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NASA SP-5945 (01)

TECHNOLOGY UTILIZATION

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## TESTING METHODS AND TECHNIQUES: ENVIRONMENTAL TESTING

A COMPILATION



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## Foreword

The National Aeronautics and Space Administration and the Atomic Energy Commission have established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace and nuclear communities. By encouraging multiple application of the results of their research and development, NASA and AEC earn for the public an increased return on the investment in aerospace and nuclear research and development programs.

This compilation describes various devices and techniques for testing hardware and components in four special environments—low temperature, high temperature, high pressure, and vibration. Organized in four sections according to the type of environment in which the innovations are used, the compilation includes items ranging from an automatic calibrator for pressure transducers to a fixture for testing the susceptibility of materials to ignition by electric spark.

This compilation is not intended as a complete survey of the field of environmental testing. Rather, it gives a sampling of many diverse activities. The innovations presented have been selected for their potential value, in terms of improved quality control, cost savings, or more realistic simulation of actual environmental conditions.

Readers interested in testing in related fields may find additional information in NASA SP-5943 (01) Testing Methods and Techniques: Testing Electrical and Electronic Devices, and in NASA SP-5944 (01) Testing Methods and Techniques: Strength of Materials and Components.

Additional technical information on individual devices and techniques can be requested by circling the appropriate number on the Reader Service Card enclosed in this compilation.

Unless otherwise stated, NASA and AEC contemplate no patent action on the technology described.

We appreciate comment by readers and welcome hearing about the relevance and utility of the information in this compilation.

Ronald J. Philips, *Director*  
*Technology Utilization Office*  
*National Aeronautics and Space Administration*

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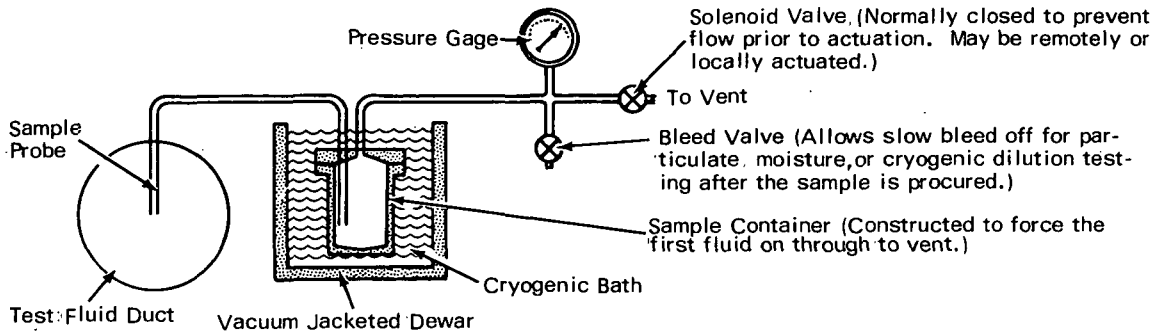
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## Section 1. Cryogenic Testing

### CRYOGENIC FLUID SAMPLER PERMITS TESTING UNDER HAZARDOUS CONDITIONS

A remotely controlled sampling device consisting of a calibrated container, a dewar, a solenoid valve, a pressure gage, and a manual bleed valve takes timed samples of cryogenic

The pressure gage indicates the presence of sample fluid in the container and serves as a warning indicator if boil-off begins. The bleed valve permits slow evaporation for particulate



fluids during hazardous tests. This capability permits accurately determining the fluid properties, knowledge of which is useful in analyzing the test results.

The sampler is initially submerged in a dewar containing a liquid with a boiling point no higher than that of the fluid to be sampled. When the boiling in this chilling bath ceases, the container is ready for sampling. Samples are obtained by activating the solenoid valve, thus initiating flow from the duct into the sample probe pipe. The fluid enters the sample container near the bottom, forcing any purging contents in the container out through the vent.

moisture, or cryogenic dilution testing. To prevent spurious contamination of the sample, there is no valving between the test duct and the sample container.

When a satisfactory sample is obtained, the solenoid valve is closed. The sample container is removed after the test is completed.

Source: J. A. Mitchell of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-1927)

*Circle 1 on Reader Service Card.*

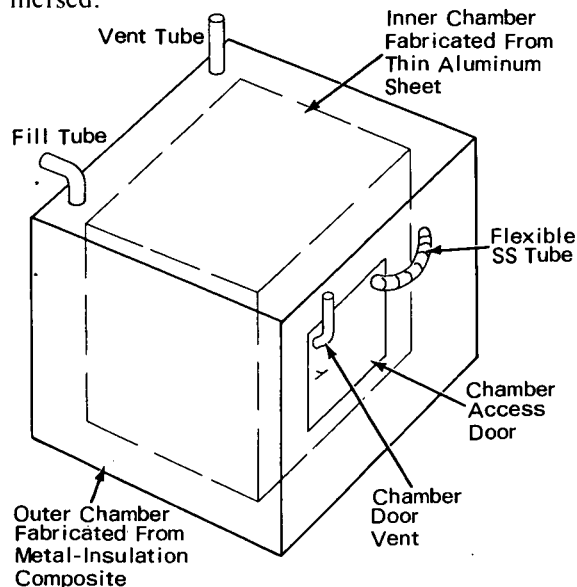
### CHAMBER FOR "DRY" CRYOGENIC TESTING: A CONCEPT

This test chamber design, for establishing and maintaining a "dry" cryogenic environment, would eliminate the need for complex temperature controls while providing a test environment virtually free of temperature gradients. The design, a diagram of which is shown in the figure, might be applied in any

testing situation which requires exposure to very low temperatures without immersion in cryogenic liquids.

Techniques for producing cryogenic environments generally require the use of cryogenic fluids. In most cases, cryogenic temperature exposure may be accomplished by immersion in

a liquid cryogen. In other cases, for various reasons, the part to be tested cannot be immersed.



In such cases, the cryogenic environment must be generated by a system comprising a chamber, a temperature controller, and a liquid cryogen. Cooling is accomplished by flowing cryogenic fluid into the chamber. Fluid flow rate is determined by the controller, which senses chamber temperature and adjusts flow rate accordingly.

This technique, however, has certain weaknesses, among which are: (1) it requires the use

of expensive temperature control systems, (2) it cannot accurately control chamber temperature fluctuations, and (3) it cannot eliminate temperature gradients within the chamber.

The proposed double-chamber design would eliminate these weaknesses. As conceived, the inner chamber would be made from a cryogenic-temperature resistant, thermally conductive material such as aluminum. The outer chamber would consist of a thermal insulator such as a metal-ceramic composite. The inner chamber would be cooled by filling the volume between it and the outer chamber with a cryogenic liquid. Because it would be surrounded by the cryogen, the inner chamber would be very rapidly cooled to a temperature near that of the liquid. Once stabilized, the temperature would remain constant as long as the liquid level remained above the top of the inner chamber. And, since every boundary would be cooled to the same temperature, there would be virtually no thermal gradients within the chamber.

Source: F. M. Torre of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-16934)

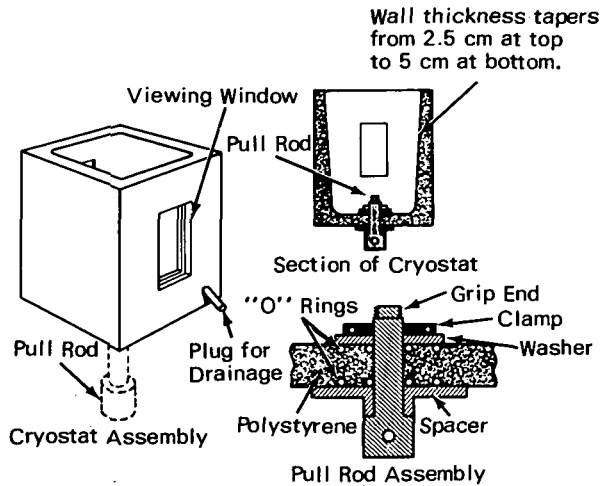
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### CRYOSTAT SIMPLIFIES TENSILE TESTING AT LIQUID NITROGEN TEMPERATURES

A lightweight cryostat made of expanded polystyrene and attached directly to a tensile testing mechanism by a special seal, can reduce misalignment effects due to cryostat weight, while facilitating viewing and loading of specimens. (In tests of irradiated tensile specimens under liquid nitrogen, a slight eccentricity in the tensile system will cause erroneous results. A conventional metal-type cryostat not only adds eccentricity to the system because of its weight, but also makes it difficult to assure that a test specimen is properly sealed.)

The cryostat, shown in the figure, is made

of expanded, nonporous polystyrene, and is much lighter than conventional cryostats. The low density material is not subject to damaging thermal stresses, and its light weight allows the cryostat to be attached directly to the bottom pull rod of the testing mechanism without causing eccentricity problems. Thus, the need for complicated dynamic seals is eliminated. A thin layer of a room-temperature-curing silicone adhesive, painted on the interior and exterior of the cryostat, increases the resistance of the material to liquid nitrogen (LN<sub>2</sub>) and keeps moisture out of the foam.



Two acrylite windows are incorporated into opposite walls of the cryostat, permitting an excellent view of the specimen and grips. The windows and pull rod assembly are sealed with

silicone adhesive; O-rings are also used in sealing the pull rod. The sealant is effective when used sparingly or when put on in separate layers.

The cryostat's design has many advantages. It is simple in design, with no moving seals or complicated assemblies. It is light weight and easy to fabricate, since polystyrene can be easily shaped with a hot-wire cutter. It is economical, showing reduced boil-off and leakage losses of LN<sub>2</sub> because the cryostat is well sealed and made of an insulating material. Finally, it is easily converted for use with many other grip assemblies and materials.

Source: R. P. Shogan and R. J. Skalka of Westinghouse Astronuclear Laboratory under contract to AEC-NASA Space Nuclear Systems Office (NUC-10522)

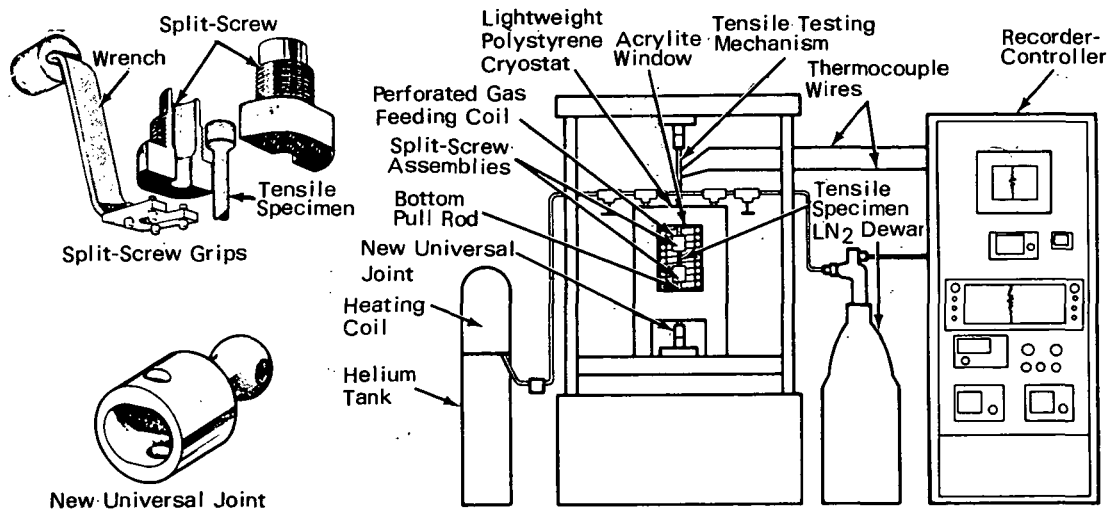
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## TENSILE TESTING OF IRRADIATED METALS

A modified cryogenic tensile testing system improves the accuracy and uniformity of results in tensile testing irradiated metal specimens at cryogenic temperatures. The modifications in-

alignment defects, which had previously been caused by the greater weight of conventional metal cryostats.

The system was developed for tensile testing



clude: (1) the lightweight, expanded polystyrene cryostat described in the preceding item; (2) split-screw grips; (3) a universal joint; and (4) a special temperature control system. These modifications have greatly reduced critical mis-

alignment defects, which had to be kept at liquid nitrogen temperatures from the time of their irradiation until after the test had commenced. There was also a need for fast, accurate control of specimen temperature during

testing to determine annealing effects at intermediate temperatures. Previous radiation-effects tensile testing of brittle-type metals indicated losses in strength and ductility after irradiation at liquid nitrogen temperatures. However, measurement accuracy was hampered by premature failure, caused by eccentricity of the tensile tester's loading system.

The split-screw grips are precision machined to the contour of the test specimen shoulders in order to reduce misalignment effects due to uneven loading. Unlike conventional split-screw grips, which are threaded to the end of the unit, the new grips are made with a guide and a beveled edge to facilitate rapid and accurate seating under LN<sub>2</sub>. Also, the heads contain precision-located holes that match pins in a specially designed wrench; this prevents jamming, and permits fast attachment of the grips to the specimen and rapid assembly of the split-screw grips into the main gripping body.

To further reduce misalignment effects, a universal joint with limited side travel is inserted in the socket located on the movable crosshead and is connected with the bottom pull

rod. Semielliptical design of the universal-joint head and socket seal limits side travel to minimize any random stresses of spillage of LN<sub>2</sub> that might be caused by "flopping" of the universal joint before slack in the system is taken up.

In the temperature control system, the specimen is surrounded by a coil containing holes, specially sized and located, through which either cold gaseous nitrogen or preheated gaseous helium may be injected. These are supplied through lines leading to the coil from an LN<sub>2</sub> dewar or a helium tank. Temperature is determined by a calibrated thermocouple at a control point near the specimen and is maintained at the desired point for testing (after the precooling LN<sub>2</sub> has been drained from the cryostat) by a controller, which actuates solenoid valves as required.

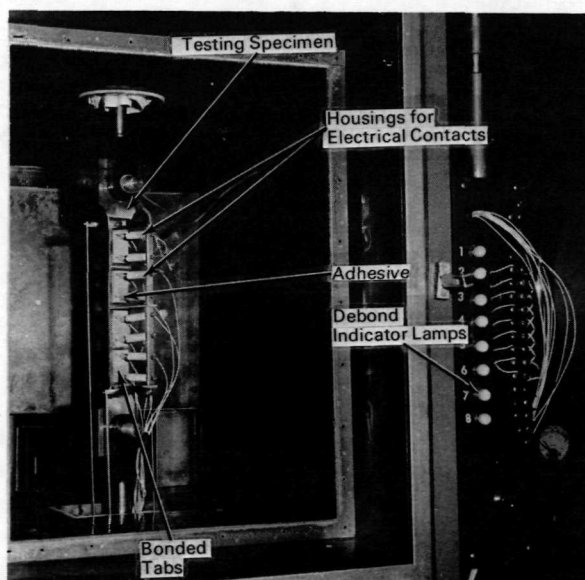
Source: P. J. Levine, R. J. Skalka, and  
E. F. Vandergrift of

Westinghouse Astronuclear Laboratory  
under contract to

AEC-NASA Space Nuclear Systems Office  
(NUC-10521)

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## TESTING FOR ADHESIVE DEBOND UNDER CRYOGENIC CONDITIONS



The illustrated testing setup is used to determine adhesive debond strength under cryogenic conditions. The test specimen is a standard wishbone tensile coupon made from 2014-T6 aluminum alloy plate. Tabs are bonded to the plate by patches of the adhesive to be tested. After the coupon is inserted in a standard cryogenic tensile testing machine, each bonded tab is connected to a pair of spring-loaded electrical contacts. Debonding of the tab permits the contacts to close, and lights an indicator lamp.

Source: W. G. Boyd of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-16794)

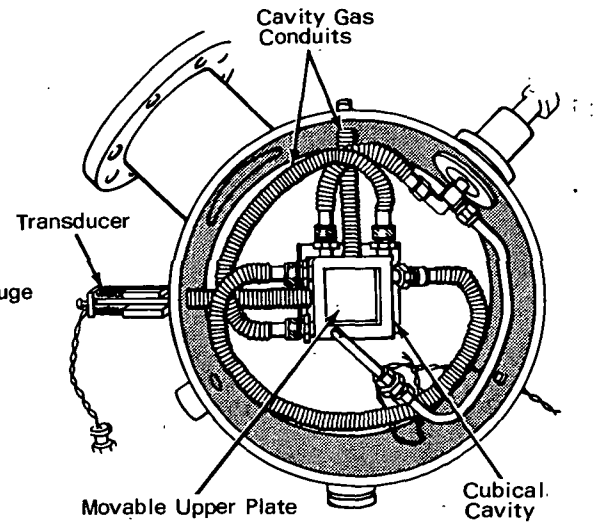
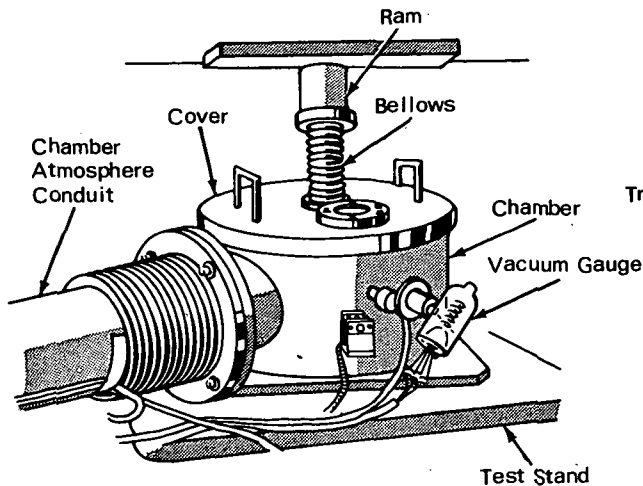
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## VARIABLE-ENVIRONMENT CHAMBER FOR MATERIALS TESTING

The illustrated controlled-environment chamber, which encloses both a test specimen and the devices used to perform a variety of physical tests, can continuously vary the test environment

ram, attached to appropriate force-registering instrumentation, is mounted directly above the chamber and led into it through a collapsible sealing bellows. In the chamber, the ram engages



through a range of pressure, temperature, humidity, and atmospheric composition. The chamber is used to determine the energy-absorbing capacity of various crushable materials through a wide range of environments. Presently available test chambers give data on specimen or assembly behavior in various fixed environments, but not on behavior during changing environmental conditions.

The chamber is firmly mounted on a static test stand so that external forces or movements will not affect it. The device is equipped with conduits to introduce heating or cooling gas, to raise or lower the pressure, or to introduce atmospheres of differing chemical makeup. A

the upper plate of a cubical cavity that contains the test specimen.

The cavity is made up of fixed and movable plates configured so that the ram, pressing on the upper movable plate, will deform the specimen through lateral expansion. The movable plates, contiguous with the crushable specimen, are spring loaded to maintain intimate contact with the specimen while permitting its deformation under pressure.

Source: A. C. Knoell of  
Jet Propulsion Laboratory  
(JPL-789)

*Circle 6 on Reader Service Card.*

## BIAXIAL TEST FIXTURE HAS CRYOGENIC APPLICATIONS

A recently developed test fixture can produce biaxial stress fields of sufficient magnitude to cause failure in large test specimens. This fixture permits determining the magnitude of a biaxial stress by simply dividing the applied load by the net cross section. With relatively minor modification, the same test fixture can be used

for biaxial stress-field testing at cryogenic temperatures.

With the development of large pressurized tanks has come a need for an inexpensive method of testing critical tank areas to failure. In all pressurized tanks there are small areas of discontinuity that require structural certification.

Since no previously existing facility had the capability of testing just these small areas, a complete tank had to be built. Testing a complete tank proved unsatisfactory, because the exact location of rupture was often difficult to pinpoint, and the design reserve of undamaged critical areas could not be established. Numerous attempts to duplicate the stress fields experienced in a pressurized tank have had limited success, and then only with very small test specimens.

The new biaxial test facility is capable of producing biaxial stress fields in panels as large as 61 cm (2 ft) square. The test panel is machined on both sides to form a frame around the test area. Clamp-type grips are used to transfer load into the corners of the test panel through bolts loaded at the centroid of area. Load is applied by hydraulic actuators attached to the grips and to load plates on the ends of the fixture. Load transmitted to the test panel is controlled by calibrated load rods between

the hydraulic actuators and the fixture frame. Since the load can be controlled to apply a uniform stress to the test panel, failure load can be determined simply by dividing the total applied load at failure by the net cross section of the panel.

For cryogenic application, a metal tub is fabricated beneath the test panel and filled with a liquid cryogen. Cryogenic liquid is also sprayed from perforated tubing onto the test panel and loading grips. A plastic thermal barrier is secured above the metal tub to control splash and air flows.

Source: J. C. Helf, R. E. Kelly, D. A. Kerr, and C. R. Waldron of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-14185 and 14189)

*Circle 7 on Reader Service Card.*

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### REDUCING THE HAZARD IN TESTING CRYOGENIC PRESSURE VESSELS

In burst testing large-capacity cryogenic storage vessels, sudden ruptures can produce an explosion of considerable magnitude. To enable testing of larger vessels without incurring the expense of installing additional safety barricades, it is necessary to reduce the internal volume of the tank. This can be accomplished simply and inexpensively by partially filling the tank with small pieces of scrap aluminum. This procedure will reduce explosive force in three ways: (1) The net liquid contents are reduced, with a corresponding decrease in burst energy. (2) The large mass and high specific heat of the aluminum scrap aid in achieving nearly isothermal compression of the liquid. This

results in a much smaller rate of energy increase with compression, as compared with isentropic compression. (3) Most of the gas formed by the sudden decompression of the supercritical liquid expends its energy relatively slowly, by friction during passage through the interstices between the aluminum chunks, and by accelerating the fragments themselves to relatively small radial velocities.

Source: H. E. Hubbard of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-13534)

*Circle 8 on Reader Service Card.*

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### ELONGATION LIMIT OF STRAIN GAGES IN LIQUID NITROGEN

A test program has yielded data on the utility of various strain gage and cement combinations for cryogenic applications in which a wide temperature range may be encountered.

A wide variety of strain gage types was tested, but no attempt was made to evaluate the effects of minor differences within a single gage type. Hence, the effects of such parameters

as thermal-expansion compensation, gage length, and cement-curing procedure were not investigated.

Each strain gage, 3.18 mm (1/8 in.) in length, was mounted on 3003-H14 aluminum beams, 23 cm long by 2.5 cm wide by 3.2 mm thick. After standard installation and curing, each beam was supported horizontally at both ends and subjected to bending under a centrally applied load.

The strain gage output was recorded on the X-axis of an X-Y recorder, and the deflection of the beam was recorded on the Y-axis; this made it possible to determine the mode of failure of the gage. For tests conducted at room temperature, the load was applied until the strain gage failed electrically because of an open circuit in the grid, or mechanically due to failure of the bond between the gage and the beam. The mode of failure was easily determined in most cases from the shape of the curve obtained on the X-Y recorder. Incipient bond failure was indicated by a decrease in the slope

of the strain-deflection plot, and electrical failure by an increase.

Cryogenic tests were performed by placing the test fixture in a liquid nitrogen bath and allowing the temperature to stabilize. Although the cessation of violent bubbling indicated approximate equilibrium, a more accurate indication of equilibrium was given by the stabilization of the X-Y plotter reading. Once the temperature stabilized, the bar was loaded until the strain gage failed.

After the gage failed, it was examined under a microscope to determine the presence of cracks in the strain gage grid and backing, and to detect flaws in the solder joints used to connect leads to the strain gage.

Source: D. W. Nicholls of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-18218)

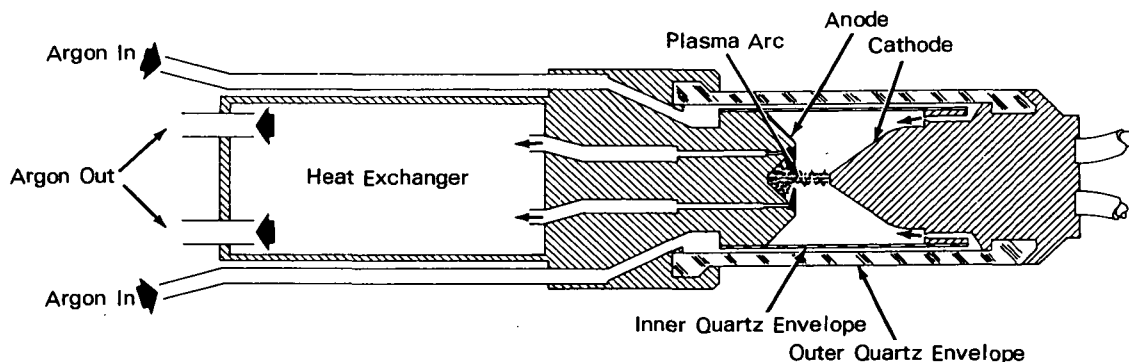
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## Section 2. High-Temperature Testing

### HIGH-INTENSITY, SUSTAINED-OPERATION HEAT SOURCE

A water-cooled, high-intensity radiation source, rated at 125 kW, with an efficiency of 31 to 34 percent, can operate repeatedly at maximum rated power for periods of 10 to 20 minutes.

entry into planetary atmospheres, the source had to be capable of high-reliability cyclic operation at maximum power for extended periods of time. Previously available sources capable



At lower power inputs it can be operated continuously for periods as long as two hours. Originally designed for evaluating ablative materials under simulated conditions of high velocity

of long-term operation were not capable of supplying the required radiant power output.

The radiation source used was a direct current device in which an argon plasma arc was created

between a tungsten-tipped copper cathode and a copper anode with a molybdenum ring diffuser. The envelope through which the radiation was transmitted was formed of two concentric quartz cylinders. The inner cylinder served as a heat shield; the outer cylinder as the pressure container.

Argon was fed in at the anode, and passed from the anode, through the annulus between the two quartz cylinders, into a gas vortex generator at the cathode. The gas was then passed through

a diffuser, collected, and recirculated through cooling coils back to the source. In passing through the annulus between the cylinders, the gas acted as a coolant for the outer quartz cylinder.

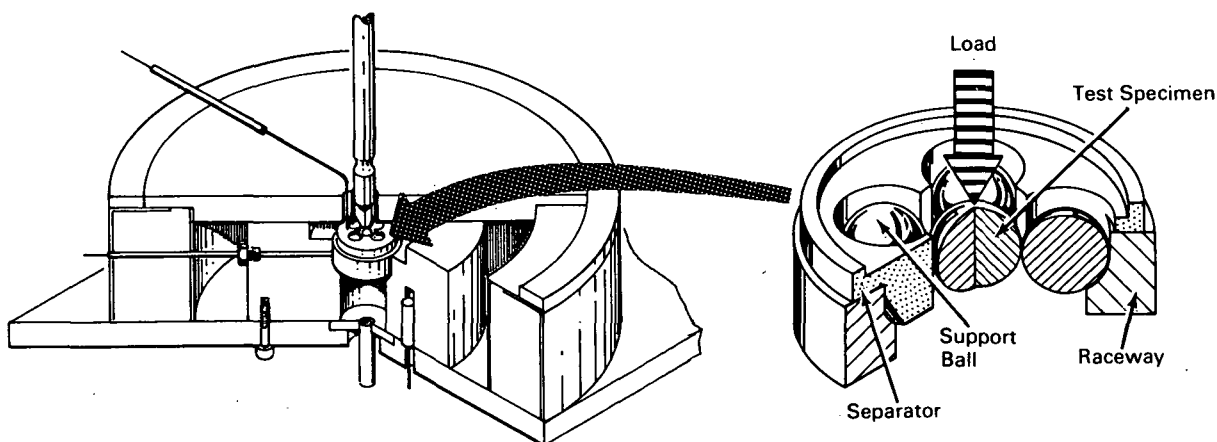
Source: W. A. Geideman and K. Muller of  
Textron Electronics, Inc.,  
under contract to  
Ames Research Center  
(ARC-61)

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### TESTER FOR STUDY OF ROLLER BEARINGS

A novel, five-ball fatigue tester enables the study of rolling element phenomena, including roller fatigue, ball-bearing kinematics, and elastohydrodynamic lubrication, over a wide

Choice of operating speed is made through stepped pulleys driven by an electric motor. A magnetic pickup feeding an electronic counter provides precise speed measurement. Temperature



temperature range (88.7 to 1366.5 K). The tester consists essentially of a driven test ball pyramided on four lower balls. The four balls are positioned by a separator and are free to rotate in an angular-contact raceway.

The upper test ball and the raceway are analogous in operation to the inner and outer races of a bearing. The separator and the lower balls are similar in function to the cage and the balls of a bearing. Specimen loading and drive is supplied through a vertical shaft. By varying the pitch diameter of the four lower balls, bearing contact angle may be controlled. With each revolution of the drive shaft, the upper ball receives three stress cycles.

is measured by a thermocouple in contact with the raceway containing the freely rotating lower balls. The test specimen is lubricated by metering droplets of fluid lubricant into an air stream that is directed at the test specimen.

Various modifications of this apparatus permit fatigue testing at temperatures ranging from 88.5 to 1366 K ( $-300^{\circ}$  to  $2000^{\circ}$  F), and testing of full-scale bearings. Automatic failure detection and shutdown systems have enabled long term, unmonitored testing.

Additional information concerning this innovation is given in NASA-TN-D-529, "Rolling-Contact Fatigue Life of a Crystallized Glass Ceramic," Thomas L. Carter and Erwin

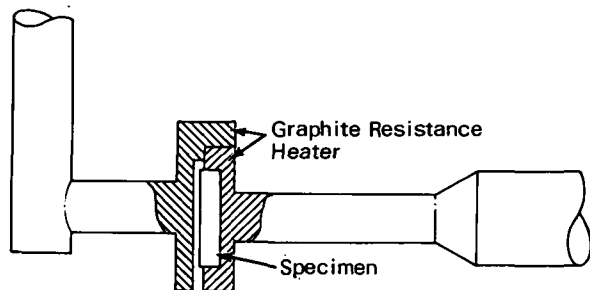
V. Zaretsky, and in NASA-TN-D-270, "Effect of Hardness and Other Mechanical Properties on Rolling-Contact Fatigue Life of Four High Temperature Bearing Steels," Thomas L. Carter, Erwin V. Zaretsky and William J. Anderson.

These documents are available from the National Technical Information Service, Springfield, Virginia 22151. Price per document: \$6.00.

Source: E. V. Zaretsky et al.  
Lewis Research Center  
(LEW-305)

### TEST-SPECIMEN HEATER

A novel graphite heater is used to hold and heat small, electrically nonconductive specimens in vacuum or other inaccessible environments. Heating is performed by passing dc currents of 100 to 400 A through the graphite. The heater,



shown in the figure, gives the greatest specimen contact area and the most uniform specimen temperature of the several heater designs tested.

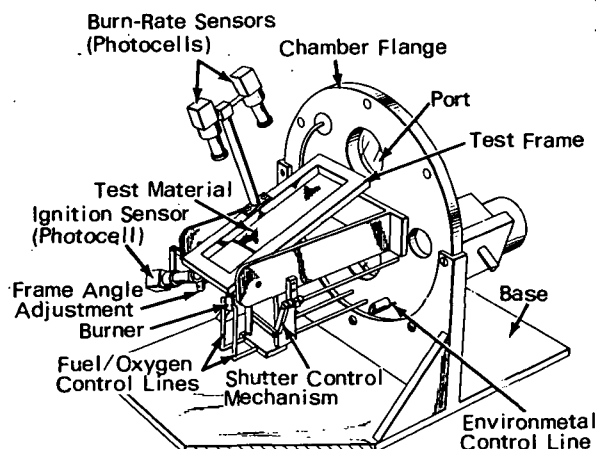
The heater was originally developed in conjunction with a research project on the formation of tektites. Operated with a heating current of 400 A, it has produced brightness temperatures as high as 1300 K in the glassy specimens used in the research.

Source: General Electric Co.  
under contract to  
Goddard Space Flight Center  
(GSC-379)

*Circle 11 on Reader Service Card.*

### BURN-RATE TESTING APPARATUS

The combustibility tester shown in the figure incorporates several improvements over previous designs. First, it has been designed to fit into a sealed chamber, so that tests may be performed under controlled atmospheric pressure and composition. Second, the material



support frame has been modified to allow rotation of the test sample, so that ignition and combustion may be tested with the sample in various orientations from horizontal to vertical.

Third, a remote-controlled ignition system has been incorporated. The system consists of a burner externally supplied with fuel and oxygen, a spark-gap igniter, a shutter which masks the flame from the sample until the flame reaches the desired intensity, and a calibration thermocouple which senses the flame temperature.

Finally, three photocells have been added, to allow automatic determination of the time required for burn-through and of the rate of flame propagation along the sample. One cell is placed to sense the start of the test; i.e., the application of flame to the sample as the shutter is removed. The other two photocells

are mounted on the test frame above the sample. One cell responds to ignition of that part of the sample immediately over the point of application of the flame; the other to ignition of another part of the test material.

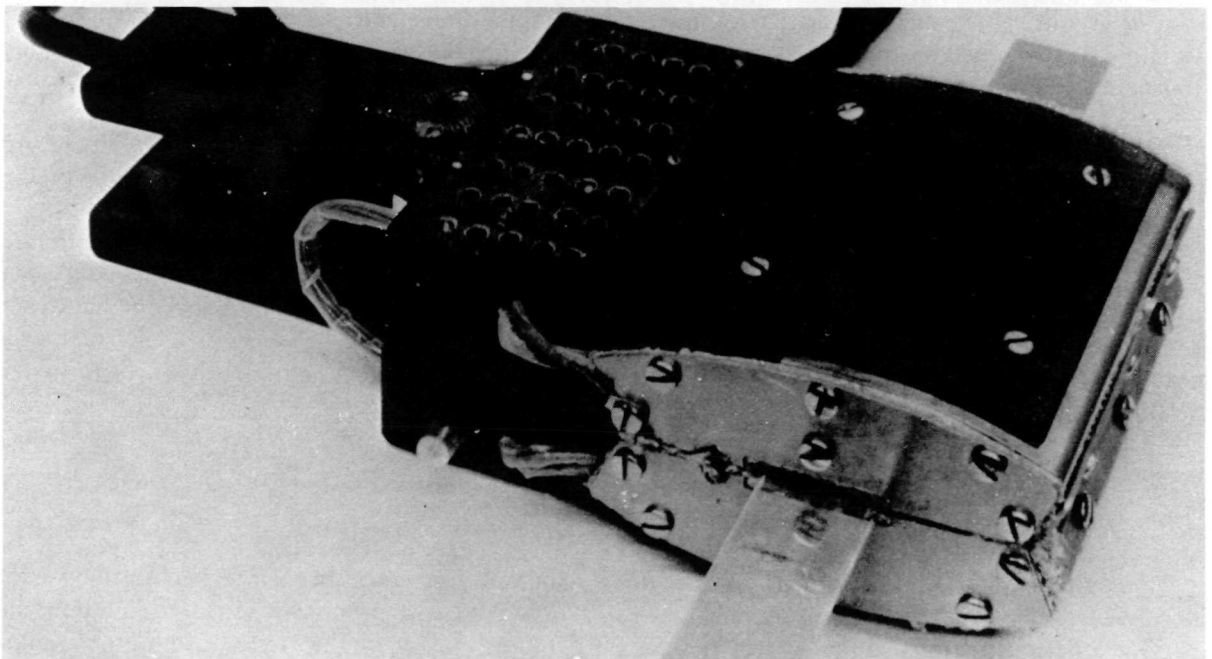
This invention is owned by NASA, and a patent application has been filed. Royalty-free, non-exclusive licenses for its commercial use

will be granted by NASA. Inquiries concerning license rights should be made to Patent Counsel, Mail Code AM, Manned Spacecraft Center, Houston, Texas 77058.

Source: F. S. Dawn and  
W. L. Gill  
Manned Spacecraft Center  
(MSC-10947)

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### PORTABLE HEATER FOR LAP SHEAR TESTING



The photograph shows a newly developed integrated heater-clamp, used for elevated lap shear testing of adhesives. The clamp allows testing to be performed on inexpensive equipment, rather than on the expensive shear-testing machines formerly used. The heater is capable of attaining test temperatures as high as 590 K (600° F).

Source: W. M. Zinsley,  
W. A. Edwards, Jr. and  
C. O. McAdams of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-17114)

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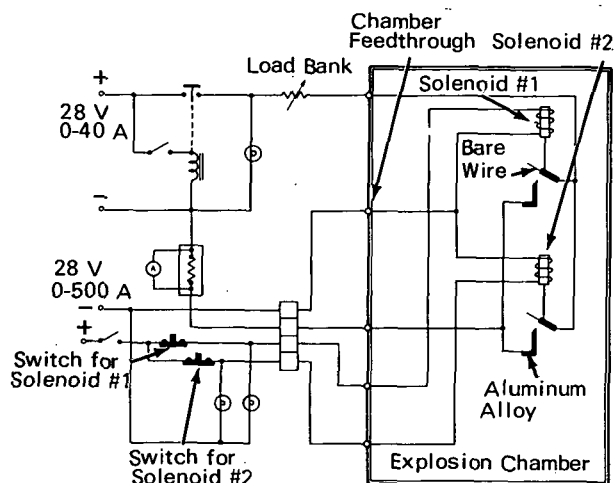
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### TESTING IGNITION SUSCEPTIBILITY OF MATERIALS

The recently designed circuit shown in the figure is used to test the ignition characteristics and flammability of specific materials in air-or

oxygen-rich atmospheres. Materials used in close proximity to electrical equipment may be subjected to incandescent metal fragments

or spalls ejected from intermittent short-circuit arcs. The apparatus simulates this real situation, in which an exposed live wire intermittently contacts a grounded structural member



in an area containing organic materials. The device consists of a solenoid actuator, wire, and aluminum alloy angle, contained in an environmental chamber in which a controlled oxidizing atmosphere can be maintained.

The desired arcing condition is produced by rapidly shorting a live wire (e.g., no. 12 AWG), carrying current from a 28Vdc, 0-500A source,

against a grounded aluminum alloy angle. Specimens to be tested are placed in the chamber at various distances from the arc-forming mechanism.

As shown in the schematic, the solenoid is used to raise and lower the bared live wire relative to the grounded angle. The solenoid is controlled by a normally closed pushbutton switch. The solenoid, normally energized (from the 28 Vdc source), holds the wire away from the shorting angle. When the pushbutton is depressed, the solenoid is deenergized. This allows the wire to drop onto the shorting angle, causing arcing and spalling.

Two arc generators are installed in the chamber, enabling two tests to be run without disturbing the chamber. The effects of the intermittent arcing on the test material are observed through a window in the chamber wall.

Source: B. J. Hamlett and  
A. L. Krupski of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-15225)

*No further documentation is available.*

## Section 3. Pressure Testing

### PRESSURE-SENSING DIAPHRAGM

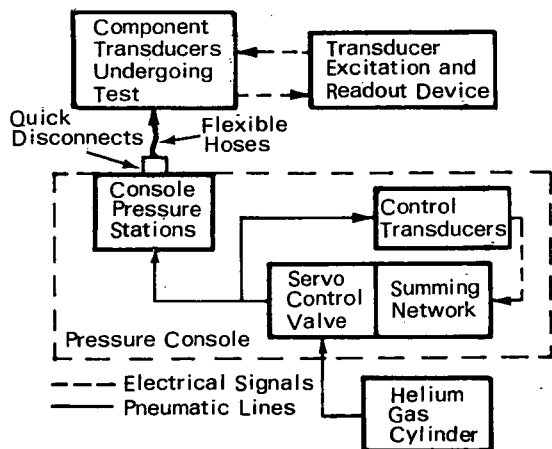
A thin, metal ring-type diaphragm seal, similar to those used on pneumatic or hydraulic sensors, is welded to the outer diameter of a spherical disk spring and to a housing in which the disk spring is enclosed. This configuration results in lower hysteresis than does the conventional seal, in which the periphery of a solid diaphragm is welded directly to the housing, with the diaphragm lying across the entire face of the

disk spring. The configuration, with its reduced edge effects, allows more precise pressure sensing than previous designs.

Source: C. W. Seltzer of  
Ametek-Calmec  
under contract to  
Marshall Space Flight Center  
(MFS-20769)

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## AUTOMATED CALIBRATOR FOR PRESSURE TRANSDUCERS



An automated, portable, transducer checker can be used to calibrate pressure transducers in the range of  $207\text{kN/m}^2$  to  $7.45\text{MN/m}^2$  (15 to 1065 psig) with an accuracy of  $\pm 0.05\%$ . The checker consists of a pressure console and equipment for producing the test pressures. The

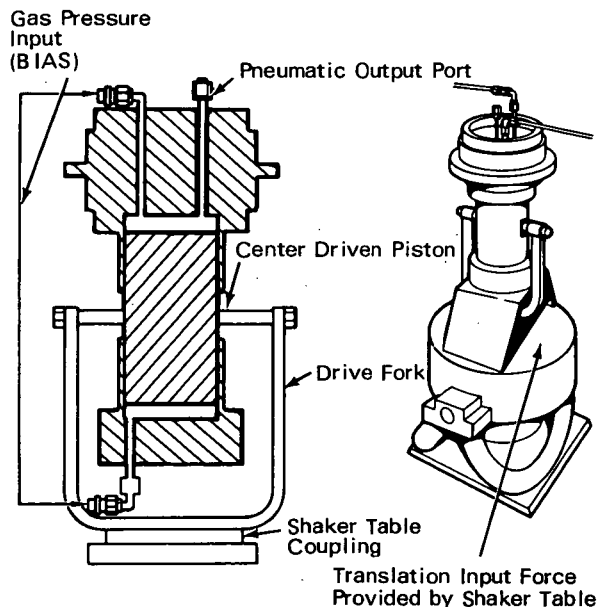
console is connected to other devices for measuring and visually displaying the electrical outputs of transducers being calibrated.

The transducers are connected by flexible hoses to quick-disconnect pressure stations mounted on the rear of the console. The console is connected to a  $13.8\text{ MN/m}^2$  (2000 psig) helium gas cylinder. A servo control valve and a summing network reduce the output of the cylinder to provide the exact desired test pressure. The outputs of the transducers undergoing test can be shown on a strip recorder or other types of display equipment.

Source: J. Brinda, J. Shaw, L. Kristoff, and M. Vuckovich of Westinghouse Astronuclear Laboratory under contract to AEC-NASA Space Nuclear Systems Office (NUC-10067)

Circle 14 on Reader Service Card.

## PNEUMATIC PRESSURE-WAVE GENERATOR USED TO TEST TRANSDUCERS



Pressure fluctuations about a bias or reference pressure level, produced by displacement of a center-driven piston in a closed cylinder, provide a means of testing pressure transducers and systems to determine their reliability or

accuracy. Standard pressure-wave generators have elaborate controls, consume enormous quantities of gas, and are severely limited in operating range by either pressure or frequency.

The generator, shown in the figure, is pre-pressurized to any desired static level (bias pressure) and is coupled to a shaker table. The transducer or system undergoing test is connected to the output port of the generator. The frequency and amplitude of the generator's pneumatic output are controlled by the movement of the piston, which is directly linked to the drive fork. The fork in turn is driven by the vibration of the shaker table. The pneumatic output of the generator is a direct function of the displacement amplitude and frequency of the shaker table. Sinusoidal or other wave shapes may be generated by controlling the operation of the shaker table.

Source: A. E. Gaal and T. P. Weldon of Westinghouse Astronuclear Laboratory under contract to AEC-NASA Space Nuclear Systems Office (NUC-10024)

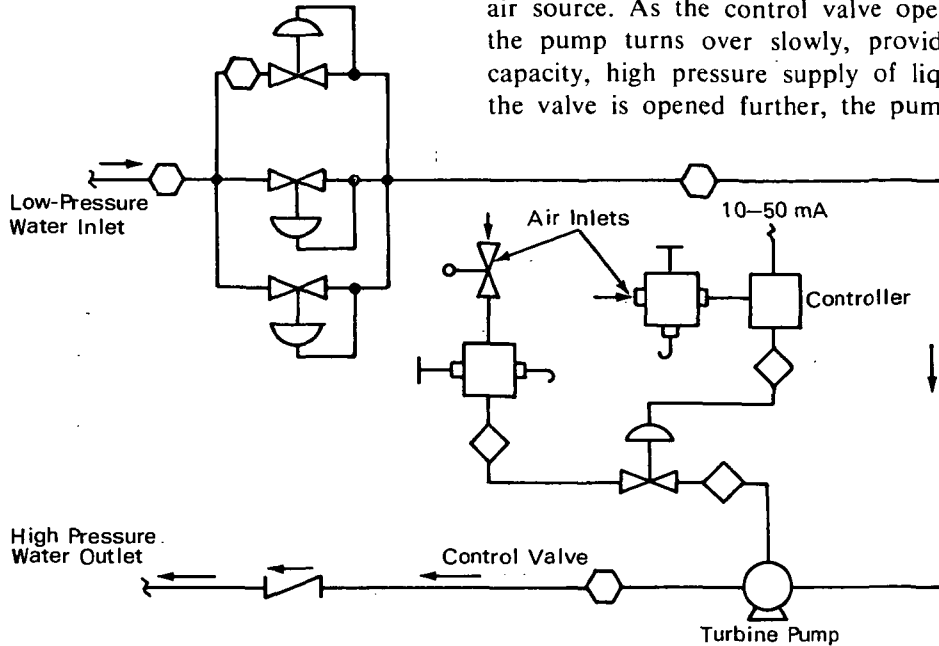
Circle 15 on Reader Service Card.



### REMOTE-CONTROLLED, AIR-DRIVEN PUMP

An air-driven pump, together with a control valve and a remote controller, combines in one device functions previously performed by two

As shown in the figure, the control valve is placed in the pump's air supply. A pressure regulator assures a high pressure, high capacity air source. As the control valve opens slightly, the pump turns over slowly, providing a low capacity, high pressure supply of liquid. When the valve is opened further, the pump provides



pumps. Pressure testing of large systems previously required both a low capacity, high pressure pump and a very high capacity pump designed primarily for filling and draining operations. The controllable features of the new system provide either high or low capacity as required, with a sufficient pressure head for most test purposes.

higher capacity at the same high pressure level; when it is completely shut, the pump stops.

Source: C. W. Kenyon of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-13615)

*Circle 16 on Reader Service Card.*

### TESTER FOR CAM-OPERATED VALVES

A tool used for high pressure functional testing of cam-operated valves can measure the actuation displacement of a valve while it is under working pressure. Previously, actuation displacement was measured by clamping the valve onto the round surface of a cam-operated roller, but this did not provide a stable reference point. Further, any rotation of the roller during pressurized operation often dislodged the clamp, resulting in loss of high pressure fluid and damage to surrounding equipment.

The tool is composed of two basic parts, a circular disk and a shank. The clamping device is positively retained in the disk by a circular depression. Welded to the bottom of the disk is a shank containing a lateral hole for the free passage of an assembly pin. The width, thickness, and depth of this shank must be such that it can freely pass into the depression in the actuator shaft. Shank height above the shaft constraints can be any convenient amount.

At each end of the assembly pin is a cross

hole for accepting a retaining pin. Adjustment so that the tool can be firmly kept in place is provided by a set screw passing through a threaded hole running between the disk and shank.

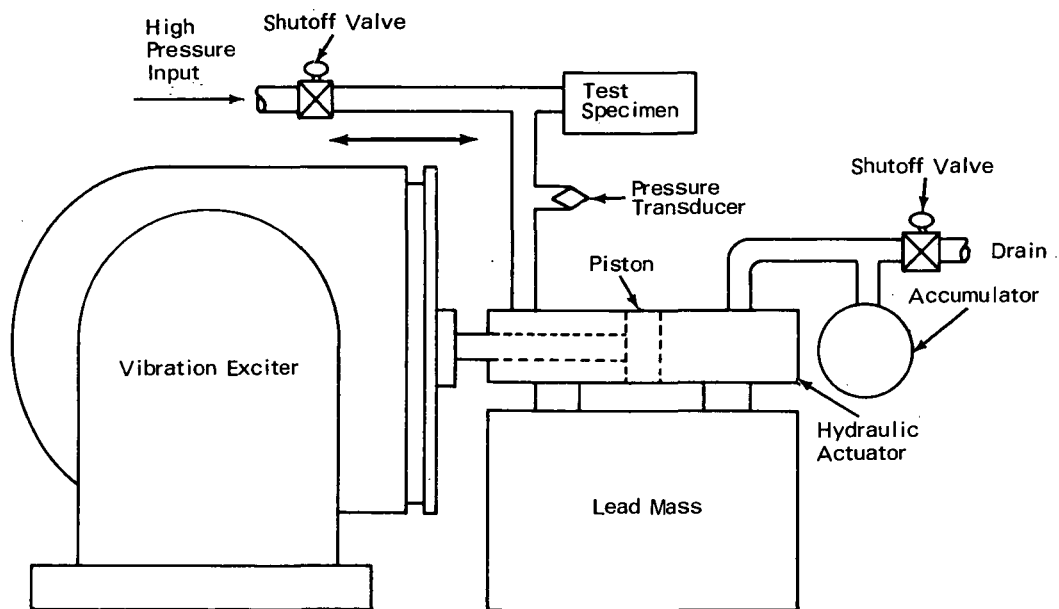
Source: R. W. Grindle, Jr. of  
The Boeing Co.  
under contract to  
Kennedy Space Center  
(KSC-10468)

*Circle 17 on Reader Service Card.*

### TESTER PROVIDES VARIABLE PRESSURE-WAVE AMPLITUDES AND FREQUENCIES

A pulsating pressure, obtained from a hydraulic actuator driven by a vibration exciter, forms the heart of a device used to test hydraulic sys-

tem components to high vibration pressure or frequency requirements. The device can also be used to test pressure transducers, switches, and other hydraulic components. The pressure levels and pulsation frequencies can be varied as test requirements dictate.



tem components to high vibration pressure or frequency requirements. The device can also be used to test pressure transducers, switches, and other hydraulic components. The pressure levels and pulsation frequencies can be varied as test requirements dictate.

As shown in the figure, the rod of a hydraulic actuator is attached to the exciter head. The rod-end port of the actuator cylinder is connected to the test specimen and pressurized to the level required by the test item. The shaker head and hydraulic actuator are maintained in the

center of their strokes by trapping the appropriate balancing pressure on the back side of the hydraulic actuator. The actuator is bolted

Source: J. W. Routson of  
General Dynamics Corp.  
under contract to  
Lewis Research Center  
(LEW-10205)

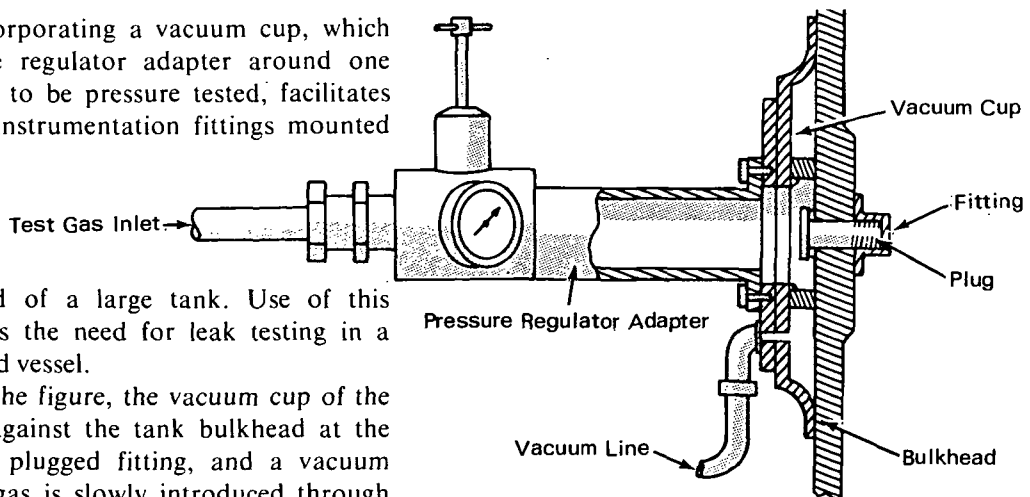
*Circle 18 on Reader Service Card.*

### PORTABLE PRESSURE TESTER FOR INSTRUMENTATION FITTINGS

A fixture incorporating a vacuum cup, which seals a pressure regulator adapter around one side of a fitting to be pressure tested, facilitates leak testing in instrumentation fittings mounted

in the bulkhead of a large tank. Use of this device eliminates the need for leak testing in a completely closed vessel.

As shown in the figure, the vacuum cup of the fixture is held against the tank bulkhead at the position of the plugged fitting, and a vacuum is drawn. Test gas is slowly introduced through the pressure regulator adapter until the pressure reaches  $207 \text{ kN/m}^2$  (15 psig). Leakage is detected with a gas sniffer at the opposite side of the bulkhead, or by the bubbling of a leak-check fluid previously applied at the junction of the fitting with that side of the bulkhead.

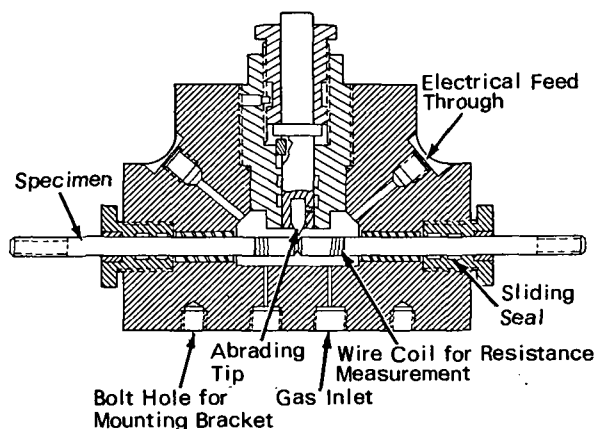


Source: G. A. Olson of  
The Boeing Company  
under contract to  
Marshall Space Flight Center  
(MFS-2032)

*Circle 19 on Reader Service Card.*

### ABRASION TESTING UNDER HIGH PRESSURE HYDROGEN

The device shown in cross section in the figure is used for abrasion testing in a high pressure hydrogen atmosphere. Constructed during a



materials evaluation program for long-term, high-pressure, hydrogen storage vessels, the device is capable of abrading cylindrical tensile speci-

mens in hydrogen atmospheres at pressures up to  $103.4 \text{ MN/m}^2$  (15,000 psi). While its surface is being abraded, the specimen can be placed under tensile load and tested to failure.

Electrical isolation between the specimen and the vessel, and special feedthroughs to pass wires through the vessel wall, permit measurement of the electrical resistivity of the specimen while it is being abraded or tensile tested. The abrader has two interchangeable tips, one for abrading a strip approximately 6 mm wide on an unnotched specimen, and the other for scratching the root of a notch (25  $\mu\text{m}$  notch radius).

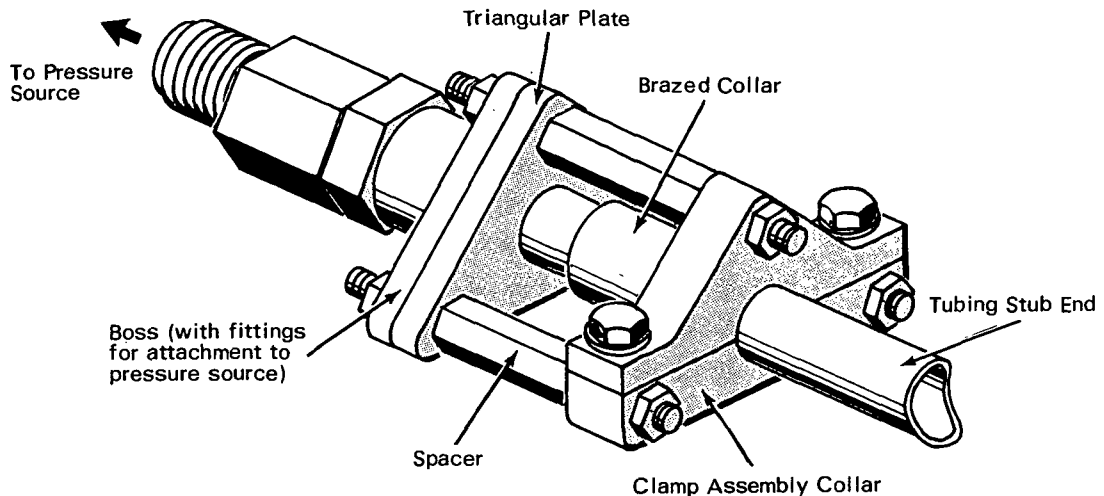
Source: G. V. Sneesby and R. J. Walker of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-18480, 18488)

*Circle 20 on Reader Service Card.*

**ADAPTER PREVENTS DAMAGE TO TUBING DURING HIGH PRESSURE TESTS**

The portable adapter assembly shown in the figure can prevent damage to tubing and injury to personnel during high pressure tests.

tubing immediately behind the brazed collar, and the triangular plate is positioned in front of it. A rubber O-ring, which serves as a seal



Capable of withstanding high pressure while securely attached to a tubing stub end, the adapter can be removed without debrazing or cutting the tubing. Tube ends often have been damaged by the use of an unsatisfactory method of attaching the tube to the pressure source, and connecting devices have often blown off the tube ends while under pressure.

The tubing stub end has a brazed collar for mechanical attachment to the adapter. The split halves of the clamp assembly are secured to the

when compressed, is slipped over the tubing. The boss plate, with fittings for attachment to the pressure source, receives the stub end tubing, and the adapter assembly is then tightened with the spacer nuts and bolts.

Source: L. L. Stinett of  
North American Rockwell Corp.  
under contract to  
Manned Spacecraft Center  
(MSC-563)

*Circle 21 on Reader Service Card.*

**BIAXIAL STRESS TEST USES ELLIPSOIDAL PRESSURE VESSEL:  
A CONCEPT**

Reliable determinations of weld-joint biaxial stress-strain characteristics could be provided by a conceptual, ellipsoidal pressure vessel. The ellipsoidal configuration, fabricated with welded joints in any appropriate orientation, would provide simple biaxial load control, and could yield data for several stress-strain ratios from each specimen. The vessel would be loaded by internal pressurization only, and strain gages would be used to collect the data.

The ellipsoidal test specimen would thus provide an alternate to the cylindrical or cruci-

form specimens commonly used in biaxial stress testing. Although the cost per specimen would be higher, multi-point instrumentation and simplified load control would give a lower cost per increment of data.

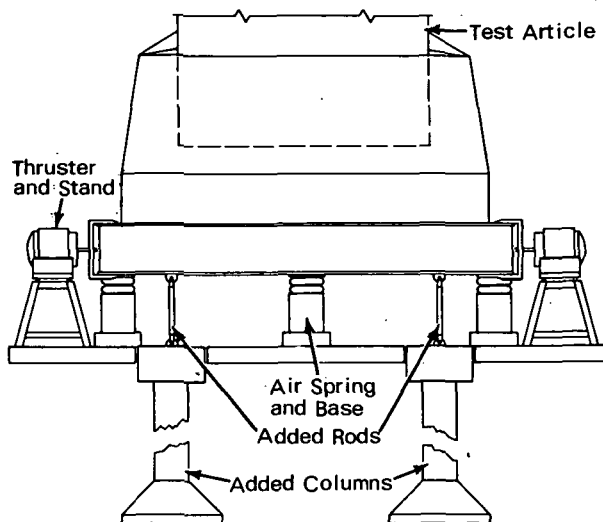
Source: W. H. Armstrong of  
The Boeing Co.  
under contract to  
Marshall Space Flight Center  
(MFS-13803)

*Circle 22 on Reader Service Card.*

## Section 4. Vibration Testing

### SUSPENSION SYSTEM FOR VIBRATION TESTER

Special thrusters, air suspension springs, and support columns are used to eliminate the need for large reaction masses and hydraulic



slip tables in the vibration testing of massive assemblies. The special thrusters are isolated so that damaging force levels are not transmitted to the supporting floor. The weight of the test article is supported by air suspension springs

positioned between the thrusters. These springs are used instead of the standard hydraulic slip tables, since the tables would limit the apparatus to motion in one direction, and would in addition, be undesirably loaded by the dead weight of the test article.

The high tensile loads generated by the horizontal testing of large articles are normally absorbed by a large reaction mass. To replace the mass in this application, four concrete columns are added to the apparatus support structure. High strength steel rods, equipped with spherical end bearings, are used to transfer the static load of the test article to the four columns. The rods do not limit the motion to one plane (considering the relatively small displacements encountered in vibration testing), but allow multidirectional vibrational testing without rotation of the test article.

Source: T. C. Martin of  
Lockheed Electronics Co.  
under contract to  
Manned Spacecraft Center  
(MSC-11001)

*No further documentation is available.*

### MULTIAXIS VIBRATION FIXTURE

A modified attachment fixture for a standard vibration tester enables three-dimensional testing with only one setup.

The usual method of vibration testing along three axes has been as follows: (1) The shaker is positioned vertically and the test specimen is mounted on a plate attached to the moving element. Instruments are installed and the test performed on the first axis. (2) The shaker is positioned horizontally and its moving element connected to a "slip" plate which rides on an oiled granite block. The item is mounted

on this plate, instruments are installed, and the test performed on the second axis. (3) The slip plate is unfastened, the item rotated  $\pi/2$  rad. ( $90^\circ$ ), and the plate reinstalled. The instrumentation is changed to the new orientation, and the test is performed on the final axis. This procedure is both time-consuming and expensive.

The attachment fixture is modified by adding a wedge and a pyramid to the shaker head. The triangular pyramid, constructed with three mutually orthogonal, equal-length edges intersecting at its apex, has sides that make an angle

of about 0.96 rad ( $54^{\circ}54'$ ) with its base. The wedge is constructed with the complementary angle, about 0.615 rad ( $35^{\circ}16'$ ).

The wedge is fixed on the shaker table so that the vibrations are parallel to its base, the pyramid is installed on the face of the wedge, and the test object is attached to one face of the pyramid. With this setup, transfer from one test axis to the next is made by merely rotating the pyramid  $2\pi/3$  rad ( $120^{\circ}$ ) about the line that runs from its apex perpendicular to its base.

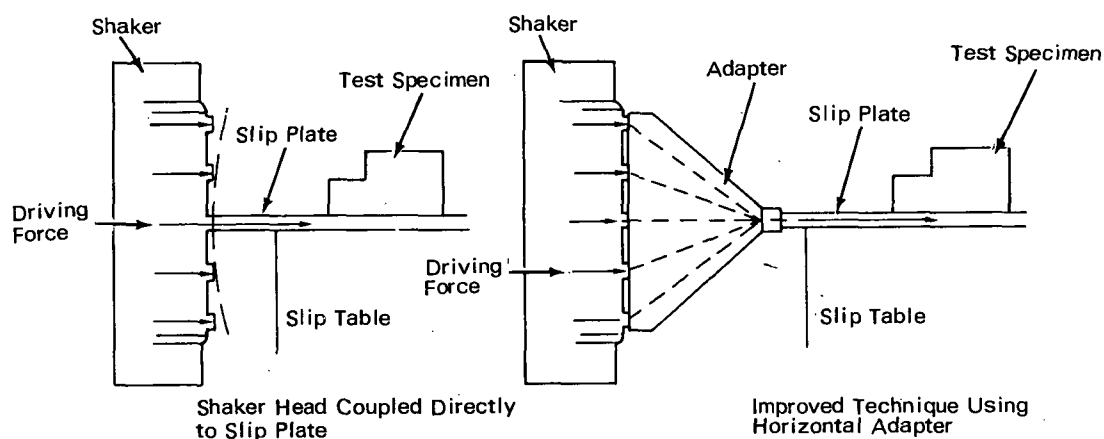
Source: C. R. Sims  
Marshall Space Flight Center and  
R. C. Taylor of  
The Bendix Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-20242)

*Circle 23 on Reader Service Card.*

### SHAKER SLIP-PLATE ADAPTER

Specimens subjected to vibration tests are commonly mounted on a horizontal slip table and associated plate, which is driven by an

casting was selected as the means of fabrication, in order to provide a structure with greater rigidity and superior damping characteristics.



electrodynamic shaker. To attach the edge of the horizontal plate directly to the shaker head would result in ineffective dissipation of the driving force, which is usually stronger around the outer bolt circle. A recently developed horizontal adapter ties in all of the shaker's attachment bosses and makes a rigid coupling which terminates in a single row of attachment bosses at the edge of the plate.

The adapter is made of a lightweight magnesium alloy and weighs approximately 18 kg. Sand

This adapter allows the entire driving force of the electrodynamic shaker to be transmitted with minimum loss, at all frequencies up to 3000 Hz.

Source: O. S. Holm of  
McDonnell-Douglas Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-14063)

*Circle 24 on Reader Service Card.*

### TRANSIENT VIBRATION SIMULATOR

A new method of vibration testing, in which the object is excited with short duration, high intensity, shaped random vibrations, has proven to be a more realistic test for certain applications than conventional tests using sinusoidal sweep excitation. The improved method was devised after sinusoidal sweep testing produced repeated fatigue failures in components that had performed successfully in actual use. Investigation revealed that the sinusoidal sweep test was too severe by a factor of almost 200:1, in terms of the number of high-acceleration fatigue cycles experienced during test, with respect to those encountered in actual use.

The improved method was based on the observation that the statistical behavior of vibration stimulants in the test system approximately conformed to a Gaussian distribution. Because

of this, the probability of very high acceleration levels (at the three sigma level) is only 0.27 percent. For this reason, actual (in use) system response can be accurately stimulated by short duration random vibration.

The peak acceleration level for each octave frequency band in the random vibration is determined in advance, in a manner similar to that used to derive the requirements for the sinusoidal sweep test.

Source: L. C. Kula and T. E. Fitzgerald of  
The Boeing Co.  
under contract to  
Marshall Space Flight Center  
(MFS-14800)

*Circle 25 on Reader Service Card.*

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### MASS-LOADING EFFECTS ON STRUCTURAL VIBRATIONS

A report on the effects of mass loading on shock and vibration in beams, plates, honeycombs, rings, and cylindrical shells presents experimental and analytical data that may be useful in the dynamic analysis of radial and axial structural vibration (transmission and attenuation) characteristics.

No general technique is presently known for analyzing the dynamic transmissibility characteristics of complex structures. Some information is available for predicting the resonance and modal response of an unloaded shell, but all practical methods for computing the transmissibility characteristics of complex structures require some arbitrary assumptions. As a result, most current designs, even of simple structures, rely on guessed transmissibilities or on arbitrarily assumed dampings. In either case, substantial errors, sometimes as high as several thousand percent, may result.

Analysis of mass-loaded shell structures is even more difficult, requiring the investigation of response-attenuation characteristics, mode shape changes, resonance disappearance, fre-

quency shift, and resonance coupling and amplification, as well as shock-spectrum response.

In the report, results of a combined theoretical and experimental investigation of the mass-loading effect on shell vibrations are presented. Essentially, a typical primary structure is represented by a cylindrical shell; auxiliary components appear as discrete masses. Non-contact-type vibrators and shock exciters are used to generate the forcing functions. For shock tests, a shock-synthesis device and an electromechanical shaker are coupled longitudinally to the specimen to determine both axial and radial transmissibility characteristics.

Test results indicate significant mass-loading effects upon the vibration response of a system. These effects include some resonance frequency shifts, many resonance eliminations, substantial response-amplitude attenuation, some changes in mode shape, and general amplification of response at resonance points. Shock response is little affected.

The effective forcing areas of mass loading

may be defined by the vibratory patterns, which change in accordance with resonance attenuation and disappearance characteristics. The transmissibility characteristics indicate some differences for beams, plates, honeycomb panels, rings, and shells.

Source: S. Y. Lee of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-20897)

*Circle 26 on Reader Service Card.*

### ANALOG EQUALIZATION FOR MULTIAXIS VIBRATION TESTER

A new method of real time equalization, using a special analog computer, achieves more effective vibration testing by realistically simulating the vibrational forces which an object will actually experience in use. The analog computer is programmed to simulate the equations of motion of the electromechanical system made up of the test structure and the multiple shakers. The input to the computer is an electrical signal representing the acceleration time histories which it is desired to be reproduced for the vibration test. The output of the computer drives separate power amplifier-shaker mechanisms which apply distinctive driving forces at different locations. The forces produce responses which correspond to the desired acceleration time histories.

Structural qualification, in particular of a spacecraft, requires that it be designed and constructed with sufficient strength to with-

stand large dynamic forces while in powered flight. However, because of the extremely high ratio of thrust energy to payload, a spacecraft must also be designed for minimum weight. Therefore, the more realistically the actual forces experienced by the spacecraft can be simulated during qualification testing, the more adequately its structure can be designed. When such simulations are only approximate, prudence dictates the use of large safety factors. When the simulations approach reality the safety factor can be reduced and considerable savings in weight and thrust energy requirements can be realized.

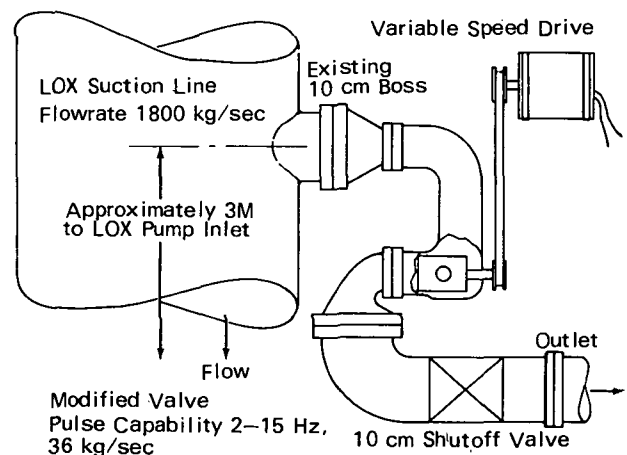
Source: M. R. P. Trubert of  
Caltech/JPL  
under contract to  
NASA Pasadena Office  
(NPO-10544)

*Circle 27 on Reader Service Card.*

### MEASUREMENT OF FREQUENCY RESPONSE TO VIBRATIONS

The frequency response characteristics of a large volume fluid system has been accurately determined by using a small, pulsating, bleed-off flowrate to perturb the system. Because of the high system flowrate, application of the conventional testing technique, involving interruption of the main flow stream, would have been very difficult and economically prohibitive.

Instead, a small valve was modified for connection to a pulsating bleedoff exciter. With the valve actuator modified so that it could be driven cyclically by a small motor, the bleedoff volume and pulsation frequency could be remotely controlled. The small bleedoff was found capable





of exciting the resonant response of the much larger system. Hence, it was found possible to measure the response of the overall system very rapidly, using existing hardware with very little modification.

Although the technique was originally developed for use with the propellant system for the Saturn V launch vehicle, potential applications exist wherever the resonant response of a large fluid system must be measured. Such situations

may be found, for example, in the fields of hydroelectric power generation, jet engines, and pipelines.

Source: R. E. Biggs of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-18445)

*Circle 28 on Reader Service Card.*

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### VIBRATION AMPLITUDE MEASUREMENT

The vibration frequency response of adhesively bonded structures may be accurately and non-destructively measured by a recently developed instrument. The instrument, which combines a modified commercially available microdisplacement meter, a fiber-optic probe, and any of several standard display or recording devices (oscilloscope, VTVM, X-Y recorder, etc.), can measure local displacements as small as  $0.12\text{ }\mu\text{m}$  ( $5\mu\text{ in.}$ ) in response to vibrational excitation in the frequency range from 10 Hz to 10 kHz, with an output sensitivity of  $0.12\text{ }\mu\text{M/mV}$  p-p.

The commercial displacement meter was designed to read static displacement. An ac amplifier-demodulator circuit was developed

to convert the instrument to read dynamic displacement. The basic circuit was modified by adding an emitter follower circuit to lower the output impedance to a value more suitable for driving other high impedance loads. Two operational amplifiers and associated circuitry were added to demodulate signals from the meter and provide a dc signal suitable for an X-Y recorder.

Source: J. F. Moore and D. S. Weinstein of  
North American Rockwell Corp.  
under contract to  
Marshall Space Flight Center  
(MFS-20396)

*Circle 29 on Reader Service Card.*

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### ANALYSIS OF BRINELLING FAILURE IN BEARINGS

Noisy operation of certain fans after exposure to high intensity random vibration has been found to be caused by brinelling of the fan bearings.

Assuming a maximum Hertz stress of  $3.17\text{ GN/m}^2$  (460,000 psi) to produce brinelling, the maximum axial load for the fan bearing was calculated as 190 N (43 lb). Dynamic analysis of the rotor-bearing spring system revealed that, with one preload spring, the maximum axial load would be 1320 N (297 lb).

Maximum vibratory bearing loads were reduced by decreasing the rotor's natural frequency and by increasing the damping through

use of a soft spring system. This required using multiple springs at both ends of the shaft. When a system of five springs at each end of the rotor was considered, the bearing load predicted was 258 N (58 lb). Actual vibration tests using this configuration showed a reduction in bearing damage. Use of belleville springs with this particular rotor-bearing configuration was found undesirable, because the collapse load of such springs would be exceeded during operation.

A bearing load-capacity computer program has been written so that, given the bearing

parameters—inner race diameter, ball diameter, diametral clearance, total curvature of the race groove and number of balls—the limiting axial load can be determined, using maximum Hertz stress and overriding of the race land as the failure criteria.

Source: W. A. Glaeser, S. K. Batra, and R. H. Prause, of Battelle Memorial Institute under contract to Marshall Space Flight Center (MFS-20968)

*Circle 30 on Reader Service Card.*

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### VIBRATION TESTING OF VIDICONS

A method for checking the performance of vidicons during mechanical vibration tests uses an external signal to modulate the vidicon electron beam during the "write" period, thereby storing the image on the vidicon face. No optical test pattern or lens system is employed.

Previously, performance was tested by storing a fine-detail test pattern on the photosensitive surface of the vidicon, using a light source and lens system. The vidicon with the stored image was then placed on a vibration table and the reading beam turned on while the tube was being vibrated. This method, however, required the tube to be moved for each test, and gave only limited resolution, due to the distance between the overlay used to produce the image and the photosensitive surface.

In the new method, the photosensitive surface of the vidicon is first primed by exposing it to light. The test pattern is then stored on the primed surface by picking the pattern up on an auxiliary camera tube and transferring it, after

amplification, into the tube under test as video modulation of the control grid during scanning. A second method involves producing black and white bar patterns, which are generated by using variable frequency scan generators with no video modulation.

The photosurface is then scanned in the normal manner and the video information is displayed on a cathode ray tube or data storage tube. Depending on the test requirements, the desired mechanical vibration may be applied during the storage period or the readout period, or during the entire sequence. Comparison of results obtained during a still condition and during various modes of vibration then yields the performance capabilities of the vidicon.

Source: B. R. Corson of Hughes Aircraft Company under contract to Jet Propulsion Laboratory (JPL-SC-113)

*No further documentation is available.*

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