NASA SP-5938 (01)

TECHNOLOGY UTILIZATION

FLUID TECHNOLOGY
(Selected Components, Devices, and Systems)

A COMPILATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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TECHNOLOGY UTILIZATION OFFICE 1970
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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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. It presents in summary form a selected group of fluid components, devices, and systems developed by NASA and AEC centers and their contractors. It also includes several computer programs that may be applicable to fluid technology. The items discussed in this document may be of particular interest to the designers and manufacturers of hydraulic and pneumatic components, fluid filtration systems, fluid calibration systems, and other fluid devices; they may also be beneficial to the petrochemical industry. These innovations are believed to be both useful and practicable.

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

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

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

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

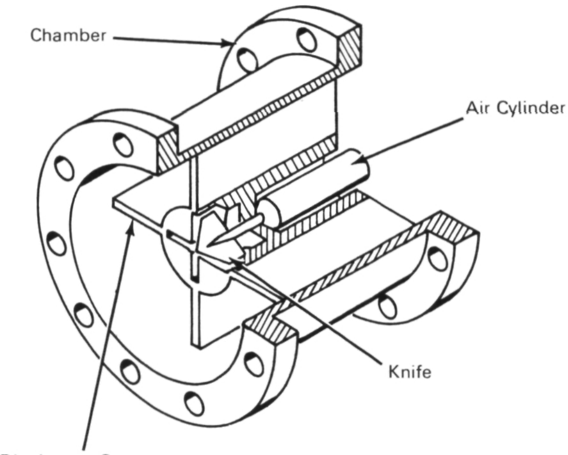
Contents

Section 1. Fluid Control

BURST DIAPHRAGM FLOW INITIATOR

This initiator, housed in a cylindrical shell that provides pressure integrity, instantaneously initiates flow from a high-pressure reservoir (normally a long tube) into a lower pressure receiver. Advantages of this innovation over previous devices include: more rapid actuation, the fact that metal particles are not introduced into the flow, and the reduced cost of fabrication and operation.

In this device a diaphragm of multiple layers of mylar or other strong film is supported normal to the desired flow on a multiple element grid. The diaphragm separates the high-pressure gas in the supply tube from the lower pressure gas, normally at atmospheric pressure, in the receiver. The number of sheets of mylar and the grid spacing are determined in such a way as to allow the diaphragm initially to withstand the desired differential pressure with a minimum mylar mass. At the desired moment, an air operator drives a cutter housed in the supporting framework through the mylar diaphragm, shearing it into four or more distinct petals. The higher pressure gas in the supply tube forces the light mylar petals to the full open position in the period of a few milliseconds, releasing the high-pressure gas.



A sufficient gap is provided between the flange faces clamping the diaphragm and the supporting grid to lightly stress the diaphragm at the grid support location when under pressure. This gap serves to promote a rapid and complete petaling action.

Source: J. W. Davis and O. E. Hill
Marshall Space Flight Center
(MFS-12915)

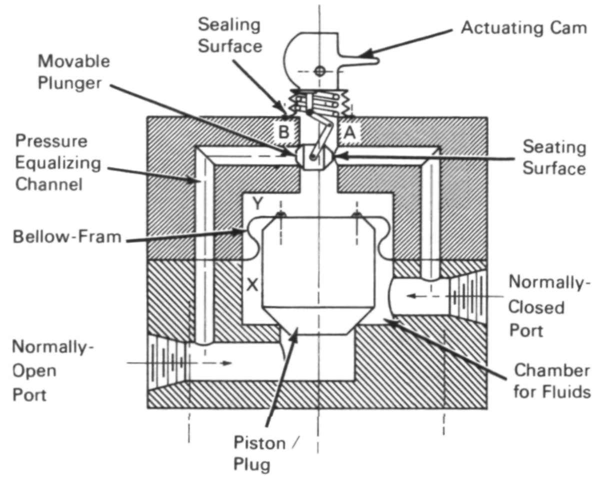
No further documentation is available.

NORMALLY-OPEN/NORMALLY-CLOSED VALVE

Another fluidic valve that will operate in either a normally-open or normally-closed position has been designed. It can be operated either manually or by pilot. This simple, cam-operated diaphragm/pressure sealed valve, which has only a few moving parts, may be of interest to manufacturers (especially in the chemical industry) of hydraulic and pneumatic components.

In the normally-closed configuration, fluid enters the normally-closed port of the valve and fills the chamber. The fluid is prevented from entering the normally-open port by the sealing action of the piston/plug against the port opening in the side of the chamber. Fluid also enters the chamber through the pressure-equalizing channel, but does not restrict the operation of the piston/plug. With the rotation of the actuating cam, the movable plunger moves from its normal position B to seat against the channel opening A. Since the pressure in the chamber on the X side of the bellow-fram is greater than that on the Y side, the piston/plug moves away from its seat at the chamber entrance to the normally-open port, allowing fluid to flow from the normally-closed port to the normally-open port.

In the normally-open configuration, the fluid enters the normally-open port and overcomes the force exerted by the bellow-fram against the piston/plug, forcing it out of the position shown, effectively opening the valve, and allowing the fluid to flow from the normally-open port to the normally-closed port. When the actuating cam is rotated, the movable plunger moves from B to A. The fluid then flows through the pressure-equalizing channel on the normally-open port side and enters the chamber, equalizing the pressures existing on either side of the bellow-fram. The bellow-fram then exerts force on the

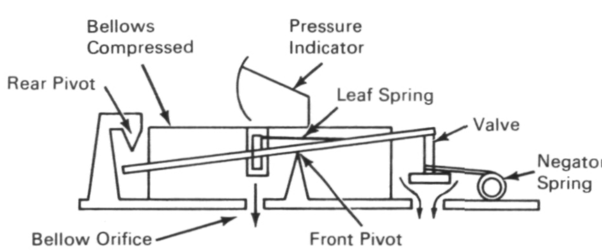


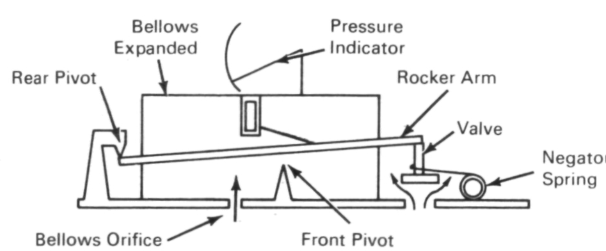
piston/plug, causing it to seal the normally-open port entrance to the chamber.

Source: B. J. Wright and G. E. Hows of North American Rockwell Corp. under contract to Manned Spacecraft Center (MSC-15068)

No further documentation is available.

BIDIRECTIONAL SELF-ACTUATING PRESSURE VALVE





A valve has been developed in which a bellows chamber and a pivot mechanism are used to maintain a predetermined pressure differential. It is a compact, lightweight device of simple design with only four moving parts. Because of its simplicity and durability, it may interest those segments of industry involved in chemical processes and pneumatic controls. This valve has already been used in an X-ray camera.

The valve automatically maintains a predetermined pressure differential across the walls of a container subjected to a varying pressure environment. If the direction of the pressure gradient suddenly reverses, the valve maintains the same or a different pressure differential across the container walls in the opposite direction. The placement of the front pivot point of the valve mechanism determines the pressure maintained in one direction while the placement of the rear pivot determines the pressure maintained in the opposite direction. Under an upward pressure gradient the bellows chamber expands, pivoting the rocker arm about the rear pivot point, again opening the valve. As the valve opens, air rushes upward through the valve until the gradient is reduced and the valve again closes. Under a downward pressure gradient the bellows shortens, pivoting the rocker arm about the front pivot point, thereby opening the valve. As the valve opens, air rushes downward through the pressure valve until the pressure on the bellows is relieved sufficiently to allow the valve to close.

Source: W. D. Fender of
Hycon Manufacturing Co.
under contract to
Marshall Space Flight Center
(MFS-20018)

No further documentation is available.

PNEUMATIC ACTUATOR TIMING-CONTROL SYSTEM

A timing-control system has been developed that can maintain a scheduled position-time transient in a pneumatic actuator subject to large variations in load and temperature. The use of an open- and closed-loop control scheme eliminates potential dynamic instability inherent in closed-loop control. This innovation should be of particular interest to the petrochemical and pharmaceutical industries for use with valves having critical timing requirements.

In the design of this system, a position controller was added in parallel to a basic pneumatic actuator to provide a closed-loop control. This controller is a normally closed, spring-loaded, diaphragm-actuated poppet valve. Appropriate sizing of the controller orifice and cavity volume results in a pressure rise on the diaphragm as a function of time. This pressure acting on the diaphragm provides a generated force, also as a function of time. During the main valve opening transient, the temperature-compensated orifice at the closing control port provides open-loop control. The controller provides closed-loop control of the opening transient only when it is slower than the commanded opening transient. Thus, flow through the controller poppet is in the opening direction only and cannot introduce any dynamic instability.

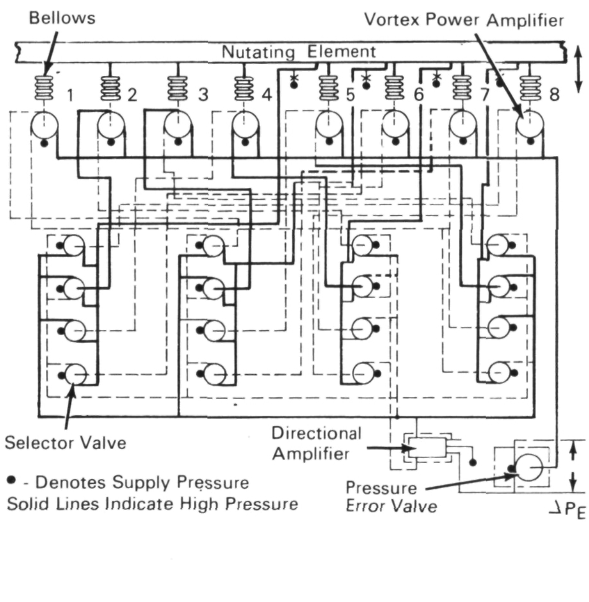
Source: J. G. Absalom of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-14580)

Circle 1 on Reader's Service Card.

FLUID-LOGIC CONTROL CIRCUIT

The fluid-control circuit shown in the sketch was developed for operating a pneumatic-nutator-actuator motor. This innovation should interest the designers of control systems that must operate in severe or hazardous environments.

The circuit consists of the following connected fluid interaction (vortex type) devices: (1) a pressure error valve, (2) a bistable directional amplifier, (3) eight vortex power amplifiers (one for each bellows), (4) sixteen vortex selector valves, and (5) four gimbal ring position pick-offs. This logic circuit has no moving parts. The input is a pressure differential which, together with four pressure-feedback signals, results in a motor output torque proportional in magnitude and direction to the input differential. An analog

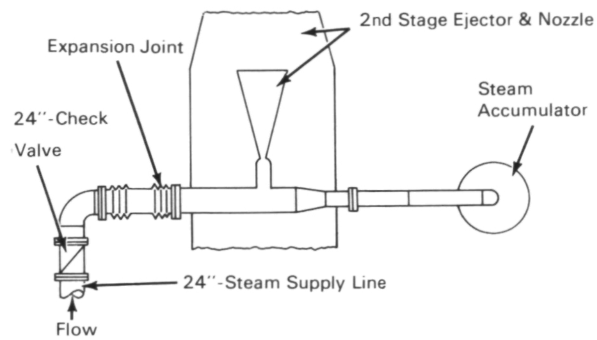


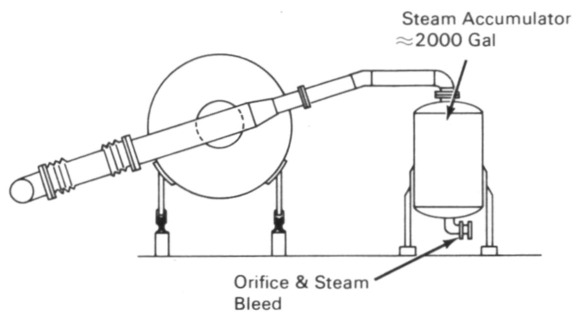
commutation was used in this circuit, but a digital commutation could be used to provide unusual versatility. The operation of this circuit demonstrates the ability of fluid interaction devices to operate in a complex combination of series and parallel logic sequence.

Source: G. R. Howland of
The Bendix Corp.
under contract to
Lewis Research Center
(LEW-90294)

Circle 2 on Reader's Service Card.

STEAM ACCUMULATOR FOR ALTITUDE SYSTEMS





A steam accumulator has been developed that can be used wherever hard vacuums are drawn for either evacuating or purging given atmospheres, as well as when equipment is subjected to damage as a result of rapid shutdown or failure.

A pressure surge occurs in high-compression, steam-jet ejector systems when the supply of steam is rapidly terminated. Such a surge can be likened to the rise in pressure that occurs in a shock tube when the shock is reflected off the end of the tube. Extending the duration of steam flow decay greatly reduces the magnitude of the shock-pressure rise. This extension is accomplished by installing an accumulator of sufficient magnitude in parallel with the main stream supply line, allowing the ejector system to shut down for a prescribed period. The accumulator is always online and, therefore, the delivery of steam to the ejector is not interrupted.

Source: G. G. Gaylord of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15903)

Circle 3 on Reader's Service Card.

ANTIVORTEX DEVICE

Another fluid-control innovation that may be of interest to industrial designers is an antivortex device. This is a hollow sphere of lightweight, durable material, floating on the surface of the liquid being drained from a storage tank. When a vortex forms, the float is drawn into it, and acts as a plug to break the undesirable column of air. As each new vortex is generated, the sphere is drawn into its center. Improved efficiency and reliability, resulting in reduced operating costs, make this device attractive to industry.

By preventing the formation of a vortex in a liquid that is being pumped, this fluid-control device eliminates the possible ingestion of gas or air and prevents slippage in the pump. In addition, it makes possible a more complete separation of mixtures of light and heavy liquids.

The innovation appears to provide a simple and effective means of controlling the formation of vortices. It could be used in such applications as (1) reservoirs that supply water at high flow rates to large storage tanks, (2) large storage vats such as those used in distilleries where the pull-down level of 60-foot-diameter (or more) vats is limited by the vortexing of the liquid to the tank outlet, and (3) propellant tanks of missiles that pump liquids at high rates.

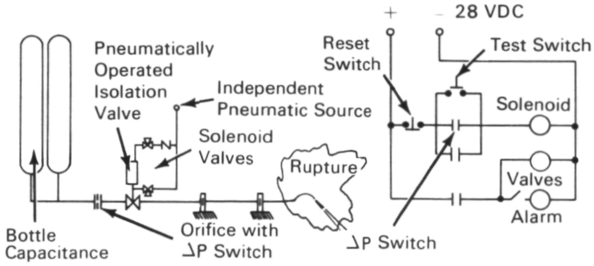
Source: F. L. Engman of
The Boeing Co.
under contract to
Marshall Space Flight Center
(MFS-14838)

No further documentation is available.

PNEUMATIC-FUSE CIRCUIT

A pneumatic-fuse circuit has been developed for a high-pressure gas line, which, in the event of line failure, will stop the delivery of gas to the line and sound an alarm. This innovation would be useful as a safety device in high-pressure public utility gas lines and petrochemical facilities.

In order to shut off immediately the high-pressure gas flow of an overland gas transmission system in the event of line failure, a pneumatic-fuse circuit can be installed in the system's gas line as shown in the sketch. This arrangement isolates any large bottle capacitance. The fuse circuit consists of a delta pressure (Δ P) switch installed at an orifice in the high-pressure line. When the delta pressure across the orifice exceeds the normal system-pressure drop in this portion of

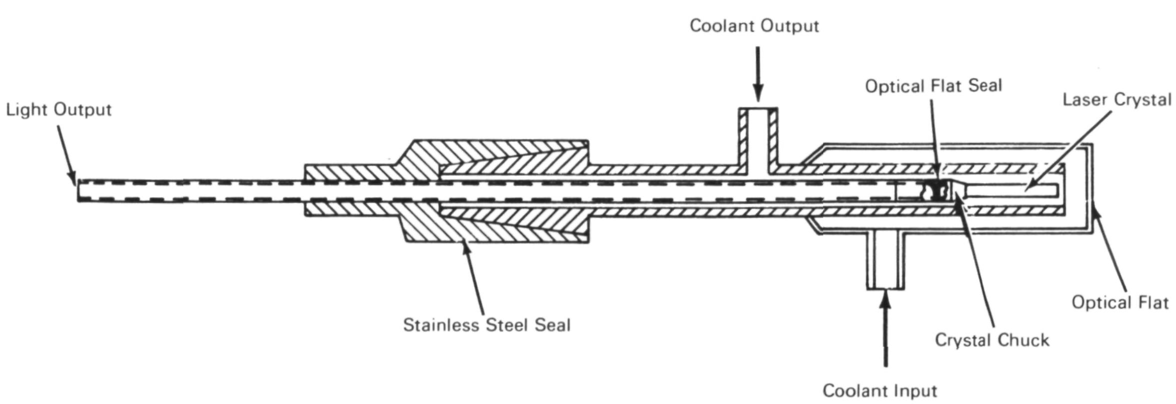


the line, the switch is activated, energizing a lock-in relay that closes the isolation valve and sounds an alarm.

Source: T. R. Spring of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18119)

No further documentation is available.

FLOW TUBE FOR COOLING SOLAR-PUMPED LASER



A flow tube that provides two major junctions in the application of a laser beam for transmission of both sound and video has been fabricated. It maintains the YAG laser at the proper operating temperature of 300°K under solar pumping conditions and serves as the pump cavity for the laser crystal.

The flow tube includes a small four-jaw chuck that holds the laser crystal in place. The laser is cooled by water forced through the flow tube under pressure and circulated through a copper coil heat exchanger mounted in a cool water bath. Pure, deionized water is used instead of tap water to prevent contamination of the laser's crystal end reflectors. The coolant section also serves as the pump cavity. The inside walls of the tube are silver plated to diffusely reflect pump light entering the flow tube at other than normal incidence so that efficient use can be made of available pump power.

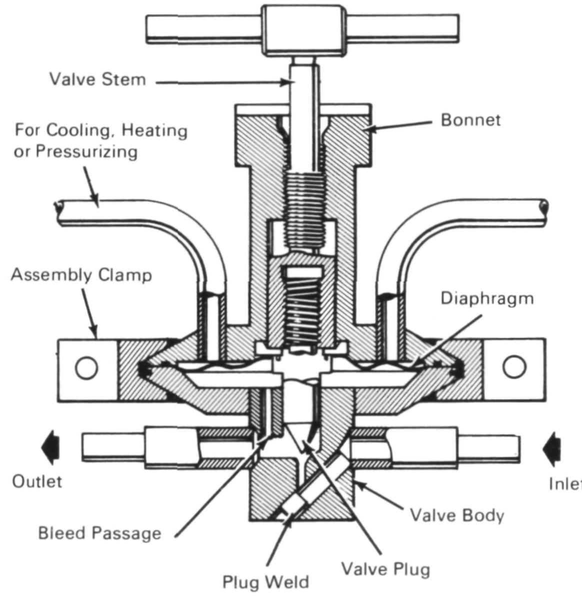
Source: RCA Corp.
under contract to
Manned Spacecraft Center
(MSC-11026)

Circle 4 on Reader's Service Card.

DIAPHRAGM VALVE FOR CORROSIVE AND HIGH-TEMPERATURE FLUID CONTROL

A monometallic diaphragm valve has been developed in which the body, diaphragm, and plug are welded together to form an integral leakproof unit. Such valves have been fabricated and successfully tested at temperatures up to 1000°F in a two-phase mercury system. This valve is cheaper and more reliable than the metallic, weld-sealed valves (usually of the bellows-seal construction) previously used.

Flow control is effected by varying the position of the conical end of the plug. The plug is moved by means of a differential thread action of two threaded portions of the valve stem. A fine thread engages the bonnet and a coarse thread engages the plug, resulting in a fine adjustment for throttling and flow control. A bleed passage connects the cavity between the diaphragm and body with the outlet or low-pressure side of the valve. The cavity between the diaphragm and the bonnet is tapped for venting or for pressurizing to counter internal pressure. The bonnet side of the diaphragm can be heated or cooled by means of these inlet and outlet passages provided in the bonnet. The body, plug, and diaphragm are welded together to form a pressure- and vacuum-tight fluid enclosure, and the bonnet is sealed by gaskets or packing.



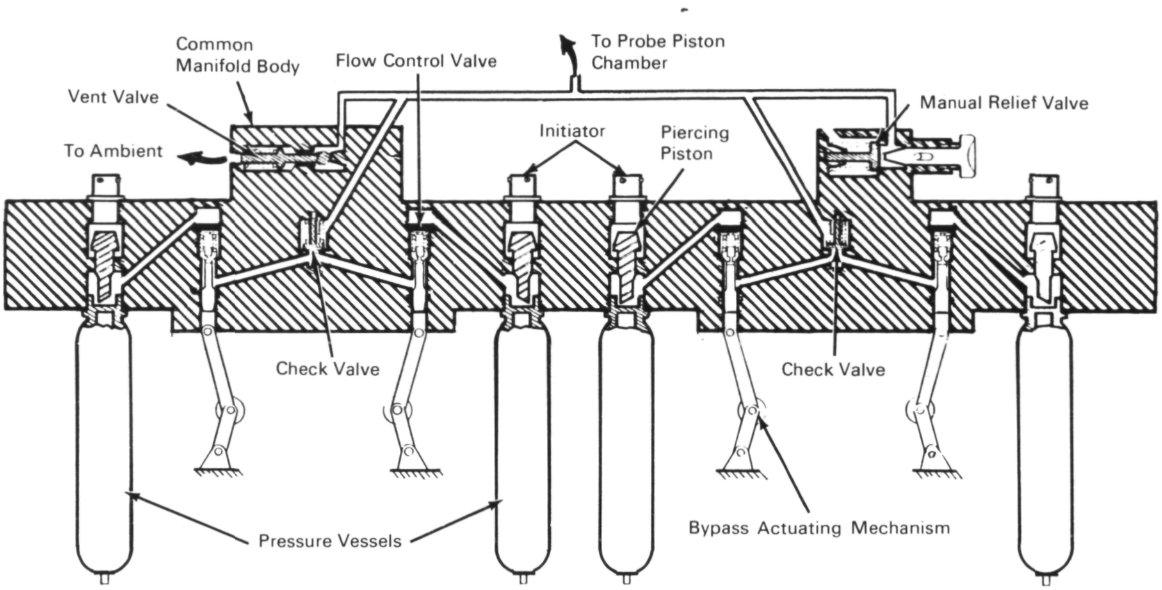
Source: A. Vary and B. T. Ebihara
Lewis Research Center
(LEW-90304)

Circle 5 on Reader's Service Card.

PNEUMATIC PRESSURIZATION SYSTEM

A lightweight, pneumatic pressurization system that was developed for use with the Apollo docking-probe retracting mechanism and the Apollo unified hatch-counterbalance system may also be used commercially as a prime-power source for actuating devices such as those which operate aircraft doors and landing gear. A hermetically sealed feature of this system affords maximum reliability.

This system, a schematic of which is shown in the figure, contains four hermetically sealed pressure vessels, socket-mounted and sealed to a common manifold body. The manifold houses a manual relief valve, two check valves, four flow-



control valves, and a common vent. The internal porting in the manifold allows the high-pressure gas flow from any bottle to pass through the manifold and be regulated to a reduced flow and pressure at the outlet port. The system is activated by electrically energizing an explosive cartridge (initiator) that drives a small piercing piston through a sealed diaphragm in the throat of the pressure vessel. Each vessel has its own initiating cartridge that is also socket-mounted and sealed in the front face of the manifold.

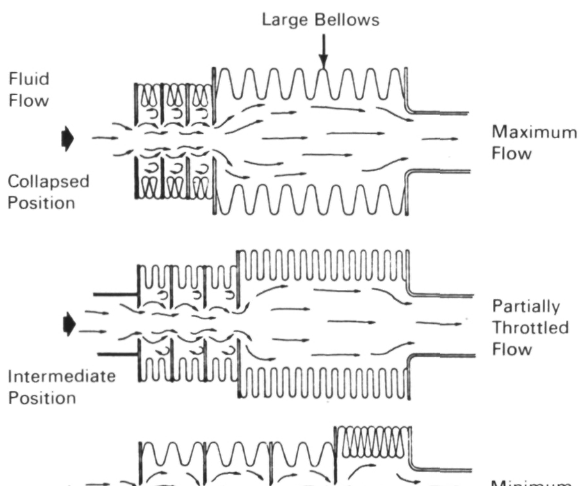
Source: G. E. Campbell, I. Nussenbaum, and K. A. Bloom of North American Rockwell Corp. under contract to Manned Spacecraft Center (MSC-11898)

No further documentation is available.

MULTIPLE-ORIFICE THROTTLE VALVE

A multiple-orifice throttle valve of all-metal construction has been designed. This valve overcomes the shortcomings of most valves having seals of organic materials that deteriorate in the presence of strong oxidizers, and sliding or rotating parts that may bind as a result of cold welding in vacuum.

The design shown in the schematic, which excludes static or dynamic seals, has simple components that do not slide or rotate. It consists of a series of orifices separated by short bellows. When the bellows are collapsed, the orifices are close together and the assembly acts as a short pipe orifice or a short corrugated pipe, providing limited restriction to fluid flow. Thus for a given pressure differential, this configuration would provide a maximum rate of flow. As the assembly is extended, the distance between the



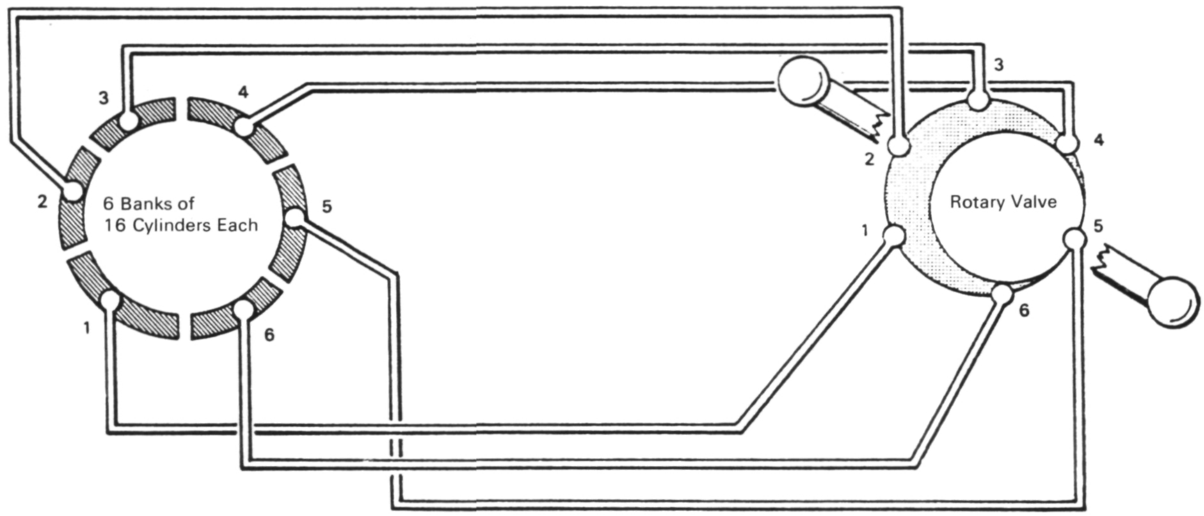
orifices increases so that each orifice separately exerts a greater throttling effect on the flow. At maximum extension of the orifice bellows, the rate of flow of the fluid is at a minimum.

A large bellows is secured to a large-diameter opening at the outlet end and to the last orifice plate at the other end. Accordingly, when the series of orifices are moved apart, the increase in distance between the first and last of the orifices is taken up by the decrease in distance between the last orifice and the large-diameter opening at the outlet end of the valve. The decrease in length of the large bellows does not substantially affect fluid flow, and therefore does not substantially offset the greater throttling due to increased separation of the orifices.

Source: L. A. Rosales and J. A. Fitton, Jr. of
TRW Inc.
under contract to
NASA Pasadena Office
(XNP-09698)

Circle 6 on Reader's Service Card.

ROTARY VALVE FOR MULTIPLE HYDRAULIC LEVELING CYLINDERS



A single rotary valve has been designed to control a circular bank of cylinders in a hydraulic leveling system that can maintain large loads within ±3 minutes of arc of a true vertical position.

The leveling system shown schematically in the figure is controlled by the rotary valve. The valve cavity has inlet ports to a common pressure source and outlet ports to the various cylinder banks. Each outlet port has the same relative position as the cylinder bank to which it is connected. The rotary spool in the center of the valve is eccentrically mounted. The position of the spool determines the flow rate to each bank of cylinders and hence the position of the cylinders.

Fluid flows into the cavity through inlet ports around the annular grooves cut in the spool (on either side of the exit ports) and out the exit ports to the cylinders. The outlet port closest to the high part of the eccentric has the lowest flow rate and the greatest pressure drop between the source and the cylinder. The other exit ports have varying flow rates depending upon their position in relation to the eccentric.

Source: The Boeing Co.
under contract to
Marshall Space Flight Center
(MFS-90361)

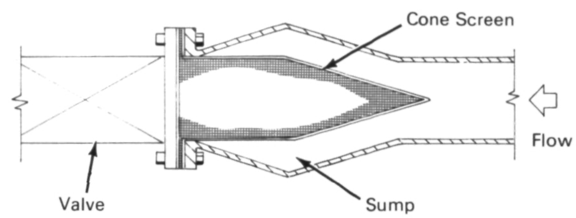
Circle 7 on Reader's Service Card.

Section 2. Fluid Filtration

CONE-SCREEN SUMP FOR ENTRAPPING FLUID SYSTEM CONTAMINANTS

A concept for an improved fluid-filtering device that can collect contaminants with little flow restriction has been developed. It would be useful to those industries that design systems in which flow restriction is a critical factor.

At the present time contaminants in fluid systems restrict flow and contribute to the malfunction of hardware. For example, the primary-seal drain-line relief valve on the J-2 fuel turbopump has a cylindrical screen filter to entrap contaminants. The carbon dust from the seal cavity, however, can restrict or block flow, making the drain-line inoperative. In addition, this valve is presently welded to the line and cannot be disassembled for cleaning. In the improved concept a cone-shaped screen-filter element is installed with the apex pointed upstream. The element has a wide diameter sump area for entrapping flow-carried particles and can be so mounted between the sealed flanges of the tube and the relief valve that it can be removed easily and cleaned.



Source: G. A. Johnson of
North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-12984)

No further documentation is available.

LIQUID-HELIUM FILTRATION

Another fluid-filtering device that may be of general interest to industry is a liquid-helium, 10-micron, absolute filter. Such a device has already been fabricated and used with ground-support equipment for the Apollo LM spacecraft. Because of its low-heat leak (0.5 Btu/hr) and light weight (1.5 lb), this filter is also suitable for airborne applications.

In order to load the Apollo's helium tanks with either liquid or supercritical helium, a helium-conditioning unit is necessary. During the loading operation the tanks of this unit must be kept free of particulate contamination to reduce to a minimum the contamination and malfunction of the spacecraft components. To meet this requirement a filtering device was placed as near as possible to the spacecraft interface to remove from the helium stream any particles generated by the functioning components in the conditioning unit. A filter element was designed and mounted on the end of a cryogenic male bayonet fitting, and a female bayonet was designed to house the element, thus forming an in-line filter at the point where the fluid enters the fill line of the spacecraft. The heat-leak rate for this filter is very low because the filter is an integral part of the bayonet coupling assembly. The filter element of this device can be replaced readily by disconnecting the bayonet coupling and retracting the male bayonet from the female bayonet.

This fluid-filtering device can be used with cryogenic fluid at any pressure level. The level of filtration can be selected on the basis of the pressure drop that can be tolerated across the filter.

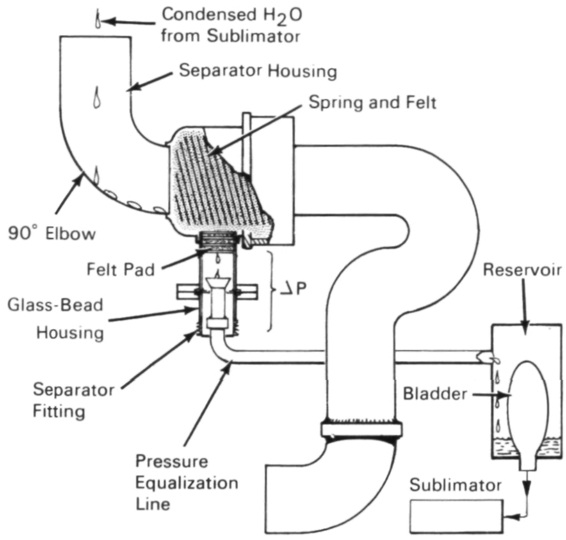
Source: Beech Aircraft Corp.
under contract to
Manned Spacecraft Center
(MSC-12095)

Circle 8 on Reader's Service Card.

WATER SEPARATOR

In the oxygen recirculation system of an astronaut's helmet, a warm, moist stream of oxygen leaves the helmet and passes through a sublimator (heat exchanger) for cooling. During this cooling process, free moisture from the oxygen stream is condensed at a rate of 5 cc/min. To ensure a supply of low-humidity oxygen to the astronaut, as well as proper operation of the fans and associated equipment, a separator was developed to remove this free moisture.

In the operation of the separator, a stream of oxygen and condensed H_2O from the sublimator enters the separator housing and is thrown against the housing wall due to the centrifugal force in the 90° elbow. The droplets of moisture are captured in an annulus of absorbent dacron felt held in place by a spring. As the felt becomes saturated, a highly capillary glass-bead housing fills with water; this housing is located in a pressure equalization line between the oxygen circuit and the collapsing reservoir bladder that supplies water to the sublimator. Since the bladder contracts when supplying water to the sublimator, it creates a pressure differential (Δ P in figure) of approximately 4 in. of H_2O. This pressure differential causes the "slug" of water in the glass-bead housing to break loose and flow down the pressure equalization line. The glass-bead housing refills immediately, draining water off the dacron sleeve and the sequence of events repeats. This percolator action causes slugs of water to flow into the backside of the collapsing bladder reser-



voir. Because the sublimator is always using water at a greater rate than the incoming quantity of separated water, a sufficient volume and suction force to remove and store the separated water are ensured.

The water separator could provide a simple, low-pressure loss, high-efficiency method of removing condensed moisture from a gas stream with no external power source.

Source: E. H. Brisson and W. W. Beauregard of United Aircraft Corp. under contract to Manned Spacecraft Center (MSC-13052)

No further documentation is available.

AUTOMATIC FILTER-BLOWBACK SYSTEM USED WITH SINTERED-METAL FILTERS

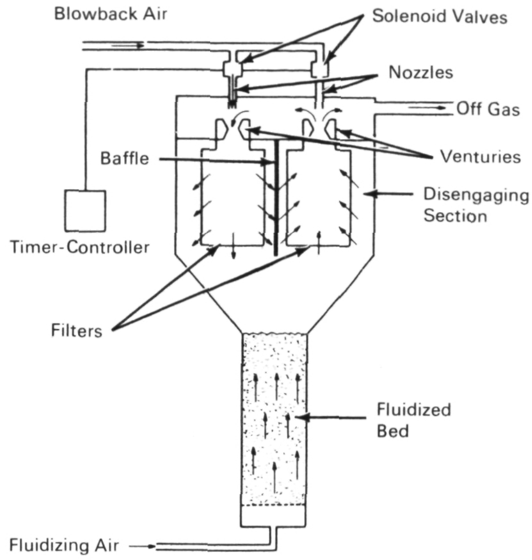
Sintered-metal filters have been used in a wide variety of pilot-plant and laboratory fluid-bed reactors to remove entrained particulate solids from the fluid-bed effluent-gas stream. Particulate solids generally accumulate on these filters as a layer that requires periodic removal. The findings that resulted from an investigation of a blowback system for cleaning these filters should be of value to the hydraulics and pneumatics industries, filter and catalyst manufacturers, and air-pollution controllers.

In this investigation, the filters were cleaned by impulse from a high-velocity, short-duration, reverse-flow air pulse; solenoid-actuated air nozzles were directed into Venturi fittings surmounting each filter. The solenoids were actuated cyclically by an electric timer. Fractional-second bursts of air at 100-lb/in^2 gave excellent cleaning of the filters; pressures as low as 15 lb/in^2 (absolute) were successful. Because of the Venturi and high-velocity air flow from the nozzle, some of the filtered gas was syphoned back to aid in cleaning.

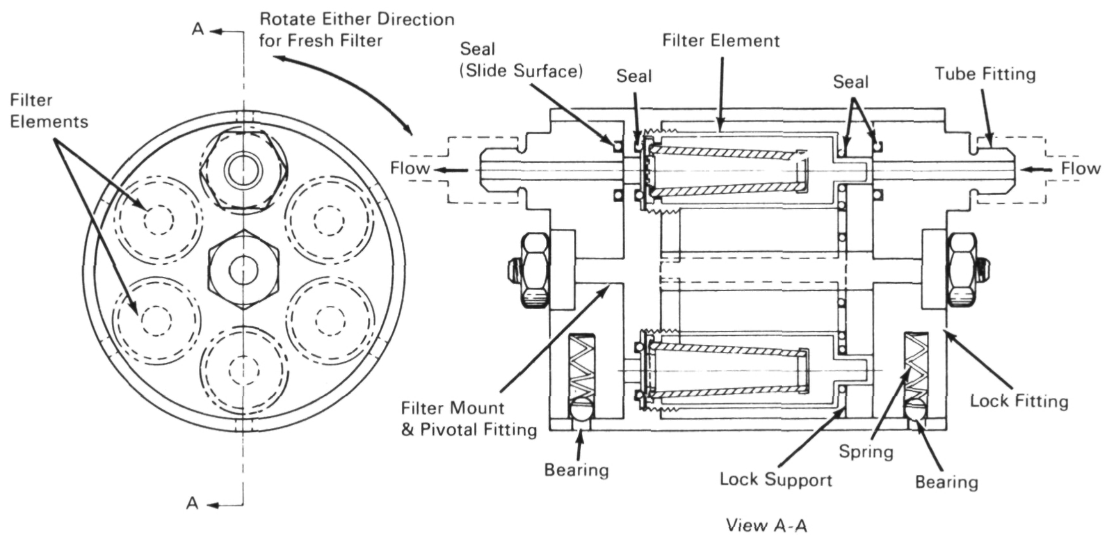
The advantages of this system are that the blowback air required is reduced from that required in a constant-flow scheme, the filters are cleaned more effectively and are on-stream for a larger percentage of time than in constant flow schemes, and operation is completely automatic. Another major advantage of pulse blowback is that it reduces the filter-plugging that occurs in continuous reverse-flow blowback systems.

Source: E. L. Carls and N. M. Levitz
Argonne National Laboratory
(ARG-10324)

Circle 9 on Reader's Service Card.



REPLACEMENT OF FLUID-FILTER ELEMENTS WITHOUT INTERRUPTION OF FLOW



A Gatling-type filter assembly that enables filter replacement without actual interruption of flow has been developed. This device can be adapted for use in gas- or liquid-filtration systems, particularly those in areas of limited accessibility.

The filter assembly is preloaded with several filter elements (six in the device shown); there are six index positions. When a filter element becomes plugged or contaminated, the inner subassembly is rotated 60 degrees (remotely or manually), positioning a new clean filter in the line.

Source: R. A. Kotler and J. B. Ward of
North American Rockwell Corp.
under contract to
Manned Spacecraft Center
(MSC-15499)

Circle 10 on Reader's Service Card.

STAINLESS STEEL FILTER ELEMENT

A stainless steel filter web has been constructed that resists the contamination of a fluid by the migration of particles from the filter medium. This filter element can hold up to five times as much particulate matter as conventional filters before reaching an arbitrary cutoff-pressure drop.

To prevent the migration of particles, a filter medium was made from relatively long 4- and 8-micron diameter stainless steel fibers. The fibers are randomly oriented in a mat-like structure that is sandwiched between two stainless steel screens of 80 by 80 mesh. This screen assembly is then pleated on a conventional commercial pleating device. The pleated assembly is clamped around a perforated center tube and sintered in a dry hydrogen atmosphere at 2050°F for 30 minutes, then cooled rapidly in the same atmosphere. The end flanges are attached and sealed with a filled epoxy resin which is cured for one hour at 250°F.

Source: P. A. Reiman of
Arthur D. Little, Inc.
under contract to
Marshall Space Flight Center
(MFS-90541)

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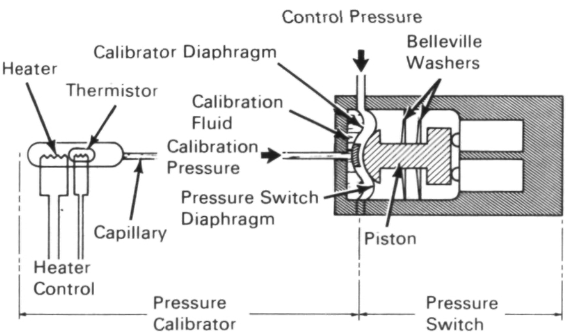
Section 3. Calibration

CONCEPT FOR PRESSURE SWITCH CALIBRATOR

A calibrator and switch design has been developed in which a saturated liquid-to-vapor phase transition at constant pressure is used to produce a known force (on a diaphragm of given area) independent of displacement over a usable range. A calibrator based on this concept would be useful where the calibration could be carried out at a relatively slow rate so that saturated vapor conditions could be maintained in the region enclosing the heater and thermistor.

As shown in the sketch, one end of a conventional pressure switch was modified by the addition of a diaphragm enclosing an appropriate calibration liquid that communicates with a controlled source of heat by means of a capillary. For the calibrator diaphragm configuration in the sketch, the calibration liquid was assumed to be cold, so that it was fully contracted. In this condition, any measured or control pressure greater than the vapor pressure of the liquid would not allow a calibrating force on the switch diaphragm. The spacing between the diaphragms would be chosen to allow for expected displacement of the fluid (liquid plus vapor) in the operating environment.

To conduct a calibration, the control pressure is reduced to atmospheric pressure (by valving) and the heater control system is actuated. As the



temperature of the fluid near the heater is increased, a point is reached at which the vapor pressure exceeds the atmospheric pressure on the liquid (plus any loading pressure from the calibrator diaphragm). The resultant force (the product of vapor pressure and calibrator diaphragm area) displaces the calibrator diaphragm until it contacts the switch diaphragm. When switching pressure is reached, the displacement diaphragm will not affect the calibrating pressure because it is essentially independent of the volume of the calibrating fluid.

Source: M. G. Slingerland of
General Electric Co.
under contract to
NASA Headquarters
(HQN-90036)

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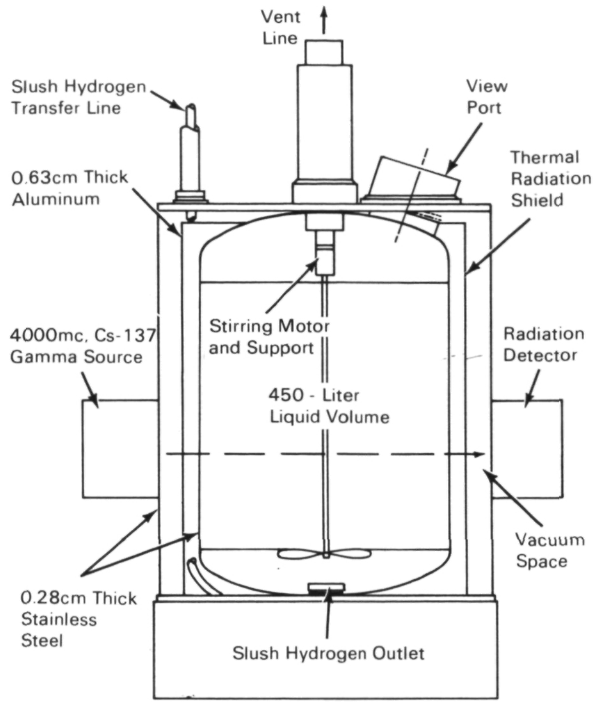
HYDROGEN-SLUSH-DENSITY REFERENCE SYSTEM

A hydrogen-slush-density reference system has been designed that can calibrate either field instruments or transfer standards. This system is based on Archimedes' buoyancy principle. The solids are weighed in a low-mass container so arranged that the solids and container are buoyed by triple-point liquid hydrogen during the weighing process. The transfer standard is an instrument that can be applied to a storage tank or pipeline containing slush hydrogen, but need not be a permanent part of a facility instrumentation.

In this reference system the container is suspended from a load cell in a separate housing above the top plate. Between this plate and the load cell is a cylinder, with windows, in which a series of calibration masses are suspended. At any time, the container can be lifted from the load cell suspension and one or more of the calibration masses substituted. After the average slush density in the container is determined, it is accurately correlated with one or more readings from the transfer standard that is being calibrated. The transfer standard transducer may be located either inside or outside the slush container. The cryostat and container walls are as thin as possible so that a favorable attenuation ratio between hydrogen slush and metal can be maintained. A nuclear radiation attenuation (NRA) device can be used for a hydrogen-slush densitometer, the transfer standard.

A 450-liter slush generator and flow loop were used in a laboratory for a year. A commercial densitometer based on gamma ray attenuation was later installed on the slush generator. The NRA densitometer, which has been applied in experimental work with a slush-hydrogen flow loop, was used to determine the solid fraction in the generator that supplies slush for the test section. The densitometer can also monitor solid fraction in a slush-hydrogen turbopump.



Source: C. F. Sindt and D. H. Weitzel of NBS Institute for Materials Research under contract to Marshall Space Flight Center (MFS-14596)

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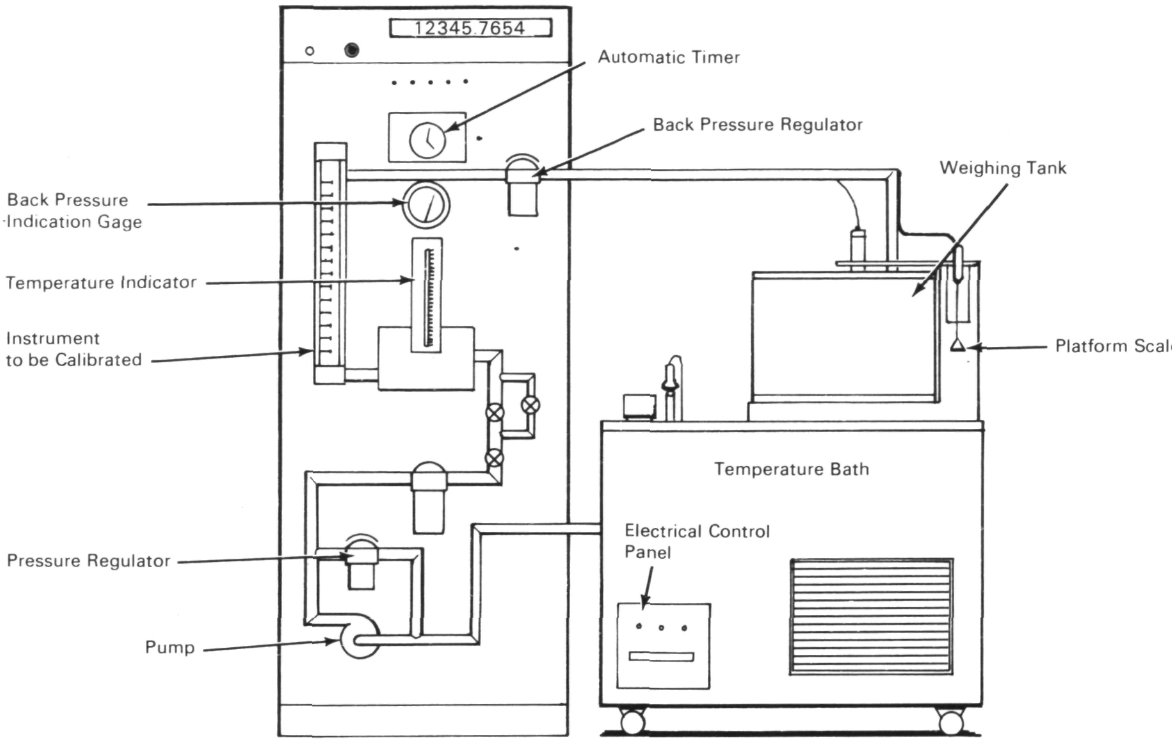
LIQUID-FLOW CALIBRATION SYSTEM

Another recently developed calibration system consisting of a platform scale, weighing tank, pressure regulator, automatic timer, and cycle-control devices may be of interest to industrial organizations that evaluate and calibrate valves and pumps and perform other hydraulic operations. This system is compact, accurate, and is made fully automatic by a unique application of a proximity switch and coaxial relays; it would be particularly suitable for calibrating liquid flowmeters.

In this system a platform scale with a capacity of 300 pounds is mounted on top of a temperature bath. A modified scale-temperature-bath combination allows an air-operated valve mounted at the bottom of an insulated collection tank to return the liquid sample to the temperature bath. A single bay cabinet, which contains the pump, power supply, proximity switch, timer, and other control equipment, is placed adjacent to the temperature bath and platform scale. For example,



when a flowmeter is to be calibrated, it is mounted in proper position and the temperature is stabilized at the desired setting. An operator then depresses the start button, selects the sample weight, and records the raw data when the weighing cycle is complete.

Source: E. E. Brown and C. Bailey, Jr. of North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-16028)

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Section 4. Computer Programs and Data Reduction

INJECTION STREAM PREDICTION PROGRAM

This program computes the velocity on the axis of a slower free jet in a faster coflow, the jet radius, and the deflection due to a crossflow as a function of distance along the jet axis. The calculations used in the program are based on the methods of Abramovich. Output is in the form of both tabulations and CRT plots.

The program is written for an oxygen jet surrounded by a hydrogen flow, but other fluids may be used. Considerable extension, to cover such areas as velocity profiles, is possible with relatively minor additions, making this a general-purpose program. An ideal application is in computing fluid jet boundaries and effects of crossflow in subsonic flow.

Language: PL-1

Machine Requirements: IBM 360, Release 11, SC-4020 CRT

Source: North American Rockwell Corp. under contract to Marshall Space Flight Center (MFS-18558)

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TURBINE FLOWMETER CALIBRATION PROGRAM

This generalized turbine flowmeter calibration data-reduction program consists of a main program with several replacement subroutines. The main program performs the standard requirements of data reduction, and the subroutines supply constants for the fluids and/or systems being used. Depending on the user's application, a choice of outputs is available.

By substitution of subroutines, the program is applicable to almost any fluid. The five subroutines supplied in the program documentation are for use with water, the intent being that an individual user will build a suitable library of subroutines for the liquids in his particular application.

Language: PL-1

Machine Requirements: IBM 360, Release 11, SC-4020 CRT

Source: North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18504)

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TURBINE FLOWMETER MATHEMATICAL ANALYSIS

This program models the data from bench calibrated flowmeters, calculates the precision of both the curve fit and the flowmeter, and provides an SC 4020 plot of the original data and the curve fit.

A linearized model is used to provide least-squares estimates of the unretarded flowmeter constant and three nonfluid drag coefficients. Estimation of the turbulence coefficient leads to an unstable solution; therefore, a fixed estimate of this coefficient is included with the raw data in the program input.

Language: FORTRAN H

Machine Requirements: IBM 360, Release 11, SC 4020 plotter

Source: North American Rockwell Corp.
under contract to
Marshall Space Flight Center
(MFS-18142)

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NASA-Langley, 1971

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