater the load, the smaller the FAR. Footprints of aircraft tires vary with the loading in both dimensions, resulting in a relatively small range of FAR's.

An empirical equation has been formulated to predict highway speeds at which hydroplaning begins for different FAR's. The equation reveals that hydroplaning begins at lower speeds with increasing FAR's, whereas previous studies indicated that hydroplaning was solely a function of tire-inflation pressure. During wet weather, therefore, drivers of lightly loaded vehicles are riding on increased FAR's and should be particularly alert to prevent hydroplaning at lower speeds.

Additional tests are planned to refine and substantiate further the dependence of the hydroplaning of tires upon the FAR's. These tests will evaluate an expanded range of the FAR's and enable the assessment of such other parameters as the net bearing pressure and the construction of the tire on the tire-hydroplaning-initiation speed.

This work was done by Thomas J. Yager of **Langley Research Center**. *For further information, Circle 69 on the TSP Request Card.*
LAR-13683

Miniature Flow-Direction/Pitot-Static Pressure Probes

Probes measure the directions and pressures of hypersonic flows at temperatures up to 500°F.

Langley Research Center, Hampton, Virginia

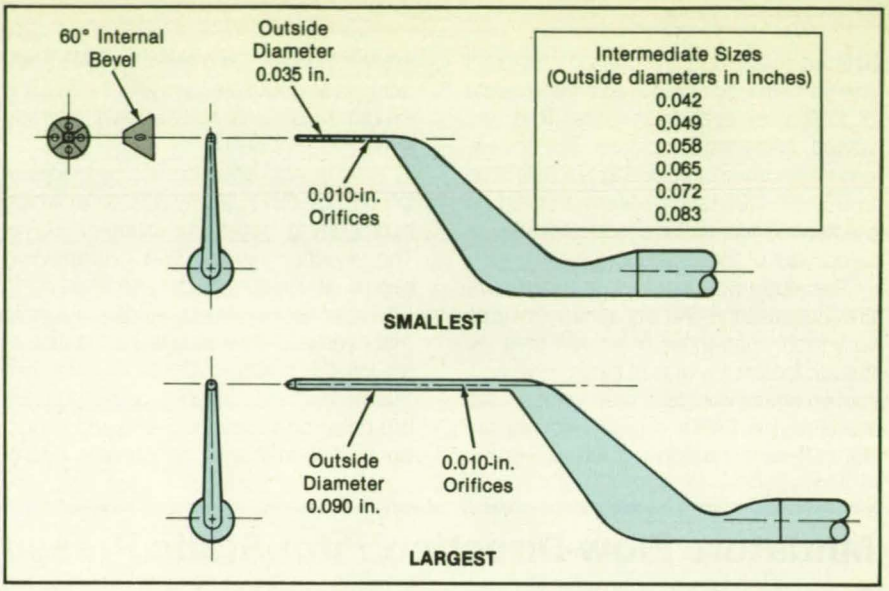
Precision flow-direction/pitot-static pressure probes, ranging from 0.035 to 0.090 inch (0.89 to 2.29 mm) in outside diameter, have been successfully fabricated and calibrated for use in the Langley 20-inch Mach 6 Tunnel. The probes will simultaneously measure the flow direction and the static and pitot pressures in flow fields about configurations in hypersonic flow at temperatures up to 500 °F (260 °C).

The probe design incorporates a combination of a "pyramid" flow-direction probe, which has four raked-back tubes 90 ° apart around a flat-face tube and a pitot-static pressure probe. The latter consists of a central tube inside an encasing tube that has 4 equally spaced static-pressure orifices with outside diameters of 0.01 inch (0.25 mm), 10 or more tube diameters downstream of the nose. An equal distance was allowed behind the orifices, between them and the wedge-shaped "gooseneck," to avoid feedback from the

wedge pressure field. The probe was made as small as possible to minimize intrusive interference. The center tube was beveled internally at 60° to reduce its sensitivity to the angularity of the flow.

The probe with the 0.035-inch (0.89-mm) outside diameter had the minimum size that could accommodate a bundle of five pieces of the smallest available tubing [0.008-inch (0.20-mm) outside diameter] together with the four alignment spacers. The other sizes (see figure) were constructed because the "pressure-settling" time varied inversely with the probe size and could be prohibitively long at the smallest probe sizes. The progressively increasing probe sizes ensure that the best compromise between the probe size and "pressure-settling" time, relative to the operating time limits of the tunnel, can be made.

For calibration, the probes were mounted in a calibration fixture and pitched through ±20° and sideslipped through ±8°. Because of instrumentation and mounting problems, complete calibrations were obtained only for those probes having outside diameters of 0.090 inch (2.29 mm) and 0.083 inch (2.10 mm). A partial calibration of the 0.042-inch-(1.07-mm-) outside-diameter probe was obtained. A least-squares fit to the calibration data is within ±1° and, in most cases, within ±0.5°.



The **Outer Tube Serves as the Housing** for the static ports and as a casing for five inner tubes that are used to measure the direction and pitot pressure of the flow.

The calibrations of the two larger probes were nearly coincident, and calibration of the smaller probe had the same slope as that of the larger probes. This leads to the conclusion that all of the probes, regardless of size, would have the same calibration slope, and that a single equation (wherein the pressure-difference parameters for each probe at 0° pitch and sideslip would be input constants) could be used to determine the flow angles from the flow measurements of any of the probes.

This work was done by George C. Ashby, Jr., David S. Coombs, John W. Eves, Howard E. Price and Peter Vasquez of **Langley Research Center**. *For further information, Circle 25 on the TSP Request Card.* *LAR-13643*

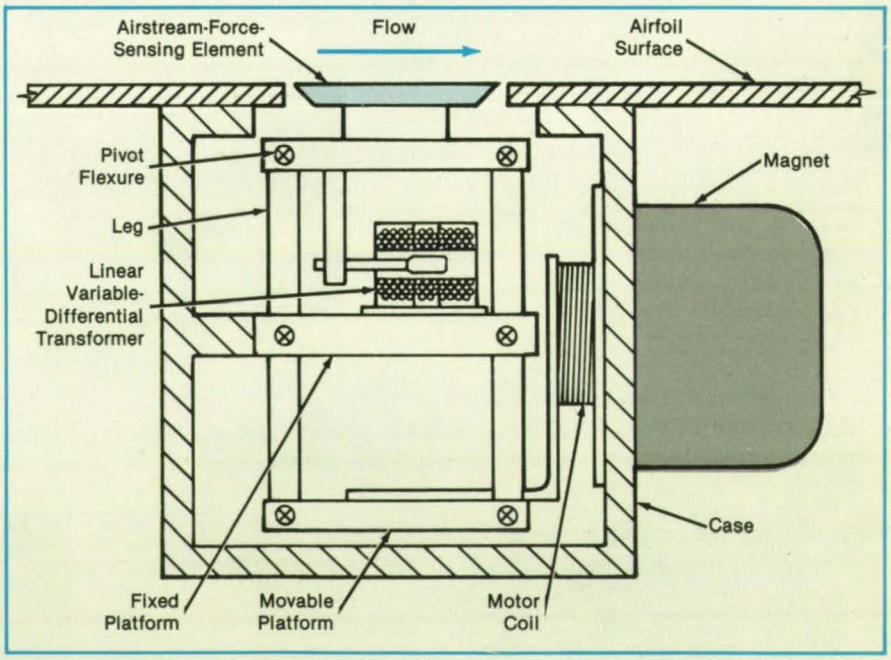
Flight Balance for Skin-Friction Measurements

The force of a tangential airstream is determined by a null-position servomechanism.

Langley Research Center, Hampton, Virginia

A skin-friction balance (flight balance) for use in flight on an aircraft fuselage incorporates a type-one, closed-loop control to make direct skin-friction force measurements. A curved surface element 2 in. (5.08 cm) in diameter is used to sense the tangential force of an airstream passed over it. A linear electromagnetic force motor exerts a restoring force that nulls the position of the sensing element. The applied skin-friction force is measured by sensing the amount of current through the motor necessary to maintain the null position. The full-scale range of the balance is adjustable from 0.1 to 1.0 g weight/cm^2 (9.8 to 98 Pa), and the overall size is approximately 8 by 5 by 5 in. (20.3 by 12.7 by 12.7 cm).

The flight balance, an electromechanical servomechanism, is a modified version of a design previously developed at NASA Langley Research Center. The unit is rugged, accurate, reliable, and easy to operate. These features are achieved through the use of an oscillating double four-bar mechanism, which enables accurate skin-friction measurements in the presence of an offcenter normal force and rectilinear vibrations in the background. The insensitivity of the balance to background rectilinear vibrations and its ability to sustain large transient loads during takeoffs and landings make it most attractive for flight testing.



The **Electromechanical Servomechanism** restores the airstream-force-sensing element to the null position.

Two identical units were fabricated and

used on a jet aircraft to make skin-friction measurements in flight. The results indicated that both balances functioned satisfactorily and that data taken from the balances in tests with similar profiles conducted on different days were duplicated within 5 percent.

This work was done by Ping Tcheng and Frank H. Supplee, Jr., of **Langley Research Center**. *For further information, Circle 24 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 22]. Refer to LAR-13710.

Inspection in Overhead Spaces Containing Asbestos

A simple method saves time and effort.

Lyndon B. Johnson Space Center, Houston, Texas

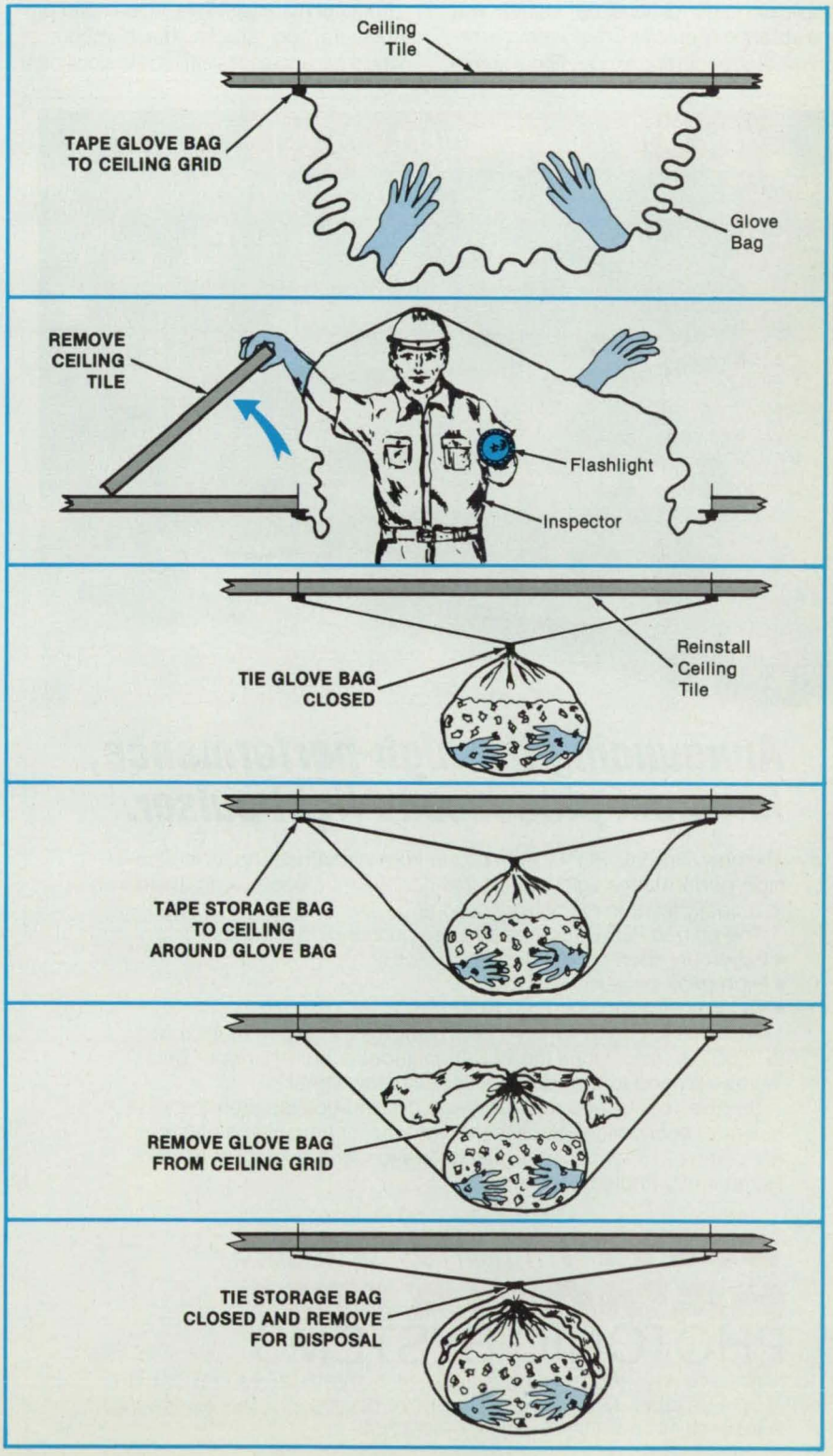
A procedure for inspection in spaces above dropped ceilings that contain asbestos saves time and effort without sacrificing safety. The conventional inspection method requires elaborate and time-consuming preparation and cleanup: People have to leave the immediate area, and the floor and furniture have to be covered with sheets of plastic. Wearing a respirator, the inspector examines the space above the ceiling. Finally, the room is vacuum-cleaned, the plastic sheets are discarded, and the inspector's tools, equipment, and respirator are cleaned.

With the new method, the only items of safety equipment needed are a glove bag, a storage bag, and a roll of adhesive tape. The inspector first tapes the glove bag tightly to the support grid around the ceiling tile to be removed. With hands in the gloves, the inspector lifts the tile gently and places it aside (see figure). Extending head and shoulders into the bag, the inspector examines the space above the ceiling with the help of a flashlight. (A lightweight, collapsible frame could be used to hold up and spread out the bag so that the inspector could maneuver more easily in the confined space.)

After the examination, the inspector replaces the tile, lowers the glove bag, ties it up close to the ceiling, and tapes the storage bag (labeled "For Asbestos") to the ceiling around the glove bag. Finally, the inspector pulls the glove bag loose, drops it into the storage bag, ties the storage bag closed, and discards the storage bag appropriately.

This work was done by Jacque Bell, George Hartwick, and Jerry Hutcherson of Pan Am World Services, Inc., for **Johnson Space Center**. *No further documentation is available.*

MSC-21362



A **Transparent Glove Bag** gives an inspector a clear view of the space above a dropped ceiling and prevents asbestos from contaminating the area below.

Ultrasonic Detection of Transply Cracks in Composites

The densities and propagation of cracks are measured nondestructively.

Lewis Research Center, Cleveland, Ohio

A nondestructive testing technique measures the densities of transply cracks and can be used to monitor the propagation of such damage in advanced polymer-matrix composite materials. The development of this technique was motivated by the requirement, particularly in aerospace applications, for dimensional stability and the absence of cracks. Cracks reduce mechanical strength and expose fibers and interfaces to environmental (moisture and thermo-oxidative) effects.

Graphite/polyimide composites are now replacing metals in zones of moderately high temperatures (up to 316 °C) in jet engines. These types of applications will introduce thermal cycling in the composite structural materials. This, in turn, can produce transply cracks, the numbers of which can increase with time to significant levels. Because these transply cracks are undesirable, nondestructive testing techniques are needed to monitor structural parts to confirm the integrities of the structures during the expected operational lifetimes.

For a demonstration of the new technique, transply cracks were introduced into tensile specimens of cross-plied (0°/90°) unidirectional tape and fabric prepreg material. In both cases, the reinforcements were graphite fibers. The cracks were introduced by loading the specimens at various loads below the experimentally-determined failure load.

An acousto-ultrasonic measuring apparatus, shown in Figure 1, was used to measure stress-wave factors (SWF's) of undamaged specimens and specimens that contained various numbers of transply cracks. Time was partitioned into 5-ms intervals and frequency into 1.285-MHz bands. SWF measurements were taken at seven different crack densities. Figure 2 shows the results of linear least-squares fits to the data from both types of specimens. The acousto-ultrasonic technique is of value because it can be used to examine damage to the material from one surface only. Access to both sides of a structure is not necessary and is normally not easily obtained.

It was found that the SWF decreased with increasing density of cracks. The

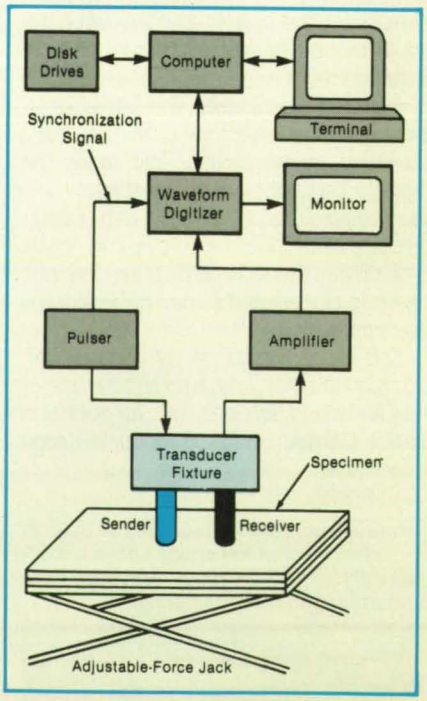


Figure 1. An **Acousto-Ultrasonic Apparatus** operates under the control of a computer, which interprets the ultrasonic measurements in terms of the density of transply cracks in a specimen.

woven fabric is less attenuating than is the cross-plied, unidirectional, reinforced material, and, at high crack densities, the attenuation is about the same in the two materials. From the data that were examined, it was concluded that not only can the acousto-ultrasonic technique be employed to assess changes in the densities of transply cracks during the lifetimes of composite structures but also that the SWF has potential utility as a measure of the number of transply cracks in a damaged structure.

This work was done by Kenneth J. Bowles, Harold Kautz, John H. Hemann, and Paul Cavano of **Lewis Research Center**. *Further information may be found in NASA TM-100224 [N88-11758], "Transply Crack Density Detection by Acousto-Ultrasonics."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14700

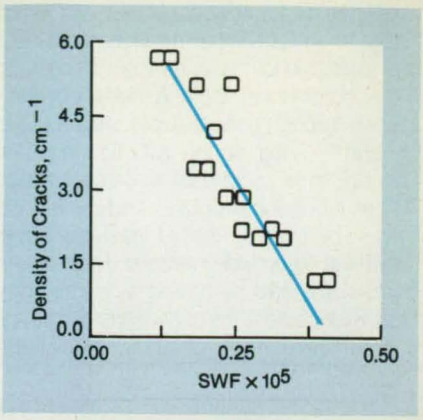


Figure 2. This **Linear Least-Squares Fit** to data from measurements at various crack densities shows that the stress-wave factor is related to the density of cracks.

Variable-Volume Container

The container expands and contracts according to changes in volume of its solid contents.

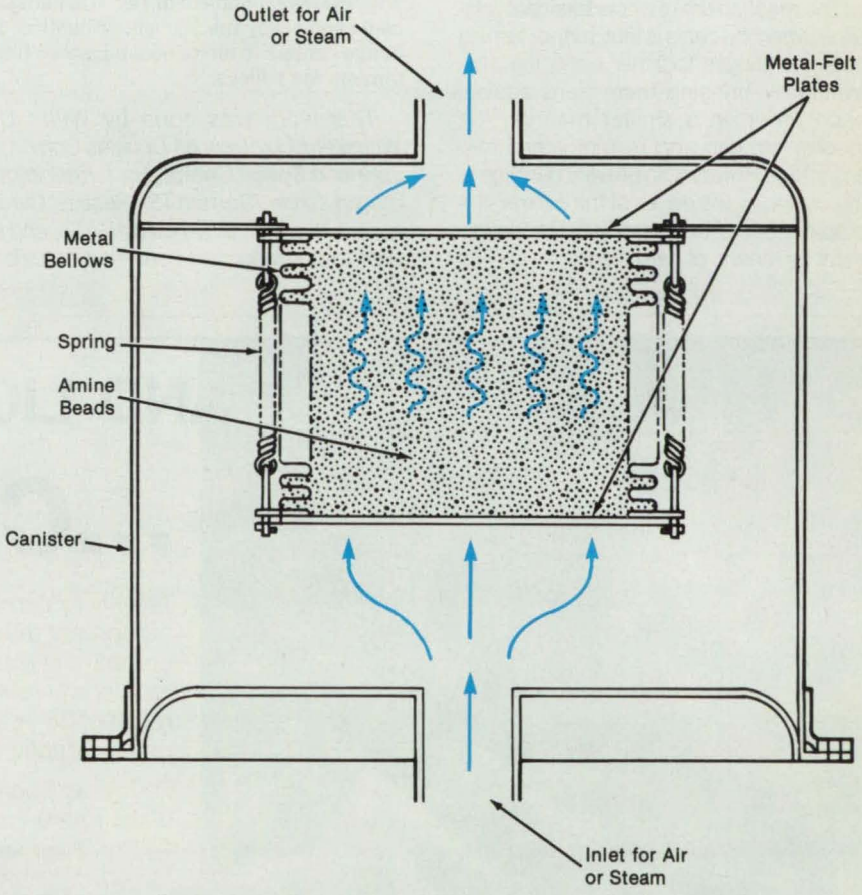
Lyndon B. Johnson Space Center, Houston, Texas

A container holds a bed of beads securely while accommodating sizable changes in volume and allowing gases to flow through the bed. The container was developed for an air-purifying system in which carbon dioxide is removed by solid amine beads.

The beads absorb CO_2 as the air flows over them. When they become saturated with CO_2, steam is passed over the beads to regenerate them. However, the beads swell as their moisture content increases. The volume of a bed increases by about 17 percent during regeneration and decreases by the same amount afterward. Simply using a container large enough to hold the expanded beads may not be acceptable. Under some conditions, dry beads would then be packed too loosely, and the air would not flow uniformly over them.

Accordingly, the container was designed to expand and contract with the beads. A metal bellows serves as the sidewall of the container, and metal-felt plates are placed at the ends (see figure). The bellows elongates as its contents expand. When the contents contract, springs return the bellows to its original length.

This work was done by A. K. Colling, T. A. Nallette, and F. Sansevero of United Technologies Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-21355



Expanding Beads create pressure in the container so that its bellows elongates, thereby increasing the volume. Springs return the bellows to its original length when the beads shrink.

Lightweight Restraint for Coupling Flanges

A cable-and-pulley mechanism allows limited motion.

Lyndon B. Johnson Space Center, Houston, Texas

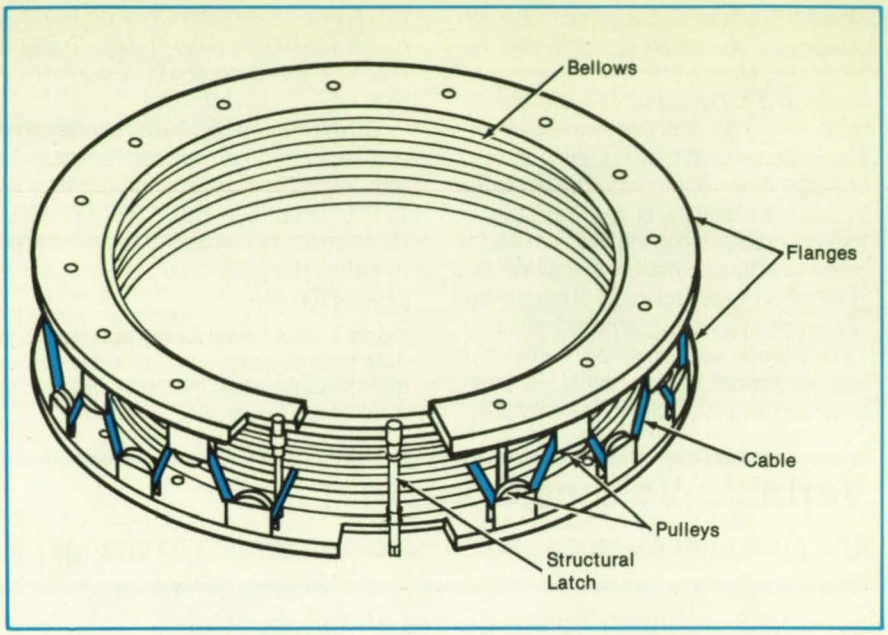
The end flanges of a flexible coupling system are restrained against excessive rotation or axial separation by an inexpensive, lightweight mechanism based on cables and pulleys. Intended to replace a cumbersome set of gimbals on a pair of spacecraft-coupling rings, the restraining mechanism can be adapted to cable, duct, hose, or passageway couplings between

vehicles, or to other applications in which angular and positional misalignments must be restricted to moderate specified values.

A continuous cable is threaded alternately through pulleys dispersed about the circumference of the two flanges (see figure). In a redundant scheme, two or more independent pulley-and-cable sets would be used so that at least one could continue to provide restraint if the others break. Instead of having a continuous cable (or cables), the cable ends can be anchored near each other on one of the flanges.

When the flanges are pulled axially away from each other, the cable stretches taut, preventing further separation. If one flange then tilts with respect to the other, the cable runs through the pulleys to allow increased axial separation on one side and decreased axial separation on the other side, while the axial distance between the centers of both flanges remains the same.

The mechanism restricts torsional rotations: when the cable is taut, further turning pulls the flanges together along the axis, eventually bringing them hard against each other. In a similar manner, the mechanism can also restrict lateral misalignment. However, to prevent damage to the cables by the edges of the pulleys, it is probably better to restrict lateral misalignment by means of hard stops.



The **Total Misalignment of Two End Flanges** is limited to the amount of slack available in the cable-and-pulley mechanism. When the cable is taut, the further axial separation of the flange centers is restrained, but small tilts are accommodated by the running of the cable through the pulleys.

This work was done by Willie D. Whitaker of McDonnell Douglas Corp. for **Johnson Space Center**. *For further information, Circle 79 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 22]. Refer to MSC-21211.

Measuring Bearing Wear Via Weight Loss

Dimensional changes are estimated from areas, weight losses, and densities.

Marshall Space Flight Center, Alabama

Wear in the critical parts of bearings can be measured via the amounts of weight lost during use. First used on the balls, races, and cage of a bearing in a turbopump of the Space Shuttle main engine, the weight-loss measurement technique is clearly applicable in general to bearings made of nonporous materials.

Previously, weight-loss measurements had not been attempted because of the belief that sufficient accuracy and repeatability could not be achieved. However, preliminary experience has shown that in comparison with measurements of dimensions, the weight-loss measurements are easier, faster, more precise, and less likely to damage the measured parts. The weight-loss measurements can be performed in clean rooms and under the constraint of extreme cleanliness for compatibility with liquid oxygen.

The technique requires an analytical balance that has a resolution of 10^{-4} g. Before use, the inner race(s), outer race, and cage are weighed individually, and the balls are weighed as a set. If the bearing is to be lubricated with a dry film, these components are weighed both before and after coating.

After use, the components are weighed again. If the bearing is lubricated with a dry film, the components are weighed both before and after the film is stripped off.

The approximate thickness of material worn off a component can be estimated as the loss of mass divided by the product of the density of the material and the area of the component. The accuracy and repeatability of the technique are sufficient to resolve a loss of about 1 mg of material: On a bearing ball of typical size, this would signify a decrease of less than 10^{-6} in. ($\sim 2.5 \times 10^{-8}$ m) in diameter.

This work was done by John E. Keba and Richard S. Moore of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29438

Machinery

Multihundred-Kilowatt Rotary Electrical-Transfer Device

Roll rings decrease friction and electrical losses.

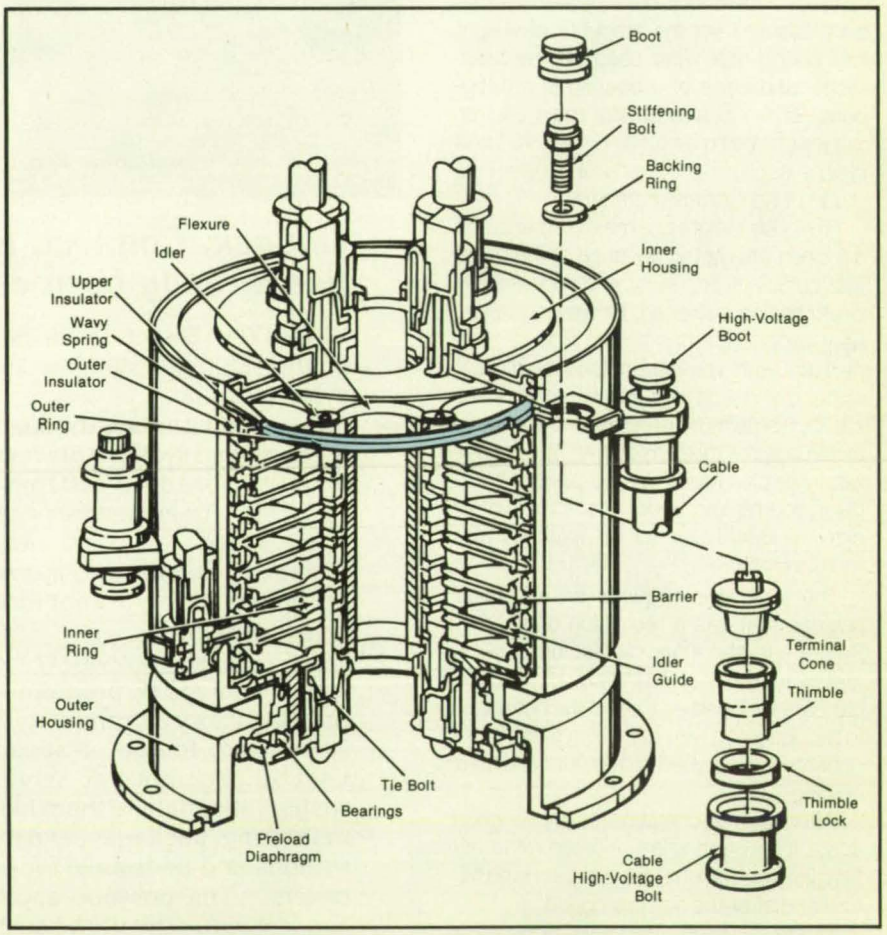
Lewis Research Center, Cleveland, Ohio

A roll-ring electrical-power-transfer device is capable of transferring high power (hundreds of kilowatts) through a rotating connection. This roll-ring assembly can transfer up to 500 V at 200 A per circuit, either dc or ac to frequencies of 20 kHz. The roll-ring assembly (see figure) has eight power circuits. An outstanding feature of this design is very low power loss — only 16 W per circuit while transferring 100 kW.

At present, slip rings are the most commonly used devices for transmitting power across a rotating joint. Slip rings can transfer only limited amounts of power. The roll-ring device eliminates sliding friction by using rolling contacts. This allows the unit to rotate with very little torque. The elimination of sliding friction makes possible the transfer of very large amounts of power per circuit with very low losses.

The roll ring has the potential to be one of the major components of the Space Station or any other space program where large amounts of power are required. It is the only known device that can transfer large currents (200 A) per circuit at high voltages (500 V, dc or ac) with very low losses. The roll-ring assembly will allow the Space Station to grow to larger power levels. Also, any terrestrial application requiring power to transfer through a rotating joint with low losses could use the roll-ring technology. It can be used in air or vacuum with no design changes.

This work was done by Peter Jacobson of Sperry Flight Systems for **Lewis Research Center**. *For further information,*



The **Roll-Ring Assembly** uses rolling contacts to transfer electrical power between the rotor and the stator. This eight-circuit assembly dissipates only 16 W while transferring 100 kW.

Circle 111 on the TSP Request Card.
LEW-14269

Miniature Centrifugal Compressor

A small machine compresses neon for cooling to temperatures as low as 30 K.

Goddard Space Flight Center, Greenbelt, Maryland

A miniature turbocompressor undergoing development is designed for reliability and long life. A cryogenic system that includes the compressor, a turboexpander, and heat exchanger will provide 5 W of refrigeration at 70 K from 150 W input power. The design speed of the machine is 510,000 rpm.

The compressor (see figure) has gas-lubricated journal bearings and a magnetic thrust bearing. When the compressor is running, there is no bearing contact and

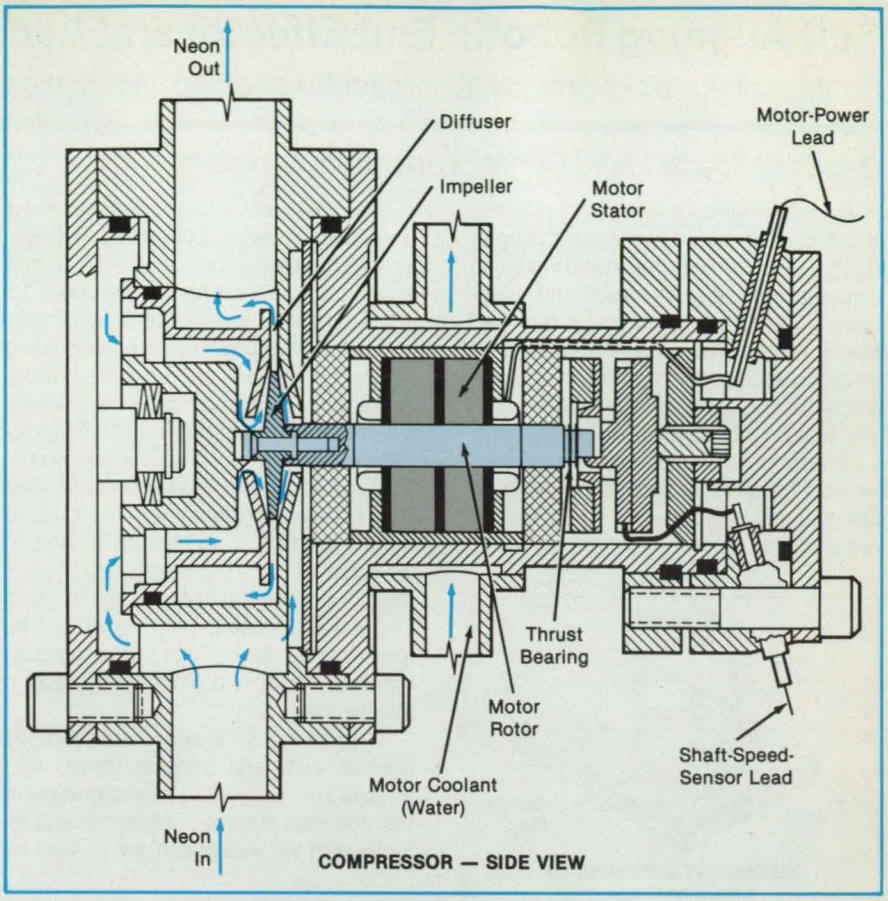
thus no wear. Wear can occur only when the machine is starting or stopping — before the bearings lift off and after they set down, and this wear can be relatively insignificant.

The solid rotor contains narrow axial grooves that direct the magnetic flux toward the axis. The flux is therefore surrounded by a relatively-large cross-sectional area of steel to carry the circulating electric current. This reduces the effective electrical resistance and increases the efficiency of the motor.

The motor stator does not contain salient pole teeth on its inside diameter because such teeth would generate eddy currents on the surface of the solid rotor. Instead, it contains internal bores for the windings. The windings are stranded copper wire insulated with polytetrafluoroethylene. The wire is threaded through circular holes in the bores of the stator; the heat generated in the wires is carried away by conduction through the stator.

The stator consists of layers of a low-loss magnetic nickel/iron alloy, with a layer of copper at every seventh layer. The copper, which has a thermal conductivity more than 30 times as great as that of the magnetic alloy, aids in the removal of heat from the windings. Cooling water circulates through a jacket around the stator to remove heat from the motor housing.

The impeller in the compressor is double-sided and symmetrical: This shape results in a far smaller axial thrust than would be generated by a single-sided impeller. The small remaining axial thrust can be handled by a magnetic thrust bearing instead of by the gas thrust bearing that would otherwise be needed. The magnetic bearing is expected to absorb less power than a comparable gas bearing, and thus to improve the efficiency of the compressor.



Neon Working Fluid Flows Symmetrically on both sides of the impeller. At the opposite end of the turbine shaft, a capacitance sensor measures rotational speed by detecting the passage of a flat surface on the shaft. The shaft has a mass of only a few grams. It exhibits little vibration because the gas bearings damp oscillations.

This work was done by Herbert Sixsmith of Creare Inc. for **Goddard Space Flight Center**. *For further information, Circle 50 on the TSP Request Card. GSC-13093*

Correlation Analysis of Vibration Data From Rotary Pumps

Fourier coefficients describing vibrations are constructed from files of FFT pump-response data.

Marshall Space Flight Center, Alabama

A proposed correlation technique represents vibration data from rotary pumps in a compact form convenient for storage in a data base. The analysis determines the coefficients of a Fourier series representing the typical response of a pump for one revolution of the pump shaft. Changes in the harmonic spectrum of the pump may indicate changes in performance caused by internal wear, rubbing of seals, and the like.

Such an analysis could be performed by averaging data in a time series for a number of shaft rotations to eliminate random contributions, then representing the averaged data by a Fourier series. However, that approach would require significant development and would be an expensive addition to the standard evaluation of data. The proposed correlation method is preferable if the dynamic data have already been stored as frames of fast-Fourier-transform (FFT) data, rather than as time series, and if one of the data tracks contains a timing signal or other similar signal with a clear once-per-revolution character that can be used both to determine the rotation period and as a phase reference for the rotation of the pump.

In the proposed technique, a set of reference harmonics would be generated based on the timing signal. The phase of each harmonic would be an integral multiple of that of the fundamental. The harmonic spectrum would be very sparse, comprising a real and an imaginary value at each integral multiple of the frequency of rotation of the pump. A simple algorithm would generate the real and imaginary values from the fundamental-frequency real and imaginary values.

The cross-correlation of the reference harmonic spectrum with the Fourier-transform data would provide the coherence spectrum, which, when multiplied by the data-channel power spectrum, would provide the powers at the harmonic frequencies. This spectrum can be carried as far as necessary to cover the range of frequencies included in the Fourier-transform data.

This work was done by James R. Fenwick of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29401*

Self-Aligning Robotic End Effector and Receptacle

Congruent surfaces provide alignment for gripping, installation, and removal.

Goddard Space Flight Center, Greenbelt, Maryland

An industrial-robot hand (end effector) and a mating receptacle include congruent male and female conical and V-shaped surfaces for positive alignment. The receptacle is part of an object to be removed from a fixed position, transported, and installed in another fixed position — for example, during an assembly process. The end effector grasps the receptacle firmly for transport, and a tool in the end effector loosens or tightens a mounting screw in the object during removal or installation, respectively.

The robot hand, which is at the end of a remote manipulator, is observed via television and guided by manual joystick control to approximate alignment within about 0.5 in. (13 mm) of the receptacle. An automatic electronic "feeling" system then takes control and quickly performs the precise final alignment similarly to the way in which a human technician aligns and pushes together mating parts. When the mating conical surfaces first make contact (see Figure 1), the control system responds to signals from force and torque sensors in the end effector by moving the end effector slightly sideways to reduce the contact forces and torques to zero. As the end effector moves farther into the receptacle, contact is made and broken repeatedly in this manner.

The end effector is also rotated about its conical axis, and contact forces and torques are used to detect the alignment of the V-shaped surfaces. When the end effector and the receptacle are pushed all the way together and all mating surfaces are precisely aligned after the final contact/repositioning cycle, the force/torque system senses only an axial contact force. The contact/repositioning cycles are so brief that to a human observer the alignment process appears to be a smooth motion.

The end effector includes parallel gripping jaws equipped with lifting pins, which are inserted in opposing holes on the receptacle once alignment is achieved (see Figure 2). While the receptacle is thus gripped, the object can be moved about or held fixed while an allen wrench or similar tool engages a mating recess in the head of the mounting screw. A remotely controlled motor in the end effector turns the tool to tighten or loosen the screw.

This work was done by Glen J. VanSant and Eugene G. Gibbs of RCA Corp. for **Goddard Space Flight Center**. *For further information, Circle 49 on the TSP Request Card.* *GSC-13152*

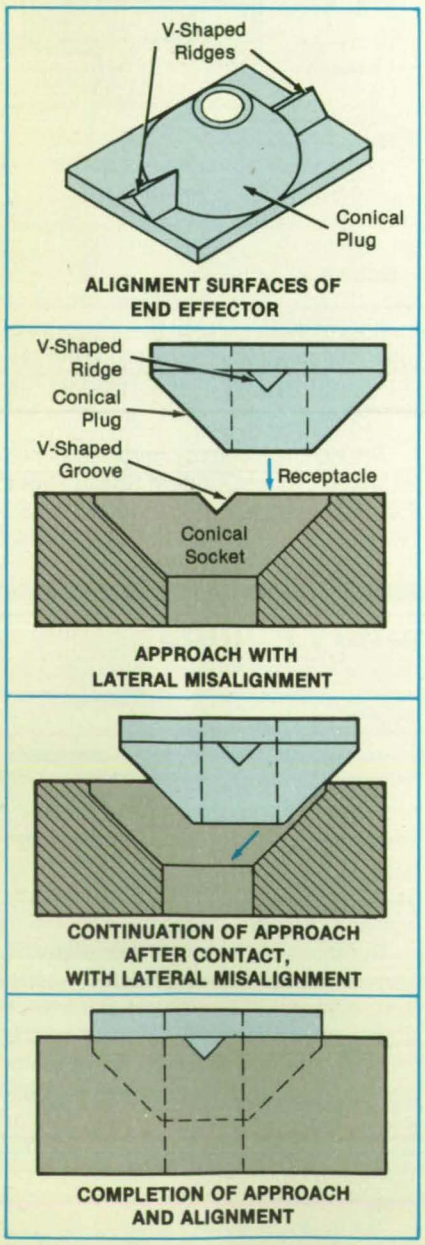


Figure 1. The **Surfaces of the End Effector and Receptacle** are keyed to each other for automatic alignment.

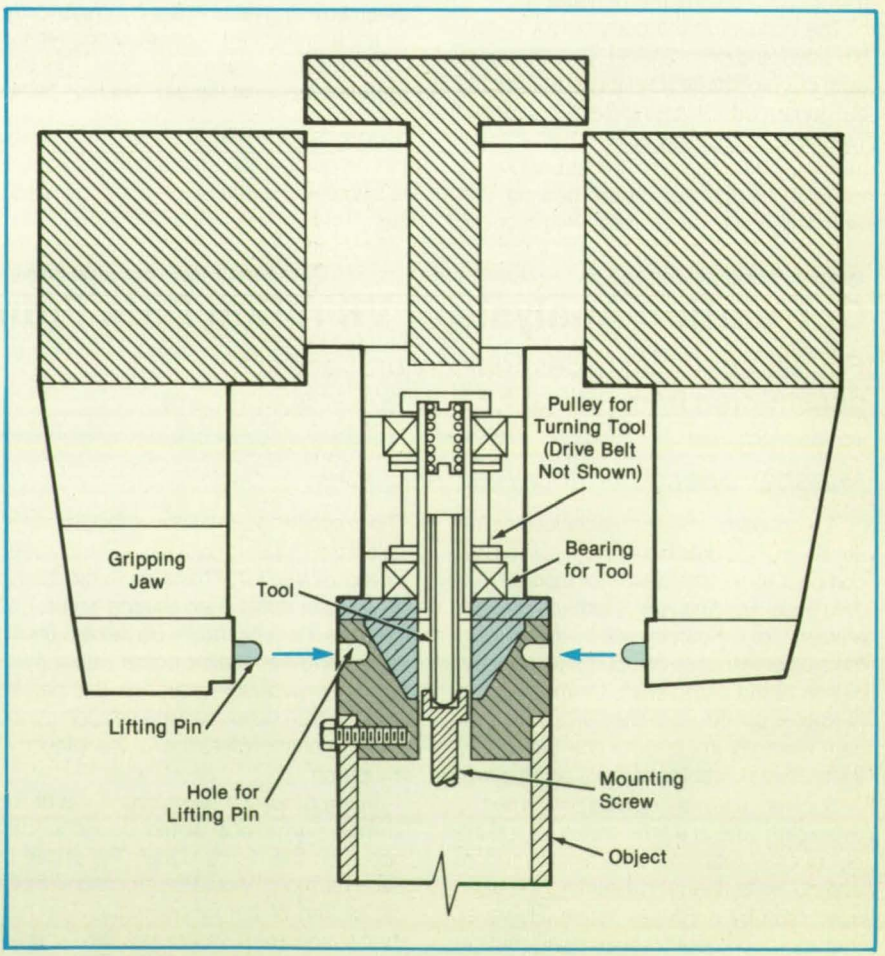


Figure 2. **Lifting Pins Are Inserted** in the receptacle to lock the end effector and receptacle together. The tool can then turn the mounting screw, and the end effector can lift the object.

Fabrication Technology

Hardware Techniques, and Processes

Endjoints for Structural Elements

Struts are joined easily and rapidly to make frames.

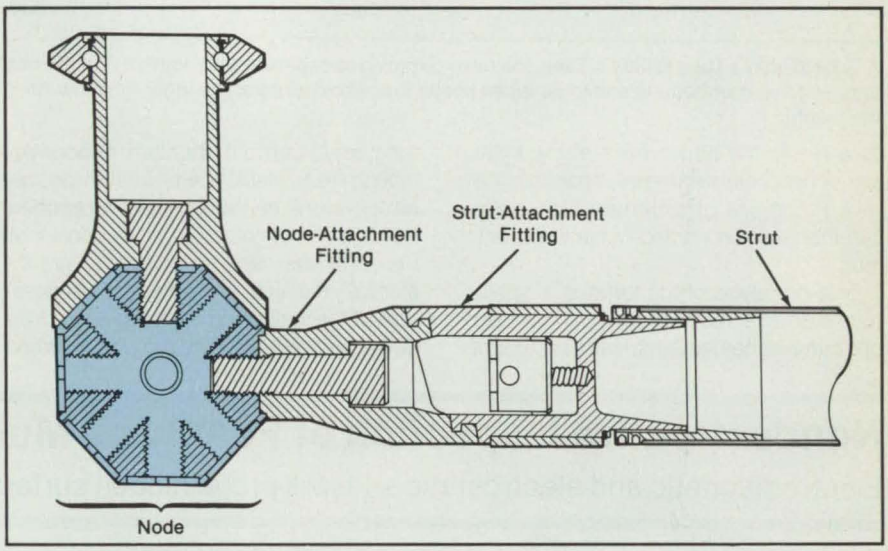
Langley Research Center, Hampton, Virginia

An endjoint and connecting-node system has been designed for use in the erection of frames. The design (see figure) includes an approximately spherical node with flat facets and tapped holes positioned at 45° to one another to provide for 18 bolted strut connections equally spaced over its surface. The design also includes fittings for attaching the nodes to strut elements.

The strut connection is constructed to facilitate rapid assembly or disassembly of the frame. The joint system utilizes internal latch mechanisms housed in the struts. A strut connection can be made quickly and simply by positioning the two mating fittings together and rotating the cammed ring to lock them into place.

The system is structurally sound and simple to operate. All nodes and struts are interchangeable. Nodes and struts can be attached to form cubic cell structures to produce beams, platforms, towers, or combinations of these. In addition to the 18 flat facets with tapped holes, the node contains 8 additional tapped holes at the cubic diagonal locations, which may be used to attach payloads either within or outside previously assembled cubic cell structures.

Although intended as an endjoint system for space-station construction, this design is suitable for use in the construction of other space structures and such terrestrial skeletal frameworks as antenna-reflector supports, roof structures for large buildings, lookout towers, radio-transmitter towers, powerline pylons, and scaffolds.



A **Node With Tapped Holes** can be attached rapidly to as many as 18 struts.

This work was done by Harold G. Bush and Martin M. Mikulas of **Langley Research Center** *and Richard E. Wallsom of PRC Kentron, Inc. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 22]. Refer to LAR-13584.

Ultraclean Radiant Furnace

Cooling of the walls minimizes contamination from outgassing.

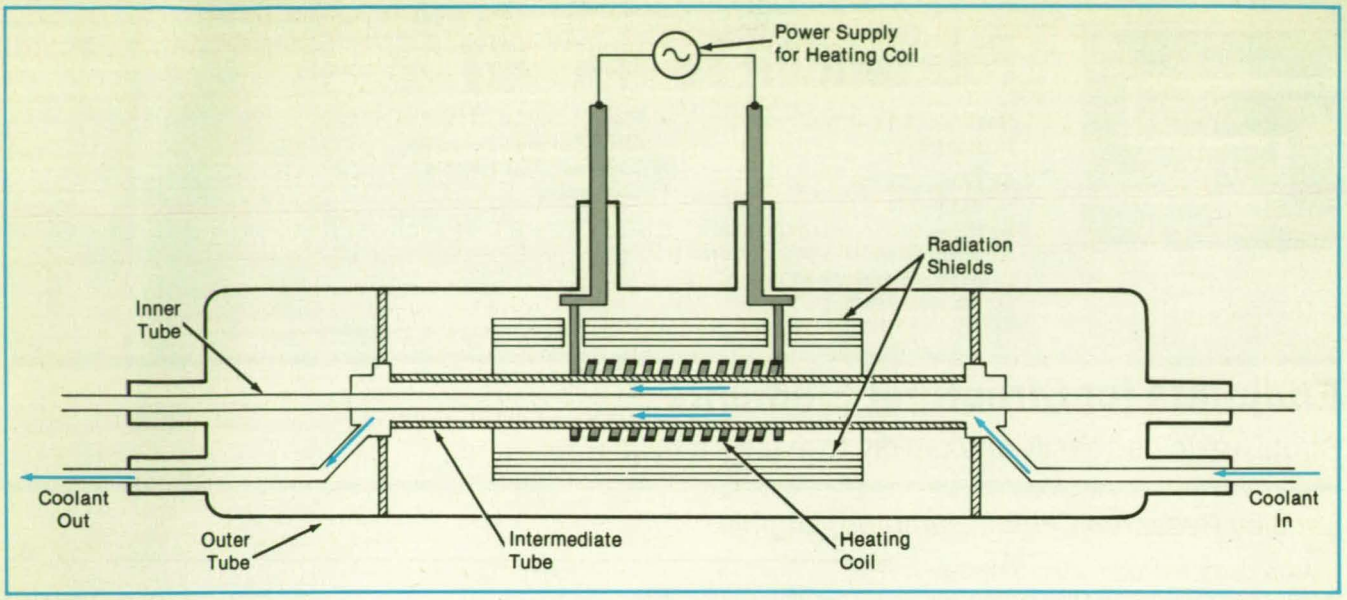
Marshall Space Flight Center, Alabama

A relatively-inexpensive radiant furnace can bring a specimen in a controlled atmosphere to a temperature higher than was previously attainable — nearly as high as the maximum operating temperature of the heating element. The heating element can be made of a refractory material like tungsten, molybdenum, graphite, or silicon carbide, or could consist of a plasma or electric arcs. The furnace distributes heat fairly uniformly over the surface of the specimen.

The heating element is kept in its own protective environment, distinct from that surrounding the specimen. The wall that surrounds the specimen is kept substantially cooler than the heating element or the specimen.

The furnace includes three coaxial tubes (see figure). The outer tube is sealed at its ends to the intermediate tube, forming a closed chamber filled with a gas that protects the heating element — for a tungsten element, a good choice is a halogenated gas. In advanced versions of the furnace, the outer tube could be designed to reflect or reradiate heat onto the specimen.

The intermediate tube surrounds the inner tube, which contains the specimen. These tubes are made of a transparent material like fused quartz or sapphire so that maximum energy reaches the specimen. Coolant flows through the space between the inner and intermediate tubes. The coolant maintains them at or below room temperature, despite the intense radiation. The vapor pressure of the inner tube is therefore kept extremely low, and



A **Tube Within a Tube Within a Tube**, the furnace provides separate environments for the heating element and the specimen. Coolant flowing between the intermediate and inner tubes keeps the temperature of the inner tube low, despite the extremely high temperature of the specimen within it.

as a result, the atmosphere of the inner tube is not contaminated by vapor from the wall. Processes of extremely high purity can therefore be carried out in the specimen.

In a prototype of the furnace, a specimen in an inner tube with an inner diameter of 6 mm was heated electrically via a coil of tungsten/3-percent rhenium ribbon. Although the available power was limited, the temperature of the specimen reached 1,885 K. The temperature of the coolant at the outlet was 748 K — believed to be substantially higher than the average temperature of the wall of the inner tube. In a fully developed version of the furnace, it should be possible to heat a sample to 3,000 K in about 10 seconds.

This work was done by David W. Blair of Princeton Scientific Enterprises for **Marshall Space Flight Center**. *For further information, Circle 28 on the TSP Request Card.*
MFS-26070

Nondestructive Inspection of Foam and Multilayer Insulations

Electromagnetic and electrostatic sensors probe hidden surfaces and layers.

Marshall Space Flight Center, Alabama

Techniques and equipment undergoing development will enable the nondestructive inspection of sprayed-on foam and multilayer reflecting thermal insulations on metallic substrates. Intended originally for the testing of thermal-protection systems on spacecraft, this technology also could be applied in factories and laboratories; for example, to inspect insulation on cryogenic tanks and pipes.

The prototype equipment (see Figure 1) can measure the overall thickness of foam insulation or the overall thickness, thickness between individual reflecting layers, locations of gaps, and/or amount of corrosion of multilayer reflecting insulation. The properties of the insulation are calculated from the responses to excitations applied to the insulation via inductive and capacitive sensors mounted in a common probe head (see Figure 2). In an inductive measurement, eddy currents are generated in the metallic layer of interest to sense the location of the layer or the size and/or location of a discontinuity, The eddy currents affect the complex impedance of the probe coil, which can be measured and processed along with ancillary calibration data to infer the quantity of interest.

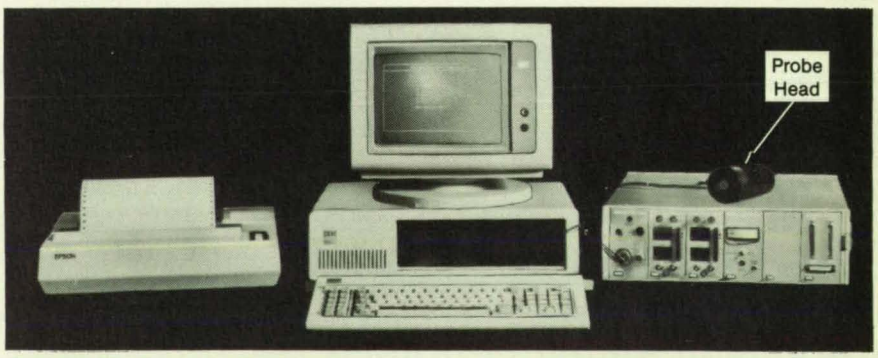


Figure 1. The **Prototype Equipment** includes a probe head, several electronic modules that take measurements via electromagnetic and electrostatic sensors in the probe head, a small computer to store and process the signals from the modules, and a printer.

For example, the complex impedance of one of the coils when excited at a frequency of 10 kHz is a known function of the distance of the coil from the metallic substrate and can, therefore, be used to infer the thickness of the insulation. The 10-kHz frequency was selected because it makes the measurement relatively insensitive to thin intervening reflecting layers and can, therefore, be used on both types of insulation. Because inductive measurements at 200 kHz are sensitive to the reflecting layers, they are used to measure gaps in multilayer reflective insulation.

The capacitive electrodes at the end of the probe head are excited at 1 MHz to serve as a proximity sensor. The capacitance between the electrodes is affected by the distance to the nearest conductive surface and/or the presence of dielectric material. The capacitance is measured to detect contact with foam insulation, to measure the thickness of foam insulation, or to measure the distance to the outermost layer of multilayer reflective insulation.

If contact tabs from the individual reflecting layers are brought out at the edge of multilayer insulation, the capacitances between layers can be measured to infer the distances between layers and the overall thickness. The capacitance between the metal coats on the two surfaces of the plastic sheet in each layer can also be measured. This capacitance can be compared with the value measured immediately after manufacture to determine the amount lost due to loss of the reflective coating through corrosion.

Also tested, but not included in the capabilities of the prototype, are an acoustical technique and a technique of real-time holographic interferometry combined with thermal probing to detect poor adhesion between foam insulation and a substrate. The ability of the acoustical technique to yield quantitative determinations of the degree of adhesion is limited. The holographic technique is more promising in this regard and is more likely to be included in subsequent versions of the testing equipment.

This work was done by Dennis R. Krause, Robert J. Bauman, and Thomas J. Davis of Spectron Development Laboratories, Inc., for **Marshall Space Flight Center**. *For further information, Circle 21 on the TSP Request Card.*
MFS-27199

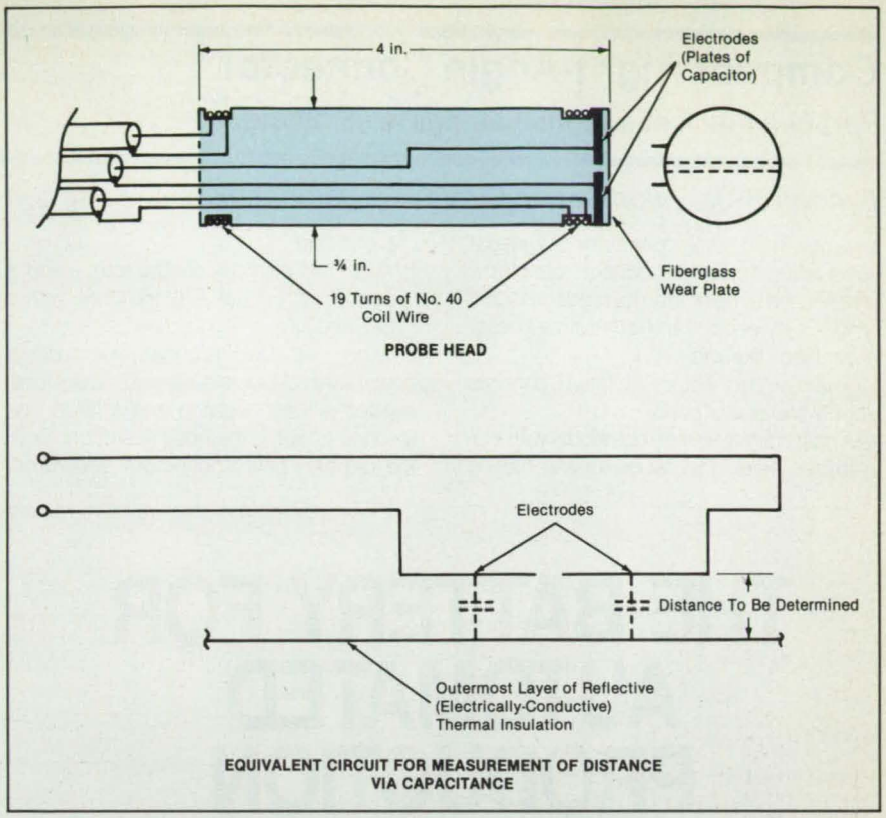


Figure 2. The **Probe Head** of Figure 1 contains two inductors and two plates of a capacitor. These elements are excited at various frequencies to obtain the various measurements. For example, a simple measurement of capacitance and the known properties of the equivalent circuit shown below can be used to determine the distance from the probe to the outermost layer of multilayer reflective insulation.

Plating Repair of Nickel-Alloy Pressure Vessels

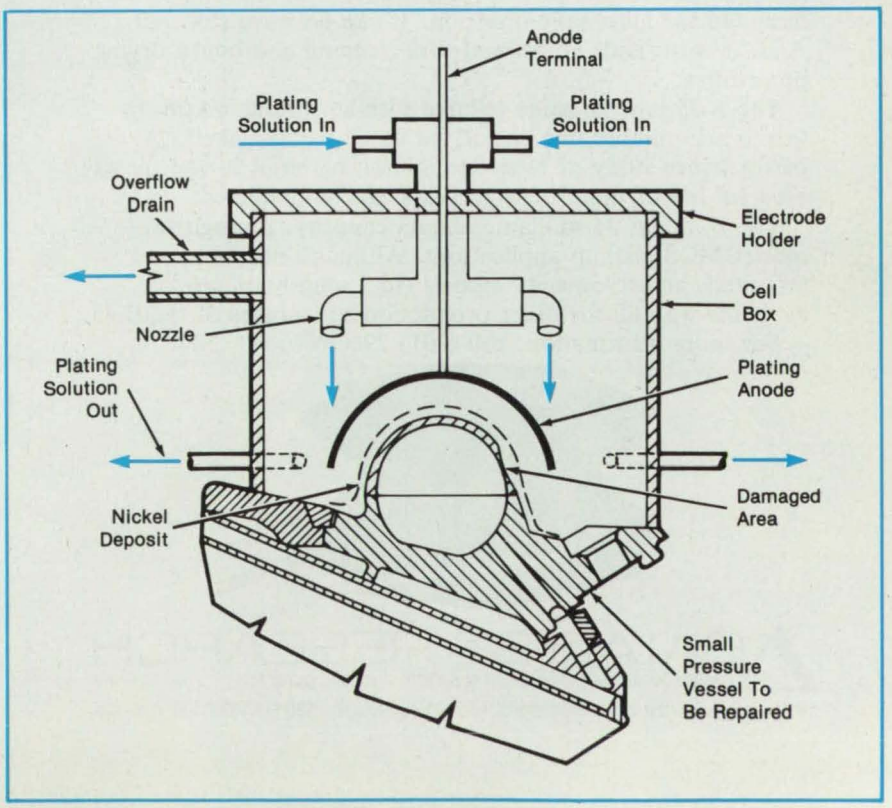
Localized plating builds up wall thickness.

Marshall Space Flight Center, Alabama

A procedure for the localized electrodeposition of nickel enables the repair of small damaged nickel-based pressure vessels. Electrodeposition can restore weakened areas of a vessel wall to at least their former strength.

The area to be repaired is cleaned and sanded. An open-bottom box is placed around the area to be repaired (see figure). Electroplating solution enters the box, flowing over and under an electrode shaped to accommodate the area to be repaired. Nickel is deposited from the solution onto the wall to a typical thickness of 0.17 to 0.23 in. (4.3 to 5.8 mm). The edge of the plated layer is ground and sanded to blend smoothly into the surrounding unplated surface.

This work was done by Steve K. Ricklefs and Kevin M. Chagnon of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 7 on the TSP Request Card.*
MFS-29304



An **Electroplating Box Fits** around the damaged pressure vessel. The plating anode is shaped to cover approximately the area to be plated.

Compact Right-Angle Connector

Part of a stack of adaptive fittings is eliminated.

Lyndon B. Johnson Space Center, Houston, Texas

A new right-angle connector between a hose and a "quick-disconnect" coupler is smaller and simpler than its predecessor. It employs fewer parts and is therefore cheaper and less likely to leak.

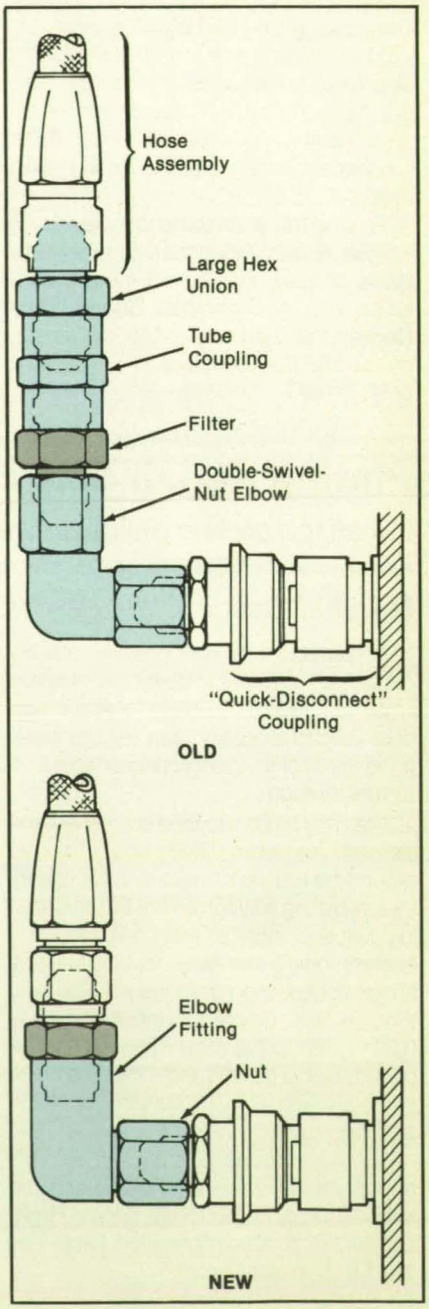
The new connector (see figure) consists of only two major parts:

1. A cast stainless-steel tube elbow with machined sealing surfaces for the mating parts, and
2. A nut that provides sealing torque and is permanently attached to the elbow with a lockwire.

In contrast, the old connector included a double-swivel-nut elbow and, therefore, needed a tube coupling and a large hex union to adapt to the hose assembly. Both the old and new connectors accommodate an in-line filter.

The new connector is unusual in that it has both an internally threaded tube on its solid end and a 37° flare-type tube fitting inside the swiveling end. Elbows with this combination of ends are not stock items.

This work was done by Salvador L. Barajas and Vonde E. Pierson of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 153 on the TSP Request Card.*
MSC-20697



The **New Right-Angle Connector** has about half the volume and weight of the old connector. Flared-tube sealing and boss-tube sealing are combined in the new elbow.

Mathematics and Information Sciences

Improved Algorithm for Finite-Field Normal-Basis Multipliers

Self-dual normal bases reduce mathematical complexity.

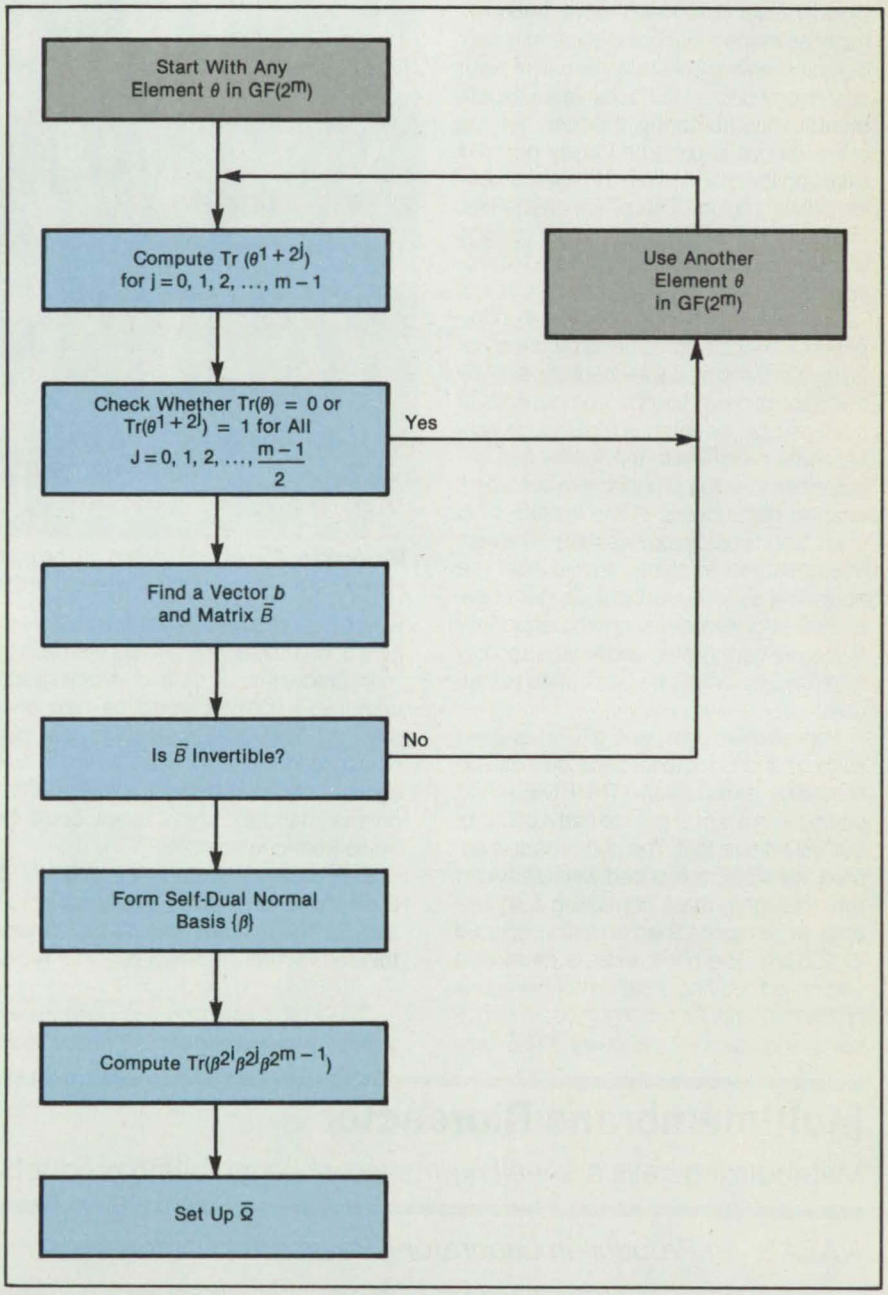
NASA's Jet Propulsion Laboratory, Pasadena, California

An improved algorithm reduces the complexity of the calculations that must precede the design of Massey-Omura finite-field normal-basis multipliers, which are used in error-correcting-code equipment and cryptographic devices. This algorithm represents an extension of the development reported in "Algorithm To Design Finite-Field Normal-Basis Multipliers" (NPO-17109), *NASA Tech Briefs*, Vol. 12, No. 5, page 82.

As described in the earlier article, the design of a multiplier requires a product function defined by a Boolean matrix. The product function is, in turn, found via an algorithm that generates a normal basis $\{\alpha\}$ and its dual basis $\{\beta\}$ in a Galois field $GF(2^m)$. It has been known for more than a decade that if m is odd, there exists a self-dual normal basis in $GF(2^m)$. Since the development of the previous algorithm, it was discovered that a self-dual normal basis yields a symmetrical Boolean matrix, and consequently, the construction of a product function for a self-dual normal basis is simpler than for an arbitrary normal basis.

The new algorithm (see figure) constructs the symmetrical Boolean matrix $\bar{\Omega}$ for odd m. It starts with the choice of any element θ in $GF(2^m)$. Using a new subalgorithm, it finds the vector $\boldsymbol{b}$ and the matrix $\bar{B}$, which are related to a basis $\{\beta\}$. It checks whether $\bar{B}$ is invertible: If so, then $\{\theta\}$ is a normal basis; if not, then another θ is chosen, and the process repeats until the resulting $\bar{B}$ is invertible. Then using a theorem that expresses the relationship between $\{\beta\}$, $\bar{B}$, and $\{\theta\}$, the algorithm calculates $\{\beta\}$, which has become a self-dual normal basis. Finally, using procedures similar to those of the previous algorithm, the new algorithm sets up $\bar{\Omega}$.

The complexity of a Massey-Omura multiplier depends on the number of ones in $\bar{\Omega}$: this number is smaller in a Boolean matrix generated from a self-dual normal basis than in a Boolean matrix generated from an arbitrary normal basis. In addition, the time required to construct $\bar{\Omega}$ can be reduced to one-third of that required for an arbitrary normal basis.



The **New Algorithm** generates a symmetrical Boolean matrix $\bar{\Omega}$, starting with the choice of any element θ in $GF(2^m)$.

This work was done by C. C. Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 76 on the TSP Request Card. NPO-17225*

Life Sciences

Hardware Techniques, and Processes

Mandrels for Microtextured Small-Vessel Implants

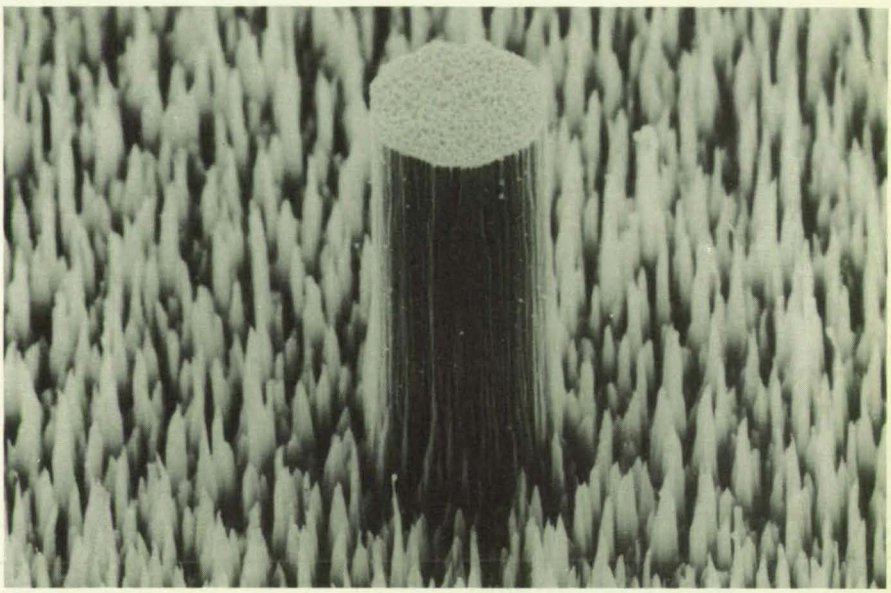
A surface-relief pattern should encourage growth of a healthy neointima.

NASA's Jet Propulsion Laboratory, Pasadena, California

Research has shown that artificial blood-vessel and heart-valve implants might be made more compatible with their biological environments by the use of regularly microtextured surfaces. In an experimental manufacturing process, an ion beam etches a patterned array of small pillars on the mandrel used to mold a tubular plastic implant. The pillars create tiny, regularly spaced holes in the inner surface of the tube. The holes are expected to provide sites for attachment of a healthy lining.

The human body naturally tries to incorporate a vascular prosthesis by encapsulating it in living tissue — neointima — by the deposition of various components of the blood on the implant material. In conventional prostheses, the intima can become overdeveloped or become detached, causing obstructions of the implant or in small blood vessels downstream. The new microtextured implants should hold the neointima securely, without danger of detachment or overdevelopment, especially in vessels having internal diameters of only 6 mm or less, which are particularly vulnerable.

Polytetrafluoroethylene (PTFE) is used as the mandrel material because it can be etched by an ion beam. The PTFE is first coated with a film of gold so that a photoresist will adhere to it. The photoresist is applied, cured, and exposed with ultraviolet light through a mask containing a square array of hexagons 9 μm on a side, spaced at 100 μm. The photoresist is developed and rinsed, leaving a pattern of hexagons on the mandrel. An argon-ion beam directed at the mandrel removes PTFE only where it is not covered by photoresist. Hexagonal pillars are thus formed (see figure).



Microscopic Pillars are created on the surface of PTFE by impacts of argon ions through a photomask. Pillars about 30 μm high are produced in 15 minutes of etching.

In production, a tube of a biologically compatible polymer would be cast on a mandrel. The inner surface of the tube would be covered with an array of hexagonal holes corresponding to the pillars on the mandrel. Many tubes could be made from one mandrel.

This work was done by William D. Deininger and Stephen B. Gabriel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 142 on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457(f)], to the California Institute of Technology. Inquiries concerning licenses for its commercial development should be addressed to

Edward Ansell,
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1207 East California Boulevard
Pasadena, CA 91125

Refer to NPO-16690, volume and number of this NASA Tech Briefs *issue, and the page number.*

Multimembrane Bioreactor

Metabolizing cells are well nourished while inhibiting products are removed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A set of hydrophilic and hydrophobic membranes in a bioreactor allows the product of the reaction to be separated, while nutrients are fed to the reacting cells and byproducts are removed from them. The separation process requires no externally supplied energy; the free energy of the reaction is sufficient.

The membranes greatly increase the productivity of metabolizing cells by continuously removing the product and byproducts, which might otherwise inhibit the reaction, and by continuously adding oxygen and organic nutrients. The membranes also allow the use of product-ex-

Three Membranes Perform Different Functions so that cells can metabolize efficiently. The membranes have been used to make ethanol, and the principle is adaptable to other biological reactions.

traction solvents that would otherwise kill the cells.

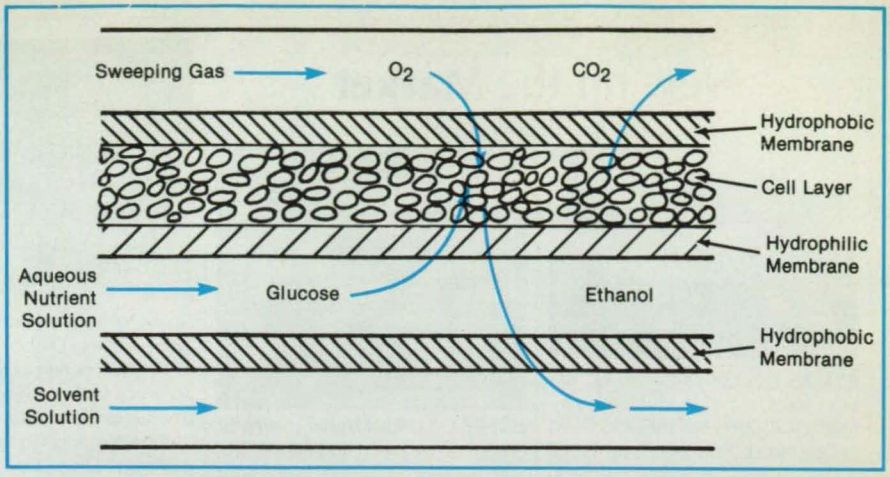
In production of ethanol by fermentation, for example, the membranes remove the CO_2 byproduct rapidly. If CO_2 were allowed to accumulate, it would displace the liquid around the cells in a few hours and stop the reaction. The membranes remove the ethanol product from the cells so that it cannot build up and inhibit cell metabolism. The ethanol is carried away by tri-normal-butyl phosphate (TBP), a solvent that would poison the yeast if it came in direct contact, but from which the product can be separated more simply and economically than from water.

A layer of yeast cells in water is sandwiched between a hydrophobic membrane and a hydrophilic membrane (see figure). Oxygen enters the cell layer through the upper hydrophobic membrane (which prevents water from leaving the cell layer). CO_2 leaves the layer through the upper hydrophobic membrane and is swept away by the gas stream that brought the oxygen.

The hydrophilic membrane readily accepts the glucose nutrient in water solution for admission to the cell layer. The ethanol product leaves the cell layer through the hydrophilic membrane and continues through the water to the lower hydrophobic membrane, after which it is carried off by the flowing TBP solvent. The lower membrane does not allow the glucose solution to pass through to the TBP nor the TBP to pass through to the glucose solution, provided that the pressure of the aqueous solution is greater than that of the solvent solution but less than the critical pressure above which it would enter the membrane.

The membranes are made of microporous polypropylene film, each treated to give the special properties needed for its function. The upper hydrophobic membrane is Celgard 4410 (or equivalent), which is a gas-permeable, water-repellent film previously used to make vents in batteries. The middle (hydrophilic) membrane is a water-wettable film of Celgard 5511 (or equivalent) previously used in sterile packaging. The lower hydrophobic membrane is Celgard K-442 (or equivalent), a newly-developed water-repellent film sandwiched between two polypropylene webs that provide additional mechanical strength.

This work was done by Toohyon Cho and Michael L. Shuler of Cornell University for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 18 on the TSP Request Card.*
NPO-17199



New on the Market

BYTEK Corp., Boca Raton, FL, has unveiled the 135-H MultiProgrammer™, a 32-pin GANG/SET (E)EPROM **programmer** that offers universal device support, including Programmable Logic Devices and Bipolar PROMs. The 135-H features four operating modes: stand-alone programming including data editing, splitting, and shuffling; computer remote control; terminal mode; and menu-driven operation using BYTEK's PROMSoft™ PC-compatible software, which allows users to edit full screens of program data or store data files. The programmer is compatible with both DATA I/O® computer remote control and PROMlink®
Circle Reader Action Number 788.

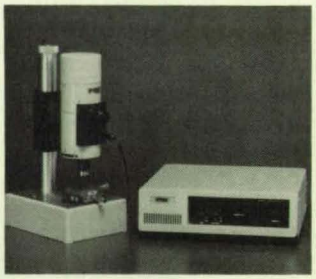
The Modem Security Device (MSD) from B&B Electronics, Ottawa, IL, **protects computers** or private bulletin boards from hackers and computer viruses via a callback method that limits access to valid users at the correct phone number. MSD intercepts each call as it reaches the modem and asks for a password. After the caller enters a proper password and hangs up, the device dials the phone number stored in its memory that matches the password. The user at that number is then allowed computer access. The MSD works with most stand-alone modems that employ the "AT Command Set."
Circle Reader Action Number 794.

The MK4 GRINDO-SONIC **nondestructive materials testing system** from CNS Inc., Fullerton, CA, rapidly and accurately determines resonant frequencies and moduli of metals, ceramics, composites, plastics, and concrete. The instrument can be used at both high and low temperatures, and its readings can be correlated with composition, mechanical properties, and microstructure. On a thin 4340 steel bar, for example, it can differentiate between the microstructures resulting from tempering at 399°C and 427°C.
Circle Reader Action Number 784.

LO/MIT-1, a **radiant barrier coating** for energy conservation and light reflection, has been introduced by the Solar Energy Corp. (SOLEC), Princeton, NJ. Designed as a low-cost substitute for metallic foils or metallized plastic films, the coating features high temperature tolerance, excellent adhesion, and the ability to produce uniformly low emissivities on a variety of substrates. Lab tests on glass substrates show emissivities lowered from 0.86 to 0.22, and spectal reflectivity increased from 7.3% to 85%. LO/MIT-1 can be applied using spray techniques for about five cents per square foot in material costs.
Circle Reader Action Number 780.

The SAGA 4000 **digital flowmeter** from Ion Track Instruments, Burlington, MA, offers microprocessor accuracy for such applications as instrument calibration and sampling pumps. The portable unit measures volumetric flow rates for any gas or gas mixture over a range of 0.1 to 500 ml/min., with +3% accuracy, according to the manufacturer. The SAGA 4000 features four pairs of transmitters and receivers along a calibrated verticle tube. A soap bubble created using the gas being measured floats up through the tube, triggering an internal quartz clock which measures the rate of the bubble's assent. This signal is transmitted to the SAGA 4000's microprocessor, which displays the flow rate on its LCD screen.
Circle Reader Action Number 782.

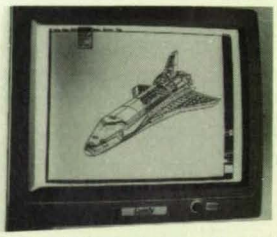
An incremental **optical encoder** featuring single-LED optics, a resolution of 524,288 counts per revolution, and accuracy to 2 arc seconds bit-to-bit rms has been introduced by the BEI Motion Systems Company's Digital Products Div., Little Rock, AR. Targeted for rotary table, rate table, and air bearing applications, the 5VL670 series encoder accurately converts rotary position change into a complementary digital output signal that can be used for position or motion sensing control. Single, thru, and hollow shaft designs are available, with a selection of line driver outputs.
Circle Reader Action Number 792.



A new **infrared microscope** from Minarad Systems Inc., Fairfield, CT, provides temperature measurements of targets as small as 0.01 mm. Designated the Model MR-100, the instrument features a standard calibration range of 15°C to 165°C, with optional extensions to 2500°C. Target temperature and emissivity setting are displayed digitally. Applications include thermal analyses of microcircuits, thermal profiles of rotating machinery, and transient temperature studies.
Circle Reader Action Number 786.

XonVu, a software program that simulates space as seen from the Voyager and Giotto spacecraft, is now available from XonTech Inc., Van Nuys, CA. Originally developed at NASA's Jet Propulsion Laboratory for mission analysis, XonVu features detailed graphics of spacecraft, planets, moons, stars, landmarks, rings, and the sun. The motions of the bodies are highly accurate, with errors no greater than 500 kilometers, according to the manufacturer. XonVu, which can be run by a novice as well as a professional astronomer, comes with an extensive user's manual and requires an IBM PC/XT/AT or compatible computer with 512K RAM, DOS 2.0 or higher, and CGA, EGA, or Hercules graphics. The program costs $79.
Circle Reader Action Number 800.

The Hot Shot® Pro, a handheld, noncontact **thermometer** from Capintec Instruments, Ramsey, NJ, can perform +1% readings on a heat source from 16 feet away. Accurate from -45.6°C to +1371°C, the thermometer records up to 1000 readings for logging or review. As an automatic data sampler, it takes readings at preset intervals from a half second to eight hours. Other features include automatic emissivity adjustment, auto-off power saving, battery life warning, and analog output.
Circle Reader Action Number 798.



An ultra-high-resolution **color display system** for IBM AT, PS/2 and compatible computers has been developed by the Computer Graphics Division of Lundy Electronics & Systems Inc., Glen Head, NY. The Lundy Model 1612 features a flicker-free 19 inch color raster monitor with 1600x1200 resolution, a graphics controller, and support for graphics standards such as DGIS and MS-Windows™. The system sells for $9,950. Applications include CAD/CAE, scientific and military simulation, medical imaging, mapping, and advanced desktop publishing.
Circle Reader Action Number 778.

The Delker Corp., Branford, CT, has developed precision-expanded **metal foils** for lightning protection and shielding of composite aircraft. Micro-Grid™ foils are produced from a solid sheet of metal that can be easily shaped, molded, and incorporated into the aircraft skin. This single-piece design eliminates the problem of contact resistance that can build between the individual wires of woven materials. Delker's mesh-like foils—which are made from aluminum, copper, or any other base metal, precious metal, or alloy—can also be applied in composites to shield electronic components on aircraft.
Circle Reader Action Number 796.

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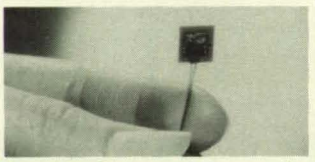
Illustration and design donated by Howard Cook

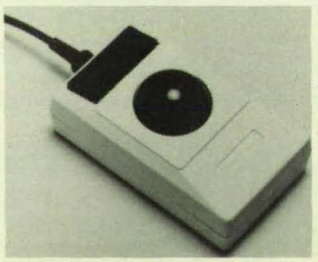
Circle Reader Action No. 586

New on the Market

A new **brushless DC motor** with a 4.8 volt bipolar drive has been introduced by Eastern Air Devices Inc., Dover, New Hampshire. The size-18 motor provides up to 65 percent efficiency, due in part to its low-voltage bipolar circuit design, and can achieve speeds of 20,000 rpm. Installed cost is low because the drive circuit is attached directly to the motor. Applications include blowers, fans, pump drives, spindle drives, and medical equipment.
Circle Reader Action Number 770.



Minco Products Inc., Minneapolis, MN, has invented a **flexible resistance thermometer** that conforms to curved surfaces and responds to temperature changes in as little as 0.15 seconds. Only 0.7 millimeters thick, the thermometer consists of a wire-wound sensing element laminated between layers of Kapton® insulation. The device offers excellent shock, vibration, and chemical resistance, and can be mounted with cements, epoxies, pressure-sensitive adhesive, tapes, and shrink bands.
Circle Reader Action Number 764.



The DIAMOND XX **Trackball**, a plug-in replacement for mouse cursor controllers, is offered by Evergreen Systems International, Westlake Village, CA. Designed for IBM PC/XT/AT and compatible computers, the trackball features RS-232 serial trans/rec lines, selective baud rate, and dynamic resolution. In addition, the DIAMOND XX emulates Microsoft, Mousesystems, Logitech, and Summagraphics formats.
Circle Reader Action Number 762.

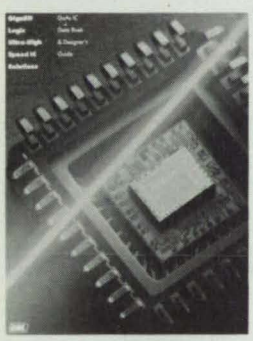
Intelligent I/O™, Tucson, AZ, has introduced the IQ-187W, a **digital I/O board**, offering 40 channels of TTL-compatible signals. Each 8-bit channel grouping can be independently programmed for use as either an input or output port. Data transfer on two of the board's five ports can be synchronized to external events by utilizing the channels in the fifth port as handshake control lines. Compatible with standard opto-isolators, the I/O board can reach speeds up to 360 KBytes/sec.
Circle Reader Action Number 760.

LeCroy Corp., Chestnut Ridge,NY, is offering a free **demonstration copy** of its EASYWAVE® Waveform Creation Software. The program, which supports LeCroy's 9100 Series Arbitrary Function Generators, enables design engineers, research scientists, and test programmers to create custom digital patterns and diverse waveforms with 5 nsec time resolution, 65 kpoint lengths, and voltage swings of up to 10V p-p. Entire waveforms or waveform segments can be manipulated mathematically to produce modulation and other interactive effects.
Circle Reader Action Number 790.

The APP 300, a high-speed **machine vision system** that interacts with personal computers, programmable controllers, and statistical processing control networks, is now available from PPT Inc., Minnetonka, MN. A 20 megabyte hard drive, 3-½ inch floppy drive, and a microprocessor that can handle up to 1,150 asynchronous images per minute are built into the APP housing, eliminating the need for a an external PC and keyboard. Instead, the user simply plugs a track ball into the unit. The vision system also features a frame grabber that provides enhanced graphics, including color overlays and frozen windows over live images.
Circle Reader Action Number 766.

New Literature

The 1989 **Test And Measurement Catalog** from the John Fluke Manufacturing Co. Inc., Everett, WA, features descriptions, photos, and ordering information for more than 650 products in 16 categories, including oscilloscopes, logic analyzers, board testers, recorders, plotters, and software. Available free of charge, the 520-page catalog integrates the product lines of John Fluke Mfg. and N.V. Philips.
Circle Reader Action Number 702.

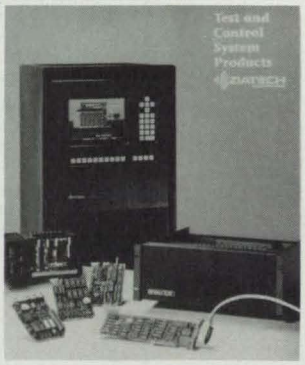


GigaBit Logic offers first GaAs IC Data Book and Designer's Guide.

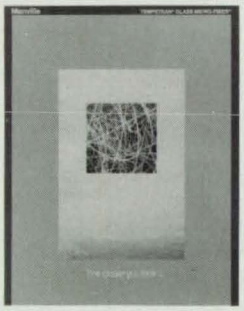
The **GaAs IC Data Book and Designer's Guide** from GigaBit Logic Inc., Newbury Park, CA, describes the company's PicoLogic™, NanoRAM™, and NanoROM™ lines, ASIC products, and foundry services. The 416-page publication also contains a design guide and GigaBit's Reliability and Quality Assurance Handbook.
Circle Reader Action Number 712.

"How Will Technology Affect America In The Next Ten Years?" is the title of a new publication from the AEG Corp., Somerville, NJ, in which experts predict future developments in six areas: transportation, automation technology, real-time computing, computer-aided programming, industrial systems, and office machinery. Experts include Arthur C. Clarke, co-author of 2001: A Space Odyssey; John Diebold, author of Beyond Automation; and Charles P. Lecht, author of The Waves of Change. The four-color booklet also describes AEG's activities in the six topic areas.
Circle Reader Action Number 718.

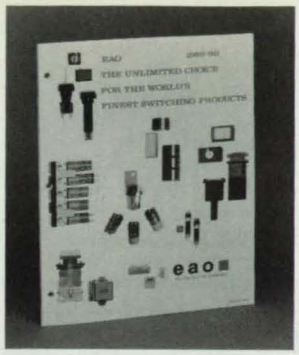
A free products brochure from the Electrophysics Corp., Nutley, NJ, features handheld and head-mounted **viewers that convert infrared (IR) radiation to visible light.** The devices are useful for observing and analyzing the output of IR lasers, laser diodes, and IR LEDs emitting in the near infrared. Also described are IR viewing television cameras, thermal video printers, IR sensitive cards, objective lenses, and filters.
Circle Reader Action Number 716.



New **STD Bus systems and IEEE 488 interfaces** are described in a free brochure from the Ziatech Corp., San Luis Obispo, CA. The 20-page publication reviews the complete line of Ziatech products, including single-board computers, I/O and development systems, industrial workstations and networks, and IEEE interfaces and software.
Circle Reader Action Number 706.



The properties and applications of **Tempstran® glass Micro-Fiber** are detailed in a four-color brochure published by Manville, Waterville, OH. Inserts describe glass paper-making with Tempstran, and highlight advantages the micro-fiber imparts to glass papers for high-purity air and liquid filtration, battery separators, automotive filtration, printed circuit boards, and friction materials. The ten-page brochure includes charts and scanning electron micrographs that illustrate chemical compositions of various micro-fiber grades; performance characteristics such as filtration efficiency and particle retention; operating temperatures; and physical, chemical, and electrical properties.
Circle Reader Action Number 704.



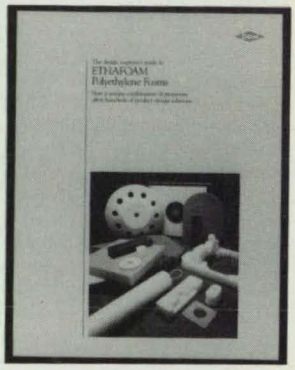
A full-color catalog illustrates **key-locks, illuminated switches, push-buttons, controls, and other switching products** offered by the EAO Switch Corp., Milford, CT. Photos, technical data, specifications, and applications are provided for each product. The 100-page catalog also lists types of illumination, lens shapes, and accessories.
Circle Reader Action Number 708.

A free brochure from Marlow Industries Inc., Dallas, TX, explains how **thermoelectric coolers** work and describes a wide range of applications—from stabilizing solid-state lasers to cooling infrared detectors and charge-coupled devices (CCDs). The booklet contains performance specifications for 52 standard modules, and includes information on custom fabrication techniques.
Circle Reader Action Number 710.

FERRUPS® —a family of **uninterruptible power systems** that protects computers and other sensitive electronic equipment from sags, surges, noise, lightning, blackouts and other power problems—is spotlighted in a free catalog from Best Power Technology Inc., Necedah, WI. When a power outage occurs, a detection circuit instantly orders the FERRUPS inverter into action. The inverter transforms DC power from the batteries into alternating current (AC), which is then fed into a transformer that conditions the raw current to achieve computer-grade uninterrupted power. Available in models from 250 VA to 15 KVA, FERRUPS offers such advantages as fewer data errors, reduced down time, lower service expenses, and prolonged equipment life.
Circle Reader Action Number 726.

A new brochure from ZYP Coatings Inc., Oak Ridge, TN, illustrates applications of **Plasma-Alumina powders**—hollow spheres of pure aluminum-oxide created through an advanced plasma process. With a mean particle diameter of 6 microns and a bulk density of only 1 g/cc, the powder is useful as a low-density, high-temperature filler for refractories, metals, plastics, glasses, ceramics, and other materials. Due to its microporous and hollow geometry, Plasma-Alumina is a practical support for catalysts, chemicals, organics, and polishing compounds, and can be applied in electronics packaging, filters, capacitors, and composites.
Circle Reader Action Number 724.

The HPS Division of MKS Instruments Inc., Boulder, CO, is offering a free brochure covering its line of **vacuum construction components**. Included are flanges, fittings, flow-actuated check valves, safety valves, and cold cathode ionization vacuum gauges. HPS' custom manufacturing capabilities and facilities piping services are also highlighted.
Circle Reader Action Number 722.



A free applications guide offered by the Dow Chemical Company, Midland, MI, explains how **ETHAFOAM™ polyethylene foams** can help solve design problems in such applications as gaskets, sealants, pipe insulation, floor underlayment, seat cushions, and padding for sports equipment. The four-color guide includes technical data on ETHAFOAM density range, buoyancy, compressive/tensile/tear strength, and other physical properties.
Circle Reader Action Number 714.

Activfilter™, an **activated carbon impregnated material** that removes contaminants, pollutants, irritants, and odors, is described in a new data sheet from the Lewcott Corp., Millbury, MA. Activated carbon is a form of charcoal in which millions of pores combine to create an internal structure of interconnected capillary passages roughly the size of the molecules being absorbed. Acting like a molecular magnet, the carbon attracts and traps impurities on its internal surfaces. Easy to handle and process, Actifilter features dual filtration and a high adsorption rate.
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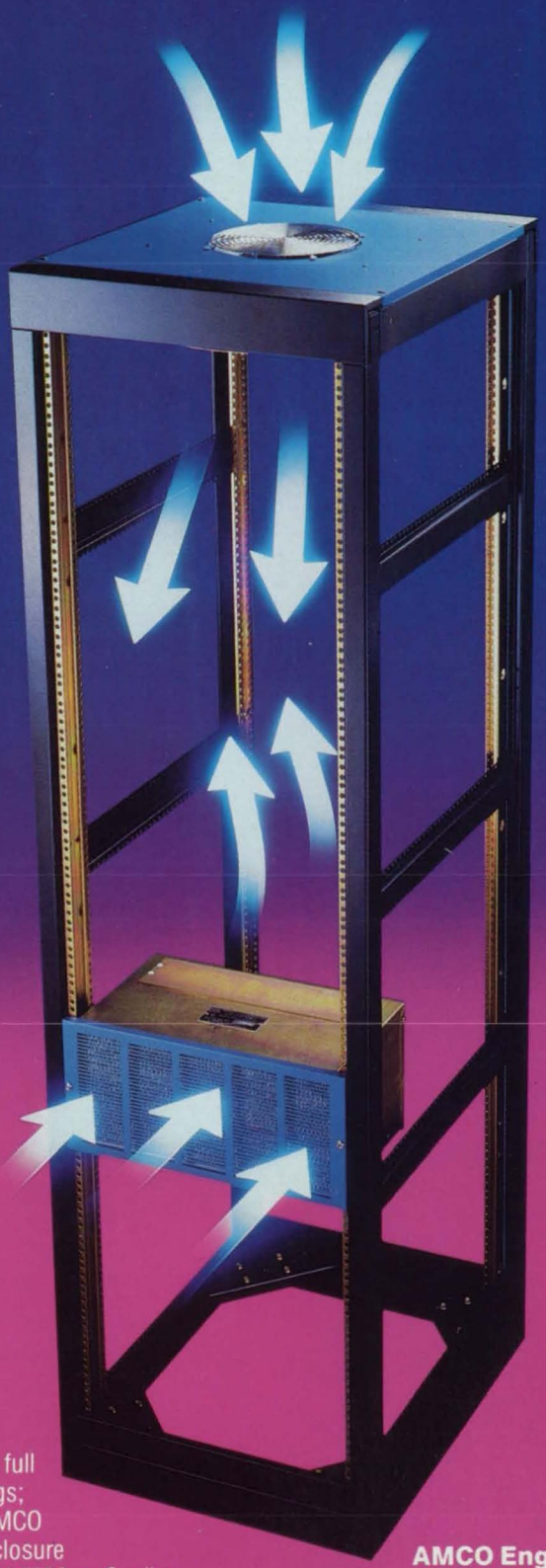

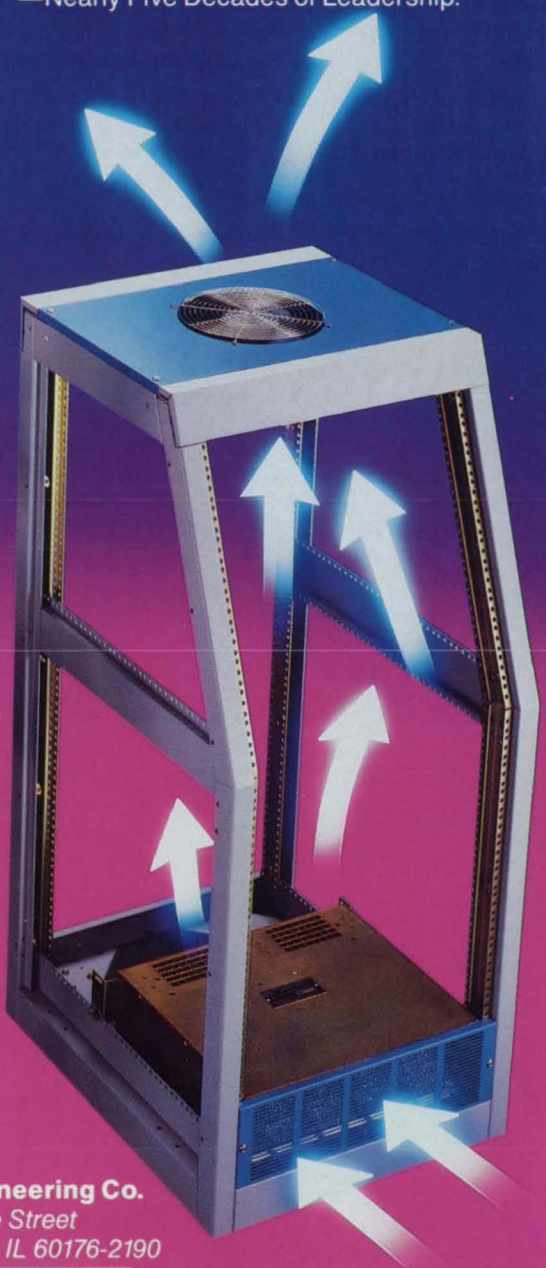

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SLIP PAST DANGER WITH A SKIN THAT STOPS THE STINGS.

Aerospace designers, paralleling a concept found in nature, are developing skins for planes that help pilots slip past danger. McDonnell Douglas systems engineers integrate sensors, processors and controls in a special "smart skin" that could detect hostile forces and create an electronic camouflage. Unhampered by blind spots, smart skin would be less vulnerable, too. The engineers are working toward an imbedded system that could reroute signals around a damaged surface, allowing the plane to continue its mission, giving America's pilots an extra edge in combat.

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