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TECHNOLOGY UTILIZATION

FLUID TECHNOLOGY
(Selected Components, Devices, and Systems)

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Foreword

The National Aeronautics and Space Administration has established a Technology Utilization Program for the dissemination of information on technological developments which have potential utility outside the aerospace community. By encouraging multiple application of the results of its research and development, NASA earns for the public an increased return on the investment in aerospace research and development programs.

This publication is part of a series intended to provide such technical information. The document is divided into three sections. In section one, the lately developed use of fluids in the operation of switches, amplifiers, and servo devices is presented. Section two presents a collection of devices and data that should prove helpful in laboratories involved with the use and study of fluids. The third section is devoted to the use of fluids as controls plus certain methods of controlling fluids. The coverage is broad and should interest a wide audience.

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 has 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

Contents

Section 1. Fluidic Applications

FLUIDIC CONTROL OF ENGINE-COUPLED OSCILLATIONS
IN A FLIGHT VEHICLE SYSTEM: A CONCEPT

A condition known as POGO has been identified as the result of changes in the vibration frequencies of the structure and the propulsion system in a flight vehicle. As propellants in the tanks are depleted, the reduction in mass causes a loss of damping and a subsequent increase in POGO frequencies. Since the frequency rate of change of the lesser mass is greater, the two will coincide at some point, multiplying the amplitude of the oscillations to a potentially destructive level.

This concept would appreciably reduce the problem by detuning the inlet line to the propellant pump. The method involves attachment of a device called a microresonator to the inlet line at the pump. The microresonator is a resonant spring-mass system tuned at or slightly above the predicted POGO frequency. At resonance, the flow provided by this device will be 180 degrees out-of-phase with the flow oscillations in the inlet line, thus cancelling them or appreciably reducing their magnitude. The device employs a gas spring to facilitate the cryogenic application.

The major advantage over an accumulator is that this device occupies about 1/10th the volume while providing equal attenuation of oscillations.
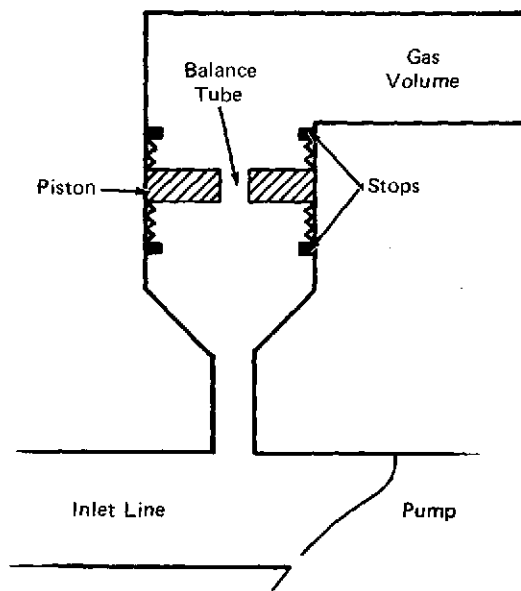
Source: E. K. Bramblett of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-18401)

Circle 1 on Reader Service Card.

FLUIDIC OSCILLATOR USED AS HUMIDITY SENSOR

COMPLETE HUMIDITY SENSOR

A test program investigated the dynamics of hydrogen-oxygen fuel cell systems. In the type of system presently being studied, the water produced in the cells is removed in vapor form by a recirculating stream of hydrogen. Part of the test program consisted of introducing controlled disturbances into the humid hydrogen stream that enters the fuel cell and of studying the effects of these disturbances.
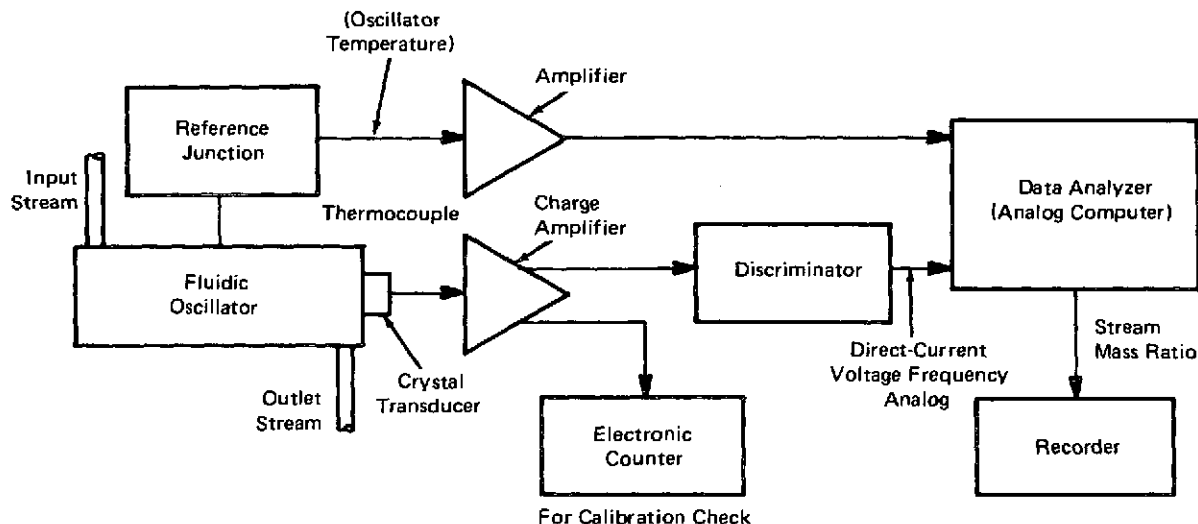
To study the effects on the fuel cell water removal processes, it was necessary to know, on a continuous basis, the humidity (steam-to-hydrogen mass ratio) of the hydrogen stream leaving the fuel cell. The instrument used for measuring the recirculating stream humidity, in addition to being a continuous reading

device, had to have a certain speed of response. Since a measurement technique or a humidity transducer with the required speed of response could not be found, an instrument based on a fluid oscillator concept was designed and developed.

A test program was conducted on the instrument to define its steady state and transient performance. The test program also resulted in a determination of the failure modes and accuracy limitations of the instrument. An analog computer program that serves as a data analyzer to convert the humidity sensor from an indirect to a direct reading instrument was also developed. The program converts the normal instrument output of frequency of oscillation at a given temperature and pressure directly to a steam-to-hydrogen mass ratio reading.

The calibration accuracy was approximately ±2 percent in mass ratio, over the mass ratio calibration range of 0.8 to 2.1. Analysis of frequency response data indicated that the response of the sensor was flat at least to the 3-Hz limit of the test apparatus.

Source: P. R. Prokopius
Lewis Research Center
(LEW-340)
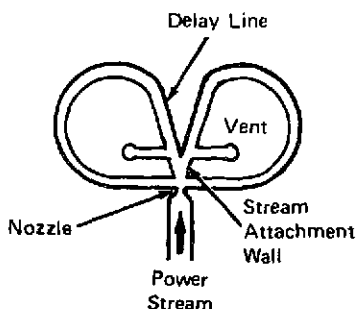
SCHEMATIC OF FLUIDIC OSCILLATOR

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VERY LOW VELOCITY FLOW SENSOR APPLIES FLUIDIC TECHNIQUES

Two designs for a versatile low velocity flow sensor have been developed that have important potential applications in V/STOL aircraft, wind tunnel instrumentation, meteorology, and gas flow measurement in hazardous atmospheres.

the two receivers is related to the wind velocity by a characteristic square-law calibration curve which saturates as the wind speed approaches a critical velocity. If the outputs of the cross-flow sensor are input to a fluidic operational amplifier, high pressure output
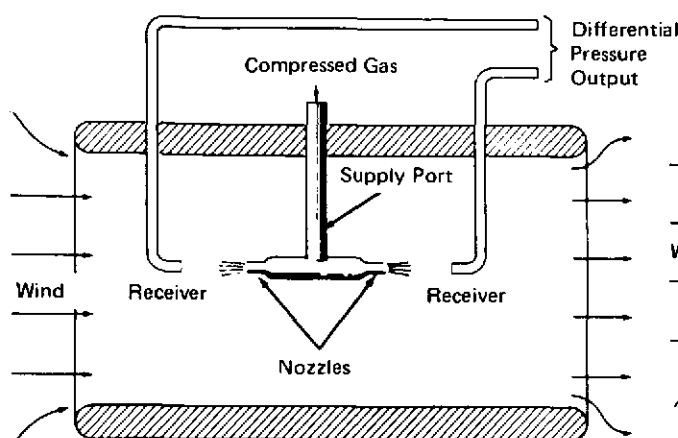
Figure 1. Parallel-Flow Wind Sensor

Figure 2. Cross-Flow Sensor Configuration

The parallel-flow configuration, shown in Figure 1, provides a differential pressure output as the wind velocity varies. Gas from the supply port expands through twin nozzles and, in the absence of wind, generates equal pressures in the receivers. When the wind flows past the sensor, the downwind jet pressure increases; simultaneously, the upwind pressure decreases. The output of this sensor is nearly linear and relatively insensitive to supply pressure over a wide range of wind velocities. The differential output pressure varies from 0 to 0.3 per unit change of supply pressure as the wind velocity varies from 0 to 27 m/sec (0 to 90 ft/sec).
ft/sec).

Figure 2 shows the basic design of a cross-flow sensor. Gas expands through a supply nozzle to form a jet. Two receivers sense the position of the jet, and their output pressures change as the cross-wind deflects the jet. The difference in output pressures of

may be obtained for low wind velocities without changing the output characteristic. In an actual test of this configuration, wind velocities from 0.31 to 4.27 m/sec (1 to 14 ft/sec) varied the output pressure from the fluidic amplifier over its full range of 143×10^3 to 191×10^3 N/m^2 (6 to 13 psig).

BISTABLE FLUIDIC VALVE IS ELECTRICALLY SWITCHED

This innovation in fluidic applications is a bistable control valve that can be selectively switched by direct application of an electrical field. The valve is inexpensive, has no moving parts, and operates with any fluids that are relatively poor electrical conductors.

In conventional fluidic switches, directing the fluid flow from one channel to another is effected by control jets of the operating fluid. In certain applica-

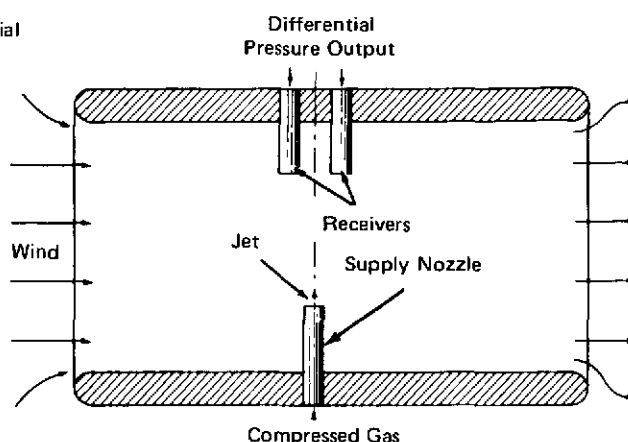In operation, the fluid input jet will initially be deflected by the apex of the divider into one of the two output channels. In either of these channels (e.g., the left channel), the fluid jet is in a stable condition and follows the channel wall as a consequence of the Coanda effect. Assuming that the jet is locked to the left wall of the left channel, the jet can be switched to the right output channel by
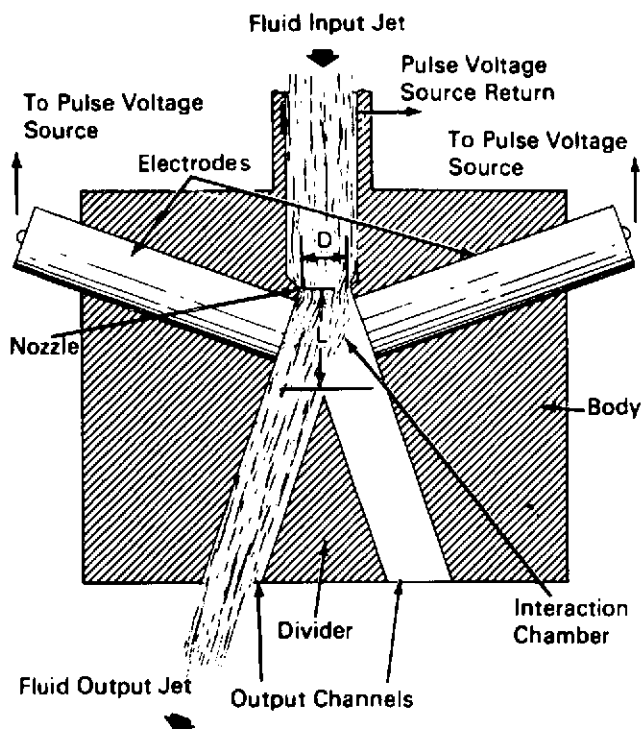
tions, it is desirable to use electrical signals rather than control jets to initiate switching of the fluid flow. However, conventional electrical switching arrangements have required relatively intricate valve designs and precision components. The complexity and high cost of such hybrid systems have limited their use.

As shown in the cross-sectional view, the body of the valve includes an input channel which terminates a nozzle (diameter D) at the entrance of the interaction chamber (length L). Two diverging output channels separated by a divider extend downstream from the interaction chamber. Two electrodes, connected to a variable dc voltage source, are mounted in the valve body on each side of the interaction chamber, with the end faces of the electrodes parallel to the side walls of the chamber.

applying a prescribed voltage pulse to the right electrode. Stable flow will then continue in the right channel until a voltage pulse is applied to the left channel. The jet can be switched back from channel to channel as required by applying a voltage pulse to the appropriate electrode. The voltage pulse is only required during the switching operation and the jet is deflected as a cylindrical body (conforming to the channel), not as droplets; it will remain attached to the wall of either channel by the Coanda effect.

The force exerted on the fluid jet by the applied electric field depends on the dielectric constant of the fluid, the fluid, the charge density, the length of the jet (L) acted upon by the applied field, the diameter (D) of the jet, and the fluid density. The ratio L/D determines the position of the electrodes

with respect to the output jets and also optimum electrode geometry.

Satisfactory operation was obtained with an experimental valve made of acrylic resin and using copper electrodes which were independently connected to a 30-kV dc voltage source; water at a moderate flow rate was supplied to the inlet channel from a plenum pressurized with nitrogen gas. Valves having a larger number of stable conditions and outputs can be designed in accordance with the principle of the bistable valve.

Source: R. J. Salvinski and O. O. Fiet of
TRW, Inc.
under contract to
NASA Pasadena Office
(NPO-10416)

Circle 3 on Reader Service Card.

STUDY INDICATES FEASIBILITY OF FLUID DIGITAL COMPUTATION SYSTEMS

The use of fluid amplifiers with no moving parts for digital computation systems is of interest primarily because of their environmental tolerance and their expected long life (shelf and operating). Their tolerance to both nuclear and electromagnetic radiation and to extreme temperature ranges appears limited only by the fabrication material. Shock and vibration tolerance also appear excellent; fluid amplifiers have withstood vibration levels as high as 50g at 5000 cycles per second. Production costs of fluid amplifier components may be low because of the lack of close-fitting moving parts and bearing surfaces.

The digital integrator is the basic building block in digital differential analyzer (DDA) systems just as the operational amplifier serves as the basic building block in analog computational systems. Since the digital integrator (DI) is the basic building block for digital computation systems, it was chosen as the most appropriate component for investigating the feasibility of fluid amplifier implementation for such systems.

The results are convincing that digital computation systems using fluid amplifiers are practical. The response speed of the fluid systems is adequate for many applications; the potential for reliability in adverse environments such as nuclear radiation, heat, and vibration is superior to electronic circuitry. Typical applications which have been considered are a satellite attitude control and a guidance computer for an escape "lifeboat" for manned orbital stations.

The work done on this project has dealt only with the digital integrator, since it was considered a key feasibility problem for digital systems. For any specific application, it will be necessary to consider other parts of the system such as power supply, sensors, displays, and digital/analog converters. Investigation of these areas can be pursued most economically by considering specific application requirements.

As far as the digital integrator itself is concerned, the following represent areas where additional effort should be applied:
1. miniaturization
2. speed
3. power consumption
4. packaging design and fabrication techniques
5. instrumentation.

The work in these areas is closely interrelated. Miniaturization is required to improve speed and to reduce power consumption; the degree of miniaturization will affect the instrumentation requirements for monitoring and testing and will dictate fabrication methods. The package design must permit very close coupling of elements to achieve high operating speeds.

The following documentation may be obtained from:
National Technical Information Service
Springfield, Virginia 22151
Single document price $6.00
(or microfiche $1.45)
Reference:
NASA-CR-61092 (N66-18313) Fluid Amplifier Digital Integrator

Source: General Electric Co.
under contract to
Marshall Space Flight Center
(MFS-520)

TEMPERATURE-CONTROLLED FLUIDIC DEVICE: A CONCEPT

A symmetrical fluidic device has been conceived that may provide an improved method for directly converting electrical signals to mechanical signals in the form of a fluid-flow parameter (pressure, thrust, flow rate, etc.). The device would have the following advantages over conventional fluidic amplifiers: 1) greater efficiency would result because all fluid would be used in the power jets; 2) there would be less danger of malfunction due to clogging, since no small-diameter control ports would exist; and 3)

Many parameters affect the magnitude of the departure angle. Among them are: 1) the nozzle geometry; 2) the Reynolds number and Mach number of the jet; 3) the ratio of nozzle exit pressure to the static pressure in the space outside the nozzle; and 4) the ratio of the temperature of the curved wall to the jet stagnation temperature. Of these, the wall temperature is the easiest to control, with, for instance, an electric heating element or Peltier-effect device.
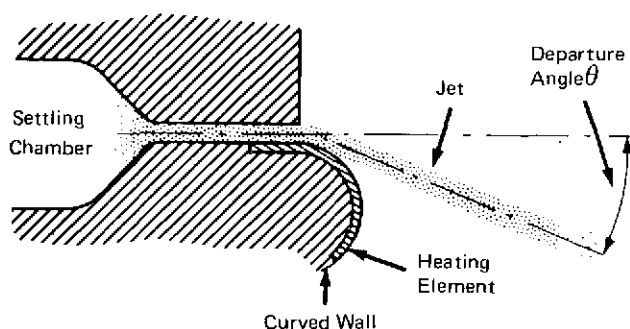

Figure 1. Jet Deflection by the Coanda Effect

Figure 2. Temperature-Controlled Fluidic Device

higher gain would be produced, because heat would be used only to deflect the jets, rather than to change momentum or pressure.

The jet deflector could be applied wherever there must be a good, reliable interface between electronic and fluidic systems. Such situations exist, for example, where the requirement for fast, complex logic necessitates the use of an electronic controller, but the final output must be mechanical in nature; or, where input signals are electrical (or thermal) by nature, but advantages can be gained by fluidic signal processing.

Figure 1 illustrates the basic operating principle of the device, known as the Coanda effect. Essentially, the effect describes the deflection of a fluid jet caused by its adherence to a curved wall at an asymmetric nozzle. The figure shows the deflection for a subsonic jet. In the case of a supersonic jet, however, the deflection actually occurs in a direction away from the curved wall.

The concept described here, and illustrated in Figure 2, is intended to eliminate or reduce the effects of all the undesirable parameters on the departure angle, leaving it essentially a function only of the controlled wall and jet temperatures. This is done by arranging two (or more) identical nozzles to produce a symmetrical array of primary jets, which merge at some distance downstream from the nozzles to form a single, secondary jet. Downstream from the merging point, the device behaves like a conventional fluidic amplifier. In the area of the primary jets, however, the direction of each jet is controlled by varying the temperature of the curved wall at the nozzle.

Source: F. H. Rehsteiner of
Stanford University
under contract to
NASA Headquarters
(HQN-10446)

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BYPASS FLUIDIC SYSTEM
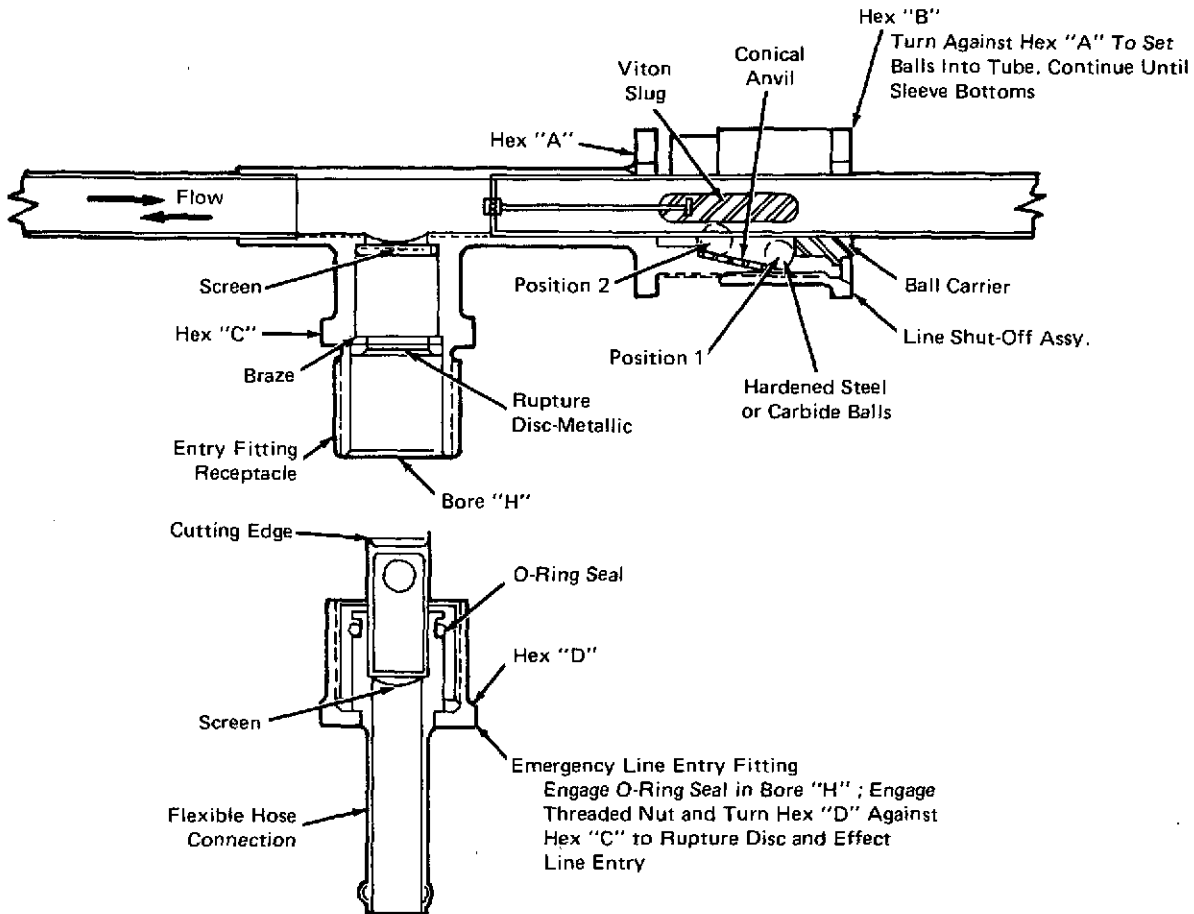
A new bypass assembly has been developed which may be useful in the fluid power industry. The innovation comprises two basic elements (see figure), a shutoff device and a line entry device. A swaging device is incorporated in the shutoff device; this squeezes the tube onto a sealing plug when a hexagonal nut is tightened. The entry fitting in the line entry assembly contains a cutting ledge, which punctures a sealing disc in its entry receptacle when the two fittings are coupled.

Wherever a shutoff device or bypass entry is required the elements can be utilized individually. It does not degrade the system to which it is fitted and it provides a means of shutting down a fluidic system without extra seals and consequent possibility of leakage. Also, the system can re-establish the flow without loss of fluid. This is especially valuable where a critical or hazardous fluid is involved. The shutoff system offers a straight-through flow path for minimal pressure errors and avoids external leakage paths.

Source: M. D. Meader of
United Aircraft Corp.
under contract to
Johnson Space Center
(MSC-13809)

Circle 5 on Reader Service Card.

EXPERIMENTAL SCALING STUDY OF FLUID AMPLIFIER ELEMENTS

Supply

Control   Control

Vent   Vent

Outlet

BISTABLE ELEMENT

Supply

Control

Vent   Vent

Outlet

**BOUNDARY LAYER CONTROL
PROPORTIONAL ELEMENT**

Control

Control

Supply   Supply

Outlet
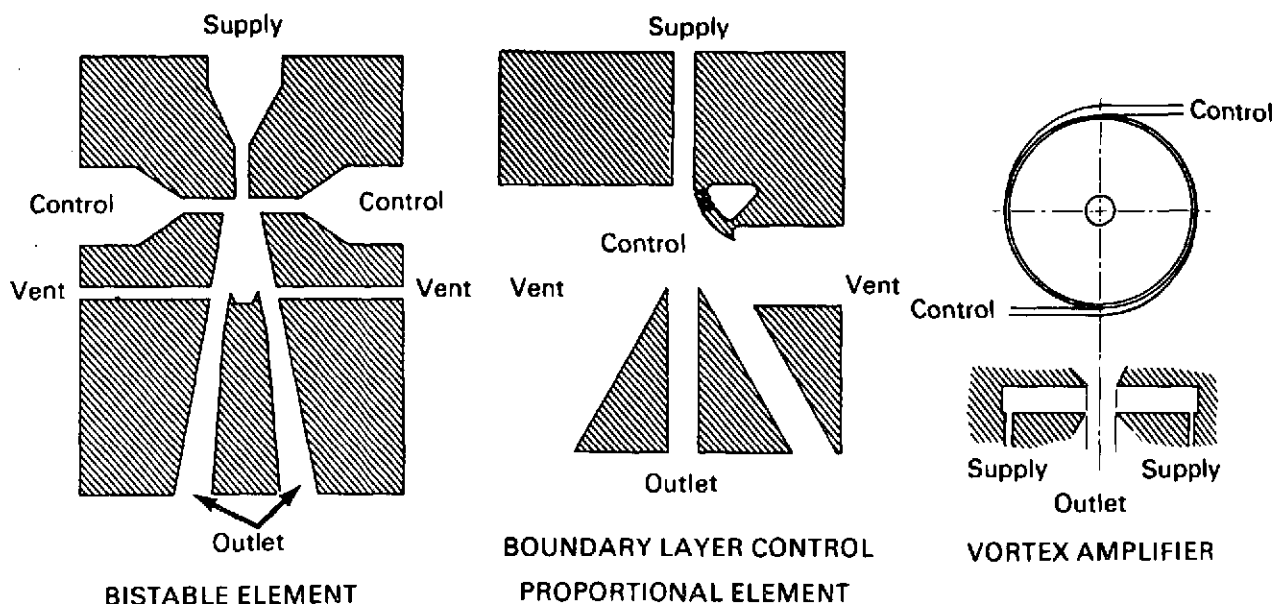
VORTEX AMPLIFIER

This study examines some of the scaling parameters of three, fluid amplifier elements. The elements are: a bistable device, a boundary layer control device, and a vortex device. In all three devices, fluid enters a box which has one or more outlet holes, one or more control flow holes, and one or more auxiliary holes. For a fixed supply condition and a fixed reservoir pressure, the rate at which fluid leaves through an outlet hole is determined by a relatively small amount of fluid entering through a control hole.

The study examines the way amplifier performance is related to size (scaling laws). It is not concerned with element design. For the purpose of determining the scaling laws, the nondimensional performance of geometrically similar elements is examined experimentally, choosing designs which have previously been developed. Consideration has been restricted to single fluid operation (that is the surrounding atmosphere consists of the same kind of fluid as the supply fluid) and to reports on experiments in air and in water. For the most part, sufficiently low fluid speeds are considered so that air can be regarded as not compressed. As is common in fluid amplifier work, consideration is

restricted to geometries in which the intended operation is two-dimensional; consequently, similarity means maintaining similar planforms. Since physical elements do not behave two-dimensionally, effects of varying the length perpendicular to the representative plane of the planform are examined to some extent; only the steady flow is considered.

Even with the restrictions imposed, the number of variables remains too large for convenient use. Consequently a major object of this study is the determination of ranges of operation in which some of the variables are not very important, and the establishment of ways of compacting the data. Hopefully, these simplifications can be applied to other elements. Obviously, an important byproduct of the attempt to establish scaling laws is the actual performance characteristics of the particular elements investigated.

Circle 6 on Reader Service Card.

FLUIDIC ANALOG AMPLIFIER
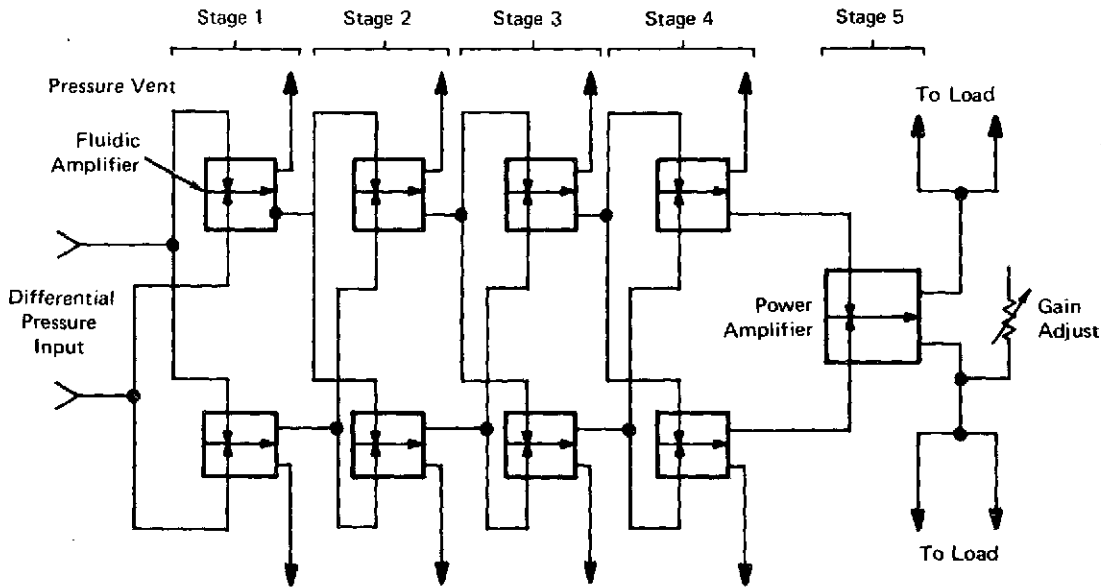
A five-stage, high-gain, push-pull fluidic amplifier has been designed to provide increased range and improved linearity compared to previous fluidic amplifiers.

A differential pressure from a pressure source (e.g., a fluidic transducer or control element) supplies the input to a pair of beam-deflection-type fluidic amplifiers in the first stage. Each amplifier, with one output vented to ambient and arranged in parallel with another amplifier in the succeeding stage, supplies an input to that stage. In this manner, the pressure signal is amplified through the first four stages. The output of the fourth stage drives the power amplifier comprising the fifth stage. An applied load is driven by the differential pressure output from the power amplifier. The pressure gain (ratio of output pressure differential to input pressure differential) is approximately 74 for the five stages.

This fluidic amplifier was designed to operate in conjunction with the fluidic transducer described in Tech Brief 68-10537. It should have general application in fluid-process control systems.

Source: Electronics Research Center
(ERC-10102)

Circle 7 on Reader Service Card.

Section 2. Laboratory Aids For Fluid Technology

DEVICE SAMPLES CONDENSIBLE VAPORS IN HIGH-PRESSURE GAS
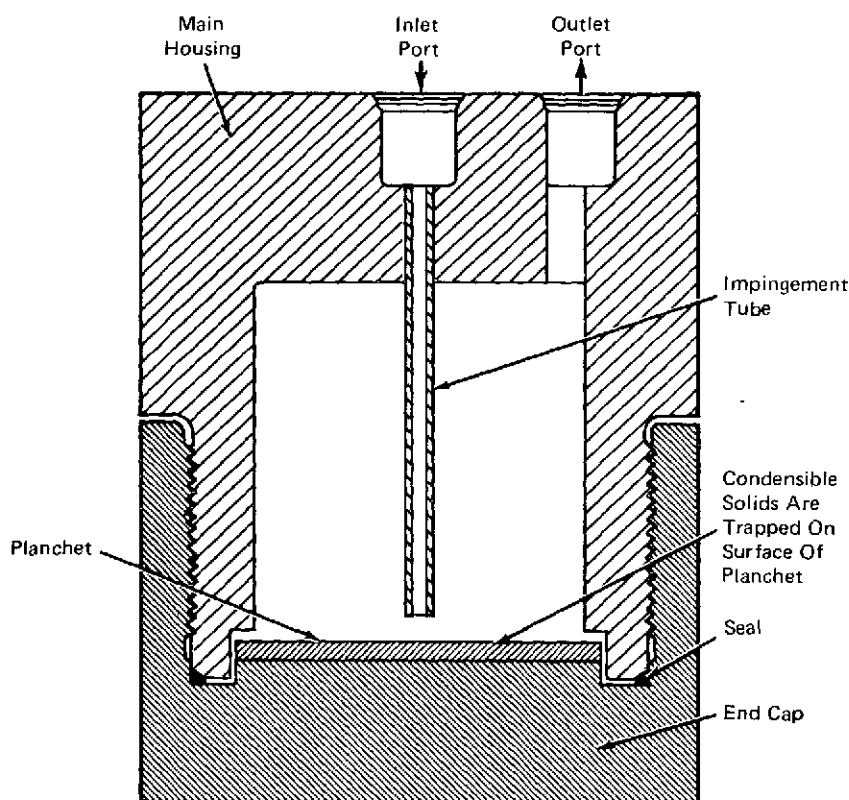
Figure 1. Gas Sampling Vessel

A gas sampling device has been developed that is capable of trapping condensible impurities in gas at high pressure. Previous techniques required that such analyses be conducted at essentially atmospheric pressure. Unfortunately, during normal reduction in pressure, adiabatic expansion of the gas can cause some of the impurities to condense in the pressure-reducing device. As a result, these impurities will not appear in the sample trapped for analysis.

The principle components of the high-pressure gas sampling device are shown in Figure 1. Operation of this device is relatively simple. When a test is to be run, it is first ascertained that the device is clean and dry. The device is then installed in a test setup as shown in Figure 2. With both petcocks closed, the high pressure gas source to be analyzed is turned on. When the device stabilizes at the bath temperature, the inlet and outlet petcocks are opened and the
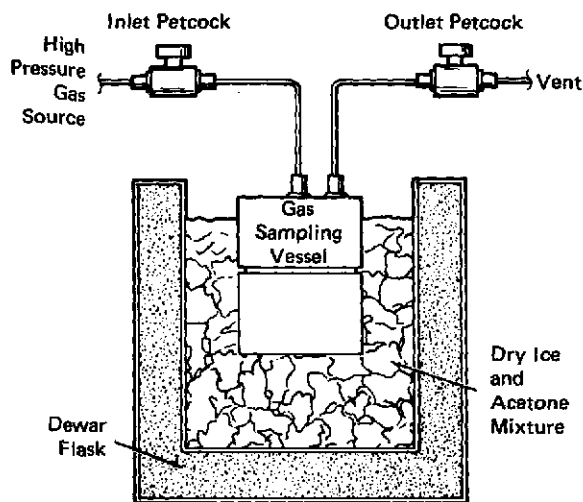
Figure 2. Test Setup

desired volume of gas is allowed to flow through the device. As the gas flows through the device, condensible impurities will be trapped on the removable planchet. After the desired volume of gas has passed through the device, the system is shut down and brought back to room temperature. The device, with the high pressure sample, is then connected to a gas analyzer such as a gas chromatograph or mass spectrograph. By slowly expanding the gas into the analysis train, any revaporized substances which had been trapped on the planchet are analyzed. The device is then opened, and any condensible solids that are trapped on the planchet can be determined by standard analytical techniques.

Source: D. Gregory and R. T. Howard of
IBM Corp.
under contract to
Marshall Space Flight Center
(MFS-20608)

Circle 8 on Reader Service Card.

LARGE-AMPLITUDE INVISCID FLUID MOTION IN AN ACCELERATING CONTAINER

A study was made to characterize the dynamic behavior of the liquid-vapor interface of an inviscid fluid in an accelerating cylindrical container and the flow of the liquid from one end of the container to the other. In particular, a combined analytical-numerical method was developed for determining certain large-amplitude motions. This large-amplitude analysis, which does not involve any linearizations in the equations of motion, is a natural extension of a previous study of symmetric fluid motion to the asymmetric case. As in the previous study, surface tension is included as a smoothing term, and the constant contact angle condition is imposed. The method applies to all but surface tension-dominated motions. Problems where the surface is initially in motion can also be treated by this method.

The method is based on the expansion of the velocity potential in a series of harmonic functions with time-dependent coefficients. The time-dependent coefficients are determined numerically by an ortho-normalizing computation in order to satisfy the required boundary conditions. Different sets of harmonic functions, depending on the container geometry and various orthogonalizing computations, have been used in the analysis. It was found that a wide variety of large amplitude oscillatory or sloshing motions could be computed over extended time periods. It was also found that large amplitude reorientation motions could be computed over relatively long periods of time, but that an instability developed in the computation in this type of motion. To eliminate the instability in the computation, which manifests itself in surface splashing, a technique of velocity extrapolation was used to predict the motion beyond the point at which the instability developed.

Source: L. M. Perko of
Lockheed Missiles and Space Co.
under contract to
Johnson Space Center
(MSC-11560)

Circle 9 on Reader Service Card.

EFFECT OF WALL ROUGHNESS ON LIQUID-OSCILLATION DAMPING IN RECTANGULAR TANKS

The dynamic behavior of contained liquids is currently the subject of intensive study. The purpose of this investigation was to determine the effect of wall roughness within tanks, specifically as a source of damping. Increasing the wall skin friction would be expected to increase the rate of damping, and earlier studies of damping in smooth-wall tanks confirmed this assumption.

To accomplish the present investigation, tests were conducted in two rectangular glass tanks using silicon carbide grit bonded to the tank walls to produce roughness. Testing procedures included the effects of roughness height, roughness location, and extent of roughness at various values as well as an in-depth discussion of flow regimes and the mechanism of damping because of roughness. Additional investigations included amplitude decay, effects of wetted perimeters on damping, and Reynolds number and boundary layer thickness data. The study of the effectiveness of wall roughness for damping liquid oscillations in rectangular tanks produced the following results: (1) The value of log decrement of damping, δ, increased in nearly linear fashion as the roughness height was increased. With roughness of which the height was 0.427% of the tank length covering 8.9% of the wetted wall area, δ was 65% greater than the smooth-wall value. (2) Roughness near the liquid surface was more effective in damping liquid oscillations than roughness deep in the tank. There was a sharp increase in damping corresponding to wiping of the roughness by the surface edge during decay. Maximum damping was produced by a particular roughness strip when the strip was at the maximum depth at which the surface edge wiped the roughness throughout decay of the oscillation. Narrow strips of roughness (3.6% of the wetted wall area) in contact with the liquid surface edge during decay were found to produce 75% as much damping as roughness covering the entire end walls of the tank (36% of wetted wall area). (3) The damping was found to increase with decreasing values of $L^{3/2}g^{1/2}/\nu$, but the increment of damping because of wall roughness remained nearly constant through most of the $L^{3/2}g^{1/2}/\nu$ range (L = tank length in cm; g = acceleration in the direction tending to hold the liquid in the tank bottom, in cm/sec^2; and ν = kinematic viscosity of test liquid in cm^2/sec). The increment of δ, because of a particular wall roughness configuration, was 34.5% of the total at $L^{3/2}g^{1/2}/\nu =$ 650,000 and was only 13.5% of the total δ at $L^{3/2}g^{1/2}/\nu = 27,000$.

A formula was constructed to fit the smooth-wall damping data through the range values of $L^{3/2}g^{1/2}/\nu$, investigated by multiplying Keulegan's equation for smooth-wall damping by an empirical constant. An expression, formed by adding a term dependent on roughness height relative to tank length to the above formula, gave a fair representation of the effect of roughness height on damping through a range of $L^{3/2}g^{1/2}/\nu$ values for a particular roughness configuration. Reynolds number and boundary layer thickness calculations indicated that the test roughness should have little effect on viscous damping. Other calculations showed that the damping because of roughness could be produced by surface tension acting on the roughness-height-dependent wetted perimeter through a changing contact angle.

This information may be of interest to designers of tanks and containers, especially truck, railroad, and marine tankers.

Source: F. M. Bugg
Marshall Space Flight Center
(MFS-20799)

Circle 10 on Reader Service Card.

FLUID FILTRATION TECHNOLOGY

A recent study of hydraulic system performance in relation to contamination tolerance levels has investigated the several parameters of fluid filtration possibilities. Principally, surface filtration media and depth filtration media were studied. The surface media consisted of fine wire screen devices, while the depth media was of randomly-spaced fiber structures. Additionally, operation of three basic factors, infiltration, generation, and filtration within a fluid system were studied. Infiltration consists of contamination from without the system, generation consists of system-produced contamination (particles from wearing members such as seals, bearings, or any sliding, scuffing, or friction-producing surfaces), and filtration consists of media (surface or depth) used to entrap such contamination.

(a) which may generate contaminant GC by its normal function and may permit the infiltration of contaminant EC. Representative fluid samples, extracted at points 6 and 1 would indicate distinct contamination levels. Also, the level at point 1 would be modified as the fluid passed through (b). This would result in disparate contamination levels at points 1 and 2. Component (c) adds EC and GC to the fluid to produce the level at point 3. At this point, the flow splits and the influence of the parallel components (d) and (e) is reflected by the level at points 3, 4, and 5, and thus yields the contamination level at point 6.

This study, which has been devoted to the measure of component tolerance of contamination within a fluid system, has employed closely calibrated filtra-

a. Component

b. Filter

c. Summing Junction
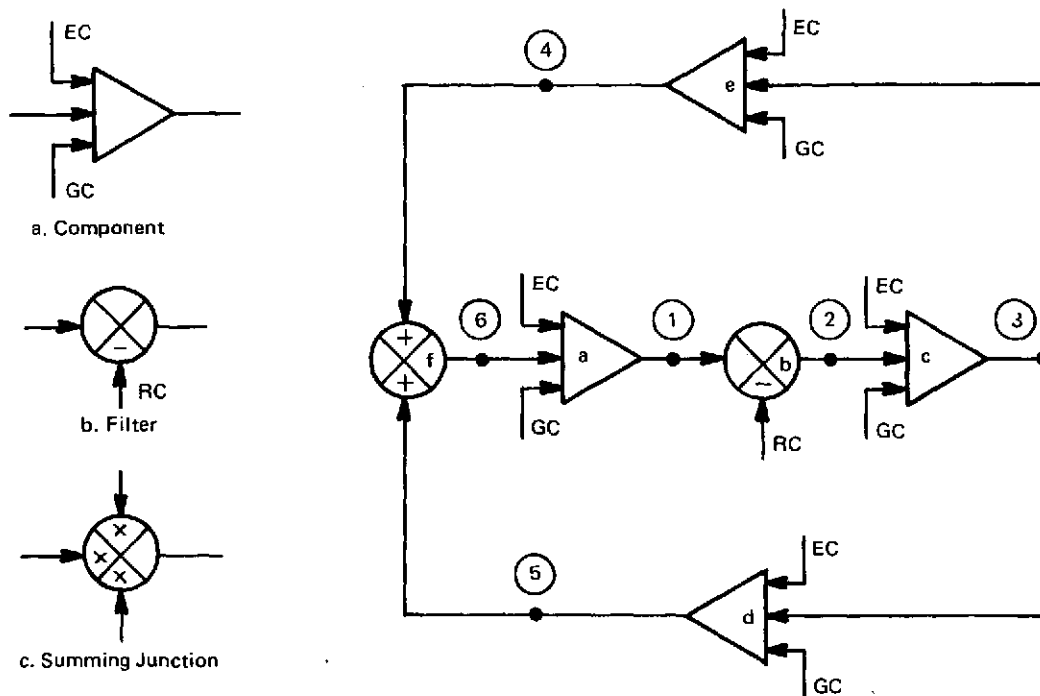
In this study, the activity of components in a hydraulic power system was used to arrive at meaningful conclusions. The diagram illustrates (a) a pump, valve, hose, actuator, or reservoir as components which exhibit generation and/or infiltration actions. Symbol (b) represents the only filtering device in the system. Symbol (c) is the summing function and characterizes the interconnection of related components in the system. The diagram depicts the contamination level at point b fed into component

tion measurement media used in conjunction with selected known contaminants.
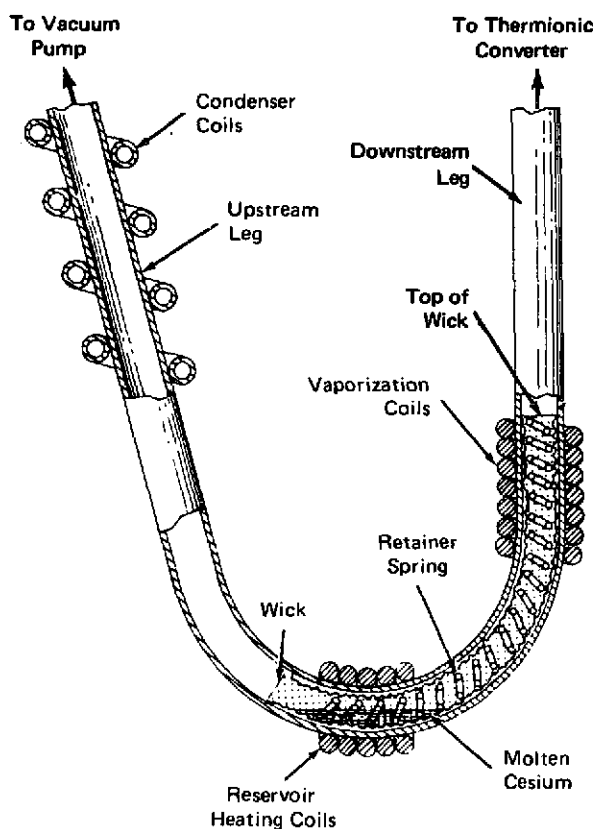
Circle 11 on Reader Service Card.

DISTILLATION DEVICE SUPPLIES CESIUM VAPOR AT CONSTANT PRESSURE

A distillation apparatus in the form of a U-tube makes a compact unit that will supply small amounts of pure cesium vapor at constant pressure to a thermionic converter (see figure). At the required converter operating pressure, the distilled cesium vapor must be maintained at 310° C.

The upstream leg of the U-tube is connected to a vacuum pump for withdrawal of noncondinsible impurities. Surrounding this leg are condenser coils for circulation of a coolant. The bottom portion of the U, which serves as a reservoir for the liquid cesium, is surrounded by heating coils that maintain the cesium in the molten state. Extending from the bottom portion into the downstream leg of the U is a wick (capillary) made, for example, from fine mesh stainless steel screen arranged in a tubular configuration to match the inner surface of the U. The wick is held in contact with the inner walls of the U-tube by a retainer spring. The wick carries the molten cesium up into the top of the downstream leg of the U by capillary action. Heating coils around the downstream leg are used to vaporize (at 310°C) the molten cesium that has risen to the top of the wick. The heating coils surrounding the reservoir at the bottom of the tube are set to a temperature sufficiently below that of the vaporization heating coils to maintain a desired pressure differential in the system. Since the thermionic converter is operated at a temperature higher than that of the top of the wick, an equilibrium occurs in which the molten cesium is evaporated from the wick. Any vaporized metal which does not pass into the converter is condensed by the condenser coils and returned to the molten cesium reservoir. The wick is continually refilled by the molten cesium, which is carried to the top of the wick where vaporization occurs, resulting in a constant pressure of cesium vapor in the converter. The magnitude of the cesium vapor pressure is determined by the evaporation rate of the liquid cesium, the temperature, and the diffusion rate of the liquid cesium from the reservoir to the top of the wick.

Source: A. Basiulis and P. K. Shefsiek of
RCA Corp.
under contract to
NASA Pasadena Office
(XNP-08124)

Circle 12 on Reader Service Card.

To Vacuum Pump — Condenser Coils — Upstream Leg — Wick — Reservoir Heating Coils — Downstream Leg — To Thermionic Converter — Top of Wick — Vaporization Coils — Retainer Spring — Molten Cesium

GAS/LIQUID SEPARATOR

This novel centrifugal device forcibly removes gas bubbles from liquids, thus enhancing the performance of fluid-handling devices such as pumps and heat exchangers. Two steps are employed in this technique of separating the gas from the liquid (see figure). First, the gas is forced into a central core by centrifugal action linked with a helical guide. Secondly, the liquid filters radially out of the center chamber through a micro-mesh screen that prevents the escape of any remaining gas bubbles. Due to its construction, that features the helical flow path and the absence of moving parts, this device can be operated efficiently
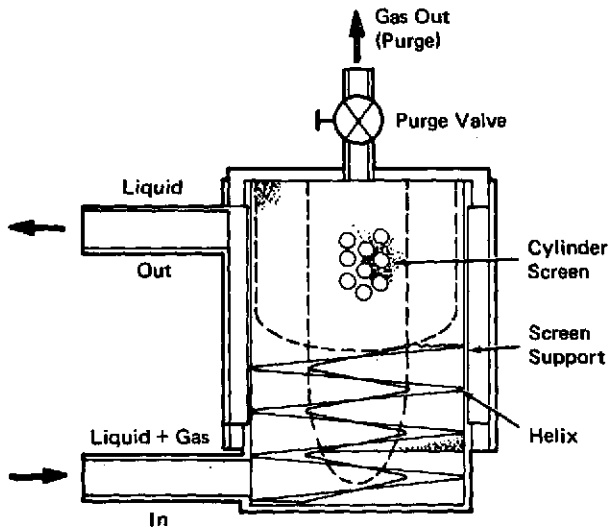
and purged under both zero gravity and gravity field conditions. The helix also serves to maintain the flow velocity necessary for separation of gas from liquid at low pressures.

Source: R. P. Callaghan and L. A. Manchester of
United Aircraft Corp.
under contract to
Johnson Space Center
(MSC-13799)

Circle 13 on Reader Service Card.

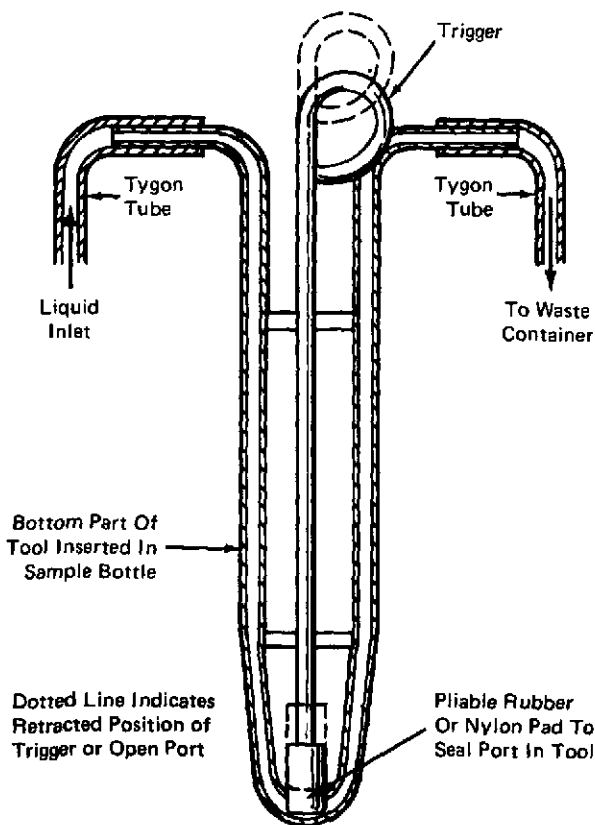## TOOL OBTAINS AIR-FREE SAMPLES OF WATER GLYCOL: A CONCEPT

This tool should prove useful for taking water glycol or other liquid samples for dissolved gas testing without entrapping air while sampling.

As illustrated, the tool consists of a pliable tubular structure equipped with an inlet, an outlet, and a valve arrangement in its base. The tool is inserted into the sample bottle, its inlet is connected to the sample supply source, and its outlet is connected to a waste container. The water glycol supply is turned on and allowed to flow through the tool until a clear, bubble-free flow is observed entering the waste container. A clamp is fastened to the waste line, and the trigger is simultaneously pulled, unseating the valve at the base of the tool, permitting air-free liquid to fill the sample bottle to the desired depth.

The tool can be shaped to fit the particular .collection bottles used.

Source: B. J. Smith and B. M. Fairburn of
Rockwell International Corp.
under contract to
Kennedy Space Center
(KSC-10631)

*No further documentation is available.*

WIDE ANGLE SCREENED CYLINDER DIFFUSER

This diffuser has the advantages of simplicity and low cost when compared with conventional nozzle types. In addition, it is short in length, produces a low pressure drop, and has a multi-source capability. The device diffuses well at all flow rates up to the choked-flow condition of the inlet lines.

The diffuser (see figure) consists of a cone that is fed by two high-pressure gas-supply lines having different near-critical flow rates. The cone is made up of a

some small angle (about 7° for most gases). Thus, many low pressure-drop, small holes can diffuse a gas flow better than a few large holes of equal pressure drop for a given (short) axial distance.

In tests, this diffuser smoothly distributed flows in a short axial distance across large exit areas, with simply machined cylindrical shapes and with multiple (and also unequal) source flows, and operated with a minimal pressure drop.
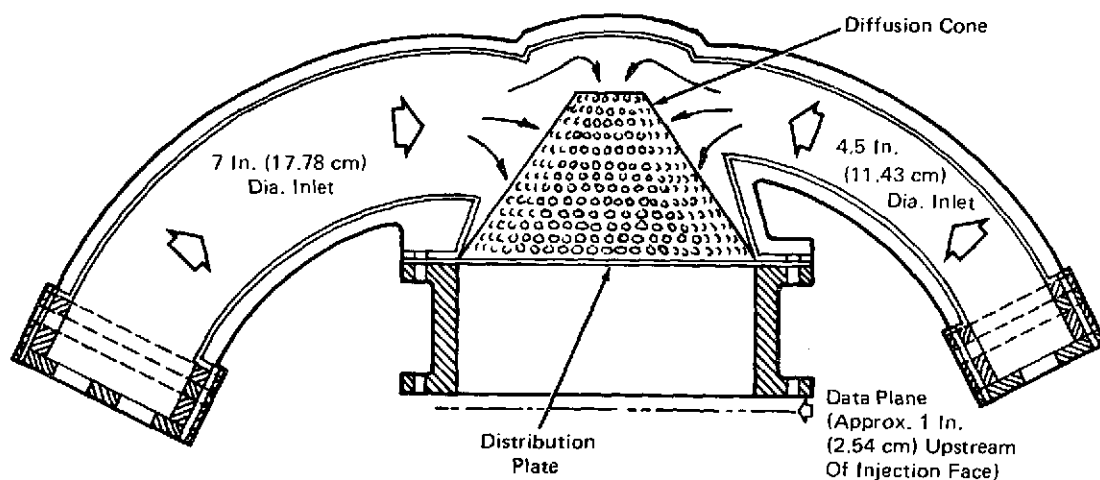
Hot Gas Manifold Cold Flow Schematic

series of multi-orifice plates and wire mesh screens arranged in a graduated manner that offers larger and larger plate orifices and screen meshes to the gas flow.
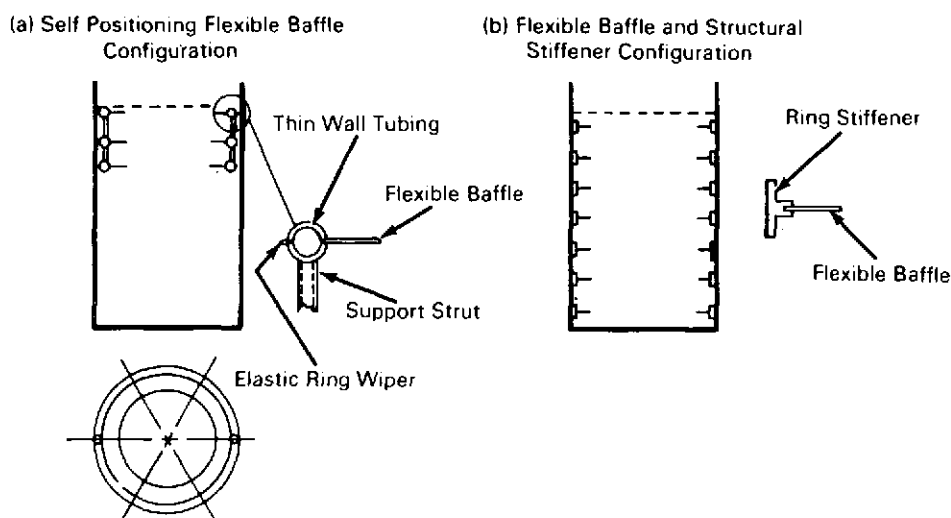
Theory of this diffuser relies on the fact that gases will fill a plenum if a small pressure drop exists, and that the boundary layer formed at each orifice in perforated plate or screen will diffuse at

Source: R. A. Hewitt of
Aerojet Liquid Rocket Co.
under contract to
Marshall Space Flight Center
(MFS-21507)

Circle 14 on Reader Service Card.

Section 3. Fluid Control Devices

FLEXIBLE RING BAFFLES FOR DAMPING LIQUID SLOSHING

(a) Self Positioning Flexible Baffle Configuration

Thin Wall Tubing

Flexible Baffle

Support Strut

Elastic Ring Wiper

(b) Flexible Baffle and Structural Stiffener Configuration

Ring Stiffener

Flexible Baffle

These baffles are smaller, more flexible, and less costly than conventional baffles used to damp out sloshing in liquid tankage that is subjected to rigorous motion.

The tank is fitted with a series of baffles which are capable of moving, deforming, and/or deflecting with respect to the tank wall. The flexible baffles are positioned within the tank by means of a support-guide system as shown in the sketch. Sketch (a) illustrates a guided, self-positioning flexible baffle configuration. Several flexible rings are supported by buoyant tubes fitted around the tank periphery which position the baffles slightly below the liquid surface. As the propellant is consumed, the baffles follow the mean level of the propellant due to the buoyant action of the liquid while the tank walls provide constraint for any lateral or pitching oscillations. If stiffeners are required in the tank, the flexible

baffles and support rings shown in sketch (b) may serve the dual purpose of slosh damper and stiffener.

The following documentation is available from:
National Technical Information Service
Springfield, Virginia 22151
Single document price $6.00 (N67-19888) or $3.00 (N71-34284)
(or microfiche $1.45)

References:

NASA TN-D-3878 (N67-19888) Effectiveness of Flexible and Rigid Ring Baffles for Damping Liquid Oscillations in Large-Scale Cylindrical Tanks.
NASA-CR-1880 (N71-34284) Engineering Study of Flexible Baffles for Slosh Suppression.

Source: D. G. Stephens and G. W. Brooks
Langley Research Center
(LAR-90194)

FLUID TECHNOLOGY

DUAL DAMPING ATTENUATOR: A CONCEPT

Forward Damping   Return Damping
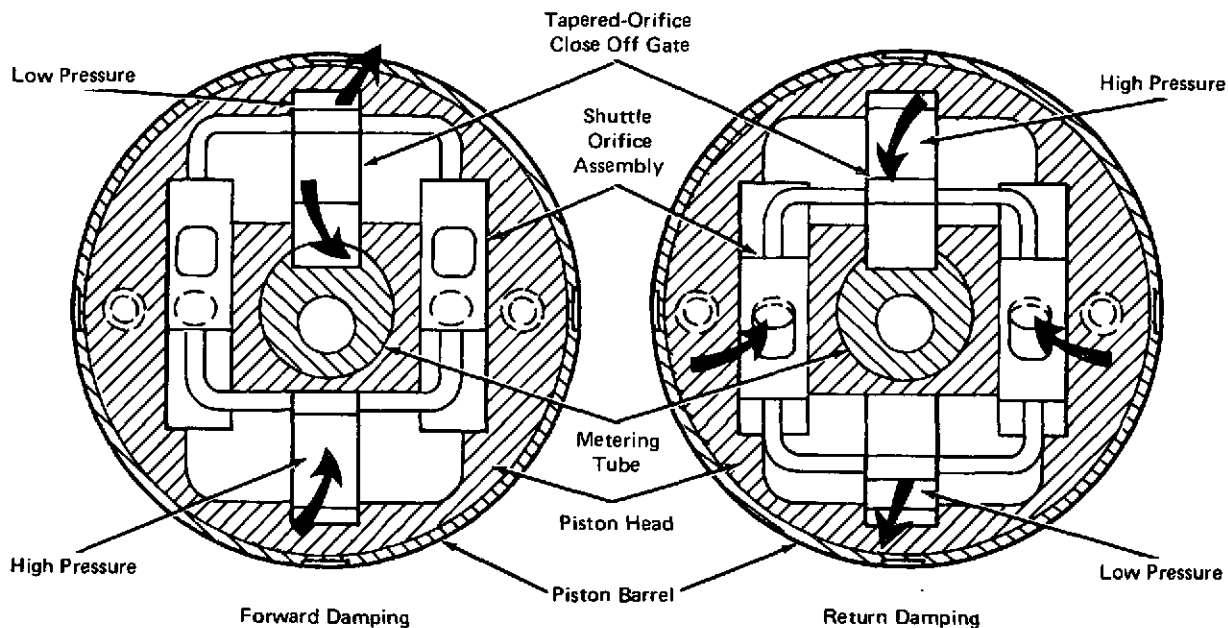
This conceptual device would employ variable orifices in a hydraulic cylinder to provide load attenuation in both compression and extension strokes. Uniform deceleration and damping force assures that no shock loads are imposed on the mechanism at either end of the piston stroke. This attenuator concept is based on the use of a tapered-slot metering tube for damping during the compression stroke, and a slotted piston head for damping during the extension stroke. By using a variable orifice, a uniform force (neglecting friction forces) results in constant deceleration.

During compression, the higher pressure on the forward side of the piston face provides the necessary force to hold the shuttle orifice in the up (forward damping) position. This provides any desired damping effect by proper sizing of cross section area and slot length. Should the piston tend to reverse direction, the higher pressure will act on the reverse side of the piston head. This will force the shuttle orifice down, sealing off the tapered slot while opening two variable orifices in the piston head (return damping). Desired return damping effects may be produced by the sizing of these orifices.

This self-actuating attenuator may be used to isolate shocks (earthquakes, wind gusts) from stationary structures and to provide controlled deceleration of loads.

Source: C. Vibbart, T. F. Ryan, and A. P. Arora of
Service Technology Corp.
under contract to
Johnson Space Center
(MSC-13841)

No further documentation is available.
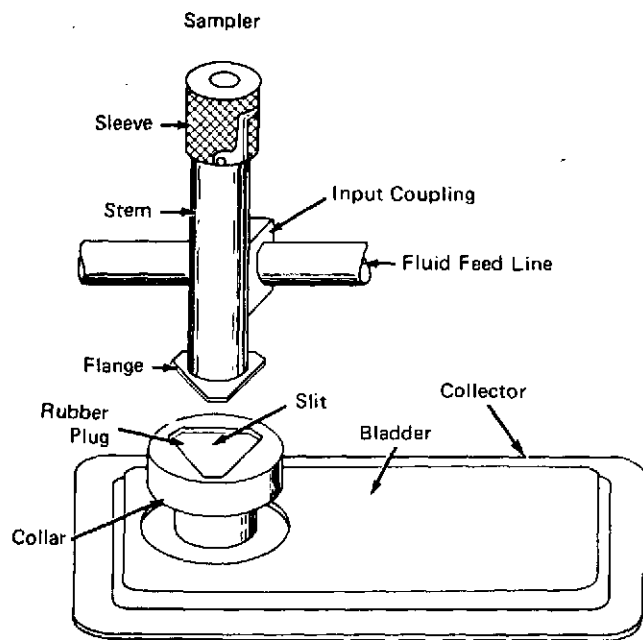
FLUID SAMPLE COLLECTION AND STORAGE DEVICE

Figure 1. Fluid Sampling Device

Figure 2. Cross-section of Fluid Sampling Device

A fluid sampling system has been developed which enables the user to quickly and easily collect a sample from a low-pressure fluid system and to store it for an indefinite period, with little risk of contamination of either the sample or the surrounding environment. Its two major components, a collector and a sampler, are shown in Figure 1.

The collector is a plastic bladder, fitted with a collar which is sealed with a tight-fitting, slitted rubber plug. The sampler comprises the following: 1) an input coupling, which connects the fluid feed line to the sampler; 2) a hollow stem, with a flange which fits into a recess on the collector collar; 3) a hollow probe inside the stem, which may be extended through the rubber plug into the bladder; 4) a double-acting valve, which passes fluid from the input coupling through the hollow probe and into the bladder, only after the probe has been extended and then rotated into the correct orientation; and 5) a sleeve, mounted outside the stem, which controls the extension and rotation of the probe, and which is furnished with a lock screw to secure the probe in
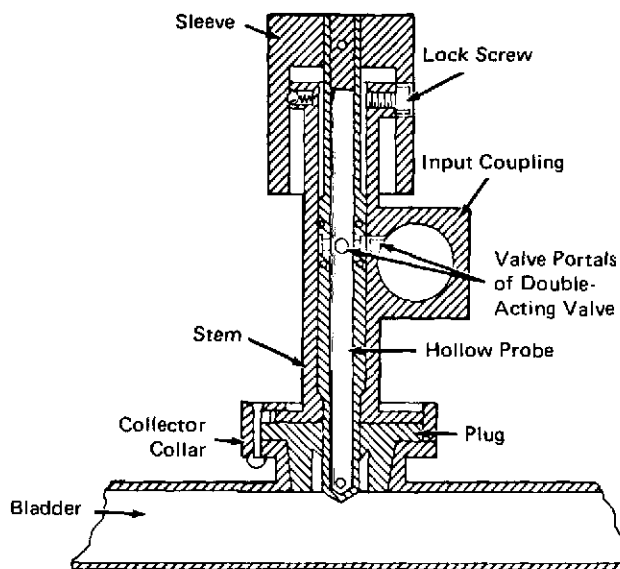
any desired position. The cross-section presented in Figure 2 shows the sampler and collector coupled, with the probe extended through the plug and the valve closed by a 90 degree rotation of the sleeve.

After the sample has been collected, the valve is closed, the probe is withdrawn, and the collector is separated from the sampler. The slit in the rubber plug recloses, sealing the sample within the bladder.

This invention has been patented by NASA (U.S. Patent No. 3,438,263). Inquiries concerning non-exclusive or exclusive license for its development should be directed to Patent Counsel, Mail Code AM, Lyndon B. Johnson Space Center, Houston, Texas 77058.

U.S. Patent No. 3,438,263 may be obtained from the United States Patent Office. Price $0.50.

Source: D. Cohen and S. E. Stone of
The Whirlpool Corp.
under contract to
Johnson Space Center
(MSC-10962)

FLUID MIXING TECHNIQUE INCREASES GAIN AND OUTPUT POWER OF CO_2 LASER SYSTEMS
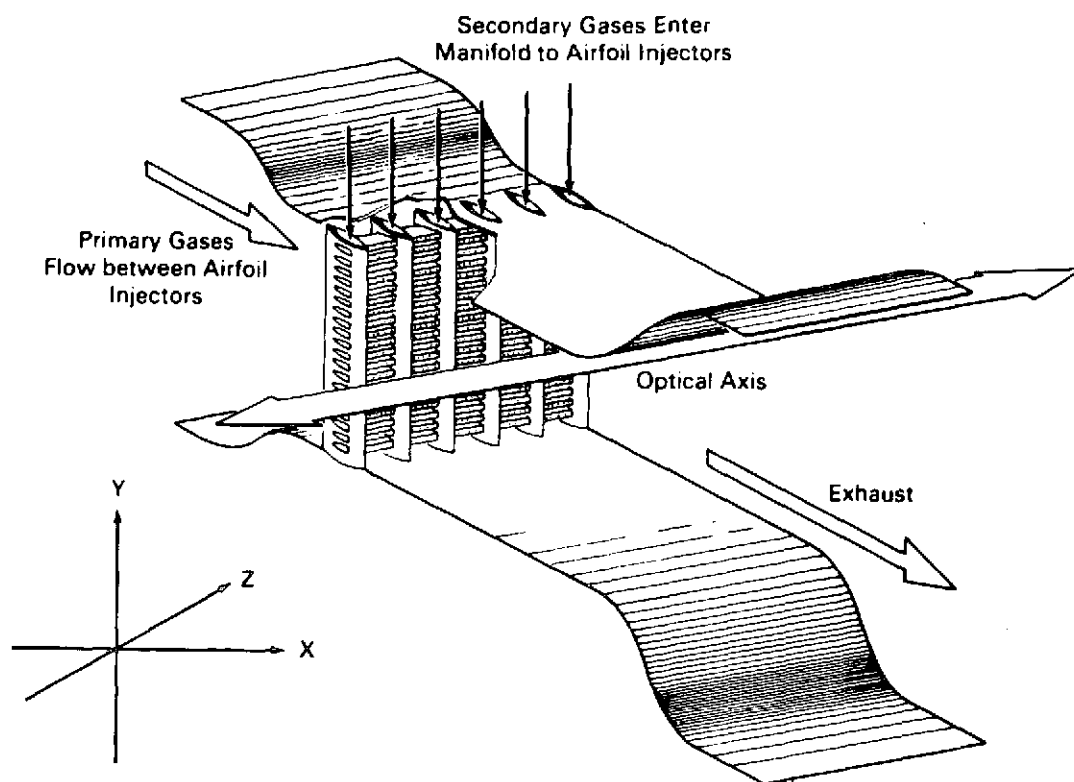
Carbon dioxide lasers which use conventional slow flowing gas systems are limited in gain, tube size, and ultimate output power by the properties of the surrounding surfaces.

A high speed flowing gas system has been developed that provides uniform mixing in times that are short (on the order of 10^{-4} sec) when compared to flow transit times and CO_2 vibrational relaxation times. This type of high speed flowing gas system minimizes the effects of the surrounding surfaces and provides a uniformly high gain that is independent of dimensions transverse to the flow direction.

Injectors with openings or slits along their length are stacked in a parallel array shown in the figure, such that a gas enters the injector ends. Another gas or gas mixture flows through the space between adjacent injectors. The injectors and openings are of such size and spacing that mixing by diffusion is more rapid than the characteristic collisional relaxation times for excitation energy of the mixed gases at typical (1 to about 100 torr) pressures in gas laser systems. Additionally, there is no appreci-

able loss of excitation energy to the wall surfaces from the insignificant wall collisions at the injector surfaces by particles in the gas flow.

Multiple injector arrays are formed by multiple manifold-injector combinations. The procedure of adding manifold sets with their axes lying alternately in the X and Y directions can be indefinitely continued, subject to the finite pressure drop associated with the gas flow through the manifolds, injectors, and openings. Thus the gases passing between adjacent injectors may be prepared in special ways (e.g., excited by an electrical discharge, heated, dissociated, ionized, etc.) and retained in the prepared state with minimum destruction at wall surfaces.
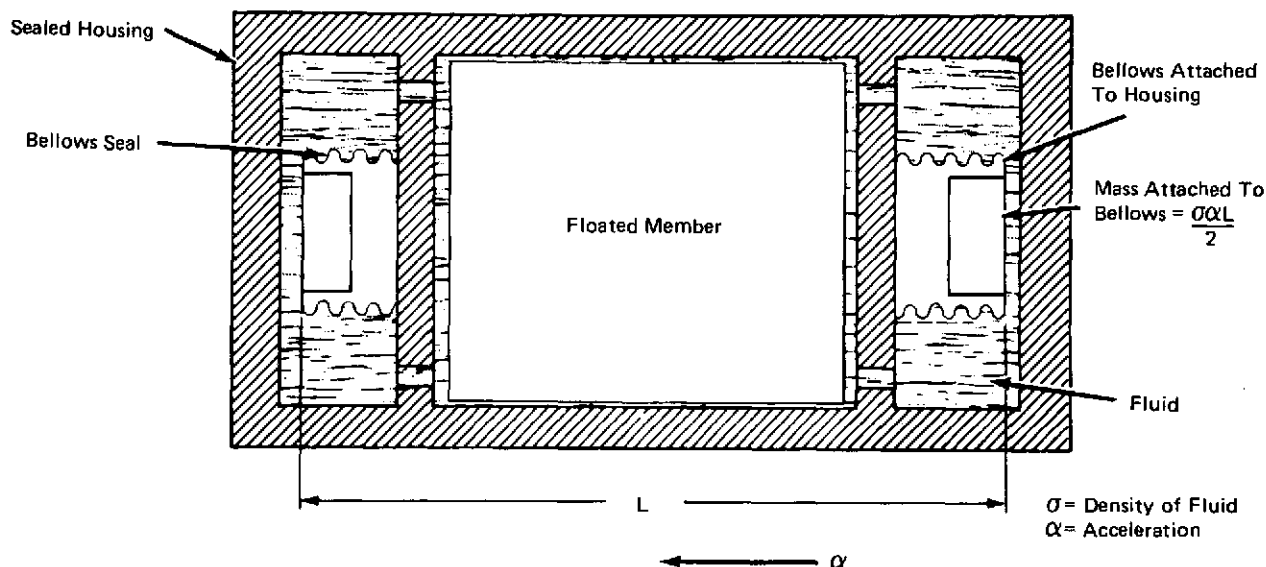
Among the important advantages offered by this high speed flow system are: (1) a uniform and low translational gas temperature can be maintained by rejecting unused energy with the exhaust flow rather than having this energy dissipated at the wall surfaces; and (2) a more uniform electrical excitation can be achieved by minimizing ion losses produced by surface recombination.

This high speed fluid mixing technique can also be used in air pollution studies, gaseous combustion systems, and fundamental investigations that deal with gas kinetics.

ACCELERATION-INSENSITIVE FLUID EXPANSION COMPENSATOR

Sealed Housing

Bellows Seal

Floated Member

Bellows Attached To Housing

Mass Attached To Bellows = $\dfrac{\sigma \alpha L}{2}$

Fluid

L

α

σ = Density of Fluid
α = Acceleration

To achieve high performance levels in floated-angle and acceleration-sensitive instruments, the floated member must be free to rotate about the output axis with minimum friction. The floatation plus magnetic suspension provide a friction-free rotational axis for the floated member. Float motions parallel or perpendicular to the output axis will, due to extreme rotational sensitivity of the float, produce error rotations about the output axis.

A device has been reduced to prototype stage that compensates for temperature and acceleration effects on a fluid-floated mass in a sealed container. It compensates for the action of these parameters on the floated member of a high performance angle- or acceleration-sensing instrument.

An essentially incompressible fluid, with a cubic expansion greater than the sealed housing containing it, will at some increased temperature create a pressure sufficient to rupture the container. However, fluid pressure can be maintained below the rupture

strength of the container by a volume compensation capsule.

The volume compensation capsules (sealed bellows) used in present-day sensing instruments are required to have a volume compensation-to-pressure relationship that is sufficient to maintain a specified pressure level over a known temperature range. The bellows are mounted in holes about the floated member of the instrument. As the fluid expands with increasing temperature, the bellows contract and the fluid pressure remains essentially constant within predetermined limits.

In a hole without a bellows, expanding fluid must flow to equalize the pressure. The floated member has a small clearance with the walls of its container (a few thousands of an inch) and is a restriction to the fluid flow. Because of the fluid flow restriction, the pressure in the hole will rise and act on the surface of the float, resulting in motion of the floated member. Temperature changes cannot cause float

motion if bellows are mounted in all the holes surrounding the periphery of the floated member since the fluid pressure forces are then held in equilibrium.

However, bellows mounted about the periphery of the floated member, in particular two bellows mounted on opposite sides of the float, cannot compensate for acceleration-induced float motion. With this configuration, a pressure gradient is created by the fluid head that accompanies a change in acceleration and will expand one bellows while contracting the other. The differential behavior of the bellows will result in a motion of the floated member.

In summary, one or more bellows mounted along one side of the fluid container will compensate, within certain limits, for float motions induced by acceleration changes. Bellows mounted on opposite sides of the float will compensate for float motions induced by temperature changes. However, neither configuration will compensate for both sources of float motion.

The object of the device described here is to eliminate float motion induced by both temperature and acceleration changes. Having the dimensions of the float, the container, and the constants for the bellows,

calculations can be performed to determine the added force placed on the bellows by a fluid head change caused by a change in acceleration. Knowing the force added by the fluid head, a mass can be determined that will produce the same force on the bellows for any acceleration. This calculated mass can be fastened to one end of the bellows and the other end of the bellows fastened to the container. The bellows end fastened to the container is the one towards the center of the float.

With a change in acceleration, the force acting on the bellows changes due to the fluid head in the usual manner, but the mass fastened to the end of the bellows applies an equal and opposite force; therefore, there is no motion of the bellows.

If every hole distributed about the float has a bellows with an attached mass as above, the float will not move due to acceleration or temperature changes.

Source: L. F. Hughes of
Massachusetts Institute of Technology
under contract to
Electronic Research Center
(ERC-10152)

Circle 16 on Reader Service Card.

SYNCHRONIZED CIRCUIT IMPROVES ACCURACY OF FLUID TRANSFER MEASUREMENTS
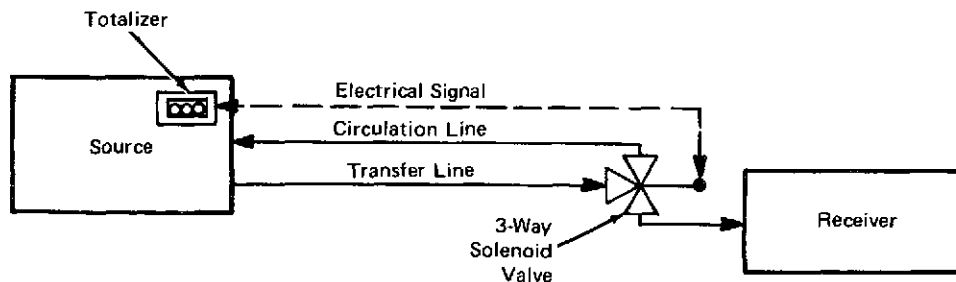
In order to account for residual fluid in transfer lines, a shutoff valve at the destination, synchronized with a sensor that maintains full transfer lines, gives an accurate measure of fluid delivered.

The liquid is circulated from the receiver back to the source by means of the circulation line to establish a stabilized flow and a full transfer line. When fluid is to be transferred to the receiver, a valve diverts the flow from the circulation line and, at the

same time, sends an electrical signal back to the quantity totalizer. The totalizer measures the volume of fluid entering the transfer line to replace the fluid being taken out. When the predetermined quantity has been transferred, the quantity totalizer stops and sends an electrical signal that closes the valve and again begins circulating the fluid.

A three-way solenoid valve is used at the receiver end of the transfer line. In one position it permits the fluid to flow into the receiver. The solenoid valve and the totalizer operate in synchronization.

The error in measurement occurring during valve opening and closing is minimized by this technique. The totalizer begins functioning at the same time the valve starts to open. It stops functioning at the same instant that the valve begins to close. Since the quantity transferred during valve opening is approximately the same as the quantity transferred during valve closing, the potential errors between actual and measured quantities are effectively cancelled.

Source: C. J. Vendl of
Rockwell International Corp.
under contract to
Johnson Space Center
(MSC-11167)

No further documentation is available.

RELIABLE LIQUID LEVEL MONITORING SYSTEM
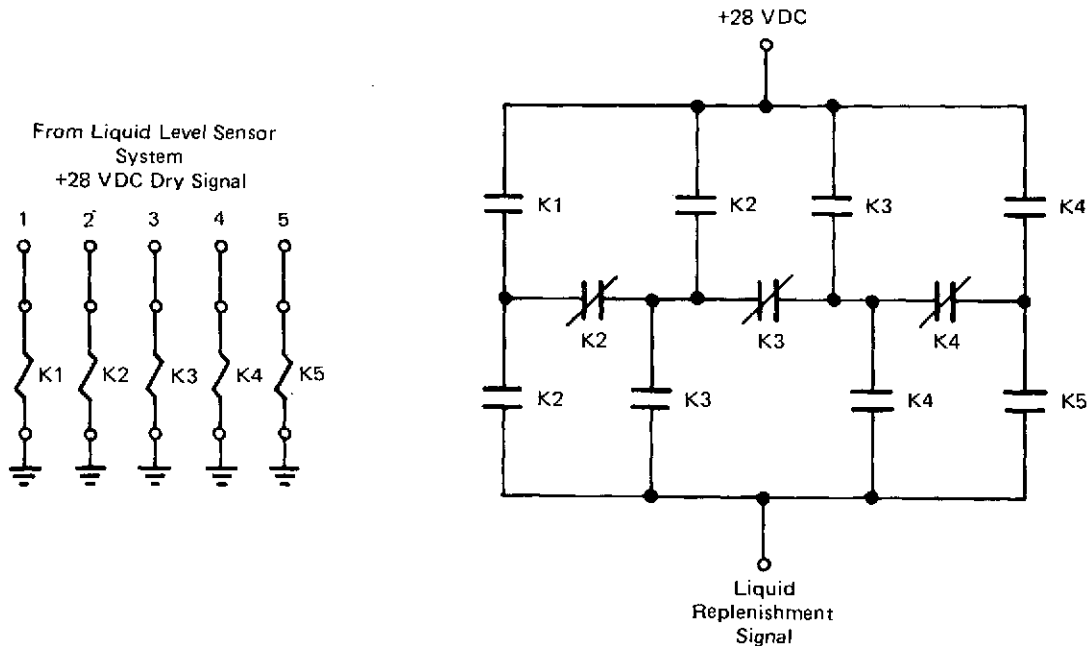
This is a multiple liquid level detection and monitoring system, that enables operators of fluid storage and supply systems to automatically actuate desired functions, within a given system, as fluid levels change. By means of sensors and related circuitry, depletion of stored fluids is used to either actuate system cutoff devices, or to institute replenishment of the stored fluid.

As shown in the sketch, "Dry" signals are received from the sensors sequentially as the fluid level falls, until the level selected for the immediate application is reached, at which time a clear signal path through the relays is provided to actuate the fluid replenishment cycle.

Source: H. Wolfson of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-16788)

No further documentation is available.

FLUORESCENT PARTICLES GIVE GAS FLOW VISIBILITY

A simple method has been devised to provide a visual representation of the flow patterns of gases at velocities that are too slow for characterization by Schlieren photography. To apply this method, a transparent section is first coupled into the gas line where the flow is to be observed. The gas stream is then infused with a commercially available, finely divided material that fluoresces under ultraviolet light (2537 Angstroms). The ultraviolet light is directed into one side of the transparent section and a camera with high-speed black and white film is set up to view the visible light emitted by the fluorescent particles carried by the gas stream. The observations are made in a darkened area (ambient lighting extinguished). Additionally, an ultraviolet blocking filter is used on the camera lens to eliminate any back-ground reflections so as to ensure that the photographic image is due only to the fluorescent particles in the gas stream. Fine definition of the particle tracks (gas flow patterns) are obtained at slow (0.2- to 0.5-second) camera shutter speeds.

This method is a refinement of the photographic method of gas flow visualization using opaque-particle tracers in conjunction with a continuous front light source and a strobe light, as described in Tech Brief 66-10668.

Source: A. J. Wilson of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-14583)

Circle 17 on Reader Service Card.

USE OF NONWETTABLE MEMBRANES FOR WATER TRANSFER

Nonwettable vinyl fluoride membranes can be used for creating an osmotic water flow. Normally, this type of membrane is used for filtering organic solvents.

Since vinyl fluoride membranes will pass water vapor but not nonvolatile solutes at normal pressures, a water partial-pressure gradient across the membrane results in a transfer of water through the membrane. This gradient may be established either by a difference in the colligative properties of the solutions on either side of the membrane (osmotic gradient) or by a temperature differential.

Over a large pressure range, the transfer rate is independent of the pressure differential across the membrane. However, air saturation of the membrane must be maintained, and too great a pressure differential will either cause solution breakthrough (forcing liquid through the capillaries) or burst the membrane.

Rates of water transfer between two solutions separated by a vinyl fluoride membrane were measured. Using various solutes, water was transferred from a dilute solution, through the membrane, and into a saturated solution. Transfer rates varying from 0.0124 to 0.234 milliliters per hour per square cm of membrane area were observed.

The transfer of water through vinyl fluoride membranes has two unique features: (1) Very low water transfer rates can be held constant by holding temperature and solute concentrations constant. (2) The pressure gradient against which water may be transported is limited only by solution breakthrough or by the mechanical strength of the membrane.

This technique may find useful application in cases where very low, constant water evaporation or transfer rates are critical. For example, in the growth of crystals, structure is dependent on the water removal rate from the growth medium.

Source: H. G. Hausch
Langley Research Center
(LAR-10743)

Circle 18 on Reader Service Card.

IRRADIATED GASES TRANSFERRED WITHOUT CONTAMINATION OR DILUTION

Dotted Line Indicates
Available Gas Paths
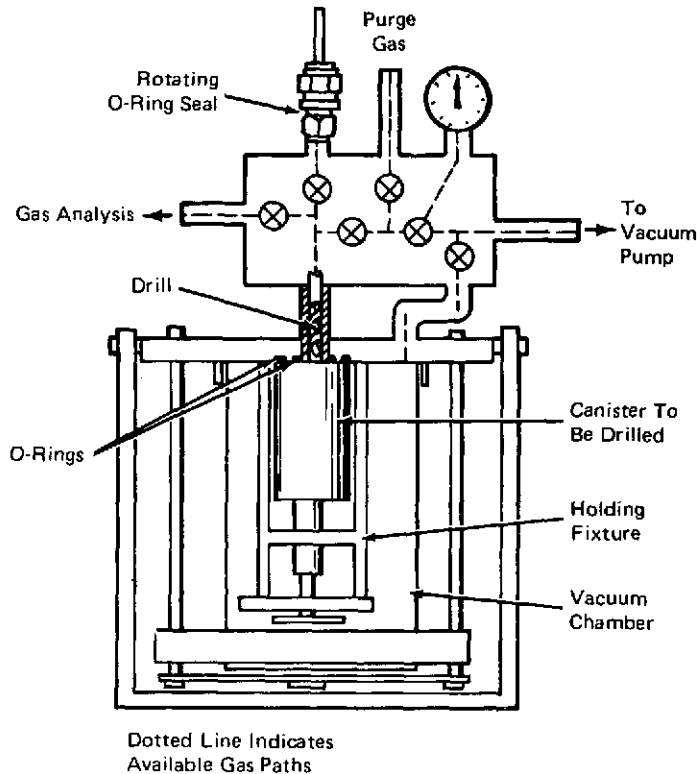
This system consists of a vacuum chamber, a manifold with valves, and a drill so mounted that integrity of the vacuum chamber is maintained with the drill in use.

The vacuum chamber contains a fixture for holding the canister, positioning it against the drill access hole in the chamber top, and forcing it tightly against the O-ring seals surrounding the drill access hole. The valved piping manifold is connected to the vacuum chamber and arranged to provide connections with a vacuum pump, a source of purge gas, and a transfer line for the canister contents. Access for the drill is provided by a passage through the piping manifold that is sealed by O-rings and a valve. The special drill has flutes only near the tip; the long shank of the drill is fluteless to provide a smooth positive sealing surface. The sealed canister is placed in the holding fixture in the vacuum chamber and mechanically forced against the O-ring seals around the drill access hole. The purge gas connection and

the transfer line are closed off by their respective valves. The vacuum chamber is sealed and evacuated, as is the drill access passage. The valve in the drill passage is opened, and the drill is moved through the valve into contact with the canister. The vacuum line valve is closed and the canister is drilled open. The drill is withdrawn and the drill passage valve is closed. The transfer line valve is opened and the canister's contents are pumped out and transferred to their destination. The transfer line is then closed off, the apparatus is purged, and the canister removed. The cycle can then be repeated.

This apparatus can be used for handling other types of hazardous and volatile materials, and materials that cannot be exposed to air, oxygen, or other than closely controlled environments.

Source: J. L. Bonn and W. Kern
Lewis Research Center
(LEW-278)

No further documentation is available.

FLUID INJECTION DEVICE FOR HIGH-PRESSURE SYSTEMS
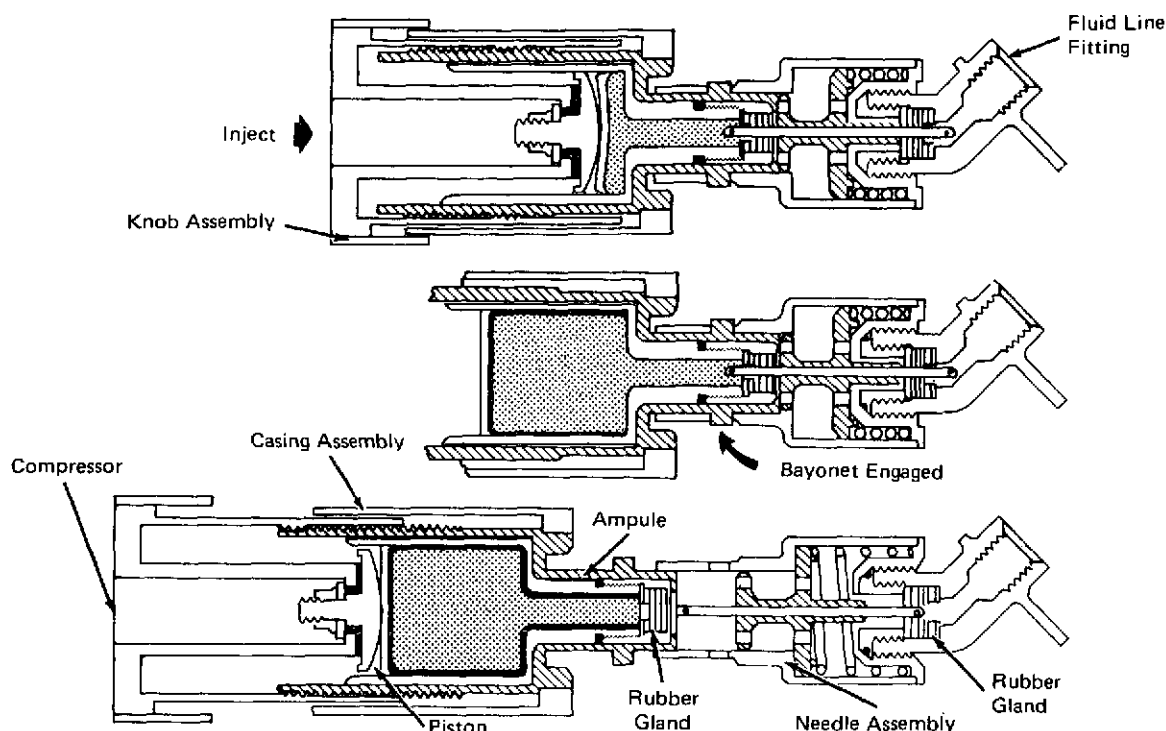
A screw-activated compressor device is proposed for the injection of measured amounts of fluids into a pressurized system. The device consists of a compressor, shielded replaceable ampules, a multiple-element rubber gland, and a specially constructed fluid line fitting.

The outer shell of the ampule consists of a rigid plastic bottle with a threaded cap. A thin-walled inner bag, made of sprayed-on layers of plastic for low permeability, empties by movement of a rigid base bonded to the bottom of the bag. Force applied at the center of the base by a spherical-ended piston expands the diameter of the base and causes its sharp edge to wipe the shell's inner diameter. As the ampule is emptied, the thin bag is prevented from extruding past the base of the applied force. The rubber gland in the cap contains three knife-slotted, silicone-rubber washers to allow a needle to penetrate the ampule and to provide a seal when the needle is removed.

A special fitting on the fluid system provides an access port and gives threaded support for the injector while the injection takes place. The fitting has a gland similar to that of the ampule except that it has four silicone-rubber washers with knife slots. Two washers form a gland while the other two constitute a redundant gland.

The injector needle assembly is essentially an adapter which connects to the panel fitting and provides bayonet slots to engage the injector casing. A blunt needle from this assembly penetrates one-half of the water-panel fitting gland depth when screwed onto the panel fittings. The gland prevents flow from the water system through the needle prior to insertion of the injector assembly. As the bayonet connection is made, the other end of the needle penetrates the ampule gland completely and the needle assembly is forced against a compression spring by the injector. This causes the assembly to pass through the panel fitting gland and establish a flow path from the ampule to the water system.

This innovation provides a sturdy, easily manipulated fluid injection device which may be of interest to the chemical and food-processing industries, and particularly to the dairy industry.

Circle 19 on Reader Service Card.

Patent Information

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

Bistable Fluidic Valve is Electrically Switched (Page 4) NPO-10416

This invention has been patented by NASA (U.S. Patent No. 3,570,513). 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

Distillation Device Supplies Cesium Vapor at Constant Pressure (Page 14) XNP-08124

This invention has been patented by NASA (U.S. Patent No. 3,563,727). 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

Fluid Sample Collection and Storage Device (Page 19) MSC-10962

This invention has been patented by NASA (U.S. Patent No. 3,438,263). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to:

> Patent Counsel
> Lyndon B. Johnson Space Center
> Code AM
> Houston, Texas 77058

Notes: