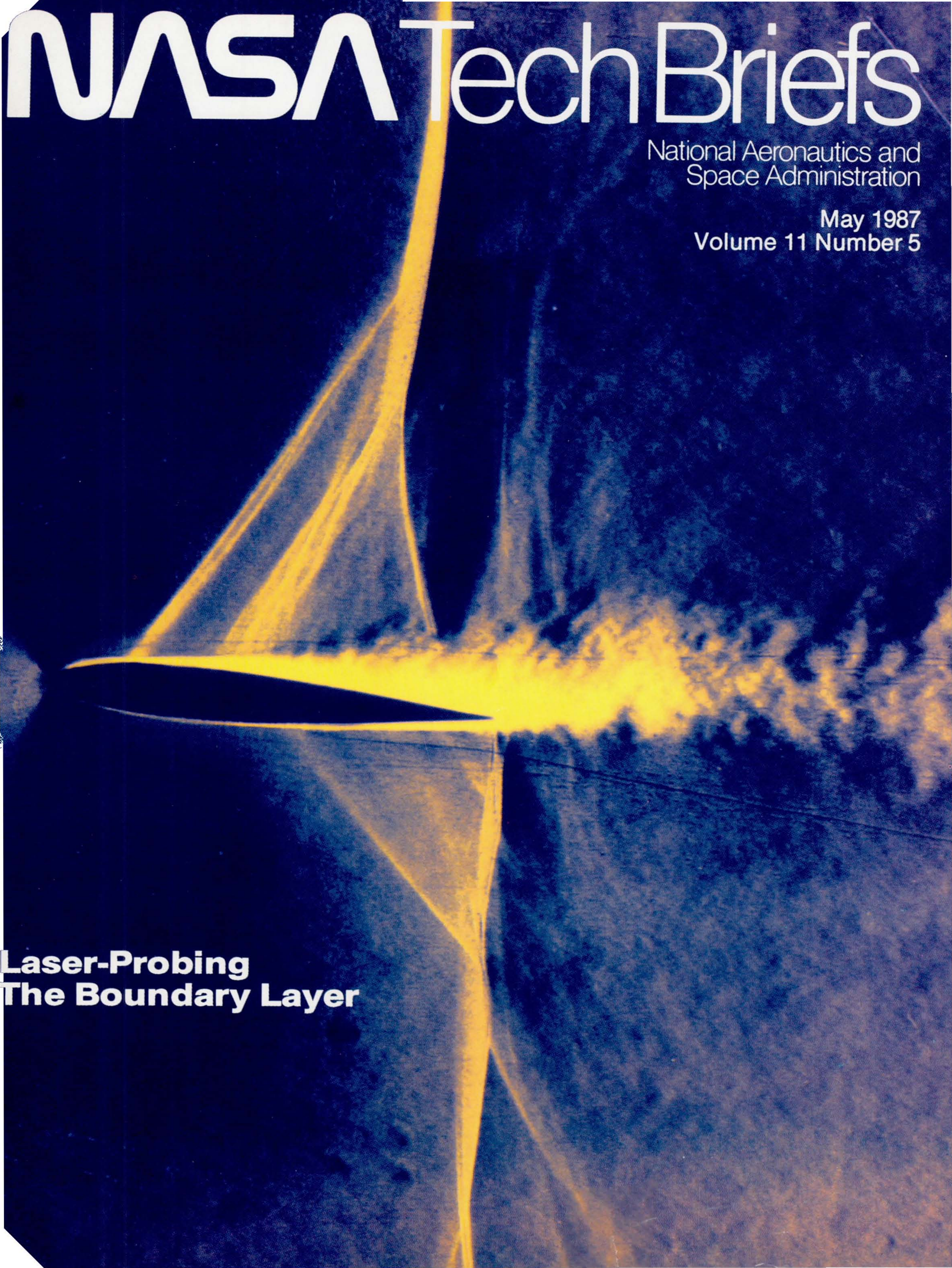
NASA Tech Briefs

National Aeronautics and
Space Administration

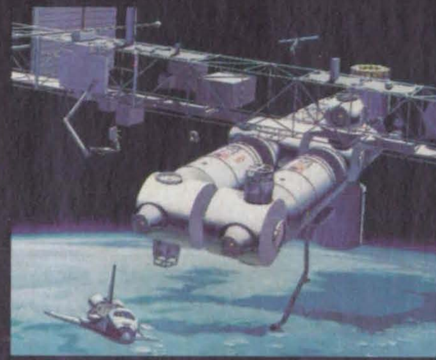
May 1987
Volume 11 Number 5



Laser-Probing The Boundary Layer

Vision:

Future generations deserve nothing less than America's continued leadership in space.



ONE POWER METER MEASURES IT ALL

. . . from picowatts to Kilowatts, UV to Far IR

The ultimate power meter has arrived. It has every feature and capability you will ever need, plus it covers a measurement range from picowatts to 3 Kilowatts—to meet all of your requirements!

The state-of-the-art Rk-5700 is available in either single or dual channel readout. This microprocessor based instrument incorporates autoranging, autozeroing, IEEE-488 interface, and a high resolution digital display selectable for readout in watts or dBm. There is also an analog bar graph display, which enables you to observe varying power levels while optimizing optical sources or systems. Additional features include a calibration set control to provide precise compensation for windows, filters, and beam splitters, plus a background cancellation control which automatically subtracts out any undesirable background signals.

The dual channel Rk-5720 provides simultaneous display of power to each channel and the ratio of these two channels. This ratiometer measures gain or loss ratio up to 10^{13} to 1, making it ideal for material damage studies, atmospheric transmission measurements, laser gain analysis, and for determining absorption, transmission, and reflectance of optical components.

Rk-5700 FEATURES

- Spectral Range: UV to Far IR
- Over 14 Decades of Dynamic Range (10^{-11} to 10^{3} Watts)
- 1 Part in 10,000 Resolution
- Interchangeable Pyroelectric, Silicon, and Thermoplile Probes
- IEEE-488 Interface
- Auto/Manual Range Modes
- Autozeroing
- Background Cancellation
- Window/Filter Compensation
- Fast Disconnect Chopper for Internal or External Use
- 2 Channel Ratioing Capability
- Cavity Detector for Ultraflat Response
- 64 Character Alphanumeric Display
- Selectable Watts or dBm Scales
- Bar Graph Analog Display
- ±5% Accuracy Traceable to NBS

The Rk-5700 is the one power meter that does it all. For more information, contact: LASER PRECISION CORPORATION, 1231 Hart St., Utica, NY 13502, or call (315) 797-4449, or telex: 646803

WINNER OF TWO IR-100 AWARDS

laser precision

. . . the Industry's Standard for Excellence

Circle Reader Action No. 427

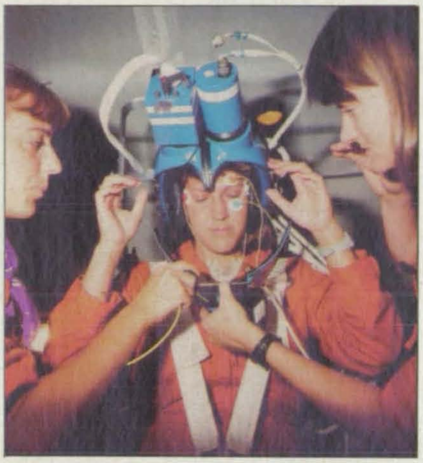
NASA Tech Briefs

National Aeronautics and Space Administration

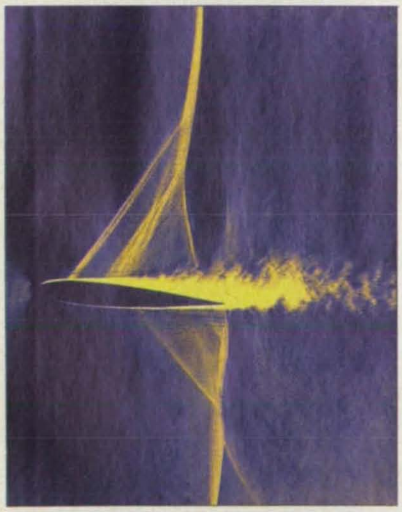
MAY 1987
Volume 11 Number 5

ABP BPA

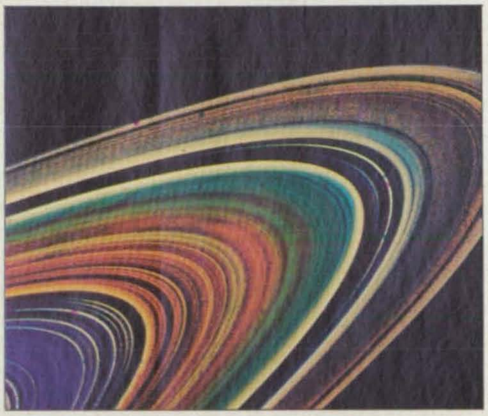
Special Features and Departments



Incorporating optokinectic modules and accelerometers, this helmet will study space adaptation syndrome on the first In-Flight Medical Laboratory. Other state-of-the-art sensor technologies are described in our feature story, beginning on page 8.



On the Cover: Schlieren photograph of transonic flow over an airfoil. The nearly vertical shock wave is followed by boundary layer separation that adversely affects lift and drag. Color added for emphasis.



Find out what's happening at NASA. See our NASA News Briefs column on page 6.

Technical Section Thumb Index

Thumb Index Technical Section

NASA Tech Briefs, ISSN 0145-319X, USPS 750-070, copyright © 1987 in U.S., is published monthly except July/August and November/December (10x per year) by Associated Business Publications Co., 41 E. 42nd St., New York, NY 10017-5391. The copyrighted information does not include the individual Tech Briefs which are supplied by NASA. Editorial, sales, production and circulation offices at 41 E. 42nd Street, New York, NY 10017-5391. Subscriptions for non-qualified subscribers in the U.S., Panama Canal Zone, and Puerto Rico, $75.00 for 1 year; $125.00 for 2 years; $200 for 3 years. Single copies $15.00. Remit by check, draft, postal or express orders. Other remittances at sender's risk. Address all communications for subscriptions or circulation to NASA Tech Briefs, 41 E. 42nd Street, New York, NY 10017-5391. Second-class postage paid at New York, NY and additional mailing offices.

POSTMASTER: please send address changes to NASA Tech Briefs, 41 E. 42nd Street, Suite 921, New York, NY 10017-5391.

NASA Tech Briefs

National Aeronautics and
Space Administration

NASA Tech Briefs:

Published by .... **Associated Business Publications**
Editor-in-Chief .... **Bill Schnirring**
Publisher .... **Thomas H. King**
Associate Publisher .... **Frank Nothaft**
Associate Publisher .... **Robin J. DuCharme**
Managing Editor .... **R.J. Laer**
Associate Editor .... **Leo D. Kluger**
Technical Advisor .... **Dr. Robert E. Waterman**
Art Director .... **Melanie Gottlieb**
Production Manager .... **Rita Nothaft**
Traffic Manager .... **J.T. Pramberger**
Circulation Manager .... **Anita Weissman**
Controller .... **Neil B. Rose**

Technical Staff:
Briefs prepared for National Aeronautics and Space Administration by **Logical Technical Services Corp.**, NY, NY
Technical/Managing Editor .... **Ted Selinsky**
Art Director .... **Ernest Gillespie**
Administrator .... **Elizabeth Texeira**
Chief Copy Editor .... **Lorne Bullen**
Staff Editors .... **James Boyd, Larry Grunberger, Jordan Randjelovich, George Watson**
Graphics .. **Israel Gonzalez, Luis Martinez, Huburn Profitt**
Editorial & Production .... **Beatriz Flores, Bill Little, Frank Ponce, Ivonne Valdes**

NASA:
NASA Tech Briefs are provided by the National Aeronautics and Space Administration, Technology Utilization Division, Washington, DC:
Administrator .... **Dr. James C. Fletcher**
Assistant Administrator for Commercial Programs ... **Isaac T. Gillam IV**
Director Technology Utilization Division ... **Henry J. Clarks**
Publications Manager .... **Leonard A. Ault**

Associated Business Publications
41 East 42nd Street, Suite 921
New York, NY 10017-5391
(212) 490-3999
President .... **Bill Schnirring**
Executive Vice President .... **Frank Nothaft**
Vice President .... **John K. Abely**

Advertising:

New York Office: (212) 490-3999
Sales Manager .... **Robin DuCharme**
Account Executive .... **Dick Soule**
Account Executive .... **Michelle Schmitz**
Advertising Assistant .... **Erving Dockery, Jr.**

Los Angeles Office: (213) 477-5866

ABP BPA

Data Shield®

Precision Glass Tape Reels

Reel Insurance

How reels can fail.
How ours don't.

We found a better way to answer your instrumentation, professional video, professional audio and archival tape needs. Better design, greater protection, long-lasting material.

Longer Tape Life and Optimal Equipment Performance
Corning's tape reels have a solid flange design. Tape life is increased and signal quality protected because temperature and humidity changes are uniform, rather than concentrated at flange holes. No dirt. No stray electrostatic charge.

Greater Protection to Tape Edges
Not only are our flanges solid, they're made of Chemcor®, chemically strengthened components which increase resilience. Corning reels don't warp or permanently bend and cannot be dented.

When you need the best data protection, call (607) 974-4286 or write Corning Glass Works, Advanced Products, Main Plant 8-4, Corning, NY 14831.

CORNING

Circle Reader Action No. 454

NASA NEWS BRIEFS

NASA has issued Requests for Proposals to U.S. industry for design and construction of a permanently manned Space Station to be operational in low-Earth orbit in the mid 1990's. The program's first phase, approved by the President in April, would include the U.S. laboratory and habitation modules, four resource nodes, the U.S. polar-orbiting platform and experiment provisions outside the pressurized modules.

Five companies have been selected by NASA to submit designs for new Space Shuttle solid fuel booster rockers. They are: Aerojet Strategic Propulsion Co., Atlantic Research Corp., Hercules Aerospace Co., Morton Thiokol Co., and United Technologies' Chemical Systems Division.

Three experiments submitted by scientific teams at NASA's Ames Research Center have been selected by an international panel of scientists for participation in the Comet Rendezvous Asteroid Flyby (CRAF) mission, the first of the new Mariner Mark II spacecraft series being considered for launch in the early 1990's. The mission objective is to characterize the nucleus of a short-period comet.

Ames' three CRAF proposals are: The cometary ice and dust experiment (CIDEX), thermal infrared radiometer experiment (TIREX), and an interdisciplinary scientist for exobiology (IDS).

Chief Astronaut John Young has been appointed to a Johnson Space Flight Center post as special assistant to the center director for engineering, operations, and safety. Young will help resolve issues affecting Space Shuttle flights, and will advise center director Aaron Cohen on the proposed Space Station and new initiatives such as the National Aero-Space Plane.

The first government agreement transferring commercial operations of an expendable launch vehicle (ELV) has been signed by NASA with General Dyanamics Space Systems Division, California. General Dynamics will manufacture and launch the Atlas/Centaur vehicle using NASA-controlled facilities and capabilities.

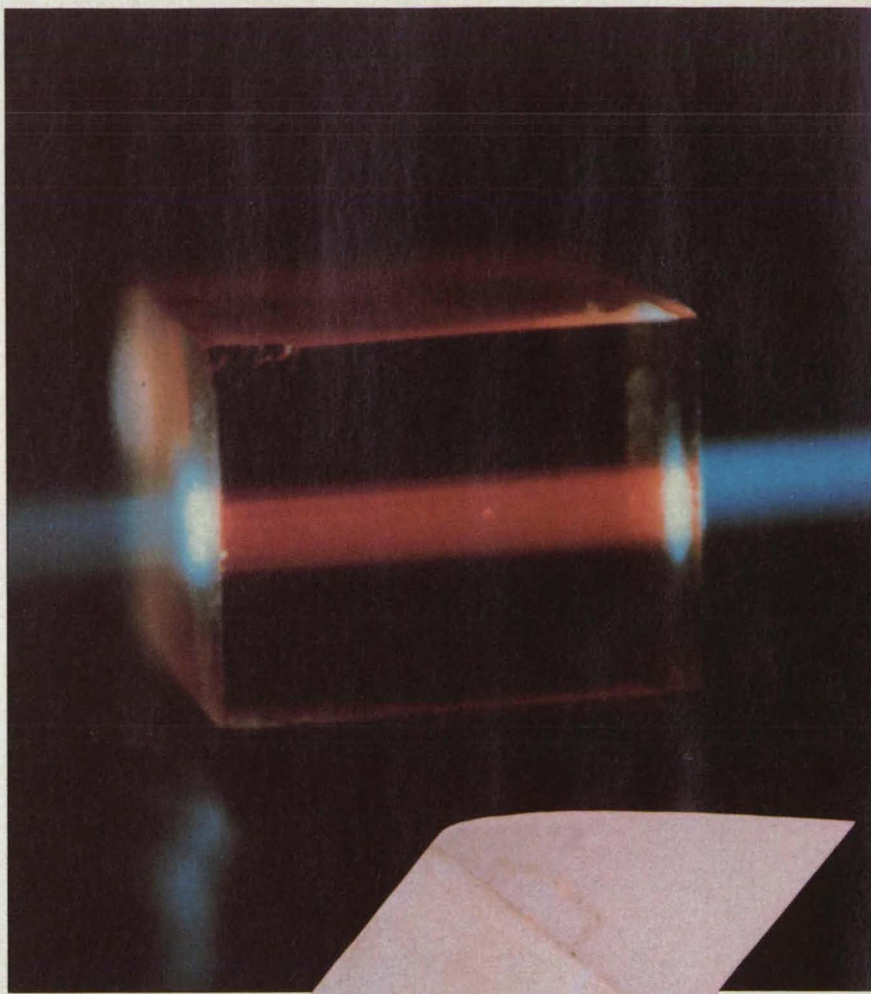
Boeing Aerospace Operations will build the Industrial Space Facility's (ISF) Shuttle docking system, enabling the ISF to attach to the Space Shuttle in orbit. Shuttle astronauts could then move freely between the Shuttle mid-deck and the ISF without wearing space suits.

William Sheehan, former director of The Executive Television Workshop, Inc., has been appointed Associate Administrator for Communications, NASA Headquarters.

October, 1990 is the target date for launching of the joint NASA/ESA Ulysses mission to the Sun. The Ulysses spacecraft, to be launched using the Space Shuttle, will begin to return prime data in 1994.

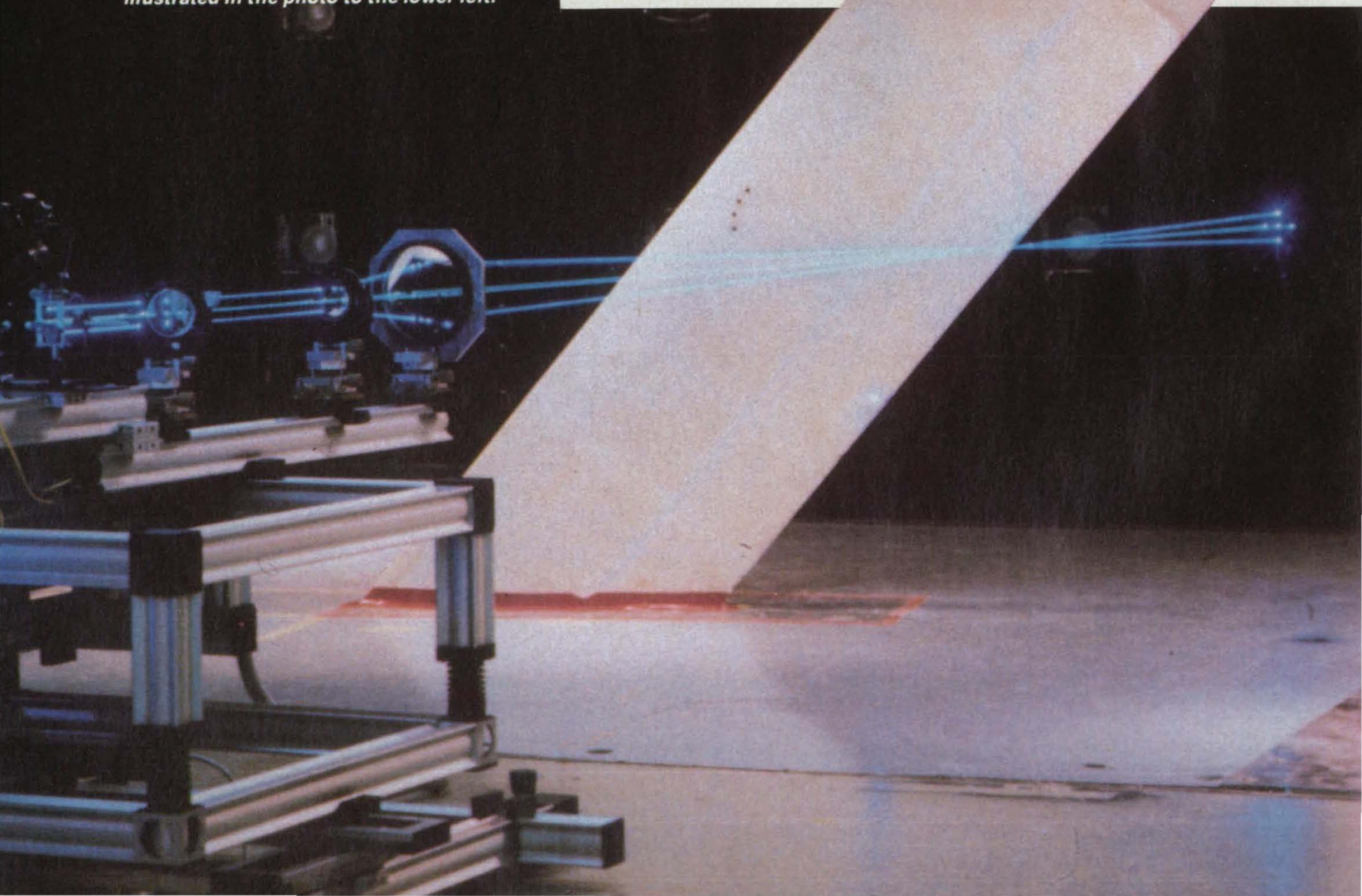
Exploration of Mars should be the United States' primary goal in space, according to a recommendation by the NASA Advisory Council. Other initiatives being considered by NASA as space goals include: expanded earth systems study; enhanced solar system exploration; and a permanent scientific base on the moon.

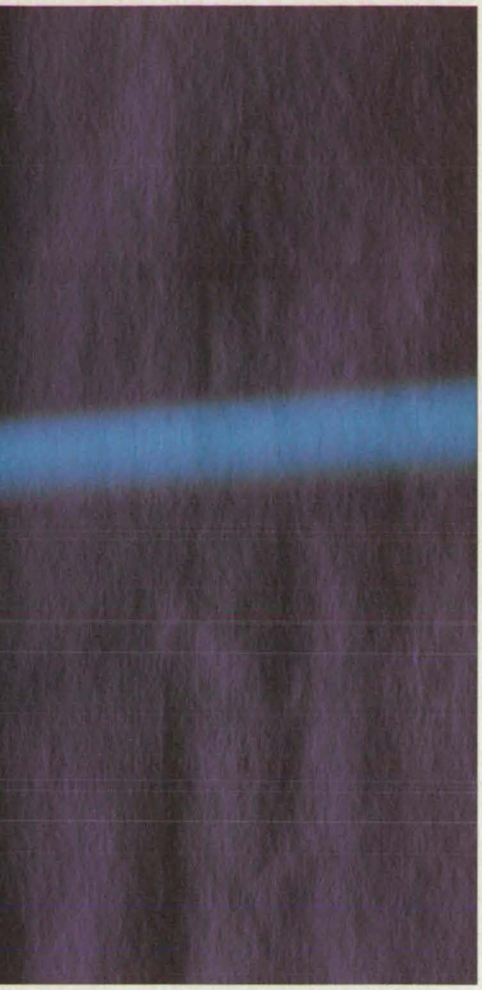
NASA has selected Lockheed Engineering and Management Services Company, Houston, for negotiations leading to the award of a contract for engineering support at Johnson Flight Center. This effort consolidates work currently performed by Lockheed, McDonnell Douglas Corp., and Northrop Services, Inc., under three separate contracts.



Upper left: This sensor-studded helmet was developed by Johnson Space Flight Center researchers to study space adaptation syndrome aboard Spacelab.

Upper right: Promising new solid state laser crystals offer enhanced spectral coverage as well as higher power, longer life and greater efficiency. Increasingly useful in sensor systems, lasers are used to measure three-dimensional flow velocities over aerodynamic surfaces, as illustrated in the photo to the lower left.





Sensor Technologies—

from Aerospace to Zephyrs

By Bruce A. Conway
Assistant Chief, Flight Electronics Division, NASA/Langley Research Center

A wet finger testing the breeze was the first sensor. Since then, detecting and measuring has become more of a science than a physiological phenomenon. Nowhere is the technology more refined than in the aerospace field, where NASA's sensor research enhances the quality of flight of both aircraft and spacecraft. The need to know the characteristics of what a pilot flies and what he flies through has propelled NASA's sensor research for decades. Most of the work is conducted by the Office of Aeronautics and Space Technology (OAST), whose sensors and sensor concepts spinoffs benefit a wealth of non-aeronautic fields.

Space remote sensing research and development activities of OAST include laser and laser radar (lidar) systems that detect and study aerosols, trace constituents and winds (including the "zephyr," or west wind, presided over by Zephyrus in Greek mythology!). Another activity researches sub-millimeter wave sensors for imaging and spectroscopy from space. A third area investigates imaging detectors from the far-infared to the X-ray portion of the spectrum for terrestrial, planetary, solar physics and astrophysical applications.

These sensor subdisciplines lead to better understanding of our environment and climate by remotely probing our atmosphere from space or aircraft. Identifying unknown species or molecules gives a better understanding of dynamic atmospheric processes, allowing assessment of the biochemical effects of industrial plants, crop treatments, and volcano eruptions or nuclear accidents. Spaceborne doppler lidar will monitor the wind to show how particles are transported through the atmosphere. When coupled with enhanced identification of those particles, sensor technology will give almost real-time responses to catastrophic events such as Bhopal or Chernobyl.

Since scanning the electromagnetic radiation of a star or planet is the next best thing to being there—and a lot cheaper too—NASA's sensor technology is also used for astronomical studies. Potential spin-offs of these sensors will include more capable cameras for medical applications, "smart" sensors that will enhance police surveillance, and radiometer-type instruments to remotely monitor industrial chemical processes. Another use might be in civil engineering, where hazardous gases and fumes can be monitored during construction. Biology will also benefit, through non-intrusive species identification or habit-monitoring.

Spin-off sensor technology won't come exclusively from astronomical instrumentation. While exploring the solar system, unmanned spacecraft will themselves be probed from within. Onboard support systems such as communications, thermal control and power generation will include sensors. Many of these housekeeping sensors will find their way in some form into improved civil applications. Just as sensors bridge technologies as diverse as biology and astronomy, so too do they apply to other fields. One discipline ►

that leading edge sensor technology especially benefits is aircraft design.

What of Aeronautics?

Through mathematical models, computers have greatly eased the path from conception to design of new aircraft, while at the same time allowing complex designs previously considered impossible. Despite these highly accurate and sophisticated representations, design validation still requires empirical data. Parameters such as pressures within the boundary layer over an airfoil, airflow characteristics around wing edges, and stresses within a wing or vertical tail must be measured.

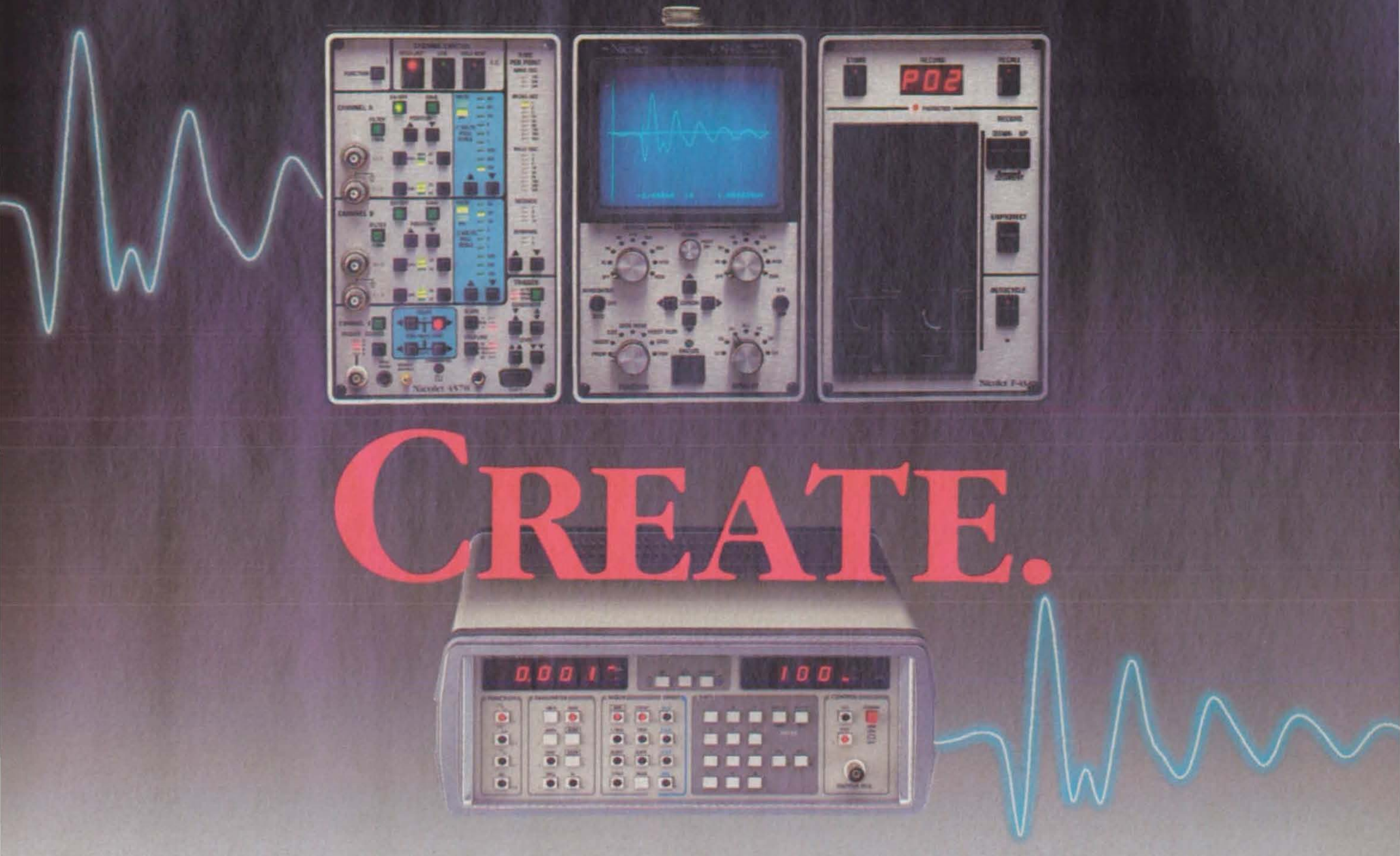
Most of the information comes from wind tunnel and flight-derived data, collected by state-of-the-art sensors. Lasers play a big part here, accurately measuring 3-dimensional flow velocities over aerodynamic surfaces and monitoring exhaust gas constituents from jet engines. Other developments include miniature strain gages mounted on jet engine compressor blades to measure stress levels *during* operation and flush-mountable transducers to determine friction drag at the wing surface-boundary layer interface.

Detecting different sound frequencies also gives useful clues. Here, ultrasonics-based systems can accurately and *nondestructively* determine internal composition and stress of materials. Deadly wind shears and vortices have one Achilles heel: They give away their element of surprise through changes in sound and pressure. To detect these minute variations, engineers are investigating tremendously small and sensitive microphones— and the proper signal processing to go with them. Preparing for a constant trial by fire, high temperature sensors are being developed for direct mounting on operating engines to provide performance data. Bringing these technologies over to commercial aircraft is a natural extension, resulting in safer, more efficient flights. It doesn't take too much imagination to perceive spin-offs to other transportation modes or industrial processes.

In the Future

Using a crystal ball (with some admittedly educated guessing) to see what lies ahead in aeronautics sensors might reveal the following: substantially increased use of fiber optics as a sensor medium for different physical parameters, including temperature, motion, electric fields, pressure, force and torque. Special piezoelectric films, sensitive as skin, will be available for surface application and temperature or pressure indications. For better ad- ►

CAPTURE.



CREATE.

Stimulate experiments with real-time analog waveforms reproduced from your actual captured data!

Connected via the GPIB interface, the Nicolet Model 4094 digital oscilloscope teamed up with the Nicolet Model 42 arbitrary function generator provides instantaneous waveform storage and generation.

800/356-3090
or 608/273-5008

Nicolet Digital Oscilloscopes

Incoming signals digitized by Nicolet's high accuracy 12-bit, 10 MHz digitizers or high speed 8-bit digitizers allow you to see things you've never seen before. Zoom expansion to X256 allows you to see the details in waveforms composed of up to 16k points. Cursor readout of measurement values, continuously variable pretrigger positioning, and built-in disk drives all contribute to Nicolet's tradition of measurement power and ease of use.

Nicolet Programmable Function Generators

NEW!

Outgoing signals are accurately generated from the 12-bit by 2k arbitrary waveform memory in the Model 42. Real-time duplication of the captured signal can be produced at speeds up to 1 μSec per data point.

Continuous, triggered, gated, and burst output modes are possible. A unique feature, arbitrary sweep, allows you to accurately program the output frequency. Standard waveforms (sine, triangle, square, sawtooth, pulse), 10 mV_{p-p} to $20V_{p-p}$ amplitudes, are all available at speeds up to 4 MHz.

Nicolet Test Instruments Division
P.O. Box 4288
5225-2 Verona Road
Madison, WI 53711-0288

Nicolet
"Instruments of Discovery"

Circle Reader Action No. 350

vance warning of clear-air turbulence or wind shear, airborne lasers will come into play. Other lasers, patterned after those being developed for space, will accurately measure very low velocities such as those of a helicopter at or near hover. Representing an ideal blend of sensing and interpretation, devices may be developed that will simultaneously sense an inefficient combustion process in an engine and adjust the fuel, air and exhaust configuration to "get back on track."

Flying in regimes only briefly visited before, the National Aerospace Plane (NASP) program will be the most advanced aerodynamic vehicle to leap off a runway. Getting it off the ground will require sensors far beyond the current technology. Before the design is "frozen," however, accurate wind tunnel simulations will require real-time atmospheric constituent monitoring and analyzing. To control the vehicle, conventional air data sensors will have to be augmented to cover the wide range of atmospheric conditions encountered during a typical flight. During reentry, accurate remote measurement of atmospheric density may be crucial. Meeting these high-flying sensor challenges will continue to require the same ingenuity and creativity first exhibited by the caveman's wet-finger-breeze-tester. □

About the Author . . .

Bruce A. Conway

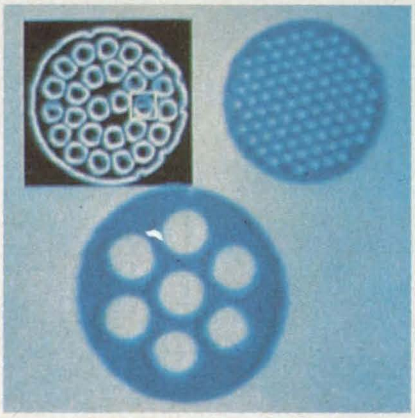
As Assistant Chief of the Flight Electronics Division at Langley Research Center since 1983, Bruce A. Conway provides technical direction of electronics sensor and information systems technology activities. Conway is also the chairman of a NASA inter-center group on aeronautical sensors that helps guide the future of aeronautic sensors research along some of the areas mentioned in his article.

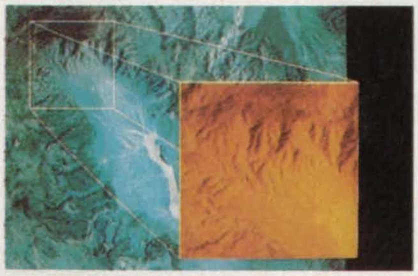
With a family background in aerospace—his father was an aeronautical engineer at NASA's Langley Research Center, Conway was a natural to work in the field of flight. Born in Hampton, VA, Conway attended the Virginia Polytechnic Institute, where in 1961 he participated in their cooperative engineering program with Langley. There he had the opportunity to work in both aeronautics and space programs.

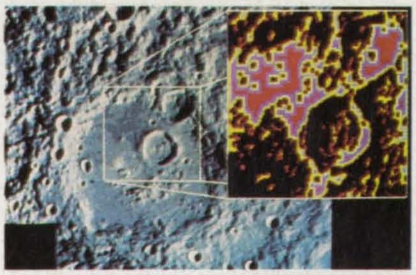
His first assignment was in a wind tunnel. "Not a typical job," Conway recalls, "we were working on some pretty neat programs, one of which became the F-111." That was shortly after NACA's transition to NASA, when the Mercury program was just starting up. "A lot was going on; they were exciting times," adds Conway.

After graduation, he worked as an aerospace technologist and, in 1972, became the Technical Assistant, Flight Dynamics and Control Division. As part of NASA's Career Development Program, Conway spent a one-year stint as Chief of Avionics at NASA Headquarters.

After returning to Langley in 1976, he became Staff Assistant to the Director of Electronics, and was appointed Technical Assistant in 1981, where he helped conceive, monitor and implement electronics research programs for aerospace applications. □







BY 2001, OUR 444R² SPACEBORNE COMPUTER WILL STILL HAVE YEARS OF LIFE LEFT.

If you launched one of our 444R² computers today, it would still be performing to spec decades from today. Control Data has built a remarkable reputation for reliability in spaceborne computers. Since 1965 we have logged more than 300,000 hours in orbit without failure. And none of our spaceborne computers has caused a delay in launch in all that time.

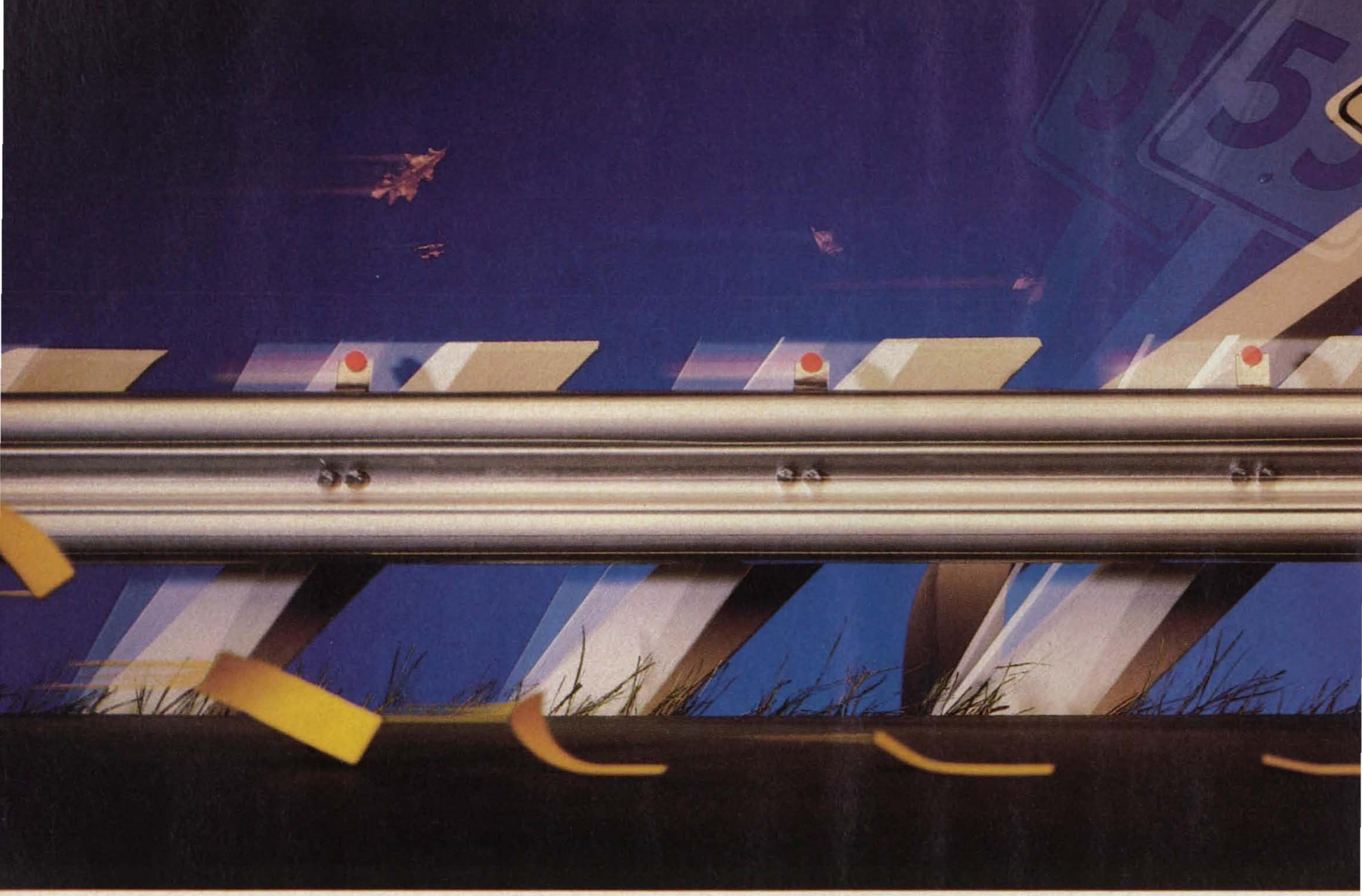
The 444R² is a certified 1750A architecture. Within its 4-inch body we've packed a radiation-hardened 3.0 MIPS processor, up to 2M word addressing space, multiple I/Os with 8 megabit/sec Serial Interface, and external system controller for test. And we've kept weight of the package in the 3-7 lb. range.

For more information about how this powerful little computer can be tailored to your application requirements, write Control Data Corporation Government Systems, P.O. Box O, Minneapolis, MN 55440. Or call (612) 853-5000.

CONTROL DATA

Circle Reader Action No. 439

200 MB/SEC I/O: APTEC BLOWS AWAY THE SPEED LIMIT



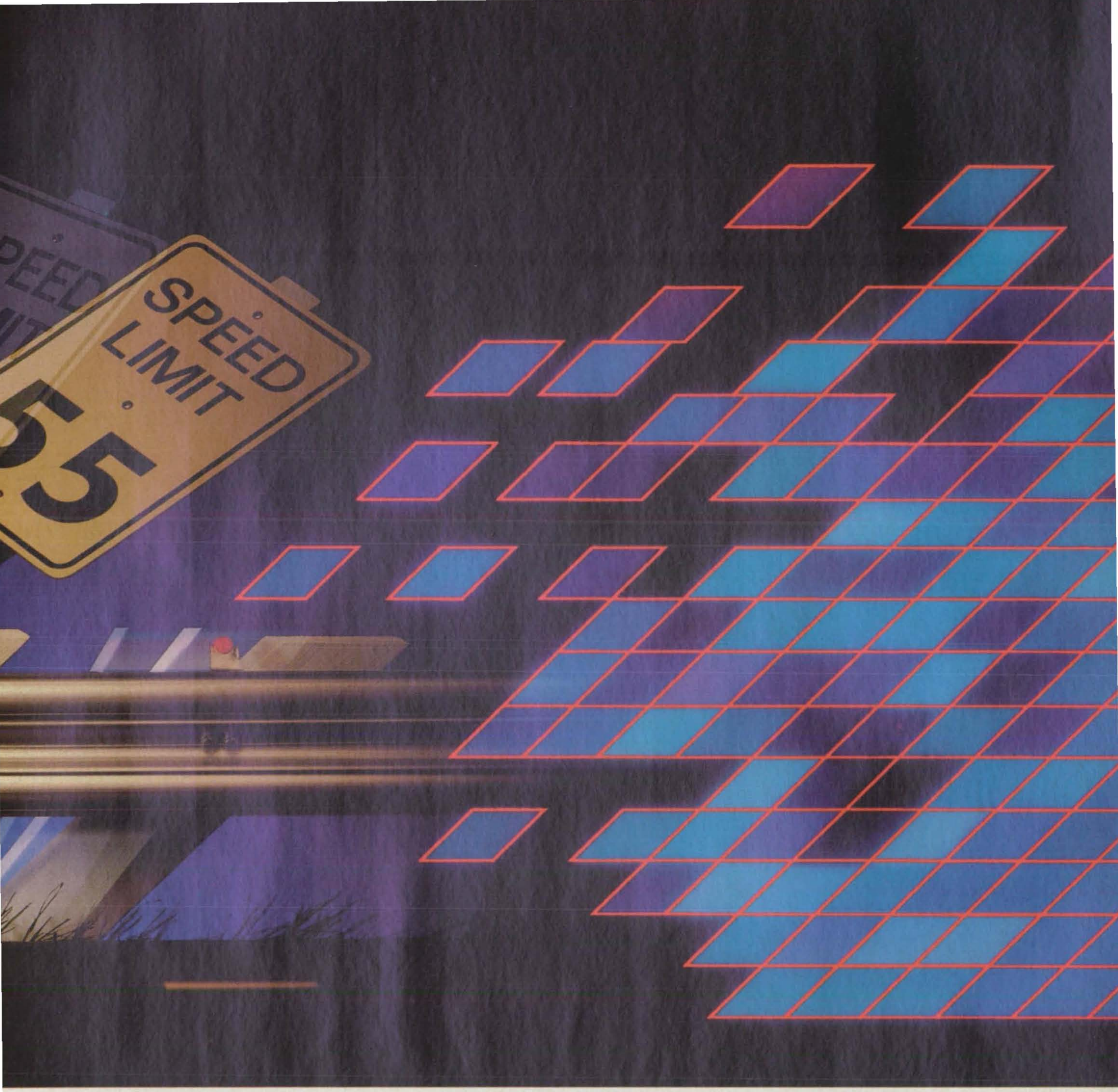
Introducing Aptec's IOC System 200: blazing fast I/O that blows past the limits of host computer and peripheral throughput.

Until now, 40 MB/sec was the fastest clocking for an I/O bus in real-time environments.

But the IOC-200—Aptec's newest, multi-processor I/O Computer—off-loads I/O from VAX™/VMS™ or other hosts at speeds of up to 200 MB/sec, sweeping away all previous barriers to peak system performance.

Now you can design systems to interact at peak speed with multiple Ibis disks. With supercomputers. With multiple A/D converters, array processors, custom devices, and more. All performing concurrently at maximum transfer rates.

There's virtually no I/O slow-down. Not even for the most strenuous real-time applications in data acquisition. Simulation. Signal or image processing.



Measure Aptec performance by the company we keep. Boeing, General Electric, Honeywell, Hughes Aircraft, JPL, Lockheed, Naval Research Laboratories—these are just a few of our *repeat* customers: proof of our product reliability and system support.

Learn how you can push your system to unprecedented limits. Call Aptec today: 1-800-552-7832.

A QUANTUM LEAP FROM THE I/O COMPUTER LEADER

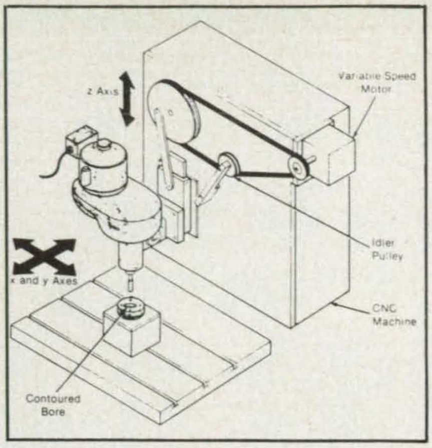
P.O. Box 6750
Portland, Oregon
97228-6750
(503) 626-9000
Telex: 467167

APTEC SYSTEMS

Circle Reader Action No. 314

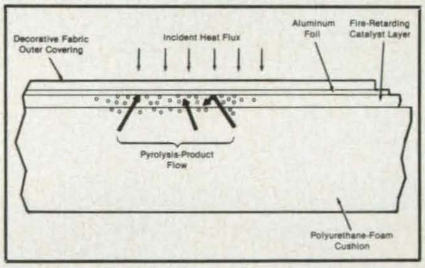
New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 19). NASA's patent-licensing program to encourage commercial development is described on page 19.



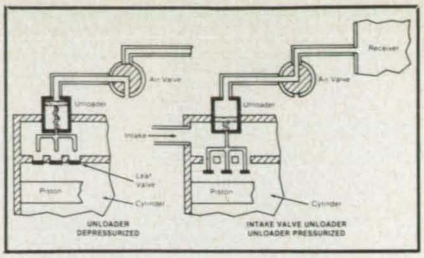
Lapping and Polishing an Elliptical Bore

A numerically controlled milling machine was modified to make the head reciprocate for the manufacture of a cryogenic vane pump that required a precise, polished surface in an elliptical bore. A vertical slide was mounted in place of the original milling-machine head. The head was mounted on the slide and driven up and down by a variable-speed motor. With this inexpensive modification, the milling machine produced the movements to trace the elliptical contour, while the auxiliary slide mechanism provided the vertical reciprocating motion required to lap the bore successfully. *(See page 70).*



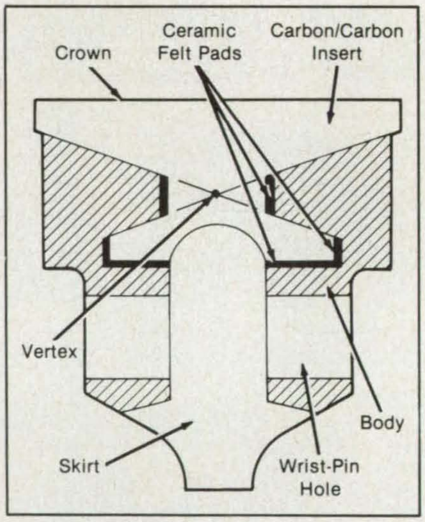
Catalytic Layer Makes Aircraft Seats More Fire Retardant

A specially constructed cushion retards fires in aircraft seats through the action of a catalytic matrix that cracks the flammable gaseous decomposition products to less flammable species. The improved cushion contributes substantially to fire safety without adding significantly to weight or to manufacturing cost. In this fire-blocking covering, flammable pyrolysis products are cracked to less flammable species by a catalytic layer covering the foam core of the cushion. The aluminum foil holds in the pyrolysis vapors to promote catalysis and prevent the spread of fire by the ignition of released vapors. *(See page 36).*



Efficient Vent Unloading of Air Compressors

A method for unloading one- and two-stage reciprocating air compressors increases energy efficiency and inhibits the deterioration of components. Instead of mechanically locking the intake valve in the open position (intake-valve unloading) to attain an acceptable duty cycle, the new method achieves unloading by allowing the compressor to vent the air to the atmosphere downstream of the compressor. This method eliminates the valve-damaging heat encountered in the conventional method and also eliminates the power surge when the pressure upstream of the check valve exceeds the receiver pressure. *(See page 58).*



Composite Piston-Cap Structure

Makers of internal-combustion engines have struggled for years with ways to incorporate heat-resistant nonmetals into the hot, moving components of these engines. A conically surfaced, composite piston-cap structure may provide the solution to this problem. The piston-cap structure, passively retained in a metallic piston and made from carbon/carbon material, is machined to the general shape shown. When the piston assembly is heated or cooled, the metal expands or contracts radially from the coincident vertex. Since the metal body is free to expand, no thermal stress is produced in the metal body or carbon/carbon cap. *(See page 69).*

EE DESIGNER™

PROFESSIONAL CAE/CAD SOFTWARE STARTING AT $975.

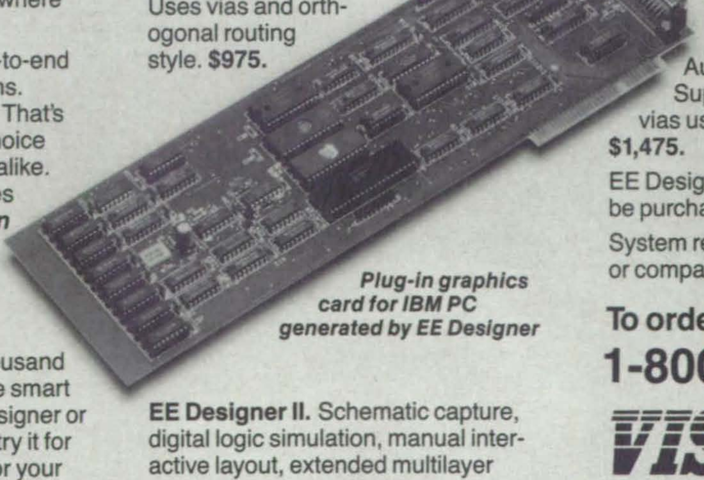
A clear path through the CAE/CAD software maze. There are many CAE/CAD systems on the market today, but most are unproven in the work environment. With over 2,000 packages sold, the one system that has been getting the job done where it counts is EE Designer!

This is the IBM PC-based end-to-end CAE/CAD system that performs. Professionally. And affordably. That's why it's quickly become first choice of small and large companies alike. And the latter category includes companies like ***AT&T, Eastman Kodak, General Electric, IBM, Motorola, Sony, Texas Instruments, Westinghouse,*** and ***Xerox,*** to name just a few.

Join them and more than a thousand other companies in making the smart move—risk free. Order EE Designer or the advanced EE Designer II, try it for 30 days and be fully satisfied or your money back.

EE Designer. Schematic capture, digital logic simulation, manual interactive layout, limited multilayer capability. **$975.**

AutoRouter. Two layer AutoRouter for EE Designer. Uses vias and orthogonal routing style. **$975.**



Plug-in graphics card for IBM PC generated by EE Designer

EE Designer II. Schematic capture, digital logic simulation, manual interactive layout, extended multilayer and surface mount (SMD) capability, enhanced graphics for symbol creation, dimensioning capabilities. Improved facilities for analog board design (improved ground planes, user definable trace widths.) **$1,875.**

AutoRouter II. Multilayer AutoRouter for EE Designer II. Supports routing with or without vias using orthogonal routing style. **$1,475.**

EE Designer II and AutoRouter II may be purchased together for **$2,975.**

System requirements: IBM PC/XT/AT or compatible with 640K memory.

To order, call toll-free
1-800-553-1177

VISA MasterCard

VISIONICS®
CORPORATION

343 Gibraltar Drive
Sunnyvale, CA 94089
(408) 745-1551

IBM PC, XT and AT are trademarks of International Business Machines Corp.

Circle Reader Action No. 473

HOW YOU CAN BENEFIT FROM NASA's TECHNOLOGY UTILIZATION SERVICES

If you're a regular reader of TECH BRIEFS, then you're already making use of one of the low- and no-cost services provided by NASA's Technology Utilization (TU) Network. But a TECH BRIEFS subscription represents only a fraction of the technical information and applications/engineering services offered by the TU Network as a whole. In fact, when all of the components of NASA's Technology Utilization Network are considered, TECH BRIEFS represents the proverbial tip of the iceberg.

On the following pages, we've outlined NASA's TU Network—named the participants, described their services, and listed the individuals you can contact for more information relating to your specific needs. We encourage you to make use of the information, access, and applications services offered by NASA's Technology Utilization Network. You can save time and money by doing so.

HOW YOU CAN UTILIZE NASA'S

Industrial Applications Centers

A nationwide network offering a broad range of technical services, including computerized access to over 100 million documents worldwide.

You can contact NASA's network of Industrial Applications Centers (IACs) for assistance in solving a specific technical problem or meeting your information needs. The "user friendly" IACs are staffed by technology transfer experts who provide computerized information retrieval from one of the world's largest banks of technical data. Nearly 500 computerized data bases, ranging from NASA's own data base to Chemical Abstracts and INSPEC, are accessible through the nine IACs, which are located throughout the nation. The IACs also offer technical consultation services and/or linkage with other experts in the field.

You can obtain more information about these services by calling or writing the nearest IAC. User fees are charged for IAC information services.

Aerospace Research Applications Center (ARAC)
Indianapolis Center for Advanced Research
611 N. Capitol Avenue
Indianapolis, IN 46204
Dr. F. Timothy Janis, Director
(317) 262-5003

Central Industrial Applications Center/NASA (CIAC)
Southeastern Oklahoma State University
Station A, Box 2584
Durant, OK 74701
Tom J. McRorey, Director
(405) 924-6822

NASA Industrial Applications Center
823 William Pitt Union
University of Pittsburgh
Pittsburgh, PA 15260
Paul A. McWilliams, Executive Director
(412) 648-7000

NASA/Southern Technology Applications Center
State University System of Florida
307 Weil Hall
Gainesville, FL 32611
J. Ronald Thornton, Director
(904) 392-6760

NASA/UK Technology Applications Center
University of Kentucky
109 Kinkead Hall
Lexington, KY 40506-0057
William R. Strong, Director
(606) 257-6322

NERAC, Inc.
Mansfield Professional Park
Storrs, CT 06268
Daniel U. Wilde, President
(203) 429-3000

North Carolina Science and Technology Research Center (NC/STRC)
Post Office Box 12235
Research Triangle Park, NC 27709
J. Graves Vann, Jr., Director
(919) 549-0671

Technology Application Center (TAC)
University of New Mexico
Albuquerque, NM 87131
Stanley A. Morain, Director
(505) 277-3622

NASA Industrial Applications Center (WESRAC)
University of Southern California
Research Annex
3716 South Hope Street
Room 200
Los Angeles, CA 90007
Radford G. King, Acting Director
(213) 743-6132
(800) 642-2872 (CA only)
(800) 872-7477 (toll-free US)

If you represent a public sector organization with a particular need, you can contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology.

Technology Application Team
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27709
Doris Rouse, Director
(919) 541-6980

A SHORTCUT TO SOFTWARE:

COSMIC®

An economical source of computer programs developed by NASA & other gov't. agencies.

Software developed by the U.S. government may be applicable to your needs. To tap this valuable resource, contact COSMIC, NASA's Computer Software Management and Information Center. Approximately 1400 computer programs and related documentation comprise the current library. New and updated programs are announced regularly in NASA Tech Briefs' Computer Programs section, and COSMIC publishes an annual software catalog.

More information about COSMIC's services can be obtained by calling or writing:

COSMIC®
Computer Services Annex
University of Georgia
Athens, GA 30602
John A. Gibson, Director
(404) 542-3265

HOW YOU CAN ACCESS TECHNOLOGY TRANSFER SERVICES AT NASA FIELD CENTERS:

Technology Utilization Officers & Patent Counsels

Each NASA Field Center has designated a Technology Utilization Officer and a Patent Counsel to facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in NASA Tech Briefs, you should request the Technical Support Package (TSP) that accompanies the brief. In the event that a TSP is not available, you can contact the Technology Utilization Officer at the NASA Field Center that sponsored the research. He can arrange for expert assistance in applying the technology by putting you in touch with the people who developed it.

If you want additional information about the patent status of a particular technology or are interested in licensing a NASA invention, contact the Patent Counsel at the NASA Field Center that sponsored the research. Be sure to refer to the NASA reference number at the end of the tech brief.

Ames Research Center
Technology Utilization Officer:
Laurance A. Milov
Mail Code 204-10
Moffett Field, CA 94035
(415) 694-5761
Patent Counsel:
Darrell G. Brekke
Mail Code 200-11
Moffett Field, CA 94035
(415) 694-5104

Goddard Space Flight Center
Technology Utilization Officer:
Donald S. Friedman
Mail Code 702-1
Greenbelt, MD 20771
(301) 286-6242
Patent Counsel:
John O. Tresansky
Mail Code 204
Greenbelt, MD 20771
(301) 286-7351

Lyndon B. Johnson Space Center
Technology Utilization Officer:
Dean C. Glenn
Mail Code EA4
Houston, TX 77058
(713) 483-3809
Patent Counsel:
Edward K. Fein
Mail Code AL3
Houston, TX 77058
(713) 483-4871

John F. Kennedy Space Center
Technology Utilization Officer:
Thomas M. Hammond
Mail Stop PT-TPO-A
Kennedy Space Center, FL 32899
(305) 867-3017
Patent Counsel:
James O. Harrell
Mail Code PT-PAT
Kennedy Space Center, FL 32899
(305) 867-2544

Langley Research Center
Technology Utilization Officer:
John Samos
Mail Stop 139A
Hampton, VA 23665
(804) 865-3281
Patent Counsel:
Howard J. Osborn
Mail Code 279
Hampton, VA 23665
(804) 865-3725

Lewis Research Center
Technology Utilization Officer:
Daniel G. Soltis
Mail Stop 7-3
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-5567
Patent Counsel:
Gene E. Shook
Mail Code 60-2
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-5753

Jet Propulsion Laboratory
Technology Utilization Manager:
Norman L. Chalfin
Mail Stop 156-211
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240

NASA Resident Office-JPL
Technology Utilization Officer:
Gordon S. Chapman
Mail Stop 180-801
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-4849
Patent Counsel:
Paul F. McCaul
Mail Code 180-801
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2734

George C. Marshall Space Flight Center
Technology Utilization Officer:
Ismail Akbay
Code AT01
Marshall Space Flight Center, AL 35812
(205) 544-2223
Patent Counsel:
Leon D. Wofford, Jr.
Mail Code CC01
Marshall Space Flight Center, AL 35812
(205) 544-0024

National Space Technology Laboratories
Technology Utilization Officer:
Robert M. Barlow
Code GA-10
NSTL Station, MS 39529
(601) 688-1929

NASA Headquarters
Technology Utilization Officer:
Leonard A. Ault
Code IU
Washington, DC 20546
(202) 453-1920
Assistant General Counsel for Patent Matters: Robert F. Kempf
Code GP
Washington, DC 20546
(202) 453-2424

IF YOU HAVE A QUESTION...

NASA Scientific & Technical Information Facility

If you have a general or specific question about NASA's Technology Utilization Network or its services and documents, you can contact the STI facility for assistance. The STI staff can answer your questions, supply documents and provide referrals to meet your needs. You can use the feedback card in this issue to contact STI directly.

NASA Scientific and Technical Information Facility

Technology Utilization Office
P.O. Box 8757
Baltimore, MD 21240-0757
Walter M. Heiland, Manager
(301) 859-5300, Ext. 242, 243

Electronic Components & Circuits

Transformerless dc-Isolated Converter

The circuit uses capacitive decoupling instead of transformer isolation.

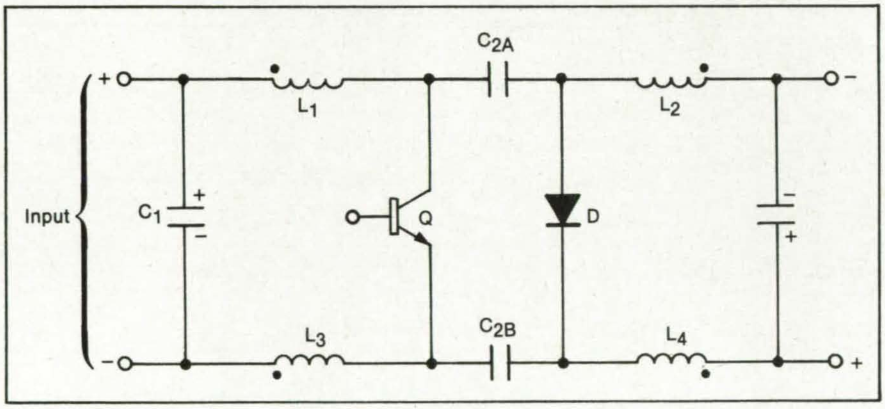
NASA's Jet Propulsion Laboratory, Pasadena, California

An efficient voltage converter employs capacitive instead of transformer coupling to provide dc isolation. It offers buck/boost operation, minimal filtering, and low parts count, with possible application in photovoltaic power inverters, power supplies, and battery chargers.

The topology of the dc-isolated converter is shown in Figure 1. The output is isolated from the input by capacitors C_{2A} and C_{2B}. When Q is on, energy is transferred from C_{2A} and C_{2B} to L_2, L_4, and the load. When Q is off, energy is transferred from the source, L_1, and L_3 to C_{2A} and C_{2B} and from L_2 and L_4 to the load. With negative coupling between L_1 and L_2 and between L_3 and L_4, either the input or the output ripple currents may be reduced to zero, depending on the coupling magnitudes.

By making $L_1 = L_3$, $L_2 = L_4$, $C_{2A} = C_{2B}$, $K_{12} = K_{34}$, and $K_{13} = K_{24}$ (where K_{ij} is the coupling between L_i and L_j), the common-mode voltage and current ripples are made zero. The ratio of output voltage to input voltage is $\eta/1-\eta$, where η is the duty cycle of Q. The peak voltage stress in Q is $V_{in} + V_{out} + \Delta V_{cpp}$, where V_{ccp} is the peak voltage on each C_2 capacitor. The peak current stress on Q is $I_{in} + I_{out} + \frac{1}{2}(\Delta I_{in\,pp} + \Delta I_{out})$, where $\Delta I_{in\,pp}$ is the peak output-current ripple.

A photovoltaic-array application is shown in Figure 2. The converter portion, consisting of Q_1, D, L_1, L_2, L_3, L_4, C_1, C_2, and C_3, converts the unregulated array output to a variable voltage, the magnitude which is controlled by the duty cycle of Q_1.



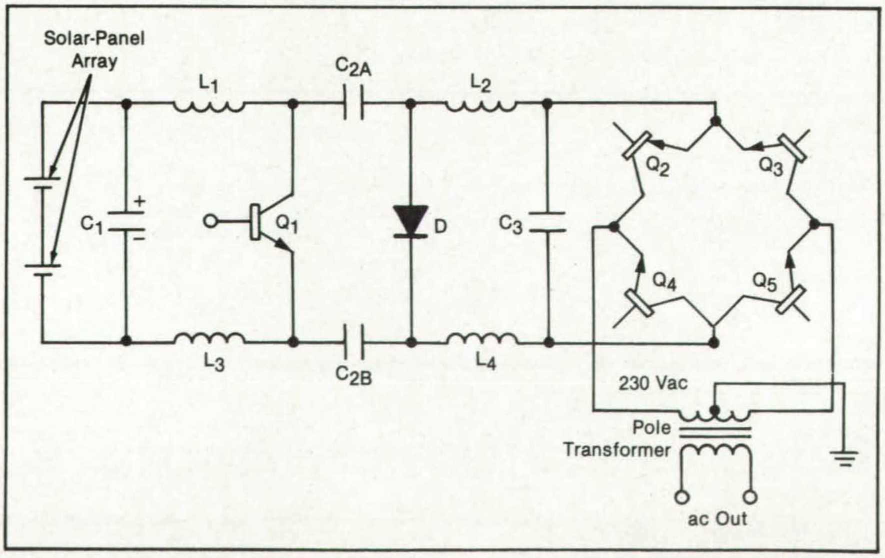
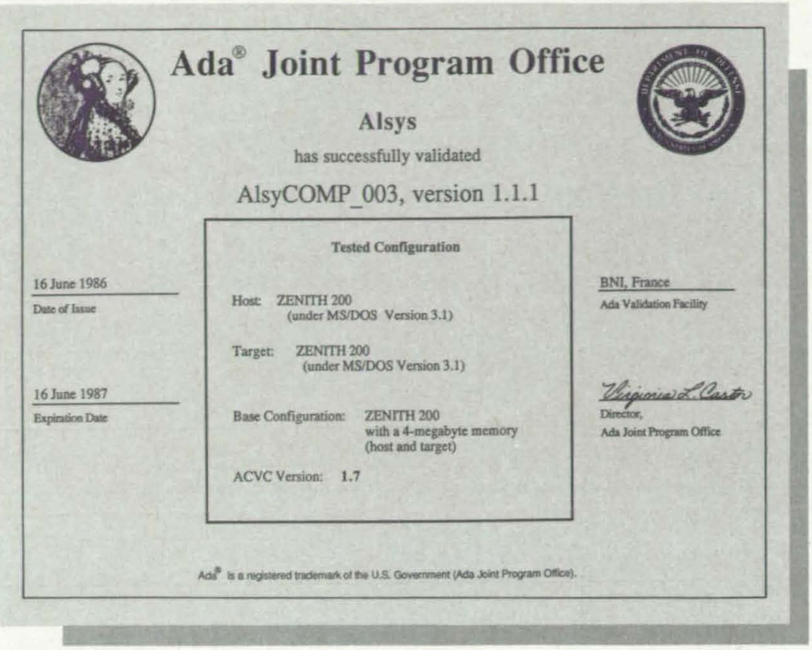


Figure 2. **In the Photovoltaic Inverter Circuit** with a transformerless converter, Q_2, Q_3, Q_4, and Q_5 form a line-commutated inverter (polarity reverser). Switching losses and stresses are nil because switching is performed when the current is zero.

Alsys validates Ada* compiler for Zenith Z-248 MS/DOS for government/military users.


Ada® Joint Program Office

Alsys

has successfully validated

AlsyCOMP_003, version 1.1.1

Tested Configuration

Host: ZENITH 200 (under MS/DOS Version 3.1)

Target: ZENITH 200 (under MS/DOS Version 3.1)

Base Configuration: ZENITH 200 with a 4-megabyte memory (host and target)

ACVC Version: 1.7

16 June 1986
Date of Issue

16 June 1987
Expiration Date

BNI, France
Ada Validation Facility

Director,
Ada Joint Program Office

Ada® is a registered trademark of the U.S. Government (Ada Joint Program Office).

Alsys has validated its Ada compiler for the Z-200 series of computers running under MS/DOS, including the Air Force and Navy contracted Z-248. The Ada Compiler, bundled with a 4 MB RAM board, is available in single unit quantities for $2,995.

The compiler, validated at the same time for the IBM PC AT, HP's Vectra, Compaq's Deskpro 286, Sperry's PC/IT, Tandy's 3000 HD and the Goupil/40 can convert general purpose desktop computers to program development workstations using the broadly mandated Ada language.

Programs developed on the Z-248 can run on the Z-120, the IBM PC, and most other PC compatibles.

Alsys is the world's leading Ada company, with other compilers validated for Sun, Apollo, HP and Altos systems.

alsys

ALSYS, INC.,
1432 Main Street, Waltham, MA 02154
NASA 5/87

ADA NOW. Tell me more about the 80286 Ada compiler.

Name __________
Title __________
Company __________
Address __________
City __________
State/Zip __________
Phone/Ext __________

In the US: Alsys Inc., 1432 Main St., Waltham, MA 02154 Tel: (617) 890-0030

In the UK: Alsys Ltd., Partridge House, Newtown Rd., Henley-on-Thames, Oxon RG9 1EN Tel: 44 (491) 579090

In the rest of the world: Alsys SA, 29, Avenue de Versailles, 78170 La Celle St., Cloud, France Tel: 33 (1) 3918.12.44

*Ada is a registered trademark of the U.S. Government (AJPO). Alsys is the trademark of Alsys, Inc. References to other computer systems use trademarks owned by the respective manufacturers.

Prices refer to U.S. only. Contact Alsys for prices in other countries.

NOW AVAILABLE
AdaPROBE™
Program Viewer and Symbolic Debugger for the AT and Compatibles

Adanow

The duty cycle of Q_1 is controlled such that the instantaneous magnitude of the output current is a sinusoid that is proportionate to the instantaneous line voltage. The proportionality constant is servo-adjusted such that the power delivered to the line is a maximum.

With appropriate coupling between L_1 and L_2 and between L_3 and L_4, the output ripple is zero, and C_3 may therefore be small. The array may be grounded at any point because of the dc isolation provided by C_{2A} and C_{2B}. With $L_1 = L_3, L_2 = L_4$, and $C_{2A} = C_{2B}$, the common-mode output ripple is also zero.

This work was done by Wally E. Rippel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 37 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 19] Refer to NPO-16141.

Thermal and Electrical Recharging of Sodium/Sulfur Cells

An efficiency as high as 60 percent may be achieved.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed thermal- and electrical-recharging scheme is expected to increase the overall energy efficiency of a battery of sodium/sulfur cells (beta cells). The scheme takes advantage of a peculiarity in the chemical kinetics of the recharge portion of the operating cycle to give a thermal assist to the electrically driven chemical reactions. Possible future applications include portable power supplies and energy storage in commercial power systems during offpeak periods.

The chemical product of the beta-cell discharge is a mixture of sulfur and sodium/sulfur compounds, including solid Na_2S_3. For charging, this salt can be partly dissociated by heating it. Of the dissociation reactions, the principal one is $5Na_2S_3 \rightarrow 4Na + 3Na_2S_5$. The thermal process helps in two ways:

1. The energy necessary to dissociate the Na_2S_3 can be supplied thermally at a higher efficiency than it can be supplied electrically as in the present all-electrical charging scheme (see top of figure).
2. The resulting increase in the activity of the sodium reduces the electrical potential that must be applied to force the sodium ions across the solid electrolyte while recharging.

In one version of the new recharging scheme (see middle of figure), the heat would be supplied to the battery from an external source — perhaps a steam generator. In another version (see bottom of figure), waste heat from a turbine would be used to heat the battery, thereby using the energy of the overall system even more efficiently.

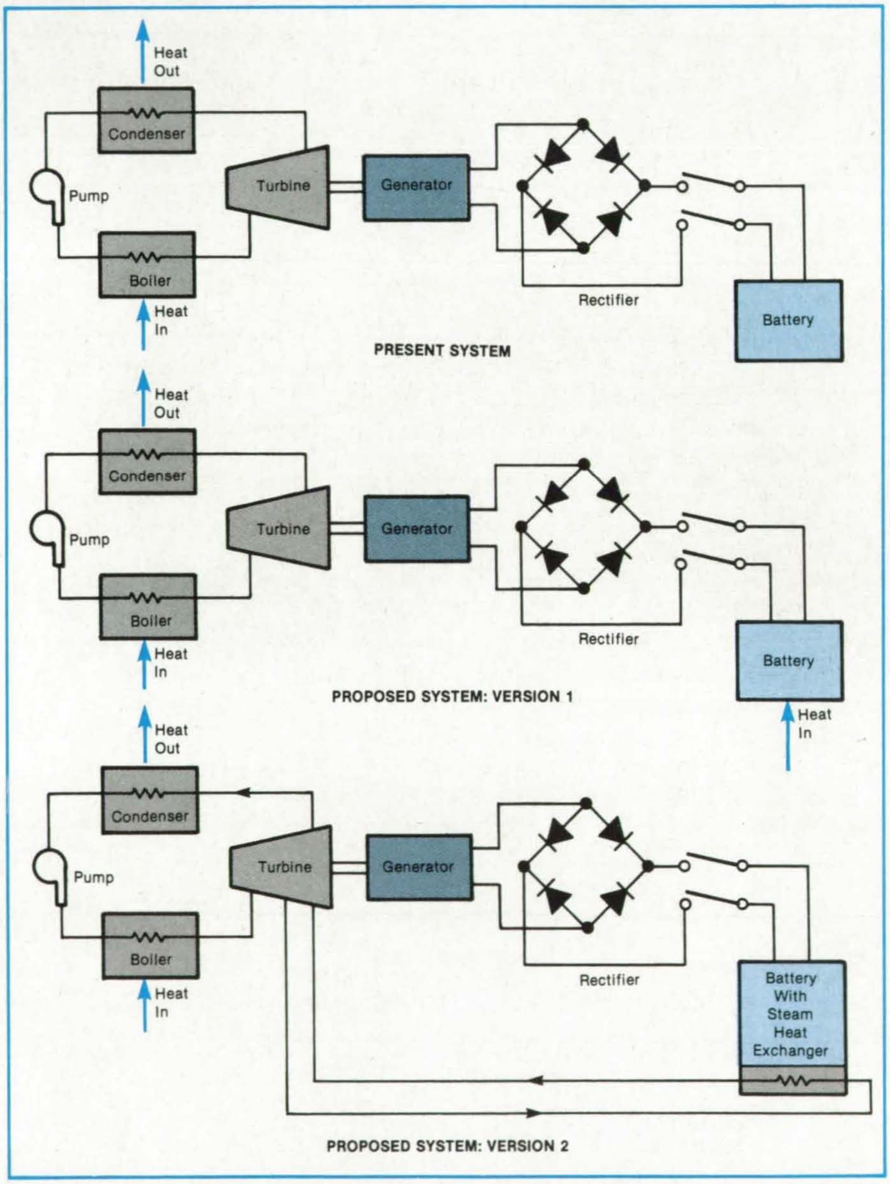
The overall charging efficiencies of the present storage system and the steam-generator version of the proposed system have been estimated by

$$\eta_{overall} = \eta_S\eta_T\eta_G\eta_R$$

for the present system and

$$\eta_{overall} = (1 - n)\,\eta_S\eta_T\eta_G\eta_R + n\eta_S$$

where η_S, η_T, η_G, and η_R denote the efficiencies of the steam generator, turbine, generator, and rectifier, respectively, and n denotes the fraction of the total energy input supplied directly to the battery as thermal energy. Using typical values of $\eta_S = 0.80$, $\eta_T = 0.40$, $\eta_G = 0.96$, $\eta_R = 0.96$, and $n = 0.6$, the efficiency of the proposed system would be 0.60, more than double the 0.29 of the present system.



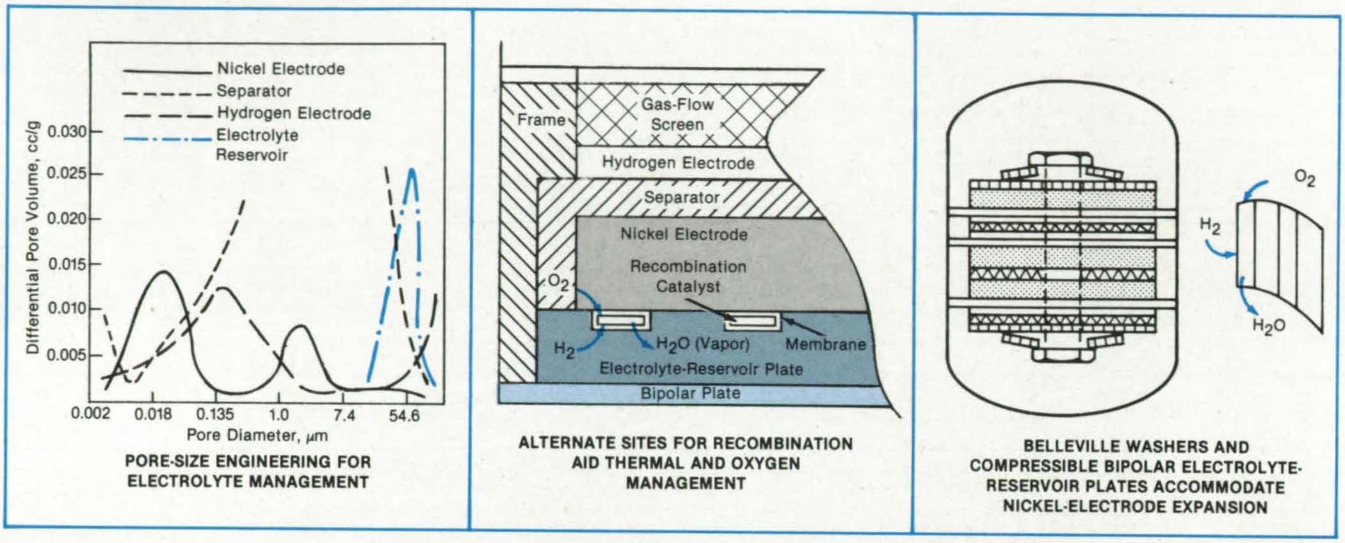
The **Present System for Charging Na/S Batteries** puts energy into the batteries along the electrical path only. The proposed systems put energy in along electrical and thermal paths for greater energy efficiency.

This work was done by Robert Richter of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 38 on the TSP Request Card.*
NPO-16139

Design Principles for Nickel/Hydrogen Cells and Batteries

New designs should prolong cell life.

Lewis Research Center, Cleveland, Ohio



The **Application of Design Principles for Ni/H_2 Cells** is based partly on previous experience and partly on extrapolations of fundamental principles. The new designs should result in longer cell life at deep discharge.

Individual-pressure-vessel (IPV) nickel/hydrogen cells and bipolar batteries are being developed for use as energy-storage subsystems for satellite applications. The design principles that have been applied to these systems draw upon extensive background in separator technology, alkaline-fuel-cell technology, and several alkaline-cell technology areas. These principles are rather straightforward applications of capillary-force formalisms, coupled with the slowly developing data base resulting from careful post-test analyses. They are based on preconceived assumptions relative to how these devices work and how they might be designed so that they display longer cycle lives at deep discharge.

The basic nickel/hydrogen cell consists of a gas electrode for the anode, a separator to form an ionic bridge to the cathode, and the cathode consisting of nickel hydroxide that is contained within the pores of an electrically conductive substrate. In addition to these basic components, there is a wide variety of options for other components that assist in electrolyte and oxygen management.

The types of shortcomings that are currently associated with nickel/hydrogen devices can be divided into two categories. The first category includes those that are obvious, based on the results of post-test analyses, in cases where failure had occurred, such as the following:

- Unaccommodated cathode expansion;
- Uncontrolled recombination of hydrogen and oxygen;
- Unreplenished loss of electrolyte within the components; and
- Component performance degradation.

The second category includes those decay processes that have not yet been identified as failure modes due to the rapid loss of performance of the device because of the first type of decay processes. The design principles employed address both classes of decay modes.

By applying design principles to nickel/hydrogen cells and batteries in the areas of oxygen management, electrolyte management and reservoiring, and thermal management and component-growth management techniques, designs and/or design modifications have been proposed for both IPV and bipolar cells and batteries. Some of the design modifications (see figure) that have come about as a result of applying these design principles to Ni/H_2 devices are summarized below:

- Oxygen management and thermal management are aided by the incorporation of alternate recombination sites. Recombination is removed from the surface of the hydrogen electrode to remote sites adjacent to a cooling surface. This protects the hydrogen-electrode surface from damage resulting from uncontrolled recombination and aids in thermal management by moving the site of the heat generation for the recombination reaction adjacent to a cooling surface.
- The principles of pore-size engineering have been applied to component designs to insure that the proper distribution of electrolyte exists within the components throughout the life of the cell. Reservoirs incorporated into both designs provide electrolyte to the cells as needed.
- Nickel-electrode expansion is accommodated in both Ni/H_2 designs. In the IPV cells, Belleville washers are incorporated at both ends of the stack core. They are designed to be compressed as the nickel electrodes expand. In bipolar cells, a compressible reservoir provides this function. These modifications should satisfy some of the needs of the nickel/hydrogen system and ultimately lead to performance and life improvements.

This work was done by Lawrence H. Thaller, Michelle A. Manzo, and Olga D. Gonzalez-Sanabria of **Lewis Research Center**. *Further information may be found in NASA TM-87037 [N85-31646/NSP], "Design Principles for Nickel-Hydrogen Cells and Batteries."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 19]. Refer to LEW-14369.

Pulse Test of Coil Insulation

The waveform of the back-electromotive force reveals defects.

Marshall Space Flight Center, Alabama

A simple pulse test reveals defects in inductor coils. Devised for use on servovalve solenoid coils on the Space Shuttle, the test should also be applicable to transformer windings, chokes, relays, and the like.

The test exploits the back-electromotive force that is generated by the coil when the current through it is suddenly interrupted. In the case of the servovalve, for example, the coil is connected to its drive circuit through a reed relay and is excited at or below its rated steady operating current and voltage (typically, 30 mA and 10 V, respectively), while the servovalve spring is loaded. The relay contact is then opened to turn off the coil current. (This also protects the drive circuit from the resulting voltage pulse.) The pulse is monitored on an oscilloscope or other suitable device.

The pulse from a typical good solenoid coil has a damped sinusoidal waveform with an initial amplitude of 500 to 900 V. A typical defective coil shows an irregular and/or truncated waveform with an initial amplitude less than 200 V. The waveform can reveal coil open circuits, short-circuited turns, and internal insulation breakdowns.

The back-emf pulse test is a convenient technique for testing coil insulation and high-voltage performance without damage to the drive circuit from overvoltage, to the coil from overcurrent, or to the associated mechanical parts from overstress. The waveform of a coil can be measured when it is new and known to be good; this waveform can then be used as a signature for comparison with subsequent measurements to determine whether the coil is still good.

This work was done by Ralph E. Kroy of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-29236.

Electronic Systems

Hardware, Techniques, and Processes

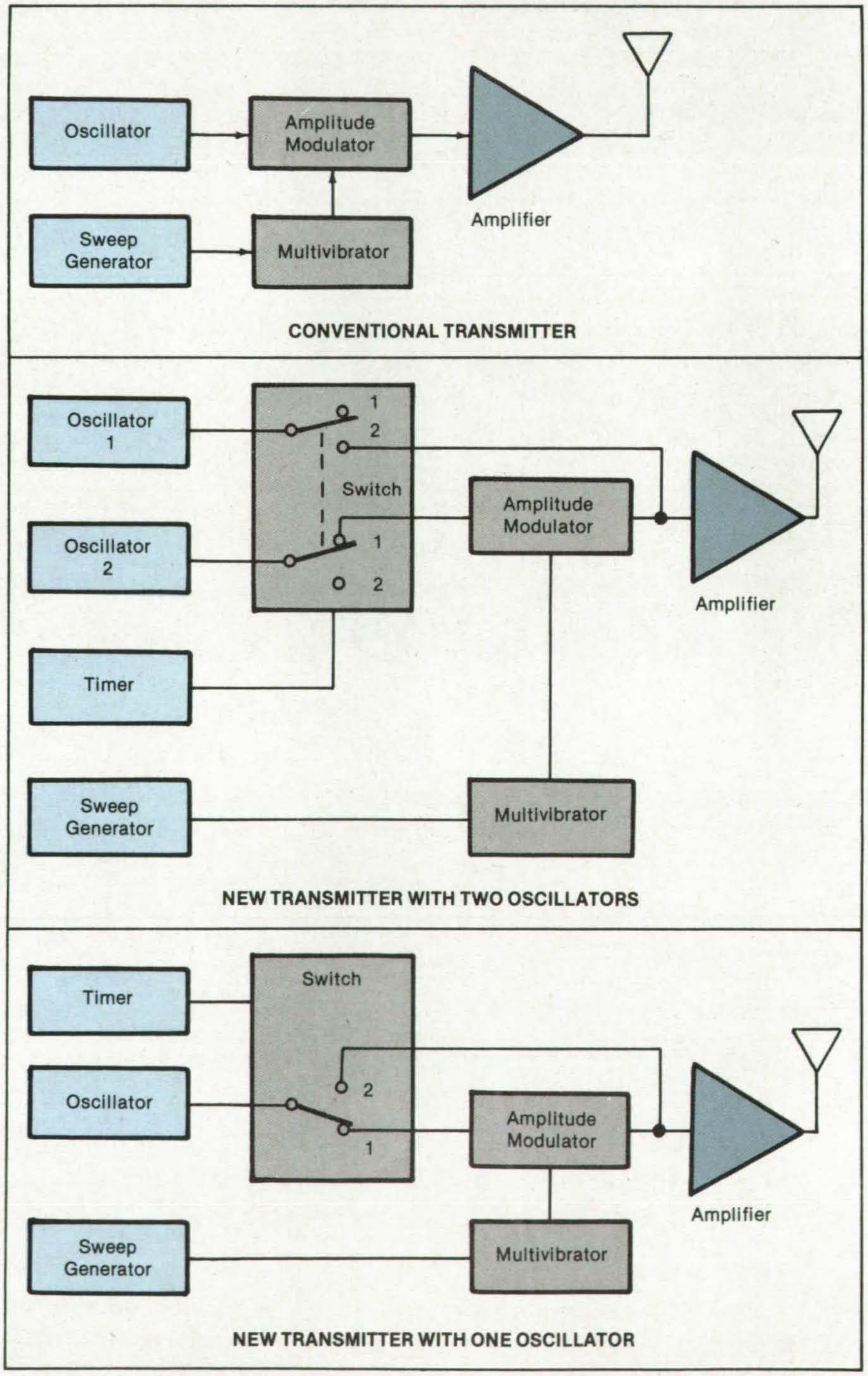
Computer Programs

Emergency-Radio Modulation Would Identify Type of Vehicle

Interruption periods would differ between airplanes and vessels.

Goddard Space Flight Center, Greenbelt, Maryland

A proposed modulation scheme for emergency radio beacons would aid searchers by indicating the kind of vehicle in distress. The transmitted signal would be similar to the present standard signal of emergency locator transmitters (ELT's) and emergency position-indicating radio beacons (EPIRB's) but would also include



The **New Emergency Beacon** is similar to the conventional one, except that the modulation is interrupted periodically while an unmodulated carrier is transmitted.

periods of unmodulated carrier.

With current standard ELT's and EPIRB's, it is particularly difficult to identify a distressed vehicle in a coastal region, where it is not immediately obvious whether one should search for a vessel or an aircraft. Furthermore the spectrum transmitted by these ELT's and EPIRB's is not readily processable by automatic receiving equipment.

In the new scheme, the two types of vehicles would be distinguishable through differences in the modulated and unmodulated periods. In addition, the periodic bursts of unmodulated carrier would enable the reception of more signal power by direction-finding equipment and allow the use of phase-locked-loop receivers.

In a typical transmitter according to the present standard, the signal from an oscillator is amplitude-modulated at a varying audio frequency. For example (see top of figure), the modulation could be applied by an astable multivibrator, the frequency of which is controlled by a sweep generator. In the new scheme, an emergency aircraft transmitter would transmit the standard audio-modulated signal for 8 seconds, then an unmodulated carrier for 2 seconds; this sequence would be repeated continuously. The new scheme for vessels would be similar, except that the audio period would be 13 seconds and the unmodulated period 2 seconds.

One way to implement the new modulation scheme is to use two oscillators and a ganged double-pole, double-throw mechanical or electronic switch that alternately connects one oscillator directly to the output amplifier or the other to the modulator. In the example shown in the middle of the figure, the switch would be in position 1 during the modulation period, then in position 2 for the unmodulated-carrier period.

The version shown at the bottom of the figure includes one oscillator and a single-pole, double-throw switch. Again, the switch would be in position 1 during the modulation period, then in position 2 during the no-modulation period. A third version would be similar to the conventional unit shown at the top of the figure, except that a single-pole, single-throw switch would be placed between the multivibrator and the modulator, to be turned on during the modulation period and off during the no-modulation period.

This work was done by Paul Wren of **Goddard Space Flight Center**. *No further documentation is available.*
GSC-12845

Interface for a Multiple-User Computer System

Diverse hardware and software are connected with minimal inconvenience to users.

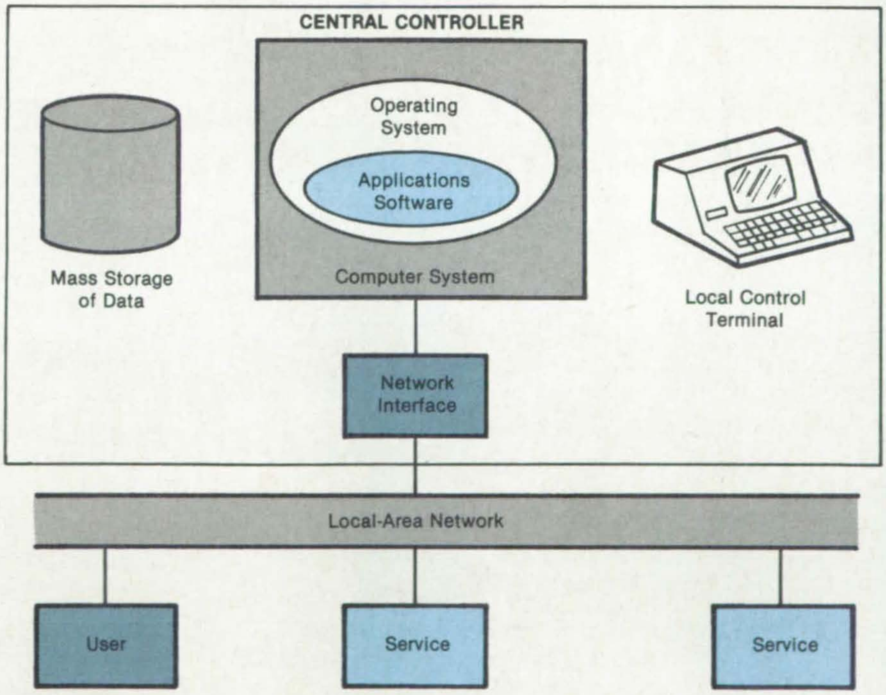
NASA's Jet Propulsion Laboratory, Pasadena, California

A central controller for a large multiple-user computer network makes the various computer services compatible regardless of the diversity of their hardware and software. With the central controller, users can readily gain access to a host computer and to other terminals and services. The users need be familiar only with the language and procedures of their own terminals, even when communicating with normally incompatible services or users.

These advantages are important; for example, in the transmission of word-processing files by electronic mail. Without the central controller, before such files can be transmitted the type of word processor used by the recipient must be determined so that the sender can have the files translated into the proper format; the sender must also learn the commands necessary to mail the file. These steps are automated by the central controller, which maintains data bases on file translation, sends commands to computers in the network to provide translation and other services, and properly converts mailing commands.

The central controller serves as an application-level protocol-exchange manager. It accepts information through a single menu-structured user interface; users learn just one technique for obtaining access to all services.

The central controller comprises computer equipment, system software, and special applications software (see figure). The equipment should support a multiple-user operating system such as DEC VMS® or AT&T Unix®.



The **Central Controller** gives a user a single interface to services available in a local-area network of computers.

The application software consists of many software modules grouped into the following four categories:

1. The command and monitor data-processor modules generate the commands to computer services; ordinarily, these commands would be furnished by the user. The module also evaluates

responses and oversees error recovery, message forwarding, and process continuation.
2. The input and output processor modules accept input and place output in the format for various types of terminals.
3. The mass-storage tables, so labeled because they are kept on tape, disks, or other storage media, contain information used infrequently by the controller, and such static information as data on terminals.
4. The active-process tables include information that must be obtained often and rapidly — for example, command-processing and translation information.

With these components, the controller can halve the number of commands a user must enter. The user requires only one account on the controller and one on the electronic mail system. The user does not need experience with other mail systems or controllers.

This work was done by Paul A. Headley of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 121 on the TSP Request Card.*
NPO-16556

Controlling Multiple Registers on a Computer Bus

The number of addressable registers is increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

A monitoring-and-controlling interface circuit expands the capabilities of a DR11-C (or equivalent) input/output port for a computer that communicates with peripheral equipment via a UNIBUS (or equivalent) data bus. Using only three address locations on the bus, the unit enables any number of external registers to be addressed, read, or written.

The status register of the input/output port has only two bits for controlling what the input and output buffer registers read from or write to an external device. Therefore, the unassisted input/output port can read or write only four external registers. This is a significant limitation because many applications require more than four.

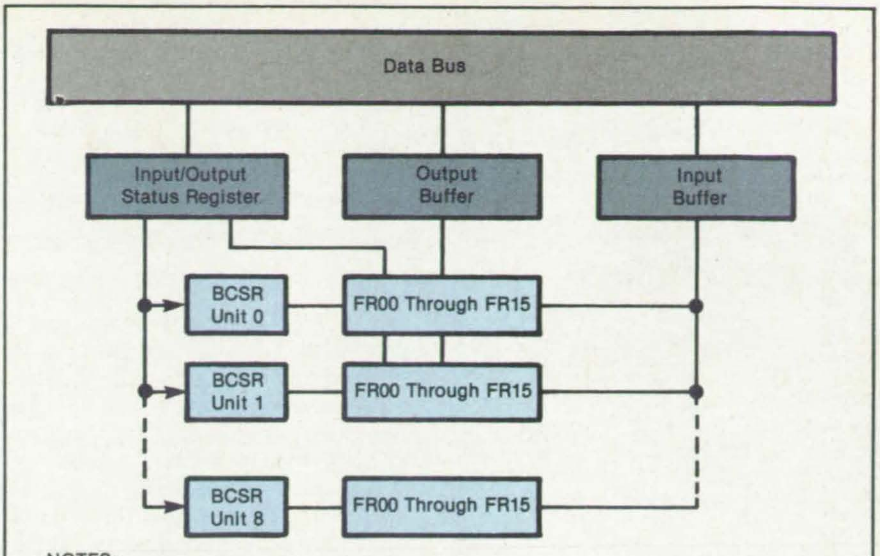
The interface circuit (see figure) uses a form of conditional indirect addressing to establish communication with a large number of external devices and registers. It uses bits 0 and 1 of the input/output port status register (CSR0 and CSR1) as pointers that denote the group of external registers and devices within which some or all units are to be read or written. An external broadcast and control status register (BCSR) finishes the task of addressing, through an address-decoding process that directs a "read" or "write" request to the desired unit(s).

For example, a particular system might be configured so that if (CSR0, CSR1) = (0,0) and a "write" operation is requested, the BCSR causes the message in question to be written to all broadcast

registers in all units. In another example, the condition (CSR0, CSR1) = (1,0) might cause a "read" or "write" to be broadcast only to those registers in those units indicated by three address bits in the portion of the BCSR called the "function-register pointer" plus three bits in another portion that are derived by an address-decoding circuit and indicate the unit to be addressed.

Another two bits in the BCSR can be used to increment the function-register pointer automatically. For example, one of them can be set to cause the function-register pointer to increment by one each time data are written into a function register, and the other could be set to cause the function-register to increment by one whenever a function register is read. Manual switches on the address-decoding circuit can be thrown to select or reject a particular unit.

This work was done by Stanley S. Brokl of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 150 on the TSP Request Card.*
NPO-16880



An **Input/Output Port** is augmented by BCSR's and by address-decoding circuits (not shown) to enable communication with a large number of external registers.

Physical Sciences

Hardware, Techniques, and Processes

Ionization Chamber Measures Extreme Ultraviolet

Absolute photon fluxes are measured from 50 to 575 Å.

NASA's Jet Propulsion Laboratory, Pasadena, California

An ionization chamber operates in nearly total photon absorption as a stable, self-calibrating detector of ionizing extreme ultraviolet radiation. The working gas of the instrument is neon, the photoionization properties of which are well known and readily applicable to absolute measurements. Designed for measurements of the solar ultraviolet flux aboard a sounding rocket, the instrument could also be used on Earth to measure ultraviolet radiation in vacuum systems. (The instrument cannot be used in air because air is opaque in its wavelength range.)

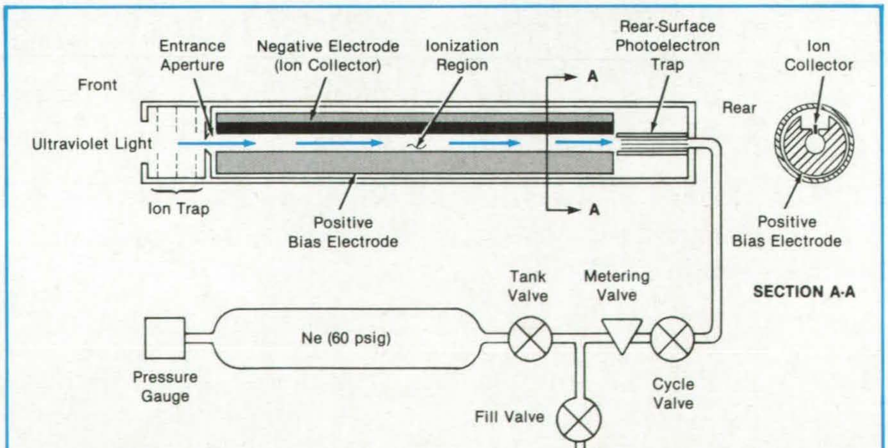
The chamber (see figure) includes a long, narrow ionization region surrounded by a gapped cylindrical positive bias electrode. A negative ion-collecting electrode is placed in the gap. A series of electrodes in front of the entrance aperture collect ions that enter from the outside to prevent them from contributing spuriously to the photoionization current.

Neon gas is periodically admitted to the chamber. Ultraviolet photons enter through the aperture and are absorbed by ionization of neon atoms. The resulting positive neon ions are repelled by the positive electrode and collected by the negative electrode, while the photoelectrons travel to the positive electrode. The ions are collected rapidly enough to avoid a significant amount of electron/ion recombination.

Care is taken to prevent photoelectrons from being emitted by solid surfaces and contributing to the measured current. When the instrument is aimed at the radiation source, the electrodes fall in the shadow of the entrance aperture, and no radiation strikes the electrodes to produce photoelectrons there. An electron trap, consisting of a honeycomblike bundle of long, thin tubes, is placed at the rear of the chamber to suppress the effects of photoelectrons from that region. However, because the instrument operates with neon pressures sufficient for nearly total photon absorption, there is very little photon energy available to excite photoelectrons at the rear surfaces.

The potential difference between the electrodes is set at 21.0 V, which is in the plateau region of the ionization-current-versus-potential curve. The instrument is operated on a 32-second cycle, during which the neon gas is admitted into the chamber, then allowed to escape through the aperture. The photocurrent is measured along with the decaying neon pressure. A pressure-independent photocurrent reading is obtained by extrapolating the upper straight-line portion of the resulting current-versus-pressure curve to zero pressure.

The long-wavelength limit of the instrument is 575 Å, corresponding to the 21.56-eV ionization potential of neon. The short-wavelength limit is about 50 Å,



The **Ionization Chamber** collects positive neon ions and electrons produced by the irradiation of neon gas by ultraviolet photons. Approximately one ion is produced by each photon; consequently, the photoionization current is nearly proportional to the photon flux.

below which the photoionization cross section of neon decreases. Between these limits, each absorbed photon produces one singly charged ion (to a close approximation) so that the photoionization current can be considered proportional to the photon flux.

This work was done by Robert W. Carlson of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 39 on the TSP Request Card. NPO-16369*

Correlation of Catalytic Rates With Solubility Parameters

A catalyst maximizes activity when its solubility parameter equals that of the reactive species.

NASA's Jet Propulsion Laboratory, Pasadena, California

The catalytic activities of some binary metal alloys are at a maximum when the alloy compositions correspond to Hildebrand solubility parameters equal to those of the reactive atomic species on the catalyst. If this suggestive correlation proves to be general, it could be applied to the formulation of other mixed-metal catalysts. It also could be used to identify the reactive species in certain catalytic reactions.

For elements, the Hildebrand solubility parameter, δ, is given by

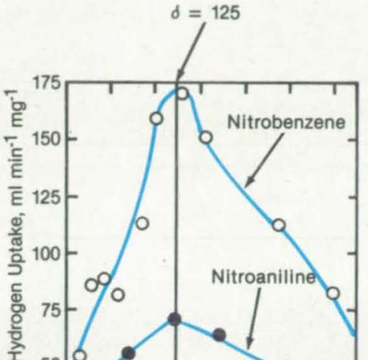
$$\delta = (|E|/V)^{1/2}$$

where E is the molar cohesive energy of the pure element and V is its molar volume. Derived from the theory of "regular" solutions, the solubility parameter of a mixed metal catalyst, δ_m, is given by

$$\delta_m = \phi_1 \delta_1 + \phi_2 \delta_2$$

where ϕ_1 and ϕ_2 represent the volume fractions of metals 1 and 2, respectively, and δ_1 and δ_2 represent the corresponding Hildebrand solubility parameters for the pure metals.

As seen in the figure, the hydrogenation of nitrobenzene and nitroaniline on an Ru/Pt catalyst is most rapid when the catalyst composition is 0.25-mole fraction Ru and 0.75-mole fraction Pt. Because the molar volumes of Ru and Pt are 8.29 cm^3/mole and 9.09 cm^3/mole, respectively, one mole of this alloy contains 2.07 cm^3 Ru (i.e., 0.25 mole Ru × 8.29 cm^3/mole Ru) and 6.82 cm^3 Pt (i.e., 0.75 mole Pt × 9.09 cm^3/mole Pt). Consequently, the volume fraction of Ru equals 2.07/(2.07 + 6.82) = 0.233, and the volume fraction of Pt equals 6.82/(2.07 + 6.82) = 0.767.



The **Hydrogenation of Nitrobenzene and Nitroaniline** occurs most rapidly when the composition of the Ru/Pt catalyst is about 25 percent Ru and 75 percent Pt. The calculated solubility parameter of this alloy is close to that of atomic hydrogen.

The Hildebrand solubility parameter for Ru is 136.38 $(cal/cm^3)^{1/2}$ and that of Pt is 121.86 $(cal/cm^3)^{1/2}$. Using these volume fractions and solubility parameters in the equation for ϕ_m, the Hildebrand solubility parameter for the alloy is given by

$$\delta = (0.23 \times 136.38) + (0.77 \times 121.86) = 125.20\ (cal/cm^3)^{1/2}$$

This is close to the Hildebrand solubility parameter for atomic hydrogen, δ_H = 124.2 $(cal/cm^3)^{1/2}$.

In the cases of the catalytic hydrogenations of nitrobenzene on Ir/Pt, of methyl ethyl ketone on Pd/Ru, and of an aromatic ether on Rh/Pt, the alloys that yield the maximum hydrogenation rates are those with solubility parameters of 123.6, 126.0, and 123.8 $(cal/cm^3)^{1/2}$ respectively, again in close agreement with δ_H.

The agreement of δ_H with δ_m suggests that a catalyst solubilizes key reactive constituents on its solid surface, the resulting catalyst/reactant complex being a solid solution, and hence falling into the domain of "regular" solution theory. Presumably the concentration of the reactive species on the catalyst is greatest when the solubility parameter of the catalyst equals that of the reactant.

The solubility parameter for the Ag/Au alloy that yields the maximum oxidation rate for ethylene is close to that of atomic oxygen. This suggests that atomic oxygen might be the active species in this oxidation, contrary to the current theory that this oxidation involves molecular oxygen ions.

This work was done by Daniel D. Lawson and Christopher England of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 69 on the TSP Request Card.* *NPO-16613*

Determing Heats of Combustion of Gaseous Hydrocarbons

The enrichment-oxygen flow rate-ratio is related to the heat of combustion.

Langley Research Center, Hampton, Virginia

As a spin-off of an oxygen-monitoring-and-control system developed for the Langley 8-Foot High Temperature Tunnel, a highly accurate, on-line technique has been developed for determining heats of combustion of natural-gas samples. It is based on measuring the ratio m/n, where m is the (volumetric) flow rate of oxygen required to enrich the carrier air in which the test gas flowing at the rate n is burned, such that the mole fraction of oxygen in the combustion-product gases equals that in the carrier air. The m/n ratio is directly related to the heats of combustion of the saturated hydrocarbons present in the natural gas.

During the development of the oxygen-monitoring-and-control system, it was

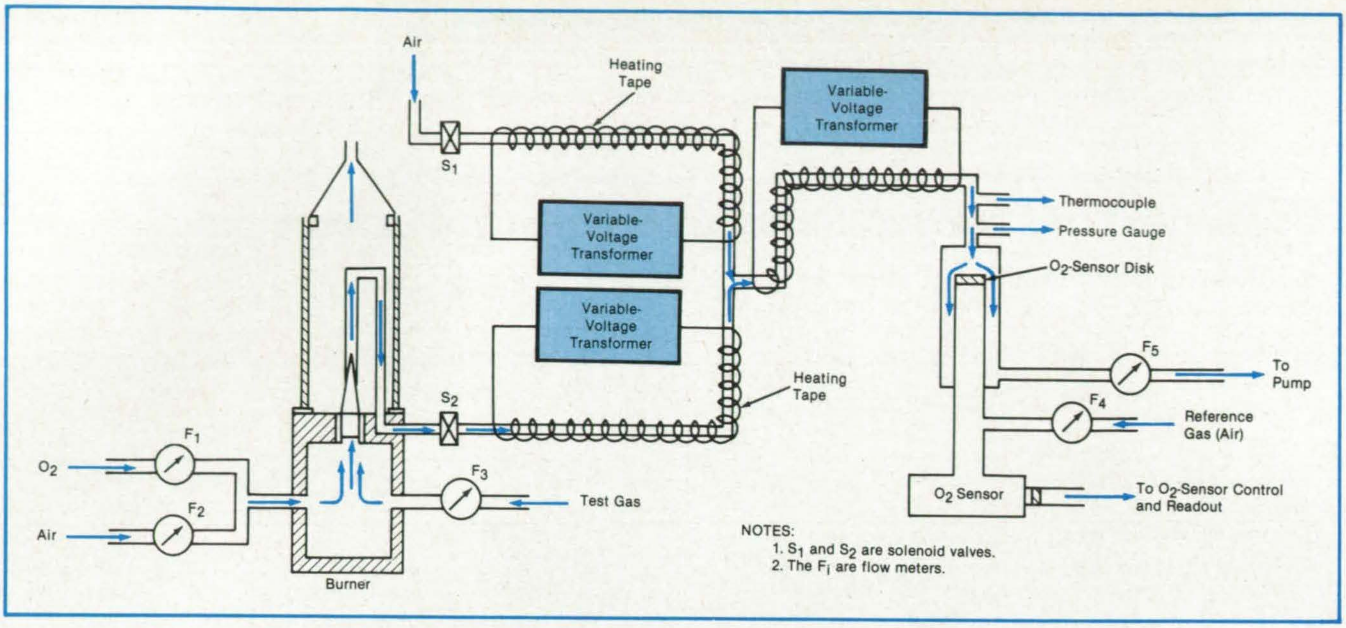


Figure 1. The **Flow Rates of the Test Gas and the Oxygen** required to enrich the carrier air to make the mole fraction of oxygen in the combustion product gases equal to that in the carrier air are measured and used to determine heats of combustion.

noted that the degree of the required oxygen enrichment of the air was very sensitively dependent on the purity of the combustible gas (CH_4). The presence of traces of noncombustible components noticeably affected the amount of oxygen required to be added to the air to make the mole fraction of oxygen, $X(O)_2$, in the combustion product gases equal to that in the standard air.

The reverse was also true; the purity of the combustible test gas could be inferred by measuring the amount of oxygen needed for the equalization of $X(O)_2$. The concept was further extended to infer the presence of heavier saturated hydrocarbons in the combustible test gas (natural gas) as well. Since the heat of combustion of natural gas depends on its effective hydrocarbon content, the measurement of the amount of oxygen needed for the equalization of $X(O)_2$ can be used for the direct determination of the thermal content of the test gas.

The system used for measuring m/n values of the test gas is illustrated in Figure 1. Pure bottled dry air was used to supply the carrier stream. A gas chromatograph was used to measure the $X(O)_2$ value of this air. The ZrO_2-sensor output was first recorded for the carrier air, and then the combustion products of selected hydrocarbons in oxygen-enriched air were directed through the O_2-sensing system. The oxygen flow rate, m, was adjusted until the ZrO_2-sensor output for combustion products matched that for air. These measurements were repeated for a number of hydrocarbon flow rates, n, keeping the air flow rate fixed. A positive-displacement dry test meter was used for measuring the true volume flow rate, n, of the test gases.

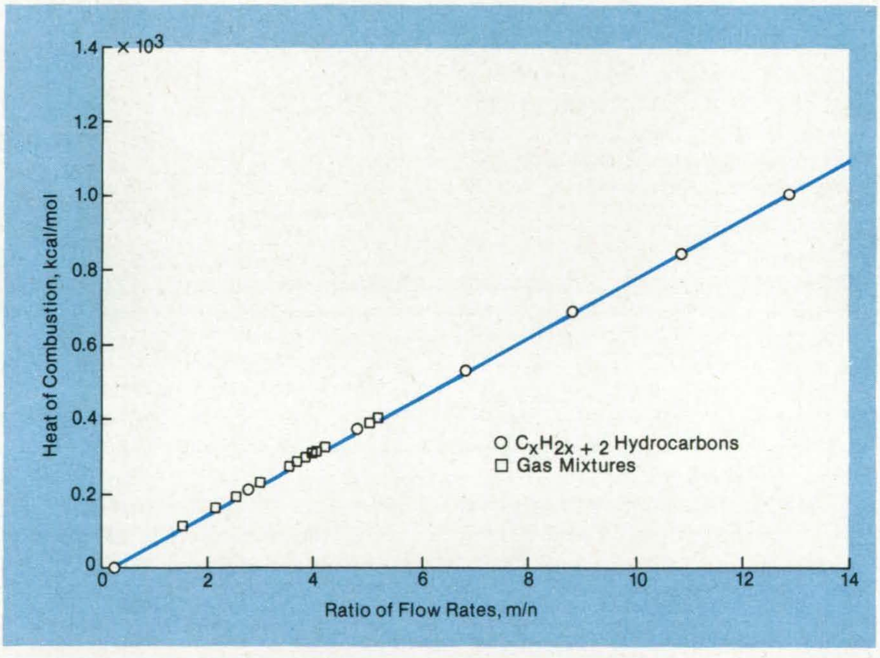


Figure 2. The **Heat of Combustion** of the test gas is directly related to the ratio of the flow rate of oxygen to that of the test gas under specified test conditions.

Together with calibration graphs relating the m/n values for pure saturated hydrocarbons to their heats of combustion, a measurement of the m/n ratio for the test gas provides a direct means of determination of its heat of combustion (see Figure 2). The accuracy of the technique, determined solely by the accuracy with which the flow rates m and n can be measured, is in the order of 2 percent.

This work was done by Jag J. Singh, Danny R. Sprinkle, and Richard L. Puster of **Langley Research Center**. *Further information may be found in NASA TP-2531 [N86-20753/NSP], "New Method for Determining Heats of Combustion of Gaseous Hydrocarbons."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 19]. Refer to LAR-13528.

Scanning System for Laser Velocimeter

Interference fringes would remain parallel
and focus-spot diameter the same.

Ames Research Center, Moffett Field, California

A scanning system is proposed for a laser velocimeter (laser Doppler anemometer) to maintain a constant beam-crossing angle and beam-waist diameter while maintaining the beam waist locations at the crossing points. Consequently, as the target fluid is scanned, the interference fringes formed by the crossing beams would remain parallel and the focus-spot diameter the same. This system would allow accurate velocity profiles to be obtained in wind tunnels and other fluid flow systems.

In a typical laser velocimeter, a laser beam is split into two beams of equal intensity. These two beams are then made to intersect (in the fluid being studied) by being passed through a positive (convex) lens. The lens also focuses the beams to a small diameter, thus increasing the light intensity and decreasing the effective probe volume.

The beams from most lasers used in velocimetry have Gaussian intensity profiles. The narrowest place, or waist, of a Gaussian beam is analogous to the focus of a typical geometric optics beam. If the waists of two crossing beams do not coincide, the resulting interference fringes will not be parallel, which would adversely affect the measurement accuracy. Moreover, if the focus-spot diameter is not constant throughout the scanned region, this will cause a variation in the light intensity and in the number of fringes that can be counted, impairing detection instrument alignment.

The system scans by varying the optical path length between an afocal pair of positive lenses (used to make the two beams intersect) and a negative lens located between the laser-beam splitter and the positive lenses. The coincidence of the real beam waists in the scanned region is maintained as follows: the real waists of the beams from the splitter are located on the side of the negative lens facing the positive lenses and are separated from the negative lens by a distance equal to the absolute value of its focal length.

In one version of the system a pair of scanning mirrors on a common mount forms a retroreflective device (see Figure 1). This device moves parallel to the optical axes to vary the optical path length, thus translating the sensitive volume. The negative lens remains fixed with respect to the laser, thereby fixing its virtual beam waists on the right side of that lens, one focal length away.

Other versions might include other means to scan the beam waists to match the movements of scanning lenses, as distinguished from scanning mirrors. Figure 2 shows a system with a negative scanning lens. If a positive scanning lens were used, the real beam waists would be scanned in such a way as to remain always one focal length away from the scanning lens on its input side.

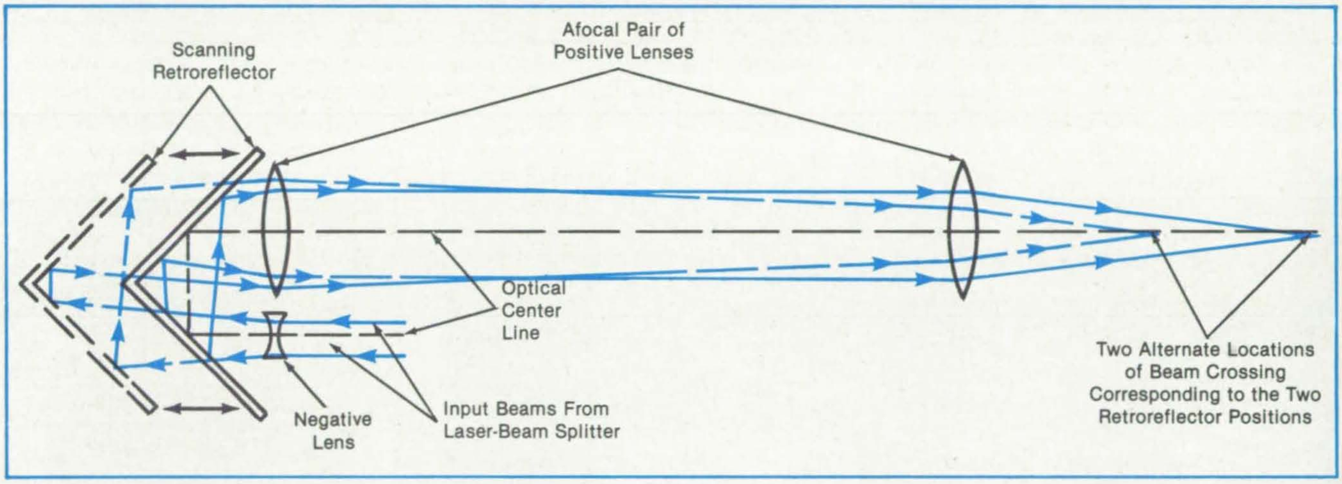


Figure 1. A **Retroreflector Is Moved** to move the beam intersection. The solid lines show the beam paths when the retroreflector is in one position and the broken lines when it is in a second position.

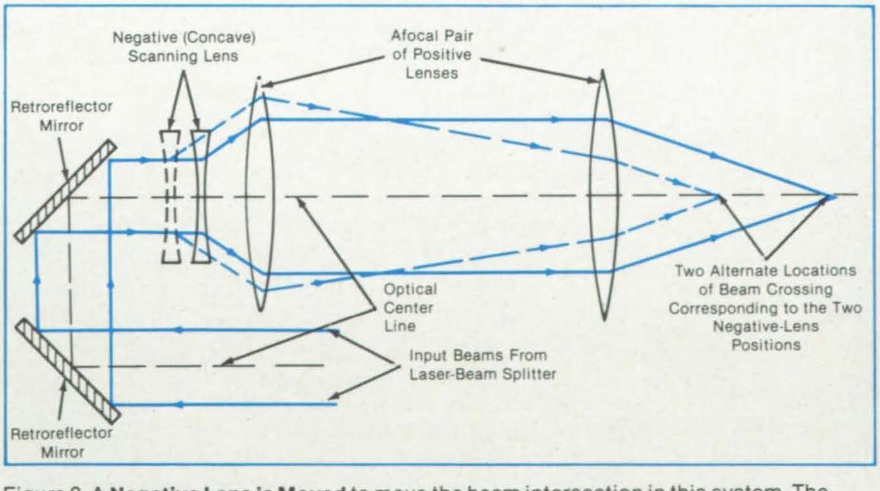


Figure 2. A **Negative Lens is Moved** to move the beam intersection in this system. The solid lines show the beam paths when the lens is in one position and the broken lines when it is in a second position.

The sensitive volume scans farther and faster than the negative lens by a factor of the square of the magnification of the afocal lens pair. An additional factor of 2 is gained when the retroreflector is placed between the scanning lens and the afocal lens pair.

This work was done by William D. Gunter and Anemarie De Young of **Ames Research Center**. *For further information, Circle 103 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11547.

CCD Luminescence Camera

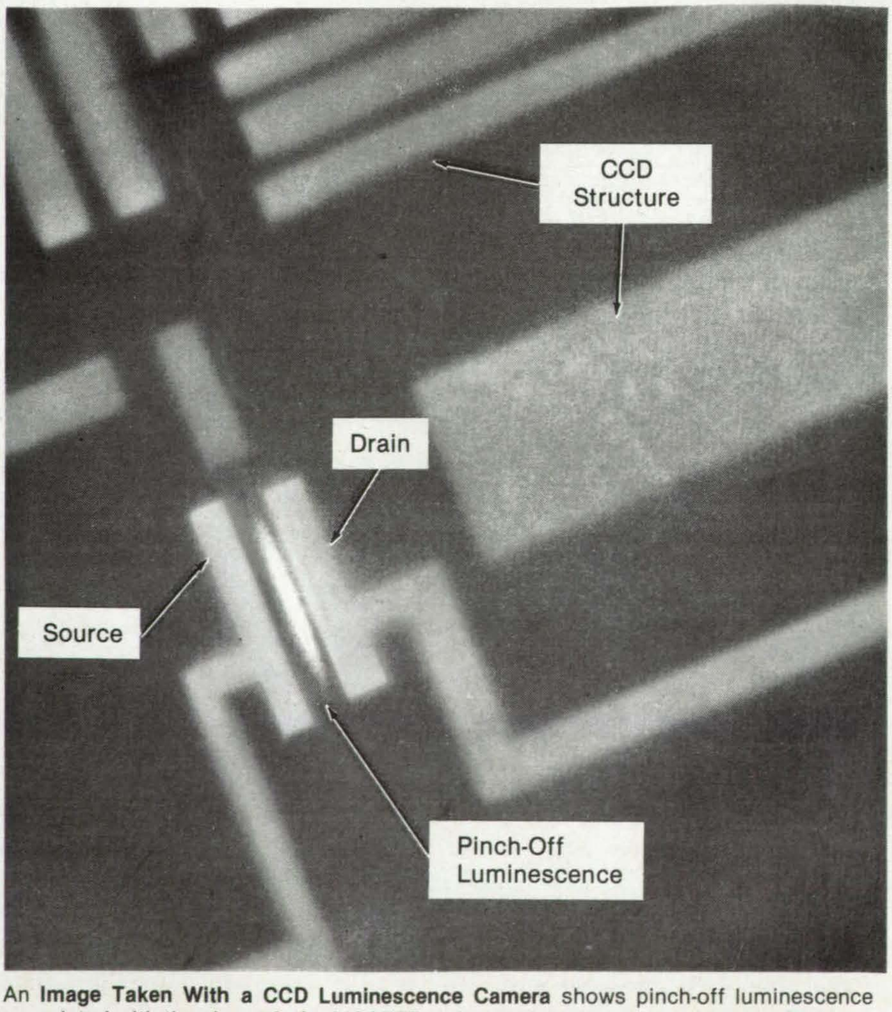
A new diagnostic tool is used to understand performance and failures of microelectronic devices.

NASA's Jet Propulsion Laboratory, Pasadena, California

A microscope has been integrated to a low-noise charge-coupled-device (CCD) camera to produce a new instrument for analyzing the performance and failures of microelectronic devices that emit infrared light during operation. For example, the figure shows for the first time a direct image of the "pinch-off" region at the drain of a metal oxide/semiconductor field-effect transistor (MOSFET) structure under nominal operating conditions. The image was generated by an exposure of several minutes under cooled conditions (−95 °C). The very weak signal observed is caused by a weak avalanche condition within the MOSFET channel and represents direct evidence of generation/recombination processes that have been theorized to be one factor responsible for 1/f noise generation in MOSFET's and junction field-effect transistors (JFET's).

The CCD luminescence camera also has been demonstrated to be valuable in identifying locations within a semiconductor part where the onset of breakdown occurs. Luminescent images have been used to help semiconductor manufacturers improve breakdown characteristics by making geometry changes to device structure. The CCD camera is also used to identify very clearly parts that have failed (specifically, oxide pinholes) where luminescence is typically found.

This work was done by James R. Janesick and Tom Elliott of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 52 on the TSP Request Card.*
NPO-16547



An **Image Taken With a CCD Luminescence Camera** shows pinch-off luminescence associated with the channel of a MOSFET under nominal operating conditions. The transistor shown here has a channel width (distance between source and drain) of only 10 μm.

The shortest distance between two points just became shorter.

DCS brings to existing, field-proven technology a new twist in innovative thinking.

The result is an FM demodulator that is a quantum leap beyond competition. For one thing, this computer controlled advance is menu-driven, with keypad entry, and stored formats. It can discriminate all 50 standard IRIG channels as well as non-standard configurations. And when you consider that the complete system is packed in a single housing and priced substantially below other units, you can understand our pride.

Innovation is not new at Data-Control Systems. For thirty years, we have been extending the leading edge in telemetry systems. Our specialty is solving problems. In fact, we've just shortened the shortest distance between two points.

DCS Announces its NEW Programmable Universal Demodulator.

DCS Universal FM Tunable Demodulator

Full 2 MHz bandwidth / Accuracy to 1 HZ / Programmable low pass filter / Tape speed compensation / Spectral display / All formats PBW, CBW-LP, CA / Large alphanumeric display / Multiple computer interfaces

Quanta Systems Corporation
Data-Control Systems
CompuDyne Defense
Electronics Group

1455 Research Boulevard
Rockville, MD 20850
(301) 279-8798
TWX (710) 828-9785

8291 Westminster Ave., Suite 150
Westminster, CA 92683
(714) 984-4471
TWX (910) 596-1802

Materials

Hardware, Techniques, and Processes

Books and Reports

Catalytic Layer Makes Aircraft Seats More Fire Retardant

A catalytic layer covered by aluminum foil converts flammable gases to nonflammable products.

Ames Research Center, Moffett Field, California

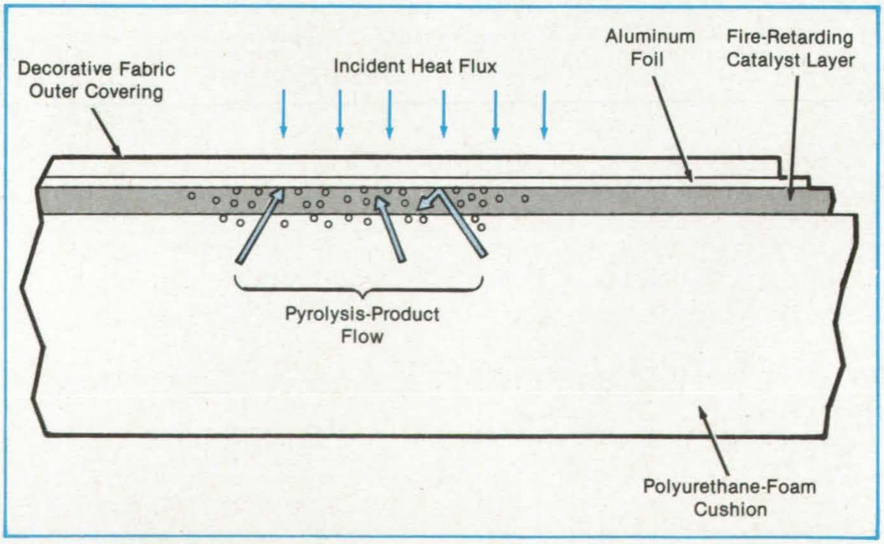
A specially constructed cushion retards fires in aircraft seats through the action of a catalytic matrix that cracks the flammable gaseous decomposition products to less flammable species. The improved cushion contributes substantially to fire safety without adding significantly to weight or to manufacturing cost.

The flammable vapors produced by the thermal decomposition of conventional foam seat cushions are considered to be among the major contributors to the spreading of fires inside aircraft. Flexible poly(urethane) foams, currently considered the best cushioning materials in view of their mechanical properties and costs, are also the most thermally sensitive: They decompose above 250 °C, yielding large quantities of highly combustible pyrolysis vapors. These foams ignite easily and sustain flame propagation even after removal of the igniting sources.

Although the fire retardants commonly added to urethane foams increase the resistance to low-temperature ignition, they have little or no effect on the maximum rate of decomposition, the temperature at which it occurs, or the vapor yield; under sustained radiant heating both fire-retarded and non-fire-retarded flexible poly(urethane) foams emit the same average amounts of combustible gases. The flammability of a cushion can be reduced by a covering that when heated emits cooling water vapor. Unfortunately, the use of such a "transpirational-cooling" material would increase the weight of each seat by an estimated 1.8 kg.

These problems are avoided in the new fire-blocking cushion shown in the figure. The flammable urethane-foam cushion is covered by a flexible matrix that catalytically cracks the combustible organic vapors at the temperature of their generation. The resulting products are coke, tar, and other less combustible species. These catalysts should be resistant to high temperatures, have low thermal conductivity, and be resistant to pyrolysis: such materials include tightly woven fabrics and felts of poly(p-phenylene terephthalamide), heat-stabilized polyacrylonitriles, and poly(benzimidazoles).

The catalytic cracking is enhanced when the catalyst is covered by a gas-barrier layer, which increases the residence time of the gases in the catalyst fabric. Heavy aluminum foil is an effective gas barrier. Its high thermal conductivity contributes further to fire resistance because it conducts the heat quickly away



In this **Fire-Blocking Covering for an Aircraft Seat Cushion**, flammable pyrolysis products are cracked to less flammable species by a catalytic layer covering the foam core of the cushion. The aluminum foil holds in the pyrolysis vapors to promote catalysis and prevent the spread of fire by the ignition of released vapors.

from the burning area.

Somewhat unexpectedly, the new cushion design was found to be more resistant to fire when the polyurethane cushion did not contain a fire-retardant material. One possible explanation is that fire-retardant materials scavenge free radicals that would otherwise take part in the cracking reactions.

This work was done by John A. Parker and Demetrius A. Kourtides of **Ames Research Center**. *For further information, Circle 84 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel. Ames Research Center [see page 19]. Refer to ARC-11423.

Making a Silicon-Nitride/Silicon-Carbide Composite

Hot pressing and nitriding produce a strong fiber/matrix material.

Lewis Research Center, Cleveland, Ohio

A fabrication method has been developed for processing a strong and tough silicon-based ceramic composite material, SiC/RBSN, which consists of reaction-bonded Si_3N_4 (RBSN) reinforced by continuous-length, high-modulus, high-strength silicon carbide (SiC) fibers prepared by the chemical-vapor deposition method. The composite is fabricated in two stages (see Figure 1): in the first stage, the composite preform (SiC/Si) is prepared by hot pressing alternate layers of SiC fiber mat and silicon cloth; in the second stage, the composite preform is nitrided at an elevated temperature in an atmosphere containing nitrogen, thus converting the silicon to a Si_3N_4 matrix. The volume fraction of fiber in the composite can be as high as 40 percent.

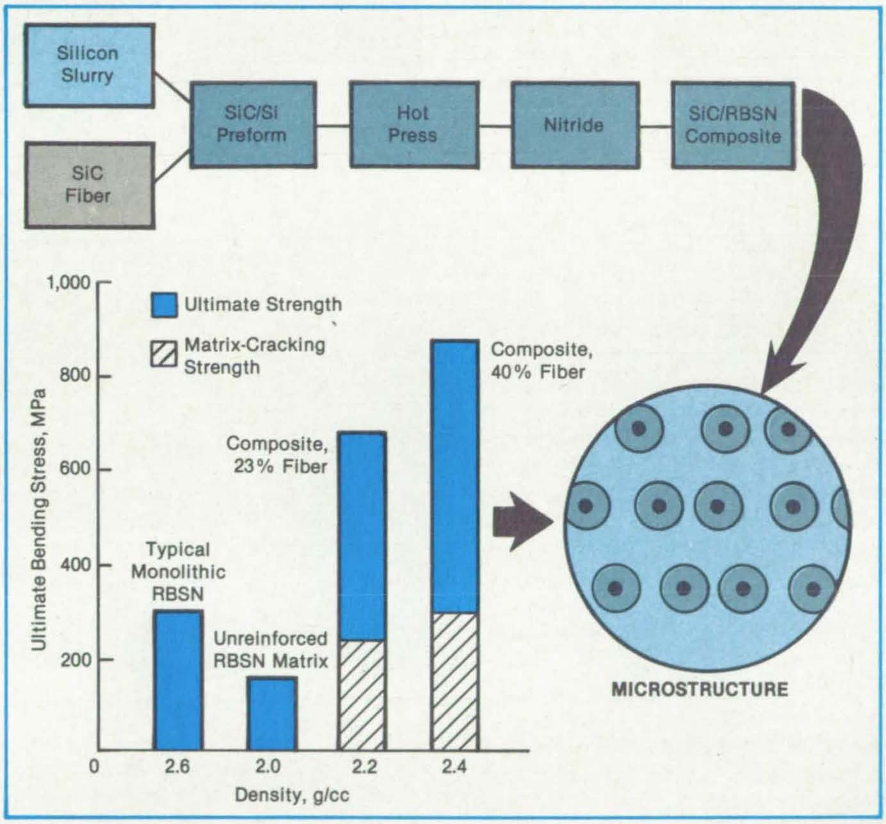


Figure 1. The **Si_3N_4/SiC Composite** made by the process shown at the top has a bending strength greater than that of the best commercial monolithic reaction-bonded silicon nitride.

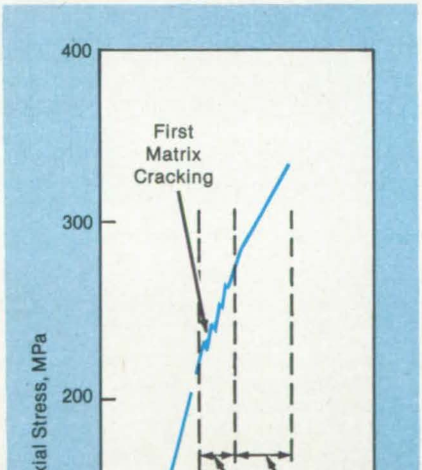


Figure 2. The **Stress-vs.-Strain** curve of the composite shows that the fibers take up a greater fraction of the load when the matrix cracks.

When the SiC/RBSN composite is stressed in tension in a direction parallel to the fiber, the composite extends elastically until the RBSN matrix fractures (see Figure 2). In contrast to unreinforced RBSN, at this stress level the composite retains its shape because of the fiber bridging of matrix cracks. In addition, because of their high modulus, the SiC fibers bear more load than does the matrix they replace, so that the composite stress at which the matrix fractures is greater than that for an unreinforced matrix of equivalent density. Because of weak fiber/matrix interfacial bonding, matrix cracks propagate around the fibers and not through them. Therefore, the strong fibers are left to carry the full composite load to higher strain levels, and fiber reinforcement prevents the brittle catastrophic failure typically observed in monolithic ceramics.

On further stressing of the composite above the first matrix fracture, the material continues to deform; multiple matrix cracking occurs until the ultimate fracture strength of the fibers is reached. Therefore, the composite is stronger than the unreinforced matrix. It is also tougher, as manifested by a high strain-to-failure and an ultimate noncatastrophic fracture that is controlled by the fibers.

The ultimate bending strength of the composite increases with increasing volume fraction of fiber and is measurably greater than that of the best commercial monolithic RBSN. The increased toughness and ultimate strength of the SiC/RBSN composite makes it a potential structural material for advanced heat engines.

This work was done by R. T. Bhatt of **Lewis Research Center**. *Further information may be found in NASA TM-87085 [N85-34223/NSP], "Mechanical Properties of SiC Fiber Reinforced Reaction Bonded Si_3N_4 Composites."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Lewis Research Center [see page 19]. Refer to LEW-14392.

Corrosion of SiC by Molten Salt

The surface becomes pitted, and strength decreases.

Lewis Research Center, Cleveland, Ohio

Advanced ceramic materials are being considered for a wide range of applications as in gas turbine engines and heat exchangers. In such applications, these materials may be in corrosive environments that include molten salts. It is well known that such salts can be very corrosive to alloys. In order to determine the extent of this problem for ceramic materials, the corrosion of SiC by molten salts has been studied in both jet fuel burners and laboratory furnaces.

In the burner studies, the specimens were held in a flame at 1,825 °F (996 °C) for about 12 hours. Specimens showed no evidence of attack when exposed to plain flames. However, when only 4 parts per million of sodium was injected (as NaCl) into the flame, severe corrosion occurred. Previous studies have shown that the sodium reacts with the sulfur impurities in the fuel to form sodium sulfate, which can then dissolve the protective oxide layer, exposing the base material to extensive attack.

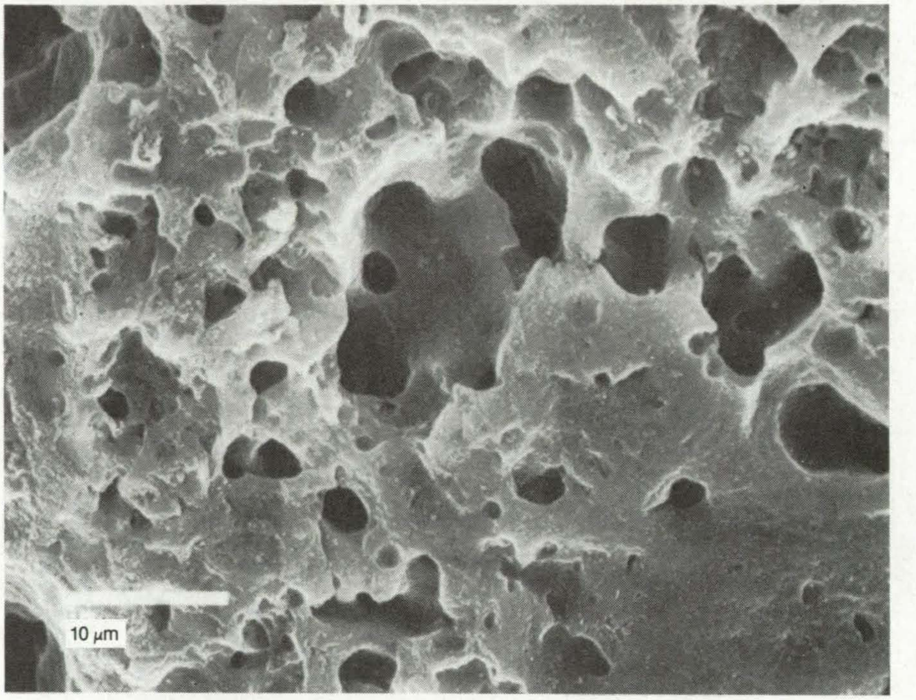


Figure 1. The **Surface of Silicon Carbide** was corroded by exposure to a flame seeded with 4 parts per million of sodium.

The SiC specimens corroded in the burner had thick glass surface layers of sodium silicate and silica. More importantly, the corrosion of the SiC substrate involved a deep pitting attack, as illustrated by the photomicrograph in Figure 1. These surface pits, which appear to act as stress concentrators, lead to strength decreases of as much as 40 percent in the corroded materials — as shown in Figure 2.

In order to study the corrosion parameters more closely, laboratory furnace experiments were also performed in which SiC specimens were airbrushed with sodium sulfate and placed in a tube furnace with flowing oxygen at 1,825 °F (996 °C). Such an exposure duplicated the attack obtained in the burner and gave a similar strength reduction as also shown in Figure 2.

This work deals primarily with corrosion caused by molten salt in heat engines; however, the general conclusions may be applicable to other salt-containing systems. Thus, although ceramic materials

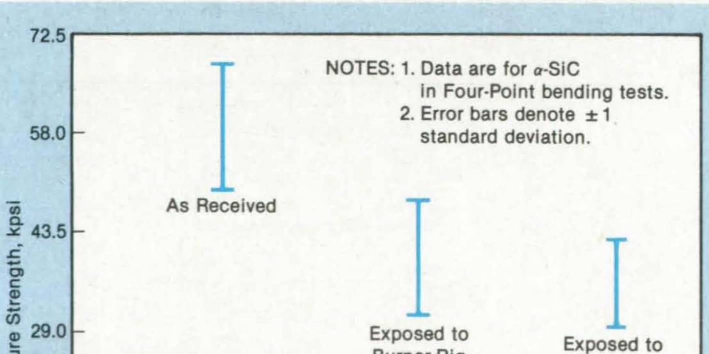


Figure 2. The **Strength of Silicon Carbide** was decreased by corrosion in flame and tube-furnace tests.

hold a great deal of promise for future high-temperature applications, the design engineer must be aware that a problem may arise when these materials are used in environments where they may encounter molten salts.

This work was done by Nathan S. Jacobson and James L. Smialek of **Lewis Research Center**. *Further information may be found in:*

NASA TM-87061 [N85-30011/NSP], "Burner Rig Corrosion of SiC at 1,000 °C" and
NASA TM-87052 [N85-30135/NSP], "Mechanism of Strength Degradation for Hot Corrosion of α-SiC."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14381

Reusable High-Temperature/Cryogenic Foam-Insulation System

Flightweight insulation withstands wide temperature cycling.

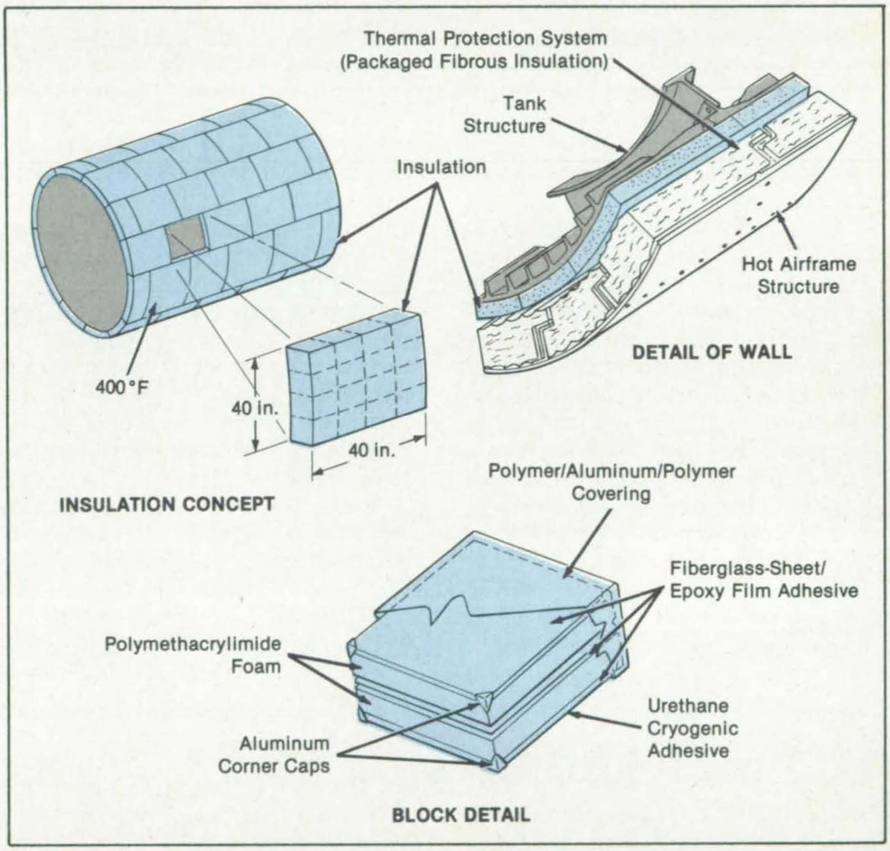
Langley Research Center, Hampton, Virginia

A reusable insulation system for cryogenic containment vessels can withstand repeated exposures to thermal environments that span the range from the cryogenic-fluid temperature [−425 °F (−254 °C)] to the maximum use temperature of the containment-tank material [+400 °F (+204 °C)]. This system was designed for use with high-speed flight vehicles.

Current insulation systems for flightweight cryogenic-containment vessels make use of spray-on foam insulation. These systems cannot withstand the temperatures generated by aerodynamic heating encountered during high-speed flight and require separate thermal-protection systems (TPS) to maintain the cryogenic insulation below its maximum use temperature of 175 °F (80 °C). These systems are not considered reusable for high-speed flight vehicles.

In the new design, a cryogenic-containment tank structure is covered with a cryogenic insulation system that is adhesively bonded to the tank structure. The insulation consists of 40-in. (102-cm) square sheets fabricated from an array of abutting 10-in. (25.4-cm) square blocks that are basically identical to each other. The thickness of the blocks can be varied to provide the required insulation function. The wall construction is completed when an exterior TPS is added to provide the cryogenic-foam blocks protection from excessive heating. Because of its higher service temperature, the new insulation system requires less thickness and weight for the external TPS than are required for prior systems.

The structure of the reusable insulation system consists of discrete blocks of polymethacrylimide foam, as shown in the figure. Two heat-treated foam blocks are bonded together using a sheet of epoxy-film adhesive on each side of a fiberglass sheet at the bond line and a single sheet of the adhesive and fiberglass on the outer faces of the blocks. The fiberglass sheet provides a vapor barrier and structurally reinforces the system to inhibit cracking.



The **Foam-Block** insulation can be used repeatedly through temperature cycles of wide range.

The outer corners of each block are machined to receive preformed metal corner seals, and the additional thickness of the polymer/aluminum/polymer (PAP) corner overwraps. An epoxy adhesive is used to bond the corner caps in place. The assembly is covered with precut layers of the film adhesive and a precut, preformed PAP cover that provides a durable covering impervious to gases.

The assembly is vacuum bagged and bonded together in an autoclave. The cured foam-insulation system is then bonded to the tank structure with a durable urethane cryogenic adhesive. The cryogenic insulation can be bonded to the interior or exterior tank wall. The repeated use of this insulation structure, from temperatures up to 400 °F (204 °C) on the hot side to temperatures of −425 °F (−254 °C) on the cryogenic side, has been demonstrated without any degradation of the insulation.

This work was done by Randall C. Davis, Allan H. Taylor, and L. Robert Jackson of **Langley Research Center** *and Patrick McAuliffe of Lockheed Aircraft Co. For further information, Circle 81 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 19]. Refer to LAR-13506.

Fire- and Heat-Resistant Laminating Resins

Imide compounds containing phosphorus are thermally polymerized.

Ames Research Center, Moffett Field, California

A class of fire- and heat-resistant bisimide resins are prepared by the thermal polymerization of maleimido- or citraconimido-substituted 1-[(dialkylphosphonyl)methyl]-2,4- and -2,6-diaminobenzenes. These polymers are expected to be less brittle and easier to process than other aromatic polyimides.

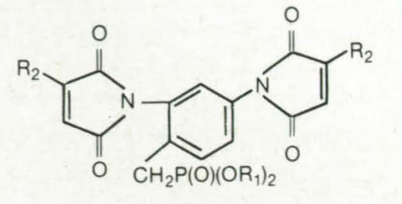
Aromatic polyimides have been developed for use as laminating resins or adhesives that must be thermally stable at or above 325 °C. However, these compounds are subject to irreproducibility and deterioration of mechanical properties, both of which are attributed to the voids created by the elimination of water or to the difficulties in the removal of the high-boiling-point solvent during polymerization. More recently developed flame-resistant polyimide resins are prepared from prepolymers containing phosphorus and end-capped with reactive maleimido rings. However, these polymers are typically brittle.

The new maleimido- or citraconimido-end-capped monomers, which have relatively low melting temperatures, polymerize at moderate temperatures to rigid bisimide resins without the elimination of volatiles. The monomers dissolve in such solvents as methyl ethyl ketone, acetone, and tetrahydrofuran, which are suitable and preferred as "varnish solvents" for composite fabrication. Furthermore, the low melting points of these compounds allow them to be used as adhesives without the addition of solvents.

The starting material is a mixture of 1-[(dialkoxyphosphonyl)methyl]-2,4- and -2,6-diaminobenzenes. The 2,4 isomer predominates, and there is no need to separate the isomers. This material is nitrated in fuming nitric and sulfuric acids to a dinitro derivative, then catalytically hydrogenated to a diamino mixture.

Thermally polymerizable N-maleimido or N-citraconimido derivatives of the diamines can be synthesized by any of several different reaction sequences. For example, the amines can be condensed with maleic anhydride to produce intermediate bismaleic acids, which are then cyclodehydrated to the final monomeric form. Polymer precursors can also be synthesized by a similar sequence involving condensation with citraconic dianhydride. A representative prepolymer molecular structure is shown in the figure.

To reduce the brittleness of the resulting bisimide resins, the formula weight and the length of the bridge between the two maleimido groups are increased by incorporating benzophenone tetracarboxylic dianhydride or methylenebis (4-phenyl isocyanate). The chain extension of monomers is expected to reduce the brittleness of the bisimide resins, because larger polymer segments should be available for internal motions after cross-linking.



NOTES: $R_1 = CH_2CH_3$ or CH_2CH_2Cl
$R_2 = H$ or CH_3

A **Polymer Precursor** is thermally polymerized to produce a fire- and heat-resistant laminating resin.

This work was done by Demetrius A. Kourtides of **Ames Research Center** *and John A. Mikroyannidis of the National Research Council. For further information, Circle 83 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11533.

Books and Reports

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

Statistical Tests of Reliability of NDE

The capabilities of advanced material-testing techniques are analyzed.

A collection of four reports illustrates a statistical method for characterizing the flaw-detecting capabilities of sophisticated nondestructive evaluation (NDE). This method has been used to determine the reliability of several state-of-the-art NDE techniques for detecting failure-causing flaws in advanced ceramic materials being considered for use in automobiles, airplanes, and space vehicles.

Defects or flaws within a structural material can effectively weaken the material or degrade its toughness to the point of catastrophic failure. For example, ceramics being investigated as replacements for metals in engines exhibit wide variability in strength and low toughness. These undesirable properties are generally attributed to impurity particles, voids, or microcracks introduced during the manufacture of these materials.

Sensitive, reliable NDE techniques are needed to detect flaws having the potential to cause failures. Reliability is difficult to assess since results are influenced by many variables, including the flaw shape and orientation, the surface texture and the microstructure of the material, and the day-to-day variability of the performance of the equipment and operator.

The development of the statistical method included the development of techniques in which specially prepared specimens (of a specific material) containing artificially seeded controlled flaws are examined with the NDE technique. Data are gathered on the number and size of flaws detected or not detected. The data are analyzed using a detailed computer program involving binomial-distribution statistics, and the reliability subsequently displayed graphically in terms of the probability of flaw detection as a function of the flaw type and size. This method was used to determine the reliability of two sophisticated NDE techniques (scanning laser acoustic microscopy and microfocus x-radiography) for detecting different flaw types in structural ceramic materials.

This program was written by George Y. Baaklini, Stanley J. Klima, Don J. Roth, and James D. Kiser of **Lewis Research Center**. *Further information may be found in:*

NASA TM-86945 [N85-21674/NSP], "Radiographic Detectability Limits for Seeded Voids in Sintered Silicon Carbide and Silicon Nitride,"

NASA TM-87035, [N85-32337/NSP], "Reliability of Void Detection in Structural Ceramics Using Scanning Laser Acoustic Microscopy,"

NASA TM-87164, [N86-13749/NSP], "Probability of Detection of Internal Voids in Structural Ceramics Using Microfocus Radiography," and

NASA TM-87222 [N86-16599/NSP], "Reliability of Scanning Laser Acoustic Microscopy for Detecting Internal Voids in Structural Ceramics."

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.
LEW-14450

Solidification Effects in MAR-M246(Hf) Alloy

Fatigue properties are degraded with crystallographic orientations greater than 10° from the [001] axis.

The influence of solidification and heat-treatment parameters on the structure and the fatigue properties of the nickel-based superalloy MAR-M246(Hf) is described in a 24-page report. Superalloys have high strength and corrosion resistance at temperatures up to 1,400 °C; their uses range from petrochemical equipment to marine, industrial, aircraft, and vehicular gas turbines. The 12 constituents of MAR-M246(Hf) — Ni, Cr, Co, Mo, W, Ta, Al, Ti, C, B, Zr, and Hf — combine to form 3 phases: the matrix (γ), the γ' and the carbides. Solidification and heat treatment affect the distribution of these phases, which in turn affects the mechanical properties of the alloy.

Examinations of directionally-solidified alloy samples showed that the carbide shapes and the degree of carbide segregation depend on the growth rate. Photographs and graphs of the data show both decreasing dendritic-arm spacings and smaller amounts of carbides with increasing growth rates. The data appear to show that the poorer fatigue properties of off-[001]-axis crystals are not caused by an increase in harmful carbides. The growth rate controls the carbide shapes: fast growth produces scriptlike carbides, which form networks for crack propagation; slow rates produce blocky carbides.

Microstructure studies showed that the γ' phase goes into solution between 1,175 and 1,200 °C. Therefore, the heat-treatment temperature could be reduced from the 1,221 °C now used. Such a decrease would help to prevent the apparent melting of the eutectic in some of the interdendritic areas.

Heat-treatment studies showed that the amount of the γ' phase reaches its maximum after the alloy has remained for 24 to 100 hours at 871 °C. Longer exposures at this temperature tend to degrade the structure, but the sizes of the particles remain stable. At 970 °C, the amount of the γ' phase reaches a steady value, but the sizes of the particles are not stable. Temperatures above 871 °C are expected to result in the deterioration of fatigue properties.

Crystallographic orientations of fatigue test specimens in both the failed and unfailed regions were determined from x-ray Laue photographs. During testing, rotation occured in the samples if they were oriented at significant angles with respect to the [001] axis. The farther the sample has to rotate before reaching multiple-slip conditions, the greater the probability for early failure.

This work was done by M. H. Johnston and R. A. Parr of **Marshall Space Flight Center**. *Further information may be found in NASA TM-82569 [N84-20675/NSP], "A Study of the Solidification Parameters Influencing Structure and Properties in MAR-M246(Hf)."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. The report is also available on microfiche at no charge. To obtain a microfiche copy, Circle 9 on the TSP Request Card.
MFS-27066

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, is the one central office established to distribute software that is developed with NASA funding. COSMIC's role as part of NASA's Technology Utilization Network is to ensure that NASA's advanced software technology is made available to industry, other government agencies, and academic institutions.

Because NASA's software development efforts are dynamic and ongoing, new programs and updates to programs are added to COSMIC's inventory on a regular basis. *Tech Briefs* will continue to report information on new programs. In addition, the 1986 edition of the *COSMIC Software Catalog* is available with descriptions and ordering information for available software. Several new programs for control systems/robotics, expert systems, thermal analysis, turbomachinery design, structural analysis, and computer graphics are offered.

For additional information on any programs described in this issue of *Tech Briefs*, circle the appropriate number on the TSP card at the back of the publication. If you don't find a program in this issue that meets your needs, you can call COSMIC directly at (404) 542-3265 and request a review of programs in your area of interest. There is no charge for this information review.

COSMIC®
Computer Services Annex, University of Georgia, Athens, GA 30602; Phone (404) 542-3265
John A. Gibson, Director

Computer Programs

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

Electronic Systems

Analyzing Feedback Control Systems

This program is a convenient, interactive, control-system-design analysis tool.

The Interactive Controls Analysis (INCA) program was developed to provide a user-friendly environment for the design and analysis of linear control systems, primarily feedback control systems. INCA is designed for use with both small- and large-order systems. Using the interactive-graphics capability, the INCA user can quickly plot a root locus, frequency response, or time response of either a continuous-time system or a sampled-data system. The system configuration and parameters can be easily changed, allowing the INCA user to design compensation networks and perform sensitivity analyses in a very convenient manner.

The transfer function is the basic unit of INCA. Transfer functions are automatically saved and are available to the INCA user at any time. A powerful, user-friendly, transfer-function manipulation-and-editing capability is built into the INCA program. Basic input data, including gains, are handled as single-input, single-output transfer functions. These functions can be developed using the function editor or by using FORTRAN-like arithmetic expressions.

In addition to the arithmetic functions, special functions are available to compute step, ramp, and sinusoid functions; compute closed-loop transfer functions; convert from the s plane to the z plane with optional advanced z transforms; and convert from the z plane to the w plane and back. These capabilities allow the INCA user to perform conveniently block-diagram algebraic manipulations for functions in the s, z and w domains.

In addition to the above-mentioned plane transformations, the versatile, digital control capability of INCA also includes a totally independent open-loop frequency-response analysis capability for a continuous-plant, discrete-control system with a delay, advanced z-transform capability for systems with delays, and multirate sampling analyses.

The INCA graphic modes provide the user with a convenient means to docu-

NON-DESTRUCTIVE TESTING: NOBODY ELSE OFFERS SO MANY WAYS TO LISTEN.

The extensive use of composite parts in the aerospace industry has created a need for fast, reliable, cost-efficient methods of testing.

As a major user of composites, McDonnell Douglas had reason to become a leader in ultrasonic testing.

We've developed four highly effective, state-of-the-art ultrasonic testing systems for our own needs. These systems are now available to you.

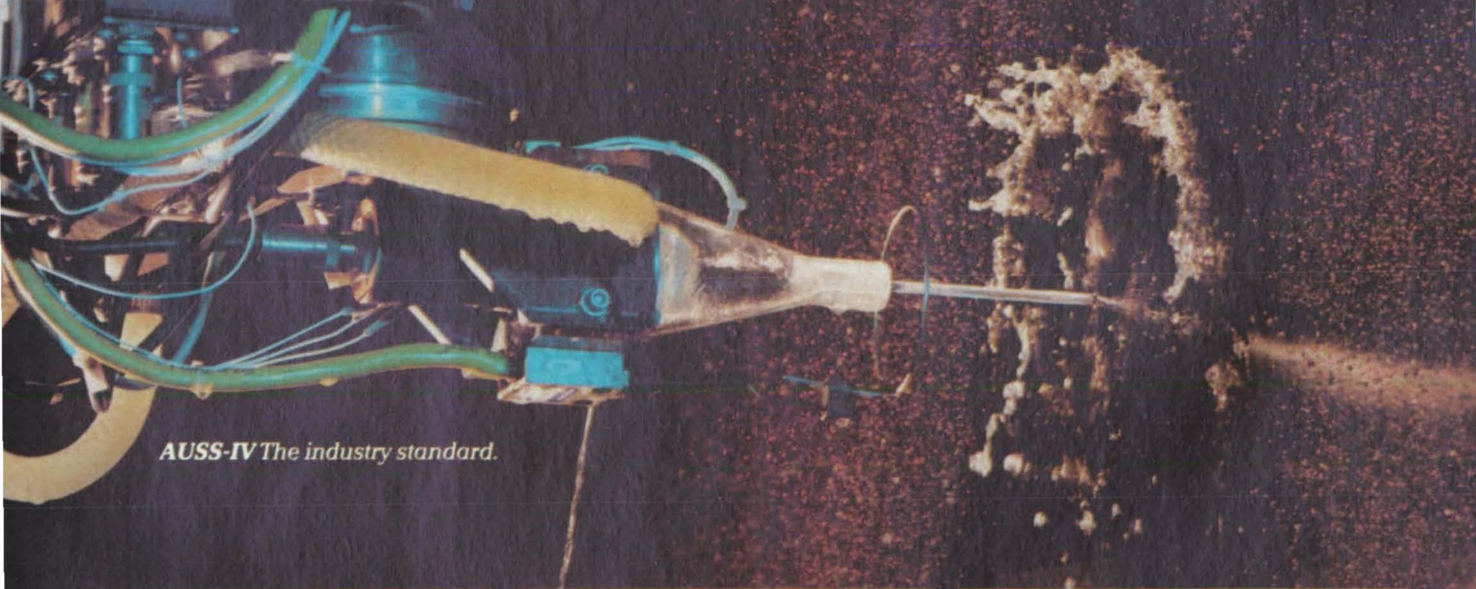
AUSS-IV, our fourth-generation Automated Ultrasonic Scanning System, is a computer-controlled machine and data handling system that automatically checks parts for anomalies.

AUSS-V, presently under development, will add totally new robotic, data imaging, and computer automation dimensions to ultrasonic testing.

ADIS, our Advanced Data Acquisition, Imaging, and Storage System, can update existing inspection units to provide state-of-the-art data acquisition, imaging, and plotting capabilities. Other features include depth measurements, cross sections, and histograms.

And MAUS, our Mobile Automated Ultrasonic Scanner, allows fast, in-place inspection of composite parts. It can scan the surface of compound curvatures without any special attachments.

To find out more about our systems, and how they can help you increase productivity while reducing costs, call or write: McDonnell Aircraft Company, Dept. 080, P.O. Box 516, St. Louis, MO 63166 (314) 232-7454



AUSS-IV *The industry standard.*

AUSS-V *Adds new dimensions to ultrasonic testing.*

ADIS *Updates existing inspection units.*

MAUS *Provides fast, in-place inspection of composite parts.*

MCDONNELL DOUGLAS

ment and study frequency-response, time-response, and root-locus analyses. General graphics features include: zooming and dezooming, plot documentation, a table of analytic computation results, multiple curves on the same plot, and displaying frequency and gain information for a specific point on a curve.

Additional capabilities in the frequency-response mode include the following:
- A full complement of graphical methods — Bode magnitude, Bode phase, Bode combined magnitude and phase, and Nyquist, Nichols, and Popov plots;
- User-selected plot scaling; and
- Gain- and phase-margin calculation and display.

In the time-response mode, additional capabilities include the following:
- Support for inverse Laplace and inverse z transforms,
- Support for various input functions,
- Closed-loop response evaluation,
- Loop-gain sensitivity analyses,
- Intersample time response for discrete systems using the advanced z transform, and
- Closed-loop time response using mixed-plane (s, z, w) operations with delay.

The INCA program is written in Pascal and FORTRAN for interactive or batch execution and has been implemented on a DEC VAX-series computer under VMS. Full INCA graphics capabilities are supported for Tektronix 4105, 4106, 4107, 4109, 4114, 4115, 4010, and 4014 terminals. In addition, support is provided for DEC VT100, VT125, and VT240 terminals. The INCA program was developed in 1985.

This program was written by Frank H. Bauer of **Goddard Space Flight Center** *and John P. Downing of Old Dominion Systems, Inc., For Further information, Circle 48 on the TSP Request Card.*
GSC12998

Mathematics and Information Sciences

Graph-Plotting Routine

A variety of scales, grids, and symbols are available.

A plotter routine for the IBM PC (AKPLOT) was designed for engineers and scientists who use graphs as integral parts of their documentation. AKPLOT allows the user to generate a graph and edit its appearance on a cathode-ray tube. This graph may undergo many interactive alterations before it is finally dumped from the screen to be plotted by a printer.

Features available in AKPLOT include the following: multiple curves on a single plot; combinations of linear and logarithmic-scale axes; Lagrange interpolation of selected curves; shrink, expand, zoom, and tilt; 10 different symbols and 4 different colors for curves; and 3 different grid types. The user must provide the data points to be plotted by one of two methods: (1) supplying an external file of x and y values for all curves or (2) placing BASIC code describing the relation between x and y in a designated section of the AKPLOT code and computing the x, y vectors. Using either technique, the x and y values are given to the computer only once, as the iterative graph-edit loop bypasses the data-input step for faster execution.

AKPLOT is written in BASIC for batch execution and has been implemented on an IBM PC-series computer operating under DOS. AKPLOT requires an IBM color monitor. This program was written in 1986.

This program was written by Anil V. Kantak of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 8 on the TSP Request Card.*
NPO-16931

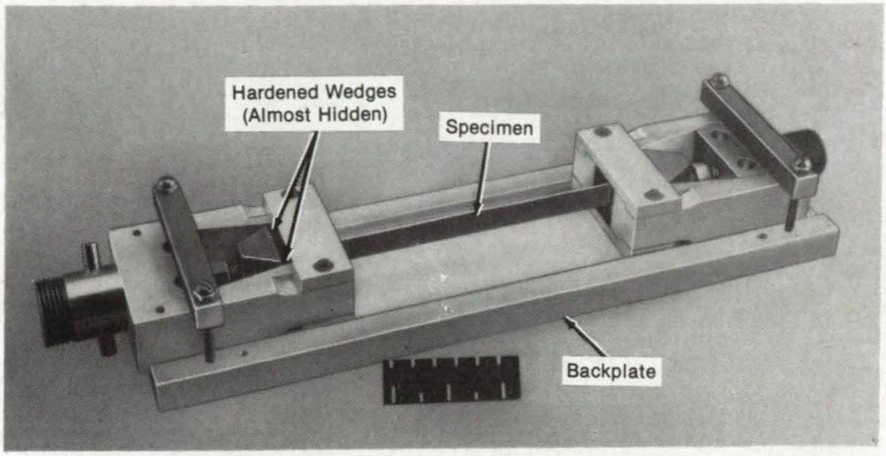
Mechanics

Hardware, Techniques, and Processes

Grips for Lightweight Tensile Specimens

A double-wedge design substantially increases gripping force and reduces slippage.

Langley Research Center, Hampton, Virginia



The **Specimen Is Held** by grips made of hardened wedges. The assembly is screwed into a load cell in a tensile-testing machine.

A set of grips has been developed for the tensile testing of lightweight composite materials. Resin-based, fiber-reinforced composite materials are more susceptible than metal specimens of comparable cross section to bending and twisting during installation and to slippage and deformation in the grip region. Even a small degree of misalignment in the specimen during tensile testing can affect the measured mechanical properties. The new grips minimize specimen misalignment and reduce scatter in the data.

The gripping force is applied by driving hardened wedges against the end tabs of the specimen. This double wedging action, actually a wedge driven against another wedge, allows a greater force to be applied over a larger area, thereby minimizing slippage and deformation in the grip region. Alignment is maintained by assembling the grips inside a backplate on a horizontal surface. This backplate keeps the specimen from twisting and bending during installation. It is removed only after the assembly has been put firmly in place on the testing machine.

More than 75 specimens of 5 different lightweight materials, typically demonstrating fractures occurring evenly along the specimen lengths, were tested and showed only a small variance in measurement data. The device shown can be scaled up or down in order to accommodate differently configured specimens.

This work was done by William G. Witte, Jr., and Walter D. Gibson of **Langley Research Center**. *Further information may be found in NASA TM-87624 [N86-11299/NSP], "Manual for LDEF Tensile Tests."*

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

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 19]. Refer to LAR-13461.

Slot-Height Measuring System

Height is displayed as a function of position.

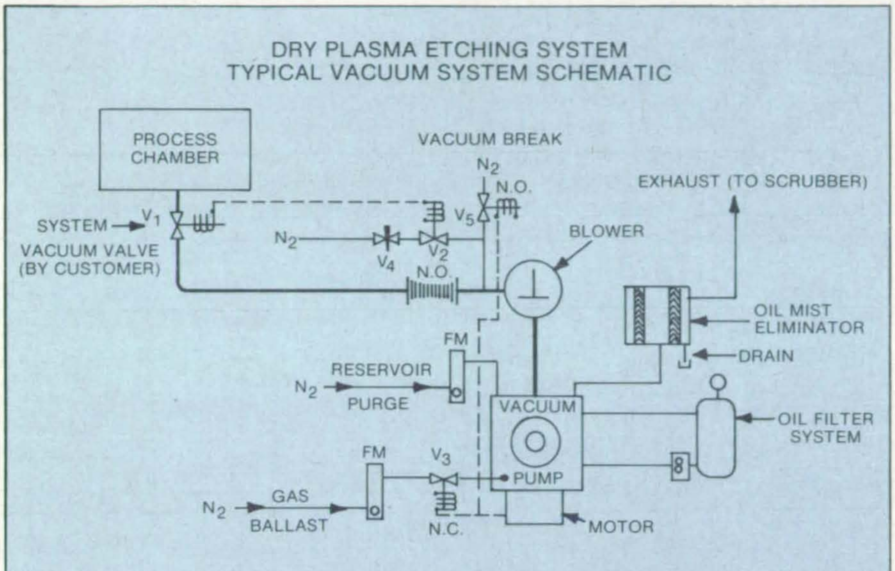
Ames Research Center, Moffett Field, California

A measuring system that includes a slot-depth transducer and a wheel-driven rotary optical encoder makes repeated measurements of slot depth vs. position along the slots on the leading and trailing edges of the blown rotor blades of an ex-

STOKES® VACUUM

VAC-TECH NEWS

How to stop water vapor from destroying your vacuum system when you're plasma etching.



NOTES:
1. ALL NITROGEN GAS BLEEDS—1 PSIG MAXIMUM
2. SYSTEM VALVE V_1 INTERLOCKED WITH VALVE V_2. WHEN V_1 CLOSED V_2 OPEN. WITH V_1 CLOSED & VACUUM SYSTEM IN OPERATION, USE NEEDLE VALVE V_4 TO ADJUST PRESSURE IN MANIFOLD TO 50-100 MICRONS.
3. SOLENOID VALVE V_3 CONNECTED ACROSS MOTOR LEADS. OPENS WHEN PUMP STARTS.
4. FM = FLOW METER
5. SOLENOID VALVE V_5 CONNECTED ACROSS MOTOR LEADS. CLOSES WHEN PUMP STARTS.

Due to the corrosive nature of the gases used and the particulates generated, plasma etching can impose harsh requirements on your vacuum system.

The presence of water vapor makes these conditions even more severe.

To keep your vacuum system performing to its capabilities, you must prevent water vapor from entering the system. If it does, you must remove it quickly.

The following installation and operation procedures will help you keep your system operating smoothly.

The right installation.

Install PVC exhaust piping instead of galvanized or black iron pipe, and an oil mist eliminator to reduce oil loss from the pump.

The exhaust line should be installed so it can easily be disassembled for periodic cleaning and the vacuum manifold must be leak-free.

The right operation.

Operate the vacuum system continuously and make sure the vacuum pump is gas ballasted during processing with a nitrogen flow rate of 1 to 2 L/M.

Purge the reservoir with nitrogen (in humid ambients it may be necessary to increase the nitrogen flow). Do not pump on the process chamber with the vacuum system at blank-off pressure as oil backstreaming may result. When necessary to shut down the vacuum system for over 8 hours, fill gas ballast with nitrogen for at least 4 hours before stopping.

The right maintenance.

Drain the exhaust oil mist eliminator weekly. If oil is clean, it can be reused by returning to the pump. If it is "milky" or cloudy, it should be decanted before returning to pump reservoir. Cleaning interval is determined by the amounts of particulates accumulated.

Monitor differential pressure across the oil filter. Replace element when filter pressure shows a significant increase above baseline pressure. Actual pressures will be determined by your own process.

Open pump reservoir at 2-month intervals to remove sediment from bottom of the reservoir. And when the particulate oil filter elements are used, replace element when filter pressure as shown on the gage is exceeded.

The right vacuum system.

Stokes is America's full-line vacuum components manufacturer so we have the right pumping package for your application. So you don't have to over-design or over-purchase.

If you have a processing design question call or write: Stokes Division, Pennwalt Corporation, 5500 Tabor Road, Philadelphia, PA 19120. 215-831-5400.

Send for free subscription to Vac-Tech News.

Keep up with the latest developments and advanced technology taking place in the vacuum industry. Just call or write and we'll see that you receive each issue.

STOKES
PENNWALT
EQUIPMENT ■ CHEMICALS
HEALTH PRODUCTS

Stokes Division, Pennwalt Corporation
5500 Tabor Road, Philadelphia, PA 19120
Phone: 215-831-5400

Circle Reader Action No. 425

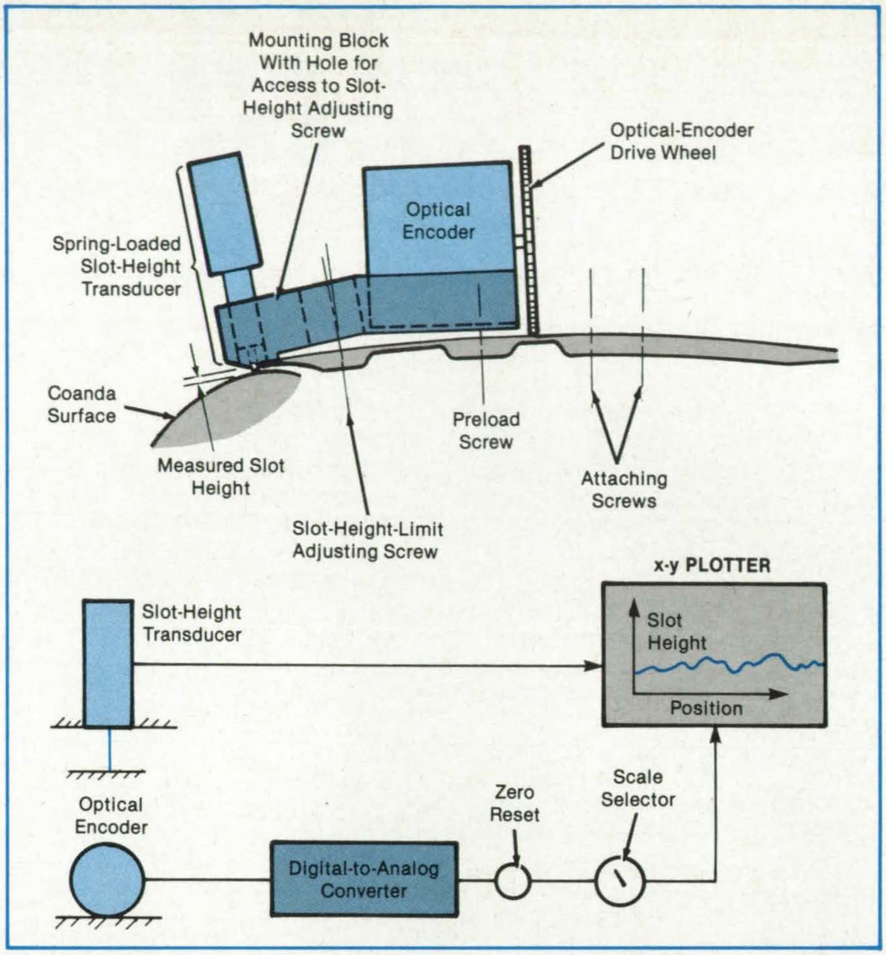
perimental aircraft. An x-y recorder plots the slot depth and position on 11- by 17-in. (28- by 43-cm) paper so that the measurements can be studied visually to monitor progress in the rotor-tuning process.

The moving parts of the measuring system (see figure) include a carriage that supports the slot-depth transducer and the wheel with the encoder. The transducer and encoder are both commercially available components. The carriage uses the upper surface and edge of the rotor slot as guides and reference points.

The slot-height transducer is a spring-loaded unit with a range of 0.1 in. (2.5 mm) and a sensitivity of 0.001 in. (0.025 mm); the transducer output drives the y-axis input of the recorder.

The output of the rotary optical encoder gives the relative spanwise location of the measuring unit as the wheel rolls along the rotor blade. The encoder output is passed through a digital-to-analog converter, the output of which drives the x-axis of the recorder.

The plotter controls include an automatic reset-to-zero switch on the position input so that a slot-height scan can be started at any location along the rotor slot and from any encoder position. A range switch for the position input allows the full plotter paper length to be used for various blade spans; for example 5, 10, or 30 ft (1.5, 3, or 9 m). The y-axis plotter scale is 1 unit for each 0.01 unit of slot height. The cost of the system is estimated to be less than $10,000.



The **Slot-Depth Measuring System** uses a spring-loaded transducer to measure the slot depth and a wheel-driven rotary optical encoder to measure the position along the slot. An x-y recorder plots the depth vs. the position.

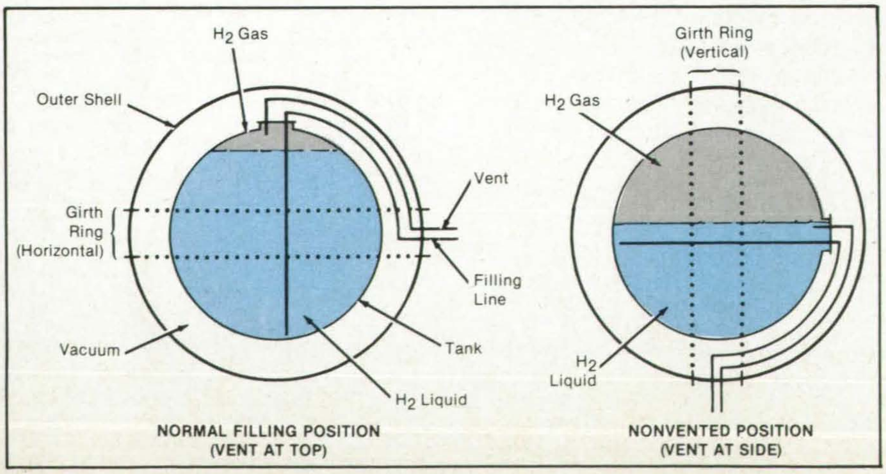
This work was done by Alan D. Clarke of United Technologies Corp. for **Ames Research Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11585.

Filling an Unvented Cryogenic Tank

Gas at the top is removed by liquefaction.

Lyndon B. Johnson Space Center, Houston, Texas



A slow-cooling technique enables a tank lacking a top vent to be filled with a cryogenic liquid. Ordinarily, a vertical vent allows the escape of gas accumulating above the liquid so that back pressure does not build up and prevent the tank from being filled to the top. In the new technique, pressure buildup is prevented through the condensation of accumulating gas, the

In the normal filling position, **Gas Escapes Through the Top Vent** (left). When the tank must be filled from the side (right), the gas must be slowly cooled and condensed instead of vented. The cross section on the right shows the tank during the 2-to 3-hour cool-down period.

Multiple Pages Intentionally Left Blank

resulting condensate being added to the bulk liquid.

The filling method was developed for vibration tests on a vacuum-insulated spherical tank containing liquid hydrogen. The tank had to be vibrated with its normally horizontal girth ring in a vertical position (see figure). The vibration fixture prevented the tank from being rotated after being filled (and vented) from the top in the usual way. Instead, the tank had to be installed with its filling port and vent at the side.

The first step in the filling operation is to place the tank on the vibrator with the ports sideways. Next, the Dewar containing the liquid hydrogen to be put in the tank is stabilized by venting it to the atmosphere for 24 hours. The tank is evacuated to a pressure of 10^{-3} torr (about 0.1 Pa), then filled with hydrogen gas.

With the vent open, the tank is supplied with liquid hydrogen until hydrogen runs out the vent. The tank is allowed to cool toward the liquid-hydrogen temperature of −423 °F (−253 °C) for 2 to 3 hours. Meanwhile, the pressure in the hydrogen-supply Dewar is adjusted to 25 lb/in.^{2} (170 kPa). When the tank temperature is sufficiently stable (dropping at a rate of less than 1 °F (0.6 °C) per minute, the vent is closed, and the filling line is opened. Liquid hydrogen flows into the tank until it is full.

Since the tank and its contents, including the hydrogen gas at the top, are well cooled, the slow introduction of additional liquid hydrogen does not appreciably compress and heat the gas in the head space. Instead, the gas gradually shrinks in volume by cooling and condenses into the liquid.

It is essential that all components in contact with the liquid hydrogen be cool. This means that the filling line must be purged with liquid hydrogen while the tank is cooling. Otherwise, the liquid may boil in the line when filling resumes; this would create enough back pressure to prevent further flow.

This work was done by Philip Beck and Gary S. Willen of Beech Aircraft Corp. for **Johnson Space Center**. *No further documentation is available.*
MSC-20652

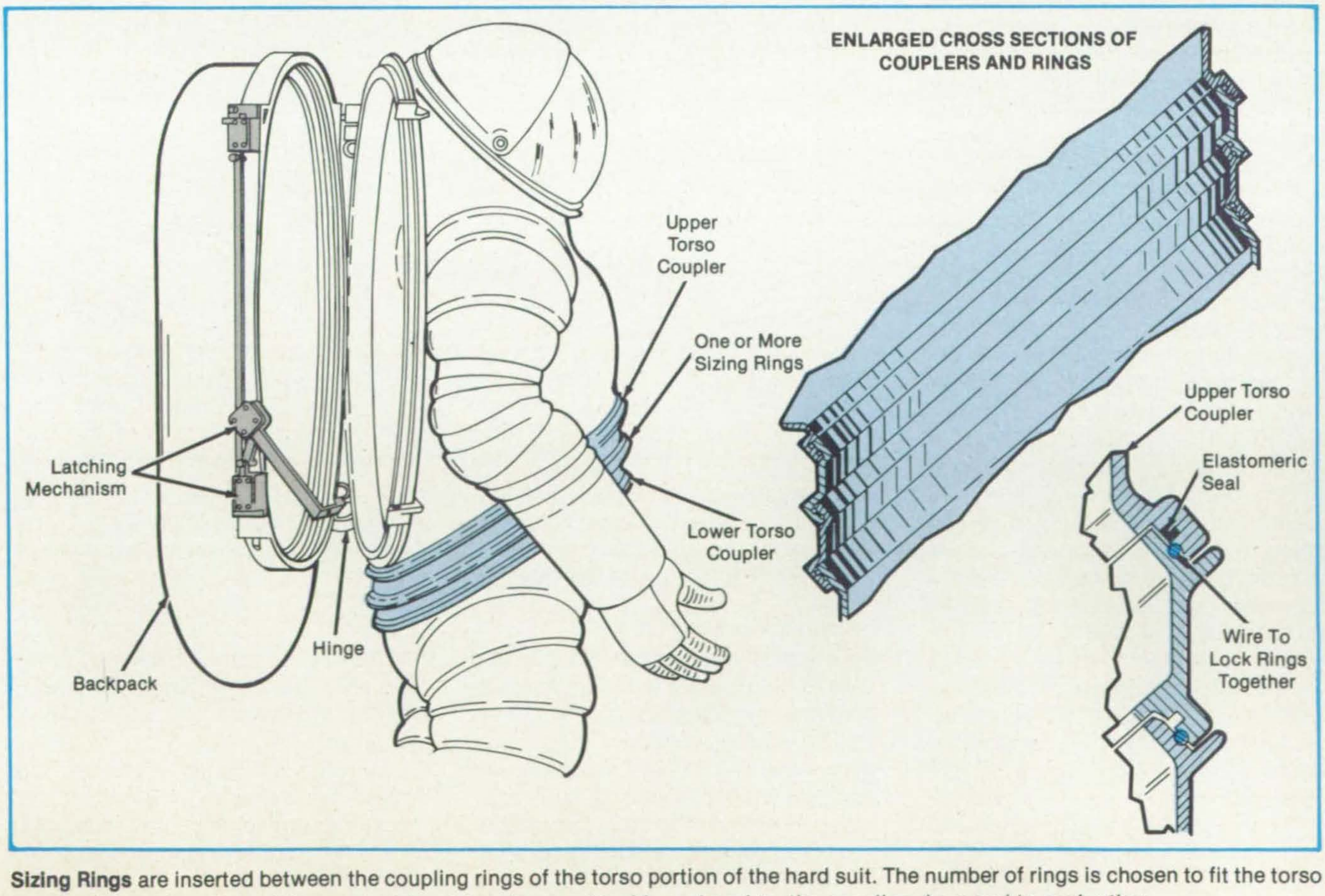
Hard Suit With Adjustable Torso Length

Torso sizing rings allow a single suit to fit a variety of people.

Ames Research Center, Moffett Field, California

A hard space or diving suit has an adjustable-length torso that will fit a large variety of wearers. Conventionally, each suit has been customized to the individual's torso length, but this process has been expensive, particularly when spare suits had to be made. The new adjustable-size concept with its cost-saving feature could be applied to other suits that are not entirely constructed of "hard" materials, such as chemical defense suits and suits for industrial-hazard cleanup.

In the adjustable-torso-length suit (see figure), sizing rings are inserted between the upper and lower torso sections to increase the torso length. When no rings are required, the coupler of the upper torso covering fits over the corresponding coup-



Sizing Rings are inserted between the coupling rings of the torso portion of the hard suit. The number of rings is chosen to fit the torso length of the suit to that of the wearer. The sizing rings mate with, and seal to, the coupling rings and to each other.

ler of the lower torso-covering section.

The sizing rings have upper and lower couplers, which accommodate the complementary couplers of the torso sections or of other rings. Elastomeric padding between the rings and couplers forms a pressure-aided hermetic seal. Two facing surfaces of each mating pair contain matching grooves, into which a flexible cable or wire may be inserted to hold the parts assembled.

The back of the adjustable torso is formed with a large opening, which is closed off by the backpack containing life-support, communication, and other equipment. This opening covers almost the entire back of the upper torso-covering section and is used for entry and exit. The coupler of the upper torso section is located immediately beneath the opening and slants up and forward — as consequently do all of the rings and the coupler of the lower torso section. This arrangement allows ample back opening for entry and exit of the largest wearer.

This work was done by Hubert C. Vykukal of **Ames Research Center.** *For further information, Circle 100 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11616.

Hydraulic Calibrator for Strain-Gauge Balances

A new instrument is based on load cells.

Ames Research Center, Moffett Field, California

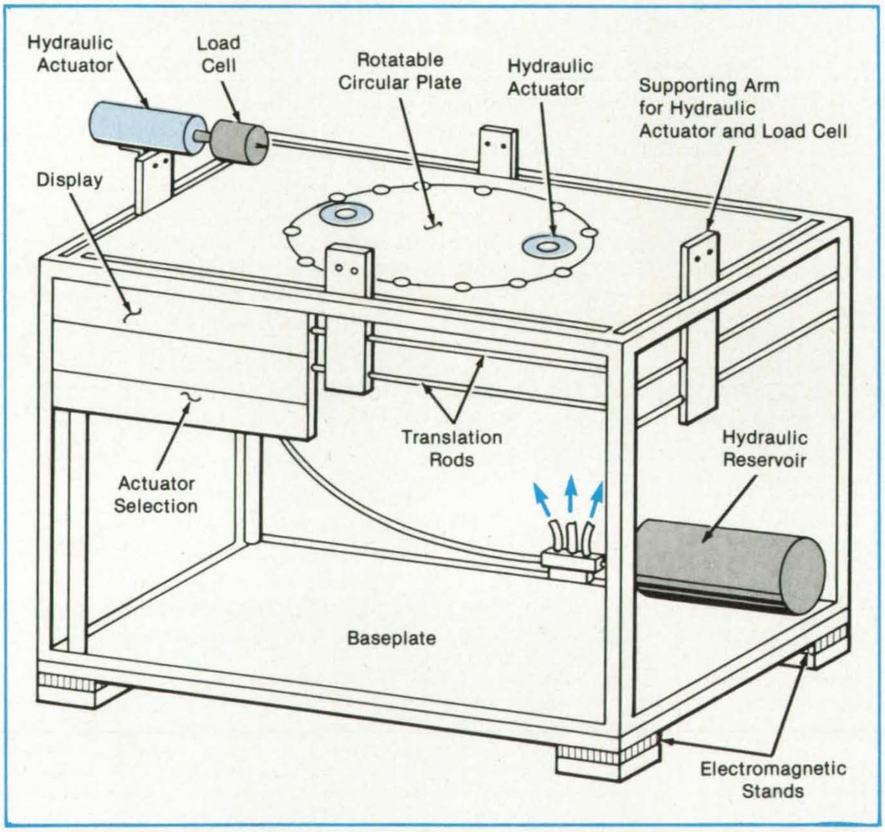
An instrument for calibrating strain-gauge balances uses hydraulic actuators and load cells instead of the cable, pulley, and weight arrangements of previous calibrators. The instrument eliminates the effects of nonparallelism, nonperpendicularity, and changes of cable directions upon the vector sums of the applied forces. The errors due to cable stretching, pulley friction, and weight inaccuracy are also eliminated.

The new instrument is rugged and transportable. It can be set up quickly. Originally developed to apply known loads to wind-tunnel models with encapsulated strain-gauge balances, it can also be adapted for use in calibrating dynamometers, load sensors on machinery, and laboratory instruments.

The baseplate of the instrument rests on electromagnetic stands. The plate supports a frame containing translation and rotation mechanisms, load cells and the accompanying electronic devices, and the hydraulic actuators, controls, and reservoir (see figure). An actuator/load-cell combination is located over the midpoint of each side of the frame. The force of a hydraulic actuator is applied through its precise load cell, which makes contact with the model at a point near the encapsulated strain-gauge balance to be calibrated. The force is set by adjusting the hydraulic control and observing the output signal from the load cell until the desired value is reached.

A central circular plate on the top of the frame holds two actuator/load-cell combinations. The plate can be rotated 180° about its center. The housing can be raised by extending legs from the magnetic stands.

The six hydraulic force actuators and load cells can be positioned with the translation and rotation mechanism: translation rods along the four sides of the frame enable the actuators and load cells to be moved laterally on their supporting arms; the supporting arms can also be adjusted vertically. Once the actuators and load cells are in position, they can then be employed to apply an accurately known single force or combination of forces, producing pure moments about the model and its strain-gauge balance at the test position in the wind tunnel.

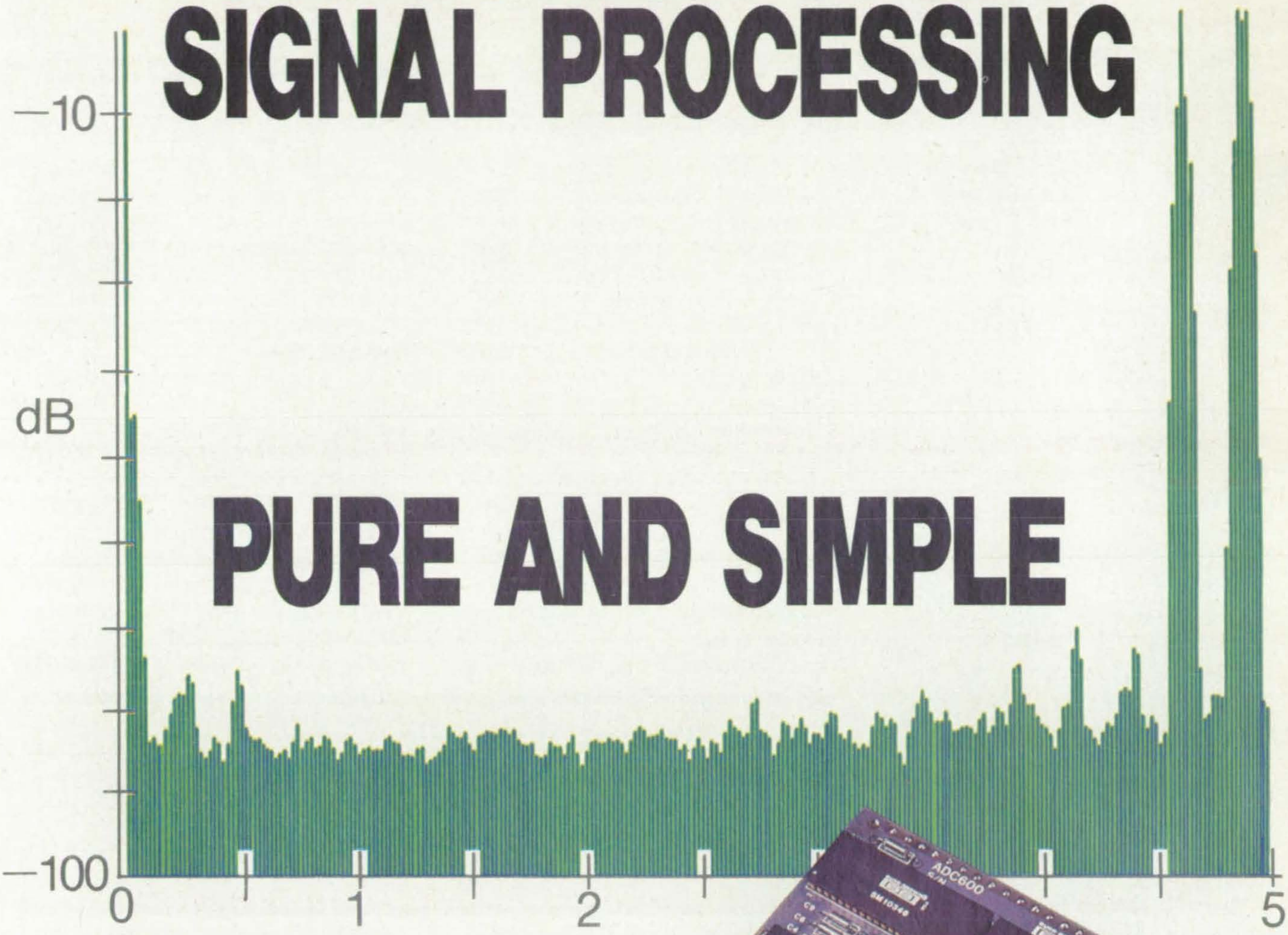


The **Calibration Frame Positions** actuators and load cells vertically, horizontally, and rotationally about the vertical axis. The force produced by each hydraulic actuator is individually controllable. The strain-gauge bridge, encapsulated in an aerodynamic model, would be suspended over the unit for calibration.

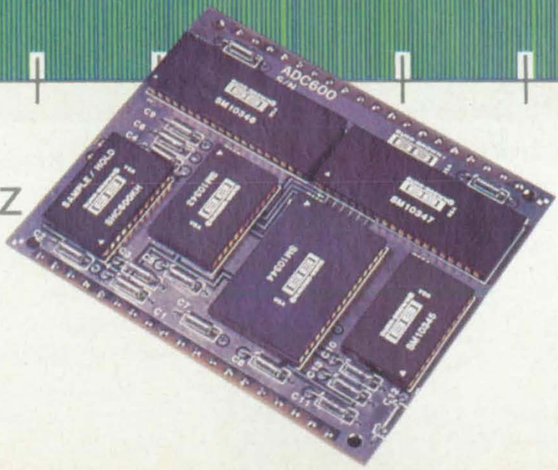
This work was done by Kenneth Skelly and John Ballard of **Ames Research Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11360.

ULTRA-*HIGH SPEED* SIGNAL PROCESSING



PURE AND SIMPLE



ADC600 GIVES YOU UNMATCHED SPECTRAL PURITY, 70MHz ANALOG BANDWIDTH, ...AND NO PROBLEMS.

ADC600 is an ultra-high speed, 12-bit A/D converter. A two-step subranging conversion technique with digital error correction can digitize signals at rates up to 10 million samples-per-second without sacrificing signal purity. It's an excellent choice for radar, sonar, ultrasound, and image processing applications. You can also use it to make a great front-end for today's advanced DSP designs.

Complete, Easy-To-Use

ADC600 requires only an external CONVERT command and powor supplies to operate. No need for external parts. And it's reliable, 100% performance tested, and already adopted for several major military programs.

Key Specifications

Resolution	12 bits
Sampling rate	10MHz
THD	−71dBc
Input bandwidth	70MHz
Power dissipation	<10W
Module area	3.75" × 4.5"

Ask For A Demonstration

ADC600 is your best ultra-high speed signal processing solution. Find out for yourself. For a free demonstration and/or complete performance, testing, and applications information, contact your Burr-Brown sales rep or Applications Engineering, 602/746-1111. Burr-Brown Corp., P.O. Box 11400, Tucson, AZ 85734.

BURR-BROWN®

Improving Data Conversion Productivity

Circle Reader Action No. 435

Machinery

Hardware, Techniques, and Processes

Fuel/Air Premixing System

Fuel and air are mixed thoroughly within a short distance.

Lewis Research Center, Cleveland, Ohio

A recent NASA investigation has led to the development of a deflector system that provides uniform fuel/air mixtures in very short units. Mixing of fuel and air to obtain uniform fuel/air mixtures is required in some combustion systems, including catalytic combustors and staged combustors with premixed main stages. In many combustion systems, length of the unit is critical, and the air/fuel mixing must be done in a minimum distance.

In the new, simplified system, a centrally located fuel injector is combined with a perforated plate mounted on the premixing-duct inlet. The plate causes some of the fuel spray to move radially outward while mixing with the air. The hole patterns in the plate are designed to enhance even burning and to prevent excess fuel from reaching the chamber walls. The individual jets of air moving through the perforated plate also cause adequate turbulence for rapid air/fuel mixing. This uniform fuel/air distribution results in improved operation and efficiencies in minimum-length combustor systems.

This work was done by E. Ekstedt of General Electric Co. for **Lewis Research Center**. *Further information may be found in NASA CR-168323 [A86-25269/NSP], "Clean Catalytic Combustor Program — Final Report."*

Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700. LEW-13953

Efficient Vent Unloading of Air Compressors

Vent unloading downstream of air compressor conserves energy and increases component life.

John F. Kennedy Space Center, Florida

A method for unloading one- and two-stage reciprocating air compressors increases energy efficiency and inhibits the deterioration of components. Instead of mechanically locking the intake valve in the open position (intake-valve unloading) to attain an acceptable duty cycle, the new method achieves unloading by allowing the compressor to vent the air to the atmosphere downstream of the compressor

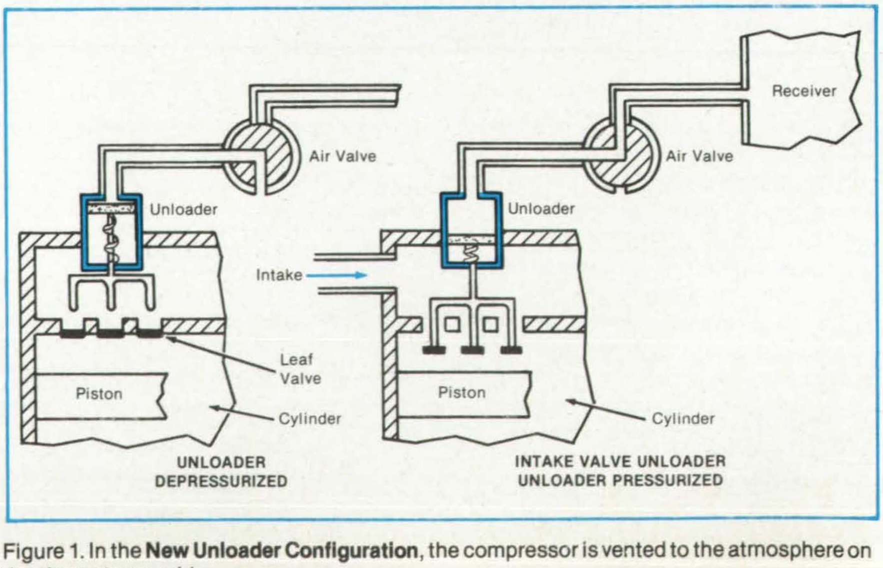
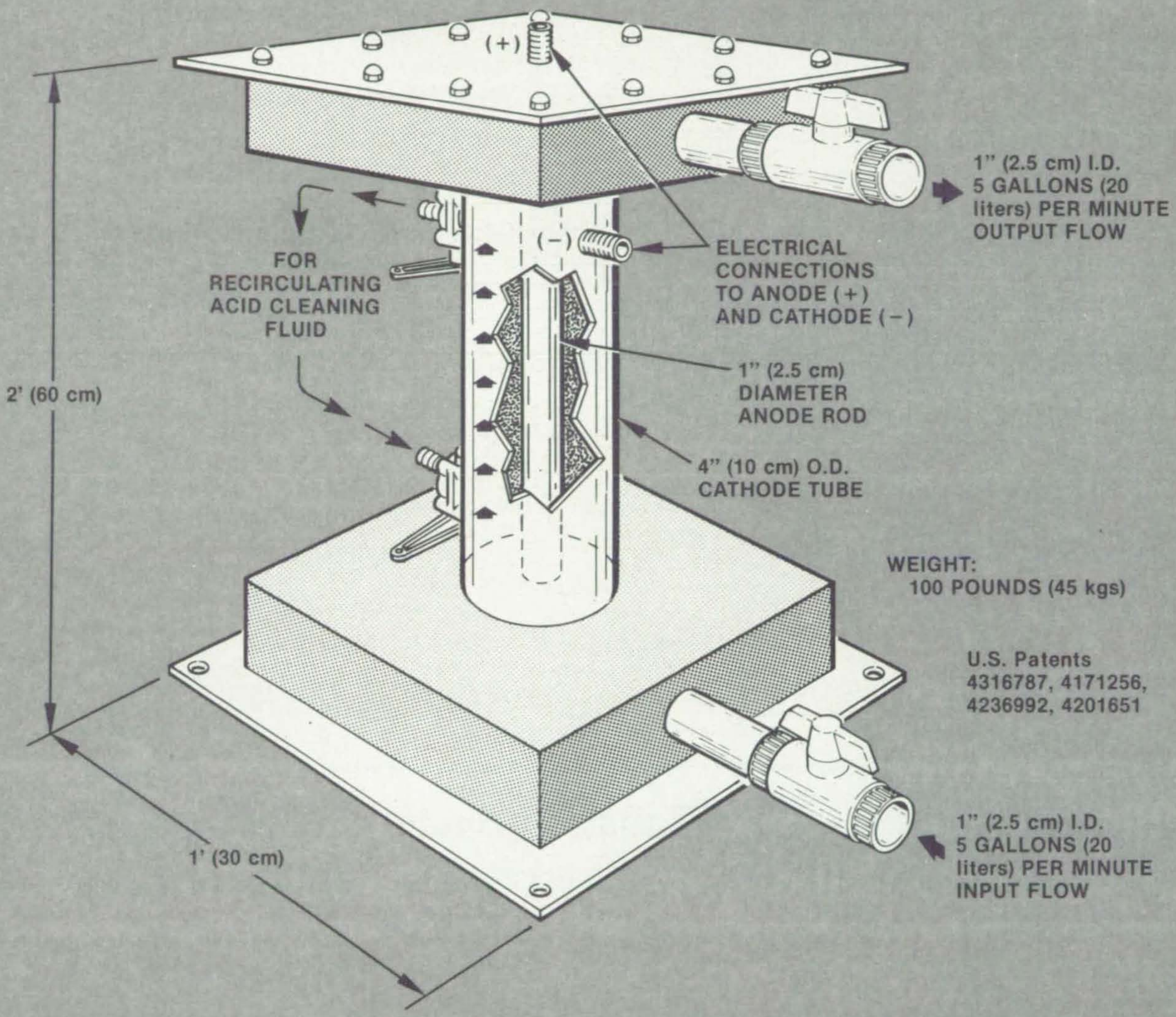


Figure 1. In the **New Unloader Configuration**, the compressor is vented to the atmosphere on the downstream side.

CYANIDE-FREE WATER
Cyna-Cell Model '125'

Without Chlorine, Bromine, Ozone, Chemicals, or Filters!
Safe, Quick, Automatic, Simple, Economical, Portable
Capacity Up To 10,000 Gallons A Day



HOW TO OPERATE THIS CYNA-CELL Model '125'

Connect its anode and cathode to a DC power supply capable of carrying 50 volts at 50 amperes - 2500 watts - 2.5 kw. The cyanide-laden water must be stationary in a tank of 50 gallons or more. Per 50 gallons (190 liters) add one pound (450 kgs) of specially formulated electrolyte salts CYNA-SALT, provided.
Recirculate at the rate of about 5 GPM (20 liters) until the cyanide is destroyed. An appropriate test kit is supplied with each CYNA-CELL.

Depending upon the type, amount of cyanide and water, destruction will take from 10 to 60 minutes. And depending upon the conductivity of the cyanide-laden water, this cell will draw from 500 to 2,500 watts.

After each day's operation, this cell MUST be acid-washed! An automatic acid-wash system is supplied with each CYNA-CELL to recirculate for 5 minutes at 35% concentration hydrochloric acid.

All plating shops have adequate DC power, pumps and experts to operate this simple cell. However, we can provide the complete system if needed. We can also design and manufacture systems to meet customer's requirements with capacities up to 50 GPM (200 liters).

The cost of this cell is $5000. The CYNA-SALT comes in 50 pound (22.5 kgs) bags and each bag costs $50. Delivery is about 90 days after receipt of order.

Manufactured in the United States of America by:

STER-O-LIZER® MANUFACTURING CORPORATION

Mailing Address: P.O. Box 27488, Salt Lake City, Utah 84127 U.S.A.
Offices: 375 West 400 North, Salt Lake City, Utah 84103 U.S.A.
Telephone: (801) 532-5600 Telex: 453-048 SMC SLC

Litho in U.S.A.

(see Figure 1).

This method eliminates the valve-damaging heat encountered in the conventional method and which is caused by the throttling of a large reciprocating flow through the intake valve. Also, this method allows each startup of the compressor drive motor to occur against zero downstream pressure. This method eliminates the power surge when the pressure upstream of the check valve exceeds the receiver pressure. Fatigue failure of air-intake filters, caused by pulsating air, is also eliminated. The method can be implemented expeditiously as a modification of existing systems as shown by Figure 2.

A crude prototype was achieved in 1980 on a 25-hp (19-kW) compressor. Receiver venting was used to obtain a suitable duty cycle for a 25-hp, 175-psig (19-kW, 1.2-MPa) air compressor. This compressor has no intake-valve unloading capability. This corrected a potentially dangerous crankcase-water-intrusion problem. The new method is derived from this modification. Until field-test data are available, the recommended operating limits are a power of 150 hp (110 kW) and a pressure of 175 psig (1.2 MPa).

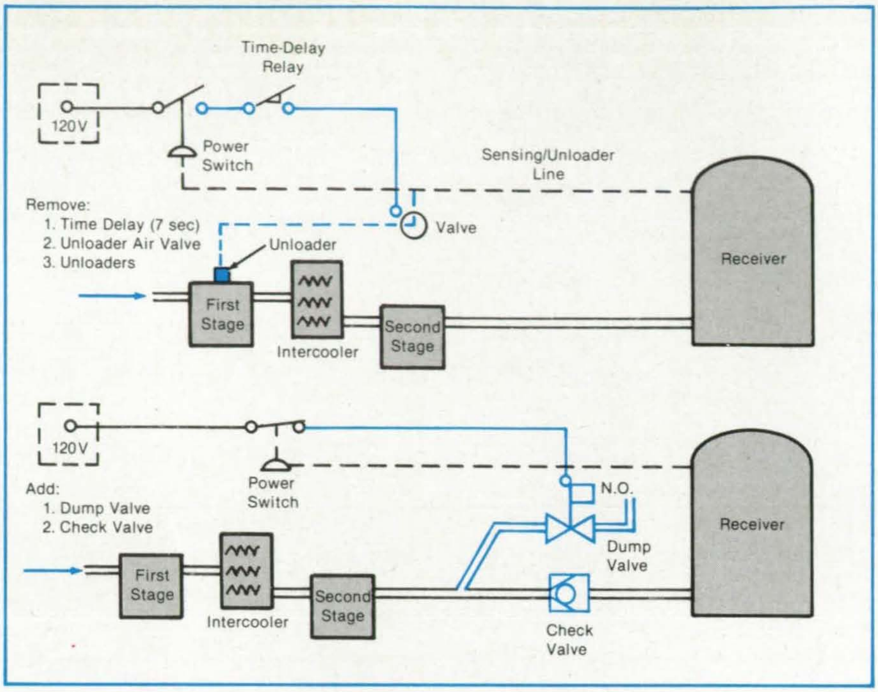


Figure 2. A **Compressor With Intake-Valve Unloading** is modified to implement vent unloading.

The sequence of functional events is as follows:

1. The pressure switch closes. The bypass valve closes simultaneously with the initiation of the duty-cycle time-delay relay.
2. The pressure increases upstream of the receiver (storage tank) check valve, and the check valve opens.
3. When the receiver comes up to the specified pressure, the pressure switch opens, the bypass valve opens, the check valve closes, and the compressor is unloaded.
4. When the delay expires, the bypass valve is set to remain in the open position. If the pressure switch closes before the end of the delay, the system returns to the first step, and the sequence proceeds once more from that point.

This work was done by Alvin J. Muhonen of Boeing Services International, Inc., for **Kennedy Space Center**. *For further information, Circle 128 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 19]. Refer to KSC-11299.

Getter Capsules for Heat-Transport Systems

A metal would absorb hydrogen dissolved in heat-transfer fluids.

Goddard Space Flight Center, Greenbelt, Maryland

Blockages by hydrogen gas in refrigerators, heat pipes, and other two-phase heat-transport systems could be eliminated by the use of degassing metals or alloys called getters. The getter could be contained in a getter capsule placed in series or in parallel with the heat-transport loop. This gas-removal technique would be more specific and more reliable in solving the problem of gas blockage than older procedures that rely on cleanliness or on refluxing or purging with the heat-transport liquid to prevent the production of hydrogen or to eliminate existing hydrogen.

The hydrogen known to exist in such heat-transport fluids as the chlorofluoromethanes and anhydrous ammonia could not be easily removed using activated charcoal, palladium, or zeolite — three materials commonly used to absorb gases: charcoal would absorb ammonia preferentially to hydrogen; hydrogen would diffuse through palladium, but this metal would be too expensive, absorb hydrogen too slowly, and be ineffective in removing moisture and other gaseous products; zeolites require high pressures and temperatures to encapsulate the hydrogen.

The proposed getter system would capitalize on the reversible reaction of hydrogen gas with a wide variety of metals and alloys. A typical reaction is the following:

$$LaNi_5 + 3H_2 \underset{\text{endothermic}}{\overset{\text{exothermic}}{\rightleftharpoons}} LaNi_5H_6$$

Because the reaction between the hydrogen and the metal or alloy is exothermic, the reaction temperature would enable the observer to note the reaction time and the completion of the reaction.

The gas-absorbing metal or alloy would be contained in a stainless steel or other metallic housing, possibly fitted with swage locks and valves and containing metallic or polymeric seals that do not react with the heat-transport fluid. The housing would be large enough to accommodate about 25 percent expansion of the getter substance during its lifetime and might contain filters to prevent hydride particles from leaving the capsule and entering the stream of heat-transport fluid. It would also have a nonleaking port that would allow the insertion of a thermometer or thermocouple.

The hydgrogen absorbed in the capsule may later be released by heating to cause a controlled blockage of the heat-transport fluid flow, thus providing a variable heat conductance. Also, hydrides may be used as switching mechanisms and as energy stores. The housing may be in the form of a cartridge, a canister, or other configuration, the overriding factor in the design being to avoid creating a significant pressure drop.

This work was done by Benjamin Seidenberg of **Goddard Space Flight Center**. *For further information, Circle 86 on the TSP Request Card.* GSC-12922

Spot Paint Sprayer

Small parts would be coated reliably.

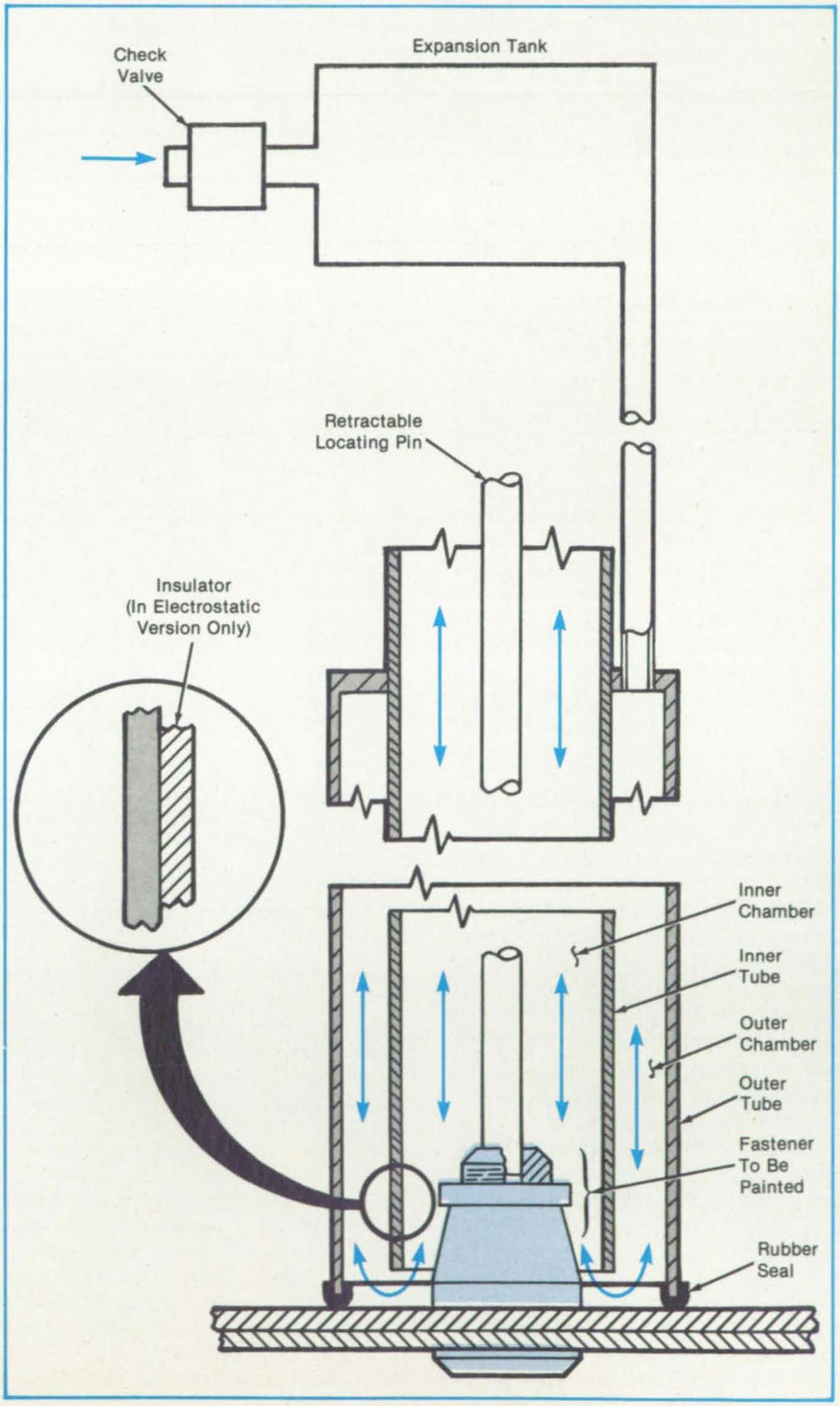
Lyndon B. Johnson Space Center, Houston, Texas

A proposed atomizing system would apply paint to small areas or objects — typically nuts, bolts, or other fasteners on flat surfaces. The system could be used in electronic and mechanical assemblies, for example, where small parts may have to be coated but cannot be reached by normal spraying techniques. Coverage by the system is expected to be more complete than that obtained by hand brushing.

The applicator would be held by hand-pressure against the surface holding the object to be painted (see figure). A rubber seal would contain the painting atmosphere and prevent the unwanted spread of paint out of the area to be coated. A locating pin would be extended to a matching hole in the object to be coated to assure the correct positioning of the applicator.

The painting sequence would include application, reapplication, and venting intervals. During the application interval, paint would be atomized and fed into the inner chamber. The residual atomized paint would flow under the end of the inner chamber to the outer chamber. The volume of residual atomized paint would be controlled by the paint pressure in the atomizer and the size of the expansion tank connected to the outer chamber. Regulators and valves could also be used to duplicate the function of the expansion tank.

The reapplication interval would begin with the evacuation of the inner chamber. This would cause the atomized paint to flow back from the outer chamber to the inner chamber, coating surfaces that were not reached during the application interval. In addition, the evacuation might be halted and resumed once or several times in a controlled manner to create



The **Paint Applicator** would contain two chambers in which the flow of air and atomized paint would be controlled to ensure complete coating of the fastener. In an electrostatic version, the inner tube would serve as one electrode, while the object to be coated would serve as the other electrode.

pressure/vacuum pulses that would alternately accelerate and decelerate the flow of atomized paint toward the fastener.

During the venting interval, the inner chamber would be evacuated more completely. The remaining paint and air in the secondary chamber would be withdrawn into the primary chamber and the check valve would open, allowing air to be drawn into the expansion tank and outer chamber. Thus, the atomized paint would be flushed from the chambers, and excess paint would be removed from the fastener.

An alternative version (see inset in figure) would rely on electrostatic attraction to apply the paint to the fastener. In this case, the inner tube would serve as a positive electrode and the fastener as the negative electrode. An insulator on the inside of the inner tube would prevent accidental electrical contact between the two electrodes. Voltage regulators and electronic sensors would help to guard against arcing.

This work was done by J. Arthur Leifsen of Grumman Aerospace Corp. for **Johnson Space Center**. *No further documentation is available. MSC-21080*

Hydraulic Fatigue-Testing Machine

Multiple specimens are tested simultaneously.

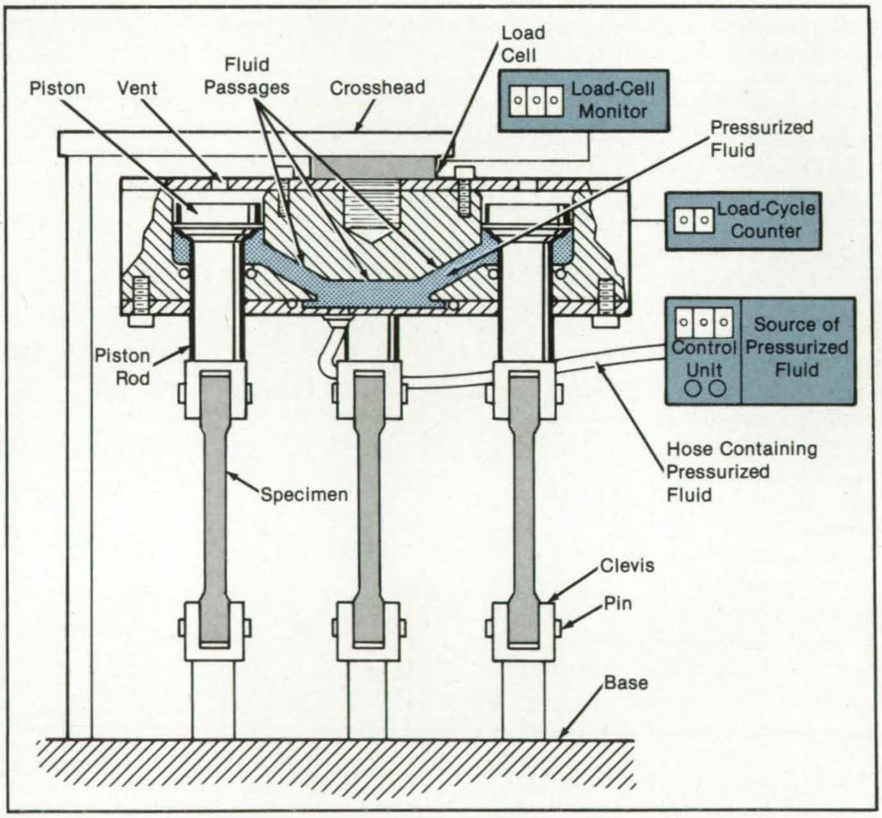
Marshall Space Flight Center, Alabama

A fatigue-testing machine applies fluctuating tension to a number of specimens at the same time. When a sample breaks, the machine continues to test the remaining specimens. Thus, the series of tensile tests needed to determine the fatigue properties of a material can be performed more rapidly than in a conventional fatigue-testing machine, which accommodates only one specimen at a time.

The machine (see figure) includes a pulling head mounted on a conventional crosshead and containing hydraulic cylinders — one for each specimen. All of the cylinders communicate hydraulically with a common fluid passage, so that all are driven at the same pressure by the source of pressurized fluid. Each cylinder contains a piston, the rod of which is attached to the upper end of the specimen by a clevis or by a threaded connection. The lower end of the specimen is attached similarly to the base of the machine. The vertical position of the pulling head can be adjusted to load and unload specimens or to accommodate different specimen lengths.

When the fluid is pressurized, the cylinders move upward, applying tension to the specimens. When the pressure is removed, the pistons move downward, and the tension is relaxed. The top of each cylinder is vented to the atmosphere to prevent the buildup of pressure or suction, thereby enabling the pistons to move freely during the relaxation periods. When a specimen breaks, the piston suddenly moves upward until it reaches the top of the cylinder. Because the piston blocks the vent hole, there is no loss of fluid, and the pressure returns to the preset value after a momentary dip.

The source of pressurized fluid is set to apply repeatedly a preset pressure and then relieve the pressure, to provide the amount of cyclical tension in each specimen required for the particular fatigue test.



Each Specimen Is Pulled by a hydraulically driven piston. When a specimen breaks, the hydraulic pressure continues to drive the other pistons.

The total tension in all specimens can be monitored by mounting the pulling head at the lower end of a load cell attached to the crosshead. A conventional mechanical load-cycle counter is used to determine the number of load cycles to which each specimen has been subjected before it breaks. From the number of cycles and the stress level at breakage, the fatigue strength and endurance limit (if applicable) of the specimen material can be determined.

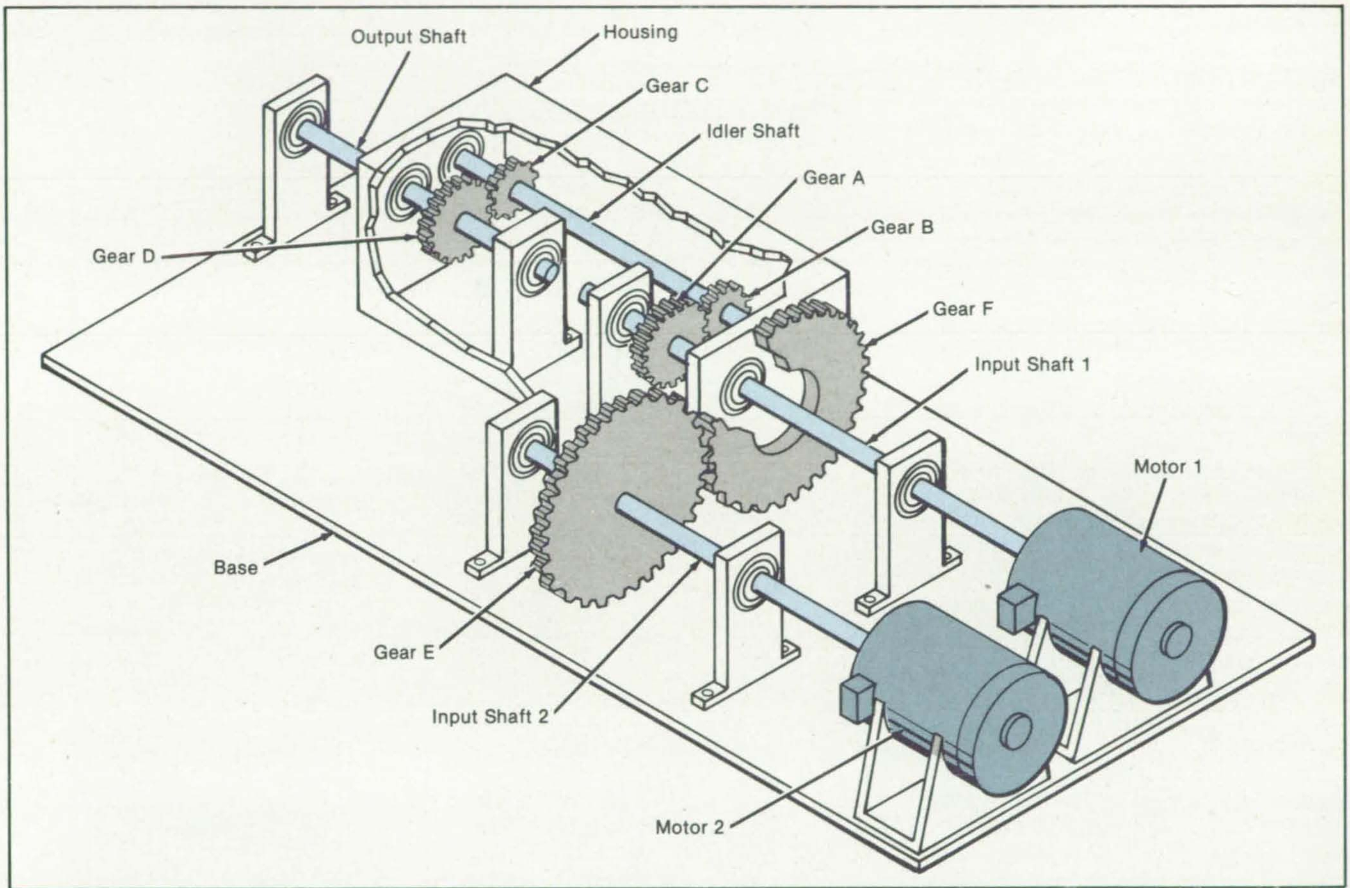
This work was done by James D. Hodo, Dennis R. Moore, Thomas F. Morris, and Newton G. Tiller of **Marshall Space Flight Center**. *For further information, Circle 18 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-28118.

Rotary Drive Mechanism Accepts Two Inputs

Shaft rotations are combined without clutches or planetary gears.

Ames Research Center, Moffett Field, California



The **Rotation of Input Shaft 2** causes the rotation of the housing and the gear-train supports within it. This relative motion is added to the motion imparted to the gear train by shaft 1.

A mechanism connects two drives to a single output shaft without clutches or planetary gears. The mechanism is therefore more reliable than a clutch-based two-drive mechanism and less bulky than a planetary mechanism. Moreover, it can be designed for any ratio of output to input speed, including a 1:1 ratio, unlike planetary gears. The drives may operate simultaneously or separately.

In the new mechanism, a gear train connects one of the drive shafts to a coaxial output shaft (see figure). The other drive shaft is connected to the rotatable housing that contains the gear train. Depending on the direction in which the housing is rotated by the second shaft, the rotation of the first shaft is either augmented or diminished in the output shaft.

An electric motor (or another source of rotational energy) drives each of the input shafts. Shaft 1 turns gear A at its end. Gear A meshes with gear B on an idler shaft parallel to shaft 1 and thus rotates gear C at the end of the idler shaft, and the meshing gear D on the output shaft. Shaft 1 thus drives the output shaft through the idler shaft.

Meanwhile, input shaft 2, which is parallel to input shaft 1, the idler shaft, and the output shaft, rotates gear E at its end. Gear E meshes with gear F, which is mounted on the gear-train housing. Gear F is concentric with shaft 1 and with the output shaft. Input shaft 2 thus rotates the housing. The rotation of shaft 2 is thereby superimposed on that of the gear train. The output shaft must be coaxial with input shaft 1 and gear F.

The relationship between the output- and input-shaft rotations is given by

$$\theta_{out} = R_{ABCD}\theta_1 - R_{EF}\,\theta_2(1 - R_{ABCD})$$

where θ = rotation angle or speed of a shaft, the numerical subscripts denote input shafts 1 and 2, R_{ABCD} = the gear ratio of the gear train ABCD in the housing, and R_{EF} = the gear ratio of the large gears E and F. Thus, the input shafts can alter the position of the output shaft separately or concurrently by the same or different gear ratios, all without any intervening clutches.

This work was done by Larry D. Webster of **Ames Research Center.** *For further information, Circle 101 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center [see page 19]. Refer to ARC-11325.

Spray Gun With Constant Mixing Ratio

A lightweight mechanism would maintain the desired ratio of two components.

Marshall Space Flight Center, Alabama

A conceptual mechanism mounted in the handle of a spray gun would maintain a constant ratio between the volumetric flow rates in two channels leading to the spray head. The concept arose from the need to assure equal flows of the two ingredients that are reacted in a spray gun to produce polyurethane foam. Without the ratio-control mechanism, the flows vary as the viscosity changes with temperature or as an orifice or channel becomes slightly clogged. With the mechanism, it should be possible to keep the flow ratio near 1:1 (or another desired ratio) over a range of temperatures, orifice or channel sizes, or clogging conditions.

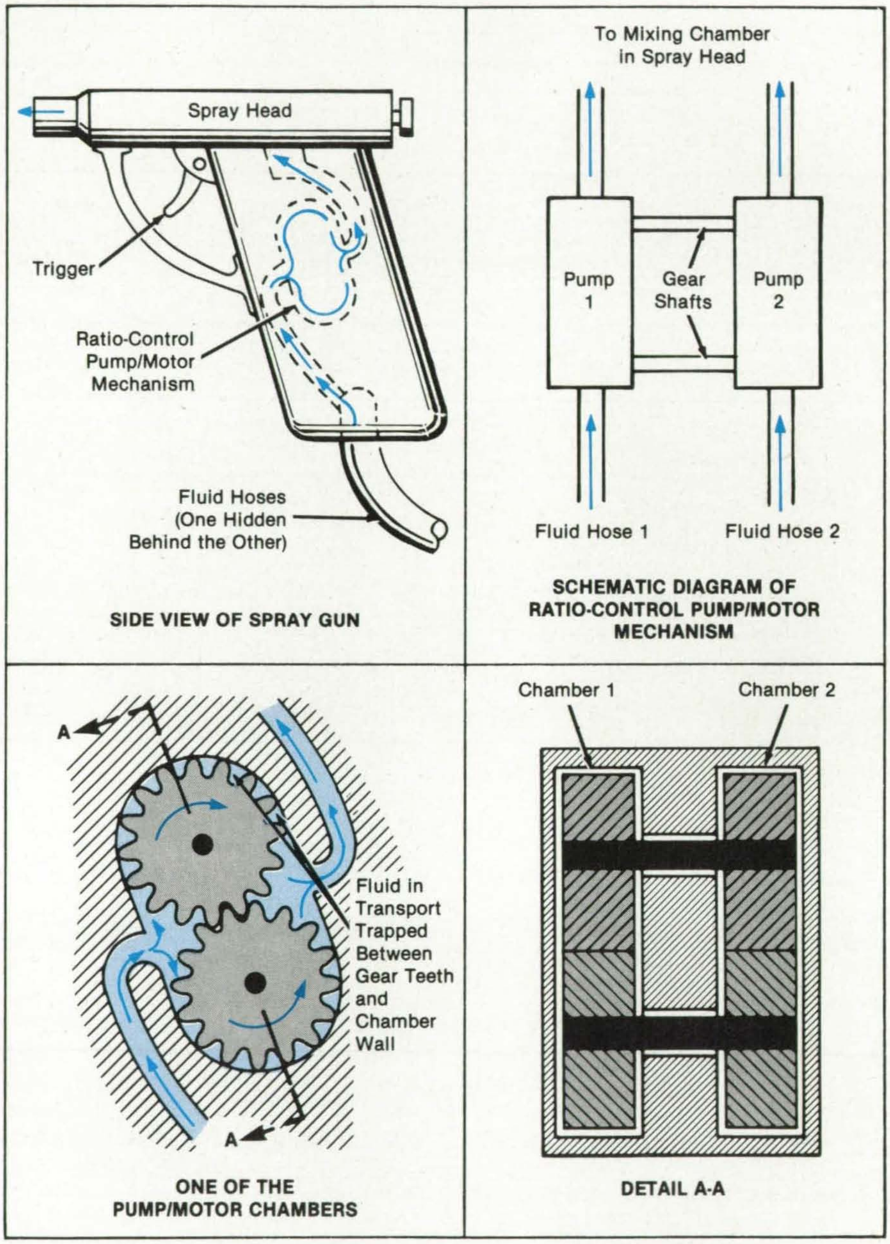
The mechanism (see figure) resembles an interconnected pair of gear-type positive-displacement oil pumps. Each pump chamber is connected to one of the fluid channels. Each chamber contains two identical meshing gears that carry the fluid around the channel periphery in the spaces between the gear teeth. The meshing action squeezes the fluid out from between the gears, thereby preventing backflow.

Each gear is mounted on a shaft that connects it to a gear in the other pump chamber. Thus, the two pumps are constrained to operate at the same rotational speed. If the flow tends to slow down in the first channel, the greater flow in the second channel causes the second pump to act, in effect, as a motor that turns the first pump.

Neglecting leakage, the flow in each channel is proportional to the product of the gear rotational speed and the volume between the gear teeth. Since the rotational speeds are equal, the flow ratio depends only on the volume between the gear teeth. Thus, the flow ratio is set by the selection of the sizes of gear teeth in each pump chamber. For equal flows, both chambers would be equipped with identical gear sets.

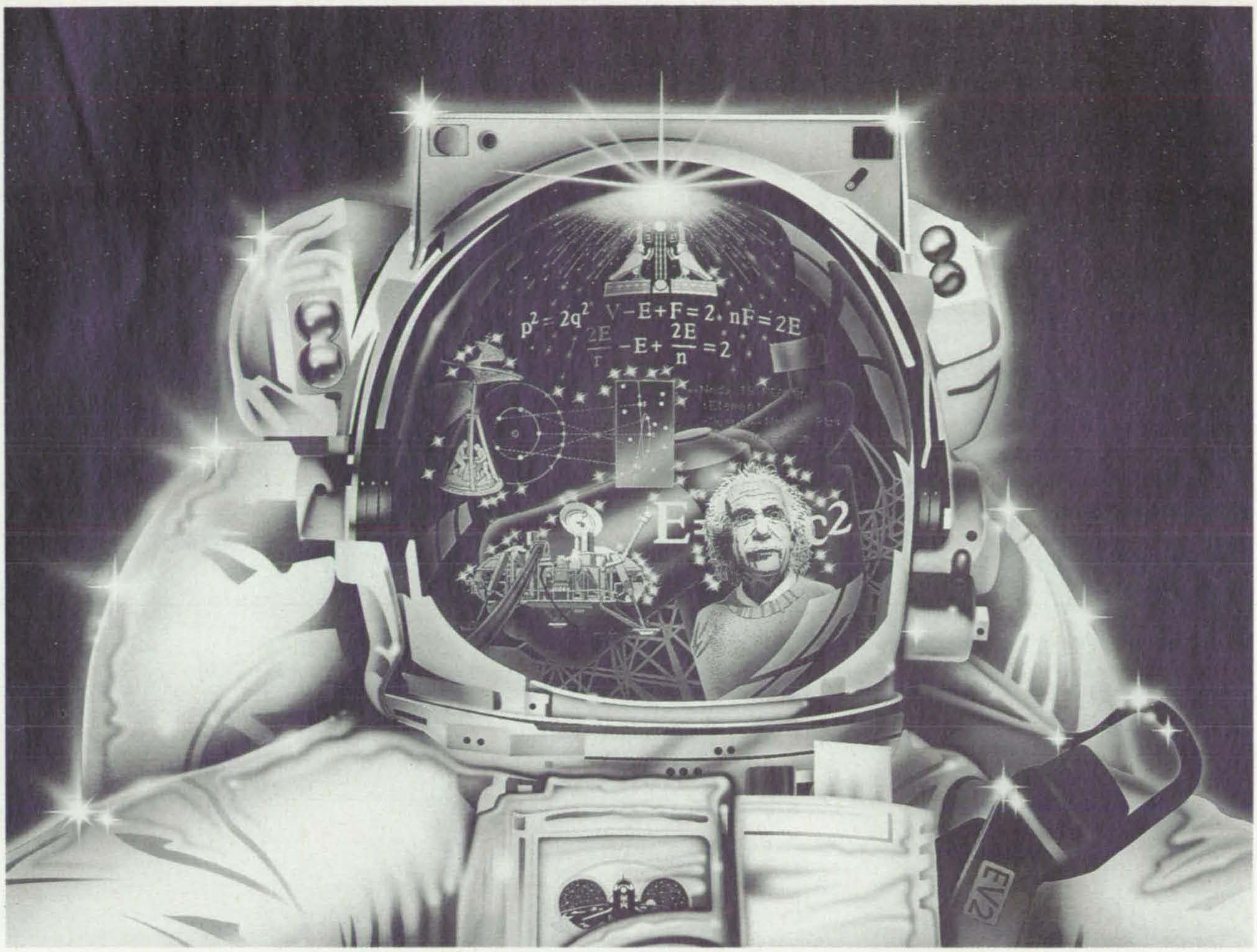
This work was done by William G. Simpson of **Marshall Space Flight Center**. *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 19]. Refer to MFS-28135.



Two Interconnected Gear-Type Positive-Displacement Pump/Motors regulate the flows in two channels to maintain them at a constant volumetric ratio over a range of temperatures, fluid pressures, and orifice or channel-clogging conditions. The pumps receive power from the fluid flow. If the flow tends to drop in one channel, the pump/motor pair assists by transferring some of the power from the other channel.

M A R T I N   M A R I E T T A   D E N V E R   A E R O S P A C E



With your help, we'll mastermind still more of tomorrow's space and defense systems technologies.

Mastermind a Dream.

If an idea is good, it shouldn't stay an idea for long. At Martin Marietta Denver Aerospace, dreams—even the "impossible" ones, the long shots—can come true.

Working with highly advanced equipment in state-of-the-art facilities, our engineers tackle a broad variety of interesting and challenging assignments each day—an unmatched repertoire of advanced launch and space propulsion systems, spacecraft, instruments and strategic defense systems.

We're looking for top engineers with a B.S. degree or equivalent (advanced degree desirable) in electronic engineering or physics and 5 to 15 years of experience to take several leading-edge programs from the conceptual stage forward.

Antenna System Engineers
Antenna Design Engineers

Several opportunities exist in conceptual design, analyses and laboratory development of advanced microwave antennas or similar work in electromagnetics.

Communication Systems Engineers

Explore exceptional opportunities in spacecraft and missile communication systems design and analysis.

Microwave and Millimeter Wave Systems Engineers

We have multiple opportunities in the conceptual design and analysis of advanced microwave and millimeter wave systems.

Sr. Spacecraft Controls System Analysts

Here are several opportunities for specialists with 5 to 10 years of experience which includes digital computer modeling and flexible/rigid bodies.

Sr. Guidance and Control Hardware Engineers (PIE)

You'll need 5 to 10 years of experience in systems integration and knowledge of subcontract work involving gyros, accelerometers, momentum wheels, star trackers, star scanners, sun sensors and related areas.

AN EBI/SBI BACKGROUND INVESTIGATION MAY BE REQUIRED.

Please send your resume to Martin Marietta Denver Aerospace, Personnel Department, P.O. Box 179, G1311, P70042, Denver, Colorado 80201. No agencies, please. We're an Affirmative Action Employer actively seeking veterans and the handicapped. U.S. Citizenship is required.

MARTIN MARIETTA

Circle Reader Action No. 418

Alkali Metal/Salt Thermal-Energy-Storage Systems

Systems would couple high energy-storage density with minimal corrosion and thermal ratcheting.

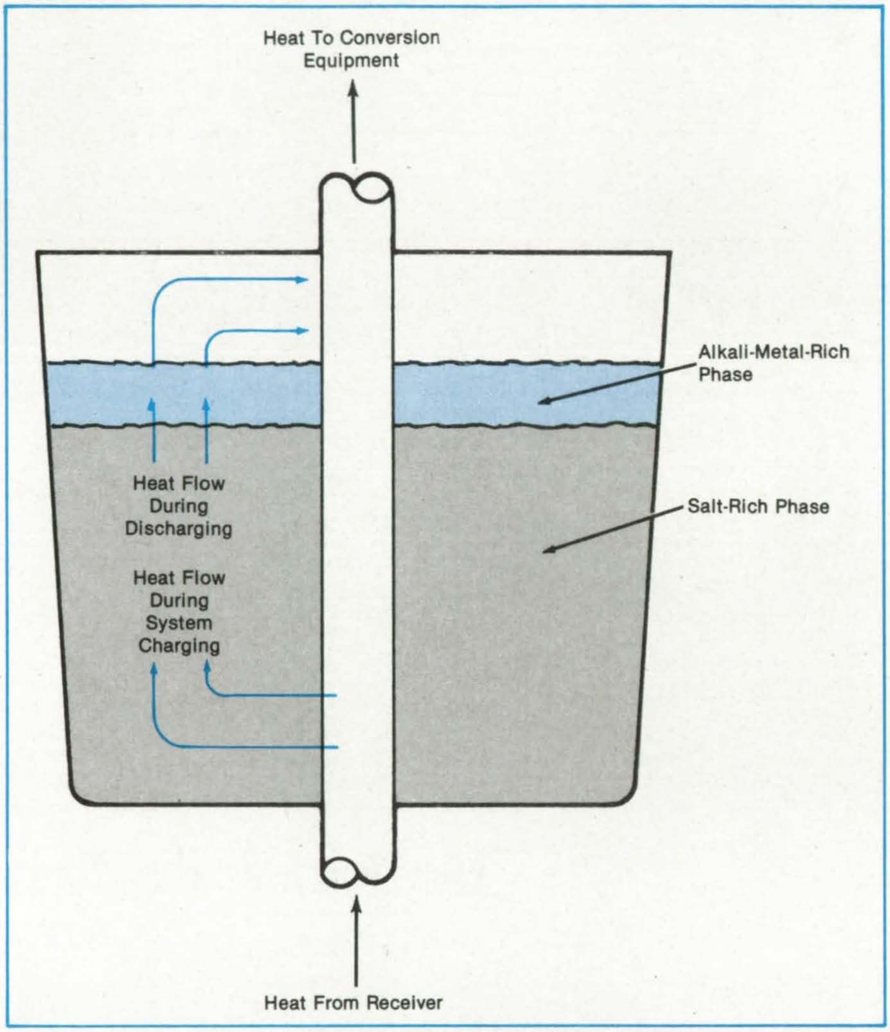
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed thermal-energy-storage system is based on a mixture of an alkali metal and one of its halide salts; the metal and salt form a slurry of two immiscible melts. The use of the slurry is expected to prevent the incrustations of solidified salts on heat-transfer surfaces that occur where salts alone are used. Since these incrustations impede heat transfer, the system performance should be improved.

Designed specifically to be coupled with solar-thermal-power systems, this system would allow heat to be stored at times of maximum brightness and delivered at times of maximum demand. In terrestrial applications, density differences would produce stratification, with the alkali-metal-rich phase floating on the denser, salt-rich phase. The salt should solidify at the interface between the two melts. Release of the heat of fusion of the salt will boil the alkali metal. The alkali-metal vapor will condense on heat-transfer surfaces and, because of its high purity, will dissolve any salt deposits from these surfaces while releasing its heat of vaporization. The heat-transfer surfaces will thus be kept clean, maintaining efficient heat transfer. If the density of the solid salt is sufficiently larger than that of the salt-rich melt, it will sink to the bottom of the container. This will keep molten salt at the interface between the alkali-metal-rich phase and the salt-rich phase, allowing the process to be continuous.

At the operating temperatures of some Brayton systems [1,500 °F (816 °C)] and Stirling systems [1,160 °F (627 °C)], sodium and potassium have enough vapor pressure to function effectively as heat-pipe fluids. To obtain a reasonable amount of pseudo heatpipe heat transfer, around 400 °C for organic Rankine applications, the alkali metal must be cesium, or else the system must be designed to be charged at higher temperatures where sodium is an effective fluid for heat transfer. Cesium salts form eutectics above 400 °C with many of the lithium, sodium, and potassium compounds considered for Brayton and Stirling applications.

As shown in the figure, the same heat-transfer surface or loop would both charge and discharge the storage system. The boiling and condensation of the metals could eliminate hot spots during charging. Under microgravity conditions, a single distinct interface will not exist, and capillary forces coupled with stirring and pressure differentials produced by alkali-metal vaporization and condensation will be needed to achieve similar heat transfer.



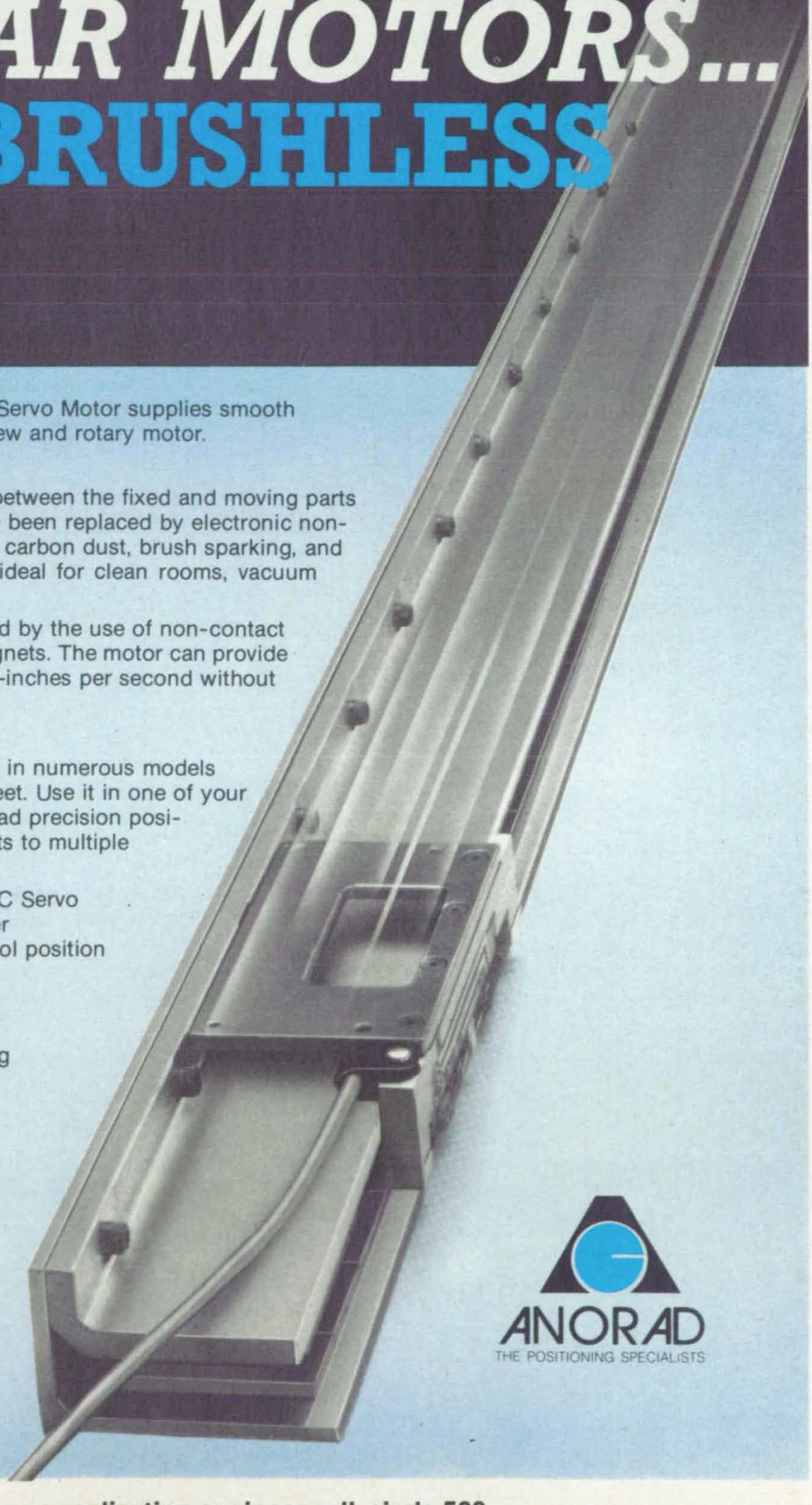
In The **Thermal-Energy-Storage System**, the charging heat-exchanger surface is immersed in the lower liquid, which is rich in a halide-salt, phase-change material. The discharging heat-exchanger surface is immersed in the upper liquid, which is rich in an alkali metal.

Experiments have been performed to investigate corrosion and thermal ratcheting in metal containers filled with either of two mixtures: the metal/salt mixture was 10 weight percent Na with 90 weight percent NaCl; for comparison, a salt-only mixture of eutectic NaF/MgF_2 was also tested. Each mixture was placed in a capsule of 321 stainless steel or 9Cr/1Mo alloy steel. The capsules also contained tensile tabs, and some contained zirconium getter foils to remove impurities.

Cycling the Na/NaCl system ±150 °F (±83 °C) past the salt melting point 2,600 times during 4,000 hours resulted in moderate corrosion of the 9Cr/1Mo alloy containers but negligible corrosion of the 321 stainless-steel containers. Under the same conditions, the NaF/MgF_2 systems without the sodium addition produced significant corrosion of the 321 stainless-steel containers. The Na/NaCl system did not reduce the tensile strength of the 321 stainless steel, although ungettered samples showed some decrease in yield strength. In contrast, the 9Cr/1Mo alloy showed significant decreases in strength. Thermal ratcheting was not observed in the Na/NaCl slurry system with 321 stainless steel but did occur with the 9Cr/1Mo alloy.

This work was done by Wayne W. Phillips and John W. Stearns of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 49 on the TSP Request Card.* *NPO-16686*

REVOLUTION IN LINEAR MOTORS...
DC BRUSHLESS



The new Anoline™ Brushless Linear DC Servo Motor supplies smooth motion... direct. Not through a drive screw and rotary motor.

Greater Performance and Reliability

There is absolutely no physical contact between the fixed and moving parts of the motor. Conventional brushes have been replaced by electronic non-contact commutation. The elimination of carbon dust, brush sparking, and RF noise makes the Anoline Brushless ideal for clean rooms, vacuum chambers, and volatile environments.

Maintenance-free operation is guaranteed by the use of non-contact design and highly efficient rare earth magnets. The motor can provide accelerations of 4g's and velocities to 60-inches per second without backlash or stepping action.

A Motor or a System

The Anoline Brushless Motor is available in numerous models with standard travels of 2-inches to 10-feet. Use it in one of your systems. Or specify it for use in an Anorad precision positioning table from simple straightline units to multiple X-Y-Z Configurations.

Typically, an Anoline Brushless Linear DC Servo Motor is used with linear encoder or laser interferometer transducer. You can control position from .001-inch to .000001-inch depending upon the feedback device.

Specify an Anoline Brushless Linear DC Motor... a revolution in motor-positioning table design and application.

ANORAD CORPORATION
110 Oser Avenue, Hauppauge, NY 11788
TEL: 516/231-1995
TWX: 510-227-9894
FAX: 516-435-1612

ANORAD Number 1 in precision positioning tables

ANORAD
THE POSITIONING SPECIALISTS

For information, circle: 508. To have an application engineer call, circle 509.

Fabrication Technology

2

Hardware, Techniques, and Processes

Ensuring Fully Soldered Through Holes

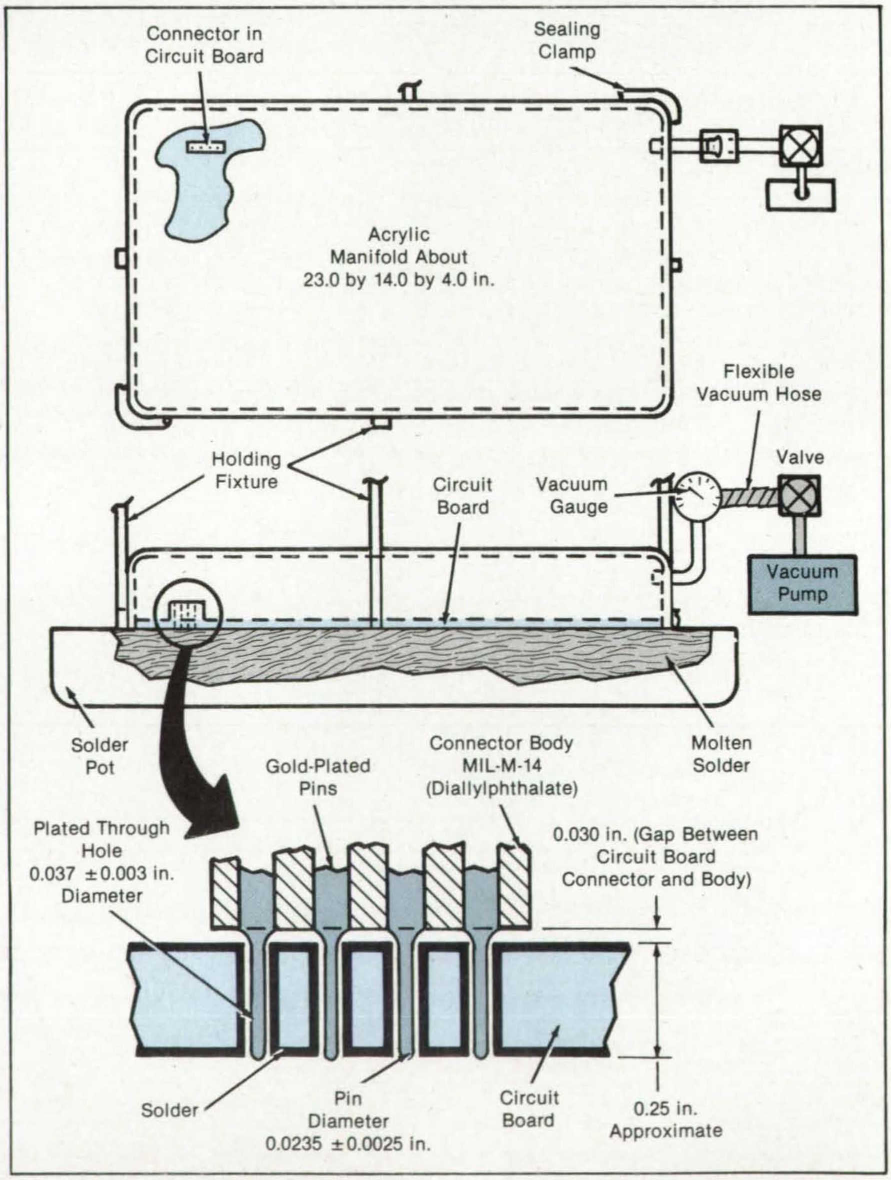
A vacuum draws solder into holes, even in thick circuit boards.

Marshall Space Flight Center, Alabama

A simple differential-pressure soldering method provides visual evidence that hidden joints are fully soldered. The method is intended for soldering connector pins in plated through holes in circuit boards.

Such conventional methods as hand soldering, wave soldering, and vapor-phase soldering do not allow visual inspection of the joints under the connector body. There is no way of ensuring that the solder has completely wet the through holes. In fact, in wave-soldered circuit boards of 0.187 in. (4.75 mm) or greater thickness, destructive testing by microsectioning shows that full wetting is unlikely: usually, only 30 to 40 percent of a through hole contains solder. The new method, in contrast, gives positive evidence of at least 90 percent filling (as shown by tests of sampling holes adjacent to the connector holes).

A clear acrylic vacuum manifold is placed on the component (upper) side of



Molten Solder Flows Into Plated Through Holes, drawn by the vacuum in the manifold over the circuit board. The differential-pressure process ensures that the solder wets the entire through hole around a connector pin.

the assembled circuit board, and its periphery is sealed to the board (see figure). The circuit board is preheated to 300 °F (149 °C), then is held in contact with a bath of solder. The board is allowed to stand on the solder for about 20 seconds, after which a slight partial vacuum is applied to the manifold. The pressure difference draws the solder up into the through holes.

The board is removed from the solder and allowed to cool while the partial vacuum is maintained. The top surface of the board can be viewed through the manifold. The appearance of the sample inspection holes next to the connector will indicate whether the solder has flowed through the holes to the solder pads on the top of the board and has shrunk back into the holes in an acceptable manner.

It is intended to use the differential-pressure process to solder components to an 18-layer board 0.200 in. thick, 21.9 in. long, and 12.8 in. wide (0.5 by 55.6 by 32.5 cm); about 10,200 solder connections on the board cannot be directly inspected. The process is expected to be usable on boards as much as 0.375 in. (9.5 mm) thick.

This work was done by Raymond K. Blow of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29120

Composite Piston-Cap Structure

The design eliminates thermal stress between the composite cap and the metal piston.

Langley Research Center, Hampton, Virginia

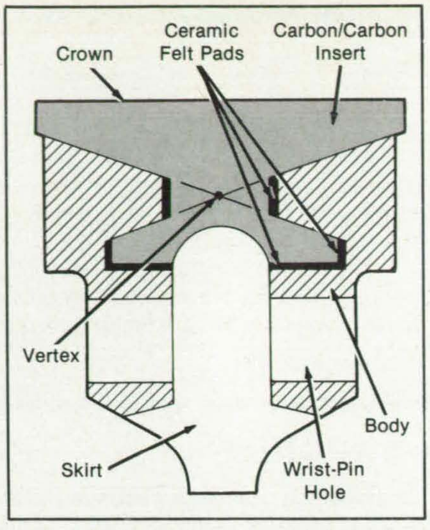
Makers of internal-combustion engines have struggled for years with ways to incorporate heat-resistant nonmetals into the hot, moving components of these engines. Differences in thermal-expansion characteristics and the brittle nature of the materials have prevented success. A composite piston-cap structure designed at Langley Research Center may provide the solution to this problem.

The efficiency of an internal-combustion engine increases directly with its operating temperature. However, the operating temperature may be limited by the materials from which the engine components are manufactured. Ceramics, carbon/carbon composites, and other heat-resistant materials are excellent candidates for such applications, except that their mechanical properties are so poor that they cannot be used in monolithic form. Current schemes to attach nonmetallic caps to metallic pistons involve such mechanical fasteners as pins or bolts, which increase the complexity and weight of the piston and result in thermal stresses between the materials, leading to premature failure of the pistons.

A new, conically surfaced, composite piston-cap structure, passively retained in a metallic piston, is shown in the figure. The piston cap, made from carbon/carbon material, is machined to the general shape shown. This shape includes conical faces, the conical extensions of which intersect at a common vertex on the cylindrical axis of the piston body, allowing thermal-stress-free retention of the cap at all temperatures. When the piston assembly is heated or cooled, the metal expands or contracts radially from the coincident vertex. Where the metal makes contact with the carbon/

carbon cap, the snugly fitting conical faces slide without interference. Since the metal body is free to expand, no thermal stress is produced in the metal body or carbon/carbon cap.

In fabrication, ceramic-felt pads are bonded to the machined cap in the areas shown. The piston body is cast around the cap. The pads prevent the body material from touching the cap surfaces, where thermal stress could be generated. The pads are not required structurally; they provide a mechanism to maintain a void between the body and the carbon/carbon cap. This arrangement allows stress-free movement between the cap and the piston body. The piston cap is larger in diameter than the piston body, allowing the body to expand to the cap diameter at the operating temperature. In fact, the cap may be designed to remain larger in diameter than the piston body and be lapped to fit the cylinder bore in order to preclude the need for piston rings.



Conical Surfaces allow thermal-stress-free movement between the nonmetallic cap and the metallic piston.

The limiting temperature of this design will be the use temperature of the cap material reduced by some factor dependent on the thickness of the cap, which affects heat transfer into the piston body. This design provides a simple means of retaining the piston cap without imparting thermal stresses, while retaining positive engagement along the conical surfaces between the cap and piston body to transfer loads. In addition, the structure makes possible a lighter piston assembly than does an all-metal piston, as the cap material has only about two-thirds the density of aluminum.

This work was done by Allan Taylor of **Langley Research Center**. *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 19]. Refer to LAR-13435.

Lapping and Polishing an Elliptical Bore

A numerically controlled milling machine
is modified to make the head reciprocate.

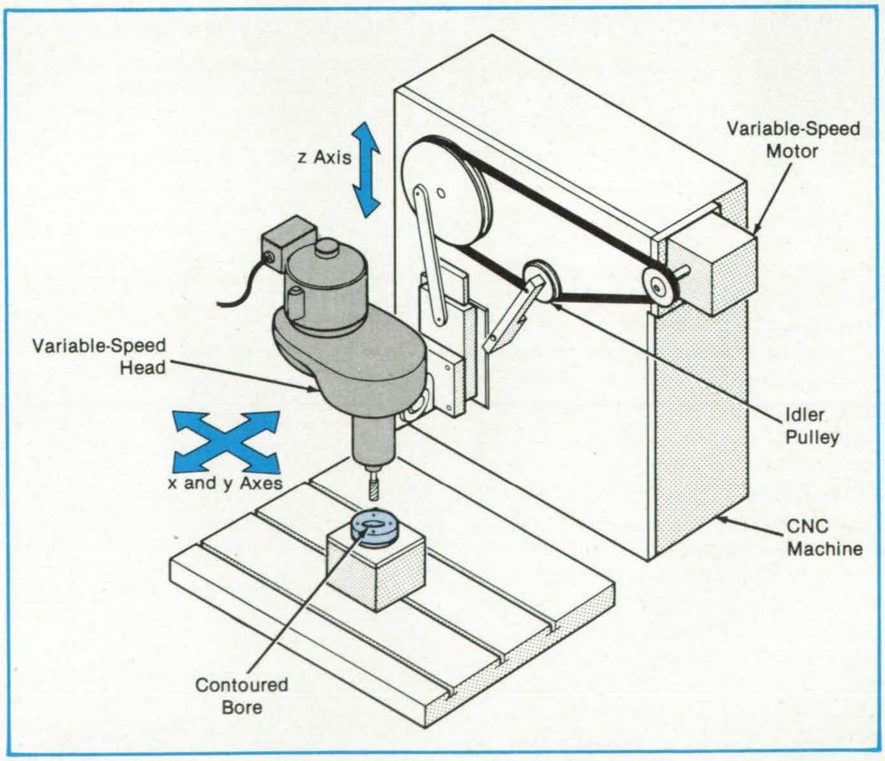
Lewis Research Center, Cleveland, Ohio

The manufacture of a cryogenic vane pump requires that a precise, polished surface be produced in an elliptical bore. This bore comprises the sealing and pumping surface of the pump and must be highly polished to provide for vane-tip sealing and for long vane life.

Because of the nature of the hard, wear-resistant material used in the construction of the pump, the only process capable of producing the required surface finish was the lapping process. To lap a bore effectively requires the application of a rotating and reciprocating lap charged with the proper abrasive. Critical to the resultant surface finish is the ratio of the rotating surface speed to the reciprocating surface speed.

The only machine capable of tracing the elliptical bore with sufficient accuracy is a computer numerically controlled (CNC) milling machine programmed with the elliptical contour. While this machine traces the contour by its x and y movements, it is unable to move fast enough in the z (vertical) direction to provide the proper reciprocating speed. Consequently, a machine modification was required to allow the manufacture of the pump parts.

This modification was accomplished by removal of the original milling head from the machine and by mounting a vertical slide in its place (see figure). This vertical slide was driven up and down by a connecting rod bolted off-center to a drive pulley. The pulley was driven by a belt from a variable-speed electric motor. The milling-machine head was then attached to the vertical slide. This mechanism allowed the independent control of the reciprocating surface speed through



A **Vertical Slide** is mounted in place of the original milling-machine head. The head is mounted on the slide and driven up and down by a variable-speed motor.

variation of the speed of the electric motor.

With this inexpensive modification, the CNC milling machine produced the movements to trace the elliptical contour, while the auxiliary slide mechanism provided the vertical reciprocating motion required to lap the bore successfully. The required surface finish was obtained with the precise contour.

This work was done by John J. Logan, Jr., and Scott D. Meyer for **Lewis Research Center.** *No further documentation is available.*
LEW-14149

Application of Powdered Resin for Foam Insulation

Electrostatic spraying and heating replace cutting and gluing.

Lewis Research Center, Cleveland, Ohio

A process has been developed to apply the necessary insulation to valves, fittings, lines, etc. on such space vehicles as the Centaur rocket stage. The new process can replace the state-of-the-art process in which insulation (often of polyurethane) is foamed in molds and sold to the user in blocks and sheets that must be cut, fit, and bonded to the parts to be insulated. This is a cumbersome and expensive process, and some of the foam materials outgas and burn, generating smoke and toxic gases.

In the new process, electrostatic equipment is used to apply powdered polyimide resin directly to the part to be insulated. The part is then heated to the resin-foaming temperature; the resin foams and adheres to the part. The thickness of the final insulation is controlled by the amount of powdered resin applied to the part. The resulting excellent insulation will not emit smoke or toxic gases, even when exposed to an open flame.

This work was done by Glenn R. Morris of General Dynamics Corp. for **Lewis Research Center**. *No further documentation is available.*
LEW-14147

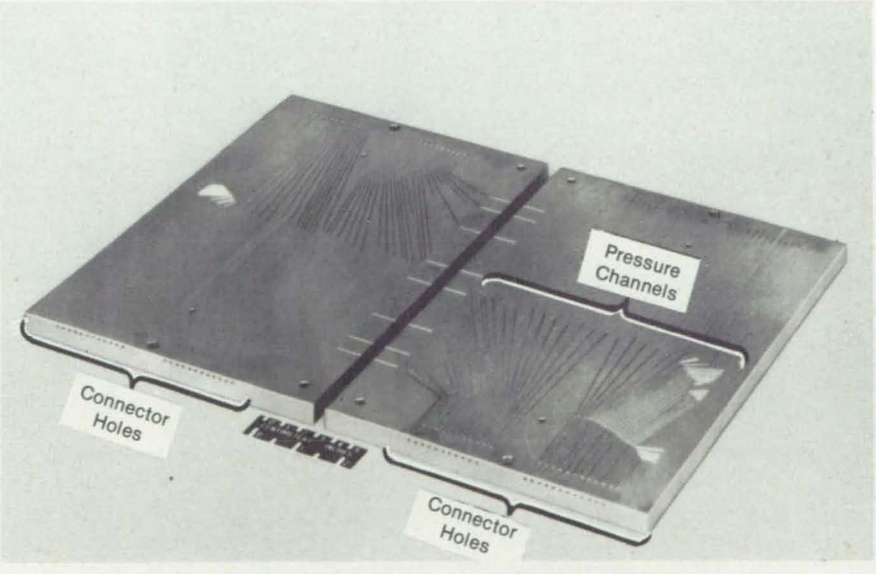
Bonded-Plate Airfoil Construction

A new technique offers greater capabilities for wind-tunnel researchers.

Langley Research Center, Hampton, Virginia

A developmental effort at Langley Research Center to improve the technology for constructing two- and three-dimensional models for cryogenic wind tunnels encountered many problems having a common source in the plumbing required for access to the surface-pressure orifices. It was decided that better integration of the plumbing into the model structure would eliminate many of the problems. The most promising scheme involved grooving channels into the face of a plate, bonding this plate onto a second plate to form pressure channels, and then contouring the resulting plate sandwich into an airfoil.

The airfoil design chosen for testing in the 0.3-m Transonic Cryogenic Tunnel was a symmetrical supercritical shape, which was consistent with the flat-bond-plane bonding-and-channeling technology that had been developed in this effort. A proposed ambitious pressure-orifice layout not only duplicated normal practice but also fully exercised the new capabilities offered by this construction method.



Plates With the Pressure Channel Layout will be brazed and contoured into an airfoil model.

The photograph shows the two halves of the model surfaces to be bonded. The channel layout is for 94 orifices. Most of the orifices were predrilled at the proper angle and depth to emerge from the model surface during contour machining. At the ends of the model where the channels are parallel, alternate channels terminate in "down holes" drilled perpendicularly to the mating surface. The other half of the channels mate with "down holes" drilled in the mating plate. These "down holes" are intercepted by connector holes drilled from the end of the plate. Tubes are to be brazed into these connector holes to form a connection with the wind-tunnel presssureinstrumentation system. This model was successfully machined to contour, validation measurements were taken, tests were run, and data analysis was begun.

This technique offers greatly increased flexibility in orifice and pressure-channel layout compared to conventional model-construction methods. The capabilities demonstrated by this construction method include the ease of installation of trailing-edge pressure orifices and the provision of a row of orifices at the juncture of the wing stagnation line and the wall of the test section. In addition, there are no appreciable voids in the model to promote structural irregularities during mechanical or thermal stress. The bonds, which are almost as strong and tough as the parent metal, offer an enhanced margin of safety because the bond line acts as a crack stopper, and a failure in one-half of the model will not easily propagate to the other half.

This work was done by Pierce L. Lawing of **Langley Research Center**. *Further information may be found in:*

NASA CR-3891 [N85-23804/NSP], "Technology for Pressure-Instrumented Thin Airfoil Models" and

NASA TM-87613 [N86-16234/NSP], "The Construction of Airfoil Pressure Models by the Bonded Plate Method: Achievements, Current Research, Technology Development and Potential Applications."

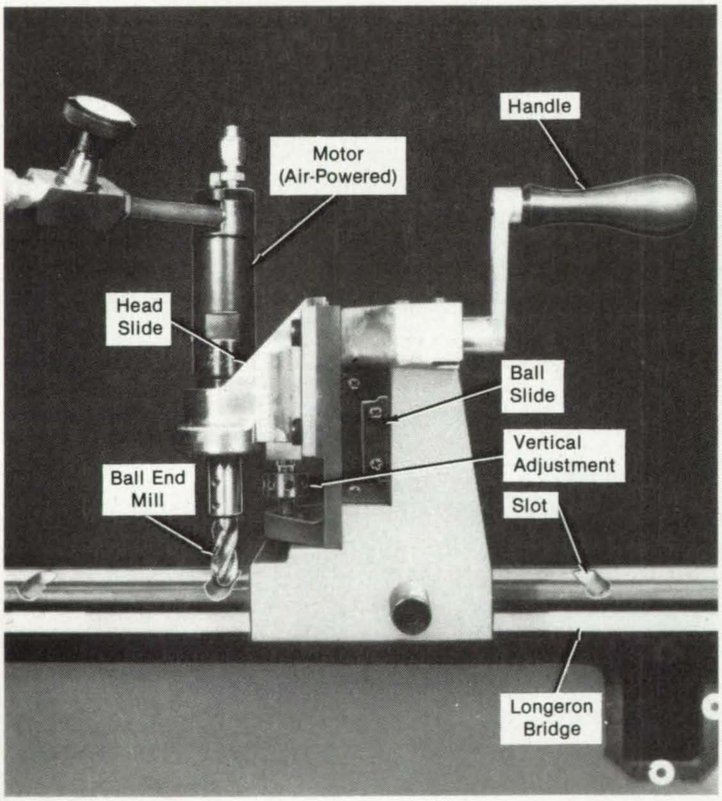
Copies may be purchased [prepayment required] from the National Technical Information Service, Springfield, Virginia 22161, Telephone No. (703) 487-4650. Rush orders may be placed for an extra fee by calling (800) 336-4700.

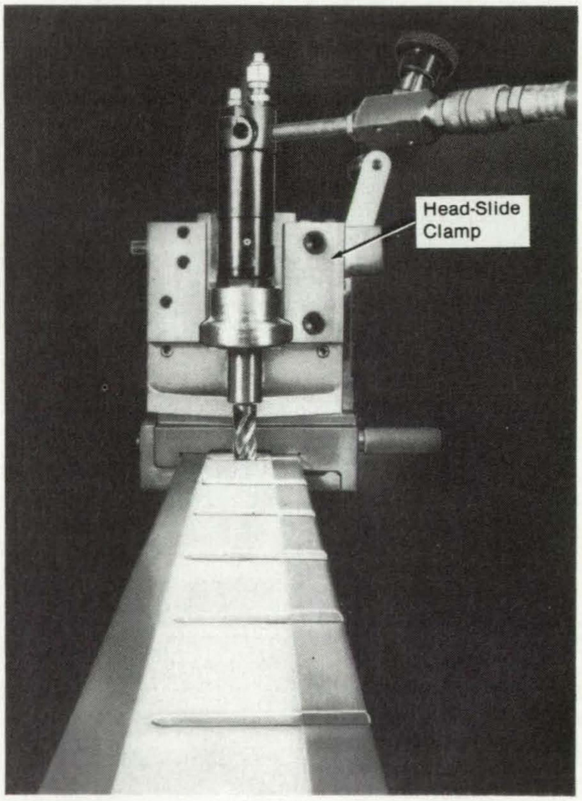
LAR-13526

Portable Slot-Sizing Tool

Field modifications can be done with this tool made from commercially available parts.

Lyndon B. Johnson Space Center, Houston, Texas





This **Portable Slot-Sizing Tool** is shown being used to remachine and size half-hole slots on a longeron bridge.

A portable milling tool consisting of an air-motor-driven cutter held in an adjustable moving slide made possible the local removal of chromium plating in a close-tolerance, onsite remachining and sizing of half-hole slots on longeron bridges (see figure). Sending the bridges back to the manufacturer for rework would have been considerably more expensive, in addition to introducing project delays. An adaptation of the portable sizing tool could be useful for the field modification of such large equipment as trucks, aircraft, and ships, which are not easily returnable to factories.

The tool is made from commercially available parts, including an air motor capable of variable speeds up to 900 rpm, a ball end mill, a revolving handle, two miter gears, and a ball slide. The tool is clamped to the longeron-bridge rail, and the cutter is lined up with a given slot, approximately at the midpoint of the hole length. After the cutter is lowered to the proper depth, the motor is turned on and the crank handle used to move the cutter along the groove to remove the chromium, thereby restoring the slot to its specified dimensions.

This work was done by Nelson T. Zuver of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 119 on the TSP Request Card.* MSC-21088

Metal-Clad Graphite/Epoxy Tubes

Structural parts feature low weight, low thermal expansion, and high stiffness.

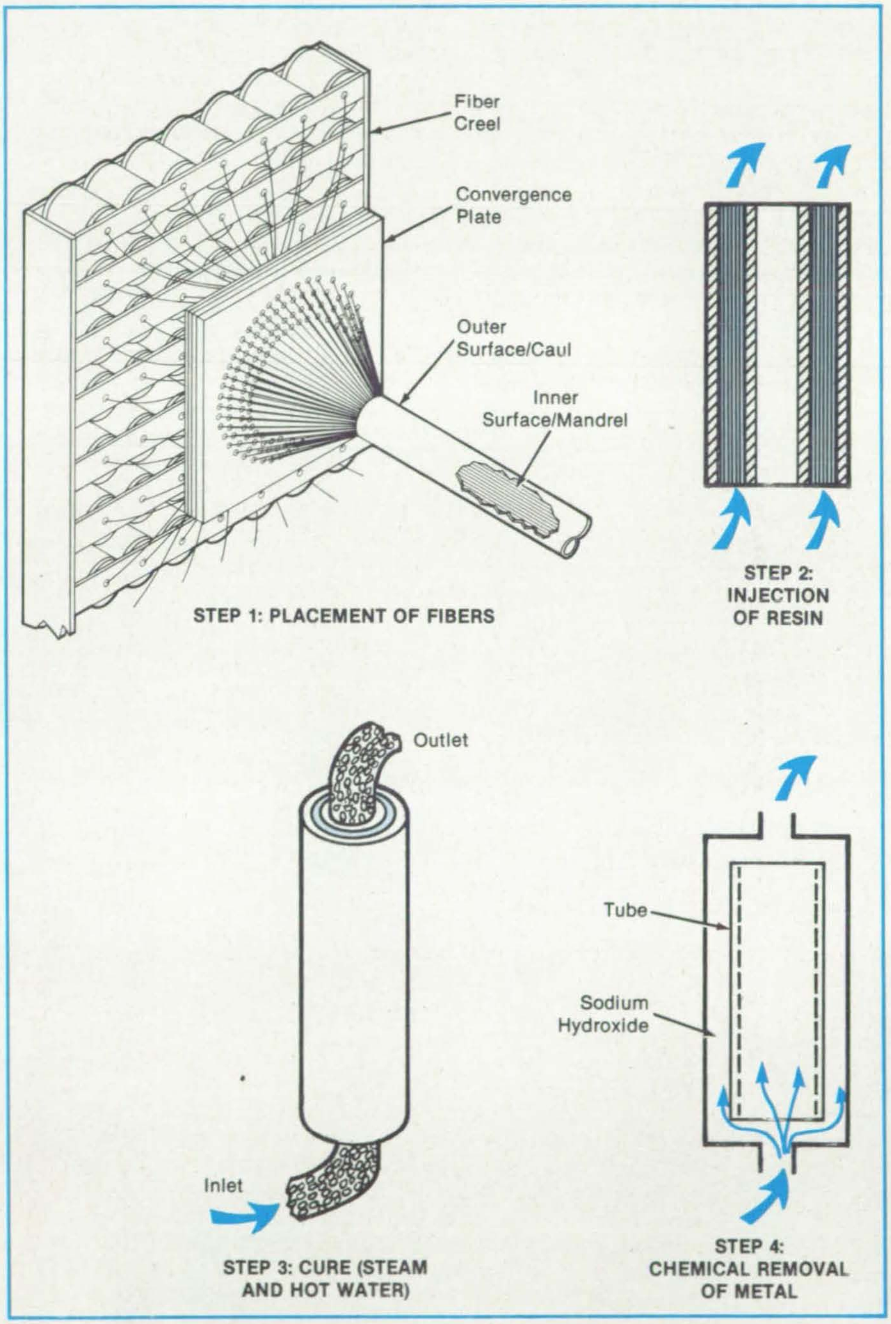
Langley Research Center, Hampton, Virginia

The desired characteristics of Space Station struts include low weight, high stiffness, low coefficient of thermal expansion (CTE), and dimensional stability. These struts are required to be resistant to damage by handling and to be unaffected by the atomic oxygen in the environment. A unique, non-labor-intensive manufacturing process has been developed for fabricating aluminum-clad graphite/epoxy (Gr/E) struts which meet the Space Station requirements.

Initial efforts to fabricate the 2-in. (5-cm) diameter tubes with a wall thickness of 0.060 in. (1.5 mm) concentrated on producing damage-tolerant struts having a high modulus of elasticity of 40 Mpsi (0.28 TPa). Subsequent studies have shown the severity of the effects of atomic oxygen on Gr/E over the projected life of the Space Station and indicate the need for a protective surface such as aluminum. A readily available aluminum alloy was selected to demonstrate the manufacturing process. The epoxy resin used was formulated specifically for resin-injection processing and permits full vacuum deaeration without the loss of low-boiling-point diluents while providing a low injection viscosity. It has a glass-transition temperature of 212 °F (100 °C) when cured at 165 °F (74 °C), facilitating isothermal detooling without cooldown — a requisite for using metallic fixtures with low-CTE materials. Experimental evaluations of the CTE, the effects of thermal cycling, and mechanical properties were performed.

The fabrication process is illustrated in the figure. The prespooled, collimated, dry graphite fiber, attached to an end-plug spigot in the inside metallic tube, is drawn into an outer tube of larger diameter. Resin is injected into the annulus between the two tubes containing the dry fiber. Pressurized hot water is pumped through the inner tube to provide heat to cure the resin and to support structurally the inner tube to prevent buckling due to the resin pressure. Following the cure, the thicknesses of both metallic walls are reduced to the desired size by chemical processing.

This method of manufacturing struts provides a procedure for using the Gr/E material system in a very efficient manner. The technique places all the fibers in the longitudinal direction for stiffness and strength. The aluminum surfaces provide transverse strength and resistance to the atomic oxygen in the environment. Overall dimensional stability is achieved by a nearly zero CTE with no hysteresis, and by postfabrication adjustability of the CTE by the chemical removal of metal.



Resin Is Injected Into an Annulus containing fibers between the two metal tubes.

This work was done by Harold G. Bush of **Langley Research Center** *and Raymond M. Bluck and Robert R. Johnson of Lockheed Missiles and Space Company, Inc. For further information, Circle 157 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 19]. Refer to LAR-13562.

Backlash-Free Locking Hinge

Tight joints are achieved without precisely machined parts.

Lyndon B. Johnson Space Center, Houston, Texas

A hinge for foldable structures can be locked with a minimum of force by a human operator. Once locked, the hinge makes a strong, tight joint. The loose fit, or joint slop, common to commercial locking hinges is eliminated. Despite its tight fit, however, the new hinge concept does not impose close tolerances on the manufacture of its parts. Developed for erecting unfoldable structures in space, the hinge can be used on collapsible scaffolds and similar terrestrial structures.

The two sections of the hinge housing are joined by a hinge pin extending through lugs in the sections and secured by retaining rings (see figure). A latching bar has a guiding ear that protrudes through a slot in one of the housing sections and a locking ear that, in the locked position, engages a slot in the other housing section. A guiding slot in the latching bar straddles and pivots on the hinge pin.

Spacers are mounted on the hinge pin on either side of the latching bar. A groove in spacer 2 engages a pin in the housing, forcing the spacer to rotate when the housing is rotated for locking or unlocking. The stub pins in spacer 2 engage an annular groove in the latching bar. When the hinge is in the unlocked position, the stub pins keep the latching bar depressed, but when the hinge is rotated into a nearly locked position, spacer 2 moves the pins so that they release the latching bar.

Forced by the latching-bar spring, the guiding ear and locking ear enter their respective slots, locking the two sections of the housing together. The engaging surfaces of the ears are at an angle with their paths of travel so that they exert a wedge force on the two housing sections. The wedge action ensures a tightly locked joint free of backlash — without the expense of machining parts to precise dimensions.

A pair of springs extend between sections, riding in the grooves in the spacers. The springs provide the main locking torque once the operator initiates rotation

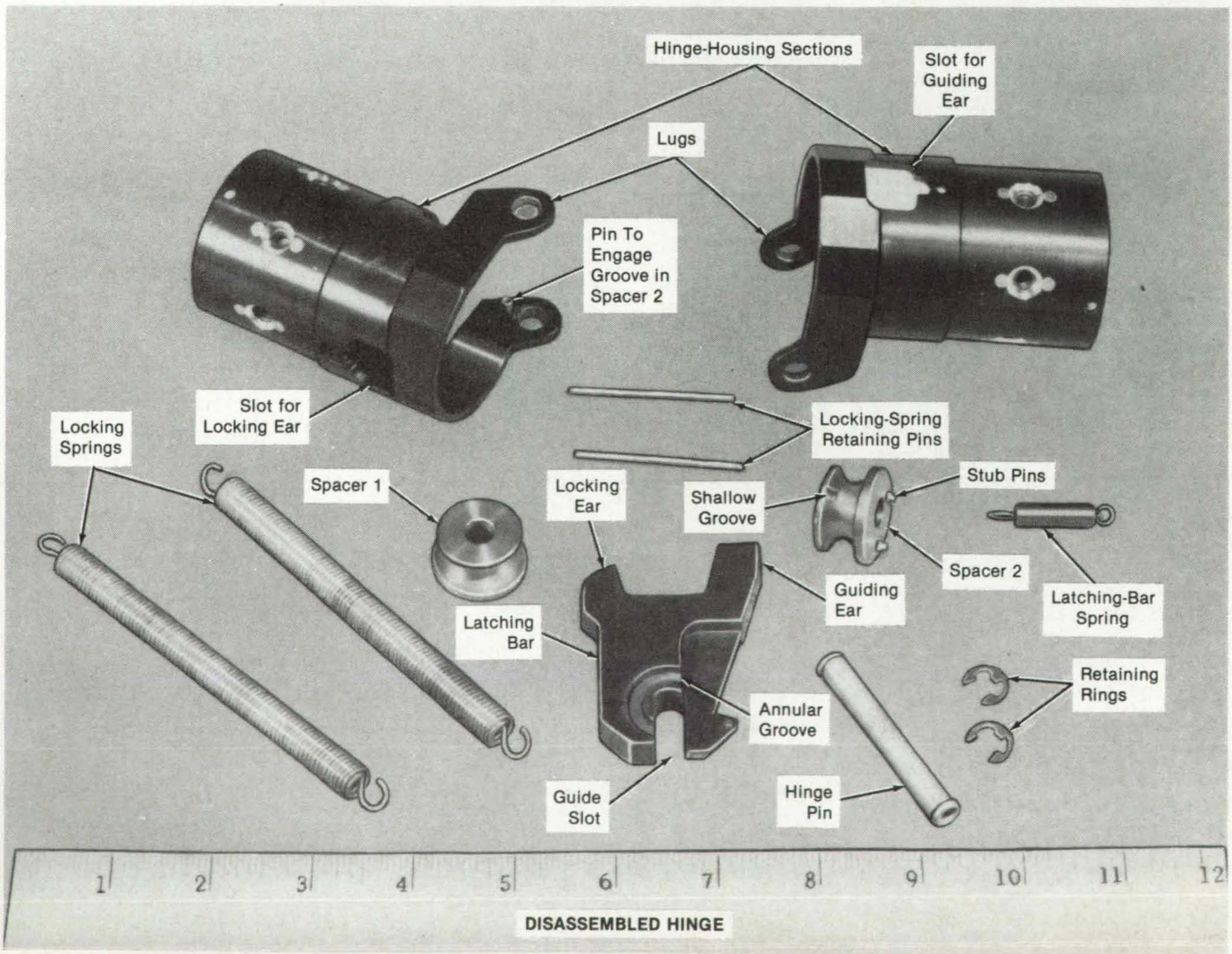


Figure 1. The **Parts of the Locking Hinge** are assembled into a unit that clamps shut with a little push from the operator.

toward the locked position.

This work was done by Clarence J. Wessekski of **Johnson Space Center.** *For further information, Circle 3 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Johnson Space Center [see page 19]. Refer to MSC-21056.

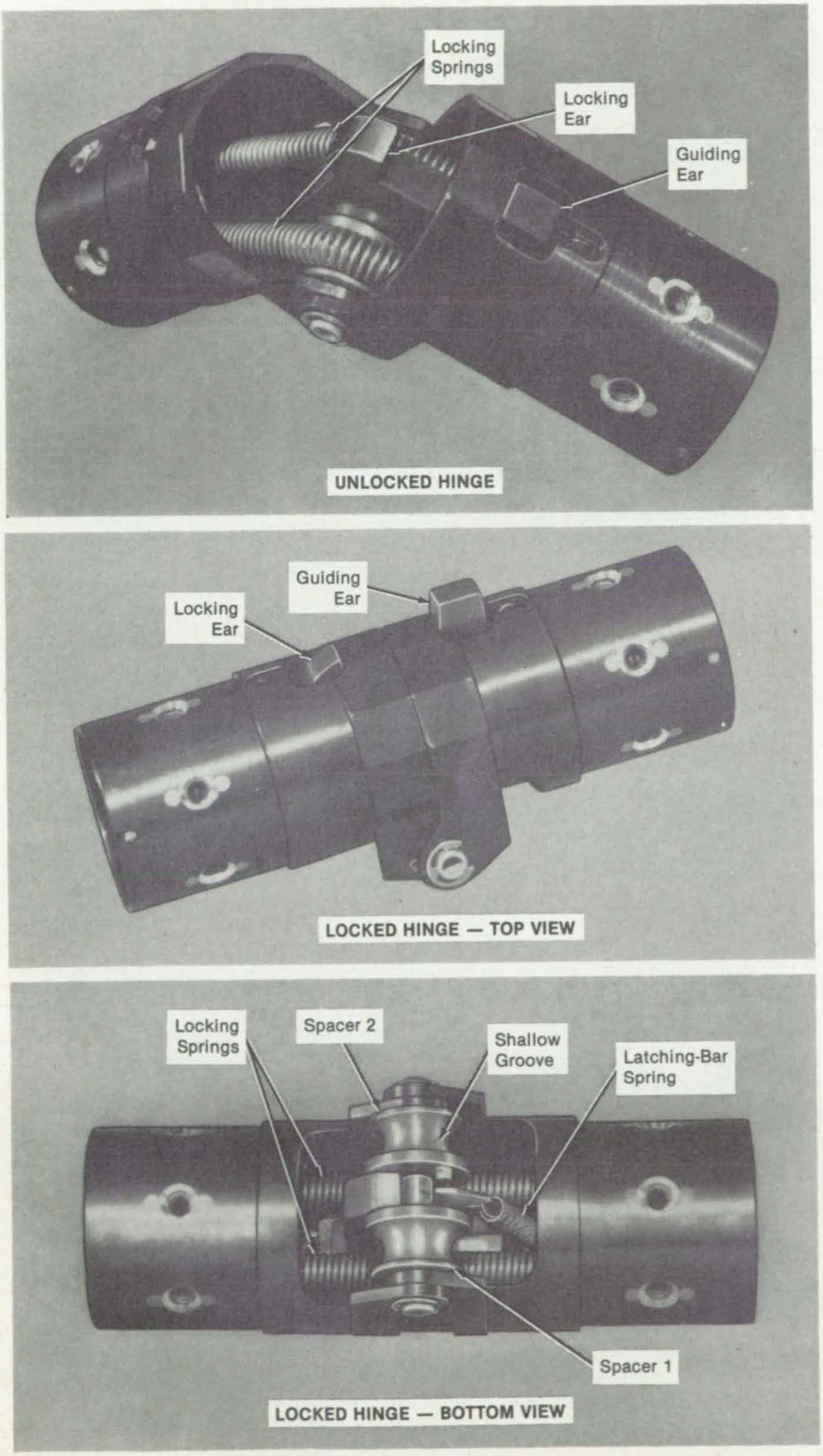


Figure 2. The **Large Locking Springs** augment the torque supplied by the operator. The small spring on the latching bar snaps it into place in the slots in the housing sections.

Drilling Holes in Graphite/Epoxy

A relatively long-lived bit produces high-quality holes.

Lyndon B. Johnson Space Center, Houston, Texas

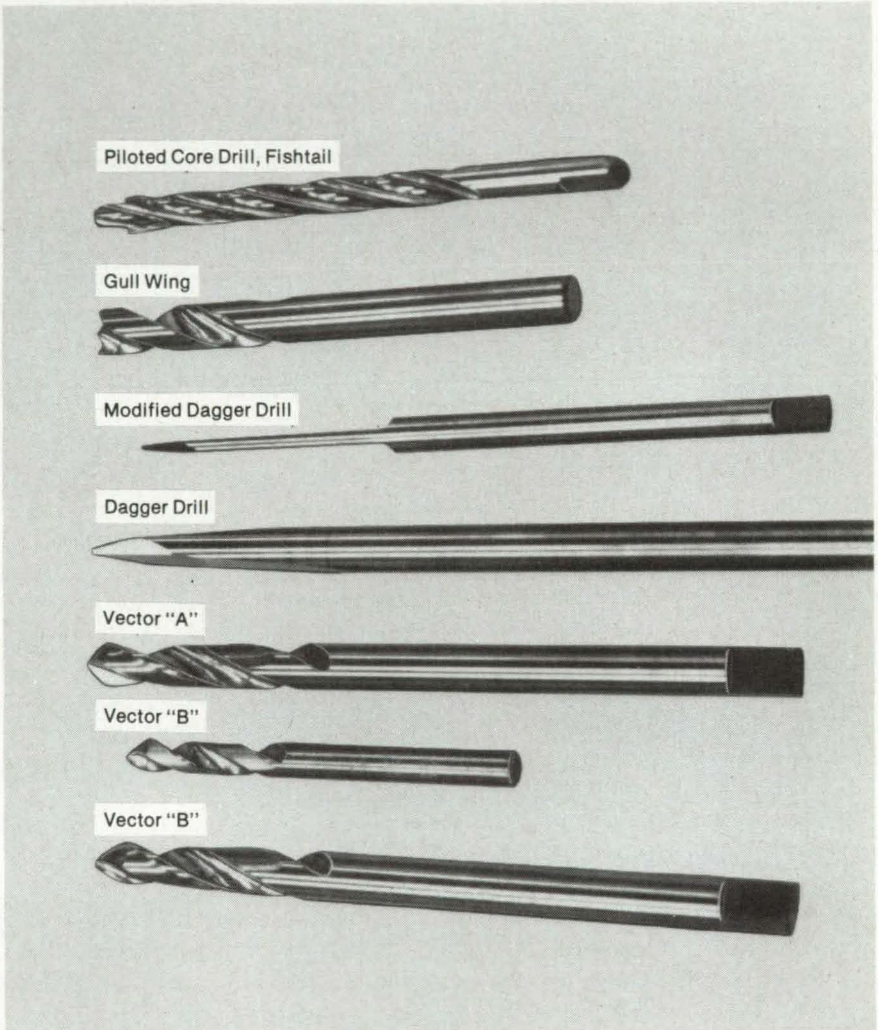
An effective combination of cutting-tool design, feed, and speed have been determined for drilling 3/16- and 1/4-in. (0.48- and 0.64-cm) diameter holes in a 0.18-in. (0.46-cm) thick GM3013A (or equivalent) graphite/epoxy corrugated spar without backup material and without coolant. Developed to produce holes in blind areas, the optimal techniques yielded holes of high quality, with minimal or acceptable delamination and/or fiber extension on the drill-exit side.

The cutting tools that performed the best were drills with the vector "B" point, made of C-2 tungsten carbide (see figure and table). Automatic air-controlled and controlled-feed portable drill equipment show a marked improvement over hand-feed equipment — which always produced holes with excessive delamination and/or fiber extension — but none equalled portable equipment of the power-feed, lead-screw type. Portable power-feed, lead-screw control is preferred to ensure a uniform feed and to prevent breakthrough surges.

When operated at 2,100 r/min with a feed of 0.005 in./r (0.013 cm/r), the vector "B" drill bit for 3/16-in. (0.48-cm) holes had a life of 30 holes per resharpening, for a total life of 90 holes. Under the same conditions, the modified dagger drill had a life of 20 holes per resharpening, for a total life of 80 holes.

Experiments in which a temperature-indicating liquid, Tempilaq (or equivalent), was applied locally on the exit surface of the test spar showed that, with a 3/16-in (0.48-cm) vector point "B" bit at a speed of 5,000 r/m and a feed of 0.0005 in./r (0.0013 cm/r), the temperature reached 325 °F (163 °C) and that, with the 1/4-in. (0.64-cm) vector point "B" bit, the temperature reached 350 °F (177 °C).

This work was done by Ronald Minlionica of Grumman Aerospace Corp. for **Johnson Space Center**. *For further information, Circle 162 on the TSP Request Card.*
MSC-21120



The **Cutting Performance** of various drill bits shown in the figure were determined using portable power-feed lead-screw equipment.

Drill Style	Drill Diameter, in.	Speed, r/min	Feed, in./r	Maximum Delamination, %	Maximum Fiber Extension, %	Maximum Temperature, °F
Vector Point "B"	0.187	5,000	0.0005	0	5	325
Vector Point "B"	0.250	5,000	0.0005	0	5	350
Vector Point "A"	0.250	5,000	0.0005	0	15	350
Dagger Drill	0.250	5,000	0.0005	0	30	350
Dagger Drill	0.190	5,000	0.0005	0	20	350
Vector Point "B"	0.250	1,100	0.0005	0	10	250
Gull Wing	0.190	1,330	0.002	60	30	
Piloted Core Drill	0.190	1,330	0.002	60	50	
Dagger Drill	0.190	1,330	0.002	0	5	

Of the **Tested Drill Bits**, the vector point "B" exhibited the best combination of longevity and hole quality.

Mathematics & Information Services

Hardware, Techniques, and Processes

Books and Reports

Computer Programs

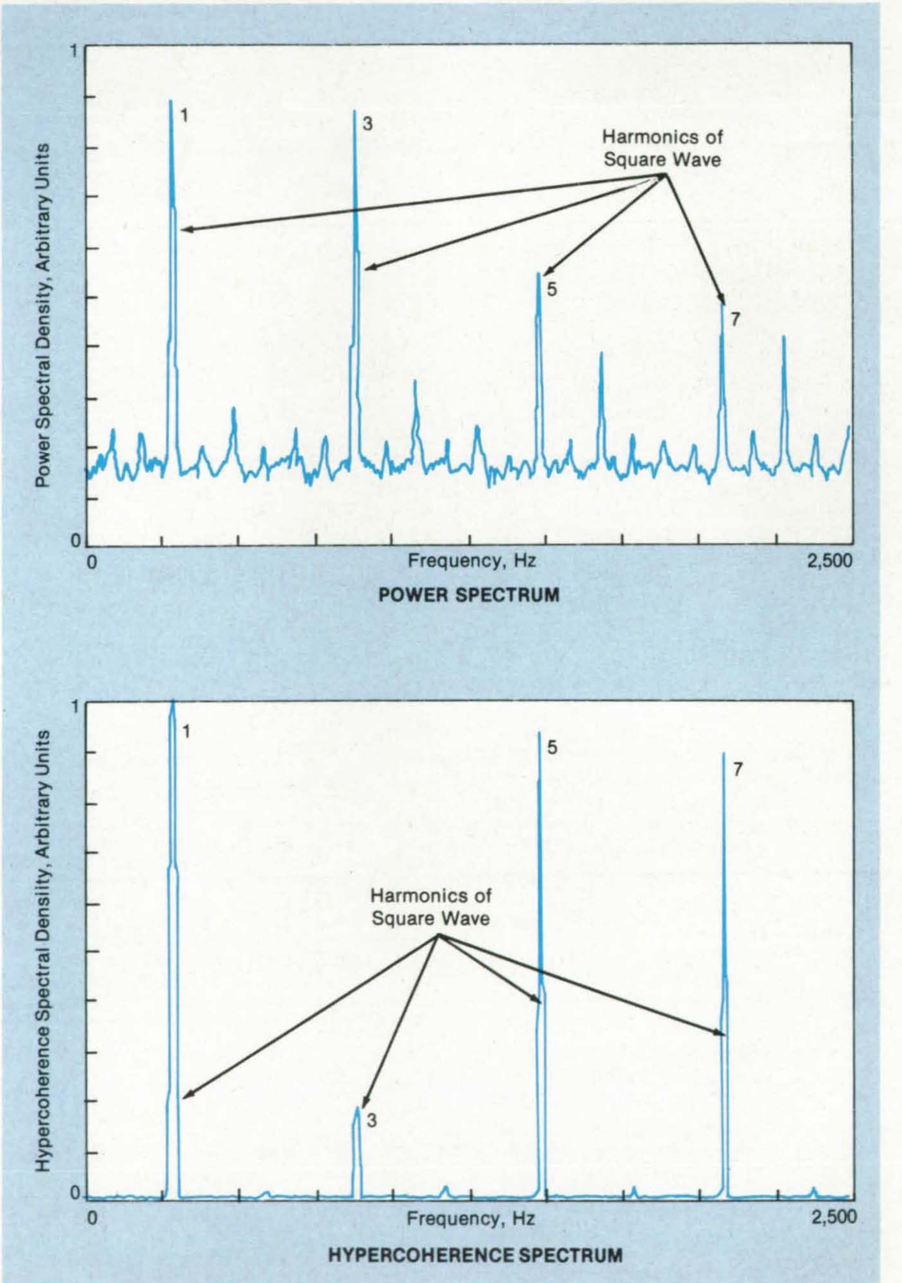
Nonlinear Coherence Function for Machinery Diagnosis

Vibration spectra are analyzed for signs of trouble.

Marshall Space Flight Center, Alabama

A nonlinear coherence function assists in the analysis of the vibration spectra of machinery for signs of incipient failure. It is useful primarily in determining whether an apparent harmonic in a complicated vibration signal indicates a possible defect or whether it could be due to an independent vibration source or to extraneous noise.

Spectral peaks at the fundamental rotational frequency and its harmonics may indicate such malfunctions as misalignment, imbalance, bent shaft, rubbing, and oil



Power and Hypercoherence Spectra were computed for a synthetic vibration signal consisting of a square wave, plus an uncorrelated sine wave at three times the square-wave repetition frequency, plus noise. The power spectrum shows both correlated and uncorrelated signals, while the hypercoherence spectrum suppresses the uncorrelated components almost completely.

whirl. Spectral peaks at multiples of a pulse-repetition frequency may indicate impacts due to bearing-component wear. In both cases, the customary autocorrelation function or power-density spectrum shows the spectral peaks but does not reveal whether the apparent harmonics are indeed correlated with the fundamental (and therefore likely due to the same defect) or uncorrelated with the fundamental (and therefore likely due to an independent cause or to mere noise).

The hypercoherence function $H_n(f_1)$ expresses the nonlinear correlation between the vibrational component at fundamental frequency f_1 and the components at integral multiple frequencies nf_1. To obtain the hypercoherence, it is first necessary to measure the vibration amplitude X(t) by sampling it at suitably short intervals. The time series for X(t) is converted to a Fourier transform X(f). Then the hypercoherence function is defined by

$$H_n(f_1) = |E\{X^n(f_1)X^*(nf_1)\}|^2 / E\{|X^n(f_1)|^2\}E\{|X(nf_1)|^2\}$$

where E{} denotes the expectation operator and the superscript * denotes the complex conjugate.

The computation is straightforward by fast-Fourier-transform methods. It results in a line spectrum of correlation coefficients as a function of the harmonic number (see figure). As such, it provides a concise summary of a succession of higher order coherence functions in only two dimensions, with correlated peaks displayed more clearly than in the power-density spectrum.

This work was done by Thomas Coffin and Jen Y. Jong of **Marshall Space Flight Center**. *For further information, Circle 47 on the TSP Request Card.* *MFS-28171*

Books and Reports

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

Mathematical Models for Doppler Measurements

Error analysis increases the precision of navigation.

A report presents improved mathematical models for the analysis of Doppler measurements and measurement errors in spacecraft navigation. To take advantage of the potential navigational accuracy of Doppler measurements, precise equations relate the measured cycle count to the position and velocity. Drifts and random variations in transmitter and receiver oscillator frequencies are taken into account. The mathematical models can also be adapted to aircraft navigation, radar, sonar, lidar, and interferometry.

Because the frequency errors of the transmitter and receiver oscillators contribute to the Doppler errors, the report begins with a discussion of the frequency-error statistics. The difference between the actual and nominal frequencies of an oscillator is represented as the sum of a bias error (which varies approximately linearly with time), a time-correlated random error, and a non-time-correlated random error consisting of small, rapid fluctuations.

The one-way Doppler model is developed for transmission to a moving receiver. The receiver converts the incoming signal to a new frequency, called the composite frequency, which equals a constant bias frequency plus some chosen multiple of the Doppler frequency shift measured by the receiver. The number of cycles of the composite frequency during a given interval is expressed theoretically in terms of the receiver position and velocity and the various oscillator frequencies: it is equivalent to a range measurement plus a constant of integration. The rate of change of the constant of integration is treated as an exponentially correlated random variable, the parameters of which are used to design a Kalman filter.

In a high-precision Doppler system, the composite frequency is integrated in time by counting positive-slope zero crossings of the signal to obtain the cycle count. Equations are derived for the effect, upon the composite frequency and cycle count, of errors in the transmitter and receiver oscillator frequencies: thus, one can predict the cycle count of real, imperfect equipment.

Similar considerations also lead to two- and three-way Doppler models and the associated errors. In this case, the constant of integration is treated as a random-walk variable. With the drifts removed by Kalman filtering, the measurement noise becomes uncorrelated in time, and the navigational filters become optimal.

This work was done by William M. Lear of TRW, Inc., for **Johnson Space Center**. *To obtain a copy of the report, "Mathematical Models for Doppler Measurements," Circle 163 on the TSP Request Card.* *MSC-21150*

Approximate Feedback Control for a System With Memory

The nearly optimal feedback gain can be calculated.

A report presents an algorithm for calculating the feedback gain for control of hereditary dynamical systems (dynamical systems with memory) with control delay. The problem is to approximate the optimal feedback gain that minimizes a cost function of the state and control. The theory is applicable to the design of controllers for mechanical systems subject to thermal deformation, for electrical systems with delay, for electrical systems with plasma components, and for other systems that exhibit memory.

The cost is expressed as a quadratic functional of the state variables of the system and of the control variables, over a fixed time interval. The exact feedback law is derived from the dynamic-constraint equation of the system. Making extensive use of function-space theory, the author discretizes the cost function to obtain a relatively simple approximation of the feedback-control law. The result is a sequence of approximate feedback-control laws that tend toward the optimum one sought.

Stronger convergence results are obtained for this algorithm than for previous algorithms of systems without control delays. This algorithm is particularly advantageous in that the feedback operator can be expressed in terms of the fundamental matrix of the dynamic constraint, and it is never necessary to consider finite-dimensional approximations of the entire evolution operator of the system.

One disadvantage of the algorithm is that it requires much computation: at each time step, it is necessary to calculate and store the fundamental matrix, and to perform several quadratures and matrix inversions. However, the separable structure of the feedback kernel makes possible its real-time implementation by parallel processing. Thus, by increasing the number of processors one can make the computation time for the feedback law somewhat independent of the order of the approximation.

This work was done by Mark H. Milman of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "A New Approach to Approximating the Linear Quadratic Optimal Control Law for Hereditary Systems With Control Delays," Circle 125 on the TSP Request Card.* *NPO-16841*

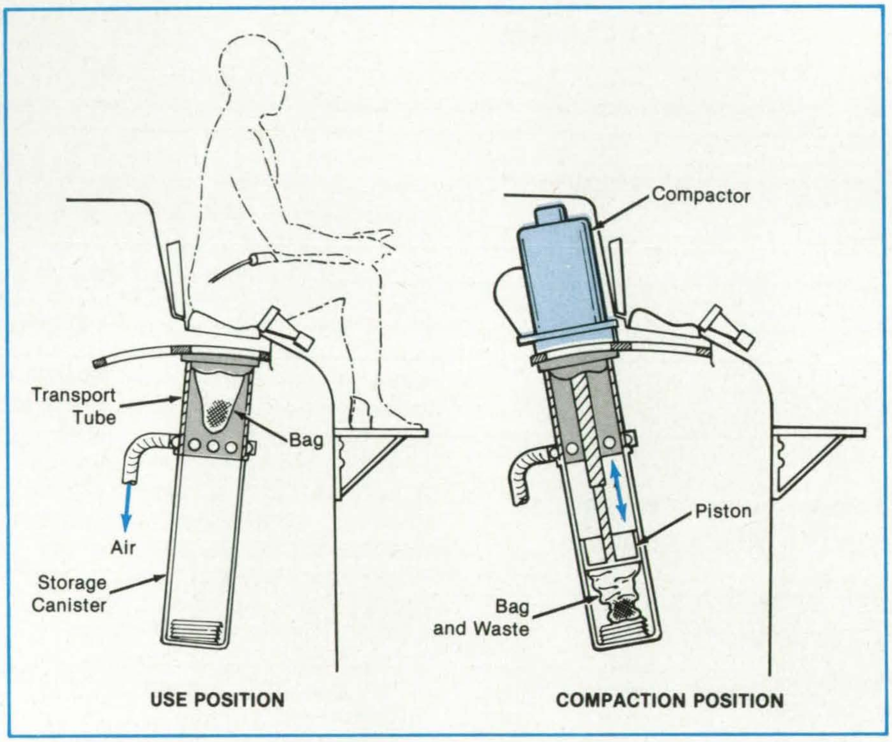
Life Sciences

Hardware, Techniques, and Processes

System for Odorless Disposal of Human Waste

A conceptual system would provide clean, hygienic storage.

Marshall Space Flight Center, Alabama



A **Canister Can Be Alternated** between the forward (use) and rearward (compaction) positions. The canister, 8 in. (20.3 cm) in diameter, can hold 50 to 60 compressed bags.

A proposed disposal system would store human wastes compactly. It would release no odor or bacteria and require no dangerous chemicals or unpleasant handling. The system would stabilize waste by a natural process of biodegradation in which microbial activity eventually ceases and odors and bacteria are reduced to easily contained levels. It would be simple and reliable and need little maintenance.

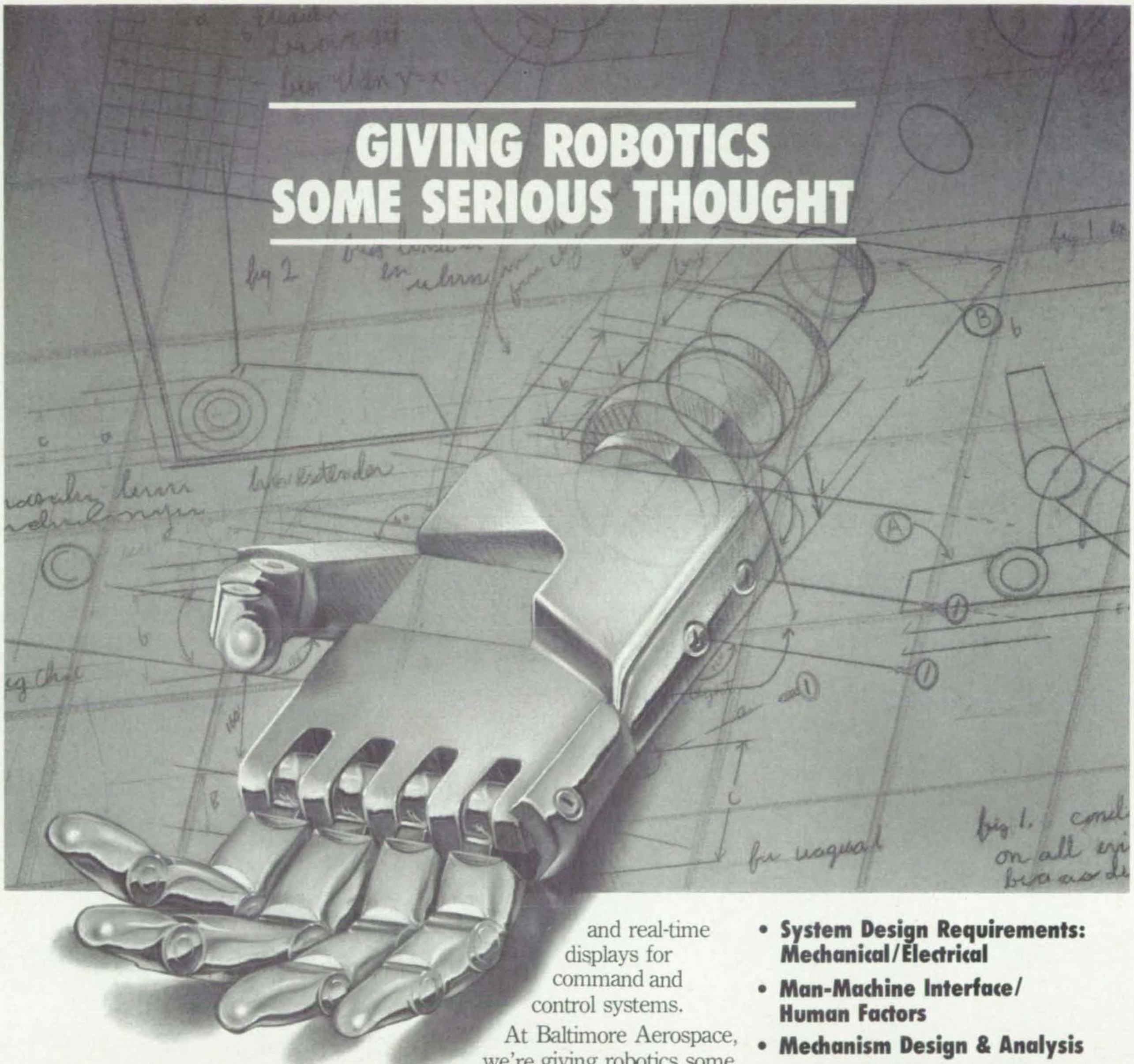
The system would accommodate human wastes other than urine, including feces, diarrhea, vomitus, menstrual discharge, expectoration, and wipes. It would consist of a commode and storage canister (see figure). A waste-disposal bag with a lid would be placed at the top opening of the commode. After use, the canister would be tilted in the commode so that it aligns with a compactor piston. The piston would push the bag and its contents to the bottom of the canister, compressing the bag and stacking it on previously used bags.

When a canister is full, it would be removed and covered with a cap. Activated charcoal in the cap would allow nonodorous gases — primarily carbon dioxide — to leave the canister, but would capture odorous gases and bacteria. An integral hydrophobic filter would prevent liquids from leaking from the canister regardless of its orientation. A new canister would be inserted in the commode.

This work was done by Dave Jennings and Tod Lewis of United Technologies Corp. for **Marshall Space Flight Center**. *For further information, Circle 153 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 19]. Refer to MFS-28193.

MARTIN MARIETTA BALTIMORE AEROSPACE



Imagine a robotic device that will allow the operator to see and feel what the robot is seeing and feeling. A device controlled easily and reliably, in much the same way as a human hand. This is "telepresence." And it's a technology being advanced at Martin Marietta Baltimore Aerospace.

Telepresence is just part of the work being performed in military automation and robotics at Baltimore Aerospace. There's also on-going research in autonomous underwater vehicle systems, supervised control of remote vehicles, military robotics, expert systems for battle management and C³I systems, and real-time displays for command and control systems.

At Baltimore Aerospace, we're giving robotics some serious thought. In fact, we're investing millions for research, equipment and facilities to further advance these technologies.

We invite you to be a part of this effort. If you have experience in robotics or artificial intelligence, give some serious thought to a career at Baltimore Aerospace. We have opportunities available in the following areas:

- **Servo Control Analysis & Simulation**
- **Sensor System Design & Applications**
- **Autonomous Underwater Vehicles**
- **System Design Requirements: Mechanical/Electrical**
- **Man-Machine Interface/ Human Factors**
- **Mechanism Design & Analysis**
- **Real-Time Hierarchical Control Systems**
- **Real-Time Computer Graphics for Animation**
- **AI Programming**
- **Operation Analysis**
- **C³I**
- **Biomedical Engineering**
- **Unmanned Vehicle Systems**

If interested please send your resume to: Martin Marietta Baltimore Aerospace, Employment Dept. NTB387, 103 Chesapeake Park Plaza, Baltimore, Maryland 21220. U.S. Citizenship Required. An Equal Opportunity Employer m/f/h/v.

MARTIN MARIETTA

Subject Index

Advertiser's Index

***RAC** stands for **Reader Action Card.** For further information on these advertisers, please circle the RAC number on the Reader Action Card elsewhere in this issue. This index has been compiled as a service to our readers and advertisers. Every precaution is taken to ensure its accuracy, but the publisher assumes no liability for errors or omissions.

Circle Reader Action No. 396

Mission Accomplished

Through the technology transfer process, many of the systems, methods and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.

The Ride Quality Meter provides engineers with real-time data on passenger comfort.

An invention geared for the transportation industry could mean fewer bumps in your daily grind. Called the Ride Quality Meter, it's helping engineers to develop vehicles with a smoother, more comfortable ride.

The portable meter, produced by Wyle Laboratories, Hampton, Virginia, offers the first verifiable method of measuring ride quality, through its innovative capability for indexing noise and vibration effects.

"In the past, measuring ride quality was something totally subjective and non-repeatable," explained John Wood, Program Development Manager for Wyle Laboratories. "One had to depend solely on the subjective judgement of the individuals involved. This led to costly adjustments. But the meter gives a consistant, accurate reading, which means major savings in man hours and design costs."

Using an external accelerometer and a sound level meter, the Ride Quality Meter simultaneously measures five axes of vehicle vibration and interior noise. It processes these measurements through a NASA-conceived algorithm, then outputs, via an integral printer, a set of indices representing the passenger discomfort produced by the vibration and noise. The discomfort level is also presented on a liquid crystal display (LCD).

This system is based on a computer model developed by NASA's Langley Research Center. NASA began studies in the early 1970's involving application of active controls for smoother rides in aircraft and surface transportation. To develop ride quality criteria, researchers needed a mathematical model for estimating acoustic and vibration effects on passenger comfort. Tests were initiated using a Langley ride quality simulator. While exposed to controlled combinations of vibration and noise, subjects described their level of discomfort.

Based on the responses of more than 3000 test participants, Langley developed a computer model that takes as input a vehicle's vibration and noise characteristics, converts the physical data into subjective discomfort units, and combines the units into a cumulative index.

In order to acquire data in actual vehicle operations, Langley created a prototype ride quality meter, designed by Wyle Laboratories under NASA contract, which provided the technology for Wyle's own version.

Since its commercial inception in 1984, the meter has proven to be a reliable "passenger jury," delivering an accurate verdict on the ride quality of automobiles, trucks, buses, trains, aircraft, and a variety of special transportation vehicles. Many of the major U.S. transportation manufacturers—including Ford Motor Company, Firestone Tire and Rubber Company, General Motors, and Navistar—have implemented the Ride Quality Meter in their product development process.

"The meter's a major step forward in helping a ride engineer do his job," according to Charles Powell, Senior Product Development Engineer for Navistar, the nation's leading manufacturer of large trucks. "It's become an indispensible tool as we work toward giving our customers the smoothest possible ride." □

Feedback

The Feedback column is designed to encourage a wide exchange of ideas among *NASA Tech Briefs* readers. To contribute a request for information or to respond to such a request, use the feedback cards in this issue, or write or call: Manager/Technology Transfer Division, P.O. Box 8757, Baltimore/Washington International Airport, MD 21240; (301) 859-5300. While we can print only a small number of letters, we will endeavor to select those that are of varied and wide interest.

ABSTRACT TO CONCRETE

As a consultant in aerospace composites manufacturing and manufacturing research and development, the articles having to do with advances in that field are of special interest. I have applied some of the information in Beech's *Starship* development over the past few years before leaving Beech to become a consultant. The recent article on improvements in tackifying of polymide prepregs will be of special interest on a contract I am negotiating. Also, the article on Semi-Interpenetrating Polymer Networks will undoubtedly prove of value, as research continues to define new materials combinations.

R. E. Featherston
Arrowhead Resources Company
Wichita, KA

My work involves development of advanced shelter systems and life support for remote terrain applications. Products and design ideas relating to the space station are very important in stimulating parallel terrestrial applications or spin-offs. One example was using plants to purify air and water—work done by Dr. Wolverton of Mississippi was particularly helpful.

Ted Bakewell
Bakewell Corporation
St. Louis, MO

The *NASA Tech Brief* on satellite positioning and F/D ratios allowed us to build a more efficient satellite reception microwave collector. We were also able to produce a program to enhance a polar mount to move between satellites for a very reasonable cost and commercial price of less than $150.

Gus Wirth Jr.
G. H. Wirth Inc.
Cedarburg, WI

Your article on balancing flexible shafts was particularly useful here. Balancing turbine-generators and pump and motor shafts and rotors causes concern because of their influence on the life of the machines. Our units do not fly as high as an F1 turbopump but they are worrisome when 40 or more tons of rotating machinery begin shaking.

Wayne L. White
Supervisor OMT
LA Department of Water and Power
Sun Valley, CA

A LOOK AT NASA

I enjoy the articles dealing with NASA history and projections of future adventures. Your articles have also made me keenly aware of the danger we face in our space program due to lack of funds and cutbacks to some of the planned projects. Please continue to push for funding for the peaceful development of space.

Larry Ferreira
Lab Service Technician
R & D Productivity
Hewlett-Packard
Santa Rosa, CA

ABOUT THE NASA TECHNOLOGY UTILIZATION PROGRAM

Thumb Index

This document was prepared under the sponsorship of the National Aeronautics and Space Administration. NASA Tech Briefs is published ten times a year and is free to engineers in U.S. industry and to other domestic technology transfer agents. It is both a current-awareness medium and a problem-solving tool. Potential products...industrial processes...basic and applied research... shop and lab techniques...computer software...new sources of technical data...concepts...can be found here. The short section on New Product Ideas highlights a few of the potential new products contained in this issue. The remainder of the volume is organized by technical category to help you quickly review new developments in your areas of interest. Finally, a subject index makes each issue a convenient reference file.

Further information on innovations—Although some new technology announcements are complete in themselves, most are backed up by Technical Support Packages (TSP's). TSP's are available without charge and may be ordered by simply completing a TSP Request Card, found at the back of this volume. Further information on some innovations is available for a nominal fee from other sources, as indicated. In addition, Technology Utilization Officers at NASA Field Centers will often be able to lend necessary guidance and assistance.

Patent Licenses—Patents have been issued to NASA on some of the inventions described, and patent applications have been submitted on others. Each announcement indicates patent status and availability of patent licenses if applicable.

Other Technology Utilization Services—To assist engineers, industrial researchers, business executives, Government officials, and other potential users in applying space technology to their problems, NASA sponsors Industrial Applications Centers. Their services are described on pages 18-19. In addition, an extensive library of computer programs is available through COSMIC, the Technology Utilization Program's outlet for NASA-developed software. See special section on computer programs on page 42.

Applications Program—NASA conducts applications engineering projects to help solve public-sector problems in such areas as safety, health, transportation, and environmental protection. Two applications teams, staffed by professionals from a variety of disciplines, assist in this effort by working with Federal agencies and health organizations to identify critical problems amenable to solution by the application of existing NASA technology.

Reader Feedback—We hope you find the information in *NASA Tech Briefs* useful. A reader-feedback card has been included because we want your comments and suggestions on how we can further help you apply NASA innovations and technology to your needs. Please use it; or if you need more space, write to the Manager, Technology Transfer Division, P.O. Box 8757, Baltimore, Maryland 21240.

Advertising Reader Service—Reader Action Card (RAC): For further information on the advertisers, please circle the RAC number on the separate Reader Action Card in this issue.

Change of Address—If you wish to have *NASA Tech Briefs* forwarded to your new address, use the Subscription Card enclosed at the back of this volume of *NASA Tech Briefs*. Be sure to check the appropriate box indicating change of address, and also fill in your identification number (T number) in the space indicated.


DELTA II
FLOOD