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TECHNOLOGY UTILIZATION

AUTOMATIC CONTROLS AND REGULATORS

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REGULATORS: A COMPILATION Technology
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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 publication is part of a series intended to provide such technical information. The devices, methods, and techniques presented derive from the discrete requirements for control and regulation of the mechanical/physical functions involved in implementing the space program. The compilation is presented in two sections, with section one treating of automatic controls, which are considered to be, essentially, start-stop operations or those holding an activity in a desired constraint. Section two deals with devices that may be used to regulate activities within desired ranges or subject them to predetermined changes.

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

Patent Statements reflect the latest information available at the final preparation of this Compilation. For those innovations on which NASA and AEC have decided not to apply for a patent, a Patent Statement is not included. Potential users of items described herein should consult the cognizant organization for updated patent information at that time.

Patent information is included with several articles. For the reader's convenience, this information is repeated, along with more recently received information on other items, on the page following the last article in the text.

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

Jeffrey T. Hamilton, *Director*
Technology Utilization Office
National Aeronautics and Space Administration

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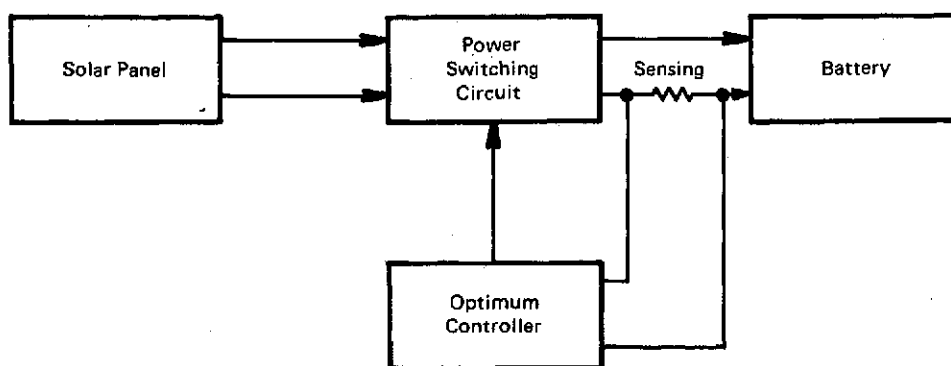
For sale by the National Technical Information Service, Springfield, Virginia 22151.

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Section 1. Automatic Controls

NONDISSIPATIVE OPTIMUM CHARGE REGULATOR



System Block Diagram

In systems that depend on storage batteries for their operating energy, constant level charge/discharge control of the batteries is essential. Where the power supply (such as the solar cell array in a spin-stabilized satellite) offers a widely varying input to the batteries, an optimum charge regulator has been designed that provides the desired control.

The basic power transfer and control is performed by the system shown in the block diagram. The solar panel is coupled to the battery by the power switching circuit. Power transferred by the switching circuit is a function of its switching duty cycle, which is controlled by the optimum controller as it senses the battery current and modifies the duty cycle of the switching circuit, in a manner which maximizes the current available to the battery at all times. The basic power transfer mechanism is that of energy storage in an inductor (a component of the optimum controller circuitry) during the first portion of a switching cycle, followed by release of this energy to the battery during the following portion of the switching cycle. In the power switching circuit a transistor is

driven by a fixed-frequency, variable-duty-cycle square wave. As the duty cycle changes, the amount of energy stored in and subsequently released from the inductor changes.

This innovation could be useful in remote site battery-powered applications where power inputs may vary.

The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price \$6.00
(or microfiche \$0.95)

Reference:

NASA-CR-79093 (N67-12215), Nondissipative Solar Array Optimum Charge Regulator

Source: Robert Rosen and
Jerome N. Vitebsky of
Hughes Aircraft Co.
under contract to
Goddard Space Flight Center
(XGS-10439)

FILM TENSION CONTROL

This is an improved device that accurately controls the transport within a camera of very thin photographic film. The camera operated unattended and was actuated remotely. This placed a high premium on positive film transport without jamming, without jamming.

The standard camera, using 122 meter (400 ft) rolls of 0.011 cm (0.0044 in)-thick film was modified to operate in an intermittent fashion with a 671 meter (2200 ft) roll of 0.006 cm (0.0025 in)-thick film by adding a film tension control comprised of a spring and microswitch.

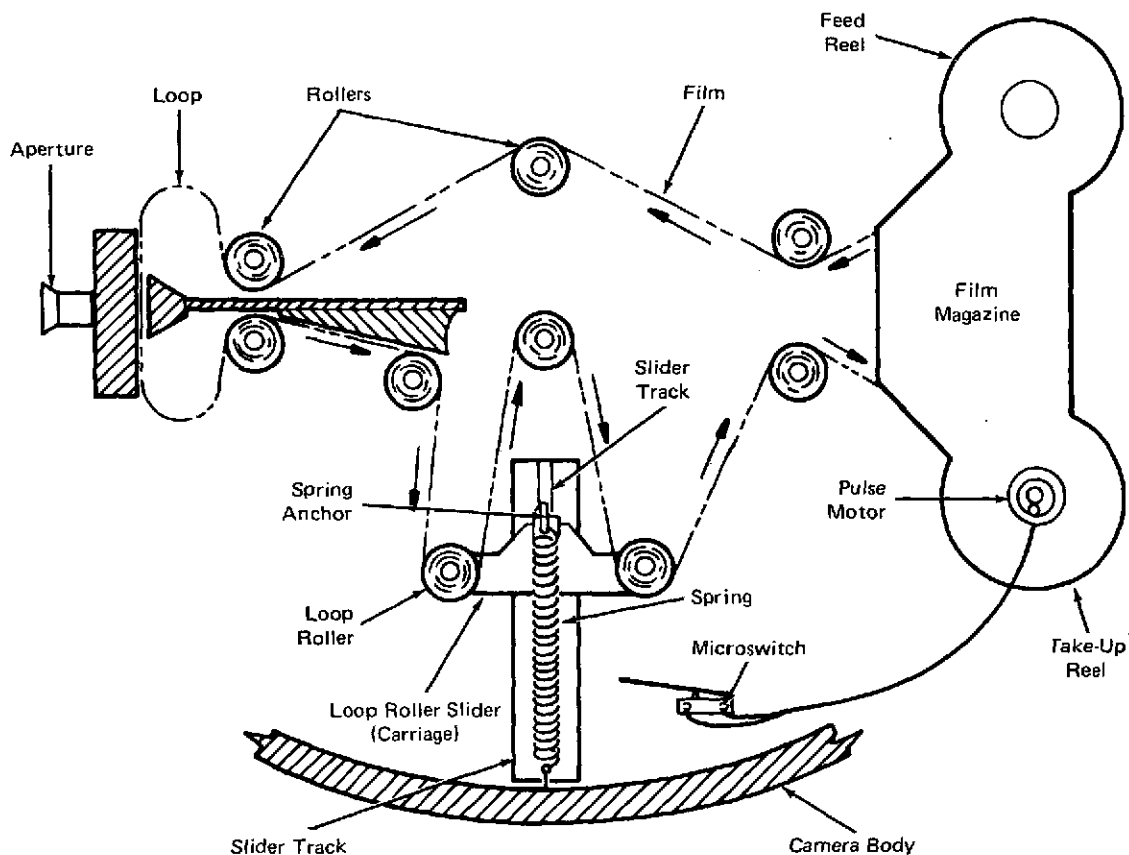
One end of the spring is anchored to the body of the camera, and the other end is secured to a spring anchor and to a loop roller slider. The loop roller slider is fitted to a track and secured by a slider

keeper. A microswitch is mounted at the lower end of the slider travel.

Abrupt changes in film tension are automatically compensated by spring action while accumulated changes are controlled by the microswitch, which turns on a pulse motor that rotates the take-up reel to rewind the excess film and maintain proper tension.

Source: N. R. Anderson of
The University of California
under contract to
Johnson Space Center
(MSC-12431)

Circle 1 on Reader Service Card.



DIRECTIONALLY-COMPENSATED SHOCK ATTENUATOR

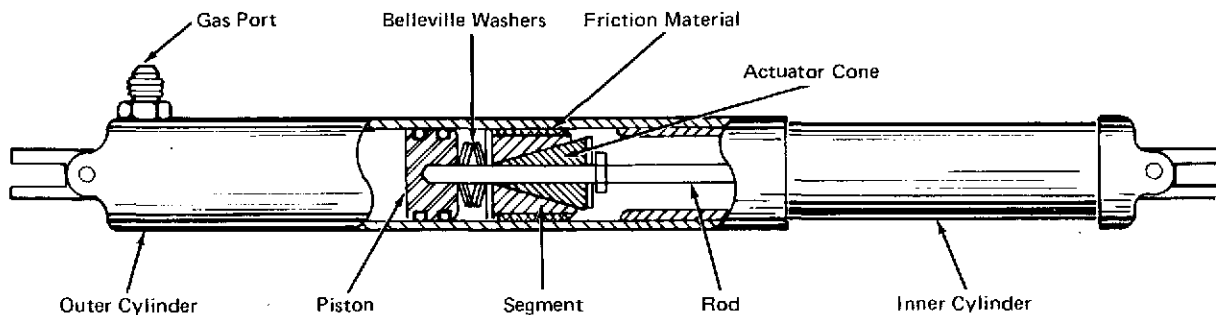
Quite different from the usual fluid-filled shock attenuator, this device uses a number of Belleville washers attached to the piston, which, when forced to move suddenly, impresses the edges of the washers against the inner wall of the stationary cylinder containing them.

As can be seen in the illustration, selection of the number, thickness, and tensile strength of the Belle-

ville washers permits the design of shock attenuators over a wide range of loading and response.

Source: W. D. Sherborne
Johnson Space Center
(MSC-12114)

No further documentation is available.

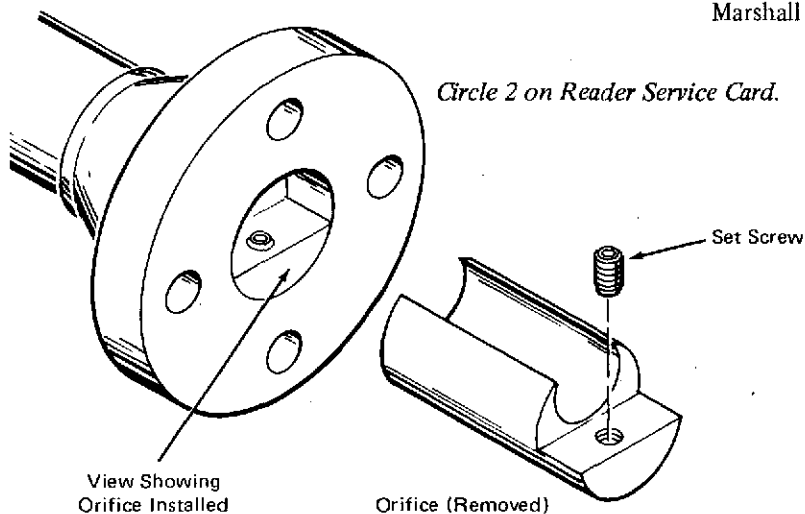


IN-LINE CRYOGENIC ORIFICE

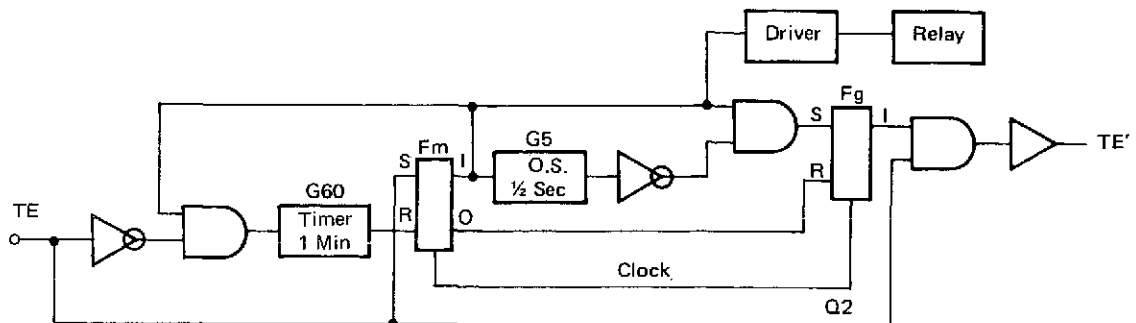
This item is designed to modify an existing bleed line in a permanent cryogenic test system in order to constantly control bleed off at a reduced rate. The orifice is machined in an eccentric configuration for insertion into an existing flange of the cryogenic fluid piping system. A locking screw forces the

orifice against the inside diameter of the pipe flange so that no movement is possible and a smooth, controlled bleed rate is assured.

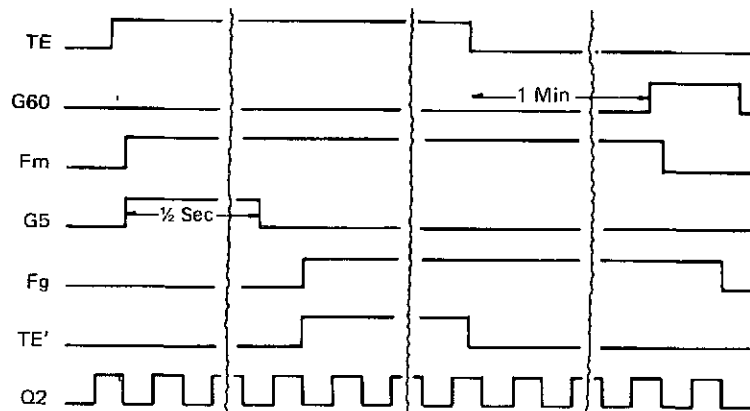
Source: T. J. Gilmore of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-91121)



AUTOMATIC CONTROL OF TYPEWRITER POWER ON SDS-920 COMPUTER



$$\begin{aligned}
 S F_m &= TE \cdot Q2 \\
 R F_m &= G60 \cdot Q2 \\
 S F_g &= G5 \cdot F_m \cdot Q2 \\
 R F_g &= F_m \cdot Q2 \\
 S G5 &= F_m \\
 R G5 &= .5 \text{ Sec} \\
 S G60 &= TE \cdot F_m \cdot 1 \text{ Min} \\
 R G60 &= G60
 \end{aligned}$$



This arrangement reduces typewriter running time from a full 24 hours to approximately 6 hours in each 24 hour period. The resultant increase in reliability and decrease in maintenance requirements are obvious.

Originally, the term TE (typewriter enable) went directly through a buffer amplifier and became TE'. In this new arrangement, a term Fg (gate flip-flop) is "anded" with TE to delay TE' for 1/2 second while applying power to the typewriter and allowing the motor to come up to operational speed. TE immediately sets Fm (motor flip-flop) which excites the motor relay via a relay driver. Fm triggers G5 (1/2 second one-shot) which delays the setting of Fg by

1/2 second. Additional TE commands will be forwarded without any delay while Fg is set. When TE drops out, G60 (1-minute timer) starts up; each time TE goes positive, the time is reset. If TE remains out for 1 minute, G60 fires, resetting Fm and Fg, removing power from the typewriter.

Source: C. R. Caplinger of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-16329)

No further documentation is available.

A DIGITAL CONTROLLER FOR A BAUM FOLDING MACHINE

Use of this controller resulted in substantial cost and time savings in the preparation of printed documents. Previously, a manually controlled Baum folding machine had been used, requiring hand counting of the individual sheets to ensure that the correct number was available for job orders.

Since the feed head on the folding machine is vacuum operated, it was decided to build a controller, incorporating decade counters, to interrupt the vacuum whenever required to fold a predetermined number of sheets and then shut down. The Number of Copies Selectors shown in the figure are 30 push button switches that permit the operator to command the folder to handle groups of two to 999 copies in a given run. Single copies must be folded by operation of a manual control because of the placement of the control unit sensor. The Number of Copies Indicators are seven-segment lights that show the numbers entered into the control unit by the operator pushing the Selector switches. Once a Selector switch has been depressed, no other switch in that decade can be operated without the Reset switch being operated.

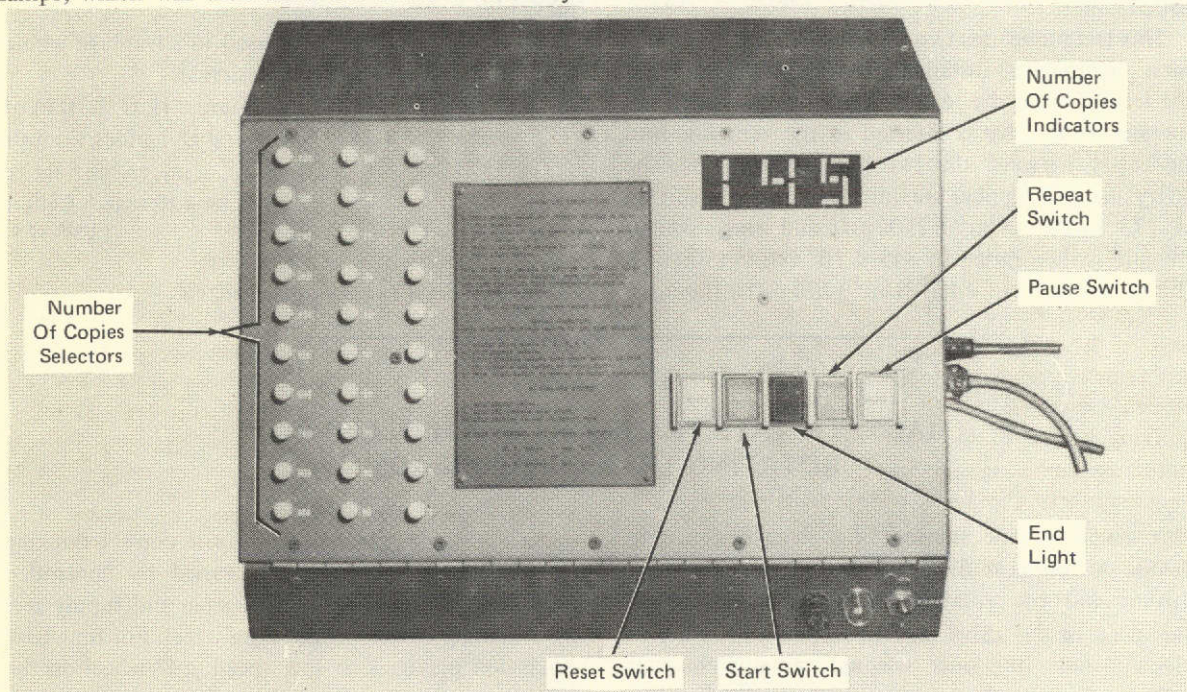
The Reset switch causes all segments in each indicator to light, thus affording a quick check of the lamps, which will then show the number 888. Any

other number indicates a defective bulb or drive transistor that should be replaced. The Reset switch also returns the control unit to its original condition.

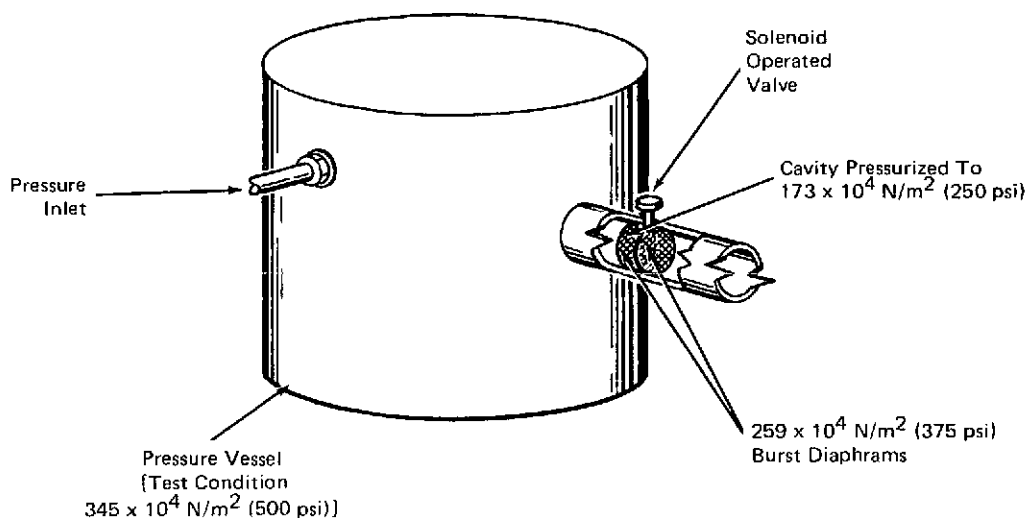
With the Power switch in the On position (indicated by the neon lamp beside it) the Start switch is depressed to actuate the folding machine. An End Light signals when the number of copies set into the controller has been reached. The controller automatically goes into the Stop condition, lighting either the Reset (if the repeat condition is off), or Pause (if the repeat condition is on) switch button. The Repeat switch makes it possible to fold several groups of the same number without re-entering a command to the controller. The Pause switch can be used to stop the folding machine at any time without altering the count set into the controller. Should such a stop be made to clear a paper jam, the number of copies actually folded will not agree with the number set into the counter, because the sensor detects the sheets before they are folded.

Source: W. H. Bryant
Langley Research Center
(LAR-10688)

Circle 3 on Reader Service Card.



HIGH SPEED BLOWDOWN SYSTEM



Rapid blowdown of a test chamber is achieved by a somewhat novel use of commercially available burst diaphragms. The system takes advantage of discretely maintained differential pressures between a burst diaphragm exposed to the test chamber and another exposed to the ambient. Sudden upset of this pressure differential achieves rapid blowdown of the test chamber.

This technique uses two $259 \times 10^4 \text{ N/m}^2$ (375 psi) burst diaphragms, installed in series in a large vent line leading from the test chamber. A small solenoid-operated vent valve is inserted in the vent line into the cavity between the two burst diaphragms. The cavity and test chamber are simultaneously pressurized to $173 \times 10^4 \text{ N/m}^2$ (250 psi) and the chamber pressure is then raised to $345 \times 10^4 \text{ N/m}^2$ (500 psi). This results in a $173 \times 10^4 \text{ N/m}^2$ (250 psi) differential

across each diaphragm, resulting in a $86 \times 10^4 \text{ N/m}^2$ (125 psi) safety margin. When the solenoid is actuated, pressure in the cavity between the diaphragms falls to ambient, and the diaphragms are sequentially exposed to the $345 \times 10^4 \text{ N/m}^2$ (500 psi) test chamber pressure. This instantly ruptures the diaphragms, and rapid blowdown of the test chamber takes place.

This technique could be used to advantage where the use of pyrotechnics is undesirable.

Source: H. C. Brittan of
General Dynamics/Convair
under contract to
Lewis Research Center
(LEW-375)

No further documentation is available.

MAGNETIC TAPE TRANSPORT CONTROLLED BY ROTATING TRANSDUCER HEADS

A magnetic tape transport has been designed to include a common drive for both the tape drive capstan and the rotating record/reproduce heads. The speed of the drive may be varied within a pre-selected range, but, once selected, remains constant so that the head and capstan are driven in synchronization and at constant speed for the duration of the

operating mode selected. To ensure correct tracking by the heads, tape speed is varied by controlled tension on the tape between capstan and supply reel by a braking device on the supply reel. For time-base expansion playback at low speed, a flywheel on the motor, capstan, and head drive shaft provides more constant speed. Switching of the heads is accom-

plished by circuitry mounted on the head drum, and the low-speed reproduce signal is amplified by additional circuitry mounted on the head drum in order to improve the signal-to-noise ratio at the lower speed.

The tape is guided from the supply reel by conventional means into a transversely curved concentric relation to a head drum so the heads successively sweep the width of the tape as the head drum rotates. Synchronization between head drum and tape capstan is achieved through a worm drive formed by threads on one shaft from the drive motor engaging a gear on the capstan and by a second shaft from the opposite end of the drive motor, on which the head drum is mounted. To assure that the heads correctly track on the tape during the playback mode, regardless of dimensional changes that may have occurred subsequent to recording, a tachometer operates in conjunction with a light source, photocell, and electronic circuitry to impress a control track on the tape by means of a transducer on the head drum

during the record mode. A second transducer "reads" this control track during playback and varies the torque of a braking motor coupled to the supply reel to vary tension on the tape. This physically stretches or relaxes the tape to alter the mass rate of flow of the tape past the capstan even though the capstan speed remains constant.

This system eliminates the need for the usual capstan motor and associated servo control circuitry. The recorder also combines 1500 ips record/reproduce and 30 ips reproduce in a single head.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to the Ampex Corporation, 934 Charter Street, Redwood City, California.

Source: J. D. Sperry, J. Chupity, and G. Salcedo of
The Ampex Corp.
under contract to
Goddard Space Flight Center
(GSC-483)

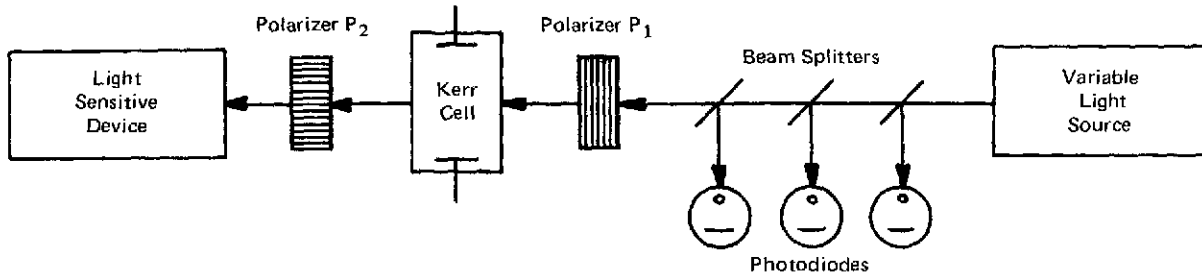
RAPID-RESPONSE, LIGHT EXPOSURE CONTROL SYSTEM

It is often desirable to study luminous phenomena or light sources whose brightness varies over a wide range during the period of interest. Examples of such phenomena include metal combustion, exploding wires, pulsed gas discharges, laser operation, and nuclear explosions. In many of these phenomena, brightness changes, which occur within milliseconds or even microseconds, often exceed the exposure latitude of presently known photographic materials or the linear ranges of light-sensitive detectors, resulting in either underexposure or overexposure.

One technique that has been used to overcome such a problem requires the use of photographic film which incorporates several emulsions of different sensitivities. The cost of such film and its processing is quite high, a disadvantage which is of particular significance when large amounts of film are required, as in highspeed cinephotography. The type of photoelectrically actuated electromechanical aperture or shutter-speed control, which is used in many commercially available automatic cameras to control film exposure, cannot be used, since such exposure-control

devices have a relatively slow response (of the order of seconds), while in many situations exposure control with response time of milliseconds or microseconds is required.

A rapid-response (on the order of a few microseconds) electro-optical, light-exposure control system, which has been devised, will maintain the light reaching a camera film or other light-sensitive detector at an essentially constant level, despite wide variations in the brightness of the light source. This system permits detailed photographic or photoelectric recording of the phenomenon under study over a range of many orders of magnitude in brightness. The system includes a pair of crossed light polarizers, P_1 and P_2 , (see figure) with a Kerr cell between them. These three components are positioned in the path of light, from the variable light source to be studied, to the light-sensitive device (camera or photoelectric detector). Light from the source is transmitted to polarizer P_1 through beam splitters which reflect some of the light to high-voltage vacuum photodiodes. The function of the beam splitters is to direct light to the



photodiodes in such a way that the brightness of the light reaching them is proportional to the brightness of the light reaching polarizer P_1 . Circuitry that is used to control the voltage across the Kerr cell as a function of the brightness of the light from the source is not shown in the schematic. In this circuitry, the Kerr cell is connected in series with a variable resistor, R_L , across a voltage source (a dc, high-voltage power supply). A series chain consisting of the photodiodes and two resistors, R_D and R_M , is connected across the Kerr cell. A high-resistance chain of three equalizing resistors is connected across the photodiodes to compensate for differences in dark current among these diodes. R_L , a series of switch-selected resistors, controls the system's sensitivity. The function of R_D is to control the minimum voltage that is applied across the Kerr cell. The voltage across R_M (a low resistance compared to R_D) is used to monitor changes in current through R_M , which are related to the changes in brightness of the light source. When the brightness of the light varies between minimum and maximum levels, the effective resistance of each photodiode varies between infinity and zero. Thus the voltage across the Kerr cell varies between a

maximum and a minimum, and the plane of polarization of light from P_1 varies accordingly between 90° and a minimum angular value. Therefore, when the brightness of the light from the light source is below a preassigned level, all of the light which passes through P_1 is transmitted through P_2 to the light-sensitive device. As the brightness increases, the voltage applied to the Kerr cell decreases automatically, so that only a portion of the light which passes through P_1 is transmitted to the light-sensitive device. The net result is that the intensity of the light received by the light-sensitive device is essentially at a constant level.

Additional documentation is available from:

National Technical Information Service
Springfield, Virginia 22151

Price \$3.00

Reference: TSP68-10502

Source: M. L. Zwillenberg and D. K. Kuehl of
United Aircraft Corp.
under contract to
NASA Pasadena Office
(NPO-10238)

HIGH-CONDUCTANCE VAPOR THERMAL SWITCH

A high-conductance vapor thermal switch has been produced to maintain heat-dissipating component temperatures within acceptable limits. The switch is a self-actuating, automatic device that regulates the rate of heat flow to control, within a relatively narrow range, the temperature of elements whose heat dissipation or ambient heat sink temperatures vary over a wide range.

The device is a sealed pressure vessel (Figure 1) of particular geometry containing a vapor with an appropriate saturation temperature-pressure relationship, a reservoir of its condensed liquid, and a pre-

determined quantity of noncondensable gas. For purposes of this discussion, water and air are the two enclosed substances.

With the gravity field in the direction indicated, there is a small pool of water wetting the entire bottom of the vessel termed "heat sink." Mounted to the exterior of this metal heat sink are the heat-dissipating components, with high thermal conductance between components and water. The vessel is constructed of thin, relatively low thermal-conductivity material such as stainless steel, so that there is no appreciable heat transfer by conduction from the

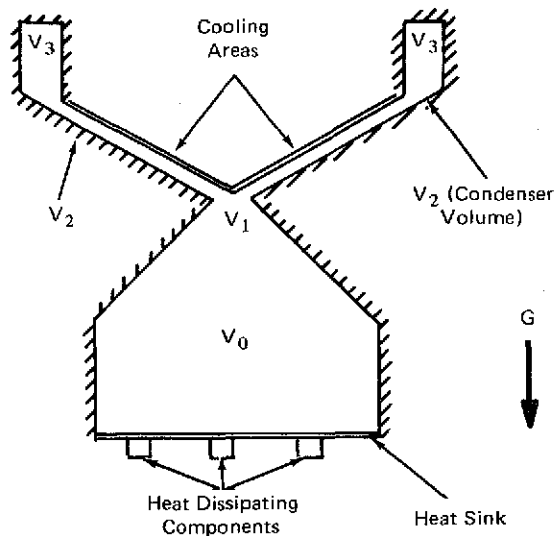


Figure 1. Sealed Pressure Vessel

heat sink bottom to other areas of the vessel. Pressure within the vessel is well below atmospheric, so that at room temperature (T_R) water vapor would occupy a volume V_0 within the vessel and air a volume of $(V_1+V_2+V_3)$ if there were an actual separation of water vapor and air. Associated with the volume V_2 is the cooling area (or condenser) of the system, the only vessel surface directly connected to the heat sink ambient. All other surfaces are thermally insulated from the ambient.

Operation of the device is as follows. With no heat dissipation, the temperature throughout will be ambient; as heat is dissipated, the temperature of the heat sink and water pool will rise as indicated in the right figure with internal pressure rising correspondingly. When the temperature and pressure rise to the design condition of T_1 and P_1 (same as T_R in Figure 2), the volume of entrapped air, distinctly separated from the water vapor, will be compressed to a volume (V_2+V_3) , with water vapor occupying the volume (V_0+V_1) . Any higher temperature (and thus higher pressure) will compress the air further and water vapor

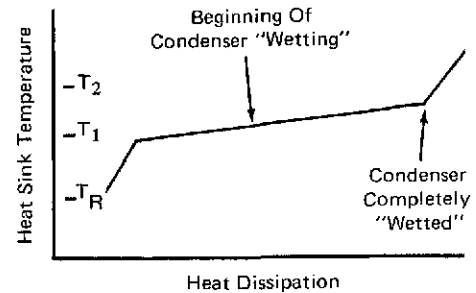


Figure 2. Temperature Plot for Thermal Switch

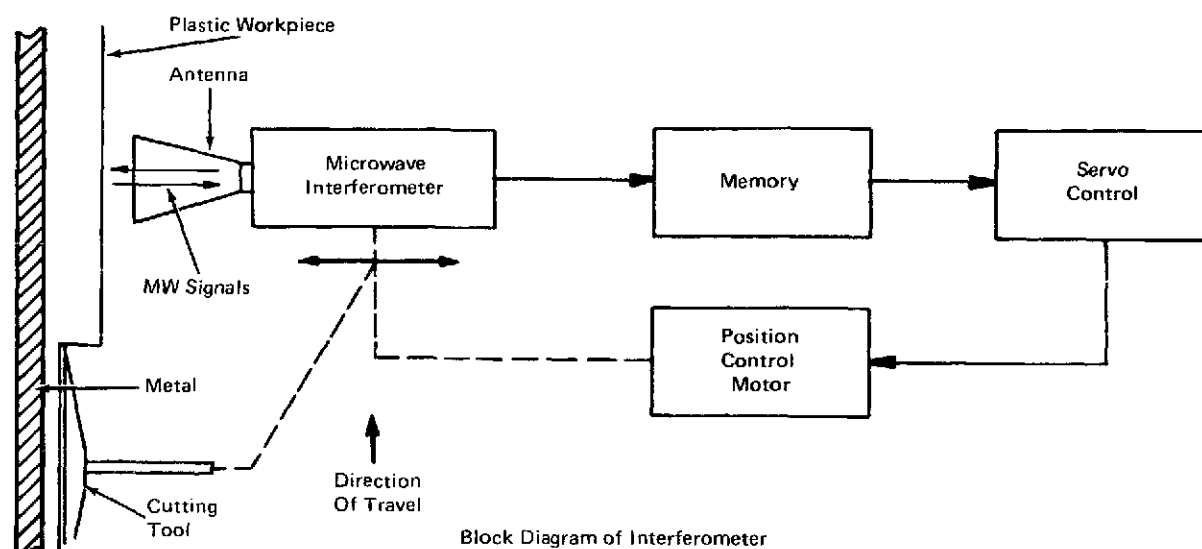
will be in contact with the cooling area associated with volume V_2 . Assuming the effective ambient temperature is lower than T_1 , heat will be transferred from the water vapor to the cooling area, with the water condensing and returning by gravity to the pool above the heat sink. Thus, heat is absorbed by the water pool as heat of vaporization, then is carried by the vapor to the cooling area (condenser) where the heat is released in condensing. As this vapor mass flow and heat transfer occurs, there will be a slight temperature and pressure gradient from the pool to the condenser area, with a resultant distinct separation of water vapor and entrapped air.

The thermal conductance of the water vapor path in the device is extremely high; the only significant thermal resistance is the path from components to water pool and from condensed water to the cooling ambient.

Source: N. L. Hyman
Goddard Space Flight Center
(GSC-10109)

No further documentation is available.

MICROWAVE INTERFEROMETER CONTROLS DEPTH OF CUT IN PLASTICS



A microwave interferometer system has been developed to control the cutting of plastic materials to a prescribed depth. Previous methods required the use of a probe to penetrate the plastic or remove test cores to determine the thickness of the cut material. These methods were time consuming, wasteful, and imprecise.

The microwave interferometer is mounted on a carriage with a spindle and cutting tool. A cross slide is mounted on the carriage to allow the interferometer and cutter to move toward or away from the plastic workpiece. The cross slide is driven by a motor which is controlled by a servo positioner. A change in distance of the part from the interferometer is compensated by the closed-loop system. A constant preset distance is thus maintained between the end of the cutting tool and the metal backing on the plastic material being machined.

The interferometer may be displaced from the centerline of the cutting tool by a preset leading distance. In this case, a tape memory unit would be connected between the microwave output and the servo control unit. For larger-diameter cutting tools a hollow cutter and hollow spindle may be used. The interferometer would be mounted in the hollow spindle and thus eliminate the need for the memory tape unit.

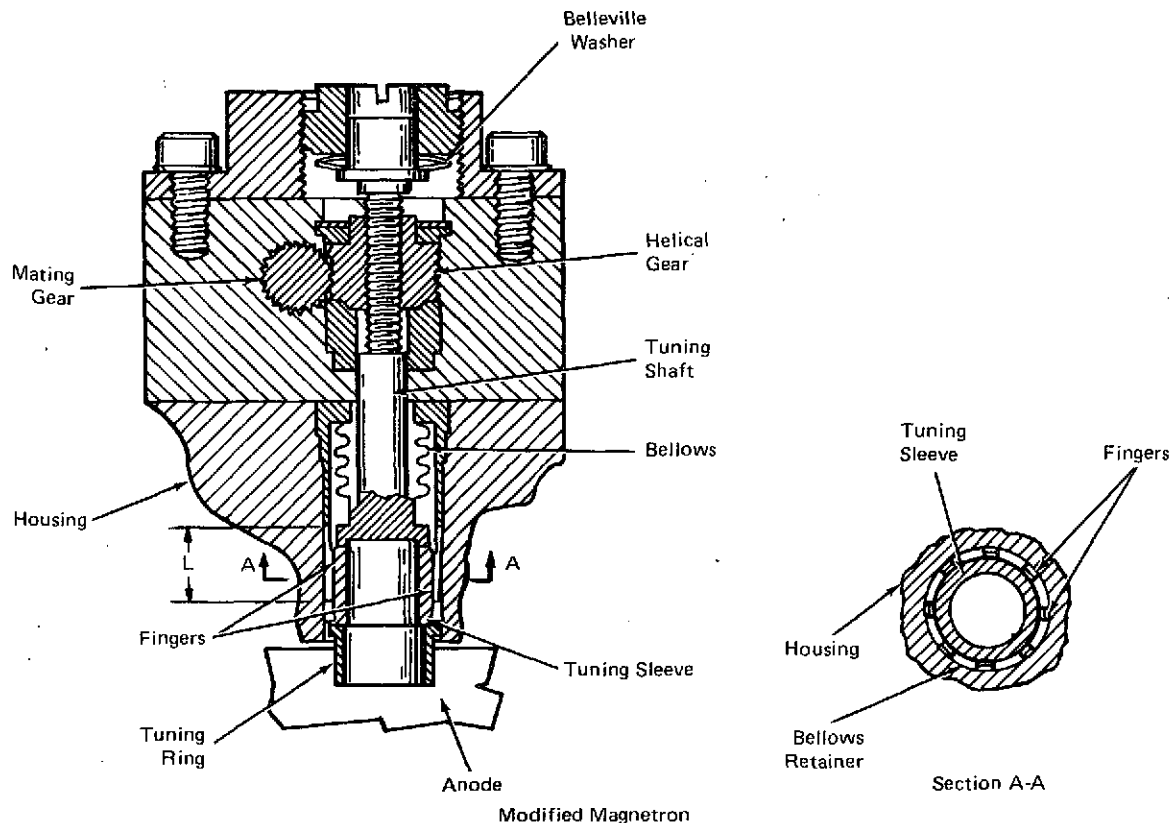
Source: W. F. Iceland and R. M. Heisman of Rockwell International Corp. under contract to Marshall Space Flight Center (MFS-14673)

Circle 4 on Reader Service Card.

MAGNETRON TUNER HAS LOCKING FEATURE

Use of a tuning element to control frequency in an electron discharge device, such as a magnetron, is well known. Tuning is usually achieved by selectively controlling the positions of metallic or dielectric elements within cavities formed by electrodes. If the frequency is not critical or the magnetron is easily

accessible for frequent tuning, a relatively simple arrangement may be used. If, however, a very precise frequency is required and the magnetron is not readily accessible for frequent maintenance, it is necessary to finely tune the elements and insure that they remain so positioned regardless of environmental



conditions of vibration, shock, or the range of temperature encountered in a given application. For example, in one application, a dielectric tuning ring has been used to adjust the magnetron frequency at a rate of 18 MHz per 0.0254 mm (0.001-inch) of ring travel. In this application, it is necessary to move the tuning ring at a very slow travel rate and, when once set at the desired frequency, to maintain the setting in the presence of the anticipated adverse environmental conditions, to hold the magnetron output frequency to within 1 MHz.

Existing tuning arrangements have proven inadequate to meet these requirements. Therefore, a new arrangement has been devised that will satisfy all requirements with a minimum of maintenance.

This new arrangement features a means of moving a tuning ring axially within an anode cavity by a system of reduction gears engaging a threaded tuning shaft or lead screw. The shaft is moved up or down at an extremely slow rate to position the tuning ring within the anode cavity so that the desired magnetron

output frequency is achieved. A Belleville washer in the upper assembly exerts a constant biasing pressure on the tuning shaft to prevent backlash during the tuning operation. A bellows within a bellows housing encloses the tuning shaft to permit axial motion of the tuning sleeve without disturbing the pressure balance within the device. The bellows retainer terminates in hardened fingers that produce interfering tolerances on a minimum circumferential surface between the inner surface of the bellows retainer and the outer surface of the tuning sleeve.

Additional documentation is available from:

National Technical Information Service
Springfield, Virginia 22151

Price \$3.00

Reference: TSP69-10119

Source: V. J. Martucci of
Metcom, Inc.
under contract to
NASA Pasadena Office
(XNP-09771)

PIEZOELECTRIC LINEAR ACTUATOR

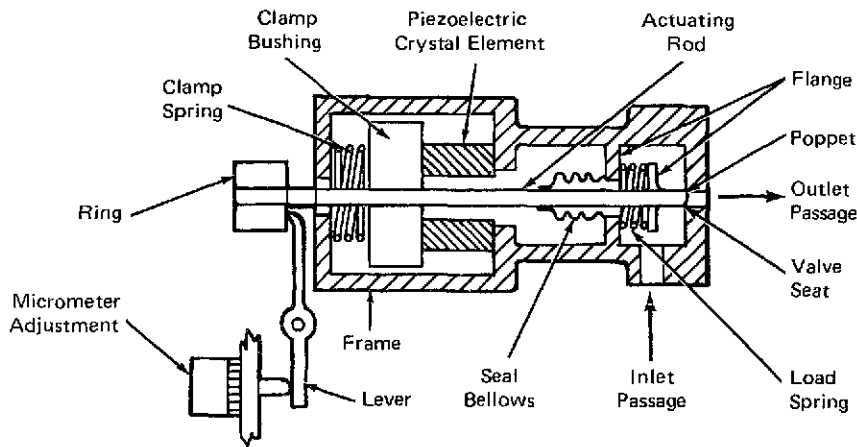


Figure 1. Cross Section of Linear Actuator Having a Single Hollow, Cylindrical Piezoelectric-Crystal Element

This device can exert linear force that is readily controllable and reproducible to microinch tolerance.

A control voltage is applied across a piezoelectric crystal element (either a single crystal or a stack of such crystals) to change the dimension of the element in the direction of the applied voltage. One end of the element is held fixed; the other end is connected to an actuating member such as a rod. The rod may be adjusted relative to the element and then locked in such position, or the whole element and actuating rod may be adjusted.

For control of a poppet valve the actuating member may be a rod extending in the direction of movement and terminating in a poppet that initially engages a seat to close the valve. The end of the crystal, facing the valve, is stationary, and expansion of the crystal, under applied voltage, opens the valve minutely and to a controllable degree.

The new actuator is constructed for extremely accurate control of a valve with adjustment over a very small range of openings; with it one could study, with assurance and repeatability, valve leakage

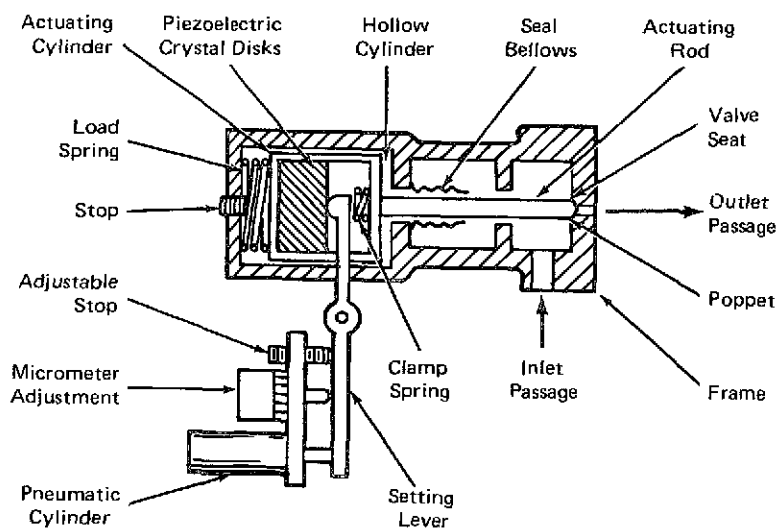


Figure 2. Cross Section of Linear Actuator Having a Stack of Piezoelectric-Crystal Disks in a Hollow, Cylindrical Housing

at very low rates of flow. The actuating rod can be used to effect the same minuscule, controlled, linear movements for other purposes also; its use should not be considered to be restricted to valve control. Figures 1 and 2 show two forms of the actuator in conjunction with a valve.

The actuator may interest those concerned with control systems or with instrumentation; it may find use (1) as a precise control for a gas-regulating valve, including remote positioning of the needle of a high pressure regulator; (2) as a variable venturi meter; (3) in fluidics for fine control of jets in proportional-type amplifiers; (4) as a micropositioner, as for remote

control of the position of radioactive or otherwise hazardous material; (5) as a microthruster for precise metering of gases, monopropellants, bipropellants, or hybrids; and (6) in reaction-control systems.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to the Astrosystems Incorporated, One Goddard Drive, Rockaway, New Jersey 07866.

Source: S. Lehrer of
Astrosystems International Inc.
under contract to
Johnson Space Center
(MSC-13194)

BIMORPH PIEZOELECTRIC DEVICE FUNCTIONS AS FLAPPER VALVE

A flapper valve, using a bimorph piezoelectric ceramic bender, has been designed to convert an electrical input into a pneumatic output signal capable of operating fluidic logic elements in a decoder and display system. An experimental unit produced sufficiently great pressure changes in the cavity feeding the control port of a fluidic element to switch the fluidic element when a 25 V ac signal was applied to the piezoelectric bimorph bender. The highest frequency at which the unit was tested was 1200 Hz.

As shown in the drawing (Figs. 1 and 2), the flapper valve incorporates a piezoelectric bender consisting of a commercially available lead-zirconate lead-titanate piezoelectric ceramic. The bender consists of two transverse-expanding plates of the piezo-

electric ceramic cemented together in such a manner that one plate contracts and the other expands when a voltage is applied to electrical contacts on the bender. When supported as a cantilever beam, the bender will bend or deflect in response to the applied voltage.

In its application in the experimental flapper valve of Figure 1, the free end of the bender is positioned above a fluid outlet nozzle in a cavity. Another outlet orifice is connected to the control port of a fluidic element. The fluid supply is connected to a third orifice in the cavity. Deflection of the bender changes the opening of the nozzle and the fluid impedance "seen" by the nozzle output flow. This impedance change will correspondingly change the pressure inside the cavity, and hence the output flow to the control port of the fluidic logic element.

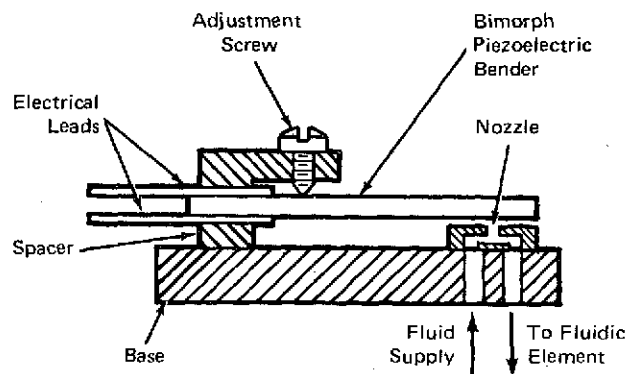


Figure 1. Flapper Valve: Basic Diagram

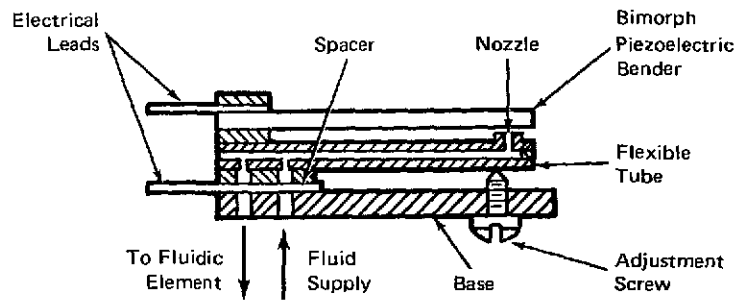


Figure 2. Flapper Valve: With Adjustment Screw

In the first experimental design (Fig. 1), the bimorph bender was clamped onto a base and positioned at approximately the required distance from the nozzle with a spacer. Final setting of the bender distance was done with an adjustment screw. The effective length of the bender and hence the deflection obtainable with this design is limited by the position of the adjustment screw. An improved design is shown in Figure 2. In this design, the nozzle is a part of a flexible tube of metal. The adjustment screw therefore regulates the position of the nozzle with respect to the bender, and thus allows the maximum effective length of the latter to be used.

The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price \$6.00
(or microfiche \$0.95)

Reference:

NASA-CR-86105 (N68-36418), Fluidic Decoder and Display Device

Source: J. Van der Heyden of
Martin Marietta Corp.
under contract to
Electronics Research Center
(ERC-10082)

REMOTELY ACTUATED RELEASE MECHANISM

Certain applications require that a device be automatically actuated from a remote location following a predetermined time increment. Many devices have been employed previously for this purpose (squibs, explosive bolts, acid acting on discrete barriers, etc.). However, when used in conjunction with delicate instruments or with optical surfaces, these devices could contribute undesirable shock or contamination, or both.

A mechanism has been developed that provides the desired actuation capability while eliminating the undesirable characteristics. In this system a restrained energy force (springs, stored pneumatic pressure, etc.) is automatically released by an electrical charge which may be applied by a manual switch or, in a remote application, by an rf impulse received by simple conventional electronic circuitry.

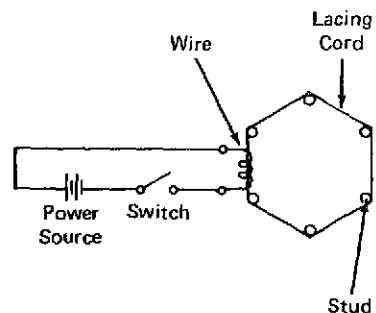


Figure 1. Release Schematic

The system is shown schematically in Figure 1. Plastic lacing cord passes around a series of studs in such a way that a set of springs, as shown in Figure 2, is restrained in the compressed (loaded) condition. A coiled loop of fine stainless steel wire is wrapped around one section of the lacing cord and terminates an electrical circuit that is interrupted by a normally open switch. When the switch is closed, approximately 0.5 amp is applied to the wire loop, raising the temperature of the adjacent lacing cord section to the melting point and thus releasing the restraint on the springs.

Figure 2 shows an application in which the sensor, within an instrument package, is protected by dust covers, held in place by springs under tension and restrained by the method of Figure 1. When the sensor is to be put into use, power is applied to the actuating circuit, releasing the springs which cause the dust covers to deploy away from the instrument package sensor apertures.

Source: J. W. Rotta, Jr. of
Caltech/JPL
under contract to
NASA Pasadena Office
(NPO-10698)

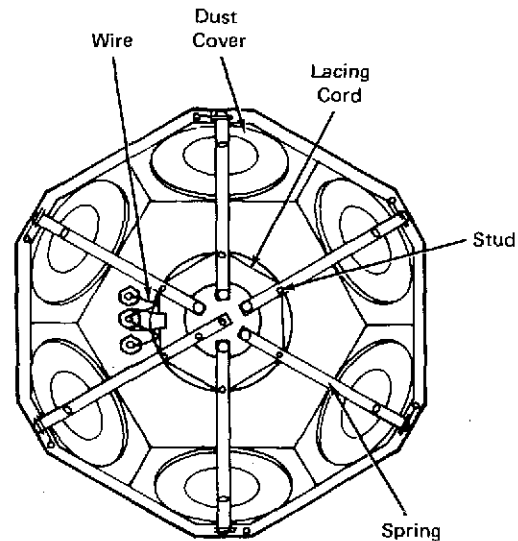


Figure 2. System Assembly

Circle 5 on Reader Service Card.

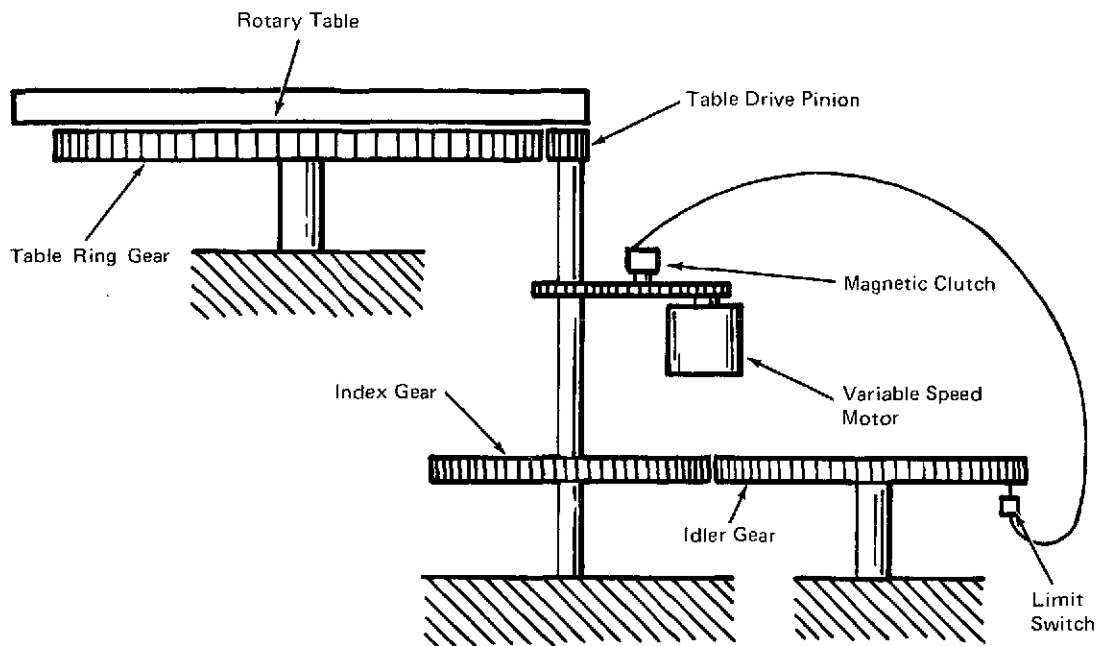
GEAR DRIVE AUTOMATICALLY INDEXES ROTARY TABLE

This combination indexer and drive unit permits its operator to quickly and accurately drill equally spaced circular hole patterns on rotary tables. The previous use of manual layout and indexing was time consuming and placed a high premium on operator skill. The unit automatically rotates the table one hole-spacing for each rotation of a special idler gear.

The unit is installed to provide power to a conventional rotary table through the original drive pinion and ring gear. An index gear fabricated with a number of teeth equal to the number of holes in the circular pattern to be drilled is installed on the original table drive shaft on the end opposite the drive pinion. An idler gear having a number of teeth numerically equal to the gear ratio between the

original pinion and table ring gear is then meshed with the index gear. A variable speed dc motor with magnetic clutch is connected to the drive shaft, and an assortment of stop and limit switches is installed in connection with the idler gear.

When the unit is actuated, the motor drives the index gear, the table, and the idler through the magnetic clutch. The limit switches are arranged so the idler makes exactly one revolution after actuation before the clutch is disengaged. The gear ratios in the system are designed so the table rotates a distance exactly equal to one hole spacing for each revolution of the idler gear. After the hole is drilled, the unit is again actuated for another automatic cycle.



When another circular pattern having a different number of holes is to be drilled, the index gear is removed and a new one is installed having the same number of teeth as the holes in the new pattern.

This unit has maintained tolerances within ± 0.0025 cm (± 0.001 inch) true location on hole patterns with up to 1.22 m (48 inches) between centers.

Source: M. F. Johns of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-753)

Circle 6 on Reader Service Card.

Section 2. Automatic Regulation

ACTIVE FREQUENCY CONTROL SYSTEM REGULATES ARGON FM LASER

The primary function of the frequency control system is to position the mirrors at either end of the laser cavity so that the mirror separation is independent of thermal and acoustical fluctuations. This condition is achieved by splitting a small portion of the laser output (10 microwatts) and directing it upon a photodetector (photodiode). The narrowband preamplifier centered at 467 MHz then amplifies the signal by 26 dB, with an 8 dB noise figure. The noise figure of the control loop is thus established, and the detected signal has sufficient power to be down-converted to 1 MHz in the mixer. The signal from the mixer is passed onto the 1 MHz I.F. amplifier, where the bulk of the system loop gain is realized. The bandpass characteristics of the 400 kHz bandwidth I.F. amplifier are important in that any phase or amplitude distortion in the detected signal will cause instabilities in the loop compensation system. It was for this reason that a "maximumly flat" characteristic was chosen.

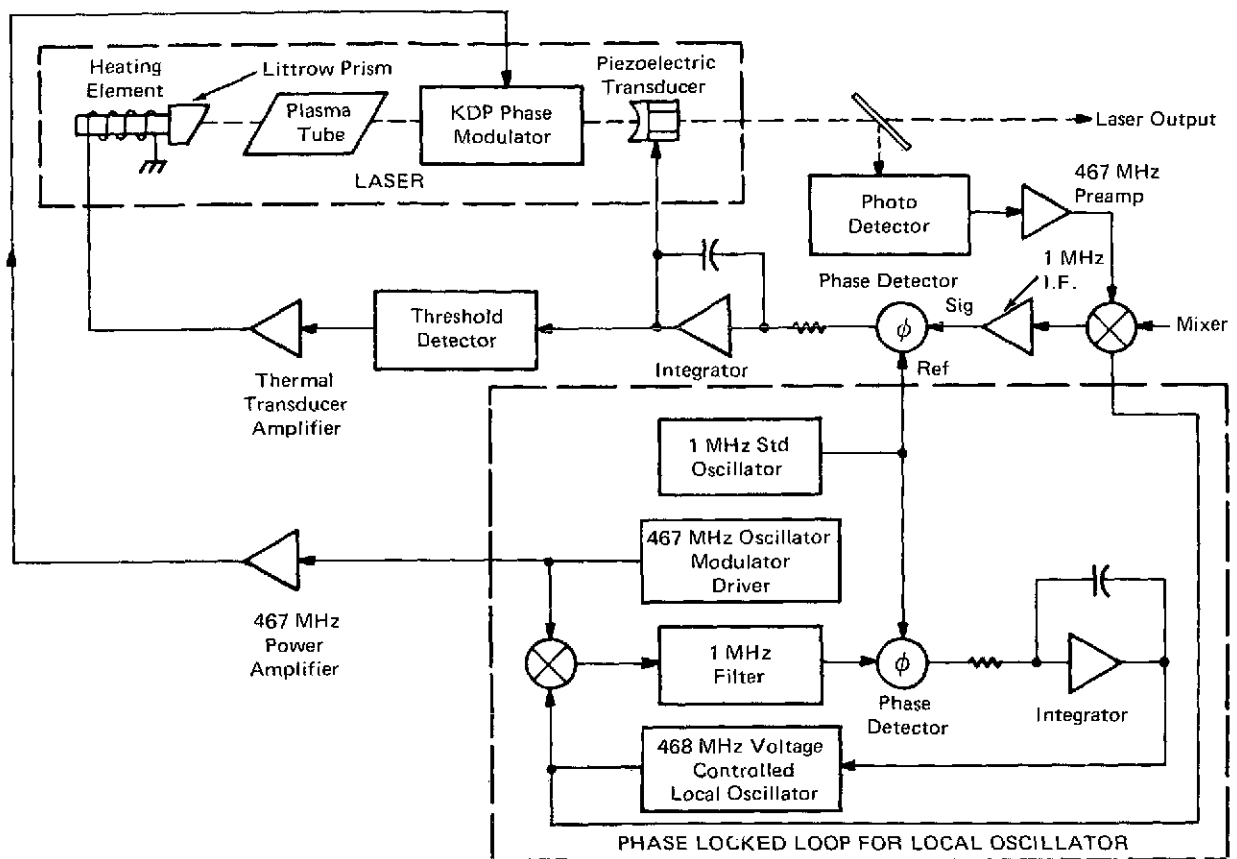
The output of the I.F. amplifier is compared with a 1 MHz standard oscillator, which yields the phase information as to which direction the piezoelectric transducer must move in order to compensate for any fluctuations in cavity length. The amplitude of this error signal determines the rate of compensation. An integrator is used between the phase-sensitive detector and the control elements, to convert the entire loop to a first-order system with no net dc positional error.

In order for the system to function correctly, three sinusoidal drive signals are required. The first signal is the 467 MHz modulator drive signal. This signal is supplied to a power amplifier which provides one to three watts of power to the KDP (potassium dihydrogen phosphate) phase modulator used to couple laser modes.

Since the change in phase of the 467 MHz beat signal from the FM laser produces the discriminant which operates the entire loop, the detected signal must be heterodyned down to a lower frequency, while preserving all the phase information. The heterodyning is accomplished by phase locking the 468 MHz voltage-controlled local oscillator to the 467 MHz modulator drive via a 1 MHz standard oscillator. As a result, regardless of the precise frequency to which the modulator drive is tuned, the local oscillator signal is offset by 1 MHz, and the difference between these is precisely fixed in phase with respect to the 1 MHz standard. Therefore, as the optical cavity drifts thermally or acoustically, the change in phase of the 467 MHz beat signal will be detected by the preamplifier and I.F. amplifier, and will then form the discriminant in the phase detector.

As a result of the phase information inherent in the FM discriminant, the error signal is always of the correct sign. Thus the system acquires lock automatically; and if lock should be lost, it is reestablished without manual intervention.

One of the problems inherent in the stabilization of lasers is that the amount of thermal expansion in the laser can be many optical half-wavelengths. The piezoelectric transducer, however, can move through only two or three half-wavelengths with maximum voltage applied. In order to compensate for the slow thermal drifts in the length of the laser cavity, a thermal transducer was placed behind one of the laser mirrors as shown in the diagram. This transducer is simply an aluminum spool wound with heating wire. When the voltage applied to the piezoelectric transducer begins to exceed the designated range, the transducer amplifier drives current into the heating element, which in turn compensates for expansion and contraction of the laser cavity. This also has the



effect of keeping the integrator dc level constant at approximately 100 volts. The thermal transducer can move the laser mirror through 80 half-wavelengths, and it has a time constant of about 5 seconds. The water flow through the base plate of the laser is adjusted to reduce its thermal drift in order to keep the current levels in the transducer at reasonable values.

Additional documentation is available from:

National Technical Information Service
Springfield, Virginia 22151

Price \$3.00

Reference: TSP69-10099

Source: J. M. French, R. Targ, J. M. Yarborough, and
L. E. Wilson of

Sylvania Electric Products, Inc.

under contract to

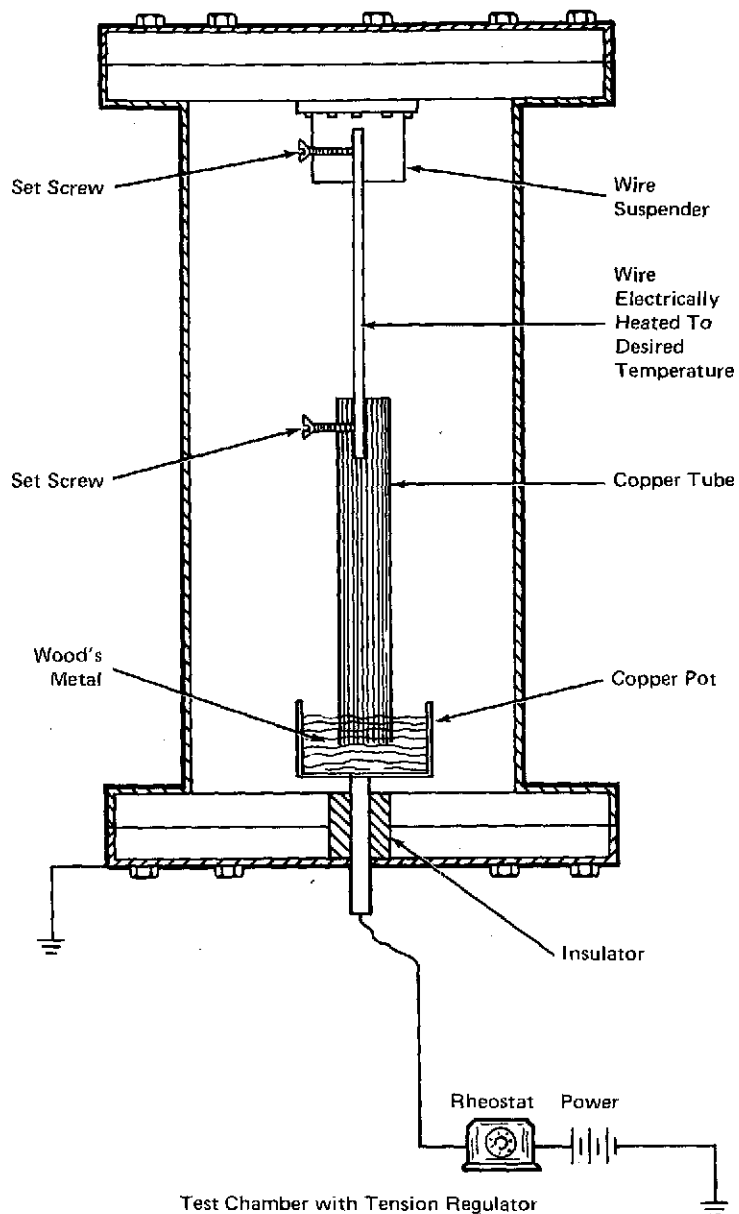
Marshall Space Flight Center

(MFS-14988)

WOOD'S METAL PROVIDES CONSTANT TENSIONING OF HEATED ELECTRICAL CONDUCTOR

In a test chamber, an uninsulated conductor, contained in a metal cylinder, was electrically heated as a part of the test. As the temperature of the conductor rose it tended to deform (bow) toward the chamber wall, until the conductor shorted out against

the wall. Insulating the conductor or chamber wall could not be done in performing the specific test, and space limitations prevented a larger cylinder to accommodate the conductor's maximum deformation.



Test Chamber with Tension Regulator

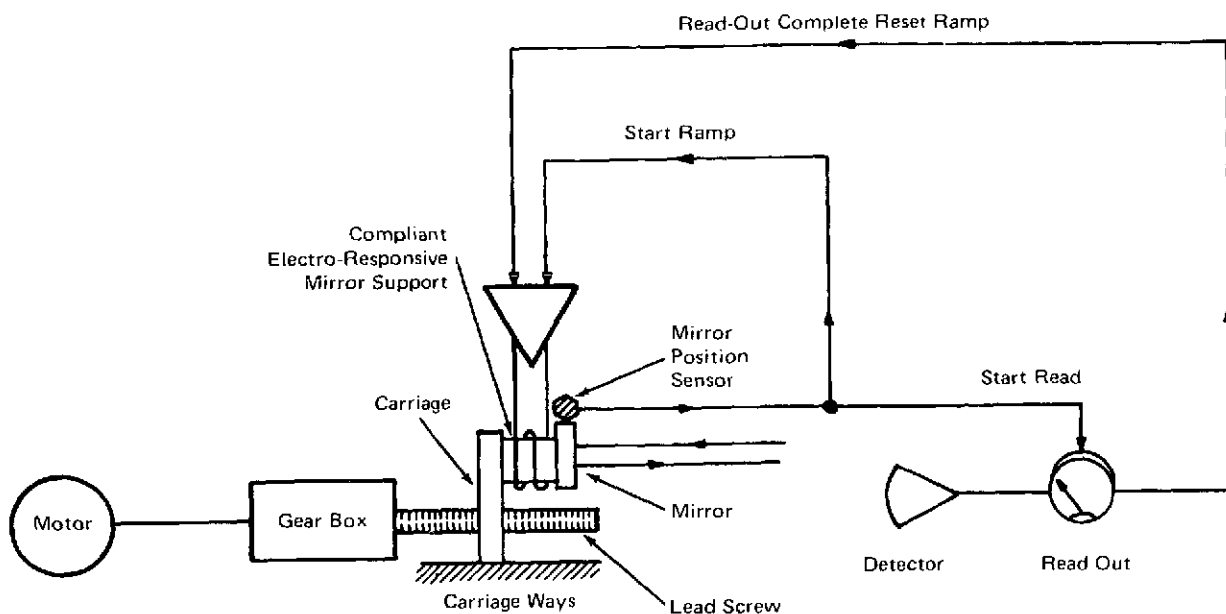
This innovation overcame the difficulty by introducing a regulating tension on the conductor throughout the heating cycle. As shown in the sketch, the conductor is suspended vertically with a short length of copper tubing attached to its lower end and held in place by a setscrew. The copper tubing rests on a quantity of Wood's metal contained in a copper pot. When current is applied to the conductor, heat quickly flows to the Wood's metal and, due to its very low melting point, it rapidly becomes molten. This

permits the copper tube to descend into the Wood's metal and exert its inertial force on the conductor. The conductor is therefore held in tension and prevented from assuming its free-state deformation.

Source: C. E. Maskell of
Aerojet-General Corp.
under contract to
AEC-NASA Space Nuclear Systems Office
(NUC-90033)

No further documentation is available.

MOTION DRIVE SYSTEM IS ACCURATELY MAINTAINED IN THE 1-MICRON RANGE



This motion drive system (see figure) can achieve discrete motion in a range of increments varying from several inches to a fraction of a micron. The system was developed for use with interferometers where accurate regulation to minuscule increments of travel is of prime importance.

The drive system can be implemented as a functional addition to a simple, continuous-motion lead screw to produce a controlled incremental motion of the driven element. Since the motion imparted to the driven element is the resultant sum of continuous motion and transducer movement, it is possible to hold the driven element motionless or move it at speeds in excess of that of the continuous motion system. By alternating these two conditions, through appropriate electrical input to a transducer, incremental motion of the driven element is realized.

In the drive system, an electromechanical transducer (electromagnetic, electrostatic, piezoelectric or magnetostrictive) is interposed between the point of continuous motion and the element to be incrementally driven. The electrical signal to the transducer produces motion within the transducer equal and opposite to that of the continuous motion within the total drive system. For the duration of the electrical

signal, and within the physical limitations of the transducer, there is no motion at the output of the drive system. Repeated occurrence of this effect produces the desired incremental driving action. The electrical signal to the transducer can be produced either by a suitable generator or from a sensor associated with the mechanical action of the drive system, resulting in a servo-type operation.

The drive system is applicable to any device that requires extremely accurate positioning control, and is generally applicable to those classes of instruments in which a movable element is used to alter the instrument's characteristics in such a fashion as to result in significant variations of an observable effect. Although described in terms of linear motion, the same technique is applicable to angular motion. Therefore, interferometers, refractometers, diffractometers, and scanning-type instruments can be utilized with the drive system.

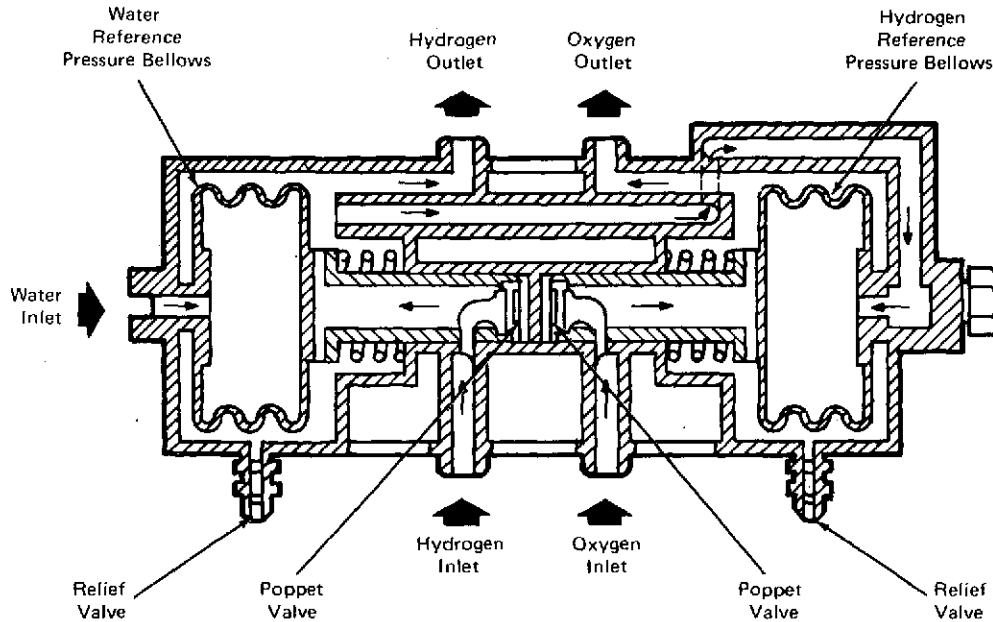
Source: J. H. Morecroft of
Caltech/JPL
under contract to
NASA Pasadena Office
(JPL-864)

Circle 7 on Reader Service Card.

DUAL REGULATOR CONTROLS TWO GASES FROM A SINGLE REFERENCE

This dual pressure regulator uses an external fluid pressure to modulate the flow of one gas, and the regulated flow of this gas is used to modulate the flow of a second. Strict separation of the two gases is maintained throughout the operation.

hydrogen pressure acts as the reference for the second gas pressure, in this case, oxygen. Oxygen enters its inlet port, passes through the poppet valve, and surrounds the hydrogen reference bellows. Modulation of the oxygen inlet poppet valve is



The dual-pressure regulator uses an internal bellows and poppet valve system to achieve the desired regulation. Two normally open plastic seat poppet valves modulate gas flow through two parallel inlets. Water or another fluid fills the reference pressure bellows. The first gas, hydrogen in the illustration, enters its inlet port, passes through its poppet valve, and surrounds the reference pressure bellows. Increasing hydrogen pressure contracts the bellows to move the hydrogen inlet poppet valve in a direction to decrease hydrogen flow through the valve into the pressure regulator. As hydrogen pressure decreases, the water reference pressure bellows expands to move the hydrogen inlet poppet valve in a direction to increase hydrogen flow through the valve into the pressure regulator.

Hydrogen in the pressure regulator is conducted through inter-connecting passageways to the interior of the hydrogen reference pressure bellows and the

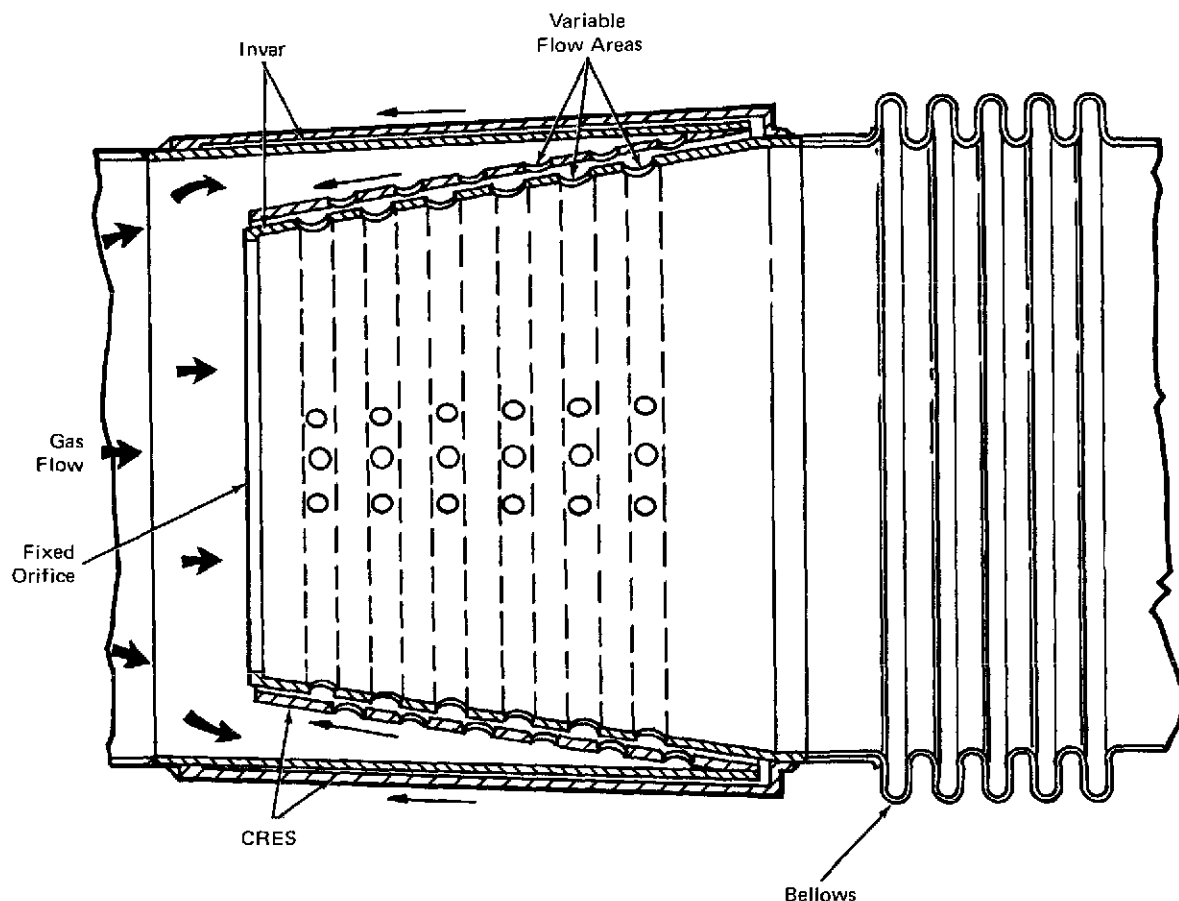
accomplished in the same manner for the hydrogen inlet poppet valve except that, in this instance, hydrogen is the reference pressure and the hydrogen reference pressure bellows is contracted and expanded by pressure from the surrounding oxygen.

A constant pressure in the reference bellows results in constant flows from the outlets. Modulation of the reference pressure will cause the outlet flows to be similarly modulated. Relief valves are provided to limit hydrogen and oxygen pressures in the regulator.

Source: K. Jackson
of The Garrett Corp.
under contract to
Johnson Space Center
(MSC-227)

No further documentation is available.

TEMPERATURE-CONTROLLED FLUID FLOW REGULATOR



A slide-type valve, constructed from materials having different coefficients of thermal expansion, acts as a fluid flow regulator by varying an orifice flow area as a function of temperature.

In this device (see figure), a cylinder with a slight taper, functioning as part of ducting, is made with a bimetallic wall consisting of an Invar inner member and an outer member of corrosion resistant steel (CRES).

The sliding valve is constructed in the form of a truncated cone with the base open and a fixed orifice as the truncating plane. The inner (Invar) wall of the cone has appropriately spaced ports. Welded to the inner cylinder wall of Invar is the outer wall of the truncated cone made of CRES with ports offset below from those in the inner core and unrestrained at the top. Thus, as the temperature increases, the CRES outer wall of the duct expands and compresses

the bellows downstream, while at the same time moving the inner wall of the sliding valve to which it is welded.

Simultaneously, the CRES outer wall of the sliding valve, which is welded to the Invar inner wall of the duct, is forced to move upstream. The response of the different metals to temperature variations thus increases or decreases the flow areas in the sliding valve as the walls of the valve move in opposite directions during temperature changes.

Source: L. E. Tomlinson of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-14259)

Circle 8 on Reader Service Card.

STABILIZATION OF INTERFEROMETER FRINGE PATTERNS

The disruptive movement of the fringe patterns formed by an interferometer is compensated, in this system, by a closed-loop servo system. The system regulates a mirror mounted on a piezoelectric crystal to maintain a constant path difference in the interferometer at one point in the field (see figure).

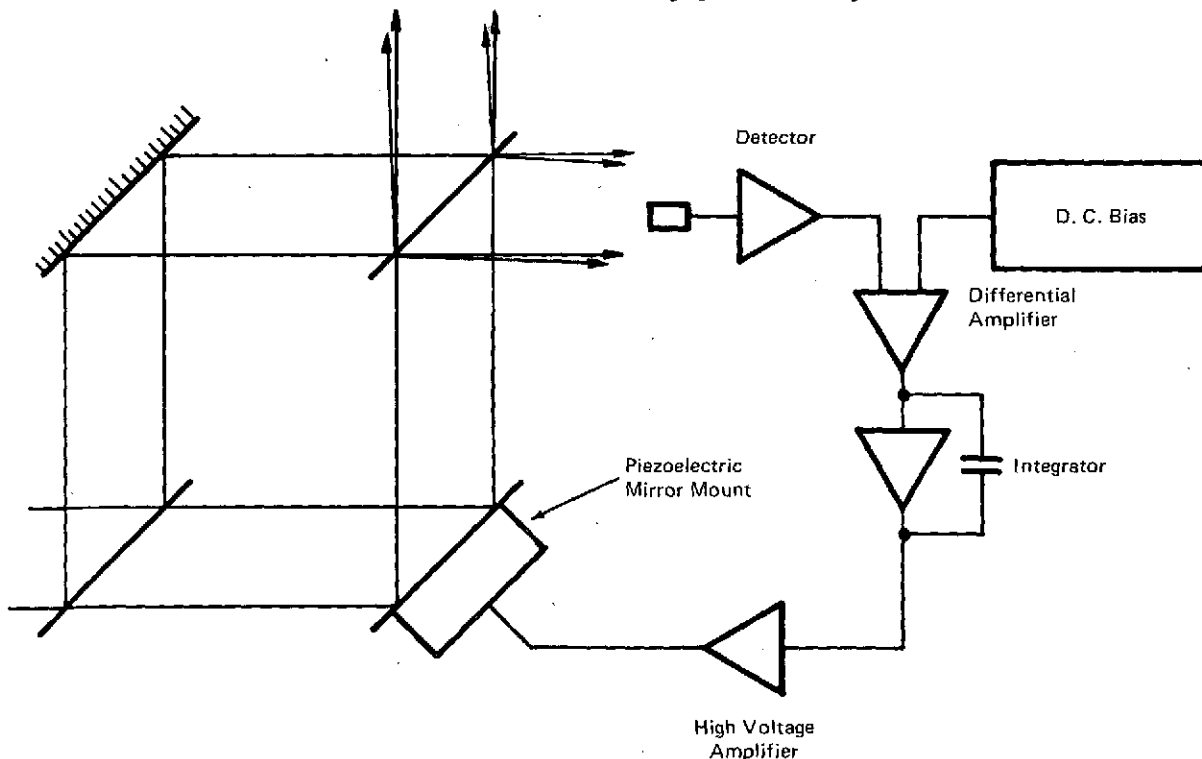
The servo control loop consists of the interferometer, a photodetector, the servo electronics, and the servo control mirror. A small photodetector, such as a p-n junction photodiode, is used to sample a small portion of the output field. The interferometer is adjusted so that the fringe spacing is much greater than the active area of the photodetector; thus, the detector integrates the light from only a small fraction of the fringe. The light intensity at this point is a measure of the position of the interference fringe.

A differential amplifier amplifies the signal from the photodetector with a dc bias signal equivalent to the average intensity of the fringes. The output of the differential amplifier is fed to an integrator, and if the signals are equal, the charge on the integrator capacitor remains unchanged. If, however, the location of the interferometer fringes changes, the input signal

will not be equal to the bias, and the integrator capacitor will charge or discharge at a rate dependent on the difference in the signals.

The output of the integrator is amplified by a high-voltage operational amplifier which drives a piezoelectric crystal. Mounted on the crystal is a mirror which serves as one element of the interferometer. Motion of this mirror will change the path length between the legs of the interferometer, and hence the location of the fringes, thus closing the loop. If the output of the differential amplifier is not zero, the change in charge on the crystal will change its length in such a manner as to return the fringes to the correct position. If the output is zero, no change is made in the piezoelectric crystal. The crystal is generally operated with a bias voltage of -700 volts for zero integrator signal so that it can be operated over a total range of 0 to -1500 volts.

The system inherently operates with a negative feedback because of the undulating nature of the interference pattern (\cos^2 function). The path change is always in a direction which will drive the output of the differential amplifier to zero, thus stabilizing the fringe pattern at the photodetector location.



The extent of stabilization depends on the nature of the motion to be compensated. Linear motion can be compensated equally across the whole field, while rotational motion is stabilized exactly only at the photodetector location; positions away from this point are stabilized to a degree dependent on the distance from the stabilized point. The amount of stabilization depends on the frequency and amplitude of the disturbing motion. With systems presently in use, stabilization to about $1/60$ of a wavelength at very low frequencies (less than 10 Hz) has been demonstrated for noise amplitudes of greater than one wavelength. Through the use of the servo control loop system described, sinusoidal path motion of one wavelength peak-to-peak, up to frequencies of 200 Hz, can be reduced to less than $1/10$ wavelength. Motions of greater than four wavelengths can be reduced to the same degree for frequencies of less than 70 Hz.

The loop gain of this system is the product of the electronic gain and the optical gain. Unfortunately,

the optical system is inefficient; for example, 100 volts are needed to cause a path change of one wavelength, the geometrical multiplication is generally between 1 and 2, and the photodetector-preamplifier has a sensitivity of about 0.2 volt per wavelength. Therefore, the gain of the electronic system must be kept very high to obtain reasonable stabilization. A loop gain of about 100 is desirable at low frequencies, so that adequate high frequency stabilization is available. Hence, there is the possibility that electronic drift will be the factor which limits the low-frequency performance of the system.

Application of this system to holography, with continuous wave laser sources, has been successfully performed.

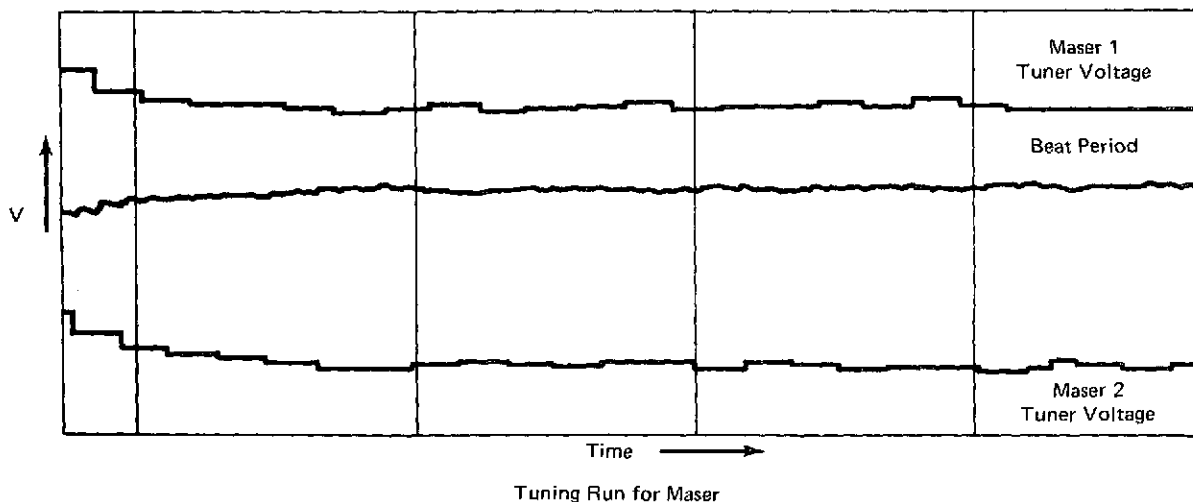
Source: R. M. Brown
Ames Research Center
(ARC-10392)

Circle 9 on Reader Service Card.

SYSTEM AUTOMATICALLY TUNES HYDROGEN MASERS

An automatic tuning system has been developed that permits frequency synchronization between two hydrogen masers. Although the system was originally designed to match a space-borne clock performance with that of a ground-based clock to test the so-called "red shift" (or effect of gravity on time predicted in Einstein's general theory of relativity), it should be of

interest to organizations concerned with industrial and educational research programs. Additionally, this system, used in conjunction with radio astronomy for long-baseline interferometer experiments, should interest the astrophysical community as a new tool for investigation of distant phenomena in the universe.



A typical tuning run is illustrated in the figure. The tuning varactor voltage for maser 1 is recorded on the upper track of a strip chart recorder, and that for maser 2 on the lower track. Full scale for both tracks is 2.0 V and each major time increment in the time axis is 10 minutes. The center track displays an analog record of a digital measurement of the beat frequency between the two masers with a full-scale range of 2.5×10^{-11} . Synthesizers in phase-lock loops in system electronics are offset by 0.6 Hz and 100-period averages are taken to provide an observation time for each measurement of 166 seconds. Maser 1 is deliberately detuned by arbitrarily setting the tuning diode voltage to 5.0 V. The corresponding initial frequency error was about 3.8×10^{-12} . Similarly maser 2 was offset about 5.5×10^{-12} by setting its tuning diode voltage to an arbitrary 4.0 V.

The loop gain on each tuner is deliberately reduced to effectively demonstrate the tuning operation. The correction process operates smoothly, as shown by the recording, alternating from maser 1 to maser 2.

After 150 minutes, the initial total error of 8×10^{-12} is reduced to less than 5×10^{-13} . Of particular interest are the fluctuations in the beat period, due to pressure changes, which can be seen clearly for the first 60 minutes of the recording. These fluctuations damp out rapidly, as expected, when proper tuning is approached.

The following documentation may be obtained from:

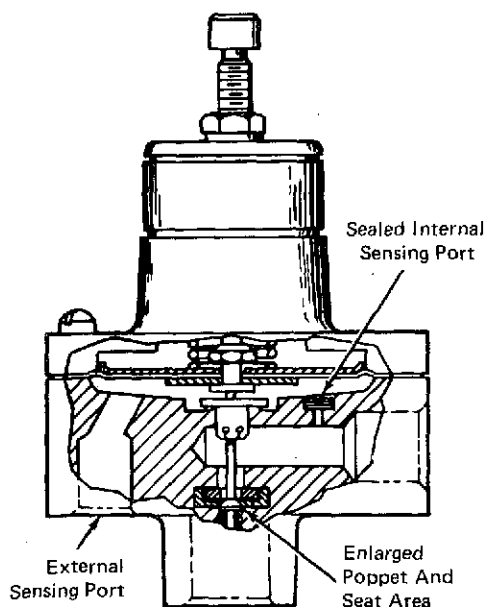
National Technical Information Service
Springfield, Virginia 22151
Single document price \$6.00
(or microfiche \$0.95)

Reference:

NASA-CR-94937 (N68-25901), Atomic Hydrogen
Maser for Space Vehicle Application

Source: R. F. C. Vessot and M. W. Levine of
Hewlett-Packard Co.
under contract to
NASA Headquarters
(HQN-10502)

LOW PRESSURE, EXTERNAL SENSING REGULATOR



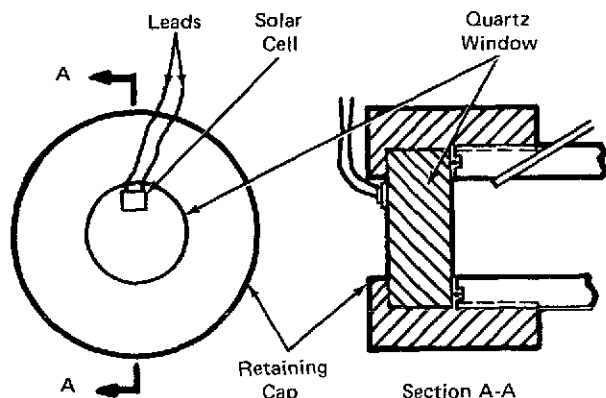
A commercially available, low pressure, LOX compatible regulator was found to be limited to a flow rate well below requirements. While increased flow was necessary, control panel arrangement did not permit a regulator body of larger size.

The solution to the problem was redesign of the existing regulator by sealing off its internal sensing port, providing an external sensing port, and enlarging the poppet and seat areas. The figure shows the modified regulator in cutaway.

Source: G. E. Anderson of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-16642)

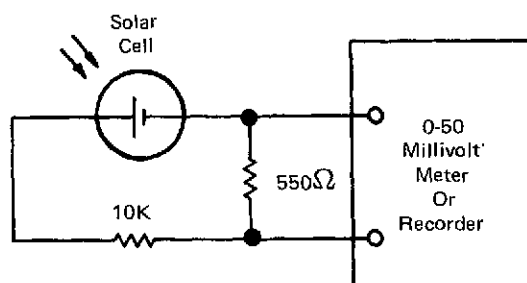
Circle 10 on Reader Service Card.

SILICON SOLAR CELL MONITORS HIGH TEMPERATURE FURNACE



Front View

Installation of Silicon Solar Cell



Recording Circuit

Silicon solar cells have been used to monitor the performance of a high temperature furnace during materials tests at an appreciable cost reduction. The technique provides continuous indications of temperatures outside design parameters and can be used with either direct-reading meters or alarm systems.

Silicon solar cells, 0.51 cm x 0.51 cm (0.2 inch x 0.2 inch), are cemented directly to the pyrex or quartz sight ports, using a clear epoxy. The cells are located on the ports to receive direct radiant emission from the hot body. Because of the small size of the solar cells it is possible, on a half-inch diameter or larger sight port, to view the same body with a conventional optical pyrometer while the solar cell is installed. This permits direct individual calibration if required. The output of the solar cells is connected directly to a voltmeter, recorder system. Solar cells thus installed on a high-temperature thermocouple test furnace have been found to operate within a $\pm 2\%$ band over

a temperature range from 1222 to 2666 K (2200° to 4800°R).

The overall cost of a solar cell/voltmeter unit is under \$50 (cells cost under \$2.00). Thermocouples capable of operating over the same range with similar accuracy would cost between \$500 and \$1000 each, and would possibly affect test assembly geometry. Readout equipment would be an additional cost. Automatic optical pyrometers for this temperature range cost approximately \$5000 each.

Source: G. J. Zellner of
Westinghouse Astronuclear Laboratory
under contract to
AEC-NASA Space Nuclear Systems Office
(NUC-10163)

Circle 11 on Reader Service Card.

A CONCEPTUAL CURRENT SURGE PROTECTOR FOR INCANDESCENT LAMPS

Insertion of a negative-temperature coefficient device, such as a thermistor, in series with an incandescent lamp filament prevents lamp failure due to high filament surge current. The initially high resistance of the thermistor inhibits the surge current.

The thermistor could be made an integral part of the incandescent lamp socket or a disc type of device could be supplied which would fit within existing sockets and would form electrical contact between the lamp and socket (see figure).

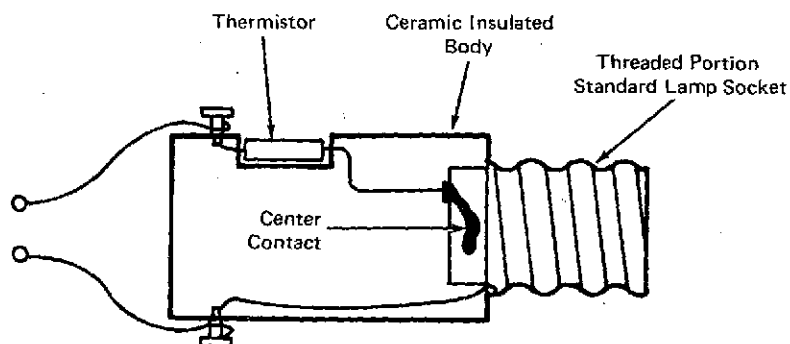


Figure 1. Thermistor as Integral Part of Lamp Socket



Figure 2. Thermistor Disc To Be Installed in Socket

The thermistor should be selected for a cold resistance approximately equal to one fourth of the normal hot resistance of the filaments to be protected. For example, a 100 watt lamp used in a 117 V ac circuit will have a hot resistance of approximately 130 ohms; the thermistor should have a cold resistance of approximately 32 ohms. Upon initial application of power, the cold resistance of the thermistor plus the cold resistance of the filament will be sufficient to prevent a destructive current surge. The thermistor resistance will immediately start to decrease due to self heating; the filament resistance will increase for the same reason until a state of equilibrium is reached. Assuming a lamp socket stabilization temperature of

475 K (400°F), the thermistor resistance at that temperature will be approximately 0.3 ohms and the power dissipated will be a minimal 0.2 watts.

This device should be extremely useful for household lighting systems. Even though the initial cost of incandescent lamps is relatively low, the high failure rate becomes costly and the "nuisance factor" of replacement is eliminated.

Source: G. A. Macomber of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-16658)

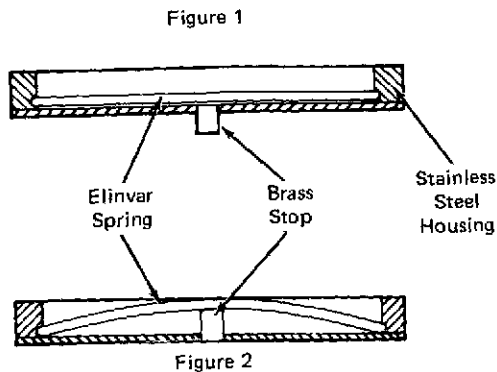
No further documentation is available.

TEMPERATURE-CONTROLLED LOCK FOR LARGE SLEEVE-TYPE FLOWMETERS

The bearings of large-diameter cryogenic liquid flowmeters are lubricated by the liquid being metered. During the initial stages of chilldown, boiloff rates are rapid, and high vapor volumes can cause the flowmeter rotor to rotate faster than design speed with the bearings unlubricated, causing galling or possible bearing failure.

This device consists of a temperature-sensitive stop that restrains movement of the rotor above liquid cryogenic temperatures. The device is operated

by temperature effects on the difference in coefficients of expansion of two metal members: one of stainless steel and the other of "Elinvar", a metal used in escapement parts of accurate timepieces. It consists of a stainless steel housing that contains the "Elinvar" spring, to which is attached a brass stop. The assembly is fitted into a slot milled in the sleeve insert, where it is retained by the outer case of the flowmeter spool.



With the flowmeter warm, the position of the stop will be approximately as shown in Figures 1 and 3, and the stop prevents rotor movement. As the temperature drops, the length of the stainless steel housing decreases but that of the "Elinvar" spring remains the same.

This causes the spring to deflect until, at liquid cryogenic temperatures, it is in the configuration shown in Figure 2, having withdrawn the stop until it no longer is in contact with the rotor rim. The rotor is then free to rotate as the bearings are lubricated by the cryogenic liquid.

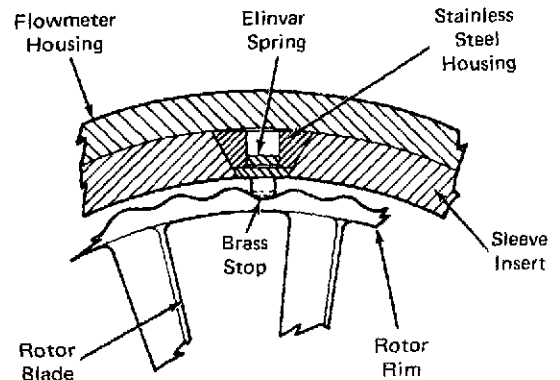


Figure 3

Source: L. W. Brantum and G. H. Wells of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-14495)

Circle 12 on Reader Service Card.

QUICK-RESPONSE SERVO AMPLIFIES SMALL HYDRAULIC PRESSURE DIFFERENCES

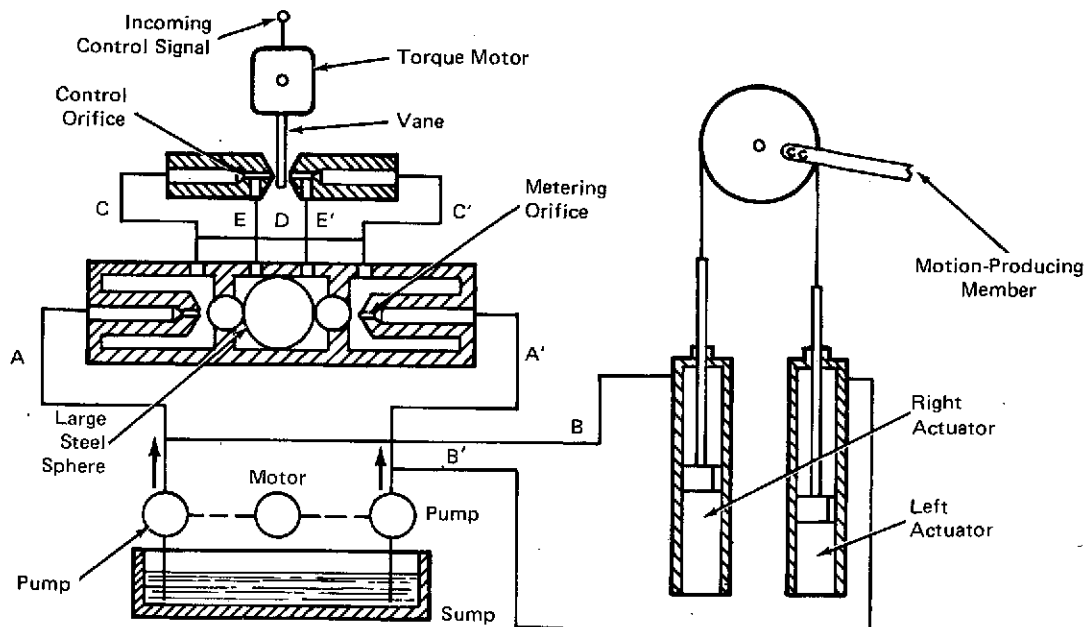
A servo has been developed to control the flow rates and pressures within a hydraulic system so that the output force of the servo system is independent of the velocity of the mechanism which the system actuates. The servo is capable of operating with dirty or impure fluids without sticking or jamming. Hydraulic servos which use flow responsive valves, variable flow pumps, or high inertia mechanical members, are too slow or require too large a signal force.

This hydraulic servo, operating within a continuous-flow hydraulic system, quickly diverts fluid to either of two actuators. Small pressure differences induced in the system by a low-power signal device are sensed by the servo and amplified through the action of a low inertia ball valve arrangement. Constant total system flow rate is maintained throughout the controlling function.

The servo is a tandem arrangement comprised of two constant speed pumps, two metering orifices, and two control orifices. Between the two metering

orifices is a chamber containing a large steel sphere. Partitions on either side of the chamber contain small steel spheres in proximity to each metering orifice and in contact with the large sphere. A vane or fin, connected to a low power torque motor, is suspended midway between the two control orifices.

Each pump delivers fluid to one metering orifice through lines A and A', as shown in the diagram. The fluid exiting from each of these orifices impinges on the adjacent small steel sphere, exits through a port, and enters the corresponding control orifice through lines C and C'. Line D is connected across lines C and C' so that each control orifice experiences an identical incoming pressure. Fluid exiting from each control orifice strikes the vane and returns to the sump. Lines E and E' extend from within each control orifice to either side of the chamber housing the large sphere so that each half of the chamber experiences the pressure within its respective control orifice. Hydraulic lines A and A' also serve lines B and B' which lead to one of two hydraulic actuators.



The purpose of the servo is to divert fluid to either of the two actuators when the vane swings toward one of the two control orifices. When the vane is midway between the orifices, no fluid flows to the actuators, and the system is in neutral operation. When a low power signal is delivered to the torque motor, the vane swings in the proper direction, for example, toward the left control orifice. Fluid exiting from this orifice is restricted by the vane so that its velocity decreases below that of the right orifice and the pressure within the left orifice rises above that of the right orifice. The line (E) leading from the left orifice to the left side of the large sphere chamber transmits this increased pressure to the left side of the sphere (see figure).

This sphere, with a pressure differential existing between its two sides, moves to the right, pushing the right small sphere ahead of it. The left sphere follows the large sphere since the pressure to its right, although increased, is still less than the pressure of the fluid exiting from the left metering orifice. The spheres displace to the right until the pressure in the right metering orifice rises sufficiently through the restricting action of the right sphere to match the force displacing the spheres. The shifting of the spheres causes an increased fluid flow through the left metering orifice, and a decreased fluid flow through the right orifice. Therefore, a portion of the fluid exiting from the right-hand pump through A' now diverts to the right-hand actuator through line B'.

Fluid flows from the left actuator to the left orifice through line B to increase the flow through this orifice. The two actuators thus operate in a complementary fashion through the action of the low inertia spheres.

This servo is a dynamic feedback control device. The combination of the valve and actuator provides a force output. That is, for a given electrical input, a specific output force is developed that is essentially independent of load velocity. In certain classes of servos, such as force reflecting master-slave manipulators, this force control characteristic is greatly desired above the velocity control characteristic of the usual flow control valve.

Since the metering action is accomplished without change in flow rate from the pumps, and since the mass of the three steel balls is low, the servo responds quickly to vane deflection signals.

The continuous flow feature of the valve provides a self-cleaning action and ensures smooth, stick-free operation without the need of externally applied vibration (dither), even with the use of dirty or impure fluids.

Additional information concerning this innovation is contained in U.S. Patent No. 3,031,846, available from U.S. Patent Office, Washington, D.C. 20231, Price \$0.50.

Source: D. E. Wiegard
Remote Control Division
Argonne National Laboratory
(ARG-99)

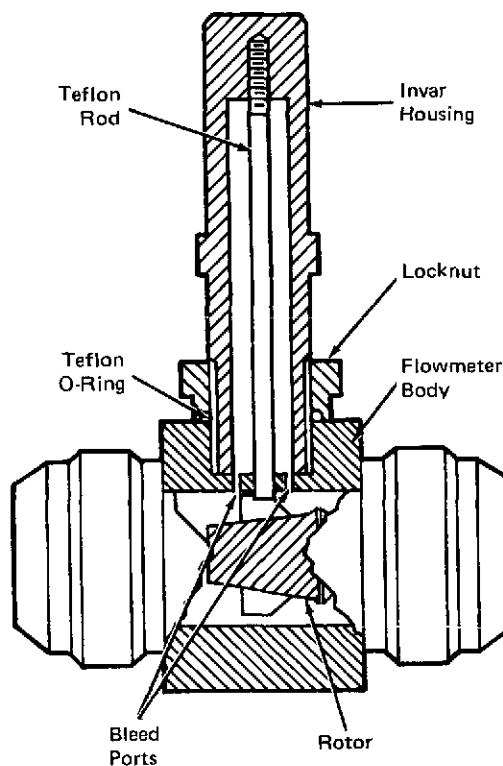
TEMPERATURE-CONTROLLED LOCK FOR SMALL TURBINE FLOWMETERS

During initial chilldown of a liquid cryogen transfer system, excessive boiloff produces a rapid flow of vapor that causes small flowmeter rotors to overspeed before the liquid reaches the rotor bearings to lubricate them. This frequently damages the bearings.

This device takes advantage of the wide difference in coefficients of expansion between a housing of Invar (coefficient practically zero) and a rod of Teflon (relatively high coefficient). The Invar housing is mounted in a boss of the flowmeter and rigidly holds a Teflon rod that, at room temperature, presses against the flowmeter rotor to prevent its movement. Bleed ports allow the cryogen to contact the rod for more effective chilling.

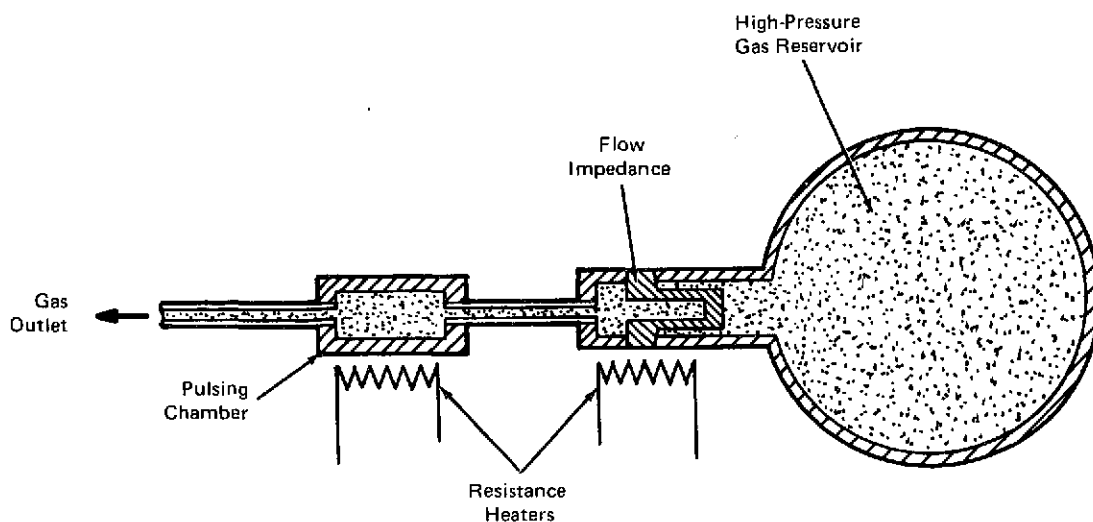
As system chilldown begins, the boiloff vapor cannot turn the locked rotor, but as the liquid cryogen fills the system, the reduced temperature causes the Teflon rod to shrink as the Invar housing length remains constant. The rod withdraws from the rotor, permitting the rotor to turn as the liquid cryogen lubricates the rotor bearings.

under contract to
Marshall Space Flight Center
(MFS-14494)



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DEVICE PROVIDES REGULATED GAS LEAKS



This device provides a regulated release (leak) of very small quantities (approximately 10^{-4} scc) of gas at low or medium pressures. It has no moving parts, requires less than 5 watts to operate, and is capable of releasing the gas either continuously or in pulses of adjustable flow rates. The device is a modification of the "palladium leak" used for many years to provide small hydrogen flow rates.

The device basically consists of a reservoir containing a gas under high pressure and a metal plug which serves as a flow impedance. The temperature of the metal plug is regulated by a resistance heater to control the rate of diffusion of the gas through the metal plug. If it is required to pulse the gas flow, a pulsing chamber is attached to the outlet of the flow impedance. The gas leaks slowly into this chamber, which is heated rapidly to expand the gas

when a pulse is required. Some of the gases and the preferred flow impedance materials are as follows:

Hydrogen: Ni, Pt, Pd, Cu, Fe, Al, Mo

Nitrogen: Mo, Fe

Carbon Monoxide: Fe

Oxygen: Ag

The most likely uses for this lightweight device would be to measure the sensitivity of leak detectors and the speed of vacuum pumps and to calibrate pressure gages.

Source: H. J. King and S. K. Kami of
Hughes Aircraft Co.
under contract to
NASA Pasadena Office
(NPO-10298)

Circle 14 on Reader Service Card.

USE OF THE CHATTER MODE IN SELF-ADAPTIVE SYSTEMS

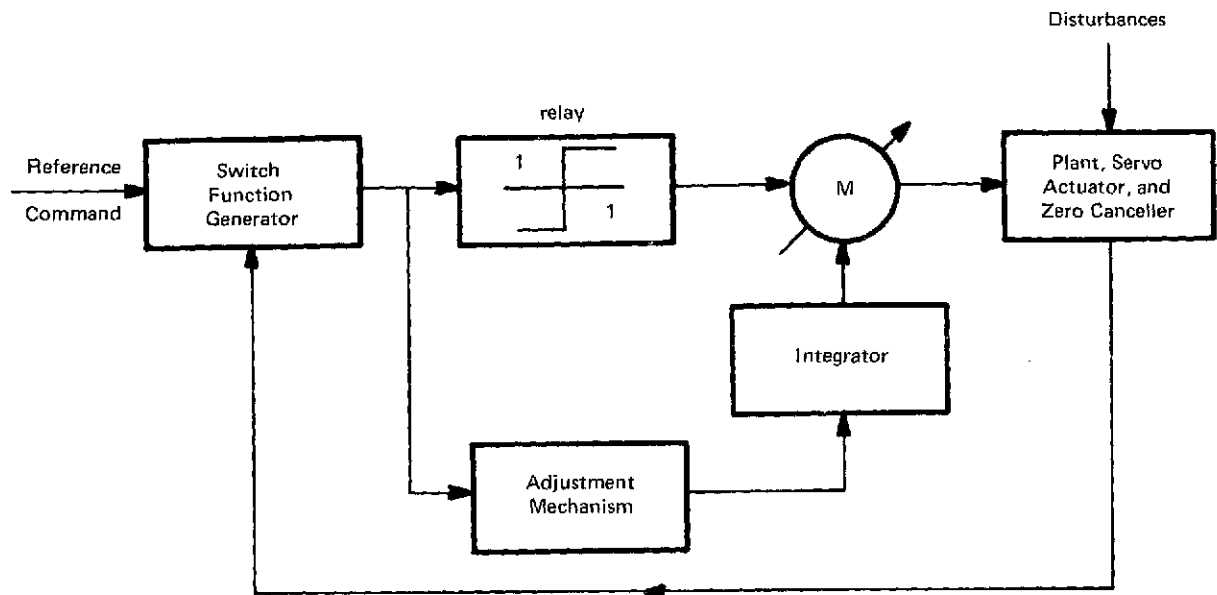
Most conventional control systems, although adaptive to some extent, cannot cope with a wide range of environmental conditions. They usually deal with a limited range of internal parameter variations, limited kinds of external disturbances, and command reference inputs, which are anticipated in the design stage. A self-adaptive control system (defined as one which can maintain satisfactory performance over a wide range of changing conditions) has the capability of organizing itself to accomplish its objectives through the internal processes of measurement, evaluation, and adjustment.

As a result of an analytical study of chatter motion (limit cycle oscillations when a linear switching function is non-optimum) in a control system with a simple relay as the controller, a new self-adaptive control principle (see fig.) has been proposed which uses chatter motion advantageously. In the on-off control system under the chatter mode, the average motion of the plant is completely determined by the equation of the switching function. This relationship can then be applied in a self-adaptive control system in which the switching function describes the model dynamics, and the chatter mode is reached. A switching level adjustment can then reduce the chatter frequency and the control force magnitude, in addition to sustaining the chatter

mode. The fundamental goal is to achieve the chatter mode as quickly as possible for any initial condition, and once it starts, to maintain it regardless of any change in operating conditions. An automatic adjustment device for the switching level or controllable gain has been proposed to meet this requirement. The scheme for the adjustment requires only two pieces of information: the instantaneous switching function and its time derivative. Furthermore, it can remove any excess amount of gain and reduce the chatter frequency as well.

The conclusions and recommendations of this study indicate advantageous use can be made of the chatter mode for self-adaptive control systems if the following basic requirements are met: the ideal model dynamics must be described by a switching function; the chatter mode must be reached quickly and then be sustained; the chatter frequency must be reduced; and, finally, any zero in the plant transfer function must be cancelled. Several examples are presented to demonstrate the analog computer simulation; the results indicate the gain adjustment mechanism performs satisfactorily.

In addition, known self-adaptive control systems are outlined with emphasis on those using a relay as a key element, and consideration is given for the application to a class of distributed parameter control



systems. As a byproduct of this study, a numerical method without integrations is proposed for the solution of ordinary differential equations.

The following documentation may be obtained from:
 National Technical Information Service
 Springfield, Virginia 22151
 Single document price \$6.00
 (or microfiche \$0.95)

Reference:

NASA-CR-88700 (N67-37384), The Use of the Chatter Mode in Self-Adaptive Systems

Source: S. Yasui of
 Massachusetts Institute of Technology
 under contract to
 NASA Headquarters
 (HQN-10159)

Patent Information

The following innovations, described in this Compilation, have been patented or are being considered for patent action as indicated below:

A Digital Controller for a Baum Folding Machine (Page 5) LAR-10688

Inquiries concerning rights for the commercial use of this invention should be addressed to:

Patent Counsel
 Langley Research Center
 Code 456
 Hampton, Virginia 23665

Magnetic Tape Transport Controlled by Rotating Transducer Heads (Page 6) GSC-483

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to the Ampex Corporation, 934 Charter Street, Redwood City, California.

Magnetron Turner Has Locking Feature (Page 10) XNP-09771

This invention has been patented by NASA (U.S. Patent No. 3,541,479). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel
NASA Pasadena Office
Mail Code I
4800 Oak Grove Drive
Pasadena, California 91103

Piezoelectric Linear Actuator (Page 12) MSC-13194

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457 (f)], to Astrosystems Incorporated, One Goddard Drive, Rockaway, New Jersey 07866.

Motion Drive System is Accurately Maintained in the 1-Micron Range (Page 20) JPL-864

This invention has been patented by NASA (U.S. Patent No. 3,501,683). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Patent Counsel
NASA Pasadena Office
Mail Code I
4800 Oak Grove Drive
Pasadena, California 91103

Quick-Response Servo Amplifies Small Hydraulic Pressure Differences (Page 28) ARG-99

This invention has been patented by AEC (U.S. Patent No. 3,031,846). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

Assistant General Counsel for Patents
U. S. Atomic Energy Commission
Washington, D. C. 20545
