NASA Tech Briefs

THE DIGEST OF NEW TECHNOLOGY

Official Publication of the National Aeronautics and Space Administration
May 1995 Vol.19 No.5

Transferring Engineering Technology to Over 200,000 Qualified Readers Throughout Industry and Government

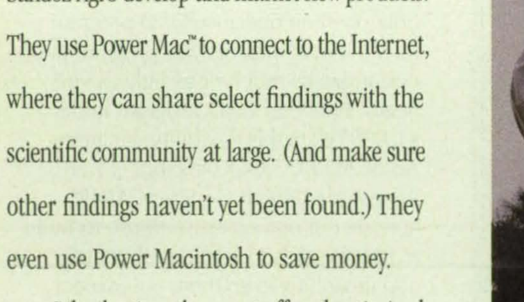
Jet Propulsion Lab: NASA's R&D Powerhouse

It's a chemist's best friend.

Ask the very enthusiastic Ben Sallard why he and his fellow chemists in Process Tech use Power Macintosh,™ and you'll get more reasons than can fit in one ad. A lot more.

Because they don't just use the RISC-based Power Macintosh to explore the intricacies of new chemical compounds. They also use it to collaborate with microbiologists, environmentalists, analysts and economists — in short, the different "ists" all around the world who help Sandoz Agro develop and market new products. They use Power Mac™ to connect to the Internet, where they can share select findings with the scientific community at large. (And make sure other findings haven't yet been found.) They even use Power Macintosh to save money.

Like the time they went off and optimized a deprotonization on a Mac™ instead of building a pilot plant. And saved $30 million. That made the whole group look good. And bred a new kind of loyalty between Ben and his Mac. The kind usually reserved for someone named Spot.



Benjamin W. Sallard, Jr.
Chemist
Network Administrator
Process Technology Group
Sandoz Agro, Inc.
Des Plaines, Illinois

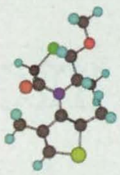
As part of a multinational life sciences company with more than 1,200 employees in the U.S. and Canada, Sandoz Agro specializes in the development and manufacture of environmentally sensitive biological, biochemical and chemical pest control products.

"If all you want to do is data acquisition, sure, you can do it on a Windows PC. But if you want to connect to a Novell server and a VAX and an AS/400, and you want to run business apps, and you need to do it now, then you need a Power Mac. Anyone who thinks there is a faster or easier way to accomplish all that is, well, barking up the wrong tree."

Process Tech scientists at Sandoz Agro are charged with finding the fastest, easiest and most cost-efficient ways to produce everything from herbicides and fungicides to flea control products for the family pet. Their latest finding? "Power Mac has the power we need to stay competitive."

Sandoz Agro chemists use LabVIEW and Power Mac to control and analyze complex chemical reactions from their desktops while they continue with other work. And that's just one example of the hundreds of powerful scientific, engineering and design applications that have been optimized for the RISC-based PowerPC™ chip at the heart of Power Macintosh.

Every Power Mac can read, write and format disks for DOS, Windows and OS/2. And every Power Mac lets you open and work with DOS and Windows files. If you need more compatibility than that, the Power Macintosh 6100/66 DOS Compatible includes both a 66 MHz 486DX2 and a PowerPC 601 microprocessor in one PC.



Macintosh® has always been known for graphical aptitude. But what kind of graphic is this? It's the Frontier® molecule, as visualized by a Sandoz Agro chemist with Chem3D Plus. And that's just the start. With Power Macintosh and Apple® innovations like QuickDraw™ 3D and QuickTime® VR, 3-D visualization and virtual reality become as easy as, well, using a Mac.

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NASA Tech Briefs

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FEATURES

TECHNICAL SECTION

(continued on page 8)

Wire-arc spraying is used to deposit protective metallic coating on thermally insulating foams. Compared to electroplating, wire-arc spraying costs less, is faster, and does not involve toxic and polluting chemicals. And unlike other thermal-spray metal-depositions methods, it does not degrade or burn the foam. For more on wire-arc spraying, turn to the tech brief on page 84.

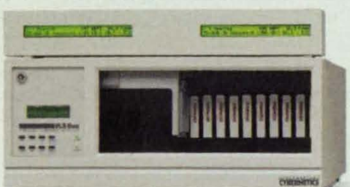
Photo courtesy of Marshall Space Flight Center

The Only 35 GB Tape Drive With Fast SCSI Compression

All tape subsystems are not created equal. Only the CY-8505 can give you capacity of up to 35 GB and transfer rates as fast as 90 MB per minute.

That's because the CY-8505 is the only tape subsystem that features switch-selectable, Fast SCSI Compression. So you get the highest performance possible — and the lowest cost per megabyte.

A MTBF of 160,000 hours ensures reliability. The bit error rate of less than 1 in 10^{17} is the best in the industry. A backlit display gives you complete status information, including command under execution, transfer rate, compression ratio, tape remaining, and more.



Our CY-CHS10A features two tape drives and can store up to 385 GB on eleven tapes — without tape handling.

The CY-8505 is the most advanced tape subsystem on the market, and it offers the most innovative options.

True Compatibility With:

Alliant	DEC TU/TA81	NCR	Silicon Graphics
Alpha Micro	DEC Unibus	NeXT	STC
Altos	Gould/Encore	Novell	Stratus
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AT&T	IBM Mainframe	Parallel Port	
Basic-4	IBM RISC/6000	PC 386/ix	Unisys
Concurrent	IBM RT	PC MS-DOS	Ultimate
Convergent	IBM S/38	PC Xenix/Unix	Wang
Data General	ICL	Pertec	Windows NT
DEC SCSI	Intergraph	PICK	*— and more*
DEC BI-Bus	Macintosh	Plexus	
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Fast SCSI Compression can increase the native 7 GB capacity by as much as five times; *Accelerated File Access* (for Unix systems) allows you to locate a file in an average of 85 seconds; *Data Encryption* lets you control access to sensitive data through the use of uniquely encoded card keys; and the *Advanced SCSI Processor* allows multiple drives to work together in striping, mirroring, cascade and independent modes. You can even copy and verify tapes off-line.

Compatible with virtually every computer system and network, the CY-8505 is available in a single or dual desktop unit, in a rack mount configuration, or as part of a tape library system that can store as much as 3 TB.

Backed by a two year warranty and our responsive in-house technical support group, the CY-8505 is fast setting the pace in data storage.

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Contents *(continued)*

DEPARTMENTS

__On the cover:__

Dr. Peter Tsou holds a form of aerogel he developed at Jet Propulsion Laboratory. Aerogels are the lightest manmade transparent solids and, as they do not conduct heat at all, are the best known insulators. Dr. Tsou found aerogel the perfect medium to capture plasma dust in space: when brought back to Earth for study, no other medium has revealed the particles so well. This aerogel will also be used as insulation for the Mars Rover to be launched in late 1996. With a density of 15 mg/cm^3, aerogel lightens the spacecraft compared to other gels. Cold does not affect it, and with a melting point of glass—1552° F—it can withstand the harsh conditions of space. For more on resources and commercial opportunities at JPL, see p. 14.

Photo courtesy of Jet Propulsion Laboratory

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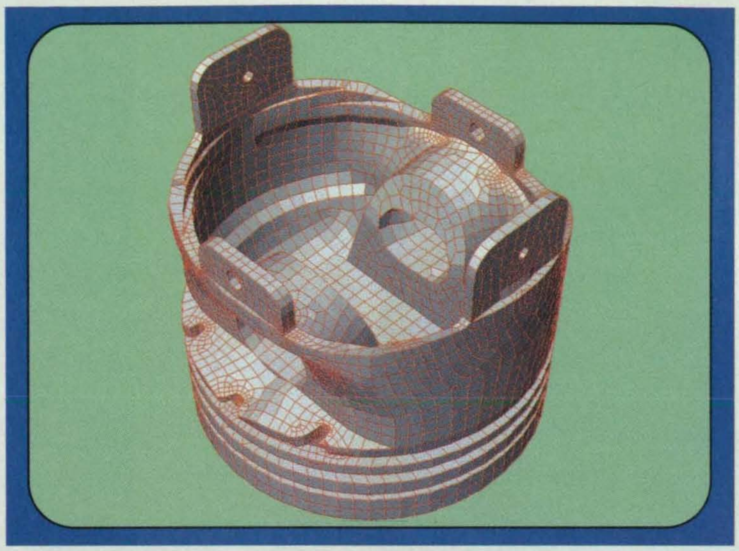


8-Node "Brick" Model by Houdini
Houdini meshed this CAD solid model directly from Pro/ENGINEER® with 8-node "brick" finite elements. Note local mesh refinement.

...Now, add Houdini™ to use 8-node "bricks" instead of Pro/MESH™ tetrahedra.

Here's how:

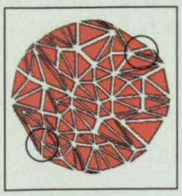
- Houdini imports solid models directly from Pro/ENGINEER® with or without Pro/MESH™. Houdini automatically meshes your model with accurate 8-node "brick" finite elements.
- Houdini creates brick elements from Pro/ENGINEER® for a wide variety of finite element analysis systems such as Abaqus, Algor, Ansys, Cosmos, Nastran, NISA, Patran, Procast and many more.

Why Houdini gives more accurate results

Houdini improves the surface mesh of the entire model as needed. Then, Hexagen™ (included with Houdini) creates a solid 8-node "brick" mesh from the complete surface inward. Brick elements generally give better results than other 3-D element shapes.

Hexagen puts the best shaped elements on the surface. This is important because the surface is where you need the best answers; where loads and boundary conditions are applied and where stress levels tend to be highest.

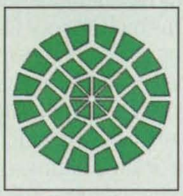
Generation of tetrahedral elements (Pro/MESH and others)



The mesh is generated using low-accuracy tetrahedral elements. This type of generation may put poorly-shaped, low-accuracy elements at the surface.

Generation of Hexahedral elements from the surface in (Houdini/Hexagen)

The mesh is created with high-accuracy 8-node "brick" elements. Houdini and Hexagen put the best-shaped elements at the surface.



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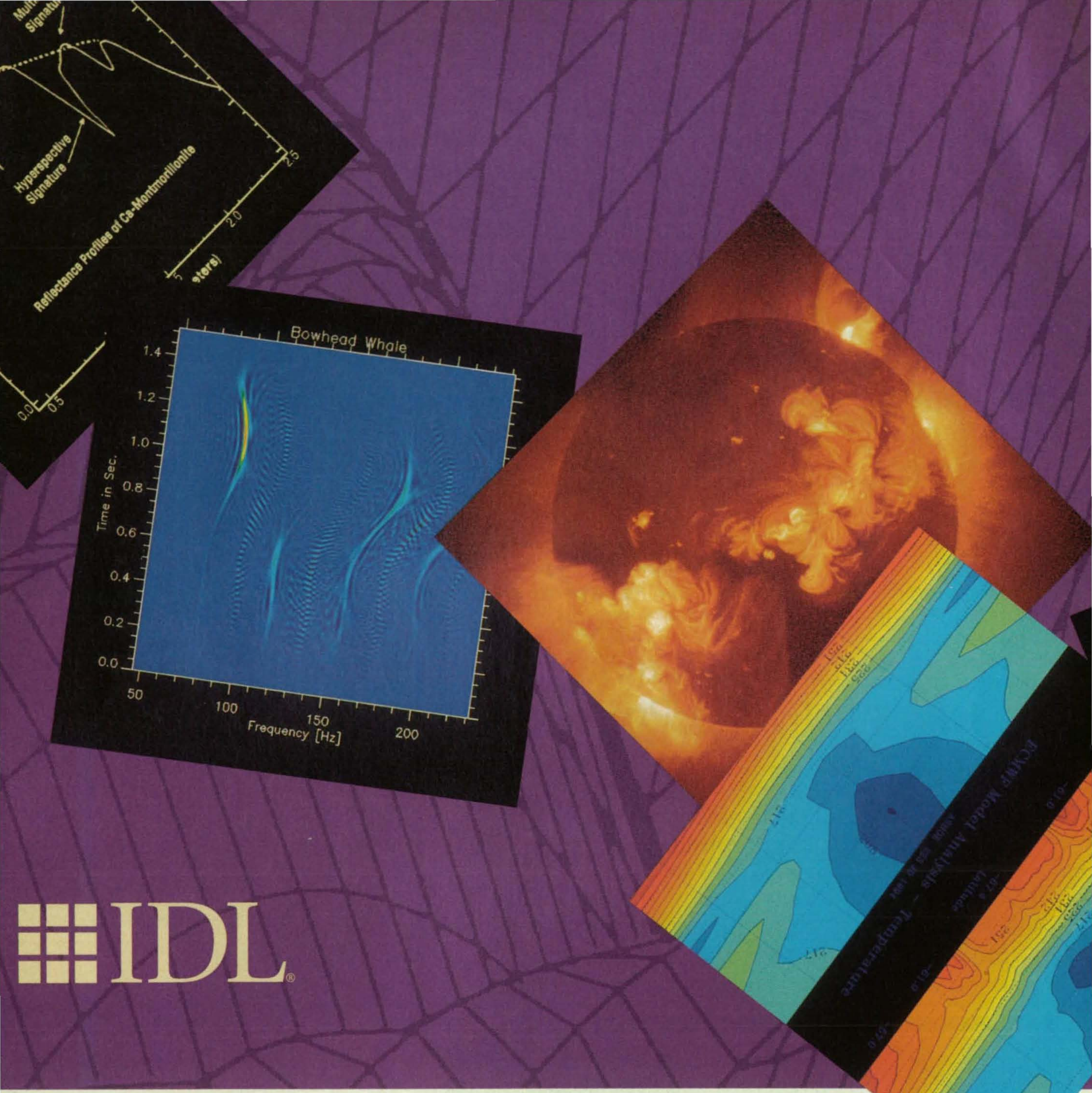
For free information on how Houdini can increase accuracy and a copy of Algor's technical white paper on 8-node "bricks" versus tetrahedra, call or fax today.



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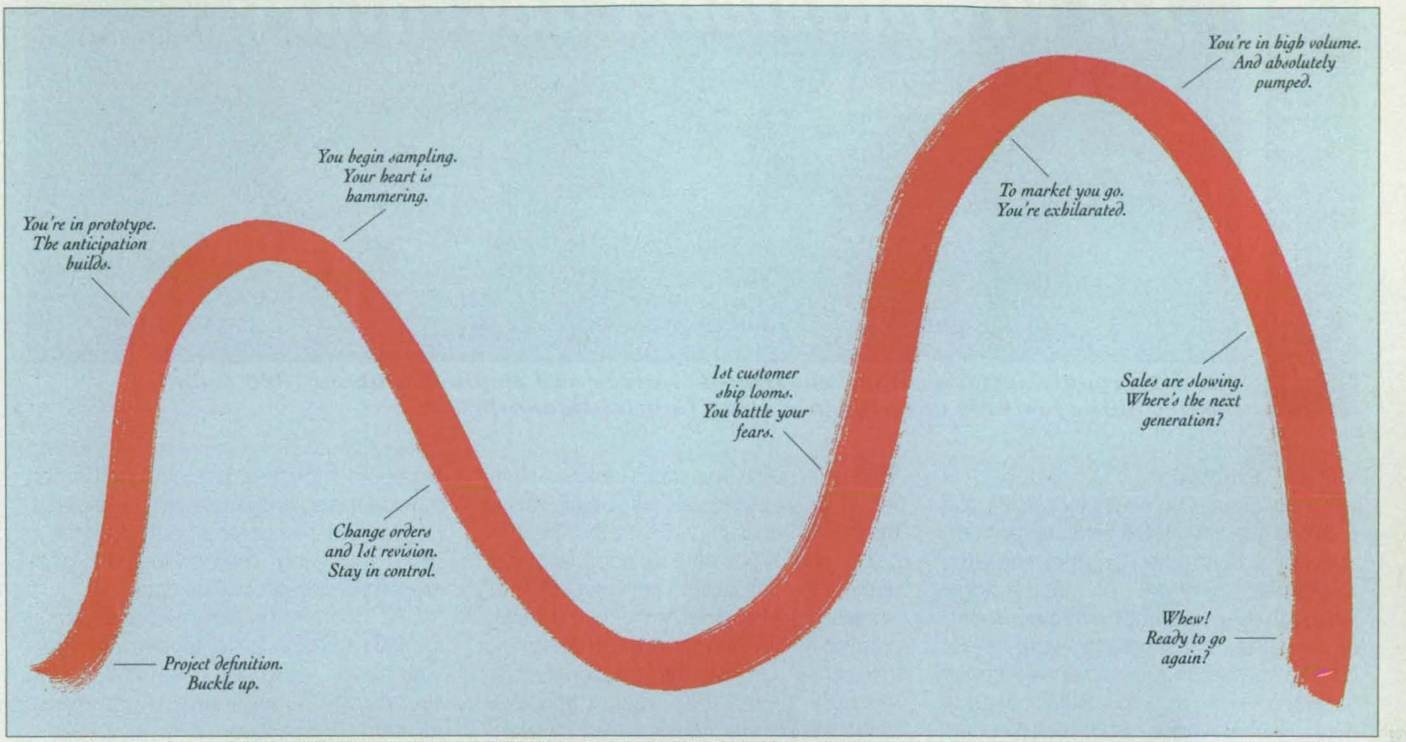

WE EVEN MAKE PARTS FOR ROLLER COASTERS.

The lifecycle of a product is a white knuckle ride. And you're sitting right up front.

The best way to prepare for this hair raising journey? Xilinx® FPGAs, obviously.

Ok, you're at the bottom of the first hill. Prototypes are made. Budgets are set. Meetings are called.

Well, thanks to reduced geometries and improved manufacturing techniques, we've reduced our FPGA prices by as much as 70%.

Nice way to start, isn't it?

You begin climbing. You feel the anticipation. But then there are last minute changes. Minor improvements. New features.

With Xilinx FPGAs, you simply reconfigure, and you're right back on track.

Again you crest the hill, head for the marketplace, and production levels start really screaming.

And now you want an even more economical, high volume solution. Quickly.

No problem.

The ticket is HardWire,™ our mask-programmed, and easily-converted-from-your-FPGA, production parts.

There's no redesign, no test vectors, no re-simulation and, since Xilinx HardWire prototypes are fully guaranteed, no risk.

We're talking weeks here, not the months you'd wait for gate arrays.

And when production inevitably slows down, we can take you back to FPGAs just as quickly.

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If you've gone with Xilinx, no sweat. Unlike gate arrays, you can make changes and still keep your product line, along with your company's profits, flying high.

Then, one day, sales start slowing down. Your product is beginning to show its age. Which means its time to take the ride with your system's next generation.

No one's better equipped to take that ride with you—and to make it pay off big time—than we are.

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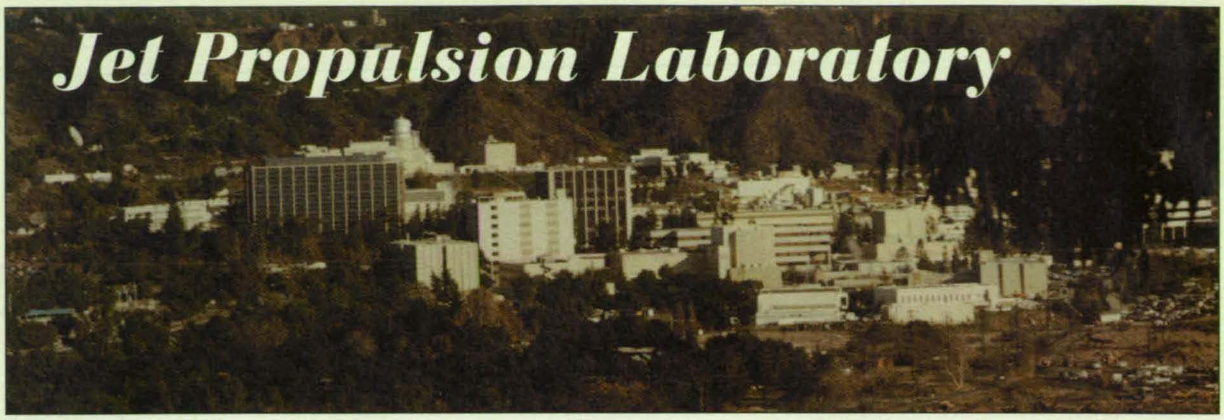

The Jet Propulsion Laboratory, covering 177 acres and employing about 7300 people, nestles in the foothills of California's San Gabriel Mountains.

Jet Propulsion Laboratory in Pasadena, CA, holds the distinction of being the only NASA field center managed by a contracted organization—the California Institute of Technology. Although JPL contracts with other federal agencies, most of its work is for NASA, specializing in unmanned space missions exploring the solar system, such as Voyager and Galileo. Its research into unmanned spacecraft has led to a rich array of spinoffs in related areas—robotics, microelectronics, lasers, software, sensors, and atomic oxygen erosion.

The laboratory began humbly in 1936 with a handful of researchers working out of a few shacks on the "jet" or rocket propulsion that gave the lab its name. Studies in solid- and liquid-fueled rockets led to jet-assisted takeoff for aircraft in the 1940s, and, in 1958, to the Explorer I, the nation's first satellite and discoverer of the Van Allen belts. That year, JPL was transferred from the Army to the newly created NASA, almost at once becoming the center for planetary exploration. In the early 1960s, JPL initiated and executed the Ranger and Surveyor missions to the moon, which paved the way to the manned lunar landings. It also began the Mariner series of flights to Mars and Venus; with Mariner 10, JPL innovated the use of one planet's gravity to boost a spacecraft to another, a now common power-saving method.

JPL built the orbiter for the 1975 Viking mission to Mars, NASA's most complex robotic spacecraft project to date, involving a planetary lander. The two spacecraft employed in the center's Voyager missions in the late 1970s and 1980s visited more planets—Jupiter, Saturn, Uranus, and Neptune, plus many of their satellites—than any before or since, and continue to relay data on interstellar space. JPL's Magellan spacecraft, after mapping the Venusian surface with a synthetic aperture radar system that penetrated the thick cloud cover, mapped variations in the planet's gravity field; Galileo is rushing toward Jupiter for a 1995 encounter; Ulysses is studying the sun outside the solar system's elliptical plane. Further, JPL has several Earth satellites in orbit gathering meteorological, geographical, and geological data.

The arm of the Robot Assisted MicroSurgery system enables relative positioning of surgical tools to an accuracy of 25 microns, improving accuracy for operations in sensitive sites such as the inner eye.

JPL involves the commercial sector in its R&D through an extensive commercialization program, ranging from Technology Cooperative Agreements through a unique JPL innovation, Technology Affiliates. The center arranges Technology Cooperative Agreements with private industry, in which personnel and expertise, but not funds, are exchanged, to enhance US global competitiveness. JPL has such an agreement with a major telecommunications company and others to develop a micro-CCD devised by a JPL senior research scientist and used by the thousands in place of a single CCD for smaller, cheaper satellite cameras. In an agreement with a US automotive company, JPL will design and customize a neuroprocessor ASIC for automobile engine health monitoring. And, in the Cray Parallel Applications Technology Program, Cray Research has access to JPL massively parallel processing experience, to rapidly increase the applications running on the Cray T3D, while JPL benefits by gaining early access to the T3D and Cray expertise.

The center's Technology Transfer and Commercialization (TTC) Program Office handles technology evaluation, intellectual property management, technical information dissemination, and the Technology Affiliates program. "Technology Affiliates is a proactive program, identifying problems for industry, matching those problems with our capabilities," said Al Pappano, TTC manager of outreach. "Industry is funding us to advance technology. In fiscal year 1995, this program is to be funded on the order of $5-6 million."

Company members of the Technology Affiliates program form strategic, "people-focused" alliances with JPL, based on one-to-one relationships and industry needs. JPL fulfills member needs by transferring technology, carrying out cooperative research and development, and providing technical information exchanges at conferences and private seminars. Under a single contract, the company funds a retainer account and individual tasks are negotiated between JPL and the company's technical staff. Over 90 companies have participated so far, completing more than 200 tasks. Technology Affiliates have included Diatek Corp., which has incorporated infrared optics into a medical thermometer; McDonnell Douglas, which used JPL neural network technology in its multispectral imaging products; and Draper Laboratories, which produced a JPL coprocessor board.

JPL's Small Business Innovation Research (SBIR) program has funded small companies to develop some of the components and devices necessary for the center's exploratory missions and research. For example, Physical Sciences Inc., Andover, MA, developed an atomic-oxygen-beam generating system for studying erosion of materials in low-Earth orbit. Supported by the SBIR program, Millitech Corp., South Deerfield, MA, generated high-performance mixers and multipliers for receiver and transceiver applications such as remote sensing, chlorine monoxide and ozone monitoring, and radioastronomy. Barr Associates, Westford, MA, produced a series of multilayer optical filters with increased durability and stability, making them particularly attractive for space applications such as the Cassini Saturn mission or the Upper Atmosphere Research Satellite. SBIR grants helped Lightwave Electronics, Mountain View, CA, develop a compact solid-state laser with annual sales of roughly $15 million, and Computer Motion, Goleta, CA, in producing the Automated Endoscopic System for Optimal Positioning, a robotic surgical tool.

Under its contract with NASA, Caltech can elect to retain the rights to new JPL technologies and pursue licensing of these technologies to US firms. In 1994, 11 non-software licenses for JPL-developed technology were negotiated with US firms. Recent examples include geopositioning satellite data acquisition for locating virtually any moving receiver on boats, cars, and pedestrians, and liquid-feed methanol fuel-cell technology for the transportation industry. The TTC office also disseminates technical information through tech briefs (over 200 published last year alone) and technical information packages, answering 40,000-45,000 information requests per year.

JPL's divisions orient their operations toward technology transfer and commercialization. The Telecommunications and Missions Operations Directorate (TMOD), which handles telemetry and tracking for deep space and Earth-orbiting missions, expressly works with partners in industry and academia to develop and transfer new capabilities to the private sector. Needing new low-cost telecommunications support for Earth-orbiting craft, JPL entered into a partnership with SeaSpace Inc., San Diego, CA, to develop a satellite terminal for unattended operations. After demonstrating the unattended terminal's viability on two missions, the TMOD is planning a network of small, automated ground terminals.

The Center for Space Microelectronics Technology publishes the quarterly *Space Microelectronics* to disseminate news of its research to the R&D community. Microelectronics research forms a crucial thrust of JPL's quest for smaller, lighter spacecraft for lowering mission costs—an essential quality with today's budget cuts. One spinoff from the microelectronics center was BEEM, or Ballistics Electron Emission Microscopy, engineered by Atomis Inc., Berkeley, CA, and marketed by Surface/Interface, Mountain View, CA. The award-winning invention allows the researcher to view the interface and surface of a microstructure simultaneously in the study of its operation and performance.

The Rover and Telerobotics Technology Program responds to opportunities from NASA space missions to seed commercial applications of emerging robotics technologies. The program's scope ranges from basic research to the synthesis of complete systems and evaluation in realistic ground and flight experiments. For JPL's virtual environment calibration technology, the center and Deneb Robotics Inc. entered into a Technology Cooperative Agreement whereby the company incorporates the technology into its commercial product, TELEGRIP, which can be used in both space and terrestrial robotics applications, and NASA gains immediate benefits for ground-controlled telerobotic servicing in space. JPL also signed a cooperative agreement with MicroDexterity Systems Inc., Memphis, TN, to commercialize the Robot Assisted MicroSurgery mechanical surgical arm, which is steadier than a surgeon's hand for delicate eye and brain operations. □

Spacecraft-designed options and operational scenarios are quickly assessed on the Mars Pathfinder Power Subsystem Breadboard at JPL.

For more information, contact Merle McKenzie, director, Technology Transfer and Commercialization Program Office, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109-8099; Tel: (818) 354-2577.

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 in further detail 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 contacting the Commercial Technology Office of the sponsoring NASA center (see page 20).

Transient-Switch-Signal Suppressor

A new circuit delays the transmission of a switch-opening or switch-closing signal until a preset suppression time. This eliminates undesirable switch actuation in response to some transient event, such as a momentary drop or rise in pressure in pipes. (See page 38.)

Polyimides That Contain Cyclobutene-3,4-Dione Moieties

These polymers are useful in structural components exposed to hot and oxidative environments, as in jet engines and on the outer surfaces of supersonic aircraft. Other potential applications are in photovoltaic, photoconductive, and photoemissive devices. (See page 64.)

Maximum-Acceleration-Recording Circuit

This circuit is simpler, less bulky, consumes less power, costs less, and does not require playback and analysis of data as do inertia-type devices. The circuit can be used to record maximum accelerations, for example, in commodities transported by trucks to determine safest packaging for fragile or sensitive products. (See page 34.)

Glass-Ampoule Breaker

A device breaks glass ampoules repeatedly and retains their gaseous contents. The device can be used in laboratories to test for chemical reactions and/or deterioration of items stored in ampoules. (See page 56.)

Controlled Thin-Film Growth of Silicon Carbide Polytypes

This process can be incorporated into the sequences of deposition and etching steps to produce silicon-carbide-based semiconductor devices. Silicon carbide is emerging as a material of choice for semiconductors that must operate at high power, high temperature, and/or high frequency. (See page 58.)

Circuit for Control of Electromechanical Prosthetic Hand

A proposed circuit would derive electrical signals from shoulder movements. The circuit would be built around the favored shoulder harness to help below-the-elbow amputees, eliminating the complexity of computer-controlled or hydraulically actuated devices. (See page 36.)

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If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

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Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Syed Shariq
(415) 604-0753
syed_shariq@qmgate.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3119
duke@louie.dfrf.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc-mail.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
William Spuck
(818) 354-2240
william_h_spuck@jpl.nasa.gov

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Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
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Selected technological strengths: Emissions and Contamination Monitoring; Sensors; Corrosion Protection; Bio-Sciences.
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If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.
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Modified Polyimides Are More Compression Moldable

Offset stoichiometries and end-capping agents impart the desired properties.

Langley Research Center, Hampton, Virginia

The semicrystalline polyimides that are synthesized from 3,3′,4,4′ benzophenonetetracarboxylic dianhydride (BTDA) and 1,3-bis(4-aminophenoxy-4′-benzoyl)benzene (1,3-BABB) can be modified to increase melt flow. In comparison with the unmodified versions of these polyimides, the modified versions are more amenable to compression molding, processing to form adhesive bonds, and use as matrices in matrix/fiber composite materials.

The first step in the synthesis of an unmodified, high-molecular-weight polyimide of this type involves the chemical reaction of BTDA with an equimolar amount of 1,3-BABB to form a high-molecular-weight polyamic acid intermediate product. To obtain a modified polyimide of this type, the first step is modified by the use of a small calculated excess of either BTDA or 1,3-BABB to obtain a polyamic acid of calculated lower average molecular weight and narrower statistical distribution of molecular weights around the average.

When excess BTDA is used, reactive anhydride groups are present at the ends of the polyamic acid chains; when excess 1,3-BABB is used, reactive amino end groups are present. In either case, the reactive end groups can cause undesired chemical reactions that result in degradation, extension, or branching of the polymer molecules. Therefore, it would be advantageous to end-cap these reactive end groups to form nonreactive end groups, making the polyamic acid and the polyimide end product more thermally stable. This leads to a second, optional modification; namely, the use of an end-capping agent in the small stoichiometric amount needed to react with all of the reactive end groups. When excess BTDA is used, the end-capping agent can be a primary amine (see Figure 1); when excess 1,3-BABB is used, the end-capping agent can be an aromatic anhydride (see Figure 2).

The resulting modified polyamide acid can be used in the usual ways: for example, while still dissolved in the solution in which it was synthesized, it can be used to impregnate glass or carbon fiber reinforcement, then dried to remove solvent and to convert the polyamide acid to the polyimide. Alternatively, the polyamide acid can be either thermally or chemically converted to the polyimide. The resulting solid can be used as is to make moldings or as finely divided particles to impregnate glass or carbon fiber reinforcement. Regardless of the imidization method used in a specific case, the stoichiometrically offset, end-capped polyimide is

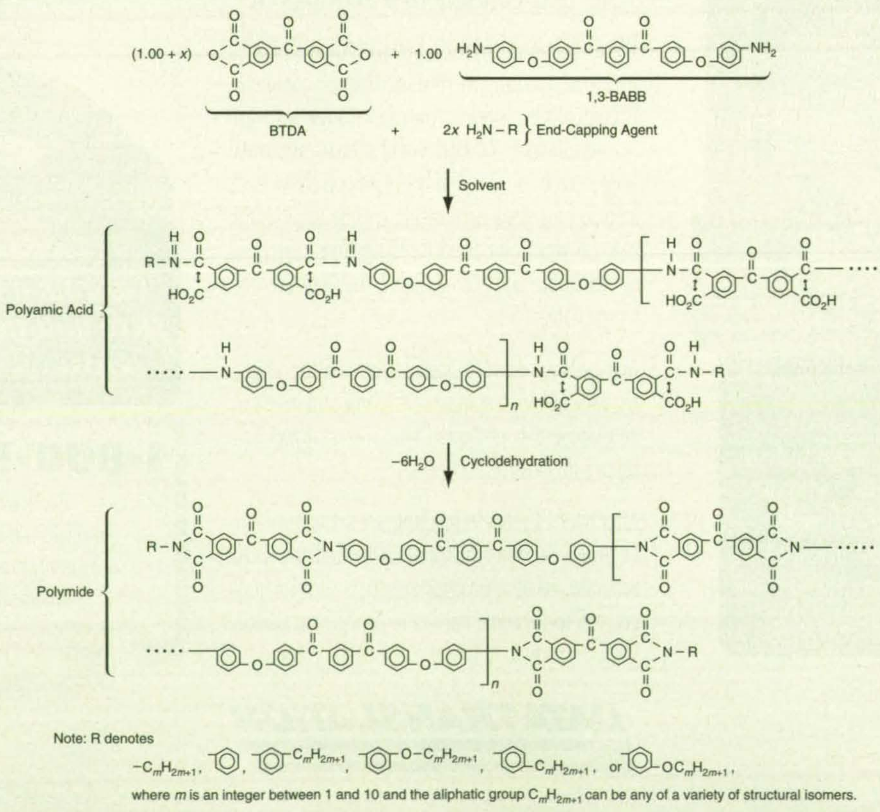
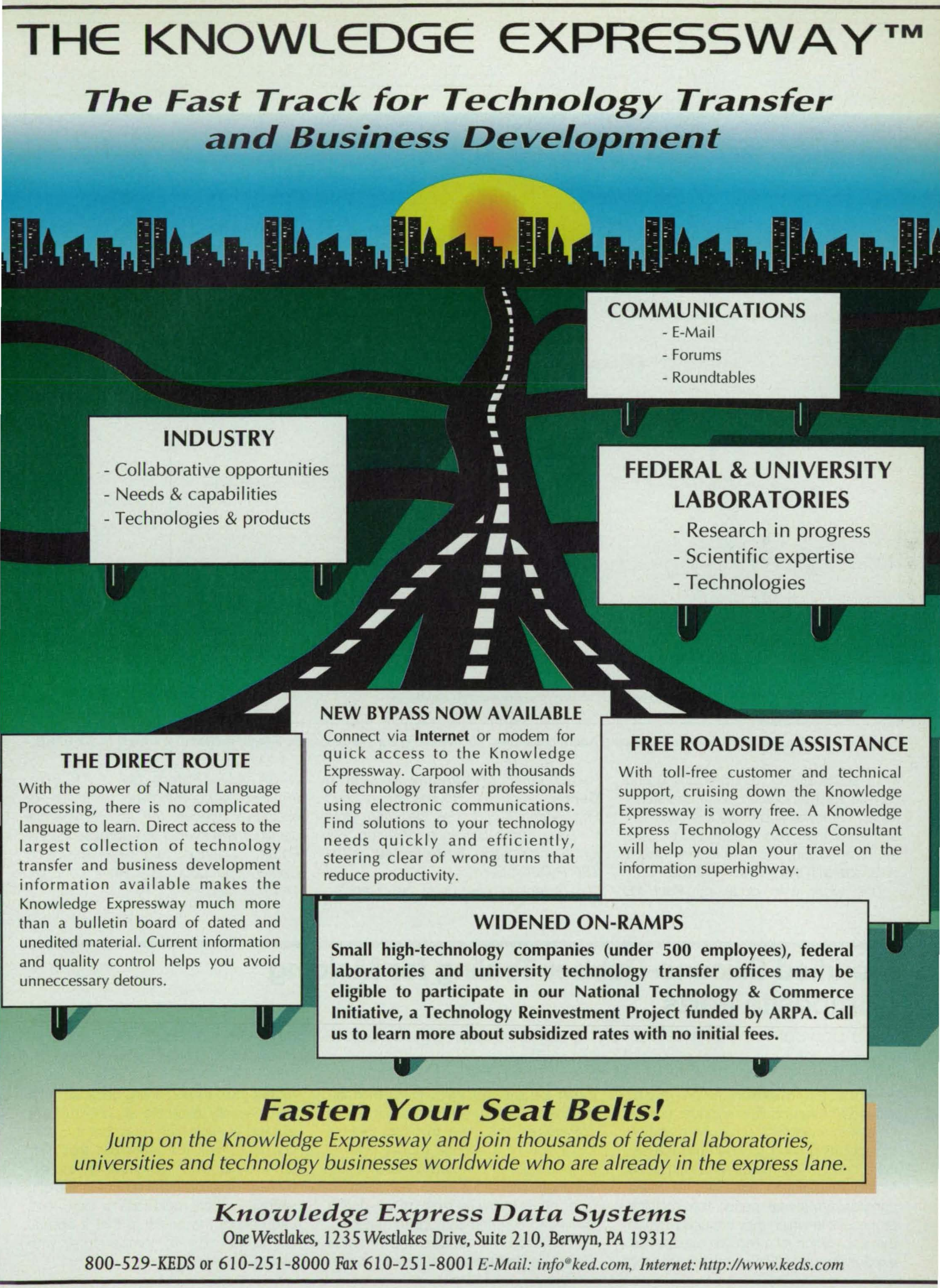


Figure 1. A **Primary Amine End-Capping Agent** passivates reactive end groups produced by a slight excess ($0 \leq x << 1$) of BTDA.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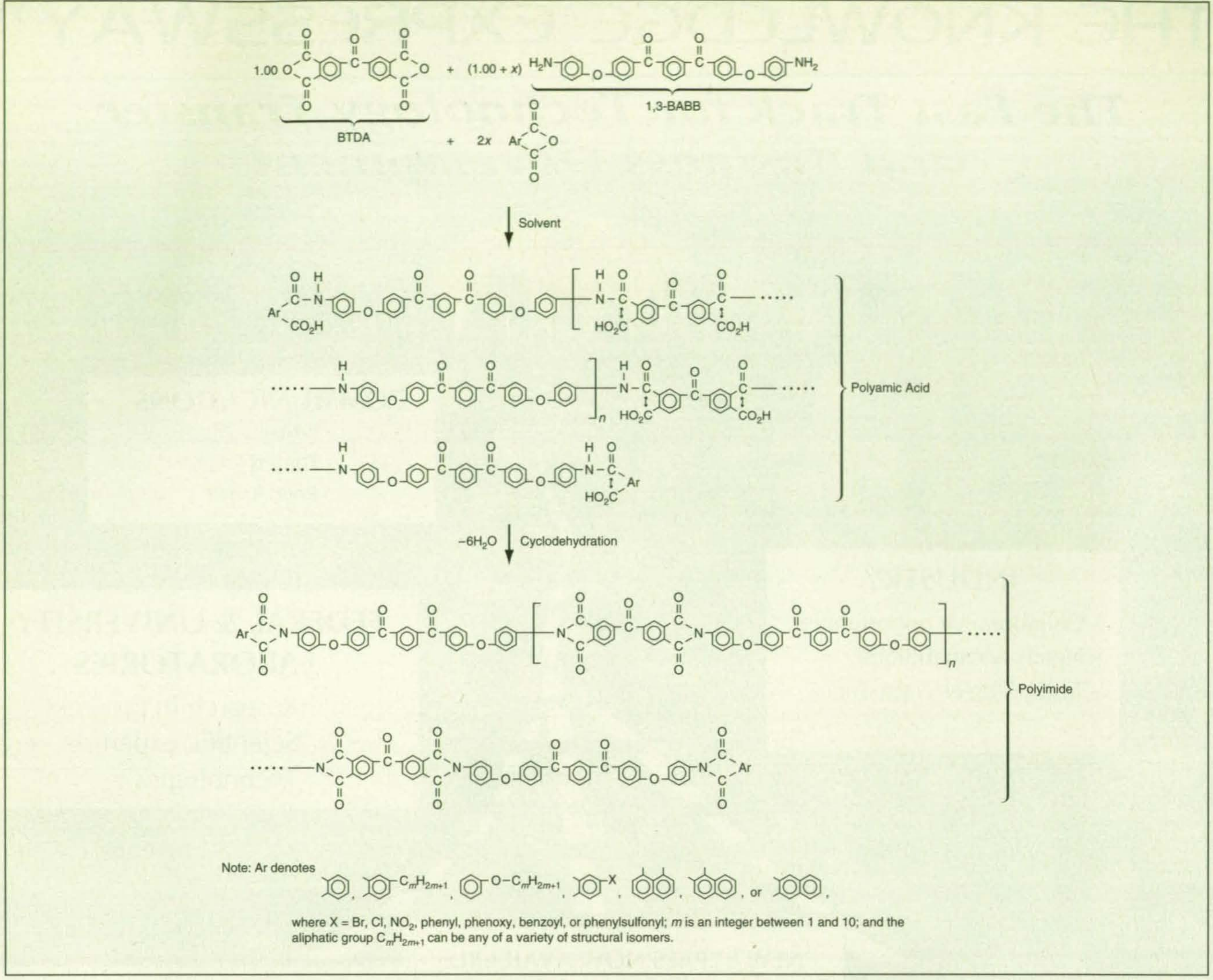


Figure 2. An **Aromatic Anhydride End-Capping Agent** passivates reactive end groups produced by a slight excess (0 £ x << 1) of 1,3-BABB.

more stable during melt processing and can be melt-processed at temperatures somewhat lower and pressures considerably lower than those needed to process the unmodified, high-molecular-weight polyimide with the same repeat unit.

This work was done by Paul M. Hergenrother of **Langley Research Center**, *Stephen J. Havens of Lockheed Engineering & Sciences Co., and Mark W. Beltz of the University of Akron. For further information,* ***write in 142*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,212,276). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14457.

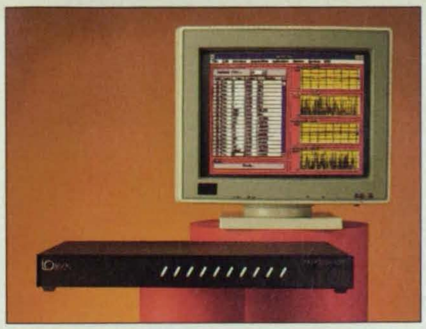
Modified Silicone-Rubber Tooling for Molding Composite Parts

Silica powder is added selectively to adjust the pressures applied to molded parts.

Langley Research Center, Hampton, Virginia

Reduced-thermal-expansion, reduced-bulk-modulus silicone rubber for use in mold tooling can be made by incorporating silica powder into the silicone rubber. The molds and associated tooling in question are used to make composite-material parts; the molding processes in which they are used involve the application of pressure via thermal expansion of silicone-rubber tooling within confines of rigid, lower-thermal-expansion tooling. For example, a typical process of this type involves thermal expansion of a silicone rubber core to press a layer of composite material outward into intimate contact with the surface of a stainless-steel mold during heating to cure the composite material.

The need to reduce the thermal expansion and bulk modulus of silicone-rubber mold tooling arises because most commercially available silicone rubbers expand at such high rates that it is difficult to control the pressures that they apply. By reducing the coefficient of thermal expansion and the bulk modulus of a silicone-rubber mold-tooling part, one can control the pressure that it applies (as a function of temperature) with greater precision.



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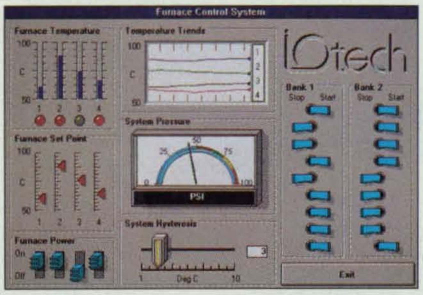

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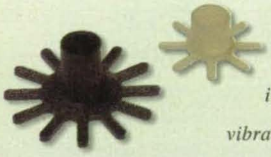

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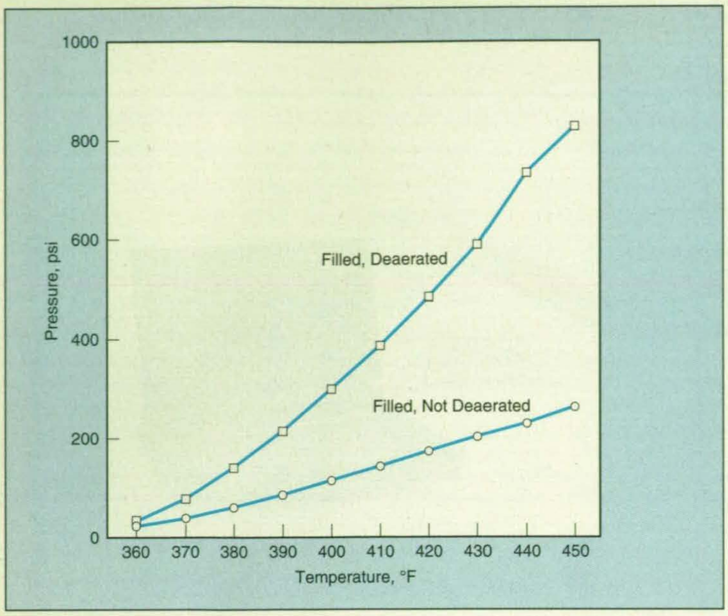

The **Pressure Exerted by Thermal Expansion** is reduced even further by allowing air bubbles to remain in the silicone rubber instead of deaerating it. The bubbles reduce the bulk modulus of the material.

Experiments to demonstrate the feasibility of this concept were conducted on a commercial silicone rubber supplied in two liquid parts (liquid rubber plus catalyst). Preparation of specimens began with mixing the two liquid parts. Silica powder in a proportion of 5 weight percent was added to the liquid mixtures for some of the specimens. Some of the mixtures were deaerated in a partial vacuum, while others were not deaerated. The liquid mixtures were cast and heated in molds to form the solid silicone rubber specimens.

Measurements and calculations for specimens in a test rig indicated that the pressure exerted by the unfilled, deaerated silicone rubber increased with temperature at a rate of about 20 psi/°F (about 250 kPa/°C), while that of the filled, deaerated silicone rubber increases with temperature at about 10 psi/°F (about 120 kPa/°C). The bubbles that remained in the filled, nondeaerated specimens reduced their bulk modulus, so that the pressure that they exerted increased with temperature at a very manageable rate of about 2 psi/°F (about 25 kPa/°C) (see figure).

This work was done by Robert M. Baucom and John J. Snoha of **Langley Research Center** *and Erik S. Weiser of Georgia Institute of Technology. For further information, contact*

John Hildebrandt
Tecnico Corporation
831 Industrial Avenue
Chesapeake, VA 23324

or Greg Manuel of NASA-Langley Applications Group at (804) 864-3864.
LAR-15217

Metal-Matrix Composite Parts With Metal Inserts

Appendages for connection to other parts are cast in place.

Marshall Space Flight Center, Alabama

A developmental fabrication process produces metal-matrix composite (MMC) parts with integral metal inserts. With the inserts, the MMC parts can readily be joined to similar parts by use of brazing, welding, or mechanical fasteners. Until now, the difficulty of joining MMC parts has inhibited the exploitation of the light weight, strength, and dimensional stability of MMCs.

The process was conceived to make strong, lightweight components of structures to be erected in outer space. MMCs may also be useful on Earth, in such automotive parts as rocker arms, cylinder liners, and pistons. Potential industrial applications include parts that are subjected to high stresses at high temperatures, as in power-generation, mining, and oil-drilling equipment.

The feasibility of the process has been demonstrated by making parts of magnesium-matrix/graphite-fiber composite material with titanium inserts (Figure 1). The parts were formed to final shape in a single casting step; no finish machining was necessary. In general, the process involves pressure casting in partly reusable molds made of inexpensive materials.

In the demonstration, the parts were made in a pressure-casting machine that is capable of operating at temperatures up to 1,400 °C and pressures up to 800 lb/in.2 (5.5 MPa) and can accommodate parts up to about 4 in. (≈ 10 cm) in diameter and about 6 in. (≈ 15 cm) long.

The machine features a balanced-pressure mold, in which the internal pressure exerted by the molten metal is balanced by an equal pressure on its outer wall from a compressed inert gas (Figure 2). (The internal pressure is needed to make the metal-matrix material infiltrate the graphite-fiber reinforcement.) Because these pressures are balanced and are low relative to compression yield stresses of cheap, machinable, nonstructural-grade materials, it is feasible to make the mold out of such materials. In addition to the graphite and salt used in the demonstration, such materials could include ceramics, quartz, and sheet metal.

In the demonstration, a graphite-fiber preform destined to become the fiber reinforcement of the composite part was placed in the mold along with the titanium insert. The mold and its contents were purged with argon, then evacuated. The magnesium was heated in a

Figure 1. These **Clevis Tube-End Fittings** are made of magnesium-matrix/graphite-fiber composite with titanium inserts. The composite parts were molded to their final dimensions in a single step.

crucible to a temperature of 660 °C, while the preform in the mold was preheated to 530 °C. A pneumatic system raised the crucible so that a snorkel on the mold dipped into the crucible. The chamber that contained the crucible was then pressurized with argon at 800 psi (5.5 MPa) to force the molten magnesium into the mold cavity, where it infiltrated the preform. After about 3 minutes, the crucible was lowered and the mold allowed to cool. A boron nitride coating on the graphite mold ensured that the mold released the part easily.

The process temperatures, times, and pressure were chosen to produce complete infiltration of the densely packed preform while ensuring quick solidification of the melt (thus inhibiting chemical reactions that could degrade the interface between the matrix and the fibers). These conflicting requirements are satisfied by maintaining the magnesium alloy 60 °C above its liquidus temperature while maintaining the preform at a temperature 60 °C below the liquidus temperature of the magnesium at the chosen pressure.

When tested to failure, a part made by this process fractured at a tensile load of 2,803.1 lb (12,468 N). The fracture occurred in the body of the composite material, well away from the insert, indicating that the interface between the insert and the composite material transferred the tensile load efficiently.

This work was done by T. Majkowski and U. Kashalikar of Foster–Miller, Inc. for **Marshall Space Flight Center**. *For further information,* ***write in 94*** *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 20].

MFS-27306.

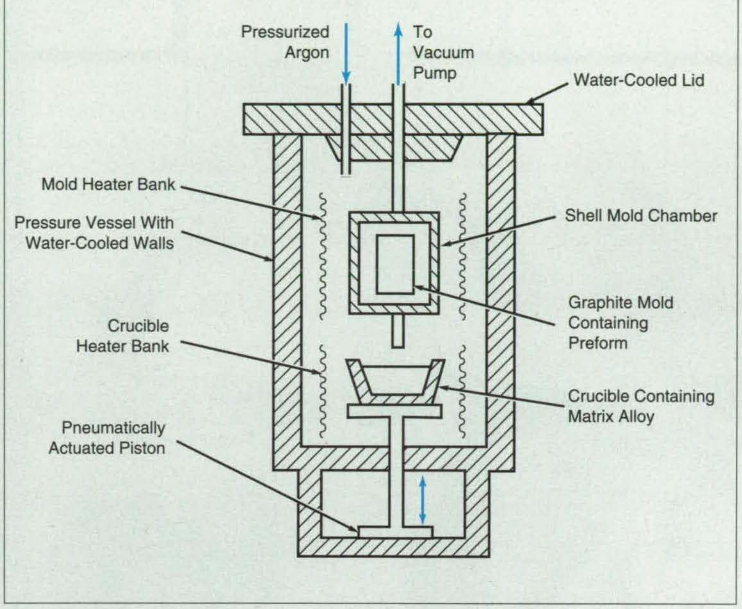

Figure 2. The **Pressure-Casting Machine** molds under conditions that promote complete infiltration of molten metal into a fiber preform, followed by rapid solidification to ensure good bonding.

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Fixture for Crush Testing of Composite Plates

Plate specimens are used instead of tube specimens.

Langley Research Center, Hampton, Virginia

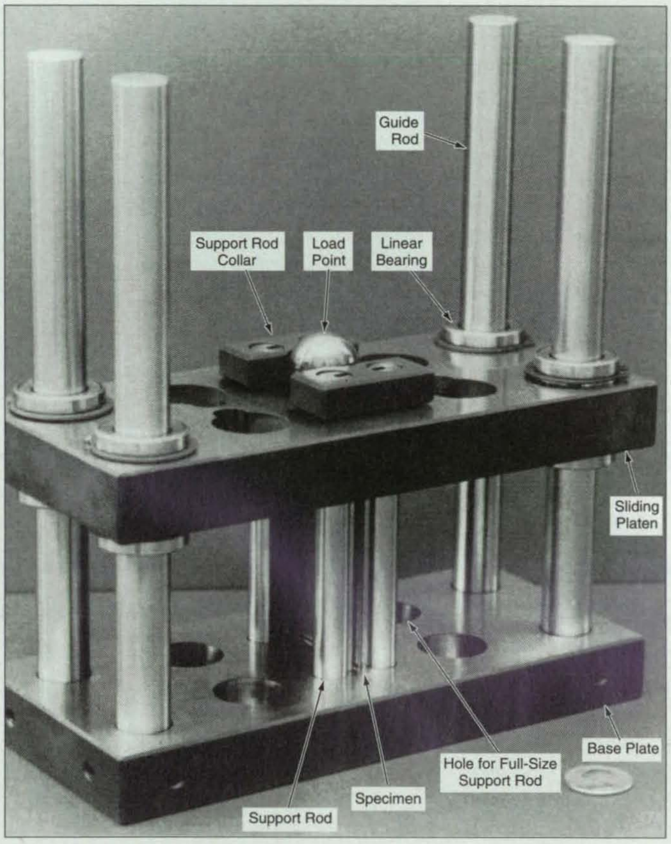
A test fixture holds composite-material (matrix/fiber) plate specimens for crush testing in a universal compression-testing machine to determine energy absorption characteristics of the composite material system and laminate. Crush tests contribute to the development of more crashworthy composite-material structural components of aircraft. Previously, crush tests of composites were performed on cylindrical specimens instead of flat plates. The cylinders were not only expensive and difficult to fabricate, but also yielded data that could not easily be related to aircraft structural components, which are typically platelike.

The fixture accommodates specimens of two different sizes: 6 by 4 by 0.16 in. (≈ 15 by 10 by 0.41 cm)] and 3 by 2 by 0.08 in. (≈ 7.6 by 5.1 by 0.20 cm), designated as full scale and half scale, respectively. The fixture includes a platen equipped with four linear bearings that enable it to slide freely on four vertical guide rods (see figure). The loading rod of the testing machine applies the load to the platen via a large steel ball bearing, which is kept centered by a dimple in the center of the platen and a corresponding dimple in the center of the lower end of the loading rod. The platen, in turn, bears down upon the specimen.

The specimen is aligned by four knife edges attached to four vertical support rods. To eliminate a source of frictional force that could distort the results of tests, clearance holes in the platen prevent contact between the platen and the support rods. Collars are placed over the two pairs of opposing support rods to prevent the support rods from bending apart, thereby ensuring that the knife edges continue to keep the specimen aligned along its entire length while it is being crushed. In so doing, the collars also prevent the support rods from coming into contact with the platen.

This work was done by Karen E. Jackson of **Langley Research Center** *and J. Andre Lavoie and John Morton of Virginia Polytechnic Institute and State University. For further information,* ***write in 300*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. LAR-15212.



The **Test Fixture** as shown here is holding a half-scale specimen. To accommodate a full-scale specimen, the support rods would be moved to the more-widely-spaced holes in the base plate.

LaRC™-IA Copolyimides

Glass-transition temperatures and retention of shear moduli at high temperatures are increased.

Langley Research Center, Hampton, Virginia

Copolyimides that are modified versions of LaRC™-IA thermoplastic polyimide have been formulated by incorporating moieties of 3,3′,4,4′-benzophenonetetracarboxylic dianhydride (BTDA) and, alternatively, isophthaloyldiphthalic anhydride (IDPA) into the LaRC™-IA polymer backbones (see figure). In comparison with unmodified LaRC™-IA, the resulting copolyimides exhibit higher glass-transition temperatures and retain greater fractions of their lower-temperature shear moduli at higher temperatures. This enhancement of high-temperature performance is achieved without sacrificing the melt-flow processibility of unmodified LaRC™-IA polyimide: like unmodified LaRC™-IA polyimide, the LaRC™-IA copolyimides can be synthesized as semicrystalline powders that exhibit high melt flow at temperatures in the vicinity of 330°C. These copolyimides can be spun into fibers or used as adhesives, molding powders, or matrix resins in many applications, especially in the fabrication of strong, lightweight structural components of aircraft.

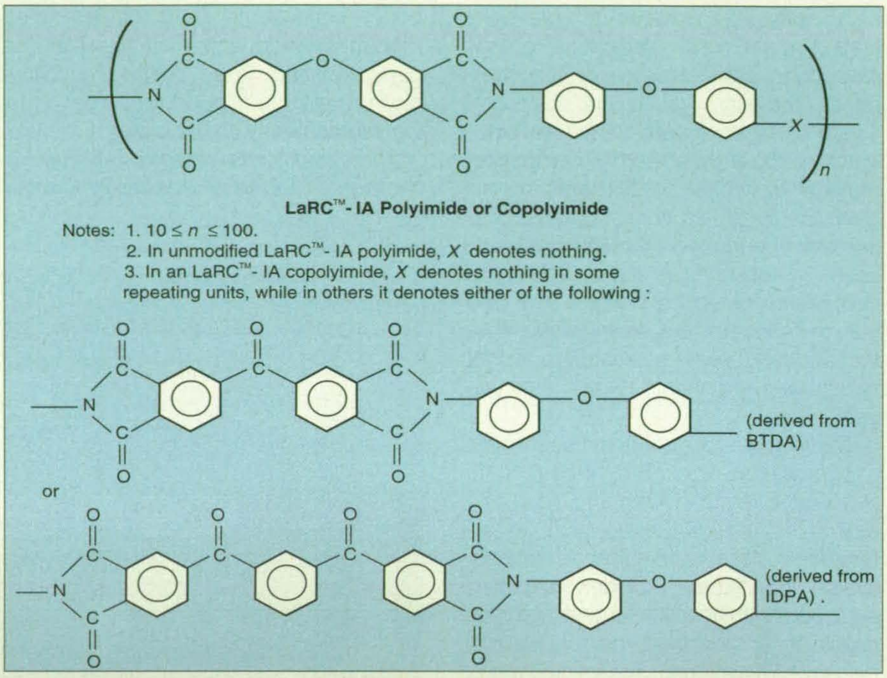
The incorporation of BTDA or IDPA follows a cohesive-energy-density approach to obtain the desired enhancements in thermomechanical properties. The BTDA and IDPA bring in additional carbonyl moieties; the cohesive energy density is directly related to the number of carbonyl moieties per polymer repeat unit. Thus as the number of carbonyl units increases, interactions between chainlike polymer molecules also increase.

Unmodified LaRC™-IA has been synthesized from 3,4′-oxydianiline (3,4′-ODA) and 4,4′-oxydiphthalic anhydride (4,4′-ODPA) at 15 percent solids content dissolved in g-butyrolactone. In synthesizing an LaRC™-IA copolyimide, one substitutes BTDA or IDPA for some portion of the 4,4′-ODPA in the reaction mixture (see figure). The molecular weight of the copolyimide is controlled by using a slight excess of 3,4′-ODA and reacting this excess with monofunctional phthalic anhydride, which thus serves as an end-capping agent. Eventually, glacial acetic acid is added to the reaction mixture, and the mixture is heated until the copolyimide forms and precipitates from the solution.

For example, in one experimental synthesis, 33 mole percent of 4,4′-ODPA was replaced with BTDA, and 3,4′-ODA was present in about 3 mole percent excess. The resulting copolyimide powder exhibited a glass-transition temperature of 238.0°C (vs. 229.6°C for unmodified LaRC™-IA). At a temperature of 150°C, this copolyimide retained 77.0 percent of its lower-temperature shear modulus (vs. 72.6 percent for unmodified LaRC™-IA).

This work was done by Terry L. St. Clair of **Langley Research Center** *and Alice C. Chang of Lockheed Engineering & Sciences Co. 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 20].
LAR-15109



In a **Molecule of LaRC™-IA Copolyimide**, some fraction (usually 20 to 50 percent) of repeating units contain moieties derived from BTDA or IDPA.

Revealing Slip Bands in a Metal-Matrix/Fiber Composite

Plastic flow of the stressed matrix can be detected.

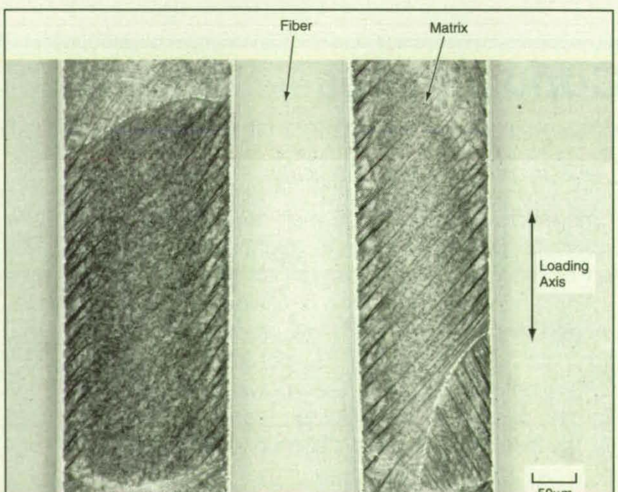
Lewis Research Center, Cleveland, Ohio

An experimental procedure that includes heat treatments and metallographic techniques has been developed to facilitate studies of the deformation of a metal-matrix/fiber composite under stress. The procedure reveals slip bands, which are indicative of the plastic flow that can occur in the matrix during mechanical tests of specimens of the composite (usually at low temperatures).

The composite material in question consists of SiC fibers in a matrix alloy of 76Ti/15V/3Cr/3Sn/3Al (numbers indicate weight percentages). Prior to mechanical testing at room temperature, a specimen of the composite is heated at a temperature of 700 °C for 24 h in a vacuum. After mechanical testing, the specimen is heat-treated at 427 °C for 24 h in a vacuum. The second heat treatment precipitates fine particles on slip bands. The particles are believed to be a-phase titanium.

Following the second heat treatment, the specimen is mounted and polished by metallographic techniques, then etched by a 3-percent aqueous solution of ammonium bifluoride. This solution preferentially attacks the a phase of titanium and thus highlights the slip bands (see figure).

This work was done by Bradley A. Lerch of **Lewis Research Center**. *For further information,* ***write in 172*** *on the TSP Request Card.*
LEW-15729



Slip Bands Can Be Seen in a heat-treated, polished, and etched specimen of the composite material described in the text. This view shows a plane in the middle of one ply of an eight-unidirectional-ply, continuous-fiber specimen that had been strained to 0.85 percent.

Electronic Components and Circuits

Maximum Acceleration Recording Circuit

Coarsely digitized maximum levels are recorded in blown fuses.

Lyndon B. Johnson Space Center, Houston, Texas

A circuit feeds power to an accelerometer and makes a nonvolatile record of the maximum level to which the output of the accelerometer rises during a measurement interval. In comparison with inertia-type single-preset-trip-point mechanical maximum-acceleration-recording devices, the circuit weighs much less, occupies less space, and records accelerations within narrower bands of uncertainty. In comparison with prior electronic data-acquisition systems designed for the same purpose, the circuit is simpler, less bulky, consumes less power, costs less, and does not require playback and analysis of data recorded in magnetic or electronic memory devices. The circuit could be used, for example, to record accelerations to which commodities are subjected during transportation on trucks.

The circuit (see figure) includes three 9-V batteries, one of which supplies the 9 V needed by the circuit, and all of which supply the 27 V needed by the accelerometer. Power is supplied to the accelerometer through field-effect diode D1, which regulates the accelerometer current to keep it in the range of 2 to 4 mA. The accelerometer puts out an ac signal that peaks at a full-scale value of 5 V when the ac component of acceleration reaches 50 g (where g denotes normal Earth gravitation). The acceleration signal is coupled through C_1 and D_2 into C_2, which retains the peak value for a short time.

The signal is fed through potentiometer R_1 to the input terminal (pin 5) of a 10-level display driver, which is basically an analog-to-digital converter. The converter can be an integrated circuit (LM3914) that has equally spaced levels, each representing 5 g; or it can be a similar circuit (LM3915) that has logarithmically spaced levels, each succeeding level representing division of the next higher level by a factor of $\sqrt{2}$ (3 decibels/step).

Depending on the level of the input signal, the display driver energizes 1 of its 10 output lines, each of which is connected to 1 of 10 2-mA transparent-cap microfuses plugged into a module. If the fuse on a line is still intact, then when that line is energized, the driver delivers a current of 10 mA, blowing the fuse. The fuses can be inspected visually or electrically at any convenient time thereafter to determine which (if any) has blown, thereby determining what level of acceleration was reached.

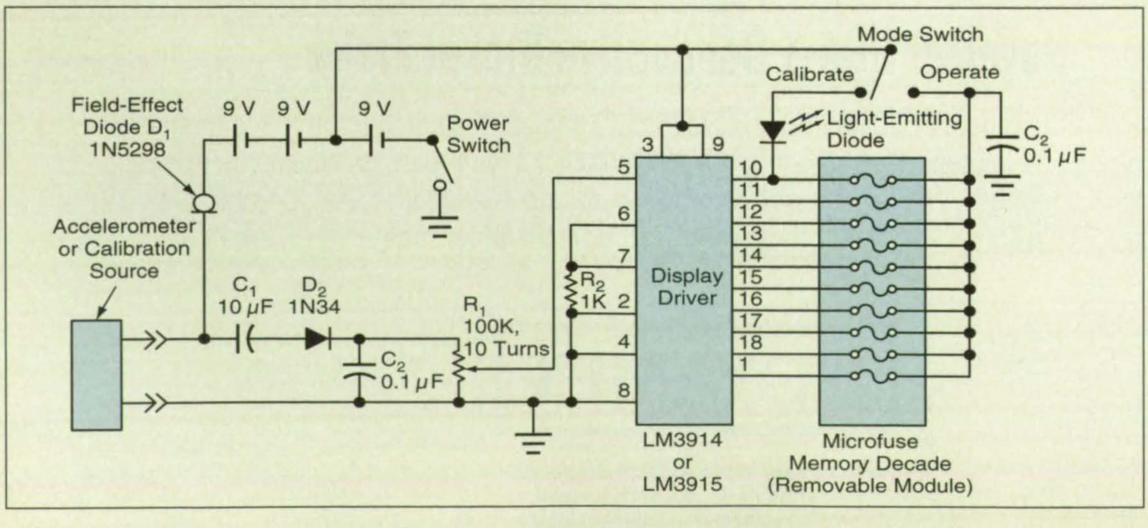
The circuit is calibrated with the accelerometer disconnected and a 5-V peak-to-peak signal at a frequency of 500 Hz coupled capacitively to the accelerometer terminals. Mode switch S_2 is placed in the "calibrate" position, and power switch S_1 is closed to turn the power on. The potentiometer is first set to minimum, then the setting is increased to the level of the signal reaching the input of the display driver. The circuit is deemed to be calibrated at the setting at which the light-emitting diode on output line 10 (which represents the full-scale signal level) flickers on. The power is then turned off.

The calibration source is disconnected, the accelerometer is connected, and the power is turned on. Next, mode switch S_2 is turned to the "operate" position. (Capacitor C_3 absorbs the resulting turn-on transients and prevents inadvertent triggering of the open-collector drivers in the display-driver circuit.) The circuit can then be left unattended to record the maximum acceleration.

This work was done by Richard J. Bozeman, Jr., of **Johnson Space Center**. *For further information,* ***write in 78*** *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 20].

MSC-21922.



This **Circuit Blows One or More Fuses** in a module. The position of the blown fuse(s) in the module indicate(s) the maximum level(s) of acceleration reached during a measurement.

Switch Box for Controlling Flows of Four Gases

Each of four gas controllers can be connected to any one of six mass-flow controllers.

NASA's Jet Propulsion Laboratory, Pasadena, California

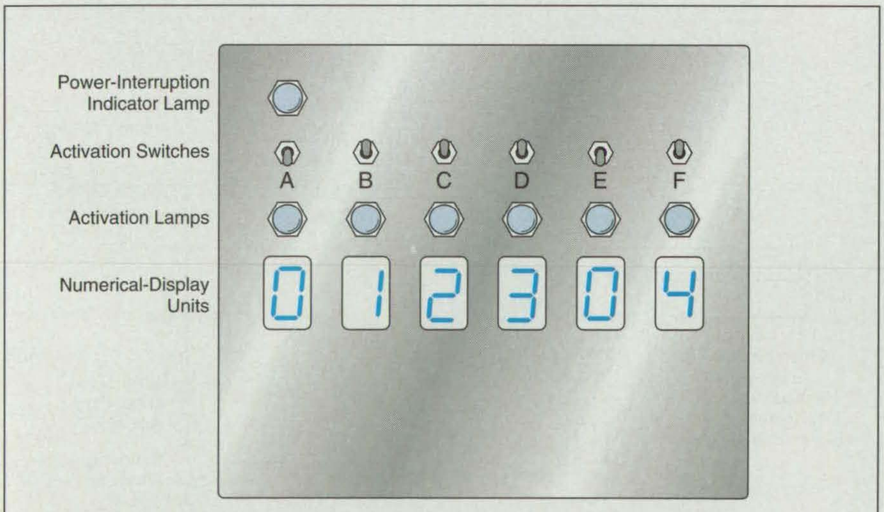
A switch box has been designed for use in simultaneously controlling the flows of as many as four out of a total of six available gases into a semiconductor-processing chamber. The switch box contains switches, relays, logic circuitry, display devices, and other circuitry for connecting each of as many as four gas controllers to any one of as many as six available mass-flow controllers. As used here, "gas controller" denotes that part of the programmable process-control circuitry that commands the flow of a specific gas at a specific rate. "Mass-flow controller" denotes that part of the process-control equipment that electromechanically effects the regulation of the flow of one of the six gases at a rate commanded by whichever gas controller is connected to it via the switch box.

To select one of the six gases to be fed to the chamber, the technician flips one of six activation switches on the front panel of the switch box (see figure). The logic circuitry (which includes logic gates and delay circuits) in the switch box seeks a gas controller for that gas and activates an appropriate relay when it finds an available gas controller. The switch box contains 12 relays on a board. Each relay is assigned to a specific gas controller and mass-flow controller. When a relay is activated by the logic circuit, its assigned gas and mass-flow controller are also activated.

Mounted on the front panel, along with the switches, are six activation lamps, six seven-segment light-emitting-diode alphanumerical-display devices, and a power-interruption indicator lamp. The activation lamps correspond to the six gases, labeled A through G, while the numbers displayed on the devices correspond to the gas controllers. When the technician turns on a switch for a gas, its activation lamp lights up, and a number from 0 to 4 appears on the adjacent display device. A display of 0 indicates that no gas controller has been assigned to that gas, and so the gas is not flowing. A display of 1 to 4 represents the gas controller to which the gas and its mass-flow controller are assigned.

The power-interruption indicator lamp lights up when power has been interrupted. It tells the technician that all of the mass-flow controllers have been disconnected from all of the gas controllers and thus all flows of gases have been stopped. The technician must reset the system to make the flows resume.

This work was done by James R. Wishard and James L. Lamb of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 28*** *on the TSP Request Card.*
NPO-19201



The **Front Panel of the Switch Box** apprises the technician of the statuses of the flows of the various gases. Gases that have been selected are indicated by illumination of the corresponding activation lamps. The gas controllers assigned to those gases are indicated by the numbers on the numerical-display devices.

Circuit for Control of Electromechanical Prosthetic Hand

Control signals would be derived from shoulder movements.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed circuit for the control of an electromechanical prosthetic hand would derive electrical control signals from shoulder movements. The circuit can be regarded as an updated, electronic version of a prosthesis, developed in the 19th century, that includes two hooklike fingers actuated via cables from a shoulder harness. Many below-the-elbow amputees still favor prostheses based on that design because of its low cost, reliability, ease of repair, and simplicity of operation. The proposed circuit would be built around the favored shoulder harness, yet would provide more dexterous movement, without incurring the complexity of computer-controlled "bionic" or hydraulically actuated devices.

The harness would contain a linear potentiometer (R_1 in the figure), the resistance of which would be varied by shrugging the shoulder as in the older mechanical system. The variable output voltage of the potentiometer would be fed to an attenuating potentiometer (R_2), which would be set to scale the voltage to the range of shoulder movement. The scaled voltage would be fed to an analog-to-digital converter of the type used to control a bar-graph display. Either a linear or a logarithmic converter could be used, depending on the requirements of the user.

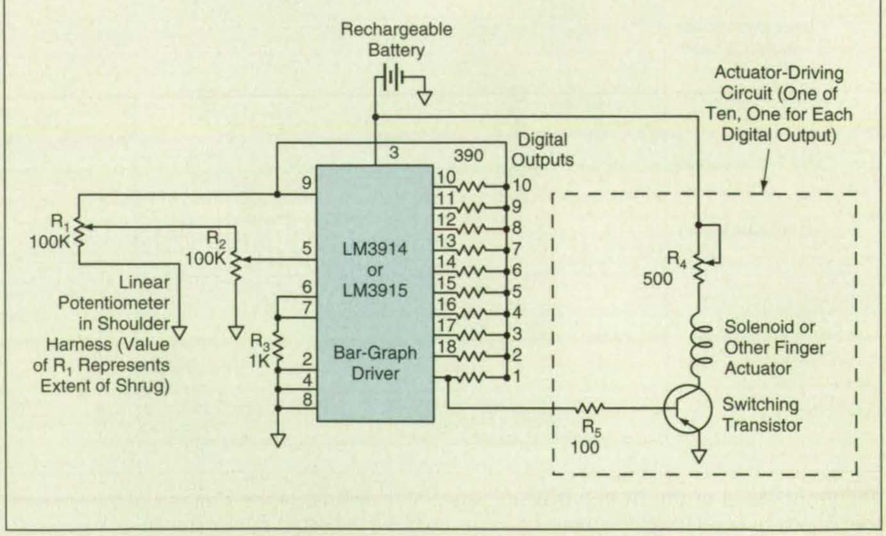
Each digital output, in continuous or single-pulse mode, would be fed to a transistor switch, which would supply current to a solenoid or motor to actuate one of the prosthetic fingers. With no shrug, the prosthetic thumb and all of the prosthetic fingers would be extended. As the shrug increased, the digital outputs would turn on in sequence, thereby causing the thumb and fingers to move sequentially to the closed position.

An additional harness and potentiometer connected to a similar control circuit could be mounted on the other shoulder. This circuit could be used to control a stepping motor that would rotate the hand about the prosthetic wrist to one of a number of angles consistent with the number of digital outputs. The finger-control signals developed by the circuit connected to the first shoulder harness would be transmitted to the prosthetic hand via sliprings at the prosthetic wrist joint.

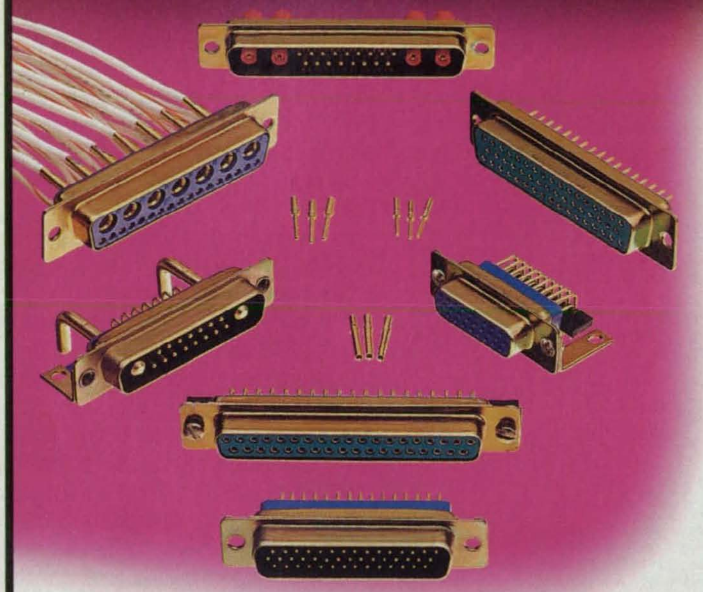
This work was done by Richard J. Bozeman, Jr., of **Johnson Space Center**. *For further information,* ***write in 79*** *on the TSP Request Card.*

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 20].

Refer to MSC-21941.



Digital Outputs of the bar-graph driver, representing a sequence of values of R1, would turn on current to actuators in prosthetic fingers.



K_u-Band Data-Communication Adapter

This adapter serves as an interface between a personal computer and a satellite communication system.

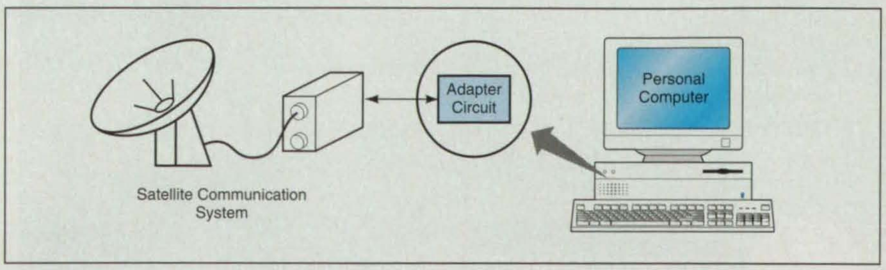
Lyndon B. Johnson Space Center, Houston, Texas

A data-communication adapter circuit on a single printed-circuit board serves as a general-purpose interface between a personal computer and a satellite communication system (see figure). The adapter circuit was designed as a direct interface with the K_u-band data-communication system for the payloads on the space shuttle, but can also be used with any radio-frequency transmission systems.

The adapter circuit supports bidirectional communications and can be used at either end of the K_u-band communication link. It can be readily installed in almost any personal computer because it is designed to be connected via the widely used Industry Standard Architecture (ISA) bus; it may also be embedded directly in the space shuttle payload electronics because it provides payload users with a well-documented, well-understood computer interface.

The adapter circuit provides extremely reliable data communications by use of a high-performance Reed-Solomon error-correcting code. The integrity of data can be further ensured by implementing computer-to-computer communication protocols, which the circuit supports by virtue of its ISA bus features and its capability for bidirectional communication.

This work was done by Steve Schadelbauer of **Johnson Space Center**. *For further information,* ***write in 53*** *on the TSP Request Card.*
MSC-22469



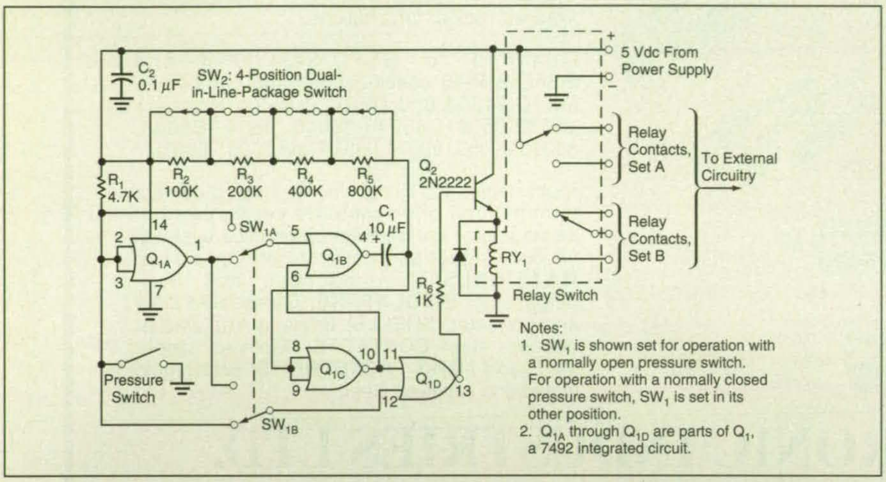
The **Adapter Circuit** serves as an interface between a computer and a K_u-band data-communication system. It can be readily installed in almost any personal computer via the widely used Industry Standard Architecture (ISA) bus.

Transient-Switch-Signal Suppressor

The switch-opening or -closing signal is not transmitted until after a preset time.

Lyndon B. Johnson Space Center, Houston, Texas

The figure shows a circuit that delays the transmission of a switch-opening or switch-closing signal until after a preset suppression time. The circuit is used to prevent the transmission of an undesired momentary switch signal. For example, a pressure switch that is meant to be held steadily on or off by a given static pressure in a piping system can also be actuated momentarily by a transient overpressure (sometimes called "water hammer") or underpressure caused by the sudden closure or opening of a valve.The basic mode of operation is simple. The beginning of the switch signal initiates a timing sequence. If the switch signal persists after the preset suppression time, then this circuit transmits the switch signal to external circuitry. If the switch signal is no longer present after the suppression time, then the switch signal is deemed to be transient, and this circuit does not pass the signal on to external circuitry; from the perspective of the external circuitry, it is as though there were no transient switch signal. The suppression time is preset at a value large enough to allow for the damping of the underlying pressure wave or other mechanical transient.



The **Transient-Switch-Signal Suppressor** transmits a switch-opening or -closing signal only if that signal persists longer than a preset suppression time.

The circuit could be incorporated into a pressure-switch housing. It includes only one transistor/transistor-logic integrated circuit (Q_1) and one discrete transistor (Q_2). It requires a 5-Vdc power supply. By use of double-pole/double-throw switch SW1, the circuit can be set to operate with either a normally open or normally closed pressure switch. The suppression time is governed by the time constant of the resistor-and-capacitor network of R_1 through R_5 and C_1; the suppression time can be set between 1 and 15 seconds, in increments of 1 second, by closing or opening the segments of switch S_2 in various binary combinations to remove or insert various combinations of R_2 through R_5 in series.

Suppose, for example, that the circuit is set to operate with a normally open pressure switch. When the pressure switch closes, the output of Q_{1A} goes to logic "high" and remains there during the preset suppression time. This logic "high" pulse gates Q_{1B} and Q_{1C}. The voltage on pin 11 of Q_{1D} is normally at logic "low" except during this pulse. The voltage on pin 12 of Q_{1D} is normally high except when the pressure switch is closed. To generate an output signal through Q_2 and the relay switch, it is necessary to bring the voltages on both pin 11 and pin 12 of Q_{1D} to logic "low"; this does not occur until and unless the pressure switch remains closed after the end of the suppression-time pulse.

This work was done by Richard J. Bozeman of ***Johnson Space Center****. For further information,* ***write in 80*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,296,750). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20].
MSC-22027.

ASIC for Complex Fixed-Point Arithmetic

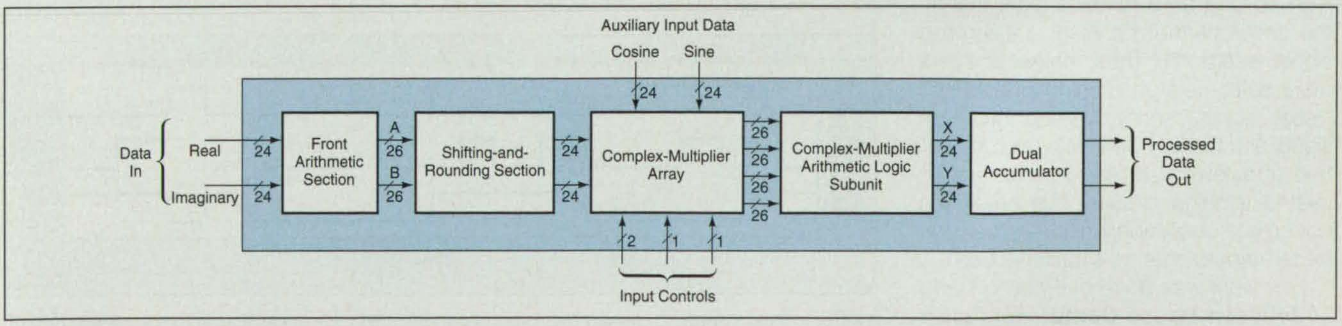
A 24-bit design reflects a compromise between precision and speed.

NASA's Jet Propulsion Laboratory, Pasadena, California

An application-specific integrated circuit (ASIC) performs 24-bit, fixed-point arithmetic operations on arrays of complex-valued input data. It is a high-performance, wide-band arithmetic logic unit (ALU) designed for use in computing fast Fourier transforms (FFTs) and for performing digital filtering functions. Other applications could include general computations involved in analysis of spectra and digital signal processing.

The ASIC was developed to reduce the complexity and cost of a 32-megachannel, 640-MHz digital spectrum analyzer while maintaining the required dynamic range. In comparison with a spectrum analyzer containing a 32-bit ALU, a spectrum analyzer that contains this 24-bit ALU contains fewer processing elements, and the bit width of the required memory is reduced.

At the outset of development of the design of the 24-bit, fixed-point ALU, the only digital-signal-processor parts



This **Digital Signal Processor** makes efficient use of an array of more than 110,000 gates in a commercial integrated circuit. It performs a pipeline butterfly FFT operation.

available were those of 16-bit, fixed-point design and those of 32-bit, floating-point design. The 24-bit, fixed-point design was selected as a compromise between the relative imprecision of the 16-bit design and the relative slowness of processing of the 32-bit design. The 24-bit circuit operates at a rate of 45 MHz in the worst case. The rate of normal operation can be as high as 66 MHz, corresponding to about 800 million operations per second.

The circuit is made from a commercial "sea of gates" integrated-circuit chip, which contains an array of more than 110,000 gates. The chip is fabricated according to 0.8-μm, three-layer complementary metal oxide/semiconductor (CMOS) design rules. The design utilizes more than 95 percent of the available gates: this high fraction of utilization is attributable to the design choice of a pipelined FFT configuration. Inasmuch as data flow in only one direction in a pipeline configuration, the interconnections among gates also flow generally in one direction, thereby making it possible to utilize the array of gates efficiently.

The ASIC (see figure) includes a front arithmetic section that performs the first part of a partitioned FFT butterfly operation. (A butterfly operation is so called because it can be represented by a diagram in which multiple input and multiple output values are shown connected by straight-through and crossover lines that form a pattern that resembles wings of a butterfly.) The front arithmetic unit contains two banks of arithmetic logic subunits, each bank working in parallel. A shifting-and-rounding section that follows the front arithmetic section downshifts the outputs of the front arithmetic section by 0, 1, or 2 bits, according to the user's choice. Ordinarily, the user would choose the downshift parameter to prevent overflow. Downshifted bits are rounded off.

The shifting-and-rounding unit is followed by a complex-multiplier array, which contains four 24-bit multipliers that work in parallel to give 28-bit truncated results. They multiply the shifted and rounded values by cosine and sine inputs. Then a complex-multiplier arithmetic logic subunit combines the products of these multiplications into a complex output, rounded to 24 bits. This completes the pipelined FFT butterfly operation.

The final section of the ASIC is a dual accumulator that makes the ASIC more versatile. The dual accumulator makes it possible to use the ASIC as a multiplier and accumulator, as might be needed, for example, in digital filtering. Each accumulator in the dual accumulator can be operated separately, and 28-bit outputs allow 4 bits of expansion before overflow occurs.

This work was done by Stephen G. Petilli, Michael J. Grimm, and Erlend M. Olson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 278*** *on the TSP Request Card.*
NPO-19102

Digital Latching Circuit for a Safety-Related Application

The "reset" input is effective in resetting the output only when the "set" input is low.

Lyndon B. Johnson Space Center, Houston, Texas

The asynchronous digital latching circuit shown in Figure 1 is designed for use in a safety-related application like turning off power in response to an alarm signal. During normal operation in the absence of an alarm, the "set" (S) and "reset" input voltages are low or off, while the output voltage (Q) is high or on. The "set" input constitutes the alarm signal: whenever "S" goes high (on), Q goes low (off), and thereafter remains low, even when S goes low. Thus, for example, the circuit keeps a power supply turned off even when the alarm has been shut off (see Figure 2).

If a safe condition has been restored, then the circuit can be reset to Q high by applying a high (on) signal to the "reset" (R) input terminal. However, regardless of the R input level, Q cannot be driven high as long as S remains high; that is, the circuit cannot be reset if the alarm signal is still on. Thus, unlike in some other safety-related latching circuits, the "reset" signal cannot override the alarm signal and thereby provide a false indication of safety. Also unlike some safety-related latching circuits, this one does not go into oscillation when the "set" and "reset" inputs change simultaneously.

This work was done by Paul A. Kemp of **Johnson Space Center**. *For further information,* ***write in 50*** *on the TSP Request Card. Refer to MSC-22421*

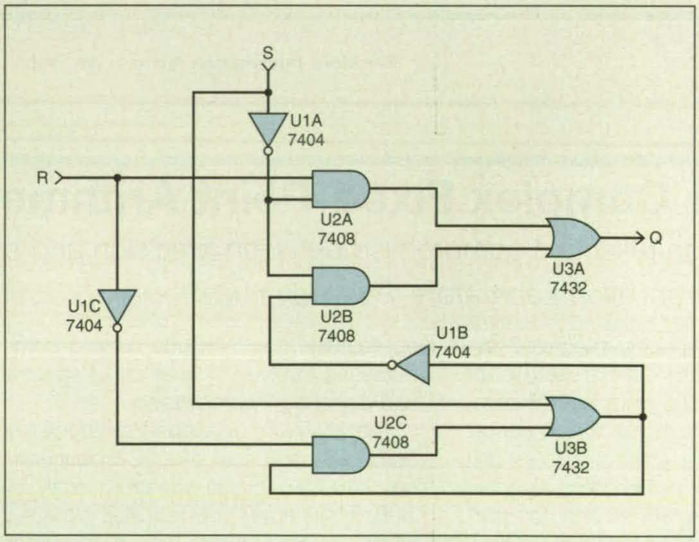


Figure 1. The **Asynchronous Digital Latching Circuit** is made of standard transistor/transistor logic (TTL) devices. U1 is a hex inverter, U2 is a quad dual-input AND gate, and U3 is a quad dual-input OR gate.

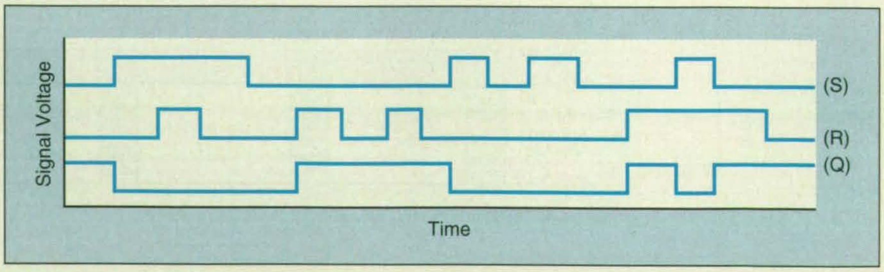
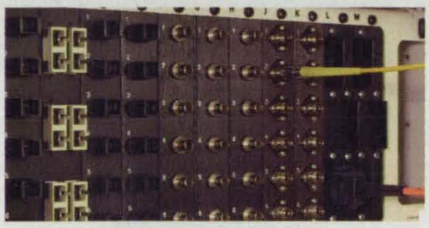


Figure 2. This **Timing Diagram** illustrates the various modes of operation of the circuit. A high S input causes the output (Q) to go low. Thereafter, a high R input can reset Q to high, but only so long as S remains low.

Light House.



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Multiprocessor Adaptive Control of a Dynamic System

A modular, hierarchical architecture combines standardized processing units.

Langley Research Center, Hampton, Virginia

An architecture for a fully autonomous digital electronic control system has been developed for use in identification (defined below) and adaptive control (also defined below) of a dynamic system. The architecture is modular and hierarchical. It combines relatively simple, standardized processing units into complex parallel-processing subsystems. Although the architecture is based on a neural-network concept, the processing units themselves are not neural networks; the processing units are implemented by programming of currently available microprocessors.

As used here, "identification" does not have its usual meaning. In the specialized discipline of mathematical modeling and control of the dynamics of complex systems, "identification" is short for "system identification," which, in turn, is short for identification of the parameters of a mathematical model that represents the dynamics of a system. "Adaptive control" denotes a strategy for adapting a control system, in real time, to changes in the parameters in such a way as to continually strive to optimize the control performance. The relevant modeling and control concepts are not limited to any particular dynamic system; however, in a typical application, the dynamic system comprises a flexible structure equipped with vibration sensors and actuators, and the control objective is to process the sensor outputs into actuator commands to suppress vibrations in the structure.

A control system of the type in question (see Figure 1) implements a model-reference adaptive control (MRAC) scheme. In MRAC, identical training stimuli are applied to both a dynamic system subject to unknown disturbances and to a reference subsystem, which is an idealized mathematical model of the dynamic system implemented in software. The sensor outputs (converted to time series of digitized samples) from the dynamic system are compared with corresponding sensor outputs from the reference subsystem. This comparison yields an error signal, which drives the adaptation of the control system so that the closed-loop input/output relations of the dynamic and control systems (from sensors to actuators) are made to match those of the reference subsystem.

Figure 2 illustrates the hierarchy of modular structures used to implement the control scheme. The processing units at the lowest level of the hierarchy are tapped delay lines and units that implement mathematical models of neurons with both forward and backward signal paths. The adjustment of each of the synaptic weights, W_{kj}, according to a local learning law, is built into each processor. Moreover, the adaptive speeds (or rates of learning) $\mu_{kj}(n)$, are updated so as to guarantee convergence in both system identification and adaptive control.

The key to using the neurons for dynamic-system identification is to organize them into larger building blocks that are reminiscent of biological ganglia and are therefore called "dynamic ganglia." A dynamic ganglion is an array of L neurons allocated as a unit to process a time series signal and its L – 1 delayed values. The neurons in a ganglion are connected to each other via a Toeplitz synapse, which is an array of synapses, the matrix of synaptic weights of which is upper triangular: the upper triangular structure is designed to preserve temporal ordering and causality. The synaptic weights in the Toeplitz synapse are adapted iteratively by a gradient-descent algorithm.

The next higher level of the hierarchy comprises replicator units, each of which comprises several ganglia connected by a Toeplitz synapse. The fundamental function of a replicator unit is to duplicate the output of a previously unknown sampled-data dynamic system when both the replicator and the system are stimulated by the same training input.

Several replicator units are combined to form an adaptive neural control system. For the present case of MRAC, the most basic adaptive neural control architecture comprises two main parts: a closed-loop modeler and a control adaptor. Each of these parts comprises at least two replicator units. The closed-loop modeler uses the training signal and the sensor outputs from the real dynamic system to adapt matrices of synaptic weights to make the closed-loop behavior of the reference system imitate that of the real dynamic system; in effect, the closed-loop modeler identifies the dynamic system within the closed control loop. The control adaptor, which generates its own internal mathematical model of the dynamic system, uses the training signal, its own output, and the output of the reference system to adjust its matrices of synaptic weights so that the reference system is replicated.

The basic adaptive control scheme involves simultaneous convergence of both the internal dynamical model and the optimal controller. However, subsequent studies have shown that a nonsimultaneous "zigzag" approach to convergence is more efficient and requires half the neural hardware involved in the basic scheme. In the zigzag approach, the control system alternates between

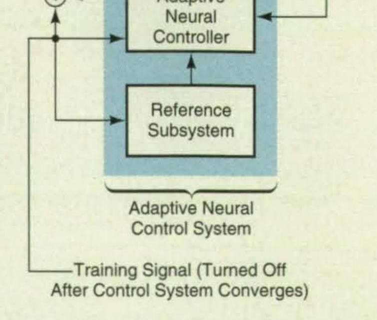


Figure 1. The **Adaptive Neural Control System** is trained to implement a model-reference adaptive control scheme.

refinement of the model and adaptation of control.

Because of the massive parallelism of the architecture, it is possible to configure the modular computing hardware in numerous different ways. As a practical matter, it turns out to be most effective and convenient to group the fundamental processing units into four types of more complex fundamental processing units that constitute the standardized processing units mentioned previously, each of which effects a mixture of neural and synaptic functions. These standard types of units are (1) a modified version of the Toeplitz synapses, (2) a modified version of the dynamic ganglions, (3) branching and summing junctions, and (4) tapped delay lines that also serve as memory units.

This work was done by Jer-Nan Juang of **Langley Research Center** *and David C. Hyland of Harris Corp. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15243.

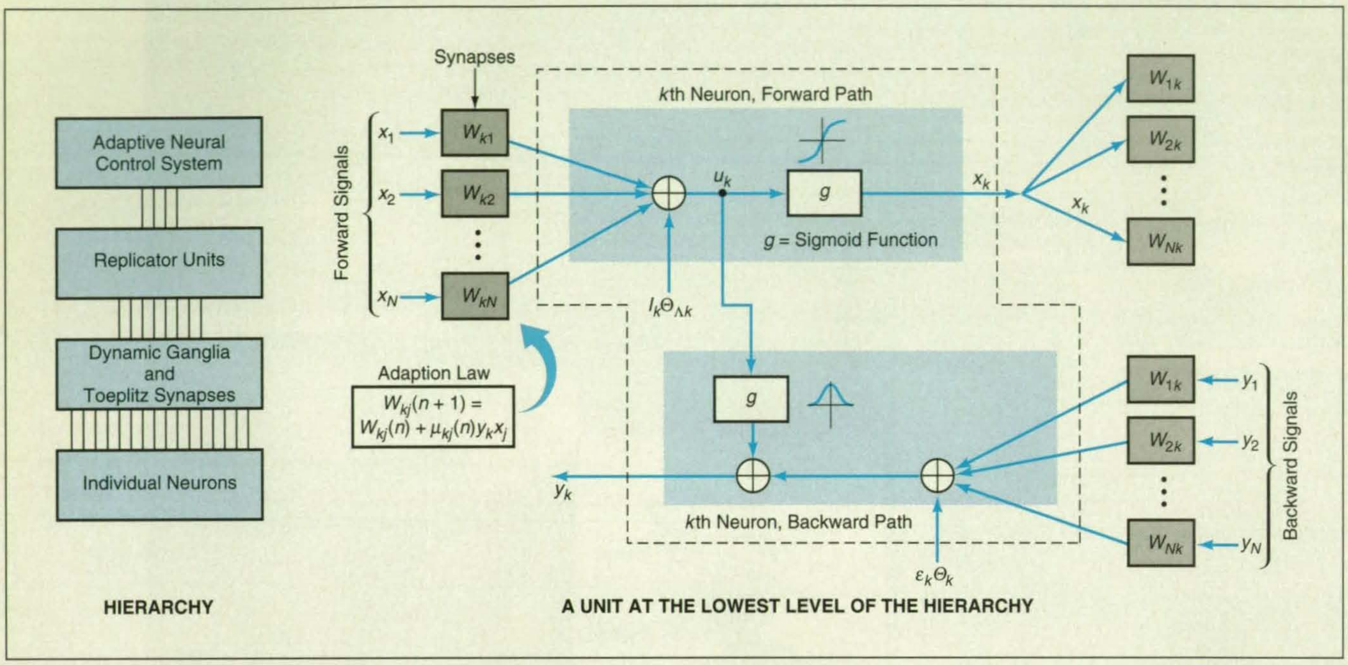


Figure 2. The **Hierarchical Structure** groups neurons and synapses into modular substructures that, collectively, perform the various adaptive control functions.

Emergency Flight Control Using Computer-Controlled Thrust

Computer-controlled engine thrust provides landing capability when control surfaces are inoperable.

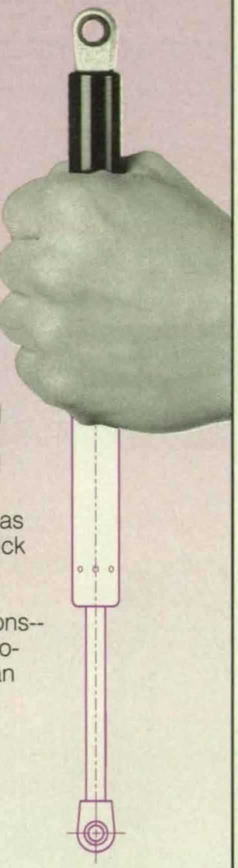
Dryden Flight Research Center, Edwards, California

Propulsion Controlled Aircraft (PCA) systems are digital electronic control systems that are undergoing development to provide limited maneuvering ability through variations of individual engine thrusts in multiple-engine airplanes. PCA systems are meant for emergency use when the flight controls become inoperative. [As used here, "flight controls" includes exterior flight-control surfaces (ailerons, trim tabs, elevators, and/or rudder) and the control systems and subsystems that affect their functions. "Flight controls" as used here does not include engine controls.] The development of PCA systems was prompted by several accidents, in each of which all or part of the flight-control system failed. The NASA F-15 research airplane was equipped with a PCA system and was the first airplane to be intentionally landed using only engine-thrust control for maneuvering.

During the initial efforts to develop PCA systems, flight experiments were performed on a variety of airplanes, from fighters to transports. These studies showed that with the pilot manually controlling the throttles and with all flight controls locked, it was possible to maintain gross control. Altitude could be maintained within a few hundred feet (≈100 m) by using both throttles together. To climb, thrust would be increased; to descend, thrust would be reduced. Heading could be controlled to within a few degrees, using differential throttle to generate yaw, which results in roll.

These same flight experiments showed that maneuvering solely through manual throttle control was not precise enough to enable landing on a runway. This was attributed to the small control forces and moments available from engine thrust, difficulty in controlling the phugoid motion of the airplane, and difficulty in compensating for the lag in engine response. Simulation studies at Dryden Flight Research Center and at McDonnell Douglas have been able to duplicate the results of the flight experiments.

Control research and simulation studies at Dryden Flight Research Center also established the feasibility of a thrust con-



trol system based on the use of a digital computer with feedbacks of such parameters as flightpath angle, pitch rate, bank angle, and yaw rate (see Figure 1). The flightpath command from the pilot is compared with the measured flightpath, and, using the pitch rate for phugoid damping, collective throttle is commanded to achieve the desired flightpath. The time required to achieve a flightpath command is between 7 and 10 seconds. The bank-angle command from the pilot is compared with the measured bank angle, and, by use of the yaw rate to stabilize the Dutch roll, differential throttle is commanded to satisfy the bank-angle command. A small bank-angle command can be satisfied in about 5 seconds.

Prior to the addition of a PCA system, the NASA F-15 research airplane was already equipped with a digital electronic control system that included a digital engine-control subsystem, a digital flight-control subsystem, and a general-purpose computer and data bus to enable these digital subsystems to communicate with each other, making it an ideal test-bed airplane for this research. There was also a cockpit computer panel through which the pilot could provide control-system inputs, select options and vary control-system gains. The only equipment added to the airplane in installing the PCA system was a control panel containing two thumbwheels; one for the pilot's flightpath command, and the other for bank-angle command. All of the needed sensors and actuators were already available from previous research on integrated flight/propulsion control. Control computations were performed in the research computer.

In flight tests of the PCA system, the NASA F-15 airplane was flown at speeds of 150 knots (77 m/s) with the flaps down and at 170 knots (87 m/s) and 190 knots (98 m/s) with the flaps up. Former astronaut Gordon Fullerton was the project pilot. Initial flights with the PCA system tested response to small-step thumbwheel inputs. Later, low approaches were flown, and finally, PCA control was used for landings (see Figure 2) without using any flight controls.

Several guest pilots, including United States Air Force, United States Navy, NASA, and contractor pilots, also flew the F-15 airplane with the PCA system. All pilots flew with a simulated failure of the flight-control system, engagement of the PCA system, recovery, descent, and landing approach. Pilots' comments were very favorable.

The simulated failure was initiated at a speed of 250 knots (129 m/s) and altitude of 12,000 ft. (3.7 km). To simulate a failure of the hydraulic system, the pilot

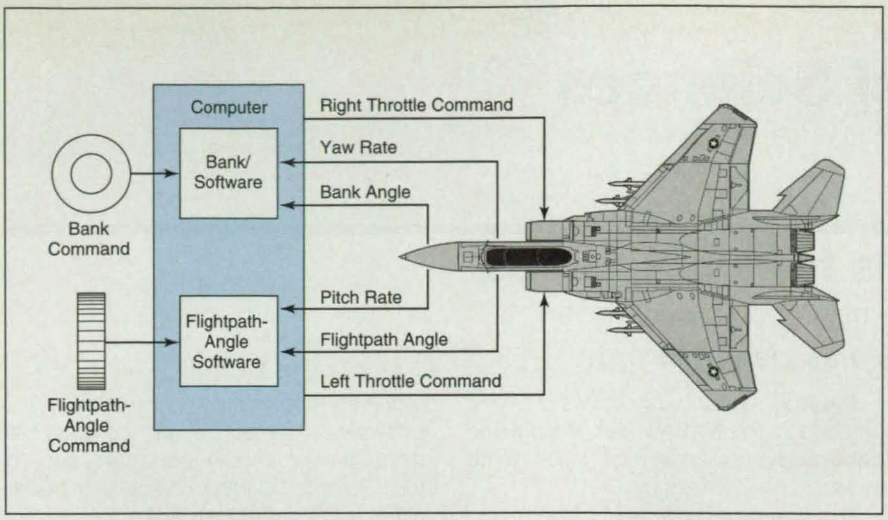


Figure 1. A **PCA System** can be installed in a multiple-engine airplane to obtain limited emergency maneuvering ability through computer control of engine thrust alone.

trimmed the airplane, then rolled into a 90° bank, released the flight controls, and engaged the PCA system as the nose dropped through –20°. The PCA system used full differential thrust to roll the wings level, then varied collective thrust to damp the phugoid motion. The pilot lowered the gear and flaps, and the airplane trimmed at 150 knots (77 m/s). The pilot then turned toward the runway at Edwards Air Force Base, initiated a descent, and made a long straight-in approach to the runway, ending 20 ft (6.1m) high over the end of the runway, in good position to land.

PCA systems can be incorporated on existing and future airplanes that include digital engine controls, digital flight controls, and digital data buses. Depending on the exact configuration, it could be possible to implement the entire PCA system in software, thus adding no weight or additional hardware to an airplane. The PCA system can make the airplane safer by making it possible to handle a total failure of the hydraulic system, depending on how surfaces respond to loss of hydraulic pressure. It may also be possible to handle broken control cables or linkages. The PCA system might also be used to save weight and cost through replacement of mechanical backup flight-control systems. Future airplanes could incorporate PCA systems that would use navigation data from the Global Positioning System for guidance to any suitable emergency runway in the world.

This work was done by Frank W. Burcham, Jr., C. Gordon Fullerton, James F. Stewart, and Glenn B. Gilyard of **Dryden Flight Research Center** *and Joseph A. Conley of Ames Research Center. No further documentation is available.*

This invention has been patented by NASA (U.S. Patent No. 5,330,131). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Dryden Flight Research Center [see page 20].
DRC-00004.

Figure 2. This **Airplane Landed** under PCA-system control only; no other flight controls were used.

Carbon/Carbon Grids for Ion Sources

Advantages would be better alignment and slower erosion.

NASA's Jet Propulsion Laboratory, Pasadena, California

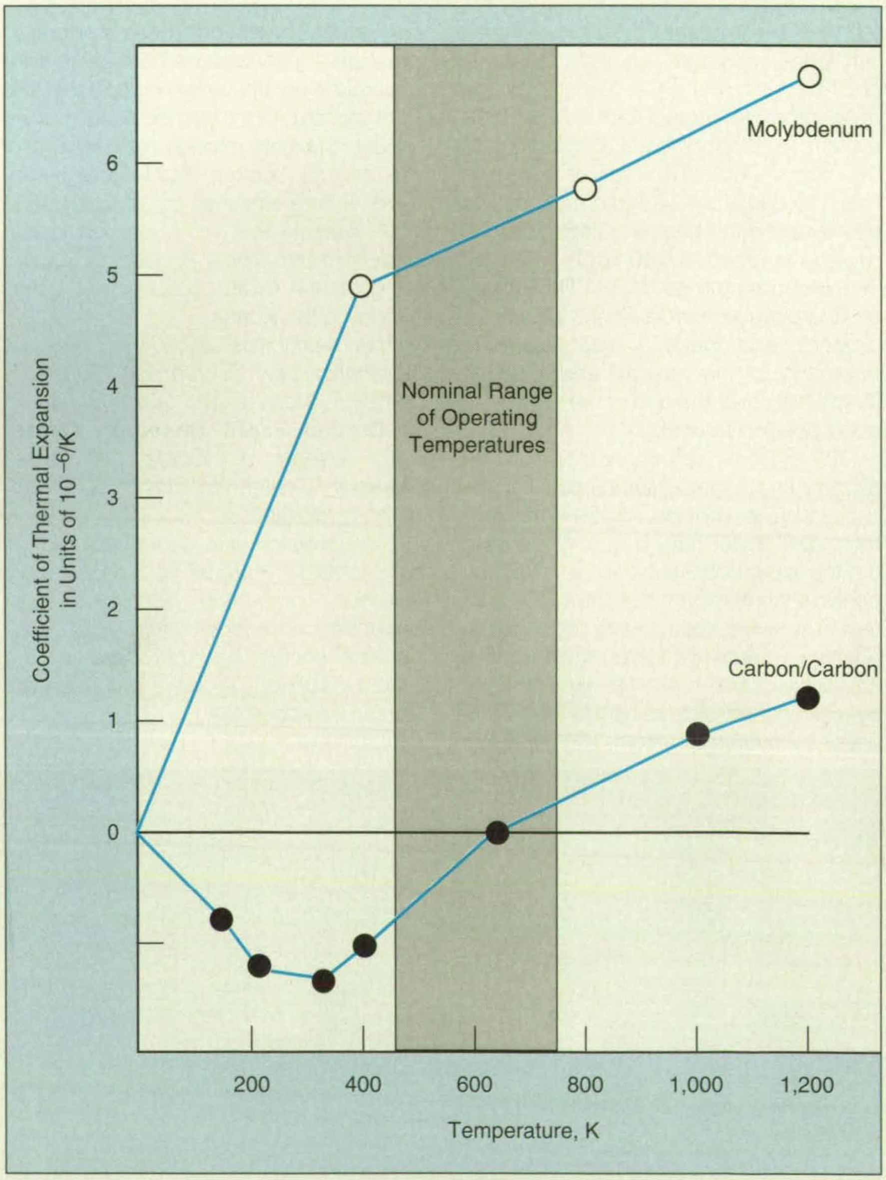
Ion-extraction grids made of carbon/carbon composites would be used in spacecraft ion engines and industrial ion sources in place of the molybdenum grids that are now used, according to a proposal. In principle, the carbon/carbon grids could offer greater extraction efficiency and longer life. A grid would be fabricated by mechanical drilling, laser drilling, or electrical-discharge machining of an array of holes in a sheet of carbon/carbon. Typically, the holes would have a diameter of 0.075 in. (about 1.9 mm) and would be in a hexagonal array with a center-to-center distance of 0.087 in. (about 2.2 mm).

The maximum ion-beam current that can be extracted from an ion source depends on how precisely the gaps between screen, accelerator, and decelerator grids are maintained and on how precisely each hole in the screen grid is kept in alignment with the corresponding holes in the accelerator and decelerator grids. At present, for example, the grids in a 30-cm-diameter ion engine are made from molybdenum sheets chemically etched to contain as many as 15,000 holes. Because of the finite thermal expansion of molybdenum, the gaps between the grids tend to change as the engine heats up. To reduce the distortion of the gaps, the grids are dished to a depth of about 0.8 in. (about 2 cm). The dishing process results in nonuniform gaps and can introduce slight misalignments between the holes, with consequent reduction of ion-beam-extraction efficiency.

Carbon/carbon materials like those to be used in the proposed grids can be made to have nearly zero coefficients of thermal expansion over the operating-temperature range of an ion engine (see figure). Therefore, dishing would be unnecessary, and without dishing, better alignment of holes should be possible. A bonus is that carbon/carbon is eroded at only one-fifth the rate of molybdenum under bombardment by xenon ions. Carbon/carbon grids should therefore last much longer than molybdenum grids do.

This work was done by Charles E. Garner of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 14*** *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 20]. NPO-19174.



Over the **Range of Operating Temperatures** of an ion extraction grid, the coefficient of thermal expansion of a commercial carbon/carbon composite material is low and, at some temperatures, even slightly negative. In contrast, the coefficient of thermal expansion of molybdenum is large and positive.

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Probes for Measuring Changing Internal Temperatures

The thermal characteristics of a probe are chosen for accuracy and speed of response.

Marshall Space Flight Center, Alabama

Improved thermocouple probes have been devised for measuring rapidly changing temperatures within layers of solid materials. In the original application, the layers in question are carbon-cloth phenolic liners in solid-rocket motor nozzles, and the probes are inserted in the layers to various depths of the order of 0.5 in. (about 13 mm) to measure changing temperatures in the layers during hot-fire tests. The basic probe concept can be adapted to measurements of temperatures inside various other layers, materials, and components, including material test specimens.

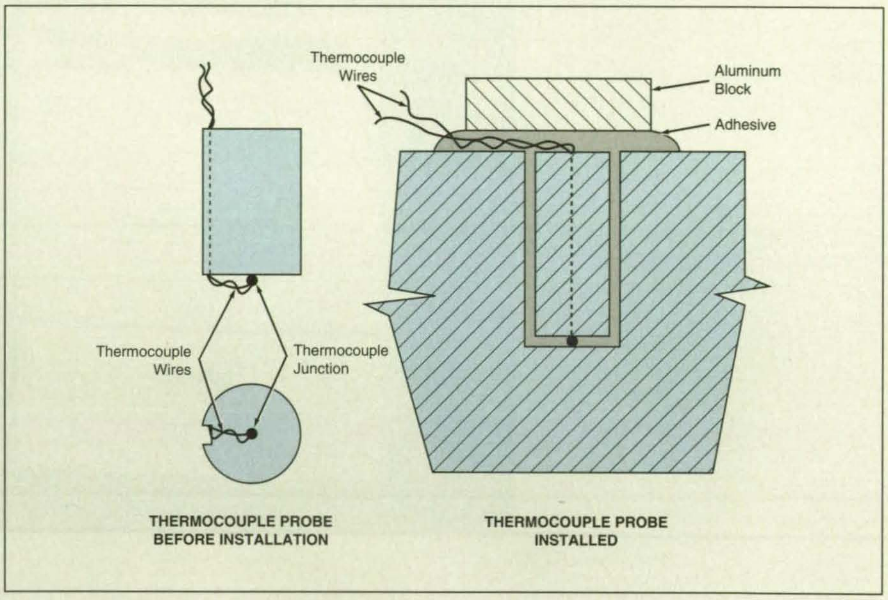
The thermocouple probes used previously to measure temperatures within the liners during the hot-fire tests responded too slowly and inaccurately. This is because the probe bodies conducted substantial amounts of heat away from the thermocouple junctions and the junctions were in poor thermal contact with the surrounding materials under test. The bodies of the improved probes are made of the same materials as those of the layers to be tested. In constructing an improved probe to be inserted in a composite material to be tested, the plies in the probe body should also be oriented the same as in the material under test. In preparation for installation of a probe, a flat-bottomed hole is machined to the desired depth in the material layer to be tested. The probe is then inserted along with a suitable adhesive to hold it in place and enhance thermal contact.

The innermost end of the probe is flat, and the thermocouple wires in the vicinity of the thermocouple junction are laid out on the flat end, which is assumed to lie on an isotherm approximately parallel to the surface of the layer to be tested: This minimizes conduction of heat along the thermocouple wires in the immediate neighborhood of the thermocouple junction, thus helping to ensure that the temperature of the junction closely follows that in the material under test. The remainder of the thermocouple wires are laid in a groove along the probe body and brought out to connect them to measuring circuitry.

This work was done by S. B. Hunt, J. Durtschi, D. Smith, Joel Maw, M Sakaguchi, L. Smart, and B. Blake of Thiokol Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 245*** *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 20].

Refer to MFS-28840.



The **Thermocouple-Probe Body** is made of the same material as that of the layer in which it is to be inserted.

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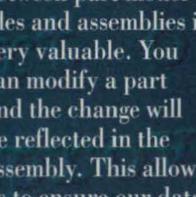

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Bakeout Chamber Within Vacuum Chamber

Outgassing of components outside the bakeout chamber does not interfere with measurements.

NASA's Jet Propulsion Laboratory, Pasadena, California

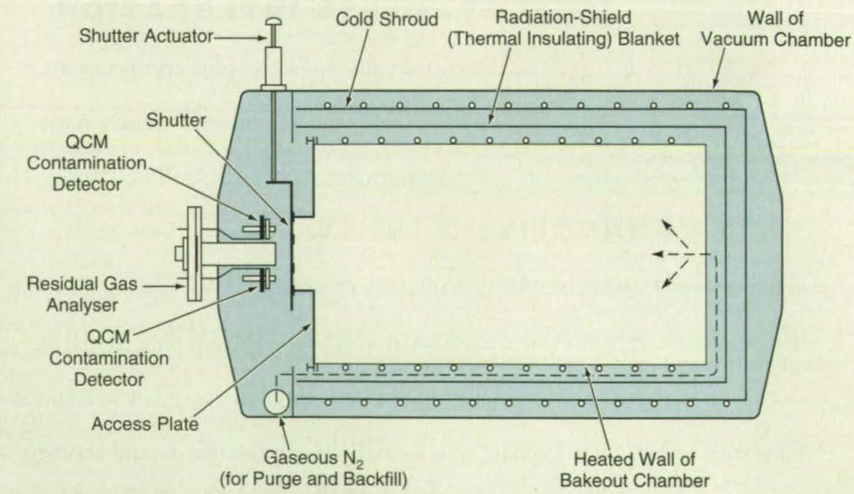
A vacuum-bakeout apparatus for decontaminating and measuring outgassing from pieces of equipment has been constructed by mounting a bakeout chamber within a conventional vacuum chamber (see figure). The concept of upgrading an old or new conventional vacuum chamber to provide a vacuum-bakeout capability has been applied before: what is new here is the specific design to satisfy stringent requirements regarding outgassing — specifically, the requirement to prevent contaminants that originate in the vacuum chamber outside the bakeout chamber from entering the bakeout chamber, where they could interfere with measurements of contamination of the piece of equipment to be vacuum-bakeout tested and/or decontaminated. This upgrade is cost effective: fabrication and installation of the bakeout chamber are simple, installation can be performed quickly and without major changes in an older vacuum chamber, and the upgraded apparatus provides quantitative data on outgassing from pieces of equipment placed in the bakeout chamber.

In preparation for a vacuum bakeout, the piece of equipment to be outgassed is placed in the bakeout chamber, which is thermally insulated from the surrounding vacuum chamber by a radiation-shield blanket. During bakeout, only the bakeout chamber is heated. A cold shroud that lies within the vacuum chamber and surrounds the thermally insulating blanket is used to reduce the background pressure in the vacuum chamber and thereby reduce the deposition of the background contamination on contamination detectors located within the bakeout chamber.

A shutter assembly within the bakeout chamber contains orifices that direct the outgassing flow to the residual gas analyzer and one of the quartz crystal microbalance (QCM) contamination detectors or alternatively to the other QCM only. In this arrangement, the detectors respond specifically to the outgassing flow; the contributions of contaminants from elsewhere in the vacuum chamber are minimized.

To reduce background contamination before a full vacuum bakeout, the bakeout chamber and the cold shroud are warmed, the bakeout chamber is purged with pure N_2, and the vacuum system removes contaminants outgassed from the shroud. The chamber is then backfilled by use of the bakeout-chamber purge.

This work was done by Daniel M. Taylor, David M. Soules, and Jack B. Barengoltz of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 121*** *on the TSP Request Card.*
NPO-18959



The **Bakeout Chamber** makes it possible to satisfy stringent requirements regarding outgassing while using an ordinary vacuum chamber.

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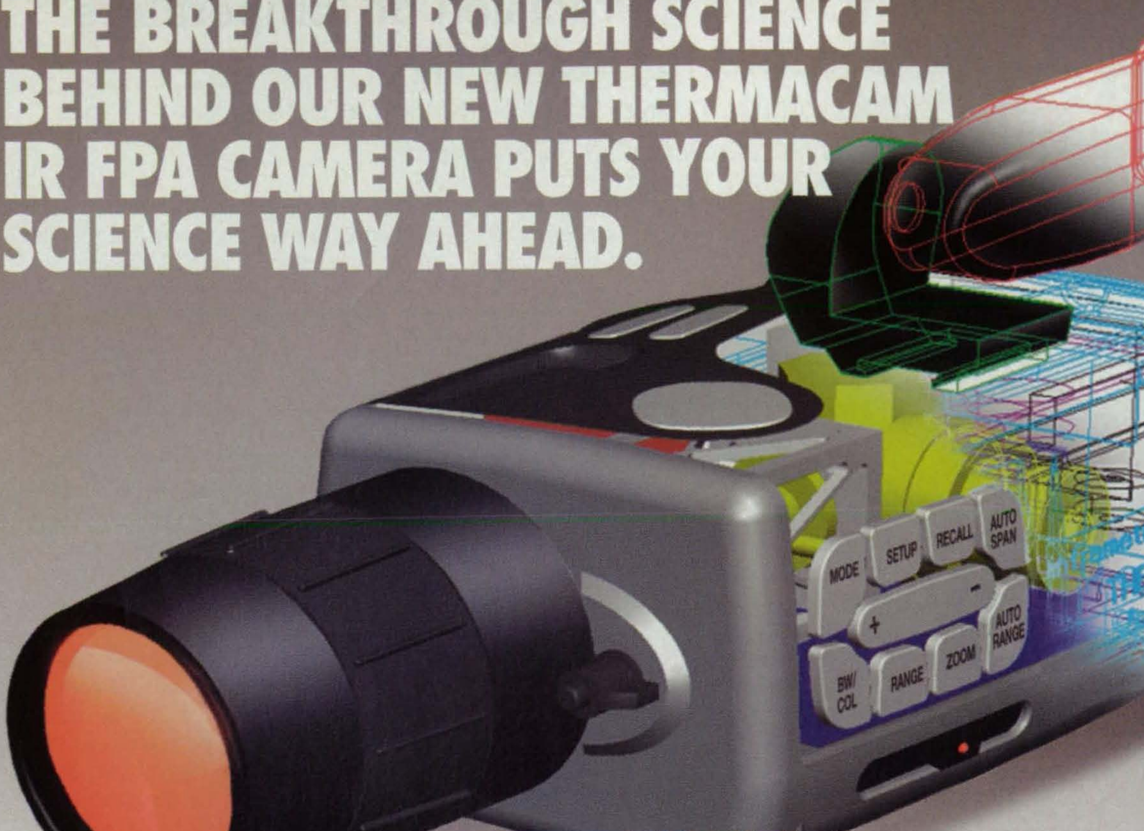

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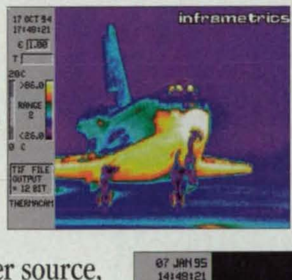

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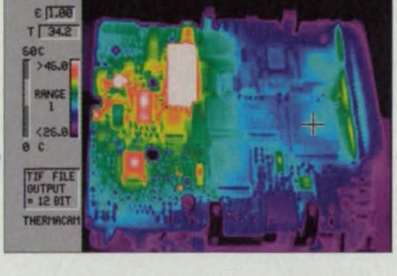

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For More Information Write In No. 590

Increasing Precision of Temperature Sensors for Liquid H_2

Recalibration involves careful attention to details.

Lewis Research Center, Cleveland, Ohio

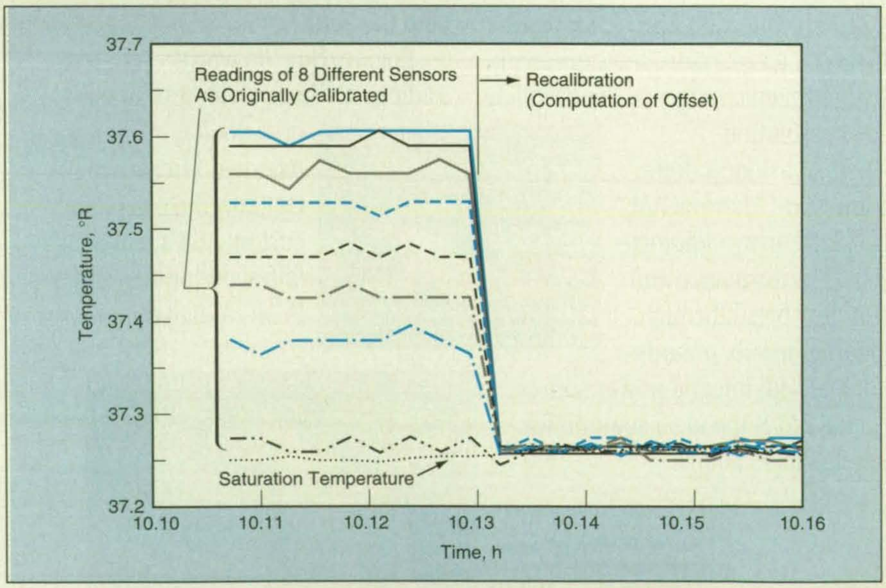
Commercial silicon-diode temperature sensors intended for use in boiling or nearly boiling liquid hydrogen at temperatures near 37 °R (about 20 K) have been recalibrated to greater precision by a method that involves careful attention to details of design, operation, and computation. The sensors were specified by the manufacturer to be accurate within ±0.90 °R (±0.5 K); after recalibration by this method, they were accurate within ±0.20 °R (≈±0.1 K) in the temperature range of interest. Because the method is based on fundamental electrical and thermodynamic principles and good engineering practice, it should also be applicable to recalibration of other temperature sensors intended for use in other boiling or nearly boiling liquids.

The sensors were prepared for recalibration by mounting them in a rakelike array that was to be subsequently immersed in liquid hydrogen. Great attention was paid to good design and installation practices to minimize spurious transfers of heat that could affect the sensor readings. For example, thermal conduction along the sensor lead wires could exert significant effects. Thus, one good design practice was to minimize the number of lead wires and connectors to minimize the number of conduction paths. Another was to minimize thermal conduction along the leads by using leads made of thin manganin wire. Still another was to run the leads along isotherms to the extent possible to minimize conduction caused by thermal gradients along the leads.

The number of leads was minimized by wiring the diodes in groups of nine in series to supply the measurement current. By supplying the current to each diode through one pair of leads while measuring the voltage between these leads, one eliminates the need to carry current on the voltage-measuring leads, thereby eliminating the voltage drop along the leads that occurs in a simple two-leads-per-diode configuration.

Another technique used to increase the accuracy of the measurement was to verify that each sensor was in contact with the correct medium, the temperature of which was to be measured. For example, each sensor had to be mounted so that it sensed the temperature of liquid or gas only — not the temperature of the mounting fixture.

The essence of the calibration procedure was the following: First, the sensors were operated while dipped in liquid nitrogen at atmospheric pressure to verify that they were functioning at least approximately as specified. Then the sensors were placed in a tank of liquid hydrogen, which was gradually brought to a boil at controlled pressure to obtain liquid/vapor saturation, as indicated by steady temperature readings and a steady rate of



Temperature Readings of each sensor were corrected, after the ninth reading, by use of an offset obtained by subtracting the average of the first nine readings from the saturation temperature.

vented gas due to boil-off. The temperature in liquid/vapor saturation depends only on the pressure; in this case, the pressure was set at about 17 psia (about 120 kPa) and the saturation temperature for the actual pressure was computed from a table of properties of hydrogen supplied by the National Institute of Standards and Technology.

During saturation, the temperature reading of each diode (according to its original calibration) was taken 20 times at intervals of 1 second. The first nine readings from each diode were digitized and averaged, and the average was subtracted from the saturation temperature to obtain an offset for recalibration. The validity of the recalibration was verified by applying the offset on the tenth and following readings (see figure) and to readings taken under a different saturation condition [pressure of 29 psia (about 200 kPa), corresponding to a temperature of 41.03 °R (about 22.79 K)].

This work was done by Paula J. Dempsey and Richard H. Fabik of **Lewis Research Center**. *For further information,* ***write in 77*** *on the TSP Request Card. Refer to LEW-15912*

Glass-Ampoule Breaker

Ampoules are fractured repeatably, and their contents retained.

Lyndon B. Johnson Space Center, Houston, Texas

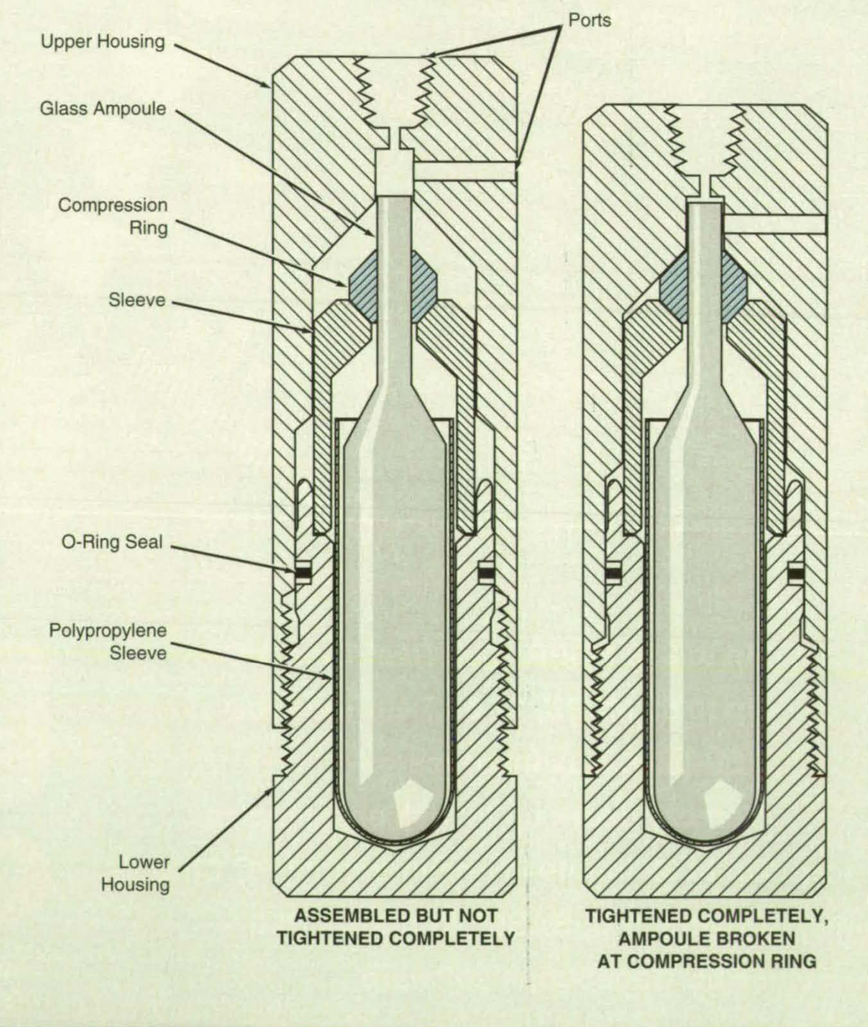
A device breaks a glass ampoule in a repeatable manner and retains its gaseous content so that the pressure of the gas can be measured accurately. The apparatus was developed for use in experiments on compatibility of materials. In such an experiment, a combination of materials (typically, a solid and a liquid) is placed in the ampoule, which is then evacuated, sealed, and stored for a suitably long time. The ampoule is then broken, and the pressure of its contents is measured. The magnitude of the pressure indicates the extent to which the materials have reacted and, thus, their compatibility.

The device (see figure) includes a stainless-steel compression ring, a stainless-steel lower housing, a polypropylene sleeve, a stainless-steel sleeve, and an upper stainless-steel housing. A technician inserts an ampoule into the polypropylene sleeve in the lower housing, slips the stainless-steel sleeve over the ampoule and into the lower stainless-steel housing, slips the compression ring over the ampoule, and threads the upper housing part way onto the lower one, leaving a small gap between the lip of the upper housing and the flange of the lower housing. An O-ring between the lower and upper housings makes a pressure seal, which makes it possible to evacuate the interior chamber created by assembly of the housings. The evacuation is performed via one of two ports near the top of the device.

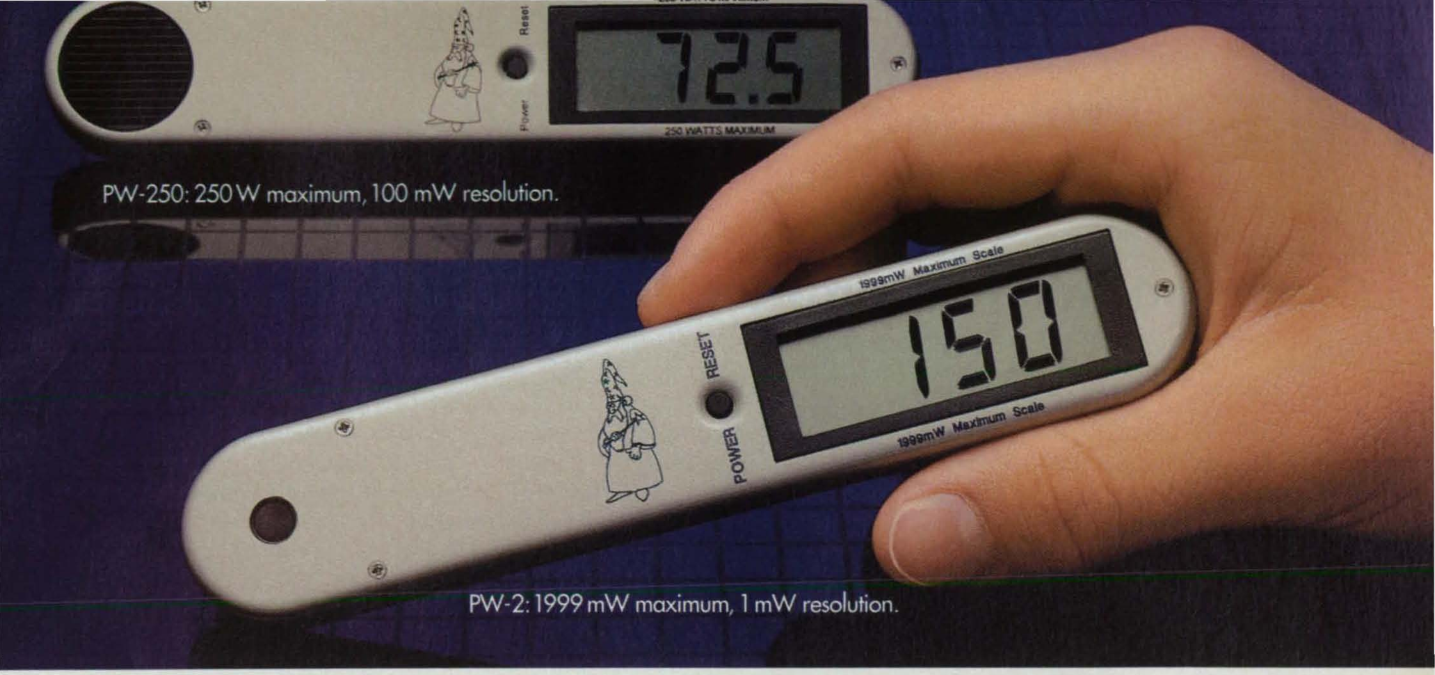
After evacuation, the technician closes a valve on the evacuation port to preserve the vacuum, disconnects the vacuum pump, and further tightens the upper housing on the lower housing until the lip contacts the flange. This final threading forces the compression ring to collapse radially against the neck of the ampoule, thereby breaking the ampoule and releasing its gas. The technician reads the pressure of the gas by use of a pressure gauge connected to the other port.

The device breaks ampoules reliably, always at the same location, forming a repeatable pressure-retaining cavity volume, thereby helping to ensure accurate measurements. In addition, it protects the technician from the gaseous contents, which may be hazardous. Broken glass and sample materials may easily be removed for disposal or analysis.

This work was done by R. C. Christianson, Surender M. Kaushik, and Dennis D. Davis of Lockheed Engineering & Sciences Co. for **Johnson Space Center.** *For further information,* ***write in 75*** *on the TSP Request Card.*
MSC-22101



The **Glass-Ampoule Breaker** maintains vacuum before breakage of the ampoule and retains the gaseous content of the ampoule after breakage.



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*Patent Pending

For More Information Write In No. 698

Controlled Thin-Film Growth of Silicon Carbide Polytypes

Layers can be grown with desired crystalline structures.

Lewis Research Center, Cleveland, Ohio

An improved deposition process makes it possible to grow thin layers of silicon carbide that have chosen crystalline structures. The process can be incorporated into the sequences of deposition and etching steps used to fabricate silicon-carbide-based semiconductor devices. This is an important advance because silicon carbide is emerging as a superior semiconductor for devices that must operate under conditions of high power, high temperature, and/or high frequency. Furthermore, the various crystalline structures of SiC have different electronic properties, each suited to a specific application.

SiC grows in many different crystalline structures called "polytypes." The most common are the cubic polytype, called "3C," and a hexagonal polytype, called "6H." The difference between the structures of the polytypes is the sequence of stacking of double layers of Si and C atoms. Each double layer can occupy one of three positions and each polytype structure has a unique stacking sequence. The 3C polytype has the sequence ABC . . . (repeating 3-layer sequence) and the 6H polytype has the sequence ABCACB . . . (repeating 6-layer sequence).

The mobility of electrons in the 3C polytype is greater than that in 6H; hence, some electronic devices made from 3C may outperform similar devices made from 6H. On the other hand, the electron-energy band gap of 6H is greater than that of 3C, and this greater band gap is needed for blue-light-emitting diodes. Thus, the different electronic properties of the polytypes make it desirable to grow specific polytypes for particular devices.

A thin film of SiC or other material is generally grown in either a homoepitaxial or a heteroepitaxial mode. In homoepitaxy, the crystalline structure of the deposited material is the same as that of the substrate as, for example, in the deposition of 6H on 6H. In heteroepitaxy, the crystalline structure of the deposited material differs from that of the substrate, as in the deposition of 3C on 6H.

Usually, homoepitaxial growth is desired. Previously, it was found that to achieve homoepitaxial growth of a thin film of 6H SiC, one must use a 6H SiC substrate with a growth surface that has been polished several degrees off-axis from the basal plane. As shown in Figure 1, the resulting growth surface consists of a series of steps and terraces formed by the exposed edges of the double layers. During growth, molecules that arrive on terraces from the gas phase migrate to steps; homoepitaxial growth involves deposition on the narrow faces of the steps, so that each terrace grows along the underlying terrace. If the terraces are large (that is, if the tilt angle is small) or if there are defects on the terraces, then 3C nucleates on the terraces, yielding heteroepitaxial growth of 3C on 6H.

The improved deposition process includes pregrowth etching of the substrate by gaseous HCl in H_2 at a temperature ≈1,350 °C. This etch significantly reduces defects caused by the cutting and polishing of the wafer, thereby eliminating sites where unwanted nucleation of 3C can occur. The result is that a thin homoepitaxial film of 6H can be grown, at a temperature ≈1,450 °C, on a 6H substrate that has been polished to a tilt angle as small as 0.1°. Previously, tilt angles > 1.5° were necessary for homoepitaxy.

A variation of the improved deposition process can be used to effect heteroepitaxial growth of high-quality 3C on a 6H substrate. First, the 6H substrate is polished with a tilt angle of < 0.5°. The growth surface is then grooved to produce millimeter-sized mesas upon which the 3C film can be grown. The 6H substrate is then subjected to a pregrowth etch to remove unintentional nucleation sites. At the highest atomic plane on each mesa, the surface can be intentionally altered to make sites for the nucleation of 3C. For example, damaging the surface or adding contamination can cause the nucleation of 3C. From these sites of intentional nucleation of 3C, a film of 3C grows laterally until the entire mesa is covered with a 3C film, as shown in Figure 2.

Because the nucleation of 3C is confined to a small region of each mesa, the 3C film is free of a defect known as double positioning boundaries (DPBs). Previously, high densities of DPBs were typically observed in 3C films grown on 6H substrates. DPBs can form because two orientations of 3C are possible on a polished 6H surface and the intersection of 3C regions with different orientations gives rise to a DPB. The improved process eliminates unintentional nucleation of 3C and yields 3C films that are free of DPBs.

The improved process has been used to fabricate 3C SiC diodes that have a reverse breakdown voltage > 200 V; this is four times the greatest breakdown voltage of any diode previously made of 3C SiC.

This work was done by J. Anthony Powell and David J. Larkin of **Lewis Research Center**. *For further information,* ***write in 74*** *on the TSP Request Card.*

This invention has been patented by

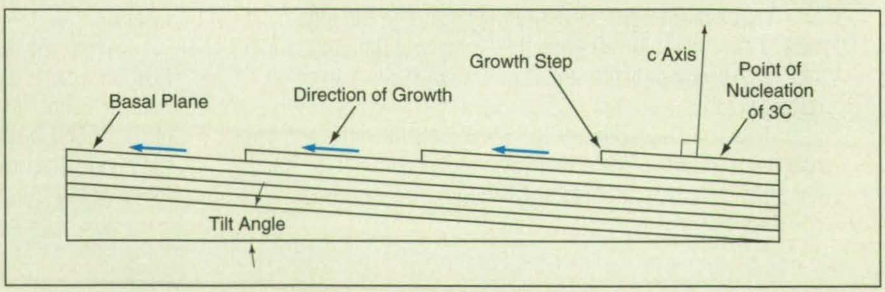

Figure 1. This **Atomic-Scale Schematic Cross Section** depicts the structure of the surface of a 6H SiC substrate polished slightly off axis (that is, at a small tilt angle).

GE TechNotes

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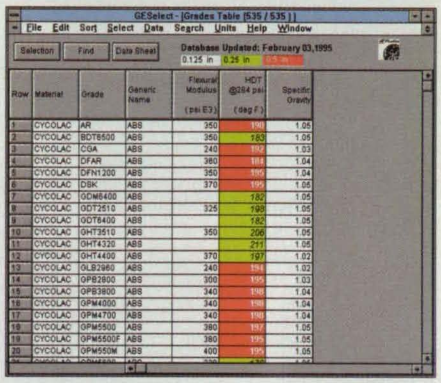

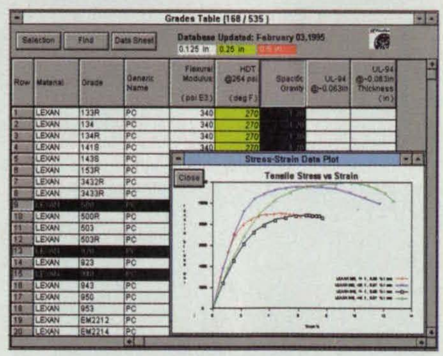

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GE Plastics

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NASA (U.S. Patent No. 5,363,800). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 20]. Refer to LEW-15222.

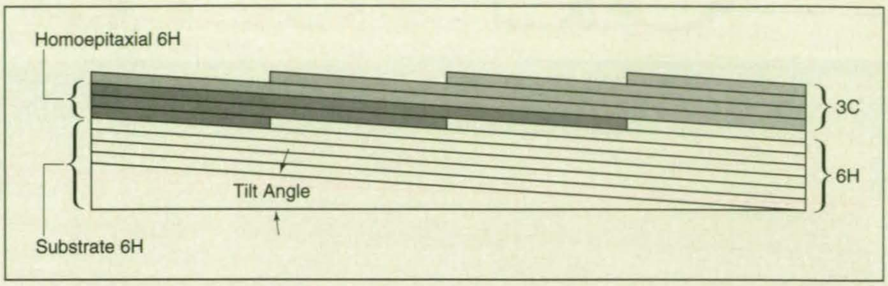


Figure 2. A **Heteroepitaxial Film of 3C SiC** can be deposited on a 6H SiC substrate, possibly even on top of a homoepitaxial film of 6H SiC.

Stabilized Alkali-Metal Ultraviolet-Band-Pass Filters

The stabilizing effect is exerted by layers of bismuth.

NASA's Jet Propulsion Laboratory, Pasadena, California

Layers of bismuth 5 to 10 Å thick have been incorporated into alkali-metal ultraviolet-band-pass optical filters by use of advanced fabrication techniques. The basic problem in making alkali-metal optical filters is to establish and maintain thin layers of alkali metal (usually sodium) with optically smooth surfaces. Heretofore, the high chemical reactivity and low melting point of alkali metals have given rise to difficulties in fabrication and to instability of the filters after fabrication. In the new filters, the layer of bismuth helps to reduce surface migration of the sodium. Thus, the sodium layer is made more stable and has a decreased tendency to form pinholes by migration.

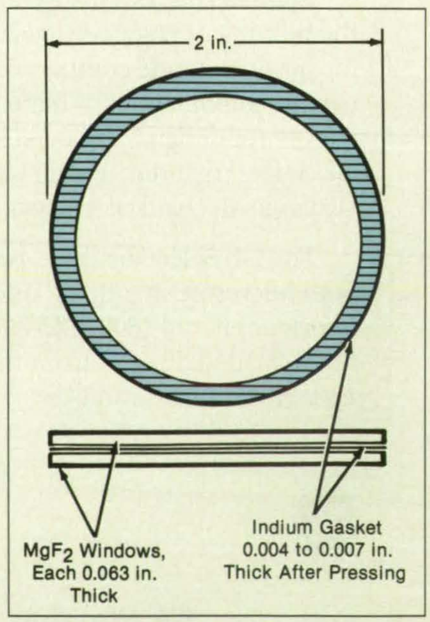
Typically, a filter of this type consists essentially of a layer of sodium 5,000 to 9,000 Å thick, sandwiched between two magnesium gasket (see figure). Prior to deposition of the sodium and bismuth layers, chromium annuli that serve as aperture stops are deposited on the windows. The windows are cleaned and placed in a vacuum deposition chamber in tooling fixtures that make it possible to perform the subsequent deposition steps without breaking vacuum. Water, oxygen, and any other reactive materials are removed from the chamber by use of a sodium getter.

The first step is to evaporate sodium onto one of the windows. Then a layer of bismuth is evaporated onto the sodium layer. Next, the same window is moved into position over the window with the indium ring, and the two windows are squeezed together by a hydraulic press mounted in the chamber, at a pressure of 800 psi (5.5 MPa). Air is then admitted to the chamber, and the completed filter is removed from the press.

This work was done by Nick Mardesich, George A. Fraschetti, Timothy McCann, Sherwood D. Mayall, Donald E. Dunn, and John T. Trauger of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 33*** *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 20].

NPO-18433.



The **Alkali-Metal Filter** is contained by two magnesium fluoride windows and an indium gasket.

Combination Thermal Barrier and Wear Coatings for Engines

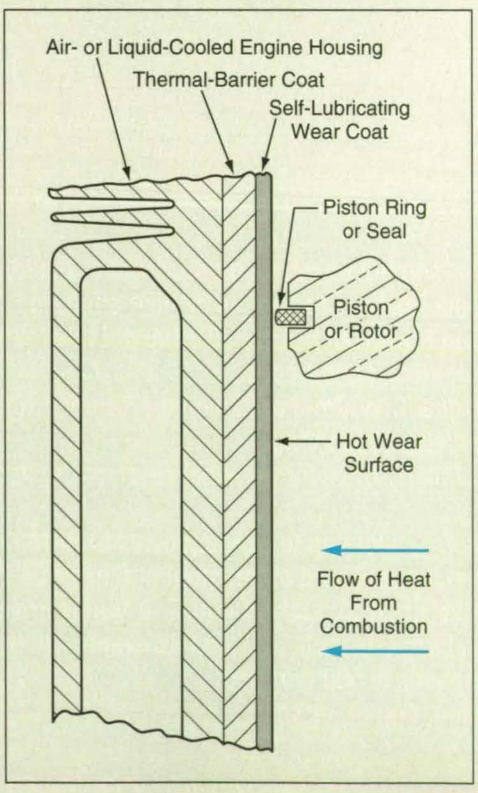
Thermal-barrier layers are covered with self-lubricating surface layers.

Lewis Research Center, Cleveland, Ohio

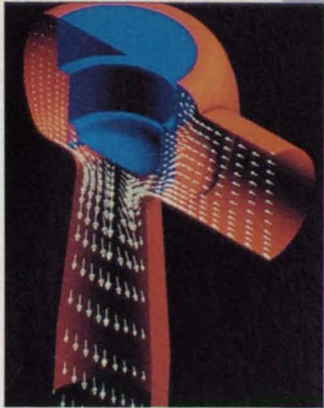
Thermal-barrier layers coated with wear-resistant self-lubricating surface layers are being developed for use as liners subject to sliding contact in advanced high-temperature engines (see figure). The thermal-barrier layers are needed to reduce cooling loads and enable operation at the high temperatures that are needed for high efficiency. For example, the power densities of air-cooled rotary engines are limited by the ability to maintain acceptable temperatures in their housings, which are typically made of aluminum. The wear-resistant, self-lubricating surface layers are needed because thermal-barrier materials are not sufficiently resistant to wear in sliding contact, and oil-based lubricants cannot survive the high temperatures.

In the development efforts undertaken thus far, zirconia has been shown to be effective as a thermal-barrier material, but it resists wear very poorly. The resistance to wear can be increased greatly by coating zirconia with PS-200, a self-lubricating material developed by NASA for use in turbine bearings and Stirling engines, where traditional lubrication with oils and greases is impossible. PS-200 consists of 80 percent silicon carbide [430 NS (Metco Powder), or equivalent] 10 percent silver, and 10 percent calcium fluoride/barium fluoride eutectic. The silicon carbide serves as a hard matrix. The silver is soft and compliant and provides low friction. The eutectic mixture provides lubricity at high temperature.

Both the zirconia and the PS-200 coatings can be applied by plasma-arc spraying to substrates made of conventional engine materials like aluminum and iron. They adhere well to



A **Zirconia Thermal-Barrier Coat** is applied to the surface of a combustion chamber in an engine by plasma-arc spraying. Then the PS-200 self-lubricating coat is plasma-arc sprayed onto the zirconia. The self-lubricating coat prevents sliding contact between the thermal barrier and the piston ring, effectively preventing both wear and the production of additional heat via friction.



Velocity vectors reveal flow patterns through the center section of this steam turbine inlet throttle valve.

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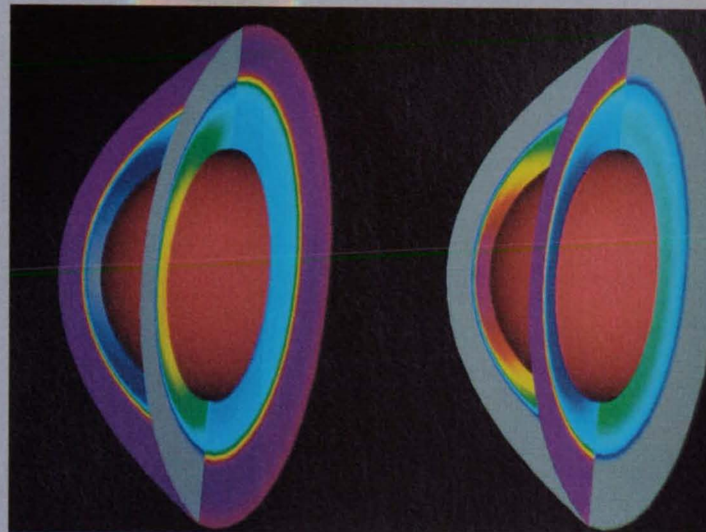

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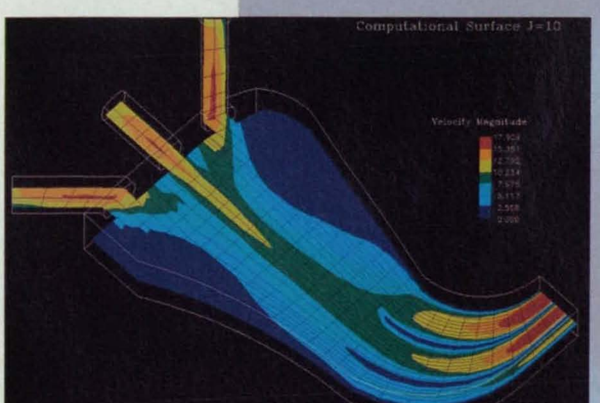

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the substrates and to each other. Other combinations of thermal-barrier and self-lubricating, wear-resistant coating materials could be used as long as the two materials adhere to each other, can be applied by use of similar or compatible processes, have similar coefficients of thermal expansion, are sufficiently strong at high temperatures [generally, > 600 °F (> about 320 °C)], and are affordable.

This work was done by Mike Weingart and Paul Moller of Moller International for **Lewis Research Center.** *For further information,* ***write in 99*** *on the TSP Request Card. Refer to LEW-15356*

Polyimides That Contain Cyclobutene-3,4-Dione Moieties

These polymers exhibit high thermo-oxidative stabilities and some potentially useful photoelectric properties.

Langley Research Center, Hampton, Virginia

Linear aromatic polyimides that contain cyclobutene-3,4-dione moieties have been synthesized in experiments. These polymers exhibit high thermal and thermo-oxidative stabilities, which make them useful in structural components exposed to hot and/or oxidative environments, as in jet engines and on the outer surfaces of supersonic aircraft. In addition, electrons in the cyclobutene-3,4-dione moieties are readily excited to states of higher energy upon exposure to ultraviolet light, giving rise to electronic properties with potential utility in photovoltaic, photoconductive, and/or photoemissive devices, for example.

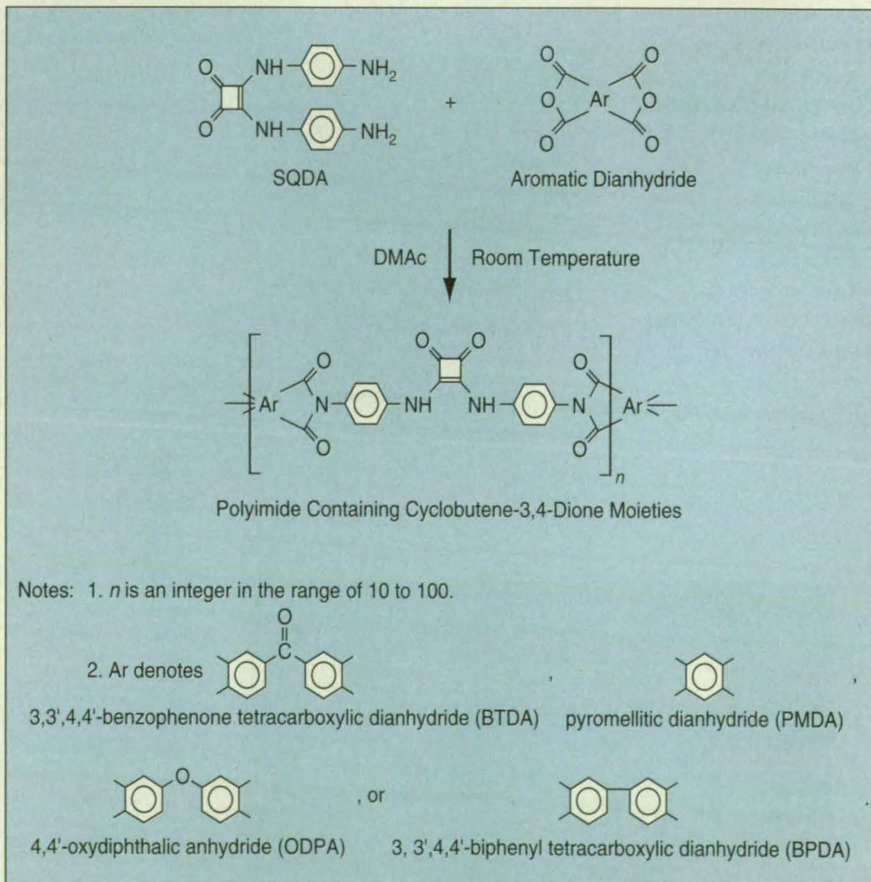
One of the monomeric ingredients of a polyimide of this type is 1,2-bis(4-aminoanilino)cyclobutene-3,4-dione, which is also known as squaric acid derivatized diamine (SQDA). It is prepared by stirring 1,4-diaminobenzene dissolved in methanol with solution of diethylester of squaric acid in methanol at room temperature under a nitrogen atmosphere. The stirring is stopped after 3 days, and the SQDA precipitates as a crystalline material when the reaction mixture is allowed to stand for several hours. The SQDA is collected by filtration, washed with methanol, and dried in a vacuum. The SQDA that was used in this work was obtained from Kyowa Hakko Kogyo Co., Ltd., in Japan.

The figure illustrates the general scheme for synthesis of a linear aromatic polyimide that contains cyclobutene-3,4-dione moieties. SQDA is mixed with an equimolar amount of an aromatic dianhydride and this mixture is dissolved in N,N-dimethylacetamide (DMAc) at a solids concentration between 7.45 and 15 weight percent, the optimum concentration depending on which dianhydride is used. The solution is stirred at room temperature, typically for 1 to 24 h, the exact time depending on which dianhydride is used. Polymerization manifests itself as an increase in the viscosity of the poly(amic acid) solution.

The polymerization is completed (the polymer is "cured") by heating the poly(amic acid) solution. For example, the solution can be cast on a plate, then placed in a nitrogen-filled dry box to evaporate the DMAc solvent and form a film. The film can then be cured by heating in a forced-air oven, typically up to a temperature between 200 and 400 °C: the exact temperature depends on the dianhydride used and on the effect of the heat treatment on various physical and chemical properties of the final polymeric product.

This work was done by Terry L. St. Clair of Langley Research Center and Catherine Fay of **Lockheed Engineering and Sciences Co.** *For further information,* ***write in 207*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,212,283). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20].
LAR-14753



A **Polyimide That Contains Cyclobutene-3,4-Dione Moieties** is synthesized from SQDA and any of several aromatic dianhydrides. Polyimides of this type are highly thermo-oxidatively stable and have interesting photoelectric properties.

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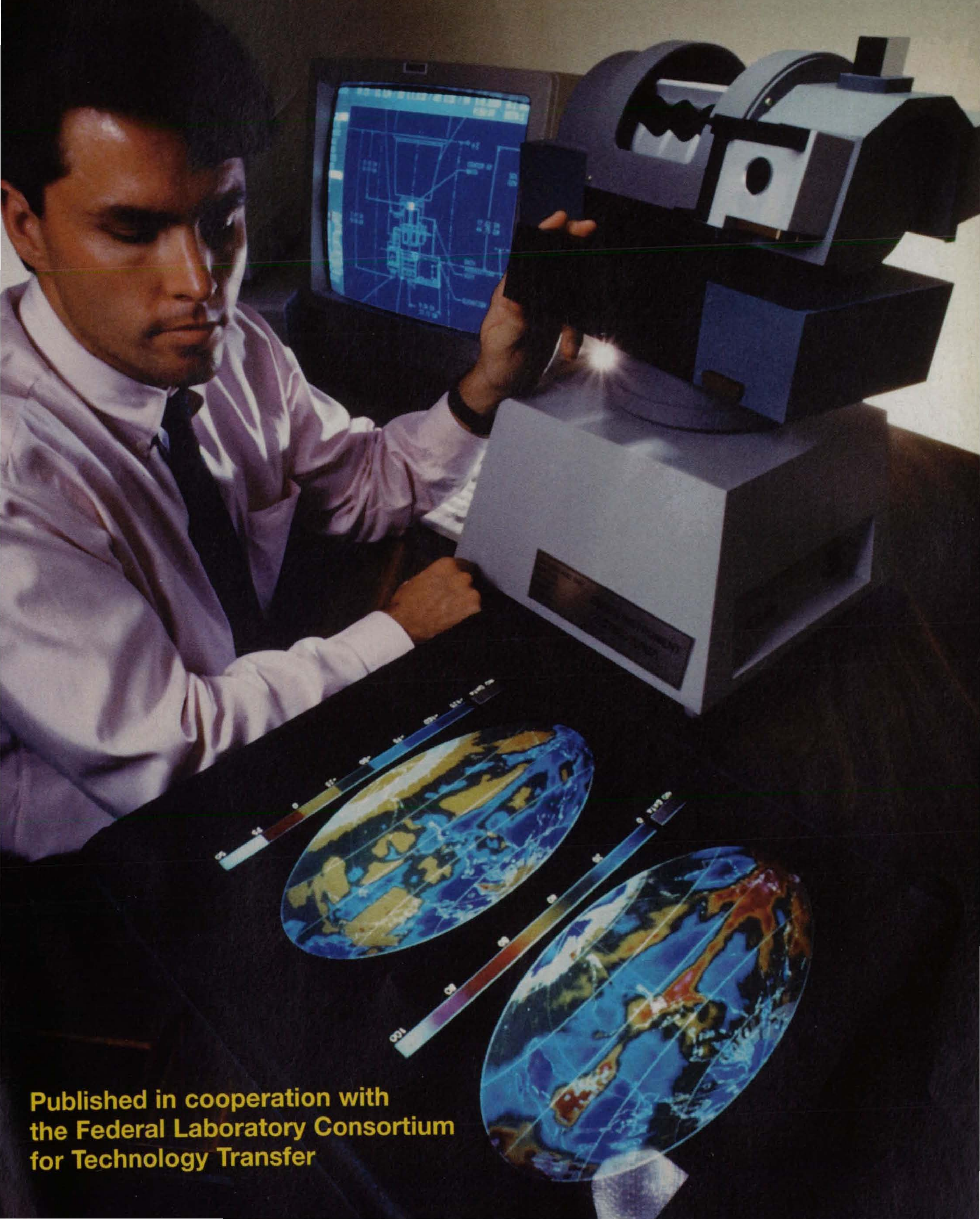

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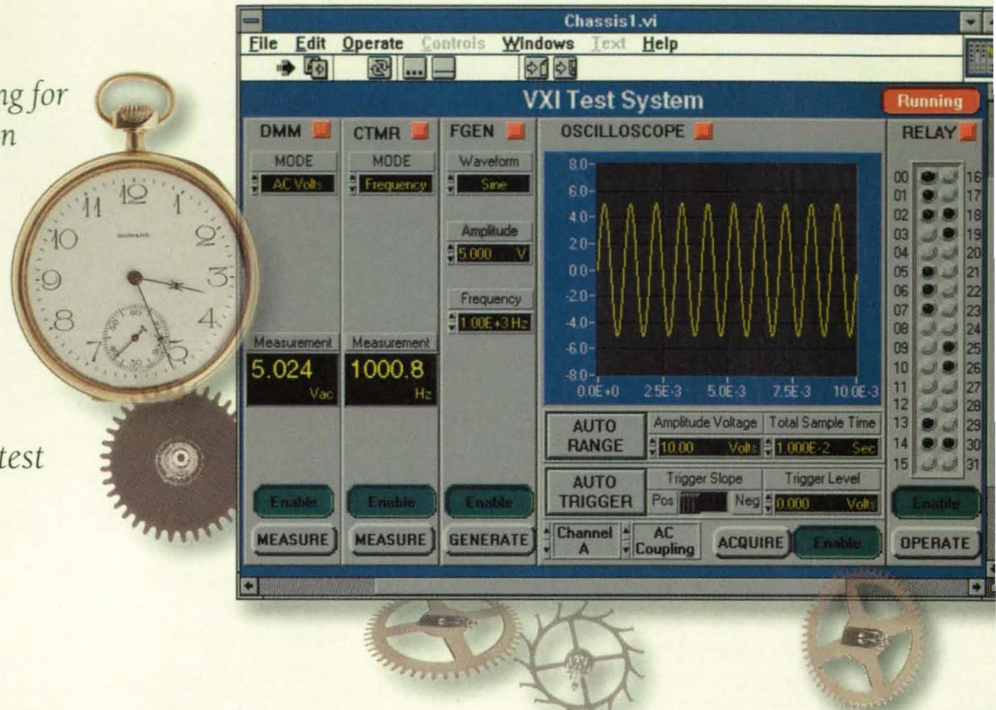

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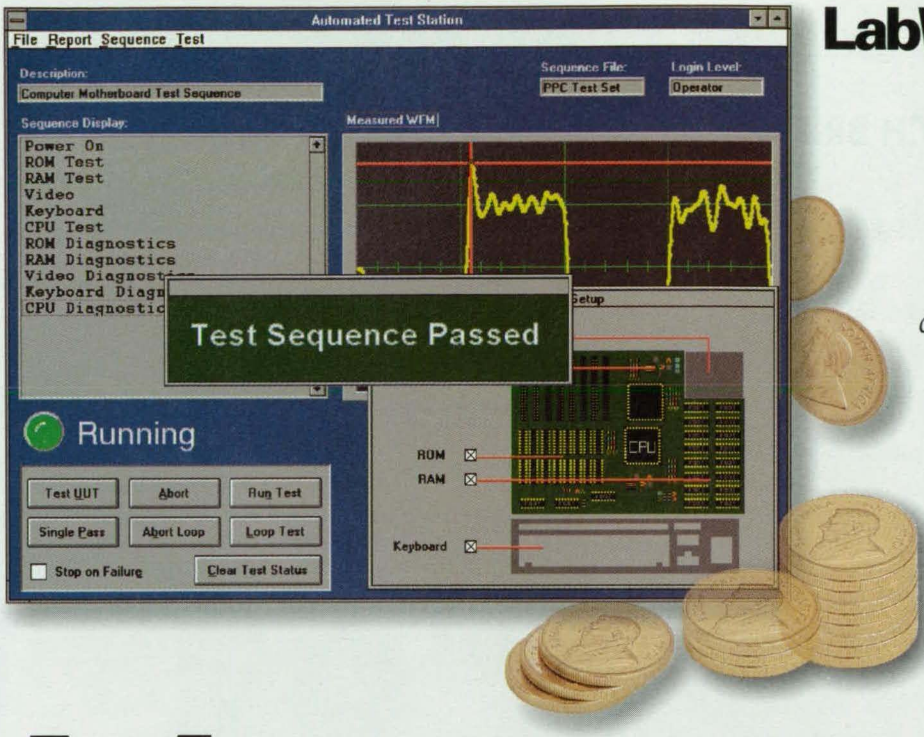

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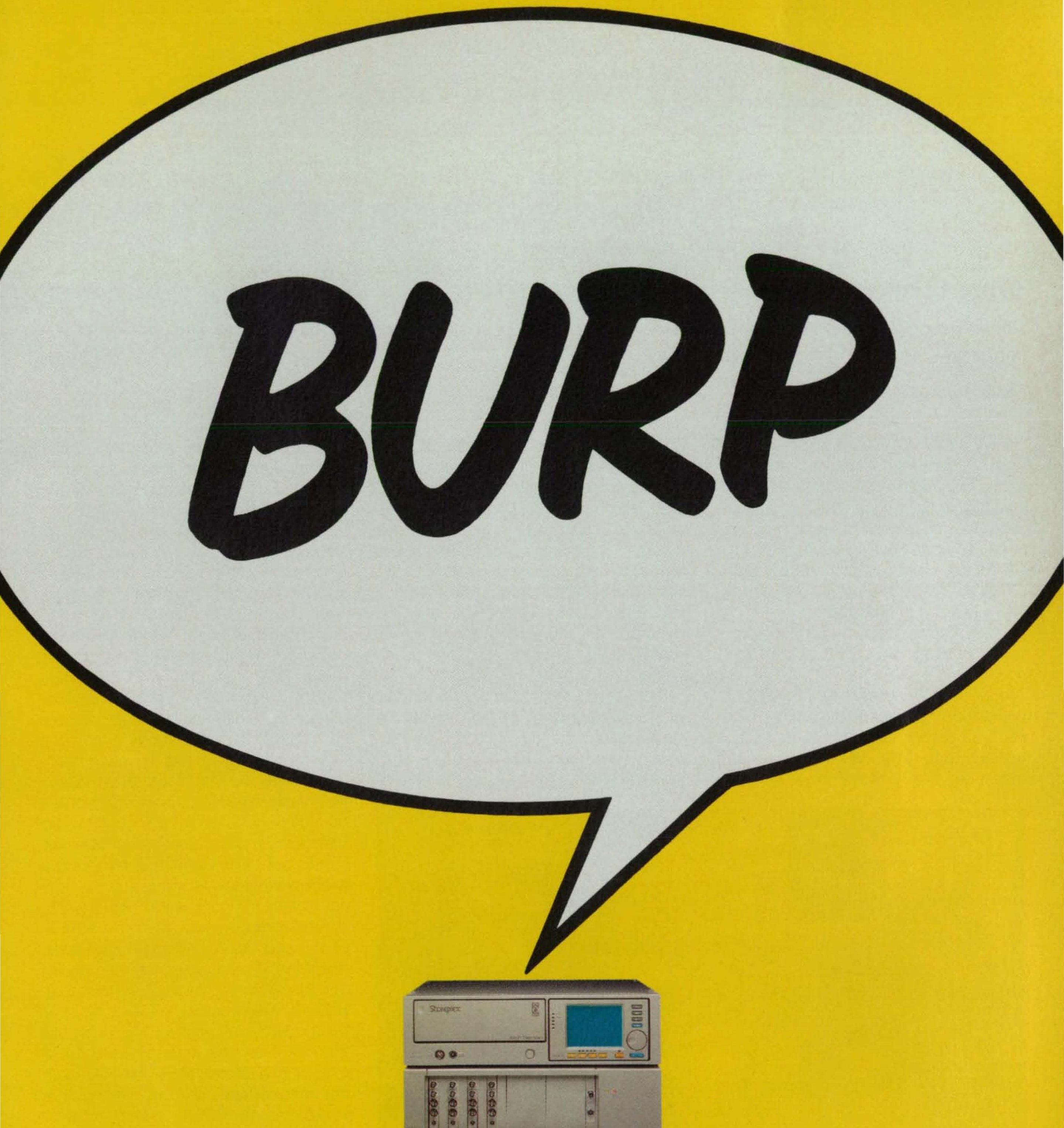
Federal Lab Test & Measurement Tech Briefs
Supplement to *NASA Tech Briefs* May 1995 Issue
Published by Associated Business Publications in cooperation with the Federal Laboratory Consortium for Technology Transfer

TEST & MEASUREMENT TECH BRIEFS

On the cover

A researcher works with a mockup of the Clouds and the Earth's Radiant Energy System (CERES), in development at TRW under a NASA Langley Research Center contract. Scheduled for a test launch in 1997, CERES will measure short and long wavelengths to monitor radiation balance and the effects of clouds on the Earth's climate. Photo courtesy NASA Langley.


BURP

Gas Chromatic Mass Spectrometer

An advanced two-component diagnostic technique defines the hydrocarbons as well as measures to the parts-per-billion level.

NASA Lewis Research Center, Cleveland, Ohio

The gas chromatograph/mass spectrometer (GC/MS) is used to measure and identify combustion species present in trace concentration. An advanced extractive diagnostic method that was originally used for measuring exhaust hydrocarbons in parts per million (PPM), the GC/MS can measure to parts per billion (PPB), as well as differentiate between different types of hydrocarbons.

The GC/MS has two components: a gas chromatograph (GC) and a mass spectrometer (MS) detector. The GC separates the test sample into selected compounds by means of column material, carrier gas-flow rate, and column temperature. The MS identifies and measures the concentration of each "separated" species.

A gas sample is obtained directly from an exhaust stream of a combustor. The sample flows through capillary columns that separate it into constituent gases on a molecular basis, which are then detected by a mass spectrometer. The MS has two operating methods: the scan mode, which scans all ions in a specified mass/charge range, and the selected ion monitoring mode (SIM), which only checks specific ions. Pentane, a compound containing five carbon atoms, for example, is ionized into many fragments. All are required for identification, but the time required to obtain the spectra limits the sensitivity of the instrument. However, the SIM mode has much greater sensitivity because only a few ions are monitored, but it cannot identify the molecular species.

Shown with NASA Lewis's gas chromatic mass spectrometer (GCMS), which identifies and precisely measures the concentration of molecular species in a gas sample to parts per billion, are Ted Brabbs (NYMA) and Dr. Chowen Wey (OIA), who developed the measurement technique.

With specially designed gas mixtures and at specified conditions, a molecular compound can be identified by its "retention time," which indicates the number of carbon atoms and type of species observed. The larger the molecule, the larger the retention time. The identification is accomplished by the use of two identical standard gas mixtures, one in PPM, the other in PPB concentrations. With the PPM mixture, the scan mode will identify the molecular species as it appears in the chromatogram. The PPB mixture, which has the same retention time as the PPM mixture, is required for measuring the concentration of the unknown species in the SIM mode. Variations in the sample loop size, the carrier-gas flow rate, and the tuneup method allow easy-to-detect concentrations of 10 PPB or lower.

Researchers who perform atmospheric chemistry modeling will be interested in the information on the species that the GC/MS obtains. From the combustion, researchers can also address the question of unburnt hydrocarbons that are currently counted by a flame ionization detector (FID). The FID does not differentiate between the kinds of hydrocarbons, which create different types of atmospheric chemical reactions. Unlike the FID, which measures only the total unburnt carbon atoms and subsequently does not identify in detail the specific hydrocarbon compounds present, the mass spectrometer both identifies and measures the concentration of the molecules present, and measures concentrations as low as a few parts per billion. The GC/MS is more difficult to use than other less precise techniques, however, because the equipment must be kept highly sanitized.

This diagnostic technique would be

applicable for petrochemical, waste incinerator, diesel transportation, and electric utility companies in accurately monitoring the types of hydrocarbon emissions generated by fuel combustion, in order to meet stricter environmental requirements. Other potential applications include manufacturing processes requiring precise detection of toxic gaseous chemicals (*i.e.*, paint industry), biomedical applications requiring precise identification of an accumulative gaseous species, and gas utility operations requiring high-sensitivity leak detection.

This work was done by Chowen Wey for **NASA Lewis Research Center.** *Inquiries concerning rights for the commercial use of this technology (LEW-16142) should be addressed to Luke Kirch, Technology Utilization Office, NASA Lewis Research Center, Cleveland, OH 44135.*

New Capabilities for National Wind Technology Center

After upgrading, the facility will offer unique wind-tunnel development and testing resources for industry and government.

National Renewable Energy Laboratory (NREL), Dept. of Energy, Golden, Colorado

The US Dept. of Energy (DOE) has committed more than $5 million to the two phases of the renovation and construction of the National Wind Technology Center (NWTC) of the NREL. The center, located on 280 acres north of Golden, CO, will feature as many as 16 test pads for machines ranging from less than 1 kW to as much as 1 MW when both phases are completed in 1996.

Phase 1, completed in July 1994, involved renovating the main office and laboratory building, the physical plant, and the test stands. The main office building now houses a high-bay laboratory for fatigue testing, ultimate static strength testing, and other techniques such as photoelastic stress analysis. Fatigue tests currently use a closed-loop, servo-hydraulic system to apply cyclic loads to blades as long as 66 ft. (20 m).

Phase II renovation and construction of NWTC will be complete next year. At that time, wind-industry partners will work side by side with NREL scientists in collaborative research and testing of advanced turbines and hybrid wind systems at the new industrial-user facility. This will include a laboratory for developing power electronics, office space, experimental laboratories, computer facilities, and space for assembling components and testing turbines.

The industrial-user facility will also include a large blade-testing area, where researchers can analyze the performance and structural stability of individual wind-turbine blades more than 85 ft. (26 m) long. New fatigue-testing equipment will be added for quicker, more accurate simulation of wind loading in the laboratory.

The advanced research facility will consist of two test machines that can be configured for the type of advanced wind-turbine component development testing that businesses are unlikely to undertake because of its risk, cost, and complexity. Operating side by side, the two machines will allow researchers to discriminate between small (5-10 percent) differences in performance and loading, while testing different machine configurations in turbulent winds.

Nearby pads will be available for testing prototype turbines developed under the DOE/NREL Advanced Wind Turbine Program. Full system research and testing will help improve basic understanding of wind-energy technology.

The first advanced wind turbines developed by industry with support from NREL are already installed at the center, including the largest one ever operated in Colorado: a 275-kW machine developed by R. Lynette and Associates of Redmond, WA. Other machines now at the site include a 50-kW turbine developed by Atlantic Orient Corp. of Norwich, VT; a 10-kW machine developed by Bergey Windpower Co. of Norman, OK; and a 20-kW experimental turbine designed and operated by NREL researchers.

The new hybrid power-test facility will focus on commercially available hybrid power systems, which combine a wind turbine with other renewable-energy systems (such as photovoltaics), battery storage, and a backup power system such as a diesel generator.

NREL's new facility will help US manufacturers develop new technology, applications, and markets for small wind and hybrid power systems. Objectives include testing systems that are nearly ready for the marketplace, collaborating with industry on new approaches that will improve performance and cost-effectiveness, making a user facility available to US companies for systems development, and training foreign nationals. Construction of the test facility will begin later this year; two or three power systems may also be ready for testing this year.

NREL's work with industry at the NWTC will help achieve DOE's goal of producing electricity from wind for less than $0.04 per kilowatt-hour by the year 2000. The current cost is $0.05-0.08 per kilowatt-hour.

The National Wind Technology Center is a part of the **National Renewable Energy Laboratory***. For more information on test and measurement capabilities at the NWTC, contact Darrell Dodge at (303) 384-6906. Inquiries concerning licensing opportunities and cooperative research agreements should be directed to NREL's Technology Transfer Office at (303) 275-3008.*

Digital Sampling Channel Probe

An innovative probe provides impulse response characterization of radio propagation channels and enables performance prediction of radio communication systems.

Institute for Telecommunication Sciences (ITS), National Telecommunications and Information Administration, Boulder, Colorado

ITS, in a joint effort with Telesis Technologies Laboratory, Inc., has developed a digital sampling channel probe (DSCP). The probe is ideal for making outdoor impulse response measurements to characterize wideband propagation in the radio channel. If the noise and interfering environment is known, impulse response measurements can be used to predict radio communication system performance either through computation of various parameters from the measured data (such as RMS delay spread) or through wireless link simulation. Therefore, these measurements aid in the design, development, and planning of radio systems, including new technologies such as personal communications services (PCS) and digital cellular systems. Because of this, the DSCP has been used extensively for propagation measurement studies in many locations for various commercial and governmental organizations.

The basic configuration of the DSCP (see figure) uses a maximal-length pseudorandom-noise (PN) code to modulate an RF carrier and produce a binary phase-shift-keyed (BPSK) signal.

This signal is then filtered, amplified, and transmitted through an antenna. The transmitted signal, modified by the propagation channel, is then received, downconverted to an intermediate frequency (IF), and digitized.

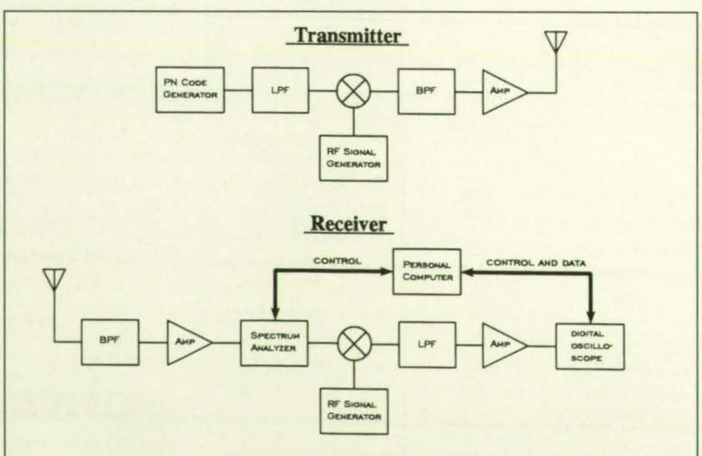
The in-phase and quadrature-phase baseband components of the received signal are determined via software. The complex impulse response is generated by cross-correlating, in software, a simulated copy of the transmitted PN code with the in-phase and quadrature-phase components of the received signal. An interval of discrimination (ratio of the power in the correlation peak to the peak noise power in the complex impulse response) within 2 or 3 dB of the maximum theoretical value (54 dB for a 511-bit PN code) can be achieved. The DSCP can also measure an impulse response much faster than the traditional analog sliding correlator probe. This allows better characterization of rapidly changing propagation channels.

Many different system configurations are available with the DSCP. Current configurations use commercially available equipment such as RF-signal generators, spectrum analyzers, digital oscilloscopes, and personal computers to achieve a high degree of flexibility and to minimize system setup time for specific field studies. Both the transmitter and receiver have a dual-channel capability allowing for transmission and reception with various combinations of two different PN codes, carrier frequencies, antenna polarizations, and antenna spacings.

In the typical configuration, the null-to-null bandwidth of the probe is 20 MHz, providing a delay resolution of 100 ns and a maximum measurable delay of 51 μs. A processing gain of 27 dB is achieved with a receiver noise figure of approximately 8 dB. The probe can be easily configured for wider bandwidths (finer time resolution) and different maximum delays. Recent improvements to the probe include the ability to measure absolute time and Doppler spread. Future plans include expanding the probe to multiple channels to help analyze the potential benefits of advanced antenna systems and antenna signal processing.

This instrument was developed by Kenneth C. Allen, Jeffery A. Wepman, J. Randy Hoffman, Lynette H. Loew, Peter B. Papazian, and Yeh Lo of the **Institute for Telecommunication Sciences** *and Andrew-Lindsay Stewart of* **Telesis Technologies Laboratory, Inc.** *A patent has been issued.*

For further information regarding the probe or impulse response measurement studies, contact Jeffery A. Wepman at the ITS, National Telecommunications and Information Administration, US Dept. of Commerce, 325 Broadway, ITS.S3, Boulder, CO 80303; (303) 497-3644; Internet address: jwepman@its.bldrdoc.gov.



Basic configuration of the digital sampling channel probe.

Basic configuration of the digital sampling channel probe.

Preserving Aqueous Field Samples with Acid or Base

A new method improves safety in field work.

Bureau of Reclamation, Dept. of Interior, Denver, Colorado

Water samples are often collected from the field for various chemical measurements. Many of these samples require the addition of either acid or base for preservation of metals, trace metals, nutrients, or cyanides.

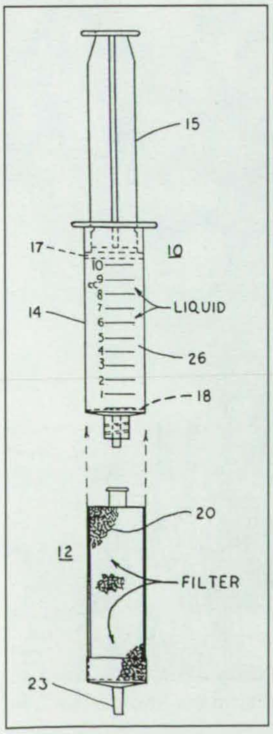
Previously, sample preservation was accomplished in one of two ways. The first was to add acid or base to a clean sample bottle in a laboratory and then ship the bottles to the field site for sample collection. However, shipping bottles with acid or base required that various shipping regulations be met, which meant added costs. Additionally, the container could not be rinsed several times with the field water without loss of the preservative. The second is taking clean sample bottles and acid and/or base to the field. But this created safety concerns in the field when handling strong acids and bases.

To solve this problem, the Bureau of Reclamation developed a device that can easily be manufactured. Basically, it consists of a syringe containing a neutral salt solution, and a syringe attachment containing either a strong acid or base ion-exchange resin in either the hydrogen or hydroxide form. When pressure is applied to the syringe plunger, the liquid travels through the resin, which results in immediate acid or base. The whole device, including the syringe, is disposable and made of plastic.

The device would be sold in a plastic blister pack, and because it is safe until used, it could be stocked in office areas. Depending on cost considerations, the device could be recycled by regenerating the ion exchange bed with either acid or base.

Benefits include a safer way of preserving field samples, lower costs for shipping of sample containers, no need to handle acid or base in the field, more representative sampling achieved by rinsing the bottle several times with the water before adding the preservative, and less awkward safety equipment for field sampling.

This device was developed by Andrew P. Murphy for the Department of the Interior's **Bureau of Reclamation.** *A US patent (5,322,800) has been issued. Licensing information can be obtained from the Research and Laboratory Services Division, Bureau of Reclamation, PO Box 25007, D-3700C, Denver, CO 80225; (303) 236-5981.*



A syringe containing liquid is connected to an ion-exchange filter and pressure is applied to the plunger to deliver either nitric, sulfuric, or sodium hydroxide.

Liquefied Gaseous Fuels Spill Test Facility

Controlled spills allow researchers to study dispersion and improve mitigation and cleanup techniques.

Nevada Test Site, Department of Energy, Las Vegas, Nevada

The Liquefied Gaseous Fuels Spill Test Facility, located on the Nevada Test Site north of Las Vegas, is the only place in the United States where federal agencies and private companies can test the characteristics of large quantities of hazardous liquids and gases. Researchers release the materials into the environment under carefully controlled conditions, and monitor the spills to determine patterns of dispersion, test mitigation techniques, and develop and refine cleanup technology and procedures.

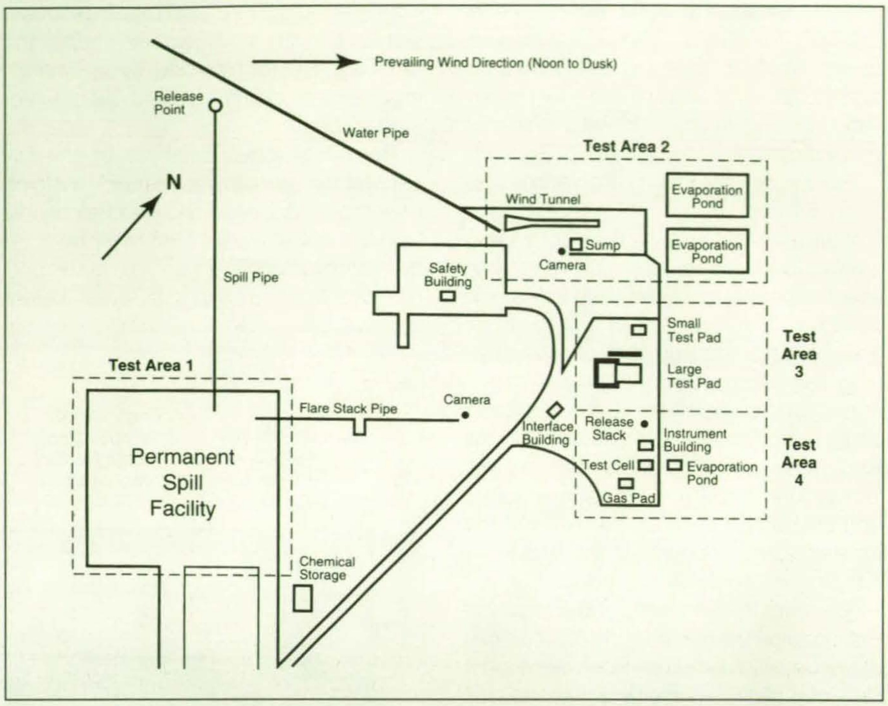
The $7.9-million facility comprises two cryogenic storage tanks that each hold up to 105 m^3 (28,000 gallons) of test fluid, as well as a noncryogenic pressurized storage tank that holds up to 90 m^3 (24,000 gallons) of fluid. An extensive piping system delivers the fluid from these tanks to the release area; noncryogenic fluids are driven through the pipes by pressurized nitrogen gas. Researchers conduct the tests from a command center and data-recording station safely located about 1.6 km (1 mile) away from the release area.

Favorable meteorological conditions at the Nevada Test Site and a remote location make the facility suitable for experiments with hazardous materials. The winds at the facility are relatively consistent and predictable from April to October. In addition the land downwind of the facility is managed by the US government and is situated away from population centers. Access to the area surrounding the facility is carefully controlled.

The facility can house both large- and small-scale tests. Its design allows researchers to duplicate, under controlled conditions, accidental releases of various materials using approximately the same amounts and spill rates that would be expected in actual industrial settings. This allows users of the facility to validate models, observe and measure new phenomena, and design and evaluate protective measures such as water curtains, vapor barriers, and foams.

A typical experiment involves discharging a measured volume of a hazardous fluid onto a surface that has been specially prepared to meet test requirements. Discharge rates for cryogenic fluids range from 5-100 m^3 per minute (1,000-26,000 gallons per minutes), while rates for noncryogenic fluids range from 2-20 m^3 per minute (500-5000 gallons per minute).

Test fluids may also be released in a wind tunnel measuring 2.5 m by 5 m by



The Liquefied Gaseous Fuels Spill Test Facility has four distinct test areas where researchers can release and study hazardous fluids.

A chemical worker contains a fuming acid released at the test facility on the Nevada Test Site.

29 m (8 ft. by 16 ft. by 96 ft.). Using the wind tunnel, researchers may control and vary intake air temperature, humidity, and release rate and volume.

Diagnostic sensors that collect test data can be placed up to 26 km (16 miles) downwind of the release area. Such characteristics as flammability, concentration, heat flux, turbulence, and vapor dispersion rate can be observed and recorded.

The spill test facility can accommodate vapor dispersion and vapor-cloud fire tests, as well as pool-fire tests on soil or on water surfaces. With modifications the facility can accommodate vapor-cloud fireball and vapor-cloud explosion tests as well.

Companies that respond to emergencies involving accidental releases of hazardous chemicals have used the spill test facility to train employees in spill containment and cleanup techniques. They also have used an enclosed test cell at the facility to determine the effectiveness of protective clothing worn by individuals who respond to such emergencies.

The spill test facility is available for use by federal agencies and private industry on a user-fee basis. An environmental impact statement approved for the facility allows the testing of more than 30 common industrial chemicals, including ammonia, chlorine, liquefied natural gas, and ethylene. Additional impact statements generally are not required.

The spill test facility is operated for the US Department of Energy at the **Nevada Test Site** *by EG&G Energy Measurements Inc. For further information, or to discuss opportunities for using the facility, contact Dr. Bruce Whitcomb, Office of Research and Technology Applications, PO Box 1912, M/S B2-22, Las Vegas, NV 89125-1912; (702) 295-3164; FAX (702) 295-3317.*

Ultrasonic Characterization of Bonded Aircraft Fuselage Structures

A new technique produces immersion-quality images without excessive surface wetting.

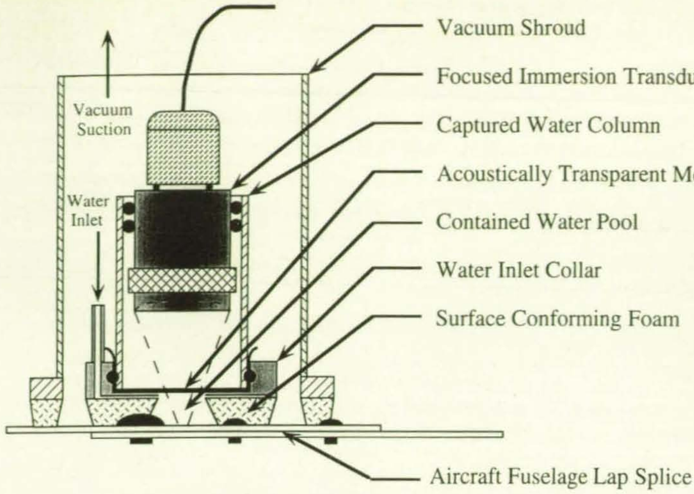
FAA Technical Center, Atlantic City International Airport, New Jersey

A new device, dubbed the Dripless Bubbler, has been developed that incorporates focused-immersion ultrasonics with portable C-scan systems for the nondestructive inspection (NDI) of aircraft fuselage lap splices, tear straps, and composites for corrosion, disbond, and other defects. The device permits a water-coupled, focused-beam ultrasonic inspection of the fuselage without the problem of uncontained water. When attached to a portable scanning device, it can be used in any scanning orientation, even on vertical and overhead surfaces. It allows the scanning of areas with surface protrusions, such as button-head rivets and lap-splice edges. Recently a motorized (hands-off) version of the Dripless Bubbler was successfully demonstrated at the FAA Aging Aircraft NDI Validation Center in Albuquerque, NM. It was also field-tested on a tapering lap-splice section of a Boeing 747-200 at Northwest Airlines in Minneapolis, MN.

The Dripless Bubbler is essentially a captured water column that incorporates a water delivery and vacuum return system, as shown in the figure. The column is sealed at one end by an acoustically transparent polymer membrane, and an O-ring that surrounds a standard-size immersion transducer seals the other end. The transducer does not come into direct contact with the surface of the sample. Contact with the surface is made with a foam water-retaining ring situated between the exit of the column and the sample's surface. Water is continuously supplied to the foam ring to provide a constant water path from the transducer to the sample's surface. The foam ring is surface-conforming so that the Dripless Bubbler can slide over irregular surface features. Water that seeps out of the ring is vacuumed away, leaving the area surrounding the inspection location dry.

The peak amplitude and time-of-flight C-scan images obtained using the Dripless Bubbler on bonded, riveted aluminum structures are superior to any C-scan image previously obtainable using contact ultrasonic scanners. Such high-quality images can be directly attributed to the focused-immersion ultrasonic transducer. The spatial resolution obtainable in a focused C-scan image is much greater with a focused-immersion inspection than with a contact ultrasonic inspection. Along with the enhanced image quality, the Dripless Bubbler can resolve disbond and corrosion defects existing around fastener holes without marring the surface of the aircraft, as a contact ultrasonic inspection often does. On boron-epoxy composite repairs, the Dripless Bubbler has been used to determine the alignment of the composite fibers, identify and size inclusions located in the composite patch, and detect the presence of resin-rich areas and disbonded regions under the composite patch.

Any standard-size focused-immersion ultrasonic transducer of center frequencies between 0.5 and 15 MHz can be incorporated into the Dripless Bubbler. Conventionally, ultrasonic inspection of adhesively bonded aluminum structures has used the higher-frequency (resolved) RF signal echo technique. Recent work with the Dripless Bubbler has shown that a lower-frequency (unresolved) focused-beam inspection is capable of mapping out disbonds and corrosion in the first and second layers in adhesively bonded aluminum lap splices. In laboratory tests, a corrosion pit located on the exterior side of the lap splice's second aluminum layer (the layer not accessible) was easily detected through the first aluminum and adhesive-scrim cloth layers using the low-frequency inspection. The pit was not readily detectable with a high-frequency inspection, where interference fringes caused by minute changes in the adhesive bondline layer complicated the image results.



Schematic of the Dripless Bubbler.

Future modifications to the Dripless Bubbler include the ability to scan slightly curving and dual-curvature surfaces, optimization of the system performance, and an overall reduction in the size and weight of the assembly. Plans for the low-frequency inspection technique include characterization of image details on actual in-service fuselage specimens. Emphasis will be directed toward differentiating defects containing both disbond and corrosion.

This work was done by David K. Hsu and Thadd C. Patton, FAA Center for Aviation Systems Reliability, Iowa State University, for the **FAA Technical Center**. *Inquiries concerning use of this device should be addressed to the Aging Aircraft Research Branch, ACD-200, FAA Technical Center, Atlantic City International Airport, NJ 08405.*

Full-Scale Curved Panel Test Fixture

The device enables determination of failure progression and residual strength of aircraft fuselage structures.

FAA Technical Center, Atlantic City International Airport, New Jersey

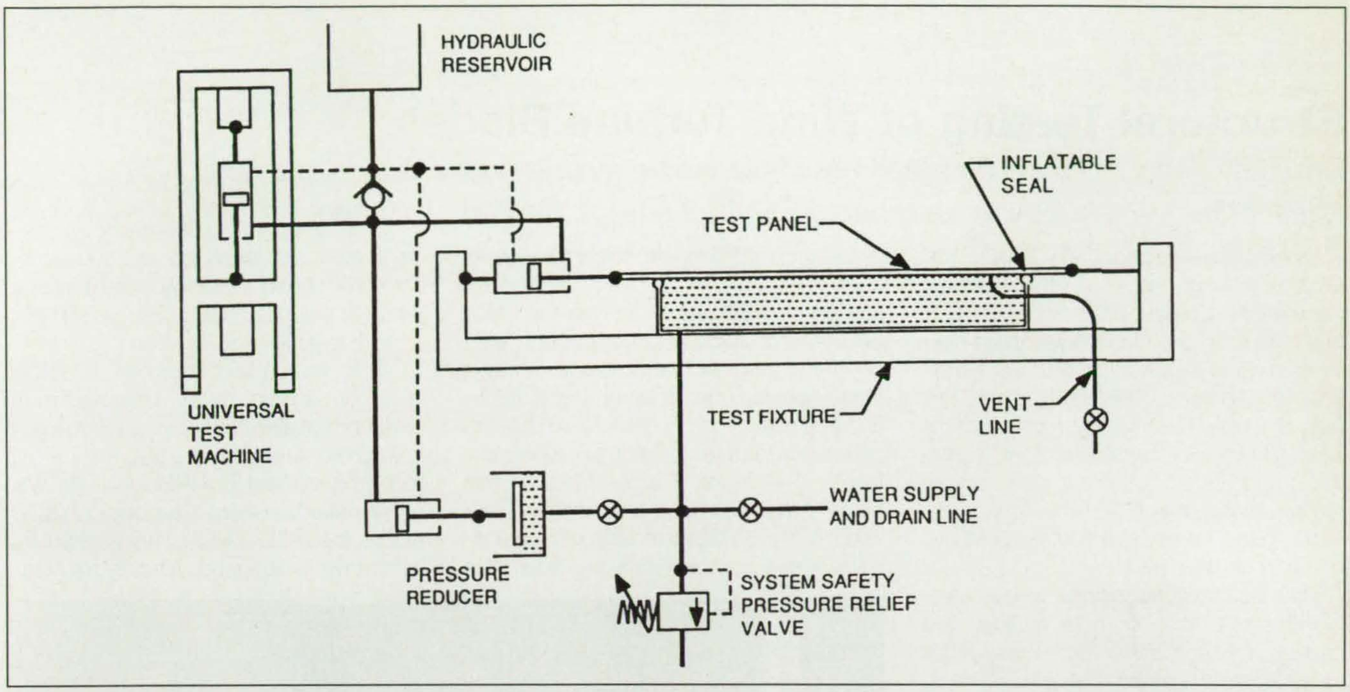
A new test fixture can accommodate 40° curved sector panels 120 in. in length, 58 in. in width, and 60-100 in. in radius. Internal pressure loading up to 20 psi and corresponding longitudinal and hoop restraining loads can be applied. Cyclic pressurization loads can be used for fatigue studies. The stress distribution in the full-size fuselage structure can be accurately simulated in the central region of the test panel.

The fixture is in use at a fatigue and fracture-strength test facility designed, built, and operated by Foster-Miller Inc. with funding from the FAA Technical Center. It can test full-size curved panel sections under internal pressure and biaxial loadings. The internal pressure is simulated using water contained within a bladder system. The biaxial loading is applied by loading one of the curved edges mechanically using hydraulic cylinders and fixing the other three edges.

The test fixture is designed to reproduce conditions of a full-circle fuselage, simulate normal pressure loadings, provide cyclic pressure loadings, and apply bending loads. The water pressurization provides safe and cost-effective testing of full-scale fuselage panels. The general approach for panel testing is to anchor the two long sides and one curved end to the fixture. A schematic of the panel loading is shown in the figure.

The universal test machine introduces in-phase hoop and longitudinal loads through a master cylinder, which is mounted as a test specimen. Hydraulic pressure from this master cylinder directly drives four longitudinal cylinders that provide loading to the test specimen through a wiffle tree arrangement. The master cylinder also provides pressure to the panel pressurization cylinder, which drives a pressure reducer. This system supplies internal water-pressure loading to the test specimen, which is positioned between two pressure-balanced pneumatic seals. This design accurately simulates the pressurization cycle of a typical commercial aircraft. Fatigue testing can be automatically controlled by the universal test machine to provide sine-wave loading at up to 720 cycles per hour. Thus, the typical commercial aircraft fuselage can be cycled to one lifetime within two weeks. Static testing can be automatically or manually controlled.

Six full-scale fatigue tests and more than twenty residual-strength tests have been performed to date using this fixture. Most recently, a repair to a fuselage lap splice joint was evaluated using high-cycle fatigue tests of identical specimens, with and without the repair. Multiple-site damage (MSD) was studied



A schematic of fuselage panel loading for failure and residual strength testing.

in both cases, from crack initiation through growth and linkup of adjacent cracks, to final failure of the panel. Such comprehensive test data on MSD crack growth and linkup is used to analyze and understand failure modes in fuselage panels. Residual-strength tests have been conducted to evaluate panels with long-lead cracks at different locations. Tests have also been performed to determine the effects of different MSD scenarios on residual strength.

This work was done by Foster-Miller Inc. for the **FAA Technical Center** *at Atlantic City International Airport. Inquiries concerning the use of the test fixture and availability of test results should be addressed to the Aging Aircraft Research Branch, ACD-220, FAA Technical Center, Atlantic City International Airport, NJ 08405.*

Structural Testing of Wind Turbine Blades

Research capabilities aid development of blades by wind-energy industrial partners.

National Renewable Energy Laboratory, Dept. of Energy, Golden, Colorado

Since its inception in 1990, the Structural Test Facility of the National Renewable Energy Laboratory (NREL) has played a key role in developing new wind turbine blades for the US wind-energy industry. The facility, at the National Wind Technology Center, offers a broad range of capabilities that enable industrial partners to participate in critical testing and research activities that most wind-energy companies find too costly to conduct on their own.

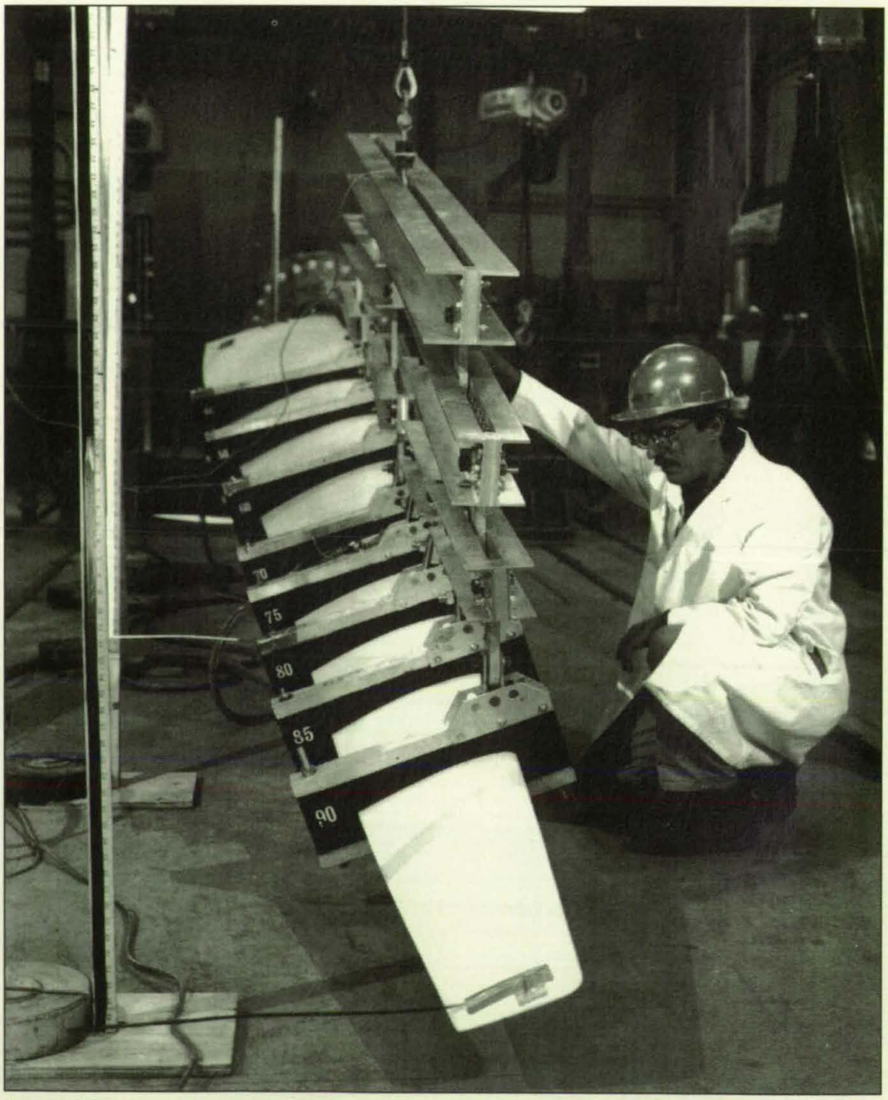
These capabilities include fatigue testing, ultimate static-strength testing, and several nondestructive techniques such as photoelectric stress analysis. To date, NREL has evaluated blades from six of the leading US wind turbine companies, including the world's largest wind-energy company, Kenetech Windpower (formerly US Windpower).

In 1991, NREL signed a nonexclusive cooperative research and development agreement (CRADA) with Kenetech to test and evaluate blades. The first phase of testing focused on a complete evaluation of the USW 56-100 wind turbine blade. With more than 4000 of these turbines in operation, Kenetech wanted to gain a better understanding of the blade's structural properties and how they age, in order to predict their expected service life and maintenance more accurately. The current program focuses on Kenetech's 33M-VS wind turbine, the leading wind turbine on today's market. A comprehensive look at the blade's fatigue and static-strength properties is now under way.

Under repeated loading, accelerated fatigue failures have helped to verify the blade's design life and manufacturing techniques, and to identify complex structural behavior under extreme loads. Testing at NREL has increased Kenetech's confidence in the 33M-VS design and has led to significant design improvements.

Zond Systems Inc. has become a leading US wind turbine manufacturer with its original 500-kW Z-40 turbine, developed from the company's extensive experience working with wind turbines of all sizes. The Z-40 project is partially funded by NREL under of one the Value Engineering Turbine Development subcontracts. As part of its mission to move these designs toward commercial viability, NREL has recently completed the first series of structural tests of the 19-m prototype Z-40 blade. Fatigue tests on this blade have helped Zond identify and improve several design features prior to beginning production early this year. This rapid feedback provided to Zond during an early phase of development should result in a solider production design and a more reliable wind turbine.

NREL has also performed structural tests on several other manufacturers' blade prototypes that have each resulted in sounder designs. The first fatigue test to be conducted at NREL's facility was on an Atlantic Orient Corporation (AOC) blade, the AOC 15/50. This is a 50-kW wind turbine designed primarily for nonu-



A technician examines a wind turbine blade at NREL's Structural Test Facility.

tility applications under the Near-Term Advanced Wind Turbine Program. Fatigue tests verified the design on this wood composite blade and led to improved manufacturing processes.

Northern Power Systems, a subsidiary of New World Power, is another NREL subcontractor developing wind turbines (known as the North Wind 250) under the Near-Term Program. Tests conducted at NREL have played a major role in the development of the turbine's unique flow-through rotor system. Although it is still in the prototype stage, structural testing of the composite joint and center section of this rotor has guided the design decisions, which have led to the current configuration.

Wind turbines have increased in size over the past few years. However, because of the high cost of each blade, the number of prototypes that can be developed is limited. With the added pressure that cost of energy, high reliability, and maximum performance demand from blade designers, most manufacturers now consider full-scale structural testing of wind turbine blades to be an integral part of the design process. NREL operates the only facility in the US that is capable of performing this type of testing.

For more information, contact Walt Musial at the National Wind Technology Center, **National Renewable Energy Laboratory**; *(303) 384-6956.*

Inquiries concerning licensing opportunities and cooperative research agreements should be directed to NREL's Technology Transfer Office; (303) 275-3008.

A Highly Capable Facility for Antenna Testing

Recent investments in new equipment make the site one of the most highly automated of its kind.

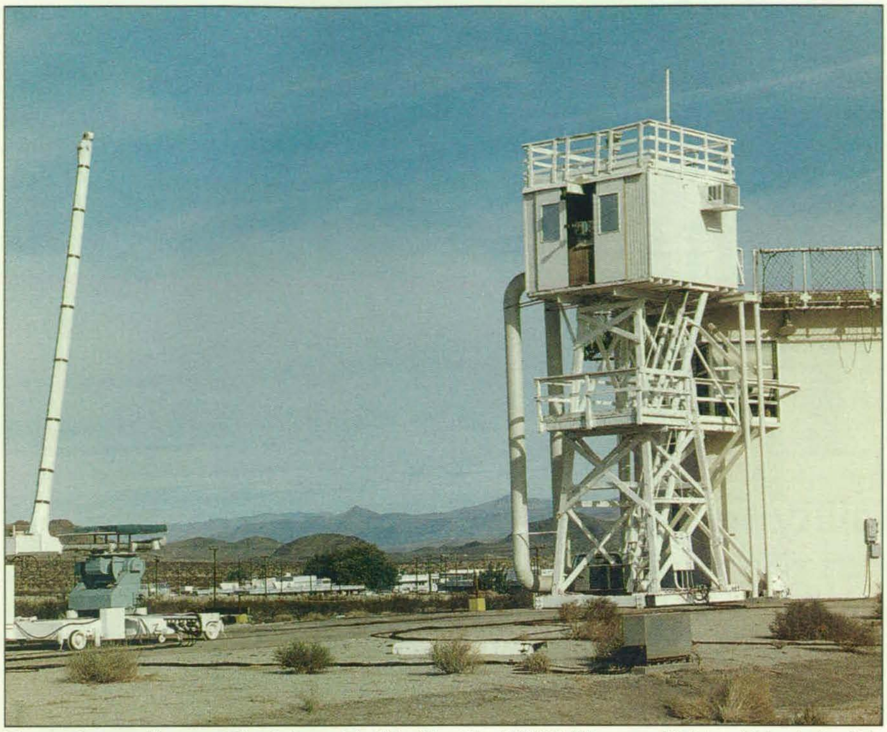
Naval Air Warfare Center, Weapons Division, China Lake, California

In continuous operation since 1971, the Antenna Test Facility at China Lake, CA, has conducted numerous tests for all branches of the military and various contractors. The Facility offers integrated capabilities to handle a variety of antenna testing needs. Years of experience in building, using, and measuring antennas have given Facility and associated Center personnel a thorough understanding of antenna design, measurement, and testing technology, and of customer needs such as collecting measurement data on an antenna or designing a specialized antenna.

Facility personnel can assist in the design process, compare an antenna's actual and predicted performance to determine why it isn't operating as expected, or judge when an antenna has reached its maximum performance level. Past work with radar cross-section (RCS) measurements has required facility personnel to push the edge of RF measurement technology to accomplish very-low-background-noise and low-observables measurements.

Major investments have made the Facility one of the most highly automated of its kind. Sophisticated software integrates the automated measuring equipment, making measurements faster, more accurate and repeatable, and also less labor-intensive, so testing at China Lake is more cost-effective than at less highly automated facilities. Capabilities are upgraded frequently to take advantage of new technology: Within the last two years, new positioners and position controllers have been added, as well as a new planar near-field measurement capability, computers, software, and data-storage capabilities.

The Facility can accommodate many types of antennas and antenna systems, including the following: slotted waveguides, linear arrays, active and passive arrays, dielectrics, monopoles, parabolic reflectors, horns, helicals, patches, lens antennas, and corner reflectors. An outdoor range for far-field measurements offers two configurations. One accommodates multiple-channel amplitude and phase measurements, with swept frequency from 100 MHz to 18 GHz. Two positioners are available: a model tower for Phi/Az/El measurements, and a roof-mounted positioner, capable of accommodating a 10,000-lb. vertical load, for Az/El measurements. The second configuration accommodates multiple-channel amplitude measurements, with single frequencies from 100 MHz to 60 GHz. In either configuration, plane or volumetric antenna cuts can be used, and the test distance is adjustable up to 110 feet. The Facility also has indoor/outdoor planar near-field measurement capability that employs a fixed horizontal 8-X-8-ft. scan-



The outdoor positioners at the Antenna Test Facility at the NAWC, Weapons Division, China Lake, CA.

ner with a 2-18-GHz range, and a transportable vertical 8-X-8-ft. scanner with 2-18-GHz range.

All measurement hardware is calibrated to National Institute of Standards and Technology (NIST)-traceable standards. Customers can select HP-UX or MS-DOS format on floppy or magneto-optical disk for data storage. Data can be presented in a variety of formats, including polar, rectangular, or 3-D plots.

Projects at all classification levels can be accommodated. Scheduling is flexible, and test setups are adaptable to customer needs. Support services include design, engineering support, complete machine-shop service, crane service, secure classified storage, and guard service.

The Antenna Test Facility is located at the **Naval Air Warfare Center Weapons Division,** *China Lake, CA. For more information about capabilities, scheduling, cost of services, or opportunities for Cooperative Research and Development Agreements (CRADA), contact Terry*

A Portable, Adaptable Phi-Theta Measuring System

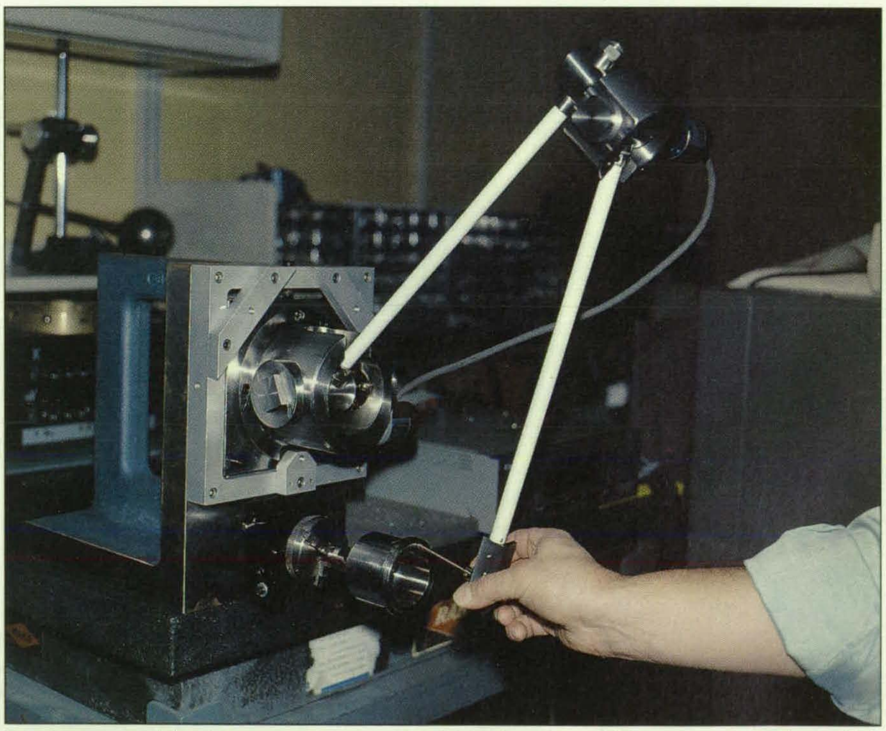
The versatile, low-cost gaging system is applicable to both low- and high-volume machining jobs.

EG&G Rocky Flats, Golden, Colorado

The Phi-Theta Measuring System is an independent gaging arm for in-process workpiece inspection on a milling or turning machine. Angular motion of each of the joints of the measuring arm is detected and translated into linear displacements within the X-Z plane for turning, and the X-Y-Z plane for milling applications. Materials insensitive to the machining environment have been used in the design of the arm, contributing to the accuracy of the system (0.0001 in. over the arm's measurement range). The system is portable and adaptable to different machine tools and manufacturing processes.

The phi-theta arm does not rely on the machine tool's guides or ways in the measurement process, thus ensuring that measurements are entirely independent of machine accuracy. The design of the arm and probe make it possible to reach all surfaces of a part and hold the probe perpendicular to these surfaces. Probe force is precalibrated, eliminating variability with operators.

Applications envisioned include precise, independent inspection of turned or prismatic parts, operation as a stand-alone measuring machine or as a universal in-process measuring system, in a variety of situations such as receiving inspection, metrology laboratories, model shops, and job shops.



Precise on-machine measurements are not dependent on machine accuracy with the Phi-Theta System.

Both low- and high-volume machining jobs can benefit from such a versatile, low-cost gaging system. It is designed to make in-process measurements independent of the machine tool's motion or guides, but without removing a workpiece from its holding fixture. Increased machining efficiency and accuracy result from the precision construction of the unit and from the immediate feedback it gives on part setup and machining performance. The system is less sensitive to operator skill level and technique than other gaging methods.

The Phi-Theta Measuring System will stand alone, or may be linked to a shop-floor control system. It accommodates a large range of part sizes and will evaluate all geometric elements. It can also be employed for digitizing unknown part shapes.

A prototype unit has been fabricated and tested. The existing prototype is run with established machine programs in the Rocky Flats production facility. Drivers will be created to interface the system to other metrology software and firmware, including commercially available shop-floor data links, data acquisition systems, and coordinate measuring machine software. A measuring arm and electronics suitable for mass production and broad factory use could be designed.

This work was done by **EG&G Rocky Flats Inc.** *under contract to the Department of Energy. A patent application is in progress. The partners seek to transfer this technology to the manufacturing sector, and will license the invention. Inquiries can be directed to Dana J. Dorr, Manager, Technology Transfer Program, Building 460, EG&G Rocky Flats Inc., PO Box 464, Golden, CO 80402; (303) 966-7978; FAX (303) 966-4845.*

Coordinate Measuring Machine for Large Products

A precision service supports the need for one-dimensional calibration of greater length and end standards and step gages.

Oak Ridge Centers for Manufacturing Technology (ORCMT), Oak Ridge, Tennessee, and National Institute of Standards and Technology (NIST)

Once available only from foreign laboratories, precision measurement services for manufacturers of automobiles, aircraft, farm equipment, and other large products are now being offered in the US. This results from a growing collaboration between the Department of Commerce's (DOC) NIST and the Department of Energy's (DOE) ORCMT, at the Oak Ridge Y-12 Plant. The services are a direct response to US companies' request for enhanced precision measurement to support improvement in manufacturing and technological development in the private sector.

The original design concept by the Y-12 Quality Division specified a manually operated positioning-type coordinate measuring machine (CMM) with state-of-the-art accuracy to support nuclear weapon production. As production demands changed, the machine requirements were refined. The finished design utilizes a multicomputer system that characterizes humidity and

The Moore M-60 coordinate measuring machine at the Oak Ridge Centers for Manufacturing Technology.

barometric pressure readings, automatically compensating for variations while operating in an environmentally controlled laboratory under rigid temperature control (68 °F). The model M-60 machine hardware, a product of the Moore Special Tool Co. of Bridgeport, CT, is equipped with Quindos Operating Software from the Leitz Division of Brown and Sharpe Co.

Production of nuclear weapon components has been halted at Y-12 since 1991, when President George Bush said the US would make no more such weapons. DOE is seeking alternatives to closing its special production facilities. These are endowed with highly skilled and adaptable technical personnel, extremely sophisticated mechanical abilities, and ultramodern equipment. The NIST/ORCMT collaboration led to an agreement to increase NIST's capabilities by making use of DOE facilities, manpower, and measuring equipment, particularly the Moore M-60 CMM.

The M-60 is a fixed-bridge moving-table design with roller bearings in double V-ways on the X and Y axes and air bearings on the Z-axis ram. The 55-ton machine, 7 meters tall, rests on air isolation pads. Equipped with a 3-D analog probe head made by Movamatic, the M-60 uses a single laser with beamsplitting for measuring the position of all three axes. The measuring volume is X=1397 mm, Y=1219 mm, and Z=1295 mm.

The original performance specification, written in the early 1980s, required that the machine positioning along the four 3-D body diagonals must not deviate from a laser position test by more than 2.5 micrometers over a 2-meter length or more than 1.25 micrometers over an 0.8-meter length. The probing performance requirement stated that the form of 49 points probed on a 25-mm precision sphere must not exceed 0.5 micrometer.

The M-60 is located in a controlled-environment laboratory approximately 7 meters wide, 8 meters high, and 10 meters long. Airflow in the room is a horizontal laminar flow with the inlet and outlet grills being 6.5 X 6.5 meters, located at opposite ends of the room. Air velocity is approximately 22 meters per minute. The air temperature is measured at 20 locations in front of the inlet grill to monitor the performance of the room's air-temperature controller and to evaluate the stratification of temperature entering the room. The 3-sigma statistical control limits for the average air temperature entering the room are ±0.005 °C. The maximum stratification of the air temperature is 0.05 °C.

Experiences with the M-60 emphasize the point that steady-state conditions of temperature are an absolute must in order to maintain machine geometry. This means controlling not only air temperature but also radiant heat sources such as people, lighting, and computer equipment. The machine and the artifact will transfer heat by convection with air, by conduction with whatever it touches, and by radiation with equipment, lights, and people. Standard policy in the M-60 facility is never to turn off the room lights or the computers, and to keep the operator outside the room as much as possible. Artifact temperature is monitored to observe the effects of moving the table into and out of light and equipment shadows. The machine is currently being used for calibrating 1-D length standards on the X axis. An analysis has been done to establish measurement uncertainty for end standards and step gauges: 2-sigma uncertainty=±(0.3 + 0.4L) microns, where L=length in meters.

The accuracy of measurements performed at Y-12 are certified by NIST, and are directly linked – are traceable – to national standards. To establish this traceability, NIST measurement experts helped Y-12 staff characterize the facility's CMMs, establish a formal quality system, and implement the statistical process controls that NIST laboratories use to assure measurement accuracy. As a result of these and other steps, measurements performed at Y-12 are NIST-certified.

Initially, NIST-certified services will be available for 1-D end standards and step gages up to 1350 mm, as compared with NIST's previous maximum of 750 mm. End standards and step gages up to 1.35 meters long will be calibrated to a certified accuracy of 0.7 micrometer per meter. Plans call for extending the upper limit to 1600 mm. As the Y-12 Centers' capabilities become more fully characterized, services will be expanded to 2- and 3-D measurements for calibrating large grid and ball plates.

The Oak Ridge Metrology Center (ORMC) also provides estimating and inspection services, at a fixed hourly rate, to meet private industry's metrology needs on manufactured products other than length and end standards. In partnership with the American Society of Mechanical Engineers, NIST and Y-12 also are proceeding with plans to develop a National Center for Gear Metrology to provide advanced measurement services critical to the manufacture and quality assurance of precision gears. Housed at the Y-12 facility, this Center recently received a $3-million grant from the Department of Defense Technology Reinvestment Project.

For information on services available through the **Oak Ridge Centers for Manufacturing Technology,** *contact Nicholas Zurcher at (615) 574-1258, or the Manufacturing Technology Information Service at 1-800-356-4USA. The Department of Energy's Oak Ridge facilities are managed by Martin Marietta Energy Systems, Inc.*

Signal-to-Noise Measurements Using an LO Offset-Frequency Technique

A technique for RF amplifier noise measurements removes test-system errors.

Naval Air Warfare Center, Crane Division, Crane, Indiana
Technology Service Corporation, Bloomington, Indiana

Signal-to-noise ratio (SNR) measurements of radio-frequency (RF) amplifiers have varied from test site to test site even when measuring the same amplifier. These SNR value variations occur because each test system has different distortion levels. An SNR measurement technique and analysis software have been developed to minimize the effect of test-system distortions. In contrast to earlier techniques that required manual equipment calibration to eliminate such distortion, the offset-frequency technique discussed here gives SNR values unaffected by these distortions. Both manufacturer and customer can test the amplifier with this technique and have SNR values typically agree within tenths of dBs.

Figure 1 shows the system diagram used in the offset-frequency technique.

Its novelty is that two synthesizers are used; one generates the signal to the device under test, designated as RF, while the other generates the local oscil-

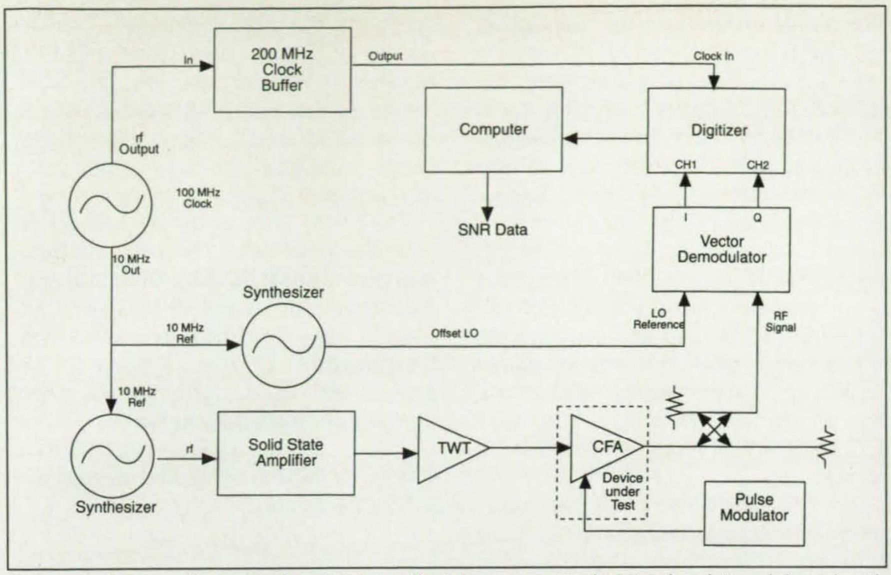


Figure 1. System diagram showing the offset-frequency technique for determining signal-to-noise ratios in RF amplifiers.

lator (LO) signal whose frequency is offset from the RF frequency by a small amount, typically 20 Hz. The LO and RF signals enter a vector demodulator (VDM) that outputs low-frequency I and Q signals. The I/Q signals are digitized and analyzed by the SNR analysis software. In a typical experiment, about 100 pulses are applied, with 100 I and Q data samples taken per pulse.

A mathematical description of the system illustrates test-system distortions. A sampled RF signal out of the device under test is given by

$$RF=(A+\Delta A)\cos(\omega t+\Delta\phi)$$

where A is signal amplitude, and ΔA and Δϕ are the amplitude and phase noises that determine SNR. The local oscillator signal is given by

$$LO=\cos(\omega t+\theta)$$

where θ originates from the offset frequency, numerically equal to the angular offset frequency multiplied by time (typically θ=2π(20 Hz)t). For an ideal VDM, the RF and LO signals are converted into I and Q signals given by

$$I=k(A+\Delta A)\cos(\theta-\Delta\phi)$$

$$Q=k(A+\Delta A)\sin(\theta-\Delta\phi)$$

where k is the loss of the VDM.

For an actual VDM, linear and nonlinear I and Q distortions may exist, as seen in Figure 2. The nonlinear distortions originate largely from the VDM mixers and may be essentially eliminated by using quality high-level mixers. The remaining linear distortions cause I and Q to be given by

$$I=k_I(A+\Delta A)\cos(\theta-\Delta\phi)+B_I$$

$$Q=k_Q(A+\Delta A)\sin(\theta+D-\Delta\phi)+B_Q$$

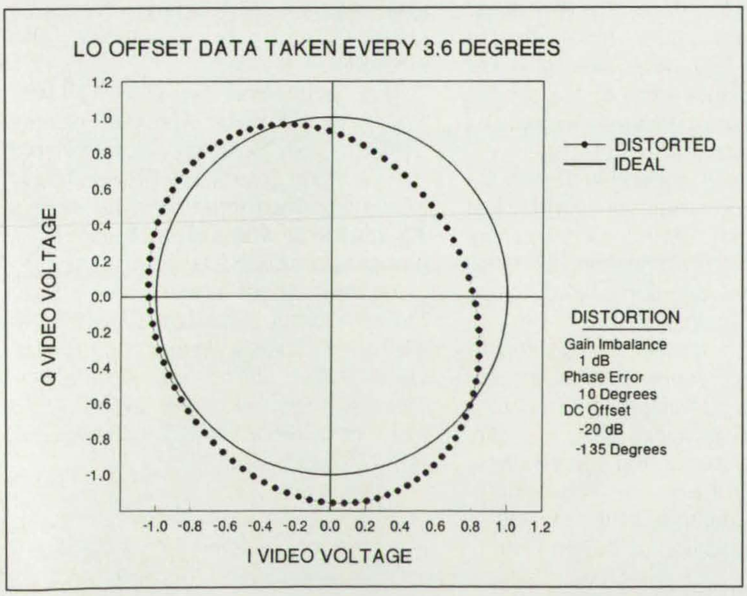


Figure 2. Plot of linear and nonlinear I and Q distortions in a vector demodulator.

where B_I and B_Q are DC offsets, k_I and k_Q represent different losses in I and Q channels, and a quadrature error D originating from the VDM hybrid coupler.

The SNR analysis software gives correct SNR value even when VDM distortions are present. The software contains both linear and nonlinear SNR analysis subroutines. The linear analysis subroutine uses statistical SNR calculation methods. The nonlinear analysis subroutine determines linear and nonlinear distortions and uses this information to correct individual data points. Because nonlinearities are eliminated at most frequencies through proper choice of VDM mixer input levels, the linear and nonlinear subroutines should give nearly identical results. The two subroutines have been found to give SNR values within 0.01 dB, neglecting nonlinearities.

Several SNR measurements of crossed-field amplifiers (CFAs) have been made and analyzed with the offset-frequency technique. Beyond the linear distortions discussed above, these measurements indicated evidence of pulse-to-pulse phase errors in the CFA RF drive signal. The phase errors appeared at frequencies of 60, 120, and 180 Hz and had magnitudes of the order of 1 percent of signal amplitude. The 1-percent distortions have a negligible effect (less than 0.01 dB) on CFA SNR values reported by the software.

The LO offset-frequency measurement technique is being implemented at several sites across the US. SNR measurements on the same CFA were made at the Naval Surface Warfare Center at Crane, and Litton Electron Devices in Williamsport, PA. The SNR values at the two sites were found to agree within ±0.25 dB at each measured frequency. Previous errors were as much as 4 dB at certain frequencies.

This work was done by Steven L. Hillenberg of the **Naval Surface Warfare Center (Crane Division)** *and Alexander McMullen and Dean M. Thelen of* **Technology Services Corporation.** *Copies of the software are available for commercial use. Contact Mr. Hillenberg at NSWC, Crane Division, Bldg. 3168, Code 8065, Crane, IN 47522; (812) 854-5271; FAX (812) 854-3676.*

Acoustic Location-Fixing Insect Detector

A novel method for the rapid quantitative and economical detection of insects and larvae in grain.

Agricultural Research Service, Dept. of Agriculture, Gainesville, Florida

The Acoustic Location-Fixing Insect Detector (ALFID) uses electronic sensors to detect and quantify insect-pest infestation in agricultural commodities. This system is effective for grading imported and exported grain, and helps prevent hidden insect populations from spreading into uninfested grain, resulting in an insect control problem.

Currently grain is checked by visually counting the number of insects in representative grain samples. The larvae of some species live inside grain kernels, however, and are not detected. X-ray and carbon dioxide release methods can detect these hidden internal infestations but are not commercially feasible.

Internal larvae produce low-level sounds that can be detected by ultrasensitive equipment. Existing acoustic techniques can only determine the presence, but not the amount, of insects in a sample. This is important, since grain is only graded as infested if the sample contains more than an allowable number of insects. ALFID offers quantitative analysis to determine if threshold levels are exceeded.

ALFID consists of a sample container for holding agricultural commodities with an array of acoustic sensors attached to the container. The sensors detect sound waves generated by insects and larvae while feeding and moving, which are then converted to electrical signals. The signals from each sensor are amplified and the data input to a personal computer. The ALFID software analyzes the data to determine the number of insects in the sample.

Though the number of insect-produced sounds in grain samples is statistically proportional to the number of insects in the sample, this information alone is not sufficient to accurately determine the number of insects. Instead, ALFID bases its determination on the number of sound locations in the grain sample.

The ALFID computer establishes sound-source locations by noting the relative arrival times of each sound at nearby acoustic sensors in the array. Subsequent sounds that display approximately the same relative arrival times at the same sensors are scored as originating from the same location or the same insect.

The grain itself generates insect-like sounds due to movement of individual kernels or grain settling. Only multiple sounds, apparently originating from the same location, are considered to be generated by an insect.

The ALFID computer is triggered to acquire data only whenever an incoming sound is detected--interrupt-driven--in order to avoid filling memory with dead space during the relatively long inter-sound intervals. At the end of the sample testing, the computer reports its evaluation of the number of insects in the grain sample.

In 296 trials using ALFID to inspect wheat infested with internal larvae, only 6 percent were incorrectly identified as having more insects present than what were actually placed in the unit. ALFID was correct in 90 percent of the trials where no insects were present.

In tests using one infested kernel in the container, ALFID was correct 70 percent of the time. And when two larvae were present the system accurately identified the number of pests in 55 percent of the cases. Current commercial inspection methods are unable to detect larvae in grain samples.

ALFID is a fast, simple, and inexpensive method of detecting insects in grains, fruits, nuts, vegetables, and legumes.

This work was done by Dennis Shuman, Richard Mankin, James Coffelt, and Kenneth Vick for the Behavior and Biophysics Research Unit of the US Department of Agriculture's **Agricultural Research Service**. *A patent application has been made.*

Inquiries about commercial use of this technology should be addressed to Ms. June Blalock, licensing specialist, USDA-ARS Office of Technology Transfer, Beltsville, MD 20705-2350 (refer to 07/963.171); (301) 504-5989; FAX (301) 504-5060.

Improved Measurement of Image Intensification Devices

High-resolution positioners with computer control make measurements simple and accurate.

Army Aeromedical Research Laboratory, Fort Rucker, Alabama

As new and improved designs for night-vision imaging systems based on image intensification technology are produced, it is advantageous to have a test and measurement system that can accurately and quickly assess the performance of various configurations of the intensifiers and associated optics.

Performance parameters of field-of-view (FOV), magnification, and distortion previously were measured manually on rotational tables, relying on human operators to set and interpret rotational angles and locations of positioners. Use of micropositioners under control of a custom-designed software package provides more accurate and repeatable alignment of the elements being tested and performs the required complex mathematical calculations. This improved test methodology can evaluate image intensification system performance in a timely and cost-effective manner.

The current Army test method for evaluation of the AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) is defined in military specification MIL-A-49425(CR), *Aviator's Night Vision Imaging System AN/AVS-6(V)1, AN/AVS-6(V)2.* The parameters and tolerances specified in this publication were used as the basis for development of the automated system.

The primary components of a system are depicted in Figure 1.

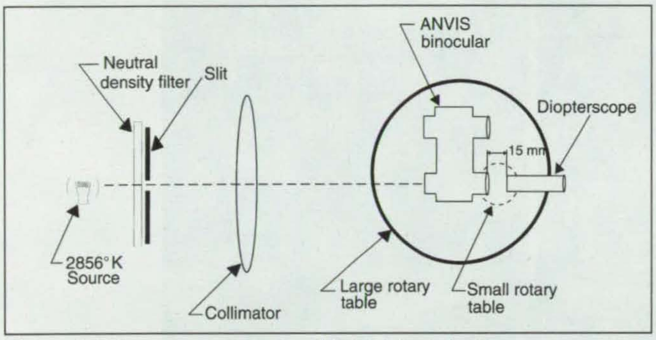


Figure 1. Primary components of the system design.

They consist of the light source, optical slit, collimator, diopterscope, and large and small rotary tables. The improved methodology described here is accomplished by automating most of the repetitive steps and procedures required for the positioning, measuring, and documenting of the FOV and magnification parameters.

The test apparatus can be divided into three functional classifications: automation control, mechanical positioning and mounting, and optical viewing. The automation components consist of a computer and an encoder controller that provide control of stepping motors. The mechanical mounting and positioning components consist of various motors, rods, rod holders, carriers, jacks, and rails mounted on specially fabricated rotary tables attached to an optical bench. Two encoder DC motors are used to position the rotary tables for the required measurement. The large rotary table holds the device under test and is used for both FOV and magnification measurements. The small table holds the diopterscope and is used for magnification measurements only. Optical viewing is accomplished using a collimated light source with a 0.025-mm-X-7-mm slit as the stationary target for measurements.

The control program for this system is written in BASIC and runs on any AT-class computer system. There are four main objectives of the control program: (1) To provide accurate control of the alignment, position, and movement of the rotary tables; (2) To perform all mathematical operations required for the calculation of FOV, magnification, and distortion values; (3) To provide hard-copy output that summarizes test results; and (4) To achieve high reliability in the measurement of FOV and magnification.

Figure 2. Prototype of the measurement system.

Seven basic elements make up the control program. These are instruction option, test item identification, setup and alignment, FOV measurement, magnification measurement, distortion calculation, and test results output. A representative prototype is depicted in Figure 2.

The hardware and software designs for this methodology were developed, fabricated, and tested by J.S. Martin, H.H. Beasley, and R.W. Verona of **UES,** *Inc. and C.E. Rash of the* **Army Aeromedical Research Laboratory**. *Inquiries concerning rights to the commercial use of this technology should be addressed to Ms. Diana Hemphill, Science Support Center, USAARL, PO Box 620577, Fort Rucker, AL 36362-0577; (334) 255-6907; FAX (334) 255-6937.*

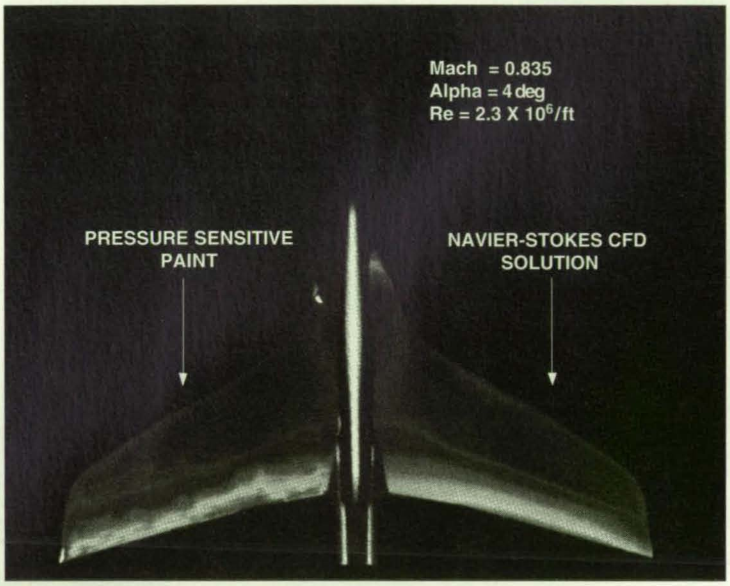
Pressure-Sensitive Paint Facilitates Wind-Tunnel Testing

An innovation permits data to be obtained earlier in the design cycle.

Engineering Development Center, Arnold Air Force Base, Arnold, Tennessee

A new technology called pressure-sensitive paint (PSP) being investigated at Arnold Engineering Development Center (AEDC) could revolutionize wind-tunnel testing and potentially save customers millions of dollars. The Center demonstrated the use of PSP during technology tests performed in its 16-ft. and 4-ft. transonic wind tunnels.

Deutsche Aerospace brought a 1/10-scale model of the Dornier Alpha Jet with data earlier in the design cycle and eliminate the design of another model and wind-tunnel test. The configuration of the model can change during the test and evaluation phase, and the use of PSP can provide pressure data on the most recent configuration. It is not feasible to build a pressure model for every configuration change. PSP can also be used to expand computational fluid-dynamics analysis.



Display of data derived from the use of pressure-sensitive paint.t

a transonic technology wing to AEDC last fall for a cooperative test effort between the German Ministry of Research and Technology, AEDC, and NASA. Wing-surface pressure distribution, force and moment data, PSP data, and flow visualization data were acquired. One wing of the model was painted with PSP, which permitted the acquisition of surface pressure over the entire wing.

The technology has significant potential to impact wind-tunnel testing and Air Force development. There are two types of wind-tunnel models. One has orifices to measure surface pressures, and the other has solid surfaces and is mounted on a balance to measure aircraft loads. Pressure models typically have several hundred pressure taps and can take approximately one year to design and fabricate. Balance models, however, are much easier to design and can be built faster and stronger.

By using balance models, customers will be able to obtain critical wind-tunnel

A wind-tunnel model is coated with PSP, and lights with special filters are used to illuminate the model. The paint glows with an intensity that varies with the amount of oxygen at the surface of the model. Black-and-white TV cameras are used to record the intensity variations resulting from different surface pressures.

AEDC's PSP technology program will be demonstrating another capacity of this technique during the Navy's F/A-18 E/F program. PSP data will be acquired on the upper and lower surfaces of the Hornet's horizontal tail. Engineers will be able to compare the loads from integrated PSP data with balance loads measured on the same horizontal tail to evaluate the integration accuracy of the PSP system.

This technology is being researched at the Air Force's **Arnold Engineering Development Center (AEDC).** *Inquiries concerning rights for the commercial use of this invention should be addressed to Capt. Jay Cossentine, 1099 Avenue C, AEDC, Arnold AFB, TN 37389-1099; (615) 454-3720.*

Gateway to Technology - Testing & Evaluation

- ***Quality Flow Meter*** **- NASA, John F. Kennedy Space Center, CA**

  Technology: The Quality Flow Meter is based on measurement of the dielectric constant variation between the phase of a 2-phase mixture. As the ratio of the two phases change, the overall capacitance changes. The meter is being used to indicate the quality of a liquid nitrogen test system and is being tested for humidity and velocity measurements using two meters connected in a series.

  Commercial Applications: Level indicators for use in modular cryogenic tanks. Humidity indicators for HVAC in commercial processes where humidity control is very important. Steam plants where maintenance of high-quality vapor is important.

  Benefits: *Higher dynamic range and quicker response* - This makes it possible to use one meter for several purposes such as humidity indication prior to phase measurement of cryogenic flows. *Velocity measurements* - Accurate measurements an be made by taking two measurements in series on a flowing, 2-phase mixture using cross correlation of the two readings.

- ***Three Dimensional Visualization of Internal Stress by Ultrasonic Techniques*** **- NIST, Gaithersburg, MD**

  Technology: The detection and avoidance of residual stress is critical. The this technology is a practical method for mapping internal stress in three dimensions. By using an acoustic microscope, an ultrasonic generator and a computer, this technology measures residual stress and their distribution as a function of depth.

  Commercial Applications: Large scale quality control systems; the detection of post-manufacturing stress in metals, ceramics, and polymers.

  Benefits: *Range of use* - This technology can be moved over a large surface and is practical for measuring large components. *Non-invasive* - Will not damage a sample that is being tested. *Cost and speed* - Faster, less expensive and safer than current measuring techniques.

- ***Surface Defect Analyzer (SURDA)*** **- NASA, John F. Kennedy Space Center, FL**

  Technology: SURDA is being developed to provide an accurate, in-the-field method of evaluating the physical dimensions of surface flaws, defects and damage on critical surfaces of the Space Shuttle and related ground support equipment. This provides an alternative to the mold impression/optical comparator of optical micrometry processes currently being used.

  Commercial Applications: Precision tooling industry, materials analysis laboratories, airlines and aircraft manufacturing industries, automobile industries, and appliance manufacturing industry.

  Benefits: *Real-time analysis* - Provides an instantaneous and accurate analysis. *Permanent record* - Once digitized, defect images can be used to produce detailed documentation for future analysis. *Portability* - Provides an easily portable system for performing accurate analysis in the field.

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For more information on these technologies or to find the research opportunities within the federal laboratory system in your area of interest call **1-800-678-6882**

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Physical Sciences

Program Helps To Determine Chemical-Reaction Mechanisms

This program implements efficient and accurate chemical-kinetics and sensitivity-analysis computations.

The General Chemical Kinetics and Sensitivity Analysis (LSENS) computer code has been developed for use in solving complex, homogeneous, gas-phase, chemical-kinetics problems. The motivation for the development of this program is the continuing interest in developing detailed mechanisms of such complex chemical reactions as those of the combustion of fuels and the formation and destruction of pollutants.

A reaction mechanism is the set of all elementary chemical reactions that are necessary to describe a process of interest. Mathematical descriptions of chemical-kinetics problems constitute sets of coupled, nonlinear, first-order ordinary differential equations (ODEs). The number of ODEs can be very large because of the numerous chemical species involved in the reaction mechanism. Further complicating the situation are the many simultaneous reactions needed to describe the chemical kinetics of practical fuels. For example, the mechanism that describes the oxidation of the simplest hydrocarbon fuel, methane, involves over 25 species participating in nearly 100 elementary reaction steps.

The validation of a chemical-reaction mechanism involves repetitive solutions of the governing ODEs for a variety of reaction conditions. Analytical solutions to the systems of ODEs describing chemistry are not possible, except for the simplest cases, which are of little or no practical value. Consequently, there is a need for fast and reliable numerical solution techniques for chemical-kinetics problems.

In addition to solving the ODEs that describe chemical kinetics, it is often necessary to know the effects exerted on the solution by variations in either (1) the initial conditions or (2) the rate-coefficient parameters. Such a need arises in the development of reaction mechanisms from experimental data. Rate coefficients are often not known with great precision, and in general, the experimental data are not sufficiently detailed to enable the accurate estimation of rate-coefficient parameters. The development of a reaction mechanism is facilitated by a systematic sensitivity analysis, which provides the relationships between the predictions of a kinetics model and the input parameters of the problem.

LSENS provides for efficient and accurate chemical-kinetics computations and provides for sensitivity analysis for a variety of problems, including problems that involve nonisothermal conditions. LSENS replaces the previous NASA general-chemical-kinetics codes GCKP and GCKP84. LSENS is designed for flexibility, convenience and computational efficiency. A variety of chemical-reaction models can be considered. LSENS incorporates mathematical models for a static system, steady one-dimensional inviscid flow, reaction behind an incident shock wave (with boundary-layer correction), and a perfectly stirred reactor. In addition, computations of equilibrium properties can be performed for the following assigned states: enthalpy and pressure, temperature and pressure, internal energy and volume, and temperature and volume. For static problems, LSENS computes sensitivity coefficients with respect to the initial values of the dependent variables and/or the three rate-coefficient parameters of each chemical reaction.

To integrate the ODEs that describe chemical-kinetics problems, LSENS uses the packaged code Livermore Solver for Ordinary Differential Equations (LSODE), because it has been shown to be the most efficient and accurate code for solving such problems. The sensitivity-analysis computations are done according to decoupled direct method, as implemented by Dunker for isothermal problems and extended by Radhakrishnan to non-isothermal kinetics. In comparison with other methods of sensitivity analysis, this method has shown greater efficiency and stability with equal or better accuracy.

LSENS is written in FORTRAN 77 with the exception of NAMELIST extensions used for input. While this makes the code fairly machine-independent, execution times on IBM PC-compatible computers would be unacceptable to most users. LSENS has been successfully implemented on a Sun4 computer running SunOS and on a DEC VAX computer running VMS. With minor modifications described in the user's guide, it could also be easily implemented on other computers and operating systems with FORTRAN compilers that support NAMELIST input. LSENS required 4MB of random-access memory (RAM) under SunOS 4.1.1 and 3.4MB of RAM under VMS 5.5.1. The standard medium for distribution of LSENS is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge (QIC-24) in UNIX tar format. It is also available on a 1,600-bit/in. (63-bit/mm), 9-track magnetic tape or a TK50 tape cartridge in DEC VAX BACKUP format. Alternate distribution media and formats are available upon request. LSENS was developed in 1992.

This program was written by D. A. Bittker and K. Radhakrishnan of **Lewis Research Center.** *For further information, **write in 66** on the TSP Request Card. Refer to LEW-15758.*

Burt Rutan Makes Vellum Fly

Two years after the Voyager completed its record-shattering around-the-world flight, you could still find its designer, Burt Rutan, working at a drafting table with pencil and paper.

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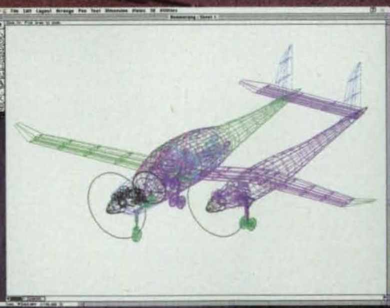

Burt's creativity and willingness to explore uncharted territory is exemplified by this sneak peek at one of his latest designs produced (of course) in Vellum.

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Physical Sciences

Program for Tracking the Sun From the Moon

The direction to the Sun is computed for a given position on the Moon.

The SUNTRACKER program computes the azimuth and elevation angles of the Sun, as viewed from a given position on the Moon, during a time defined by the user. The program gets the selenographic (moon-centered) position of the Sun at a given Julian date, then converts the selenographic position of the Sun into azimuth and elevation at the given position on the Moon.

The selenographic coordinate system is based on the equatorial plane of the Moon. The origin of this system is referenced to the mean center of the apparent lunar disk; this center is the point of the surface of the Moon intersected by the lunar radius directed towards the center of the Earth when the Moon is at its mean ascending node. Selenographic longitudes are measured positive in the direction towards Mare Crisium from the lunar meridian that passes through the origin. Selenographic latitudes are measured positive towards the northern hemisphere containing Mare Serenitatis, from the lunar equator. The selenographic colongitude is obtained by subtracting the selenographic longitude from either 90° or 450°.

SUNTRACKER performs two main operations. The first operation comprises the Julian- and calendar-date calculations. The second operation is calculation of the right ascension and declination of the Sun and Moon, on the equatorial coordinate system of the Earth, as functions of the adjusted Julian date. These coordinates are then transferred into the ecliptic coordinate system, from whence the position of the Moon is transformed into the heliocentric ecliptic coordinate system. The selenographic position of the Sun is determined in the heliocentric ecliptic coordinate system. Algorithms then compute both the physical and optical librations of motion of the Moon.

The limitations, restrictions, and assumptions applicable to SUNTRACKER are the following:

The orbital elements used in this program do not account for nutation, aberration, and precession.

The selenographic coordinates computed by this program are based on the 1961 Astronomical Ephemeris algorithms. In 1981, a new analytic theory of the librations of the Moon was adopted by The Astronomical Almanac. This theory improved the method of calculating selenographic coordinates. The selenographic coordinates computed by SUNTRACKER are identical to the pre-1981 Astronomical Almanac values. In a comparison of values computed by the program with values from the 1993 Astronomical Almanac, the maximum deviations in longitude and latitude were found to be 0.030° and 0.034°, respectively. The average deviations were 0.013° in selenographic colongitude and 0.017° in selenographic latitude.

SUNTRACKER is written in FORTRAN 77 for IBM PC-compatible computers running MS-DOS. The sample executable code included on the distribution medium requires 64K of random-access memory and the Lahey FORTRAN 77 run-time library for execution.

The standard medium for distribution of this program is a 5.25-in. (13.335-cm), 360K MS-DOS-format diskette.

This program was written by Warren K. Woods and Dustin S. Spires of **Marshall Space Flight Center**. *For further information,* ***write in 150*** *on the TSP Request Card.*
MFS-28939

Manufacturing / Fabrication

Easing the Calculation of Bolt-Circle Coordinates

This program can assist in many practical situations that arise in machine shops.

The Bolt Circle Calculation (BOLTCALC) computer program can be used to reduce the significant time consumed in manually computing the trigonometry of rectangular Cartesian coordinates of holes in a bolt circle as shown on a blueprint or drawing. Bolt circles are shown on many drawings — for example, drawings of flanges for tubes, sealing flanges, and subassemblies. BOLTCALC can eliminate the risk of computational errors, particularly in cases that involve many holes or in cases in which coordinates are expressed to many significant digits.

BOLTCALC can assist in many practical situations. For example, most small machine shops cannot afford numerically controlled machines or accurate rotary indexing tables for automatically positioning holes in bolt circles; therefore, machinists in such shops must rely on hand calculations and machine-table movements along Cartesian axes to position or index workpieces under drills in the spindles of conventional machines. Layout personnel who lack automatic equipment must perform hand calculations in order to scribe bolt-hole locations onto workpieces as, for example, when laying out locations of holes for a drill-press operation. Inspectors who lack automatic equipment must perform hand calculations in checking the locations of holes. BOLTCALC can eliminate much of the difficulty involved in all of these situations.

This program is written in BASIC for IBM PC-series and compatible computers running MS-DOS. A sample executable code, which was created by use of Microsoft's QuickBasic v4.5, is included. The program has also been successfully compiled and implemented by use of Microsoft's QuickBasic v4.0. It requires 64K of random-access memory for execution. The standard medium for distribution of this program is a 5.25-in. (13.335-cm), 360K, MS-DOS-format diskette. Documentation is included in the price of the program. BOLTCALC was developed in 1993.

This program was written by Richard K. Burley of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 16*** *on the TSP Request Card.*
MFS-30006

Improved Automatically Locking/Unlocking Orthotic Knee Joint

This joint would offer increased safety and convenience.

Marshall Space Flight Center, Alabama

Figure 1 illustrates a proposed orthotic knee joint that is an improved version of the one described in "Automatically Locking/Unlocking Orthotic Knee Joint" (MFS-28633), *NASA Tech Briefs*, Vol. 18, No. 5 (May, 1994), page 74. Both of these devices would offer increased safety and convenience relative to conventional orthotic knee joints.

Unlike a conventional orthotic knee joint, which locks only at full extension, either of these joints would lock whenever the wearer applied weight to the knee at any joint angle between full extension and a 45° bend. Thus, whereas the wearer of a conventional orthotic knee joint could fall because of lack of support during an inadvertent attempt to apply weight while the knee was bent, the wearer of either of these proposed joints would be supported by locking of the joint at any bending angle up to 45°. Either of these joints would unlock itself automatically when the load was removed, whereas a conventional orthotic knee joint must be unlocked manually. Also, both of these joints would feature hard stops to prevent overextension (that is, back bending).

The improved automatically locking/unlocking orthotic knee joint would offer an additional feature of safety and convenience: Automatic unlocking would not take place until both (1) the torque load (if any) tending to cause rotation of the joint and (2) the radial load that caused the joint to lock in the first place were both relieved. Thus, even if the wearer momentarily pulled weight back from the knee but was still depending on support by resistance of the knee to bending, the joint would provide that resistance.

Like both conventional orthotic knee joints and the joint described in the cited prior article, the improved automatically locking/unlocking orthotic knee joint would be a tang-and-clevis joint incorporating a locking/unlocking mechanism. In the improved joint, locking would be effected by meshing of gear teeth on the clevis with gear teeth on the tang, which would be designed to slide radially a short distance. The small range of radial sliding would be just enough to enable the gear teeth to be brought into and out of mesh. A small spring would bias the

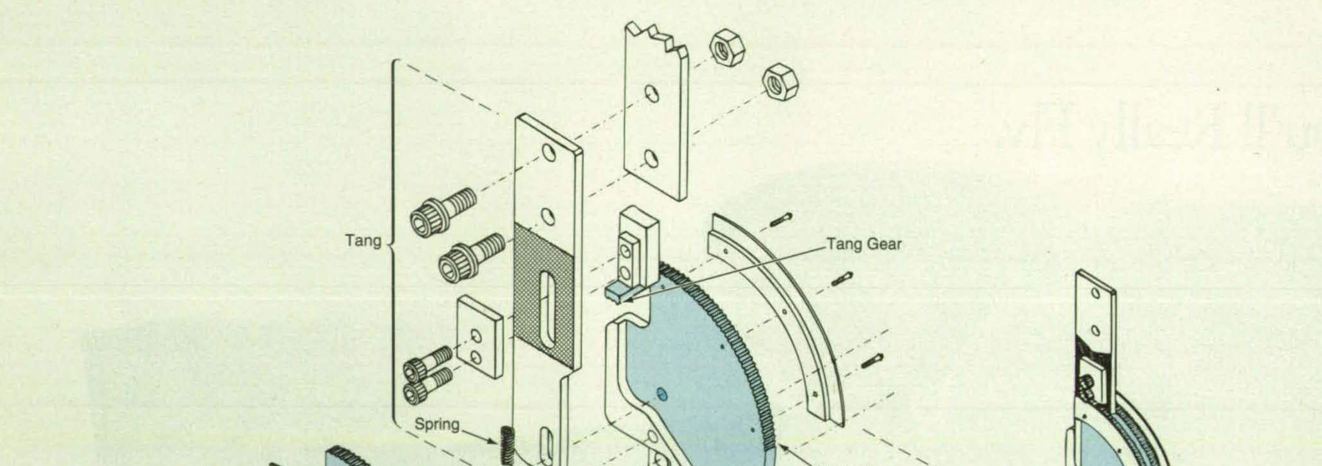
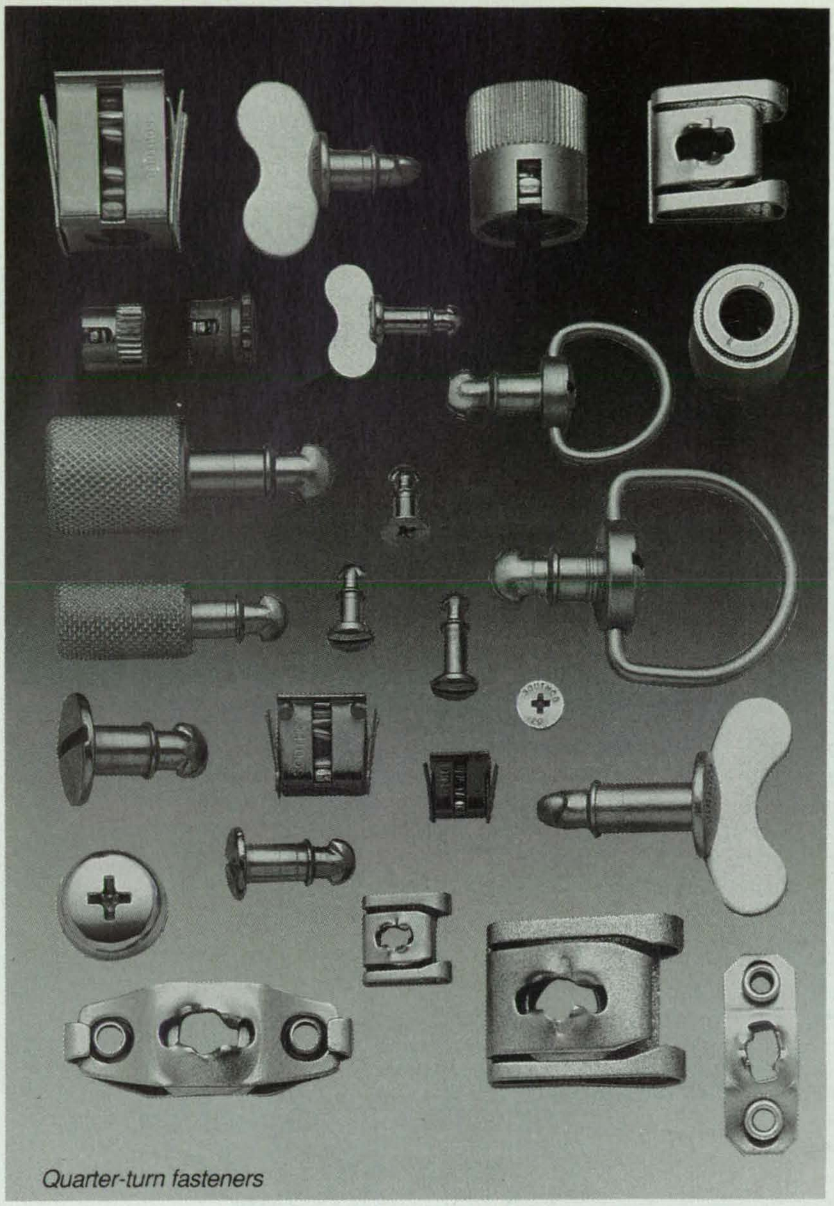
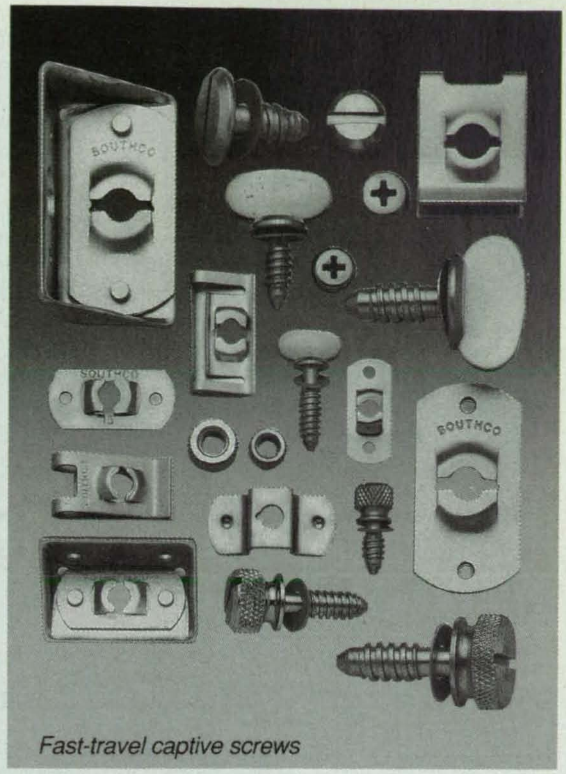


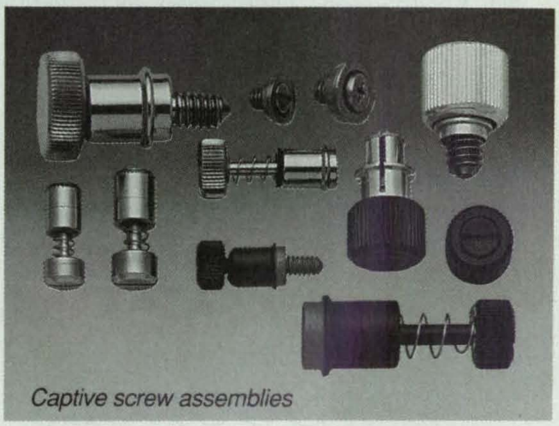
Figure 1. The **Improved Orthotic Knee Joint** would lock automatically upon initial application of radial force (the wearer's weight) and unlock automatically, but only when all loads (radial force and bending) were relieved.



Quarter-turn fasteners



Fast-travel captive screws



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tang radially outward within this range. A compressive radial load (ordinarily, the wearer's weight) would counteract the spring, pushing the gears into mesh.

The additional locking feature of the improved joint would be designed into the gear teeth. Instead of a conventional gear-tooth profile, these teeth would feature a special profile with a 7° back slope (see Figure 2). Once the gears were in mesh, the effect of the back slope would be to drive the gears more tightly into mesh whenever torque was applied in an attempt to bend the joint to a more acute angle. Thus, even when the radial locking load was removed, the gear teeth would remain meshed, locking the joint against loss of support. Only when all loads were relieved would the relatively gentle spring force be sufficient to push the gears out of mesh.

This work was done by Bruce Weddendorf of **Marshall Space Flight Center.** *For further information,* ***write in 52*** *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 20].
MFS-28997

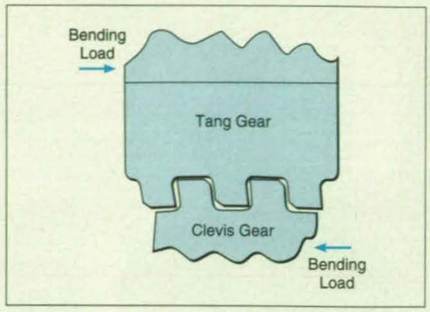


Figure 2. **The Back Slope on the Meshing Gears** would give rise to a mesh-tightening force when torque was applied to bend the knee.

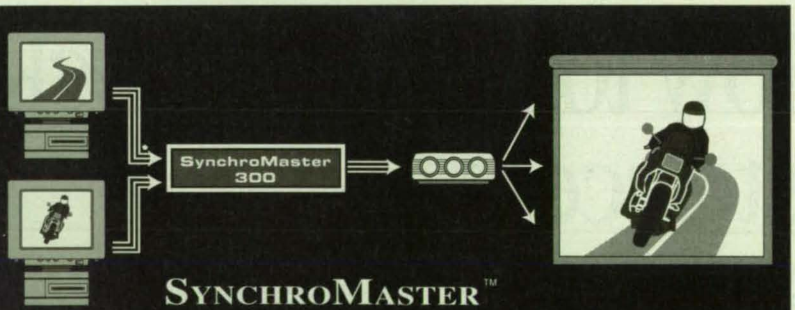
Tool Measures Diameters of Posts With Limited Lateral Access

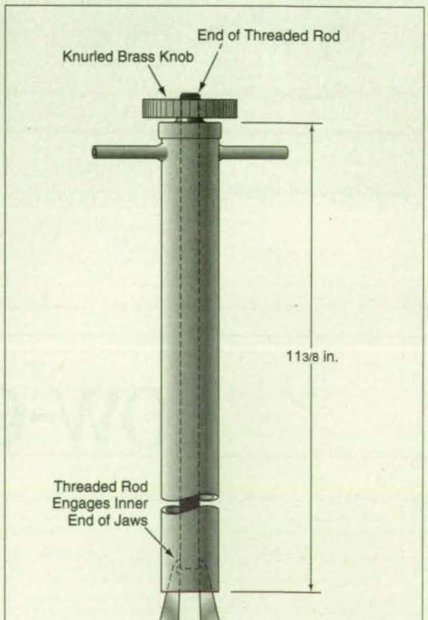
Notwithstanding limited accessibility, diameter can be measured with acceptable accuracy.

Marshall Space Flight Center, Alabama

A simple tool is used in conjunction with a conventional vernier caliper to measure the outside diameter of a round post or tube to which lateral access is limited. In the original application, the posts are liquid-oxygen-injector posts surrounded by a forest of many such posts on a rocket engine. The tool can also be used in other applications in which it is desired to measure diameters despite limited lateral access, provided that there is longitudinal access.

The tool (see figure) is made long and thin to fit within the narrow longitudinal access corridor. It includes chuck-like jaws, which are closed or opened by turning a knurled knob: the jaws can be closed snugly but gently onto the end of the post to be measured, providing a micrometer-like "slip feel" sensitivity. Once thus adjusted, the tool is withdrawn from the post and the distance between the insides of the





Chuck-Like Jaws are closed gently onto the end of the post or tube. The tool is then slipped off without changing the jaw setting, and the distance between the jaws is measured with a vernier caliper.

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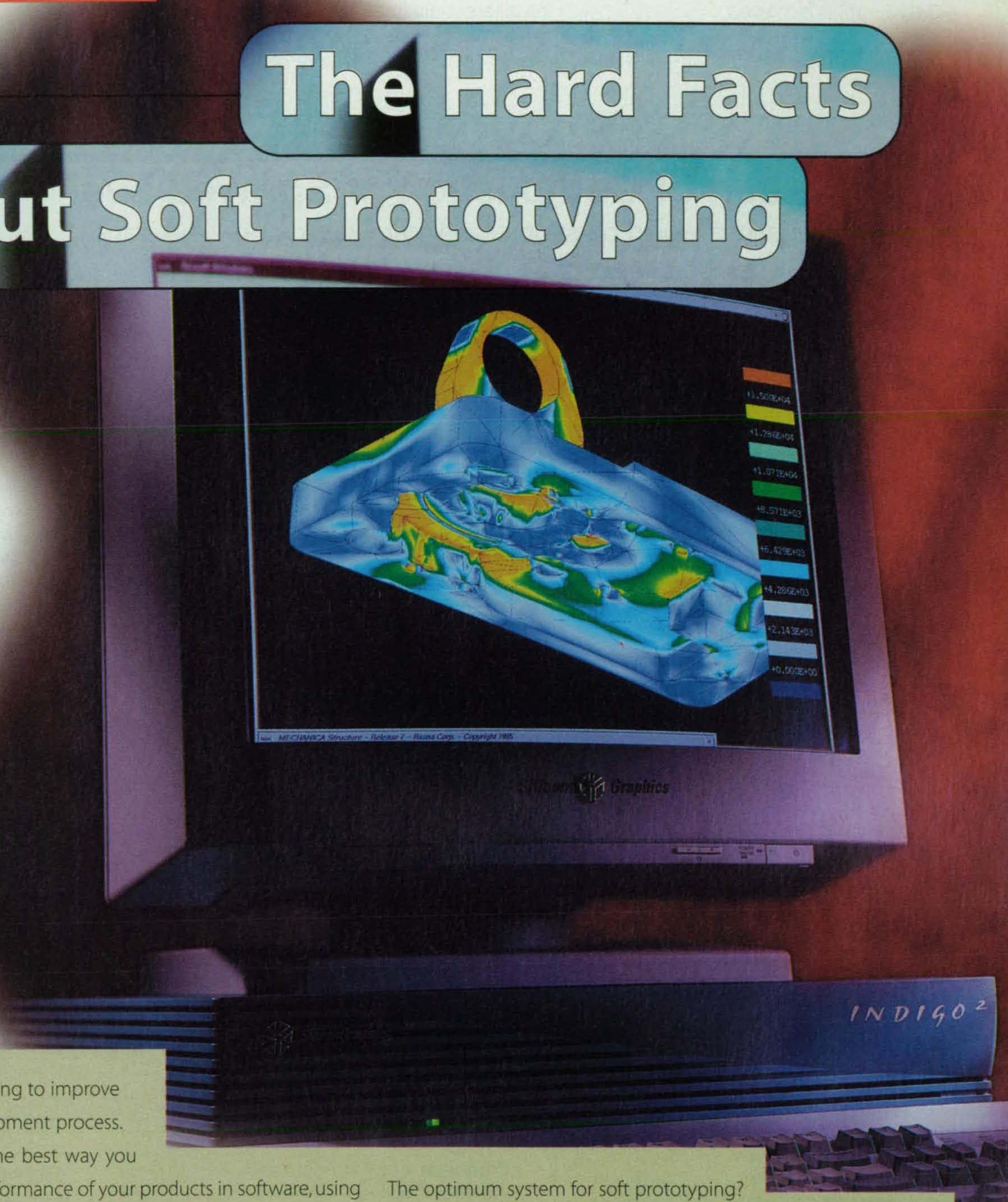

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jaws is measured by use of the caliper to obtain the outside diameter of the post. An accuracy of ±0.0005 in. (≈0.013 mm) is achieved.

The original version of the tool is designed to measure diameters within ±0.001 in.(≈ ±0.026 mm) of a nominal diameter of 0.500 in. (≈12.7 mm). Modified versions can be easily made for different diameters.

This work was done by Gene E. Morgan and Gary L. Snyder of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 98*** *on the TSP Request Card.*
MFS-29963

Stabilization of Combustion of Sprayed Fuel

Pressure oscillations would be suppressed by reshaping nozzle surfaces.

NASA's Jet Propulsion Laboratory, Pasadena, California

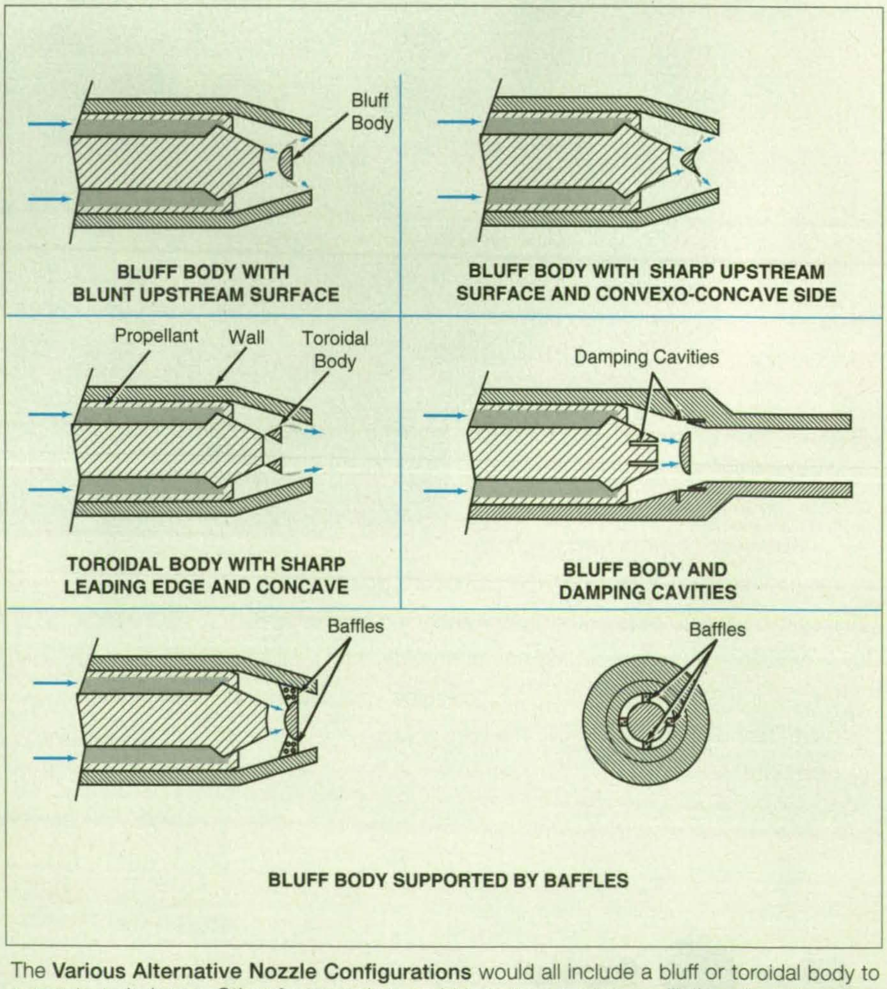
Several modifications of a nozzle that sprays a liquid propellant into a combustion chamber have been proposed to stabilize combustion. In the original application, the combination of the nozzle and the combustion chamber is called a "liquid propellant regenerative gun," and it is used to accelerate a projectile. The combustion process in the liquid-propellant regenerative gun exhibits instability in the form of pressure oscillations, which can make the projectile perform erratically or unsafely and can result in damage to the gun. The proposed changes in the design of the nozzle would alter the flow field in the combustion chamber, according to fluid-mechanical principles, in such a way as to suppress the oscillations. Similar modifications might help to suppress oscillations in industrial combustion chambers and in commercial and domestic oil-burning furnaces.

An important element of the proposed modifications is the introduction of a bluff simple or toroidal body into the flow of fuel (see figure). The bluff body could have any of a variety of alternative shapes, the exact shape being chosen to stabilize the combustion process by performing two important functions: creating turbulence to break up the flowing fuel into small drops and creating a stable downstream combustion flow.

With regard to designing a particular nozzle according to the dynamics of flow, the requirement to generate turbulence and to establish a combustion flow field that will be stable downstream could dictate that the upstream surface of the bluff body or toroidal body be sharp or blunt, and that various upstream and side portions of the surfaces near and/or in contact with the flow be cylindrical, conical, convex, concave, smooth, or rough. The downstream surfaces could also be shaped and textured as continuations of the upstream surfaces or shaped to create downstream recirculation zones to suppress oscillations. In addition, any of the surfaces could be made catalytic to assist in decomposition of the fuel.

Of course, a bluff or toroidal body could not remain suspended as shown in the simplistic views in the upper part of the figure; some structural members would have to be added. The structural members could be shaped as baffles, which could be oriented to block radial and/or circumferential flow(s). Additional baffles that do not support bluff or toroidal bodies could also be used. Small openings in the baffles would allow small radial and/or axial flow(s), under the strong influence of viscosity, thereby providing viscous damping of pressure oscillations. For a similar purpose, cavities could be added on downstream surface(s): Oscillating flows of gas into and out of the cavities would encounter viscous damping, which would help to suppress the oscillations.

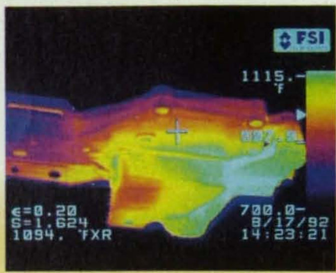
This work was done by Gerald E. Voecks and Darrell L. Jan of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 15*** *on the TSP Request Card.*
NPO-18977



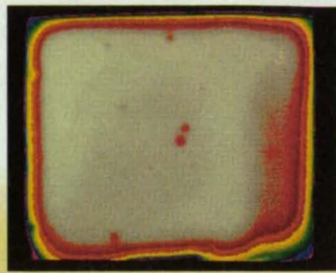
The **Various Alternative Nozzle Configurations** would all include a bluff or toroidal body to generate turbulence. Other features that could help to suppress oscillations include downstream recirculation zones, baffles, and damping cavities.

Engine development

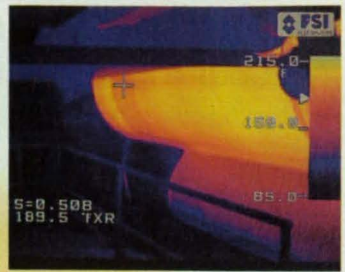
Measure casting temperatures



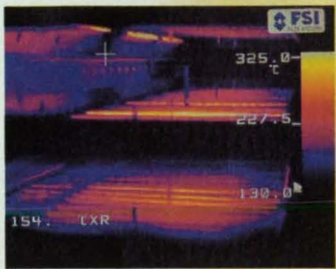
Defects in composite materials



Moisture content in paper



Monitor soldering processes



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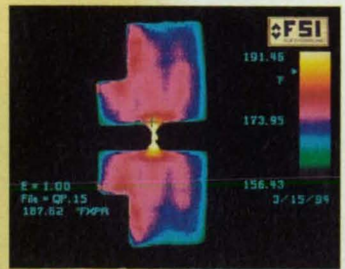
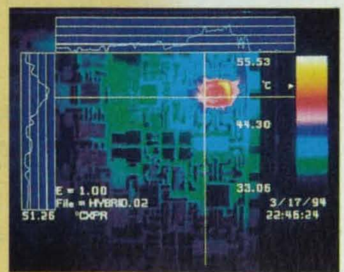
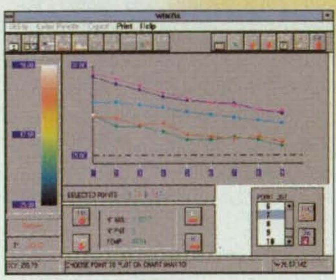


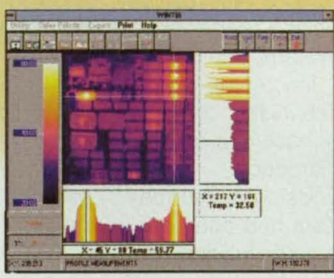
Evaluate wax injection presses



Hybrid circuit failure analysis



Analyze trend data



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Prosthetic Tool for Holding Small Ferromagnetic Parts

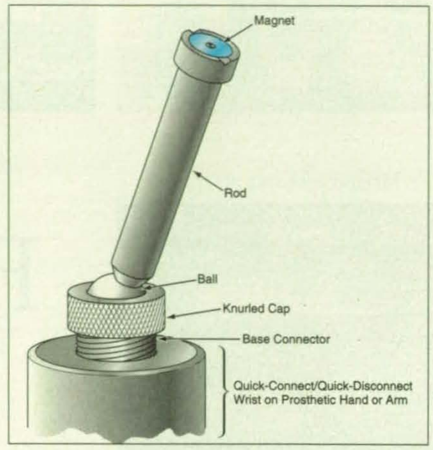
This tool can be adjusted to hold nails, screws, nuts, and the like at desired angles.

Marshall Space Flight Center, Alabama

The figure illustrates a tool that can be attached to a prosthetic hand or arm to enable the user to hold nails, screws, nuts, rivets, and other small ferromagnetic objects on a small magnetic tip. The device can be adjusted—for example, to hold a nail or screw at the proper angle for hammering or for use of a screwdriver, respectively.

The tool includes a base connector with a threaded outer surface and a lower male member that can be inserted in a standard spring-action, quick-connect/quick-disconnect wrist adapter on the prosthetic hand or arm. The magnet that holds the part to be positioned is mounted on one end of a rod in a V-notched adapter. The other end of the rod is formed into a ball, which fits into a socket in the base connector to form a ball-and-socket joint that can be used to adjust the angle of the rod. A compression spring (not visible in the figure) is placed in the socket along with the ball. A knurled cap with a hole for the rod is screwed down over the ball; the cap can be tightened or loosened to increase or decrease the spring load and friction in the ball joint as needed.

This work was done by William E. Norton, James R. Carden, and Jewell G. Belcher, Jr., of **Marshall Space Flight Center** *and Thomas W. Vest of Management Services, Inc. For further information,* ***write in 96*** *on the TSP Request Card.*
MFS-28896



This **Simple Adjustable Tool** is attached to a prosthetic hand or arm and used to hold small ferromagnetic objects like nails.

Stress-Simulating Witness Panels

Stresses should be similar to those in full-scale manufactured parts.

Marshall Space Flight Center, Alabama

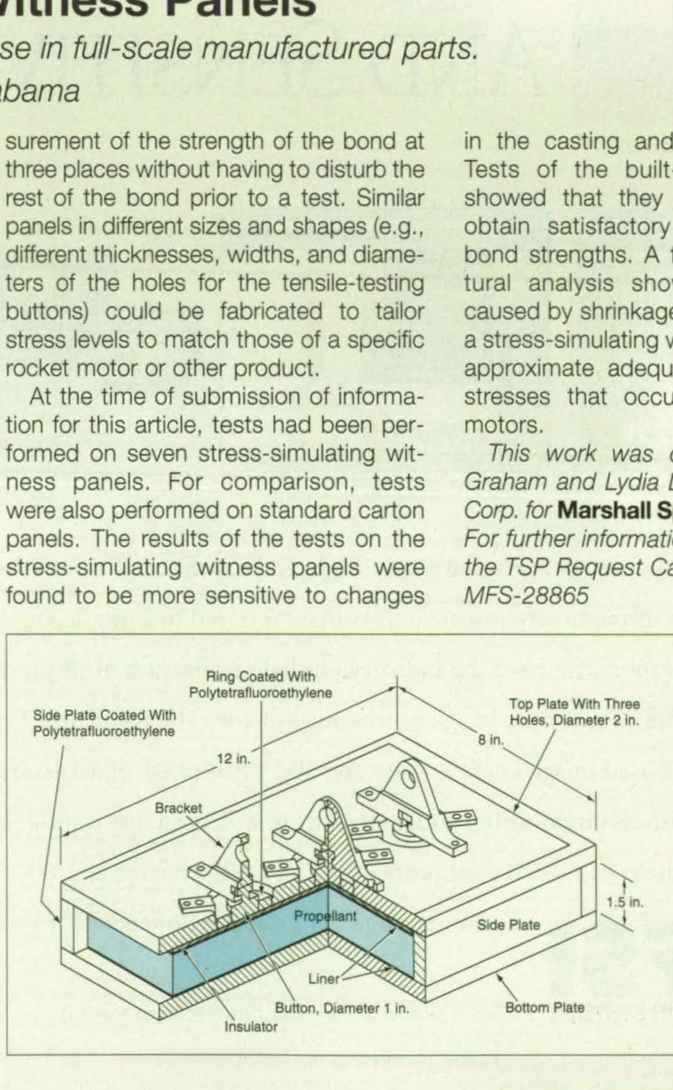
Special panel fixtures are being developed for verifying the integrity of bonds between the propellants and insulators in solid-fuel rocket motors by applying, to specimens of propellant and insulator material, stresses similar to those caused by shrinkage during fabrication of the motors. Thus, the assemblies of fixtures and specimens are called "stress-simulating witness panels." The concept may also be applicable to stress testing of bonds in other manufactured products subject to shrinkage or to swelling.

Each fixture includes two parallel steel plates: an upper and a lower plate (see figure). In preparation for use of the fixture, the insulator is bonded to the top plate. The top and bottom plates, together with side plates, constitute a boxlike mold. A specimen of propellant material is cast in the mold. Then the mold is heated to cure the propellant material under the same conditions as in casting and curing the propellant in a rocket-motor case. Stresses accumulate while the propellant is being cured. Additional stresses accumulate as the propellant shrinks more than the mold does during the postcure cooldown to ambient temperature.

Three tensile-test buttons are built into the top plate to provide for direct measurement of the strength of the bond at three places without having to disturb the rest of the bond prior to a test. Similar panels in different sizes and shapes (e.g., different thicknesses, widths, and diameters of the holes for the tensile-testing buttons) could be fabricated to tailor stress levels to match those of a specific rocket motor or other product.

At the time of submission of information for this article, tests had been performed on seven stress-simulating witness panels. For comparison, tests were also performed on standard carton panels. The results of the tests on the stress-simulating witness panels were found to be more sensitive to changes in the casting and curing processes. Tests of the built-in tensile buttons showed that they could be used to obtain satisfactory measurements of bond strengths. A finite-element structural analysis showed that stresses caused by shrinkage of the propellant in a stress-simulating witness panel should approximate adequately the shrinkage stresses that occur in typical rocket motors.

This work was done by Robert P. Graham and Lydia L. Biegert of Thiokol Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 111*** *on the TSP Request Card.*
MFS-28865



The **Stress-Simulating Witness Panel** is basically a combination of a specimen of material plus part of a mold in which the specimen was cast and cured.

Automated Facility for Cleaning Large Flex Hoses

Technicians would no longer be exposed to hazardous cleaning materials.

Marshall Space Flight Center, Alabama

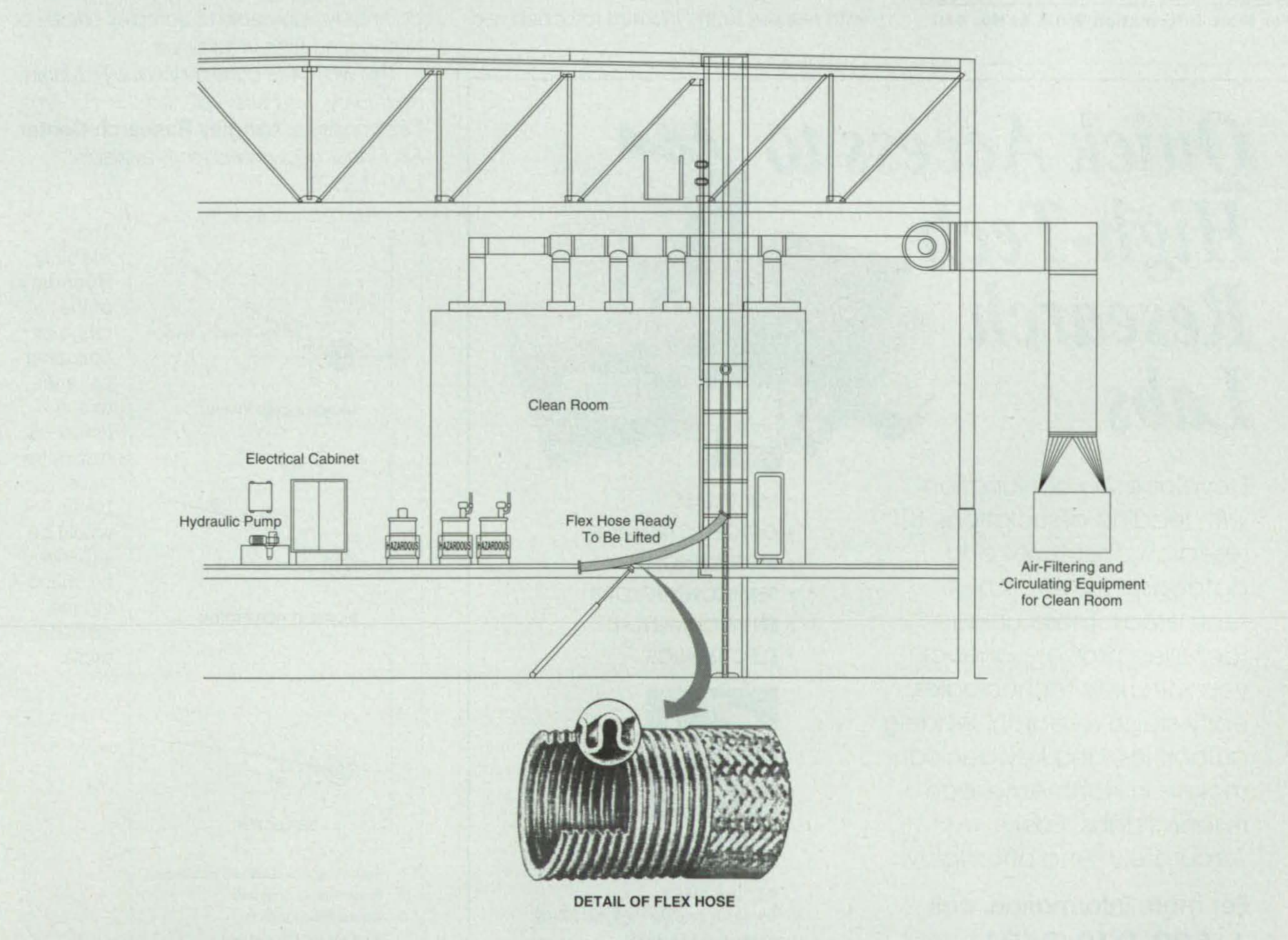
A proposed computer-controlled facility would clean bellows-type expansion joints and large flex hoses (that is, hoses with bellowslike convolutions). Heretofore, these objects have been cleaned manually in time-consuming operations that expose technicians to hazardous acids and other cleaning materials.

Major portions of the automated cleaning facility would be contained in a clean room. One of the pieces of equipment in the clean room would be a tower in which a hose or expansion joint to be cleaned would be hoisted by hydraulic machinery and hung vertically (see figure). Once the hose or expansion joint was hung in the required position, a technician would initiate a programmed cleaning procedure from a console on a computer monitoring system. The procedure could include degreasing, cleaning with detergents, rinsing, pickling, and passivating operations. (Passivation is a chemical means of increasing the corrosion resistances of metals, and of halting reactions to cleaning solutions.)

The technician would not be exposed to chemicals because all cleaning operations would be performed in the tower. During cleaning operations, a spray nozzle with radially outward jets that cover a full circle would move inside the hose or expansion joint. The jets would traverse the full length of the object to be cleaned. The programmed procedure would select the solutions to be used and the number of passes to be made with each solution.

Each sprayed cleaning material (even rinse water) would be collected from the bottom end of the hose and returned to a storage tank for reuse. A chlorofluorocarbon-solvent system could be used to inspect for nonvolatile residues. After cleaning had been completed, the technician would remove the hose or expansion joint from the tower and wrap the open ends to prevent recontamination of the interior.

This work was done by Louis E. Landry of Sverdrup Technology, Inc., for **Marshall Space Flight Center.** *For further information,* ***write in 97*** *on the TSP Request Card.* *MFS-28929*



The **Automated Cleaning Facility** could handle hoses with lengths from 3 to 25 ft (0.9 to 7.6 m) and diameters from 3 to 12 in. (76 to 305 mm).

Tailored Precone Rotor

Hub precone values would be passively tailored to increase stability and reduce blade loads.

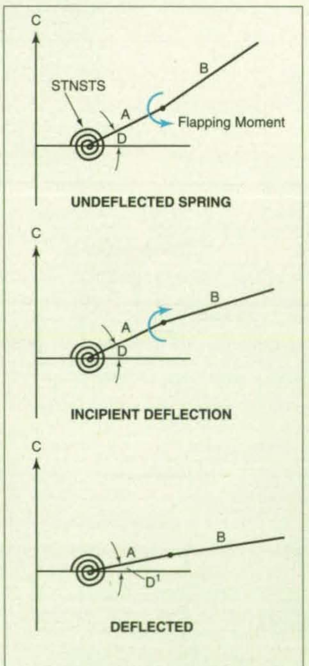
Langley Research Center, Hampton, Virginia

The concept of the tailored precone rotor (TPR) provides for changes in precone deflection in a helicopter rotor blade when such changes are needed for enhancement of stability and loads. Heretofore, hingeless rotor designs that incorporate precone deflection have called for fixed values — usually at the inboard location of the flapping flexure. Such a design can result in flap-lag instability through positive pitch-lag coupling. Inasmuch as the precone angle in such a design is fixed, limitations in range of operating parameters of the rotor in flight may occur.

The TPR concept involves the use of the device described in "Structurally-Tailorable, Nonlinear Snap-Through Spring," *NASA Tech Briefs*, Vol. 13, No. 6 (June, 1989), page 77. The structurally-tailorable, nonlinear snap-through spring (STNSTS) would be used to effect a change in precone deflection when such a change is advantageous to the stability of the rotor system. As shown in the figure, when the blade pitch axis is displaced with respect to the inboard rotor hub section, this hub section is subjected to a flap moment. When this flap moment exceeded a prescribed level, the precone angle of the feathering axis would change abruptly because of the action of the STNSTS. When the blade axis once again went above the feathering axis of the inboard hub by a prescribed amount, the precone angle of the feathering axis would return to its original value.

The ability to tailor hub precone values to critical environments during many rotor operations is of great advantage to a designer. The ability to preselect a built-in hub coning angle in a passive manner is compatible with TPR design in that the inboard station of a rotor system would become aligned with the blade, depending on the position of the blade. A typical older precone design was fixed and addressed relief of either a high- or a low-blade phenomenon relief, i.e., loads or stability. The TPR concept would satisfy requirements in both rotor states in a tailored, passive manner. The TPR concept may also be potentially applicable to complex blades of high-speed fans or turbines.

This work was done by Wayne R. Mantay and Gary L. Farley of the U. S. Army Directorates at **Langley Research Center.** *No further documentation is available.* *LAR-13878*



The **Stability Boundary** of the range of operating parameters of a hingeless helicopter rotor blade would be expanded by changing the precone angle.

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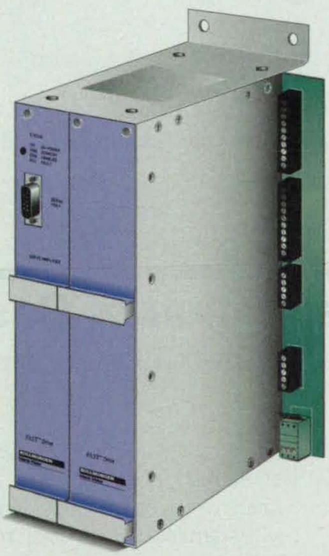

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Manifold for Flushing Tubes With Cleaning Solution

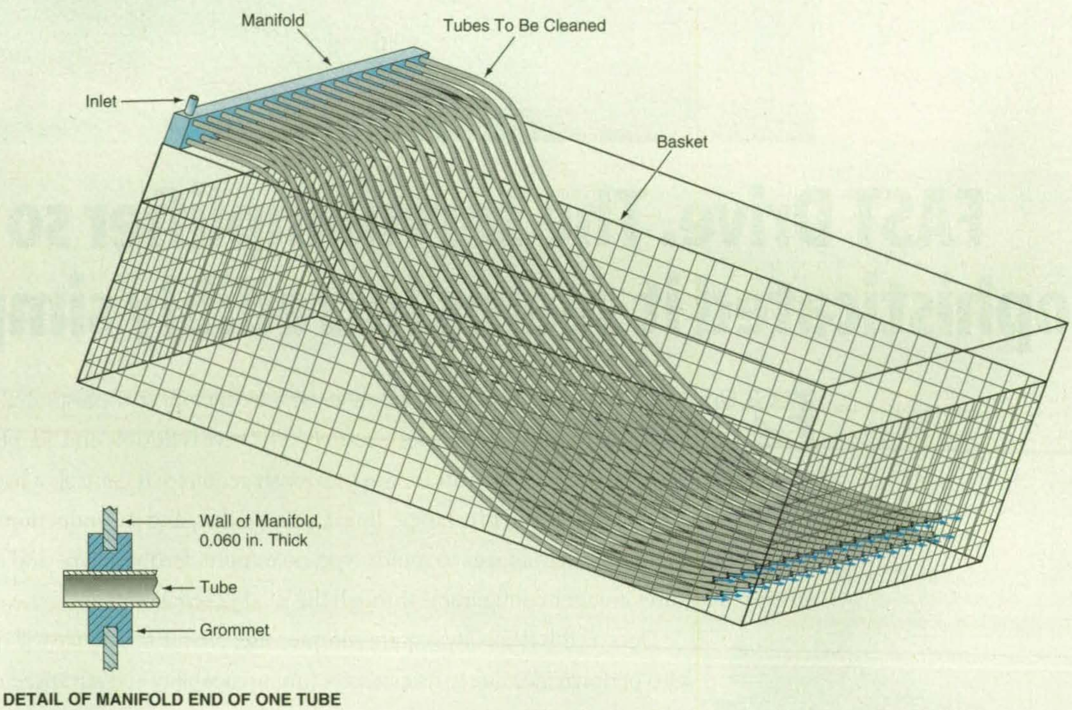
Many tubes can be cleaned simultaneously.

Marshall Space Flight Center, Alabama

A custom-built manifold mounted on a cleaning basket enables the simultaneous flushing of 80 tubes with a cleaning solution (see figure). In the original application, the tubes are components of a rocket-engine nozzle that is under construction. However, the basic manifold configuration could be adapted to other applications (e.g., fabrication of heat exchangers) in which there is need for the simultaneous cleaning of many tubes of identical size and shape.

A pump supplies pressurized cleaning solution to the manifold, which distributes the solution to the tubes. The manifold is made of stainless steel. The holes in the manifold that receive the ends of the tubes are lined with rubber grommets. Thus, it is not necessary to equip the tubes with end fittings: the tubes are simply inserted into the grommets, which act as seals.

This work was done by Gene E. Morgan and Irving Fogel of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 114*** *on the TSP Request Card.*
MFS-29964



The **Basket Supports the Tubes** that have been inserted into grommet-lined holes in the manifold. The tubes are then flushed with cleaning solution supplied via the manifold.

Computed Tomography for Internal Inspection of Castings

Internal defects that would eventually cause rejection are detected before further processing.

Marshall Space Flight Center, Alabama

Computed tomography is being used to detect internal flaws in metal castings before machining and otherwise processing them into finished parts. For example, computed tomography can reveal internal porosity and casting shrink, which cannot normally be detected by conventional radiographic inspection.

In one application, computed tomography is being used to reveal and provide information to assess shrink in a high-pressure volute casting used on a space shuttle engine turbopump. The acceptance or rejection of this casting is usually determined after final machining — during the volute leak test. The pre-machining computed tomography of this

casting is being used to remove questionable castings from the system, saving machining cost and schedule delays.

In a related application, computed tomography was used to inspect a new casting when the first article inspection data became questionable. The resulting computed tomography data was assessed by the casting foundry with corrections made in the processing to eliminate the problem, which was found to be a ceramic core shift within the investment mold when the molten metal was poured.

In these and other applications, computed tomography saves the time and money that would otherwise be wasted on machining and other processing of castings that must eventually be rejected because of their internal defects. The knowledge of internal defects gained by use of computed tomography can also provide guidance for changes in foundry techniques, procedures, and equipment to minimize defects and reduce costs.

This work was done by Timothy L. Hanna of Rockwell International Corp. for **Marshall Space Flight Center.** *No further documentation is available.*
MFS-30018

Removable Mandrels for Vacuum-Plasma-Spray Forming

The mandrels shrink away from the tubes formed on them.

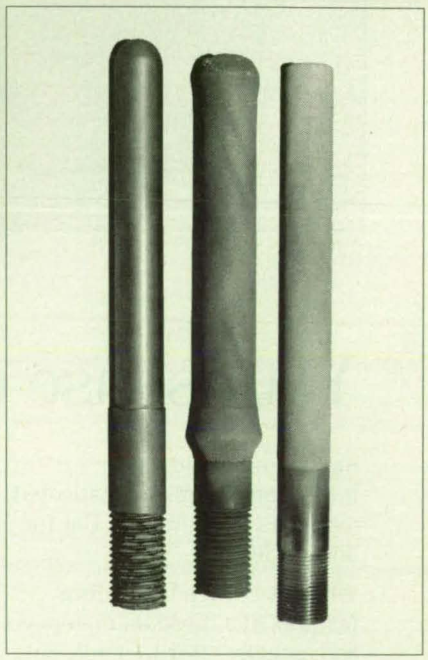
Marshall Space Flight Center, Alabama

Improved mandrels have been developed for use in vacuum-plasma-spray (VPS) forming of refractory metal and ceramic furnace cartridge tubes. The mandrels are designed so that after the tubes have been formed on them by VPS, the mandrels shrink away from the tubes upon cooling back to room temperature.

To maximize shrinkage, a mandrel of this type is made of a material that has a coefficient of thermal expansion (CTE) significantly greater than the CTE of the material to be deposited on it. On cooling, the mandrel shrinks more than does the deposited tube, so that the mandrel can simply be slipped out of the tube.

Typically, a mandrel of this type is made of stainless steel or high-CTE graphite. In addition to shrinking more than the deposited materials do, these mandrel materials can withstand the harsh, high-temperature vacuum plasma environment. The outer surface of a mandrel is machined to the desired shape of the inner surface of the tube to be formed on it, and preferably with a slight taper to facilitate removal after deposition. The tube to be formed could have a closed end with a shape (e.g., a hemispherical or flat end) that is easily machined onto the narrower end of the mandrel (see figure). Such features as a flange can also be machined onto the mandrel at its wider end.

This work was done by Phillip D. Krotz, William M. Davis, Christopher A. Power, William H. Woodford, Douglas M. Todd, Yoon K. Liaw, Richard R. Holmes, Frank R. Zimmerman, and Timothy N. McKechnie of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 39*** *on the TSP Request Card.*
MFS-30005

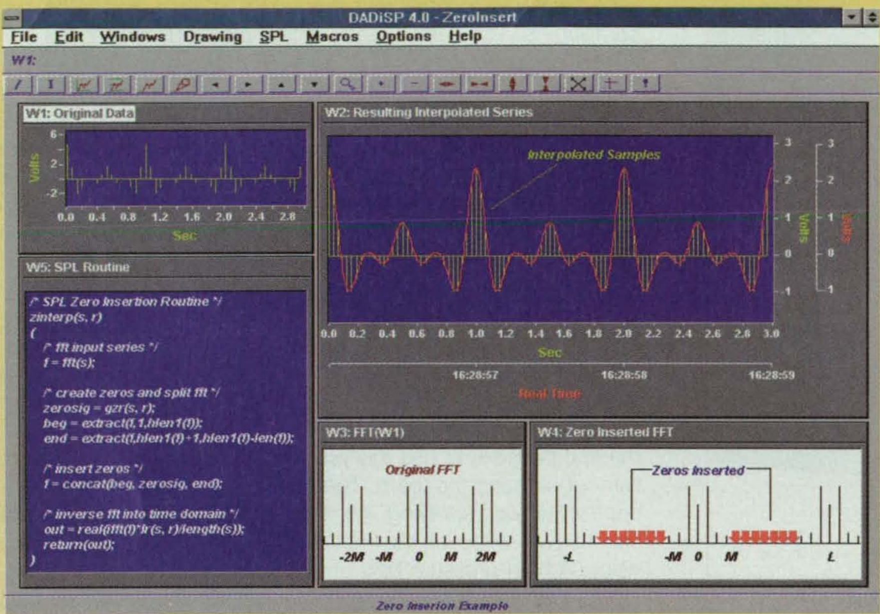


Refractory-Material Tubes of Various Shapes are formed by VPS on mandrels that have the desired shapes. The mandrels are designed for ease of separation from the tubes upon cooldown after the VPS process.

IN CASE YOU MISSED IT!

Here's what **they*** said about DADiSP 4.0

A streamlined user interface that fully conforms to Windows is the first obvious feature of a long-awaited upgrade to DADiSP, a graphical analysis program from DSP Development Corp. that's designed for the needs of scientists and engineers.



A major overhaul of the user interface, the introduction of an integrated programming language and new option modules highlight Ver. 4.0 of DADiSP...

Besides adopting a complete Windows look and feel, the overall interface scheme has gained a more streamlined look... [W]ith the flattened hierarchy on this upgrade, the software always starts up in a worksheet; indeed, when loaded, the software returns to the setup that was on the screen when the user last exited the program. Although you don't have to go through a hierarchy, the package still maintains labbooks, datasets and worksheets to provide a simple method of organizing large complex datafiles and projects.

As part of the Windows implementation, Ver. 4.0 adds support for DDE as a client or server either with functions at the command line or with Copy/ Paste Link for the pulldown menu. It performs both warm and hot DDE links with either ASCII or binary datatypes...

Ver. 4.0 also gives users the ability to define their own operations and functions to a far greater extent than the macros found in the previous version. Specifically, the upgrade marks the introduction of a programming language called SPL (series processing language). Modeled on C, it provides all the expected facilities including user-defined functions, looping and iteration, conditional statements, array references and variables. Variables can be global to a session or local to a function.

An interesting feature is the hot variable, which can contain real or complex numbers, strings, data series and matrices. A hot variable links a formula to a variable so that when a dependent element of a formula changes, the hot variable automatically reevaluates. For example, the SPL code fragment:

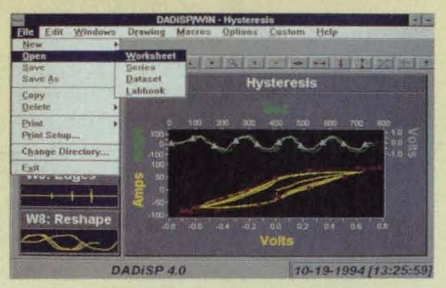
```
size := 10
W2: Movavg(W1, size)
```

performs a 10-point moving average on the waveform in Window 1 and displays the results in Window 2. The := operator establishes the hot variable. You can explore the effects of changing the moving-average length simply by reassigning size := 20 so that W2 automatically updates and shows a plot based on that new parameter.

Also improved is the package's hardcopy facility. Plot titles, legends, multiple scales, selectable fonts and a Preview mode help users produce publication-quality output...

[T]wo more modules... address advanced DSP and control applications. The AdvDSP module performs Chirp-Z transforms, N-point FFTs independent of series length and zoom FFTs. It also handles multiple forms of PSD estimation (classical, autoregressive parametric, moving-average parametric, autoregressive moving-average parametric), transfer-function estimates, Cepstrum analysis and digital interpolation. The controls module allows you to execute command line or pulldown menus, and it addresses the design, analysis and simulation of digital and continuous open- and closed-loop controllers for linear single-input/single-output dynamic systems. Among its algorithms are those that handle PID loops as well as lead and lag controllers.

* Personal Engineering & Instrumentation News 1/95



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Wire-Arc Spraying of Metal Onto Insulating Foam

This process is relatively fast and cheap, and does not damage the foam.

Marshall Space Flight Center, Alabama

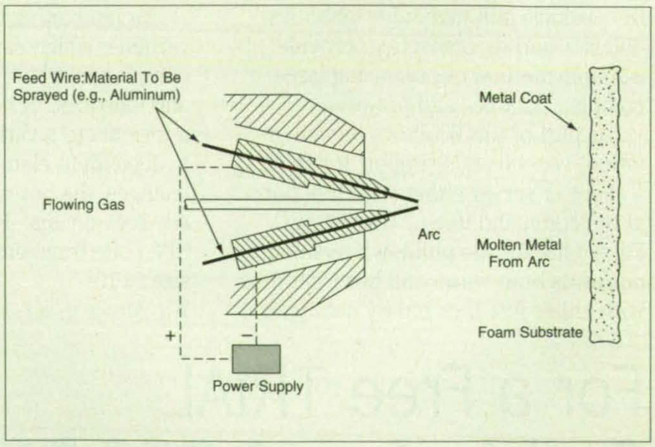
Wire-arc spraying can now be used to deposit protective metallic coats on thermally insulating foams. Heretofore, it has been common practice to deposit such coats by electroplating. Wire-arc spraying costs less than electroplating does. Wire-arc spraying is also faster, and, unlike electroplating, does not involve toxic and polluting chemicals. Moreover, unlike other thermal-spray metal-deposition processes, wire-arc spraying does not degrade or burn the foam.

Metal coats on insulating foams provide several benefits: they protect the foams against damage during handling and provide reflectivity that may be needed for optical and/or thermal-radiation purposes. On foams used to insulate cryogenic hardware, metallic coats help to prevent undesired cryopumping by sealing the foams against leakage of air from the environment to the cold surface of the hardware.

Traditionally, wire-arc spraying has been used to deposit corrosion-inhibiting zinc coats on metal structures and aluminum coats on computer components to suppress electromagnetic interference. Recent advancements in wire-arc spraying have made it possible to use this process to deposit metal on foam without harming the foam. The figure illustrates the basic concept of wire-arc spraying. An electric arc is drawn between the tips of two wires of the metal to be deposited, melting the wires. A high-pressure flow of gas (for example, argon, a mixture of argon and hydrogen, or air) accelerates the molten metal toward the foam or other substrate to be coated.

During wire-arc spraying, the sprayed surface of the foam or other substrate is exposed to temperatures in the range of about 100 to 300 °F (about 38 to 149 °C). Other thermal-spray processes produce greater temperatures, which would degrade insulating foam. In one case in which the density of the foam was so low that wire-arc-sprayed metal particles impinging at high speeds penetrated the surface of the foam, a hard epoxy surface coat was used to stop the penetration.

This work was done by James W. Bonds, Jr., Ronald L. Daniel, Jr., Phillip D. Krotz, Timothy N. McKechnie, and Heather L. Sanders of Rockwell International Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 41*** *on the TSP Request Card.*
MFS-30013



The **Arc Melts the Tips of the Wires** and the flow of gas sweeps the molten metal toward the substrate.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Nonchamber, Root-Side, Inert-Gas Purging During Welding

A simple, lightweight gas distributor replaces a more-cumbersome purging chamber.

Marshall Space Flight Center, Alabama

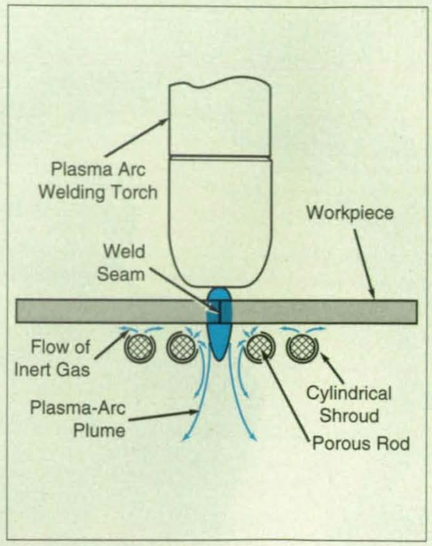
The figure illustrates an improved apparatus that distributes inert gas to protect against oxidation on the root side of a weld (the side opposite the welding torch) during welding and after welding while the joint remains hot. Unlike the more-cumbersome purging chambers that have been used heretofore, this apparatus does not obscure the view of the root side of the weld. The apparatus can be used for full-penetration plasma-arc welding of such reactive metals as aluminum/lithium alloys and titanium.

In the apparatus, the inert gas is fed into the region around the weld zone through porous sintered metallic rods, which disperse the gas evenly over their surfaces. Cylindrical shrouds partially enclose the rods and direct the flow of gas through slots toward the weld region. The jetlike thrust of the welding arc as it penetrates the metal draws the inert gas to the hot weld zone (see figure). The metal is thus protected while the weld zone remains open to view.

The apparatus is simple and lightweight; it can readily be moved along the weld path in synchronism with the torch. Because it concentrates inert gas where it is needed, it consumes gas at a relatively low rate, and, unlike in a purging chamber, it is not necessary to monitor the oxygen content of the protective atmosphere.

This work was done by William F. McGee and Daniel J. Rybicki of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 25*** *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, Marshall Space Flight Center [see page 20].
MFS-28832.



The **Welding Arc Entrains Inert Gas** as the gas flows from distribution rods. The inert gas envelopes the newly formed weld seam, protecting it against oxidation.

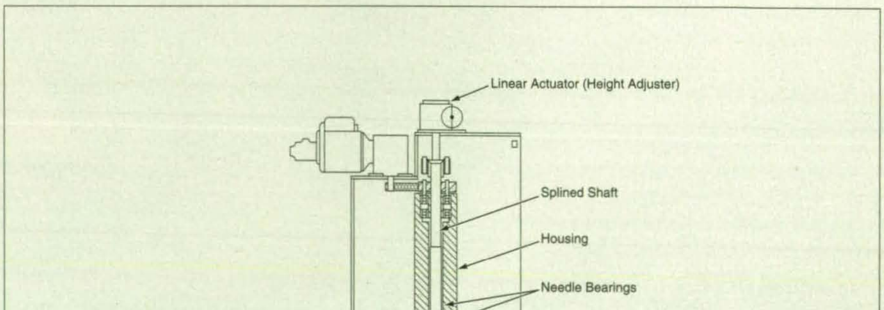
Improved Net-Level Filling and Finishing of Large Castings

Exposure of workers to casting material is reduced.

Marshall Space Flight Center, Alabama

An improved method of vacuum casting of large, generally cylindrical objects to net sizes and shapes reduces the amount of direct manual labor by workers in proximity to the cast material. The original application for which the method was devised is the fabrication of solid rocket-motor segments containing solid propellant, wherein there is a need to minimize exposure of workers to the propellant material being cast. The improved method may be adaptable to other applications that involve large castings of toxic, flammable, or otherwise hazardous materials.

In the improved method, the propellant, which has a slurrylike consistency, is gravity-fed through a deaeration assembly into a rocket-motor case cylinder mounted inside a vacuum chamber. The slurry fills an annulus around a mandrel that forms a hollow core in the casting after the propellant is cured and the mandrel removed. A laser level detector monitors the rising top surface of the slurry through a window in the top of the vacu-



Motor-Driven Ganged Rollers similar to kitchen rolling pins smooth the top surface of the casting.

um chamber, so that the flow of material can be stopped when the top surface reaches a predetermined level.

To ensure the accuracy of the final level of the cast material, the tendency of the cast material to slump upon release of vacuum after casting is taken into account. When the slurry reaches the predetermined level, filling is momentarily stopped and the vacuum is partially released, in that air is admitted up to a preset subatmospheric pressure. The laser monitor measures the slump, and the measured value of slump under this partial restoration of atmospheric pressure is used to estimate what the slump would be if full atmospheric pressure were restored. The chamber is then reevacuated and material is added in the amount needed to correct for the estimated full-atmospheric-pressure slump.

Thus, when full atmospheric pressure is restored, the final surface of the cast material should be the specified level. In the original rocket-propellant application, this approach keeps the final level within 1/8 in. (3 mm) of the specified level. After casting is completed, mold plates are presently installed on the top surface of the propellant to produce a smooth and uniform finish during the curing process. A process change under consideration, to smooth the cast material surface, is to use a remotely operated set of ganged rollers at various stages of the propellant cure (see figure).

This work was done by Erik P. Johnson and Richard F. Brown of Thiokol Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 83*** *on the TSP Request Card.*
MFS-31001

Anodizing and Sealing Aluminum in Nonchromated Solutions

Sulfuric acid (anodizing) and nickel acetate (sealing) solutions are used instead.

Marshall Space Flight Center, Alabama

An improved process for anodizing and sealing aluminum involves the use of 5 volume percent sulfuric acid in water as the anodizing solution, and 1.5 to 2.0 volume percent nickel acetate in water as the sealing solution. This process replaces an older process that raises concerns about toxicity and damage to the environment: In the older process, the anodizing and sealing solutions are chromic acid and sodium dichromate, respectively; both of these compounds contain hexavalent chromium, which is carcinogenic.

The improved process also replaces an older process in which sulfuric acid is used at concentrations of 10 to 20 percent. This older process yields anodized coats 1 to 2 mils (about 0.03 to 0.05 mm) thick: this thickness is undesirable in some applications because it is accompanied by degradation of resistance to fatigue. The improved process yields thinner coats [0.09 to 0.2 mils (about 2 to 5 μm) thick] that offer resistance to corrosion, fatigue life, and alloy-to-alloy consistency equal to or superior to those of anodized coats produced with chromated solutions.

The success of the improved process depends critically on precise maintenance of specific process parameters. In one application, for example, the process parameters were anodizing potential of 19 to 21 V, anodizing temperature of 68 to 72 °F (20 to 22 °C), anodizing time of 18 to 22 min, sealing temperature of 160 to 190 °F (71 to 88 °C), sealing-solution pH of 5.5 to 6.0, and sealing time of 10 to 15 min.

This work was done by John R. Emmons and Kelli J. Kallenborn of Rockwell International Corp. for ***Marshall Space Flight***

Center. *For further information,* ***write in 58*** *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 20]. Refer to MFS-30021.

Tools for Installing Keys on a Stud

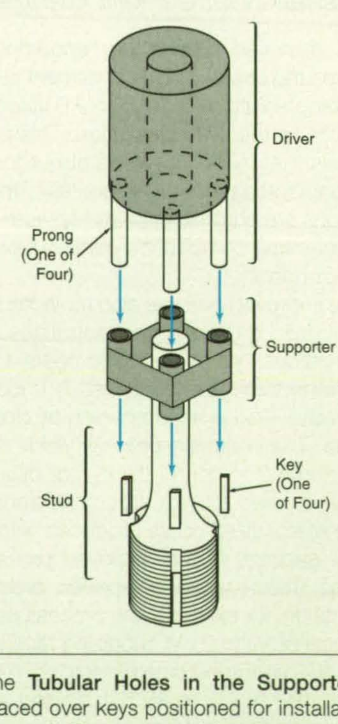
The tools stabilize the keys during installation, preventing bending and breaking.

Marshall Space Flight Center, Alabama

Two tools are designed to be used together to drive long locking keys axially to install them on a stud. The tools help to prevent bending and breaking of the keys during installation, and make it possible to install all the keys simultaneously, in one motion.

In one older technique for installing multiple keys simultaneously onto a stud, the tooling presses the keys down without support. Long keys tend to bend outward and frequently break. In an alternative older technique, the keys are driven down individually but are still susceptible to motion other than the desired downward translation. The two tools of the present technique are (1) a supporter that holds the keys in the correct relative alignment and (2) a driver that has multiple prongs, each of which fits into one of the holes in the supporter (see figure). The keys are placed in the holes in the supporter and positioned, on the stud, at the tops of the grooves along and into which they are to be pushed. The prongs of the driver are inserted in the holes, and the driver is pushed down within the supporter to drive the keys down.

This work was done by Robert D. Goodoak of United Technologies Corp. for **Marshall Space Flight Center**. *No further documentation available.*
MFS-28901



The **Tubular Holes in the Supporter** are placed over keys positioned for installation in the stud. The prongs of the driver are inserted into the holes in the supporter, and the driver is pushed down to drive the keys down.

Improved Back-Side Purge-Gas Chambers for Plasma Arc Welding

Flows are more directed and concentrated.

Marshall Space Flight Center, Alabama

Improved chambers for inert-gas purging of the back sides of workpieces during plasma arc welding in the keyhole (full-penetration) mode are based on a concept of directing flows of inert gases toward, and concentrating them on, the hot weld zones. The designs are developed and verified with the help of experiments on transparent plastic models of purge-gas chambers, in which flows of inert gases are made visible by adding smoke generated by heat-decomposing of ammonium chloride.

A typical purge-gas chamber of older design spreads the inert gas over a larger workpiece area and in a less controlled flow pattern. Depending on the rate of flow, the inert gas can become concentrated in one spot, which is not necessarily the desired spot centered on the weld keyhole. Elsewhere in the chamber, the inert gas can become mixed with air that leaks in through the opening; this is undesirable because it can bring reactive atmospheric gases (oxygen, water, hydrogen, and nitrogen) into contact with hot metal, resulting in weld defects that inert-gas purging is intended to prevent. It is especially important to prevent contamination by atmospheric gases during welding of reactive metals like aluminum/lithium alloys and titanium.

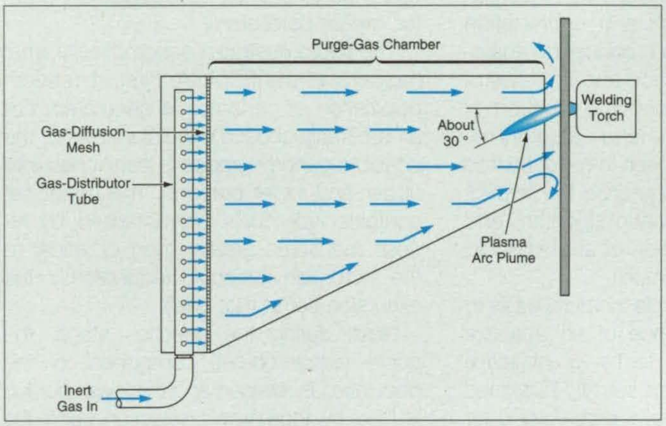
The figure illustrates a representative purge-gas chamber of the improved type. It has a tapered shape with a rectangular cross section. The inert gas enters the chamber through a distributor at the wide end, and the flow is smoothed there by use of a gas-diffusion mesh. The gas then flows toward an opening at the narrow end of the taper, where it impinges in a stream concentrated on the desired spot on the workpiece. The chamber is moved along the back side of the weld (the opposite side from the welding torch, called the "root side" in the industry) in synchronism with the weld torch on the front side, so that the opening in the chamber always faces the penetrating weld-torch plume and the adjacent hot metal.

The inert gas can be helium, argon, or a mixture of both. The choice of gas for a given application involves consideration of many factors, including the heat-dissipation requirements; the thermal properties, electrical-breakdown properties, and mass density of the gas; and which way the inert gas is required to flow with respect to gravity (depending on the orientation of the torch, it may have to flow up, down, or horizontal). For example, if the inert gas has to flow upward toward the workpiece, then helium would ordinarily be preferable because its density is less than that of the surrounding air and thus it flows upward in air. In any event, the flow of whichever inert gas is chosen can be verified in a smoke flow experiment.

This work was done by Kenneth G. Ezell, William F. McGee, and Daniel J. Rybicki of Martin Marietta Manned Space Systems for **Marshall Space Flight Center.** *For further information,* ***write in 158*** *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 20].

MFS-31012



The **Tapered Chamber Concentrates the Flow** of inert gas on the plasma arc plume and surrounding metal.

Excursion-Set-Mediated Genetic Algorithm

In comparison with other genetic algorithms, this one achieves a stronger condition for implicit parallelism.

Marshall Space Flight Center, Alabama

The excursion-set-mediated genetic algorithm (ESMGA) is an embodiment of a method of searching for and optimizing computerized mathematical models. Like other genetic algorithms, it incorporates powerful search and optimization techniques based on concepts analogous to natural selection and the laws of genetics. Going beyond the prior art of optimization via genetic algorithms, excursion sets have been introduced into the ESMGA to parameterize the implicit parallelism of the genetic algorithm and its exponential elevation of subthreshold solutions toward optimum.

Excursion sets provide a natural basis to control the performance of an adaptive genetic algorithm in terms of objective functions. An excursion set, A_u, is defined at a given excursion-level parameter u for an objective function $f(x)$ as follows: $A_u = \{x_i: f(x_i) > u\}$. Excursion sets introduce a nontrivial hierarchy in search space that is represented in the evolving genetic-algorithm population. Excursion sets and local optima above u are closely related. For example, if only local optimal solutions of importance turn out to be those above u, then these solutions certainly lie within A_u.

From one perspective, a genetic algorithm can be represented in two dimensions: (1) the way objective functions defined by the user map to a fitness measure and (2) the way a fitness measure is used to assign mathematical offspring to mathematical parents. Along these two dimensions, almost all genetic algorithms exhibit some form of multiple sampling and implicit parallelism. By mediating selection through the excursion sets and random-field theory, the ESMGA achieves a stronger condition for implicit parallelism, along with better performance.

Because one can generate excursion sets equally well in either objective-function space or fitness-function space, excursion levels introduce a natural hierarchical structure on the hypercube of available genomes. As an excursion level increases, a population is forced to rise (in terms of fitness) above the excursion level, and simultaneously the evolved population becomes distributed among the possible solutions in the excursion set. Thus, the introduction of excursion sets makes it possible to balance judiciously both internal and external representations and thus to provide a stronger condition for implicit parallelism.

The figure illustrates schematically what happens in the ESMGA. First, a random population of genomes is generated. For an arbitrarily chosen excursion level u, the possible genome space is partitioned into upper and lower portions. The upper set contains individuals characterized by fitness measures greater than or equal to the excursion threshold (equivalently, the excursion set at that level).

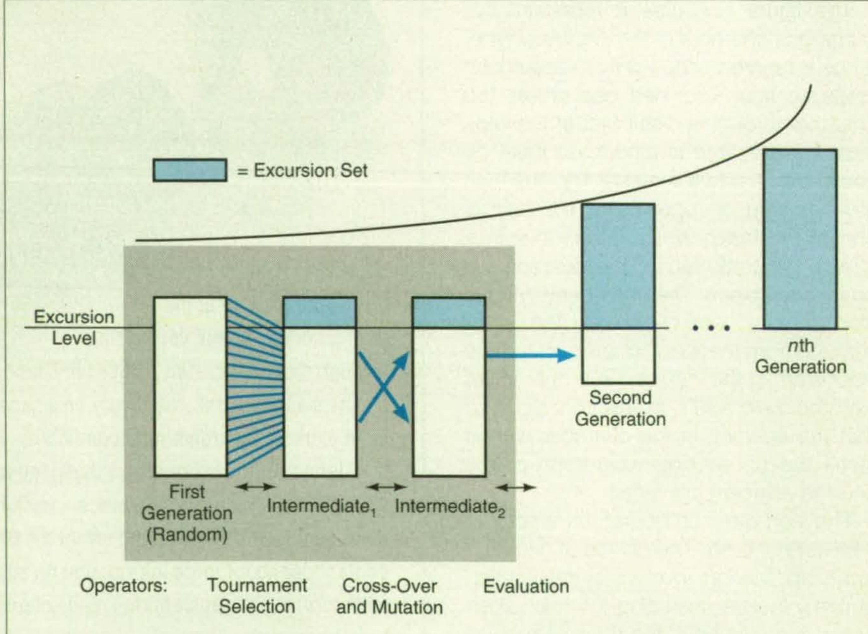
Next, during the selection stage, the upper (excursion-set) component of the population is retained and the lower portion is filled by tournament selection upon the entire population (the excursion set plus its complement). This stage introduces some bias against mating of similar individuals (analogous to prevention of incest).

The selection stage is followed by a modification stage, in which cross-over and mutation operators are applied only to the lower components. These operations produce a new population at generation 2. Finally, the new population is evaluated; individuals scoring above the excursion level are pushed up into the excursion set and preserved for future generations.

The three stages of selection, modification, and evaluation constitute one cycle of operations, which is analogous to one biological generation. The cycle is reiterated until all members of the population get pushed above the excursion level. Subsequent experiments repeat the internal genetic-algorithm dynamics for higher and higher excursion levels.

This work was done by David Noever of **Marshall Space Flight Center** *and Subbiah Baskaran of Science and Technology Corp. For further information,* ***write in 180*** *on the TSP Request Card.*

MFS-26263



The **Excursion-Set-Mediated Genetic Algorithm** includes three stages of operations in each cycle, which is analogous to a biological generation.

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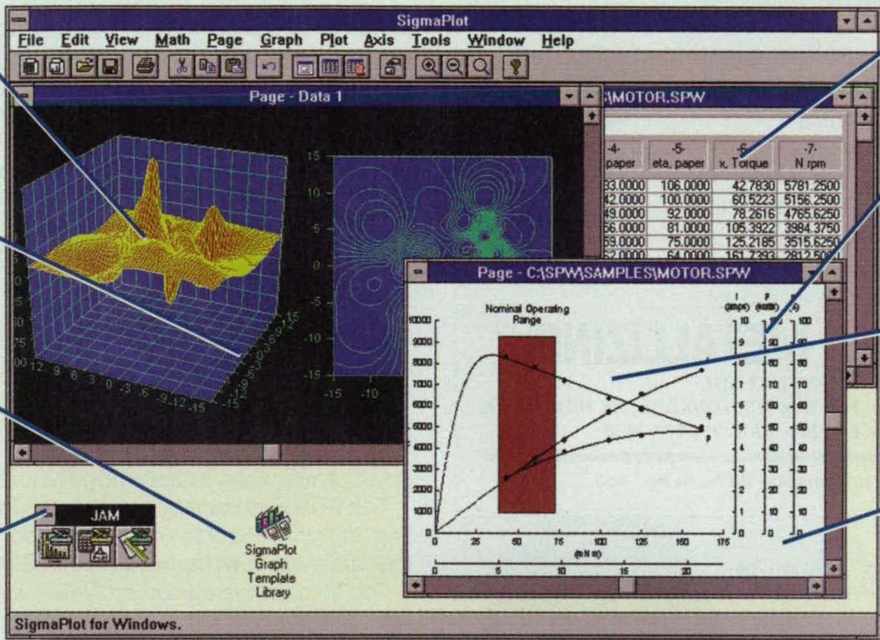

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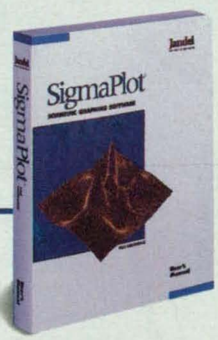

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For More Information Write In No. 692

An Image Processing Algorithm Based on FMAT

Information is deleted in ways that minimize adverse effects on reconstructed images.

Lyndon B. Johnson Space Center, Houston, Texas

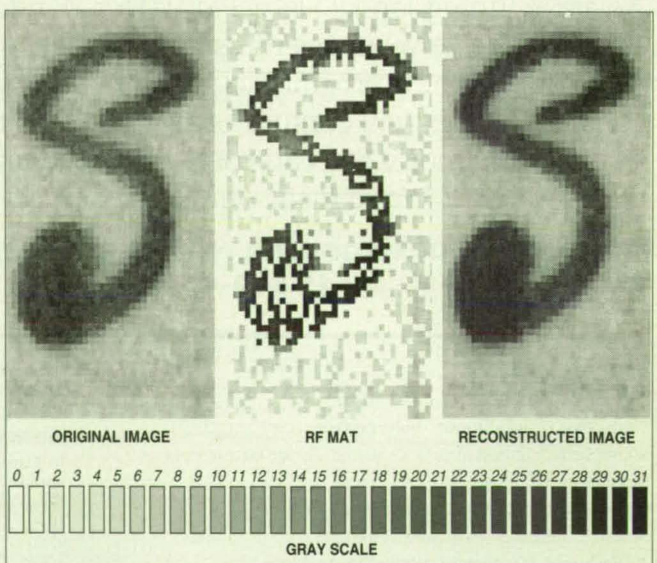
The problem of extracting medial axis transformation (MAT) and skeleton (or thinning) plays a key role in image processing, analysis, and recognition because of the simplicity of image (and hence object) representation they allow. There has been extensive research done in extracting the medial axis of a region and skeleton of elongated objects from a two-tone image.

The present work proposes a new gray-scale generalization of MAT, called FMAT (short for Fuzzy MAT). It is formulated by making a natural extension to fuzzy-set theory of all the definitions and conditions (e.g., characteristic function of a disk, subset condition of a disk, and redundancy checking) used in defining a MAT of a crisp set. As a result, it does not need the image to have any kind of a priori segmentation, and it allows the medial axis (and skeleton) to be a fuzzy subset of the input image. The resulting FMAT (consisting of maximal fuzzy disks) is capable of reconstructing exactly the original image.

An attempt of obtaining an optimum FMAT for making the image MAT representation more economical is also made by maximizing compactness of the FMAT output with its various a-cuts. Such an optimum version keeps only those medial-axis pixels that are responsible for object regions of interest while ignoring the rest. This can also be regarded as an optimum (in the sense of minimizing spatial ambiguity) fuzzy skeleton of an image.

This work was done by Lui Wang of **Johnson Space Center** *and Sankar K. Pal of the National Academy of Sciences. For further information,* ***write in 12*** *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 20].
MSC-21997



The **Original Image** of 60 x 36 pixels and 32 gray levels is converted to a reduced-redundancy FMAT (RFMAT), then reconstructed from the RFMAT.

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For More Information Write In No. 612

Growing Three-Dimensional Cocultures of Cells

Tissuelike assemblies of mammalian cells grow when the right conditions are provided.

Lyndon B. Johnson Space Center, Houston, Texas

A laboratory process provides environmental conditions that favor the simultaneous growth of cocultures of mammalian cells of more than one type. The cultures become three-dimensional tissuelike assemblies that can serve as organoid models of the differentiation of cells. The process can be used, for example, to study the growth of human colon cancers, starting from mixtures of normal colonic fibroblasts and partially differentiated colon adenocarcinoma cells.

The cells are grown, possibly on microcarrier beads, suspended in a growth medium (nutrient fluid) in a bioreactor vessel described in a previous issue of *NASA Tech Briefs*. The vessel is rotated slowly about a horizontal axis to reduce the rate of the gravitational sedimentation of the cells and beads. The combination of slow rotation and gentle circulation allows neighboring beads and cells to remain in proximity to each other long enough to interact and assemble themselves into three-dimensional structures. The gentle circulation also minimizes shear stress, which can damage mammalian cells. The exchange of respiratory gases, the supply of nutrients, and the removal of metabolic waste products can be accomplished by perfusion of the growth medium through external equipment, direct injection into the culture medium, and/or diffusion of molecules across a membrane.

As an example, the version of the process in the case of the human colon cells includes the following steps (some steps have been omitted and combined for clarity and brevity):

1. The vessel is washed, sterilized, and stood with its axis vertical (not in the operating orientation).
2. Sterilized microcarrier beads of 175-mm diameter are suspended in the growth medium at a concentration of 5 g/L.
3. The vessel is filled with the bead-and-medium mixture to 90 percent of its volume.
4. The vessel is sealed and placed for 2 h in an incubator filled with a humidified mixture of 95 percent air and 5 percent carbon dioxide at the normal human body temperature of 37°C.
5. The normal fibroblasts and the cancer cells are mixed together in the ratio of 9 to 1, trypsinized and washed on ice, suspended in the growth medium, and held on ice until inoculation.
6. The vessel is inoculated with enough of the cell mixture to obtain an average initial distribution of 10 cells per bead.
7. The small remaining empty volume in the vessel is filled with growth medium; then the vessel is sealed and placed with its axis oriented horizontally in the incubator.
8. The vessel is initially set into rotation at 10 to 15 rpm to suspend the single beads and cells and initiate growth.
9. After 24 h, the culture is inspected and the speed of rotation is adjusted, if necessary, in accordance with the progress of the culture.
10. After another 24 h, the growth medium may have to be changed, depending on the metabolism and the types of cells. The determination is made on the basis of the numbers of cells, the pH, and the O_2 and CO_2 contents.
11. After yet another 24 h, the rate of rotation is adjusted daily, depending on the sizes of the three-dimensional aggregates of cells that begin to form at this stage.
12. The experiment is terminated when the desired three-dimensional aggregates have been formed, the rotation is no longer able to keep the aggregates suspended (or else the centrifugal force of increased rotational speed smashes the aggregates against the outer wall of the vessel), and/or when the metabolism of the cells begins to demand monitoring and service more often than only daily.

This work was done by David A. Wolf of **Johnson Space Center** *and Thomas J. Goodwin of Krug International. For further information,* ***write in 113*** *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 20].*
MSC-21560.

Device Would Monitor Body Parameters Continuously

An electronic thermometer would record, process, and display temperature readings.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed miniature electronic circuit would continuously measure the temperature of a human subject. Once mounted on the subject's skin with medical adhesive tape, this electronic thermometer would remain in thermal equilibrium with the subject's body; thereafter, there would be no need to wait until the thermometer reached body temperature before taking a reading, as is necessary when using a liquid-in-glass thermometer or a conventional thermocouple- or resistance-based temperature-measuring device connected to external circuitry.

The proposed electronic thermometer would include a small battery like that in a wristwatch, a temperature-sensing circuit element, a signal conditioner, a computer, and a display unit, all contained in a disk less than 1 in. (25 mm) in diameter and less than 1/4 in. (6 mm) thick (see figure). The circuit would record and display temperature readings at specified intervals of time. It would also compute maximum, average, and minimum temperatures and the rate of change of temperature from temperature readings taken during a specified observation interval.

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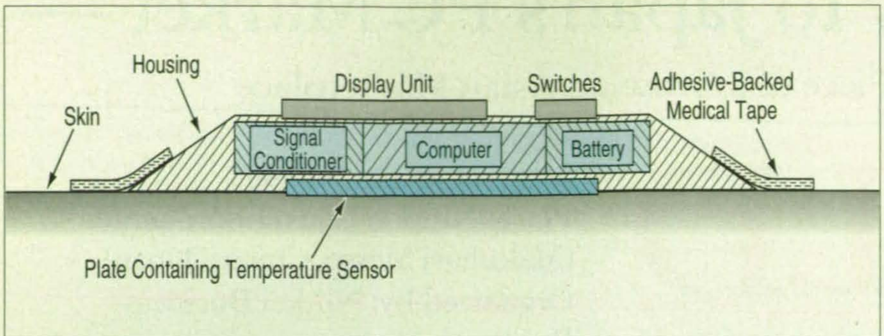

The **Electronic Thermometer** would be housed in a small disk that would be placed on the skin. The temperature sensor on the bottom would be in direct contact with the skin. This view is schematic only; it is not to scale.

The electronic thermometer would typically be positioned near the armpit because the thermal environment there is conducive to obtaining readings of internal body temperature. The device would be attached to the skin by use of an adhesive disk with an open center that would expose the display unit and small switches on the outer (upper in the figure) side of the disk.

All of the electronic components of the proposed electronic thermometer are readily available from commercial sources. The temperature-sensing element could be, for example, a thermocouple or resistance device mounted in a plate of metal or other highly thermally conductive material in contact with the skin. The temperature-sensing circuit element would produce a voltage that would vary as a function of temperature. This voltage would be fed to the signal conditioner, which would provide amplification, bridge balancing, and/or linearization as needed.

The conditioned signal would be digitized and the digitized value would be sent to the computer, which would compute the temperature from the voltage. The computer would include a microprocessor, a clock, and a memory circuit. The computer would send output data to the display unit, which could be a light-emitting-diode or liquid-crystal display device.

One of the small switches on the outer face would be used to turn the thermometer on and off. Other switches would be used to select the desired data output display. The design could provide for one or more of the switches to be used to set an alarm that would alert medical attendants if the subject's temperature exceeded a critical level. For use on a very young child, the electronic thermometer could be sewed into a shirt or other suitable garment; the device would thus be held in contact with the skin, and the child could not swallow it.

Replacement of the sensor and computing algorithm can change this continuous temperature monitor to a cardiorespiratory monitor. The replacements involve using a stethoscopic microphone in place of the temperature sensor and using a power spectrum algorithm to analyze and monitor the breathing and heart rates. Alarms would be triggered at preset levels and changes to normal levels.

This work was done by Joseph S. Cook, Jr., of **Johnson Space Center.** *For further information,* ***write in 45*** *on the TSP Request Card.*
MSC-22341

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Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Materials

Tests of Materials for Repair Coating of Carbon Steel

A report describes tests of paints (primers and topcoats) for use in recoating rusted carbon steel for protection against further corrosion. The paints selected for evaluation were all designated by their manufacturers as suitable for application over tightly adhering rust.

This work was done by Louis G. MacDowell III of **Kennedy Space Center.** *To obtain a copy of the report, "Status Report — Protective Coating Systems for Repaired Carbon Steel Surfaces — 18 Month Exposure,"* ***write in 272*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center *[see page 20].*

KSC-11635

Machinery

Aerodynamic Control-Augmentation Devices for Saturn-Class Launch Vehicles With Aft Centers of Gravity

A report describes a study of aerodynamic flight-control-augmentation devices proposed for use in increasing payload capabilities of future launch vehicles by allowing more aft centers of gravity. It has been shown, in conducted studies, that payload capability can be increased on certain Saturn-class launch vehicles by an internal rearrangement of propellant tanks. This, however, would give the vehicle an aft center of gravity and insufficient or marginal control torque. The proposed all-movable devices would not only provide increased control authority during the ascent trajectory, but would also reduce engine gimballing requirements and enhance crew safety. The report proposes various aerodynamic control surfaces that can be mounted fore and aft on a Saturn-class launch vehicle. Models have been fabricated and tested in the MSFC wind tunnel.

This work was done by Chris Barret of **Marshall Space Flight Center.** *To obtain a copy of the report, "Launch Vehicle Aerodynamic Flight Control Augmentation Devices for Launch Vehicles With Aft Center-of-Gravity Locations,"* ***write in 11*** *on the TSP Request Card.*

MFS-31032

Electronic Components and Circuits

Test of a Microwave Amplifier With Superconductive Filter

A report describes the design and low-temperature tests of a low-noise GaAs microwave amplifier combined with a microstrip band-pass filter. Two versions of the microstrip filter were used in alternate tests; in one version, the microstrips were formed as films of the high-transition-temperature superconductor Y/Ba/Cu/O on a lanthanum aluminate substrate with a gold film as the ground plane. The other version was identical except that the microstrips as well as the ground plane were made of gold, which is normally conductive. At a test temperature of 77 K, the performance measured with the superconductive filter was superior to that measured with the normally conductive filter: The noise figure with the superconductive filter was 2.1 dB lower, while the gain was 0.5 dB higher.

This work was done by K. B. Bhasin of **Lewis Research Center***; S. S. Toncich of the National Research Council; C. M. Chorey of Sverdrup Technology, Inc.; and R. R. Bonetti and A. E. Williams of COMSAT Laboratories. To obtain a copy of the report "Performance of a Y-Ba-Cu-O Superconducting Filter/GaAs Low Noise Amplifier Hybrid Circuit,"* ***write in 6*** *on the TSP Request Card.*

LEW-15908

Manufacturing / Fabrication

Applying Taguchi Methods to Brazing of Rocket-Nozzle Tubes

A report describes an experimental study in which Taguchi Methods were applied with a view toward improving the brazing of coolant tubes in the nozzle of the main engine of the space shuttle. Taguchi Methods are an integrated system of techniques for achieving high quality (robustness) in products by appropriate design of the products and of the processes used to manufacture them. In this study, Dr. Taguchi's parameter design technique was used to define proposed modifications of the brazing process that would reduce manufacturing time and cost by reducing the number of furnace brazing cycles and the number of tube-gap inspections needed to achieve desired small gaps between tubes.

This work was done by Jeffrey L. Gilbert, William J. Bellows, David C. Deily, Alex Brennan, and John G. Somerville of Rockwell International Corp. for **Marshall Space Flight Center***. To obtain a copy of the report, "SSME Nozzle Brazing Improvement Using Taguchi Methods,"* ***write in 72*** *on the TSP Request Card.*

MFS-30046

Electronic Systems

Projected-Fringe Profilometer Maps Erosion of Electrode

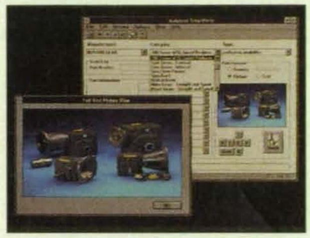
A report describes the use of a projected-fringe, phase-stepping optical profilometer to measure the three-dimensional shape of the surface of a molybdenum electrode that had been eroded in an ion engine. The instrumentation used in these measurements was very similar to that described in "Projected-Fringe, Phase-Stepping Profilometer" (LEW-14996), NASA Tech Briefs, Vol. 16, No. 9 (September, 1992), page 52.

This work was done by Gregory S. MacRae and Carolyn R. Mercer of **Lewis Research Center.** *To obtain a copy of the report "Laser Interferometric Measurement of Ion Electrode Shape and Charge Exchange Erosion,"* ***write in 69*** *on the TSP Request Card.*

LEW-15947

New on the Market

Product of the Month

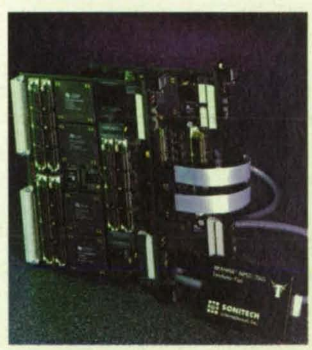


Autodesk Inc., San Rafael, CA, has introduced the first two titles in its **CD-ROM mechanical library**: PartSpec™, an interactive database of more than 200,000 ready-made parts from 17 leading manufacturers, and MaterialSpec™, continuing information on more than 25,000 material types. With PartSpec, users can search by manufacturer name or parts category and "pick and place" a precisely dimensioned drawing of the part and nongraphic data. With MaterialSpec, users can search for plastics, ceramics, metals, and composites by manufacturer, material type or trade name, application, or characteristics. Autodesk estimates that the new tools will reduce average design time by 20 percent.

For More Information Write In No. 700

The **suspended solids monitor** 9402A from Technitron Labs, Inc., Piqua, OH, reads between 1 and 120,000 ppm, and its insensitivity to color makes it applicable to a variety of processes, such as chemical, industrial, or food and water treatment. The unit can measure mediums with entrained air and high-coating tendencies. Electronic signal-handling components are remote from the sensor, increasing reliability in high-temperature and -vibration environments; digital processing and temperature compensation increases accuracy over standard meters.

For More Information Write In No. 701



Sonitech International, Wellesley, MA, has unveiled the low-cost VME SPIRIT-40 DSP **parallel processor** for applications such as array processing, image processing, and spectral and real-time data analysis. Designed for reliability, configurability, and ease of programming, the system is scaleable from 80 MFLOPS through several GFLOPS by adding multiprocessor slave cards. Each TMS320C40 DSP is directly attached to the processor, thereby avoiding heat dissipation and performance degradation.

For More Information Write In No. 702

Neel Electronics Inc., Laguna Niguel, CA, has announced the models DSA110/DSA120 **multi-function analyzers** that combine a spectrum analyzer, function generator, single- or multiple-tone generator, and narrowband tracking filter. They provide spectrum analysis up to 10 MHz, programmable frequency generation with 0.1 Hz frequency resolution and 10 mV amplitude resolution, and a multiple synthesizer up to 10 MHz.

For More Information Write In No. 703

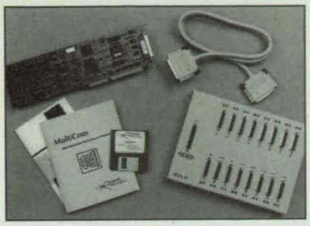
The ES8150 **engineering document system** from Xerox Corp., Rochester, NY, copies, scans, prints, plots, and stores hard copy and electronic files of engineering and technical documents up to E size. The system reduces or enlarges documents from 25 to 400 percent, and prints three E-size or seven D-size documents per minute.

For More Information Write In No. 704

Ono Sokki Technology Inc., Addison, IL, has introduced the EG-225 **digital linear gauge** for measuring dimensions, thickness, curvature, eccentricity, height, depth, flatness, variation, runnout, roundness, distortion, and deflection within an accuracy of 0.00005" throughout its 1" measuring frame. The gauge has an output speed of approximately 1.6 ms. It has an adjustable measuring force for fragile and soft compressible materials that require low pressure.

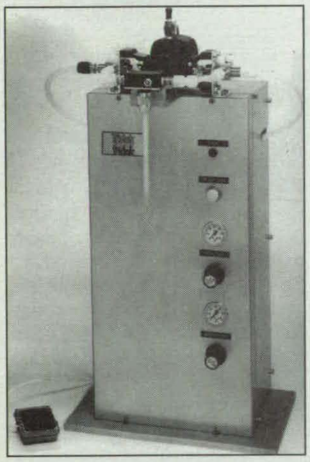
For More Information Write In No. 705

New on the Market



Multicom, a hardware/software package from Viewpoint Software Solutions, Rochester, NY, provides **high-count serial port access** that breaks the Windows nine-port limit. Tailored to the instrument control and process monitoring market, the package combines a high-functionality 8- or 16-port serial board with either a LabVIEW VI for Windows driver or a Visual Basic VBX.

For More Information Write In No. 706



Tridak, Brookfield, CT, offers the 1600 series **meter mix system** for mixing two component materials with ratios of 1:1 - 21:1. The system features static mixing, interchangeable ratios, air operation, anti-cavitation interlock, and individual reservoir pressure. Options include various size ratios, dynamic mixing, handguns, dispense valves, shot-size control, and solvent purge.

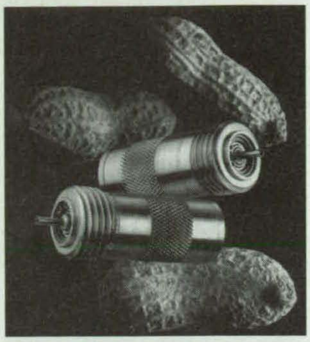
For More Information Write In No. 707

Exrust, a concentrated **chemical rust remover** from Kano Laboratories Inc., Nashville, TN, neutralizes ferrous oxide on contact, making surfaces ready for coating or plating. The product may be diluted and used as an immersion or applied directly to any metal surface.

For More Information Write In No. 708

DTM Corp., Austin, TX, has introduced Laserite® LNC-7000, a glass-filled **nylon composite material** for rapid prototyping, yielding parts with high stiffness and heat resistance. The material can produce parts with sharp edge definitions and features as small as 0.020" for electrical enclosures, connectors, assemblies, and functioning mechanical components.

For More Information Write In No. 709



The MiniMite™ **extra-small brushless DC motor** from Eastern Air Devices, Dover, NH, with samarium cobalt (rare earth) magnets, measures 0.5" OD x 1.4" long, and operates at variable speeds up to 50,000 rpm. Built-in hall-effect sensors provide velocity feedback; stainless steel construction provides corrosion resistance and suitability for high-temperature operations. Applications include antenna drives, pan and tilt platforms, bar code readers, and laser scanners.

For More Information Write In No. 710

Capacitec Inc., Ayer, MA, has unveiled GapMan, a non-contacting **thin gap measurement device** featuring a sensor on either side of the wand for position-compensated measurement of narrow gaps. Linear measurement range is 0.41 to 2.54 mm, with accuracies of 0.02 mm.

For More Information Write In No. 711

MicroSim Corp., Irvine, CA, has announced MicroSim™ **PCB design software** for Windows or with Autorouter for Windows. Instead of requiring the user to decide the size, shape, and number of layers on the board in advance, this software allows the designer to make global changes over an entire PCB board anytime during the process.

For More Information Write In No. 712

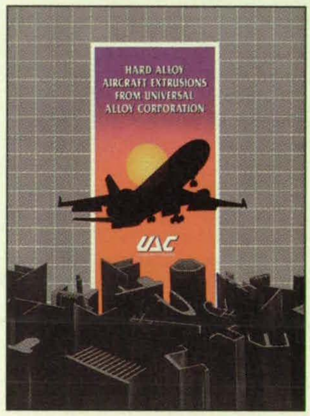
The Horizon **wiring analyzer** from Cabletest International Inc., Markham, Ontario, offers a 3" x 5" touch screen that displays file selection and tester operation via graphical menus. The device can be linked to an Ethernet network. Standard testing capabilities include: milliohm resolution, capacitance measurement, twisted pair verification, and a "faulty end recognition" circuitry that determines which end of a cable assembly has an open or short circuit.

For More Information Write In No. 713

New Literature

LNP Engineering Plastics, Exton, PA, has released a 14-page brochure on **plastics compounding**, with descriptions of Verton®, Lubricomp®, Stat-Kon® and Thermocomp® products. Services provided by the company's R&D, Customer Applications Center, Technical Services, Manufacturing, and Quality Assurance groups are described.

For More Information Write In No. 720



A 14-page brochure from Universal Alloy Corp., Anaheim, CA, describes the company's high-tech methods of producing **hard alloy extrusions** for the aircraft industry. Manufacturing capabilities described include aging and annealing, inspection and packaging, custom die making, and heat treating, stretching, and straightening.

For More Information Write In No. 721

A deep well X-ray fluorescence **coating/plating thickness measuring system** for large metal parts is described in a product sheet from CMI International, Elk Grove Village, IL. The system, designed for the metal finishing industry, accepts large metal parts with programmable travel up to 12" x 12" x 6".

For More Information Write In No. 722

Advanced Machine & Engineering Co., Rockford, IL, has published a four-page brochure on AMLOK heavy duty **hydraulic rod clamps**. Included are the Type RCH product line, design hints, assembly instructions, and technical specifications.

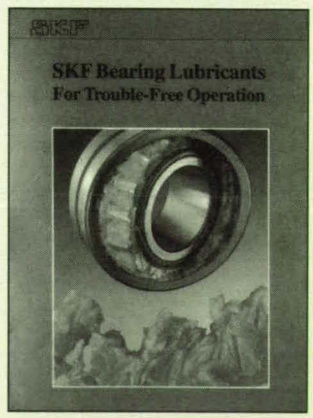
For More Information Write In No. 723

New lines of **transfer, compression and injection molded plastic encapsulation shells** are described in a catalog from Maryland Plastic Products, a division of Maryland Ceramic & Steatite Co., Inc., Bel Air, MD. Included are sections on molding and tooling facilities, as well as design, custom fabrication, screw machining, molding, tooling, terminal inspection, insert molding, cutting, slotting, drilling and inspection/deflashing services.

For More Information Write In No. 724

HPS Division, MKS Instruments, Inc., Boulder, CO, has published a product sheet describing the SensaVac® Series 907 Analog Convection Transducer, a **vacuum transducer** that measures vacuum pressure from 10^{-3} to 1000 Torr. Operating principle, specifications, pricing, and a calibration curve for vacuum measurement in gases other than air are included.

For More Information Write In No. 725



SKF Bearing Lubricants for Trouble-Free Operation, a 20-page catalog from SKF USA Inc., King of Prussia, PA, describes the company's line of **greases** and the role lubrication plays in bearing installation and maintenance. The catalog highlights the benefits of each lubricant, and provides technical charts illustrating grease NLGI grade and base oil viscosity. Also included are a two-page selector guide for choosing the right lubricant and a description of the testing and process control procedure used.

For More Information Write In No. 726

New Literature

Permeability And Other Film Properties Of Plastics And Elastomers, published by Plastics Design Library, Norwich, NY, is a 12-page publication on **barrier and film properties of plastics and elastomers**. For each material tested, the trade name, grade, supplier, generic description, recipe, fillers and/or additives used are provided. Material and test descriptions, property information, and a glossary also are included.

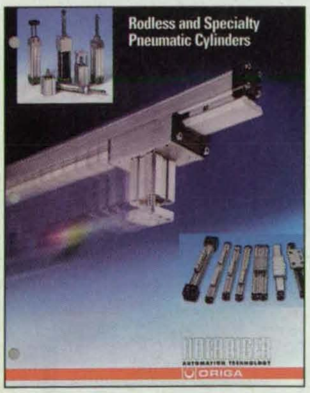
For More Information Write In No. 727

A four-page brochure from Carl Zeiss Inc., Thornwood, NY, describes the Zeiss ZVS **camera systems for high-resolution video microscopy**. It highlights the ZVS 47DE, ZVS 47DEC, and AVS 47N camera systems with technical specifications and applications in the biomedical, clinical, and microelectronics fields.

For More Information Write In No. 728

Centronic Inc., Newbury Park, CA, has released a 50-page products and capabilities catalog describing standard and specific **application photodiodes**. Included are photos, sizes, and specifications for the company's line of photodiodes and related products.

For More Information Write In No. 729



A four-page brochure describes **pneumatic rodless and specialty cylinders** from Hoerbiger-Origa Automation Technology, Elmhurst, IL. Sample products from each series of cylinder, as well as electronic pressure regulators, are highlighted with technical data and specifying information.

For More Information Write In No. 730

Optikos Corporation, Cambridge, MA, has released a six-page brochure on the VideoMTF® Image Analysis System, a **two-dimensional Modulation Transfer Function (MTF) measurement system**. The software-based image analysis tool can be incorporated into standard optical test benches or custom test stations.

For More Information Write In No. 731

Masterflex® **peristaltic pumps** and related products are described in a 16-page brochure from Cole-Parmer Instrument Co., Niles, IL. Featured are pumps with flow rates as low as 17 ml/min to 30 l/min, and a pump that uses PTFE tubing.

For More Information Write In No. 732

A spring 1995 catalog supplement from Jensen Tools, Phoenix, AZ, features **tools and test equipment for electrical and electronic repair and maintenance**. Included are inch and metric tool kits, cases, and shipping containers. Other products featured include heat guns and soldering equipment, and hand tools.

For More Information Write In No. 733

Digital storage scopes, function generators, multifunctional DMMs, and analog meters are described in a 44-page catalog of more than 70 **test instruments and accessories** from HC Protek, Northvale, NJ. The catalog features reference guides, specification data, and an updated index.

For More Information Write In No. 734

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