MIL-STD-1361A
28 September 1973
Superseding
MIL-STD-1361
5 November 1971

MILITARY STANDARD

FLUIDICS
TEST METHODS AND INSTRUMENTATION

FSC 1650

DEPARTMENT OF DEFENSE
WASHINGTON, D.C. 20301

Fluidics Test Methods and Instrumentation

MIL-STD-1361A

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. This standard was prepared by the Government Fluidics Coordination Group comprised of Army, Navy and Air Force members and represents a coordinated effort by the military departments.

3. Recommended corrections, additions, or deletions should be addressed to Commander, Naval Air Systems Command (AIR-52022), Department of the Navy, Washington, D.C. 20360.

FOREWORD

The purpose of this standard is to establish preferred test methods for fluidic devices. The tests described herein are designed to provide the data necessary to predict the performance of a device when used in a system. Because of the diversity of these devices and because of the diverse uses that can be made of any one device, a large number of tests have been established. Some of these tests will be more important than others depending on the circumstances. Not every test is meant to be used on every device. Furthermore, the standard in its present form contains methods and procedures directly applicable to pneumatic systems only; adaptations may be necessary for other systems.

Criteria for determining performance characteristics unavoidably imply utilization of certain test procedures, which, in turn, suggest the use of specific types of instrumentation. Some instrumentation is discussed here but by no means is this discussion meant to be all inclusive, nor is it the intent of this document to impose any limit on or otherwise specify types of instrumentation.

The methods comprising Appendix B have been compiled utilizing information supplied by members of the GFCG (Government Fluidics Coordination Group), NFPA (The National Fluid Power Association), and the SAE (Society of Automotive Engineers).

CONTENTS

1. SCOPE AND PURPOSE.

1.1 Scope. This standard establishes acceptable methods, procedures, and instrumentation required for testing fluidic devices. Because of the diversity of these devices and because of the diverse uses that can be made of any one device, a large number of tests have been established. Some of these tests will be more important than others depending on the circumstances. Not every test is intended to be made on every device but only those tests which yield data of interest need be used at any one time. The use of the specific instrumentation associated with these tests is not mandatory. However, the type and quality of the instrumentation used in the performance of these tests will be acceptable to all concerned.

1.2 Purpose. The test methods described herein have been prepared to serve the following purposes:

(a) To specify suitable conditions obtainable in the laboratory, which, insofar as possible, resemble those encountered by the device under service use. The tests described herein may not be interpreted as an exact representation of actual service operation at a specific geographic location or altitude or outer space location.

(b) To describe in one standard all of the tests required (excepting possibly certain tests applicable to unique operating principles) to predict the behavior of pneumatic fluidic devices when operated under specific conditions with specific performance indices. Where practicable, the tests have been made adaptable to a broad range of devices.

2. REFERENCED DOCUMENTS.

2.1 The issues of the following documents in effect on the date of invitation for bids or request for proposals form a part of this standard to the extent specified herein:

SPECIFICATIONS

Military

MIL-C-45662	Calibration System Requirements

STANDARDS

Military

MIL-STD-1306	Fluerics Terminology and Symbols

(Copies of specifications, standards, drawings and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issues in effect on date of invitation for bids or request for proposal shall apply.

International

ISO/R 1219	Graphical Symbols for Hydraulic and Pneumatic Equipment and Accessories for Fluid Power Transmission

(Application for copies should be addressed to the American National Standards Institute, 1430 Broadway, New York, New York 10018.)

3. ABBREVIATIONS, UNITS, SYMBOLS AND DEFINITIONS.

3.1 Abbreviations, units, symbols and definitions.

3.1.1 Specific definitions. The term "Device" is understood to include such items as amplifiers, active elements, passive elements, integrated circuits, logic modules, operational amplifiers and the like, as well as sensors and transducers. The term "Instrumentation" is understood to include all laboratory instrumentation (electrical, fluidic, or mechanical, etc.). Load insensitivity and insensitivity to P_s variations are defined in the appropriate test in Appendix B.

3.1.2 General. For the purpose of this standard, the abbreviations, units, symbols and definitions specified in MIL-STD-1306 shall apply. In general, the abbreviations, units, symbols and definitions which are used in this standard but are not specified in MIL-STD-1306 are common to the fluid power technology and have been standardized on an international basis. References may be made to ISO/R 1219-1970, "Graphical Symbols for Hydraulic and Pneumatic Equipment and Accessories for Fluid Power Transmissions".

4. GENERAL REQUIREMENTS.

4.1 Numbering system. The test methods are designated by numbers assigned in accordance with the following system:

4.1.1 Classification of test methods. Test methods and procedures are serially numbered in the order in which they are introduced into this standard. Test methods numbered 1001 to 1999 inclusive cover performance tests of digital elements; those numbered 2001 to 2999 inclusive cover performance tests of analog elements; those numbered 3001 to 3999 inclusive cover performance tests of multi-element devices (modules, operational amplifiers, integrated circuits, etc.), both digital and analog; unless these devices can be tested as though they were a single device; e.g., two NOR gates integrated into a flip-flop circuit should be tested as a flip-flop. Those numbered 4001 to 4999 inclusive cover performance tests of sensors, transducers and signal generators. Additional test methods will be appropriately numbered and included as they are devised.

Often two or more test methods are very similar in their form or procedure such as the case, for example, when the same input impedance is being measured for an element having different output loading conditions. The data obtained from such test methods may depend highly upon the particular form or procedure of the test method. Therefore, it is most important that these particulars be specified. To make the distinction clear one test method is referred to as a sub-method of the other. As an example, a test method numbered "1234 sub-method of 1132" is a test method like test method 1132, but it has particular features as spelled out in test method 1234. This designation may be abbreviated 1234S1132.

4.1.2 Revisions. Revisions are numbered consecutively using a period to separate the test method number and the revision number. As examples, 1001.1 is the first revision of Method 1001; 5999.11 is the eleventh revision of Method 5999.

4.2 Method of reference. When applicable, test methods contained herein shall be referenced by specifying this standard, the method number, and the date. The revision number should not be used when referencing test methods. The revision of interest will be that revision in force on the specified date. For example, a procurement specification referring to a revised test method would specify Method 2020, not 2020.2.

4.3 Test conditions. Unless otherwise specified herein or in the applicable procurement documentation, all measurements and tests shall be made at an ambient temperature of 293 ± 5 K (68° ± 9°F) and at ambient atmospheric pressure of 45 to 110 kN/m^2 (710 to 815 mm of Hg or 13.75 to 15.7 psia). Whenever these conditions must be closely controlled in order to obtain reproducible results, the reference shall be as follows: temperature 292 to 294K (66.2° to 69.8°F), relative humidity 50 percent maximum and atmospheric pressure from 98.0 to 104 kN/m^2 (735 to 780 mm of mercury or 14.2 to 15.1 psia). In the event condensation is noted anywhere within the test system envelope, the test must be repeated under humidity-controlled conditions.

4.3.1 Permissible temperature and pressure variation in environmental chambers. When chambers are used, specimens under test shall be located only within the working area defined as follows:

(a) Temperature variation within workin area: The controls for the chamber shall be capable of maintaining the temperature of any single reference point within the working area within ±2 percent of the absolute temperature scale.

(b) Pressure variation within working area: The controls for the chamber shall be capable of maintaining the chamber absolute pressure within ±2 percent.

(c) Local temperature variation within working area: Chambers shall be so constructed that at any given time the temperature of all points within the working area shall not deviate from each other in temperature (degrees Kelvin) by more than 2 percent.

4.3.2 Instrument calibration. Calibration of all test equipment used in the performance testing shall be in accordance with MIL-C-45662 and with the requirements included in Appendix A. Additionally, all electrical test equipment shall be calibrated at periodic intervals and all acceptable equipment shall display a record of the calibration dates and responsible individual or activity. The interval shall be based on the class of equipment and its history. Calibration check readings shall agree with the values recorded for each control device within the accuracy requirements of 4.6.2.

4.4 Orientation. For test methods which involve observation of the effects of applied displacements, rotations, rates, accelerations, or external forces which must be related to the orientation of the device, such orientation and direction shall be identified as follows:

4.4.1 Single axis. In a sensing device with a single sensitive axis (or axis of rotation), the sensitive axis shall be specifically designated and the other two axes are to be designated in such a way that the axes form a righthanded coordinate system.

4.4.2 Box-shapes. In a box-shaped package containing substrate planes, mounting surfaces, or laminae, the orientation with respect to applied displacements, rotations, rates, accelerations or external forces shall be specifically designated.

4.5 General precautions. The following precations shall be observed in the testing of devices:

4.5.1 Test-induced mechanical defects. While a set of tests for mechanical integrity does not form a part of this standard, test specimens subjected to repeated connections and disconnections during the testing procedures shall be examined for leaks and fractures. Such test-related mechanical defects shall be included in reported data.

4.5.2 Test methods and circuits. Unless otherwise stated in the specific test method, the methods and circuits shown are given as the basic measurement method. They are not necessarily the only method or circuit which can be used. The supplier shall demonstrate to the procuring activity that alternate methods or circuits which he may desire to use are equivalent and give results within the desired accuracy of measurement (see 4.6.2).

As a preliminary consideration, it should be mentioned that fast-moving fluid can cause erroneous interpretations of pressure readings. The usual practice is to measure pressures from an expansion tank inserted into the line for the purpose of slowing the flow to a negligible magnitude. A complication can arise here too, however, because of the possibility of total pressure losses due to the expansion tank. Carefully taken, the pressure reading at the tank is a close approximation of the true total pressure at that point. Once the reading is taken and if the tank is subsequently removed from the circuit, however, the total pressure at that point will increase by an amount equal to the loss, if any, that had been induced by the expansion tank.

Unless otherwise specified, ±5 percent error is assumed to be a reasonable accuracy for quantities required in the summary section of these test methods.

4.5.3 Apparatus.

(a) Pressure regulators: The pressure regulators must be capable of maintaining constant pressure (±5 percent) through and beyond the maximum anticipated flow rate. This is particularly true if the flow measuring device is dependent on a constant upstream pressure for accurate flow indication. In any case, downstream pressure adjustment becomes a much simpler task if the upstream source is maintained at constant pressure.

(b) Pressure sensors: The pressure sensors should be connected to the fluid lines through expansion tanks (see 4.5.2) for quasi-static tests. While this gives rise to longer transients, it may be necessary in order that pressure readings represent total pressure.

(c) Flow sensors: Flow sensors should be used at line pressures and ranges affording the greatest accuracy. The effects of resistance can be reduced by operating at higher line pressures.

4.6 Data reporting. Data reporting shall be as follows:

4.6.1 Actual data. The data resulting from application of any test method or procedure shall be reported in terms of actual test conditions. Extrapolations or "equivalent" results (e.g., performance in a non-standard atmosphere derived from standard atmospheric test conditions) may be reported in addition to the standard results but shall not be acceptable as an alternative to actual results. Results of any test method or procedure shall be accompanied by information on the actual test conditions and the date.

4.6.2 Accuracy. The accuracy of the reported data must be specified. The specified limits are for values obtained with the specific test conditions. Proper allowance shall be made for measurement errors in establishing the working limits to be used for the measured values so that the actual values of the device parameters are within the specified limits. It should also be noted that the specified limits effect the determination of load sensitivity and sensitivity to P_s variations as per Appendix B.

4.6.3 Samples. The data resulting from application of any test method or procedure shall be reported in terms of the samples tested. The data may be associated specifically with a particular device or it may be reported statistically for a larger number of devices in which case the amount of deviation from the reported data will also be given. Also the data will be accompanied by information on the total quantity of devices in each lot being tested, the number of rejections in each lot being tested, and the test method(s) under which failure criteria were established.

4.6.4 Test sample disposition. Unless otherwise specified in the applicable procurement document, devices subjected to tests may be included in the delivery. If the lot is numbered serially, the test sample serial numbers shall be noted. Otherwise, the test specimens shall be clearly identified.

Custodians:
Army - AV
Navy - AS
Air Force - 11

Preparing Activity:
Navy - AS
Project No. 1650-0223

NUMERICAL INDEX OF TEST METHODS

Method No.	Title
	Digital elements
1001	Power nozzle characteristics
1002	Control port characteristics
1003	Output characteristics
1004	Input-output pressure switching curve
1005	Pressure recovery
1006	Load sensitivity
1007	Effects of power jet pressure changes
1008	Alternate load sensitivity
1009	Circuit loading sensitivity
1100	Switching time
	Analog (proportional) elements
2001	Power supply and quiescent characteristics
2002	Differential input and output characteristics transfer curves
2003	Dynamic testing
2004	Signal to noise ratio
	Multi-element devices
3001	Evaluation of a fluidic operational amplifier
	Sensors, transducers and signal generators
4001	Electromechanical signal generator output characteristics

APPENDIX A

INSTRUMENTATION

APPENDIX A

INSTRUMENTATION

A.1 The instruments described below are widely used in carrying out the test procedures of Appendix B. While the list is not exhaustive, choices are mentioned for most applications.

A.2 PRESSURE.

A.2.1 Gages

Numerous types of pressure gages are in use including diaphragm, bellows, bourdon tube, piston, and dual differential pressure types. A description of two of these types are given below.

Diaphragm: A simple to use gage for the fluidic laboratory is the device which utilizes a diaphragm to sense and indicate differential pressure.

The diaphragm assumes an equilibrium position between the two pressures. This position is transmitted to the indicator by various means such as linkages or magnetic couplings.

Wide ranges of operation and accuracy are available. Accuracy can be ±2 percent or better of full scale reading.

Bourdon tube: The bourdon tube gage employs a curved tube which is sealed to the pressure which is to be measured. The end of the curved tube deflects with increasing internal-external differential pressure. This deflection is transmitted to the rotary pointer assembly through gearing and linkages.

The Bourdon tube gage is manufactured to a variety of cost and accuracy specifications. Accuracy varies, but quality instruments are accurate to within 2 percent at mid-range and to within 3 percent near the end points.

Bourdon tube gages can measure pressures ranging from laboratory vacuum to thousands of atmospheres.

A.2.2 Manometer

The U tube manometer is the most straightforward pressure sensor in the laboratory. With reasonable caution, the manometer can be used with the greatest accuracy of any of the pressure sensors. The meniscus height in each leg is measured and the product of the height difference and the fluid density equals the difference in pressure in the legs. The fluid density determines the scale factor.

There are sources of error inherent in any manometer; a common one being the difficulty in reading the meniscus. Other factors affecting accuracy are:

(1) Contamination due to oxidation for the case of the mercury manometer.

(2) Effects of capillary action.

(3) To a very small degree, temperature changes can cause error due to the associated change of density in the manometer fluid.

Many schemes are used to precisely measure the fluid column height in manometers making the manometer a highly precise pressure sensor. In one scheme a phototube is located so that it will be struck by the portion of light beam not interrupted by the fluid. A signal proportional to the remaining beam area is generated and activates the motor moving the scanner beam by means of a lead screw until it is centered on the meniscus and the resulting signal is at null. The position of the scanner is geared to a counter indicating the height of the fluid column to the nearest 0.025 mm (1/1000 of an inch).

A.2.3 Transducers

Strain gage: The strain gage transducer consists of an electrical network whose resistive elements are mechanically deformed as a function of the applied stress (pressure). The mechanical deformation causes changes in the electrical characteristics of the resistive elements. A change in the network output is functionally related to the change of applied pressure.

The operating ranges of strain gage transducers extend from zero to extremely high pressures.

Some strain gage units have a frequency response greater than 1000 Hz with accuracies of better than 1 percent of full scale reading.

Piezo electric: The piezo electric transducer consists of a quartz crystal and a charge detecting and amplifying network.

A charge proportional to force (pressure) is generated on the quartz crystal. The charge sensing network must have a high input impedance; generally, the lower the frequency the higher must be the input impedance of the detecting network.

The piezo electric transducer can sense pressures to 21,000 kN/m^2 (3000 psi) at frequencies of 50 KHz.

Other: a) A pressure sensitive transistor has been developed. The emitter base junction of a NPN transistor is subjected to a force mechanically transmitted from a diaphragm which is the pressure sensor. The output voltage is a linear (within 1 percent) function of pressure applied to the diaphragm.

Ranges extend from 0.7 to 140 kN/m^2 (0.1 to 20 psi). The major disadvantage is output null shifting due to temperature change, which can be as much as 0.2V/K.

The frequency response is high, greater than 10 KHz.

b) The variable reluctance-type pressure transducer is often used.

A.3 FLOW.

A.3.1 Flow meters

Float/variable area flow meter: This device is placed in the line in a vertical position. The tube is tapered inside so that the area increases slightly as the fluid stream courses upward.

The stream exerts forces on the float which is located in the tube. These forces are functions of fluid velocity and density. The float comes to rest (under conditions of steady flow), when these forces balance the weight of the float.

Interchangeable floats of various weights extend the range of measurement over which a given tube can be used. The limiting factor is usually impedance, since it is desirable to keep the impedance of instrumentation as low as possible.

Accuracy is affected by dirt, moisture and grease. Under some conditions, electrical charge can accumulate causing the float to cling to the tube walls until a substantial mechanical force overcomes the electrical force. Large errors are produced when these instruments are operated at other than calibrated conditions.

Quality instruments are accurate to within 3 percent over the entire scale except for the lower quarter.

Rates as high as 0.235 m^3/sec (500 cubic feet per minute) and as low as a fraction of a cubic inch per minute can be measured with flow meters of this type.

Linear resistor: A resistor (or set of resistors) whose pressure/flow characteristics are linear can be a convenient way to measure flow. The pressure drop across the device is a measure of the flow.

Pneumatic flow rates measurable by this type of flow meter range from 0.00005 to 0.05 m^3/sec (0.1 to 100 cu ft/min.).

A.3.2 Anemometer: This type of instrument can be used to measure fluid velocity. The quantity of heat convectively transferred from a hot wire to a moving fluid in which the wire is immersed is a nonlinear function of the velocity of the fluid. A change in the rate of heat transfer can similarly be related to a change in the fluid velocity. The heat transfer can be detected in either of two ways.

If a constant current can be maintained through the hot wire, irrespective of resistance and temperature changes due to flow rate variations, then the voltage required to maintain constant current is a function of the fluid velocity. This scheme and its associated control network is called a constant current anemometer.

If a constant temperature can be maintained by regulating the current to maintain constant resistance (and thus constant temperature) then the voltage required to maintain constant temperature is also related to fluid velocity. This scheme and its associated control network is called a constant temperature anemometer.

In the constant current anemometer, the transducer is the variable resistance leg of a bridge circuit which is excited by a power amplifier. Initially, the bridge current is balanced and any change of the transducer's resistance is detected by a differential amplifier. This voltage, after amplification, drives the current to its initial value regardless of the resistance value assumed by the transducer. The voltage is then a function of the fluid velocity.

Constant current operation does not utilize the hot-wire concept to its maximum potential. The range and frequency response can be extended by maintaining the hot wire at constant temperature, minimizing the time required for heating and cooling to register their effect.

The transducer is one arm of a bridge circuit which has another arm with variable resistance. The bridge is balanced at a voltage supplied by a servo amplifier. Any small change in the resistance of the transducer probe due to fluid velocity change, will cause a small unbalance voltage which after amplification will adjust the probe current to restore balance to the bridge. Thus, the temperature variations are kept very small and the frequency response is improved more than 100 fold.

The velocity measurable by the constant temperature operation extends from a few inches per second to beyond sonic velocity with appropriate adjustments for various mean velocities throughout the total range.

The frequency response is from DC to more than 20 KHz.

A.4 TEMPERATURE.

A.4.1 Resistance sensor: A wire or film sensor is connected as one arm of a bridge. The output voltage of the bridge circuit is a function of resistance change (and minus of the temperature change) of the sensor. The range depends on the choice of material and its resistance-temperature characteristics, but temperatures exceeding 1500°F have been measured with accuracy.

A.4.2 Thermistor resistance sensor: The sensor is a semi-conductor connected as one arm of a Wheatstone bridge. There will be a unique temperature at which the bridge will balance. Bridge voltage resulting from imbalance will then be a function of temperature variation. The range of this instrument is up to 600°F with accuracy of ±1 percent.

APPENDIX B

TEST METHODS

METHOD 1001

POWER NOZZLE CHARACTERISTICS OF AN ACTIVE DIGITAL DEVICE

1. PURPOSE. This method establishes the means of determining the power nozzle characteristics (flow versus pressure, with standard volume flow rate preferred) under fully blocked (not passing) signal port conditions. The effect on the power nozzle characteristics of blocking these signal ports shall be determined using test methods 1006S1001, 1008S1001, or 1009S1001.

2. APPARATUS. The apparatus is shown in Figure 1001.

3. PROCEDURE. Connect circuit as shown in Figure 1001 being careful to comply with the general procedures discussed previously. Note that all the signal ports are fully blocked (not passing). The effect of blocking these signal ports on the power nozzle characteristics shall be determined using another test method as described above.

The power valve must be opened slowly so that transient effects are minimal. Plot or record flow (standard volume flow rate is preferred) versus pressure. It may be efficient to perform test method 1005 while performing this test. Notice that for some devices, such as turbulence amplifiers, the recovery curves obtained from test method 1005 may define the range of operating supply pressures.

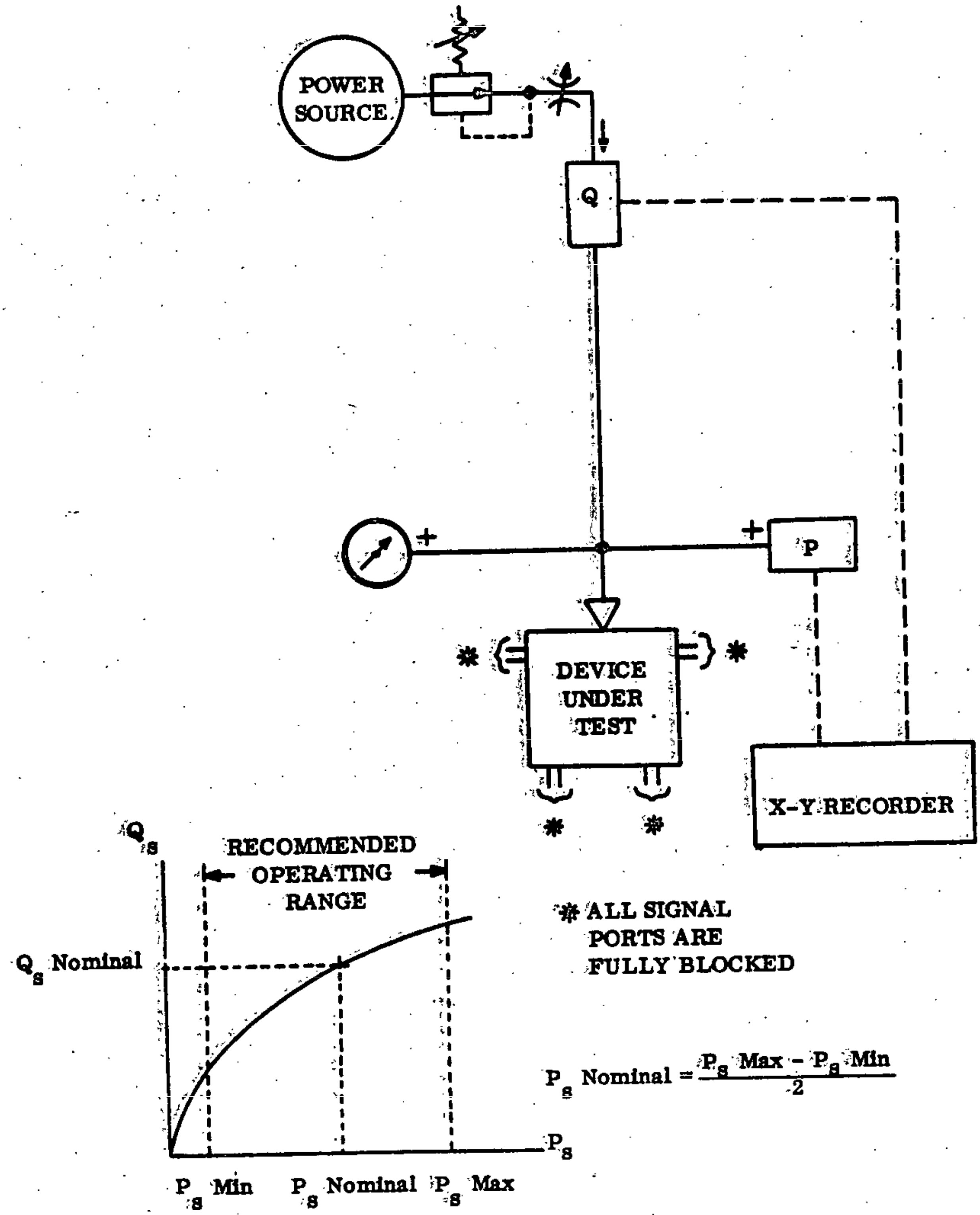
The data excursion shall at least cover the full operating range of the device and shall start from zero flow and zero pressure. In addition, it shall go beyond the operating range if such an additional excursion indicates significant information such as the criteria for establishing the operating limits.

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The recorded pressure vs. flow data and the test method number.

(b) Minimum and maximum power supply pressures, and criteria used to determine limits, and/or the pressure and flow values at the nominal operating point. These shall appear as specifically labeled points on the power supply characteristic curve (see Figure 1001) or as tabulated data.

(c) Whether or not device is load sensitive.



* ALL SIGNAL PORTS ARE FULLY BLOCKED

$$P_s \text{ Nominal} = \frac{P_s \text{ Max} - P_s \text{ Min}}{2}$$

FIGURE 1001

METHOD 1002

CONTROL PORT CHARACTERISTICS

1. PURPOSE. This method establishes the means of determining the control port characteristics of certain active digital devices. These characteristics, in conjunction with the output characteristics and switch point data enable the user to calculate gains and fanout for a specific supply pressure. If the tests are repeated for several supply pressures, as per test method 1007, gains and fanout values can be calculated as functions of power supply pressure. Depending on vent geometry, load sensitivity can be an important parameter in most jet deflection amplifiers, so that input characteristics change with load impedance. When such load sensitivity information is required, test method 1006S1002, 1008S1002, or 1009S1002 shall be performed.

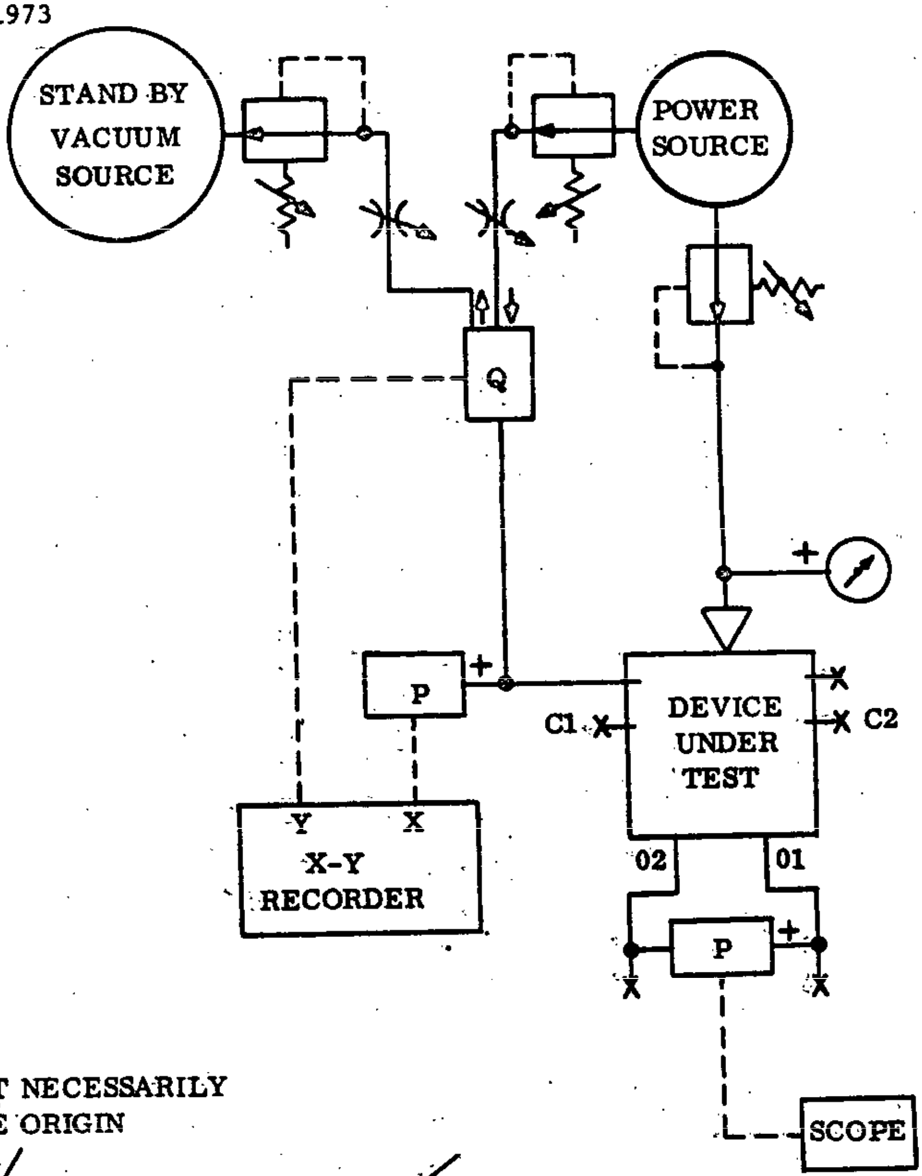
2. APPARATUS. The apparatus is shown in Figure 1002. The characteristic curve shown in the figure may lie in more than one quadrant making the vacuum source necessary. The control impedance may undergo an abrupt change when the switching pressure is reached.

3. PROCEDURE. Connect circuit as shown in Figure 1002. Note that ports not being tested are blocked. The power supply pressure shall be set to nominal; i.e., the specific design operating pressure or the midpoint of the operating range. The control valve shall be opened slowly so that transient effects are minimized. Continue increasing the control flow after switching occurs to a pressure equal to the nominal supply pressure or until instabilities become obvious. The occurence of switching is not an instability. Then slowly decrease the control pressure to a negative value equal to 50 percent of the nominal supply pressure or until instabilities become obvious. Finally, increase the control flow to the starting point. Depending on the type of the device, the switching pressures and flows may not be obvious. If not, the output pressure transducer must be simultaneously monitored to determine the level of control pressure when switching occurs as per test method 1004. It may be efficient to perform test method 1004 as this test is being performed using another data channel for the output pressure. Repeat the process for each control port.

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The pressure vs. flow data for each input along with the input designation and the test method number.

(b) Specify or label the switching points on the input characteristic curves. If the control characteristics are load sensitive, so specify and refer to data from load sensitivity tests. If the control characteristics can be normalized with respect to P_s, data from test method 1007S1002 may be referred to.


STAND BY VACUUM SOURCE
POWER SOURCE
Q
P
+
DEVICE UNDER TEST
C1
C2
02
01
Y
X
X-Y RECORDER
P
SCOPE
X ALL UNUSED SIGNAL PORTS ARE BLOCKED

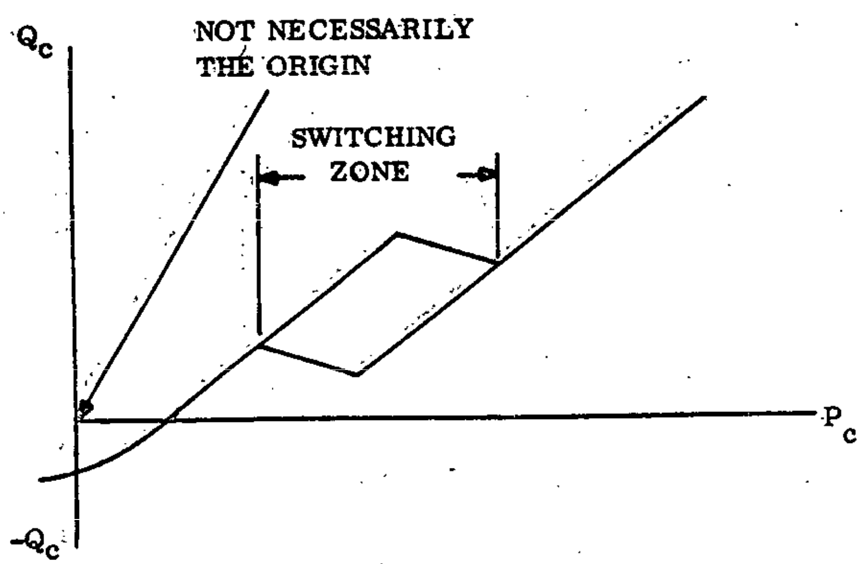

Qc
-Qc
Pc
NOT NECESSARILY THE ORIGIN
SWITCHING ZONE

FIGURE 1002

METHOD 1003

OUTPUT CHARACTERISTICS

1. PURPOSE. This method establishes the means of determining the output characteristics for jet interaction digital devices. The output characteristics show variation of output flow and pressure as load resistance varies. The behavior of an output port in its "off" or low-level state is of considerable interest since flow, while ideally zero, usually occurs as some function of the load conditions.

2. APPARATUS. Pressure and flow measuring equipment shall be connected as shown in Figure 1003-1. A vacuum source shall be used to provide pressures near and below ambient at the point between the device and the load valve.

3. PROCEDURE. With the circuit connected as shown in Figure 1003-1, set the power supply pressure to nominal. Starting with the output valve closed (or as nearly closed as stable operation permits), increase the output pressure using the source if necessary, recording or plotting flow vs. pressure until the stability limit is reached or until the pressure equals the nominal supply pressure. Now decrease the pressure. If the device has switched states, the data will trace the "off" state curve. Continue to decrease the pressure until the upper stability limit is reached or until the pressure is -50 percent of nominal supply pressure. Continue to take data by increasing the pressure until the original output conditions are reached.

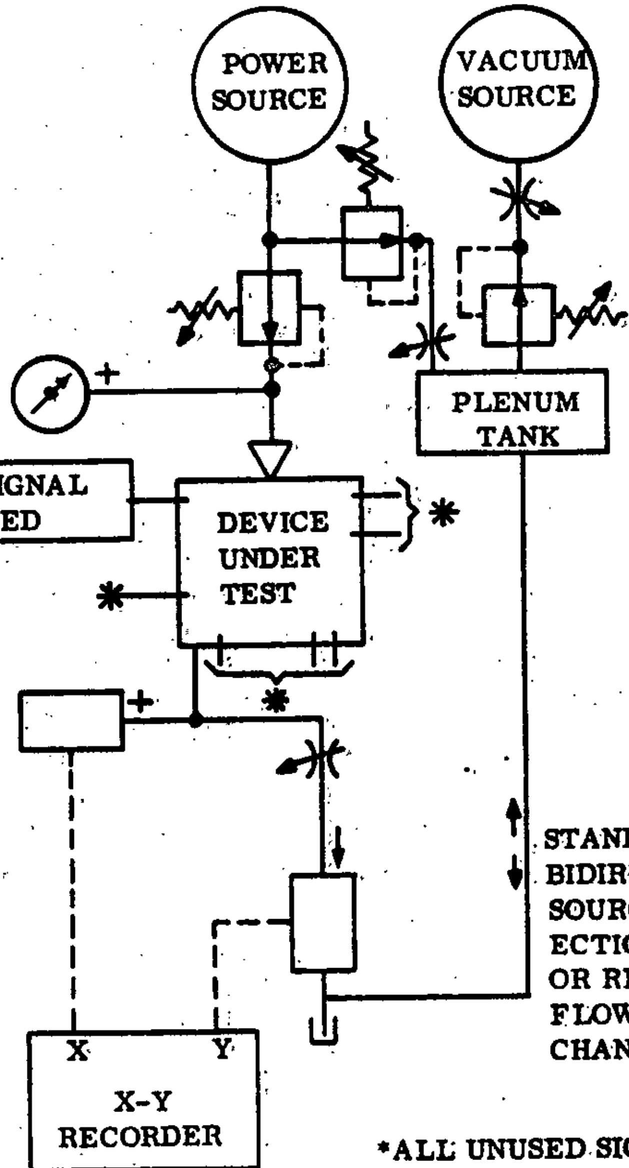
Repeat this for each output port. If reaching the pressure limits indicated above does not induce switching, then, after taking the first curve as described above, the switched curve is to be taken using a holding signal on the appropriate control. The value of the holding signal shall be equal to 125 percent of the value of the pressure required to make the device switch as indicated in test method 1004.

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The recorded pressure vs. flow data for each output port and for each output state along with the output port designation and the test method number.

(b) The control port conditions associated with each of the characteristic curves; i.e., a holding signal is needed and its strength.

(c) If the output characteristics are load sensitive, so specify and refer to data from load sensitivity tests. If the output characteristics can be normalized with respect to P_s, data from test method 1007S1003 may be referred to.



NOTE: PRESSURE SHOULD BE KNOWN DOWNSTREAM OF FLOW METER.

STANDBY REGULATED BIDIRECTIONAL FLOW SOURCE. USE BIDIRECTIONAL FLOW METER OR RECONNECT WHEN FLOW DIRECTION CHANGES.

*ALL UNUSED SIGNAL PORTS ARE BLOCKED.

FIGURE 1003-1

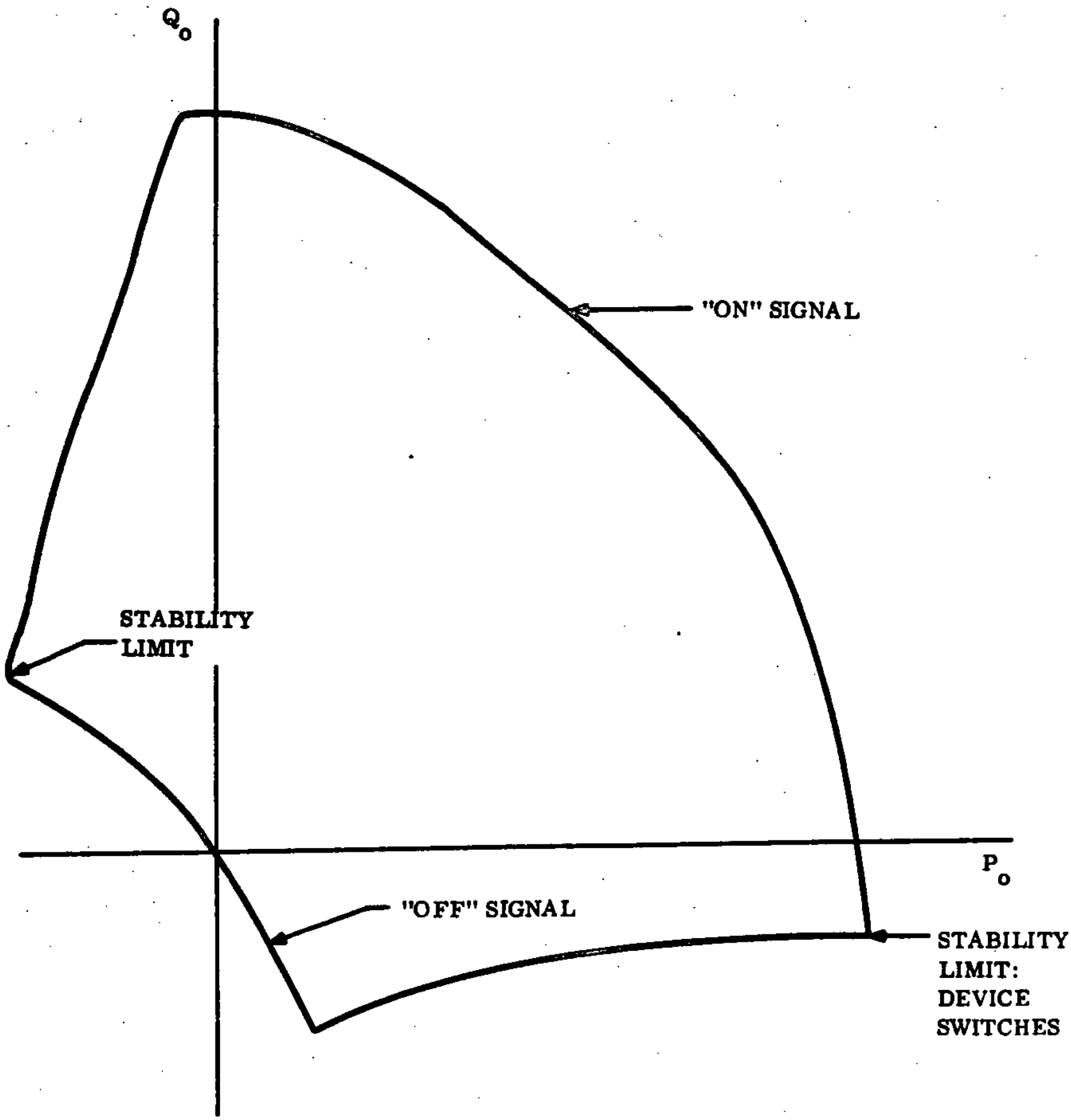


FIGURE 1003-2

METHOD 1004

INPUT-OUTPUT PRESSURE SWITCHING CURVES

1. GENERAL. The general form of the switching curve depends on the kind of device under test. Figure 1004a shows some of these curves. Still other switching curves exist for such devices as Schmidt triggers and inhibited OR gates.

2. PURPOSE. This method establishes the means of determining the specific input-output pressure switching curves for specific digital elements. These data show the relation between the input control pressure signal and the output pressure signal.

For flow information, the control flow signal for any pressure may be gleaned from the control impedance data which were derived using test method 1002, or it could be measured (as well as can the output flow signal) using a testing procedure analogous to this method but using flow rather than pressure transducers (see test method 1006).

3. APPARATUS. The apparatus is shown in Figure 1004b.

4. PROCEDURE. The exact procedure to be followed depends on the specific device which is being tested. As an example of the procedural variations that are imposed by the different kinds of devices, consider Figure 1004b showing the test setup for what might be an OR/NOR gate. To test an AND gate, the control signal would be applied to a plenum chamber to ensure that all the ports receive the same signal. Also, it is important to monitor the correct output port. Whereas, the circuit shown in Figure 1004b is good for measuring the output signal, which is a complementary function of the input signal such as a NOR or NAND output, the circuit would have to be changed to measure an output OR or AND function by monitoring the other output port. Most fluidic devices have an inverted and a non-inverted output. For such devices, it would be efficient to monitor both outputs at the same time.

With the circuit connected appropriately for a particular device, set the power supply pressure to nominal and proceed as with the procedure for test method 1002.

5. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The output pressure as a function of the control pressure for all the combinations of the output ports and the input ports which cause switching shall be provided. The test method number shall also be provided.

(b) Since the switching function is often a strong function of the loading condition, reference to data taken from test methods 1006S1004, 1008S1004, and/or 1009S1004 shall be made, or it shall be specifically stated that the device is not load sensitive.

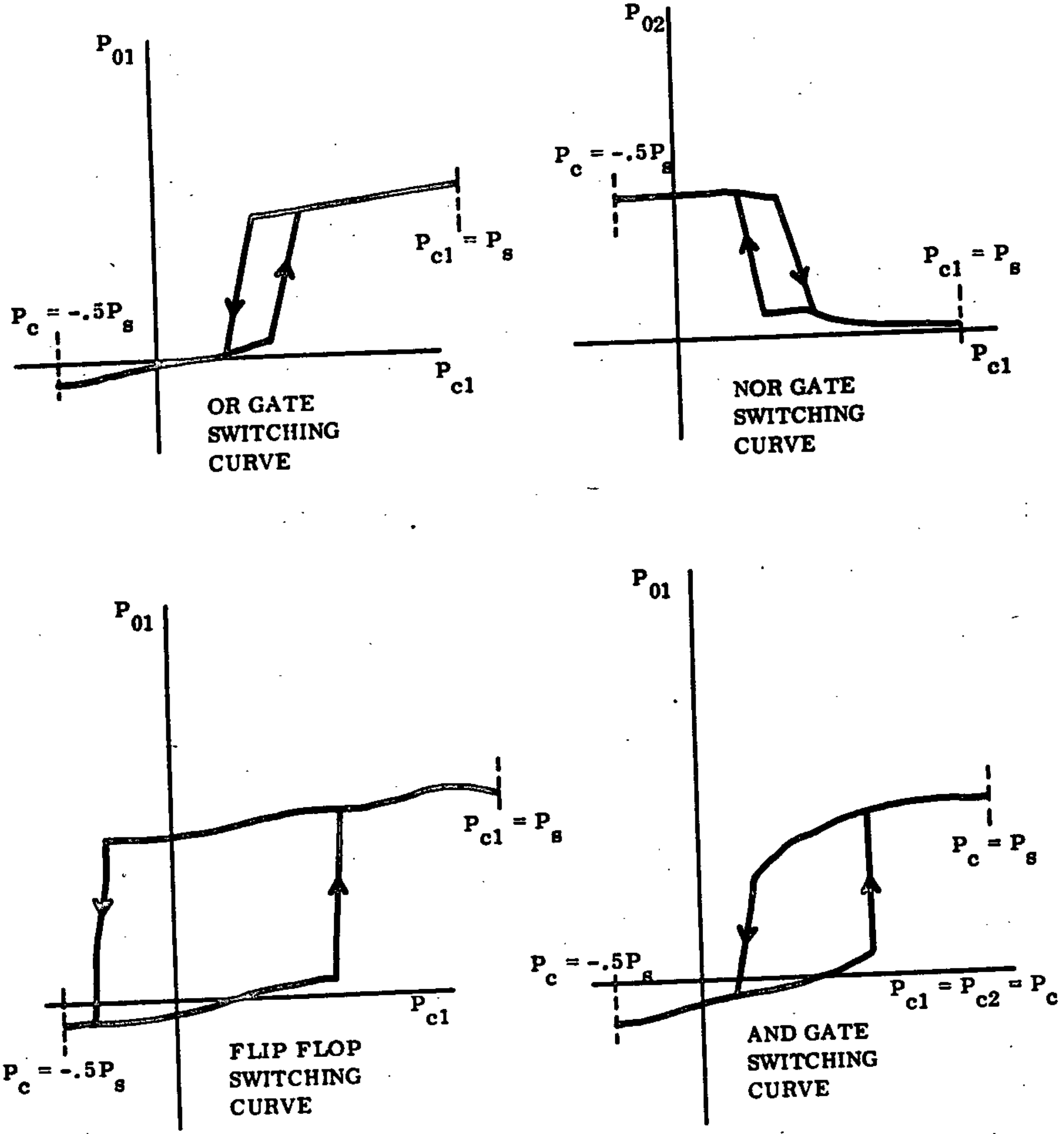


FIGURE 1004a

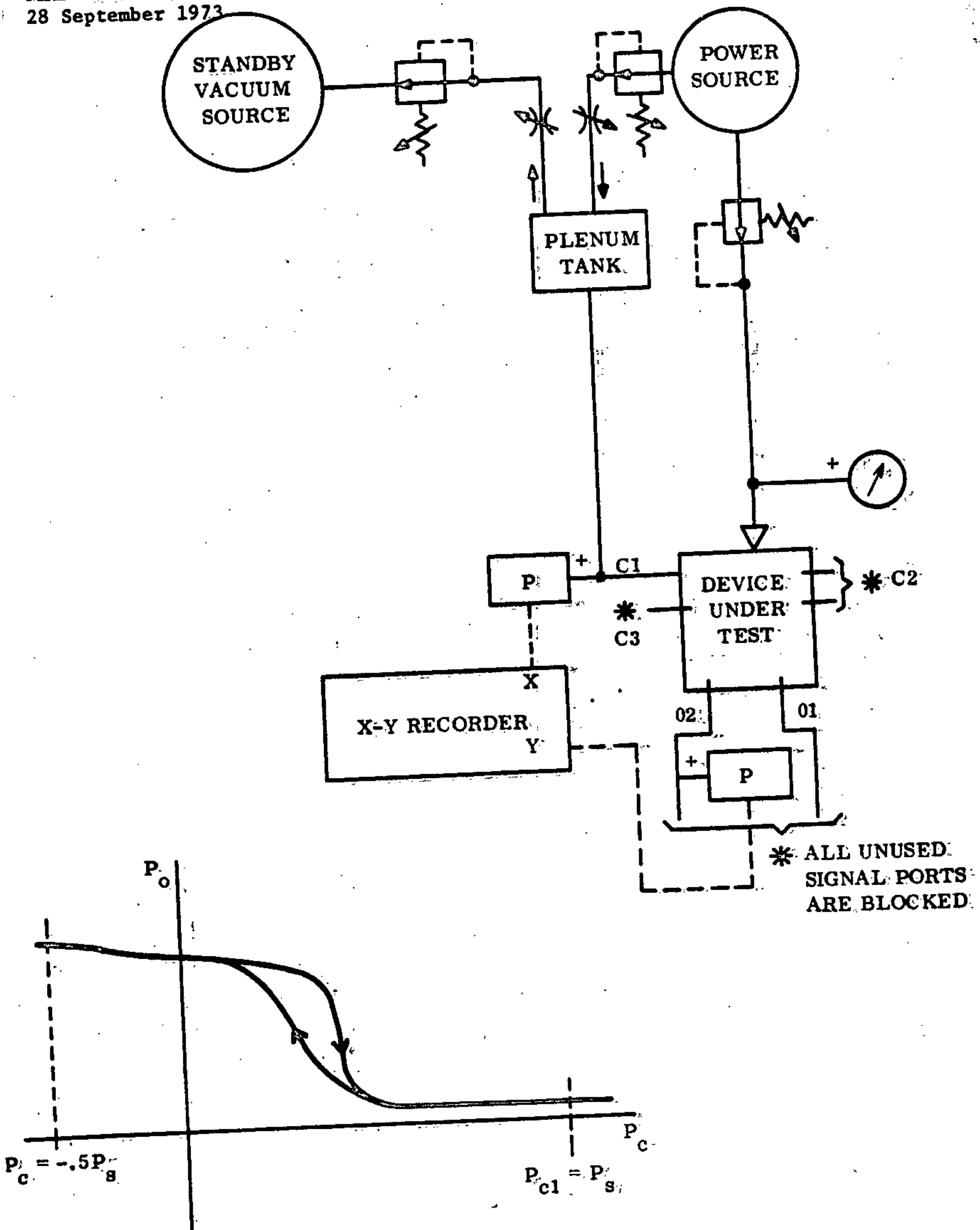


FIGURE 1004b

METHOD 1005

PRESSURE RECOVERY

1. PURPOSE. This method establishes the pressure recovered at the outputs of a device as a function of the supply pressure. These curves often help define the range of operation of the devices such as indicating the supply pressure for which bistable operation of a flip-flop can be obtained or by indicating the critical N_R for the turbulence amplifier.

2. APPARATUS. The apparatus is shown in Figure 1005. Note that this is nearly the same as that in Figure 1001 except that the output pressure is monitored.

3. PROCEDURE. Connect circuit as shown in Figure 1005. Note that all unused signal ports are blocked. The power valve must be opened slowly so that transient effects are minimal. The power jet pressure should be increased from zero to at least the maximum operating pressure and beyond if such an additional excursion will show information pertinent to the understanding of the operation of the device such as N_R for turbulence amplifiers. It might be efficient to run this test method and test method 1001 at the same time.

When the device is bistable, data is to be taken from each output port for at least two excursions of the supply pressure (one for each stable state). When the device is monostable, data is to be taken from each output port for at least one excursion of the supply pressure. Additional curves could be generated using a holding signal to switch the device from its normally stable condition. The value of the holding signal should be changed as the power jet pressure is increased to reflect the dependency of the switching pressure on the power jet pressure. The holding signal should be 125 percent of the switching pressure at a given power jet pressure.

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) Report the output data from these tests as a percentage of the supply pressure or in non-reduced pressure units or both as a function of the supply pressure and test method number.

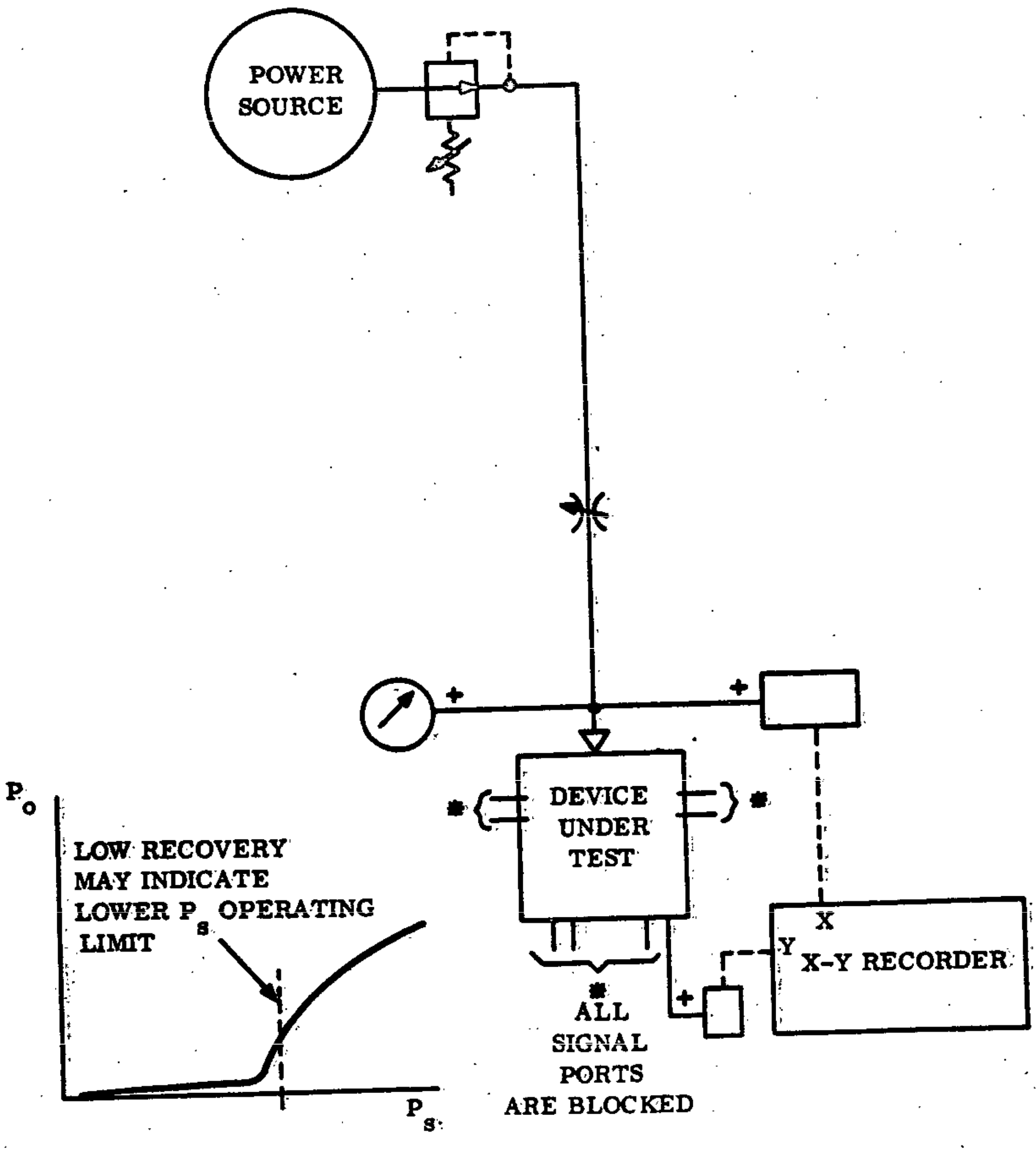

POWER SOURCE
DEVICE UNDER TEST
X
Y
X-Y RECORDER
* ALL SIGNAL PORTS ARE BLOCKED
P o
LOW RECOVERY MAY INDICATE LOWER P s OPERATING LIMIT
P s

FIGURE 1005

METHOD 1006

LOAD SENSITIVITY

1. PURPOSE. In other test methods (1001 through 1005) delineated in this appendix, it is specified that the unused signal ports are to be fully blocked (and therefore have zero flow). This specification is to give a repeatable, consistent set of data for the basic quasi-static element characteristics. Ideally, the load conditions will not effect the characteristics of any device, and fully blocked ports should not yield characteristics different from fully open ports. This may not be the case, however, and this test method shall be performed to determine the effect that loading has on the characteristics of the device.

2. SCOPE. Each of the basic quasi-static element characteristic test methods numbered 1001 through 1005 shall be modified by using fully open (passing), unused signal ports rather than nonpassing ports. Each of the five different modified tests is designated by a two-part number as specified in 4.1.1. The first part is 1006 to indicate a test using fully open (passing) unused signal ports. The second part of the designation number indicates which of the particular basic characteristics is being tested for load sensitivity. The test methods are:

1006S1001 Load Sensitivity Test of the Power Nozzle Characteristics
1006S1002 Load Sensitivity Test of the Control Port Characteristics
1006S1003 Load Sensitivity Test of the Output Characteristics
1006S1004 Load Sensitivity Test of the Pressure Switching Curves
1006S1005 Load Sensitivity and Test of the Pressure Recovery

3. APPARATUS AND PROCEDURE. The specific apparatus and procedure for each specific sub-method test can be found in the appropriate basic test method. However, rather than using blocked ports and pressure transducers, open ports shall be used with flow transducers. When each of these sub-methods are used, flow measurements at the unused signal ports may be made as were pressure measurements made in the basic tests provided caution is taken to ensure that the port is not artificially loaded by the flow instrumentation which is used. For example, during test method 1006S1001, the load sensitivity test of the amount of flow recovery (test method 1006S1005), may be simultaneously taken using a rotometer on the output legs. But then a vacuum source shall be used to overcome the rotometer impedance, and pressure gages shall also be used to ensure that ambient pressure exists at the output port.

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The data may be presented as unreduced data in the same form as that used for the data for the corresponding blocked load test, or the dependent variable data may be shown as the deviation from the blocked load test data in decibels or as a percentage deviation from the blocked load test data as a function of the independent variable. When the data taken during a sub-method test does not exceed the data from a basic test by an amount greater than the specified limits of accuracy (see 4.6.2) accorded to the basic test data, then the device may be termed load insensitive. This allows for a device to be partially load insensitive; e.g., P_s vs. Q_s may be insensitive while P_c vs. Q_c may be sensitive.

(b) When a device is load sensitive and a "short form" of this sensitivity data may be presented, it shall be presented as the maximum deviation from the blocked load test data in decibels or in percent. Thus, this short form data is a single number describing the maximum variance in a particular characteristic such as the supply characteristic in decibels or in percent caused by opening the loaded ports.

METHOD 1007

EFFECT OF POWER JET PRESSURE VARIANCE

1. PURPOSE. In other test methods (1002, 1003, and 1004) delineated in this appendix, it is specified that P_s be set at nominal. When the element characteristics are to be known for values of P_s other than nominal, this test method shall be performed.

2. SCOPE. Each of these three test methods shall be rerun. Each of the three different modified tests is designated by a two-part number as specified in 4.1.1. The test methods are:

1007S1002 Effect of Power Jet Pressure Variance on Control Port Characteristics
1007S1003 Effect of Power Jet Pressure Variance on Output Characteristics
1007S1004 Effect of Power Jet Pressure on Switching Characteristics

3. APPARATUS. Use the appropriate circuit for the particular characteristic being tested for effect of power jet variance.

4. PROCEDURE. Use the appropriate procedure for the particular characteristic being tested for effect of power jet variance. However, rather than having the power jet pressure set at nominal, set it at 75 percent of nominal and repeat again at 125 percent of nominal. These tests may be repeated as often as desired using any additional power jet pressures which are of interest.

5. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The data may be presented as unreduced data in the same form as that used for the data for the corresponding P_s = nominal test, or the dependent variable data may be shown as the deviation from the data taken at P_s = nominal in decibels or as a percentage deviation as a function of the independent variable.

(b) When a "short form" of this data may be presented, it shall be presented as the maximum deviation from the P_s = nominal data in decibels or as a percentage for both P_s = 75 percent P_s nominal and P_s = 125 percent P_s nominal. Thus, this short form data are two numbers, one for P_s low and one for P_s high, describing the worst variance in a particular characteristic, such as the control characteristic, caused by changing the power jet pressure.

(c) It is often the case that the characteristics for fluidic devices are independent of the supply pressure setting within a certain range. To demonstrate this feature of any particular device, the curves may be normalized with respect to the power jet pressure. When the data taken during a sub-method test does not exceed the data from a basic test by an amount greater than the specified limits of accuracy (see 4.6.2) accorded to the basic test data over a range of P_s, then the characteristic may be normalized with respect to P_s, over that range.

METHOD 1008

ALTERNATE LOAD SENSITIVITY

1. PURPOSE. In other test methods (1001 through 1005) delineated in this appendix, it is specified that the unused signal ports are to be fully blocked (and therefore have zero flow). Method 1006 is designed to determine the effect that loading has on the characteristics as taken in the other test methods mentioned above. This is done by using an open load. These two loading conditions should, in general, bracket the loading conditions effects. However, it may be necessary or desirable to test a given device with some other load. It is the purpose of this test method to offer such a possibility.

2. SCOPE. Any of the characteristics generated by the test methods 1001 through 1005 may be retaken using a well defined impedance load on all of the unused signal ports. To designate each different test, two-part numbers are used as specified in 4.1.1. The test methods are:

1008S1001 Alternate Load Test of the Power Nozzle Characteristics
1008S1002 Alternate Load Test of Control Port Characteristics
1008S1003 Alternate Load Test of Output Characteristics
1008S1004 Alternate Load Test of Pressure Switching Characteristics
1008S1005 Alternate Load Test of Percent of Recovery

3. APPARATUS AND PROCEDURE. It is first necessary to take the impedance characteristics of the load resistor. (If the load resistor is from another fluidic device, then the port on that device which is being used as the load resistor is to be the only port to which flow is applied.) All other ports except vents are to be fully blocked. These impedance characteristics for the load resistor shall be taken exactly as prescribed in test method 1001. The range of pressures shall include those that will be experienced by the load attached to the device under test. The impedance characteristic data shall be presented with the data generated by this test method.

The specific circuit for each of the tests can be found in the appropriate basic test method (1001 through 1005). However, rather than using blocked ports and pressure transducers, use the load resistors attached to the unused signal ports and measure the pressure at a point between the device under test and the load. (When flow information is needed, it can either be determined from the impedance characteristics of the load or it can be measured directly.)

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The data may be presented as unreduced data in the same form as that used for the data for the corresponding blocked load test or the dependent variable data may be shown as a deviation from the blocked load test data in decibels or as a percentage deviation from the blocked load test data as a function of the independent variable.

(b) When a "short form" of this sensitivity data may be presented, it shall be presented as a maximum deviation from the blocked load test data in decibels or in percent. Thus, this short form data is a single number describing the greatest change in each particular characteristic, such as the supply characteristic, caused by opening the loaded ports.

METHOD 1009

CIRCUIT LOADING SENSITIVITY

1. PURPOSE. In the other test methods in this appendix, various loading conditions are specified. In each case, the load which is specified on any single unused port is specified for all unused ports. It may be of interest to test a device with different loads on different ports at the same time as, for example, when testing for particular circuit conditions or for worst case conditions of stability.

The purpose of this test is to allow for this possibility.

2. SCOPE. Any of the characteristics generated by the test methods 1001 through 1005 may be retaken using a well defined impedance load on any unused signal port. To designate each different test, two-part numbers are used as specified in 4.1.1. The test methods are:

1009S1001 Circuit Loading Sensitivity Test of the Power Nozzle Characteristics
1009S1002 Circuit Loading Sensitivity Test of the Control Port Characteristics
1009S1003 Circuit Loading Sensitivity Test of the Output Characteristics
1009S1004 Circuit Loading Sensitivity Test of Pressure Switching Curves
1009S1005 Circuit Loading Sensitivity Test of Pressure Recovery

3. APPARATUS AND PROCEDURE. If loads other than fully open or fully blocked are to be used, then it is first necessary to take the impedance characteristics of the additional load. (If the load resistor is from another fluidic device, then the port on that device which is being used as the load resistor is to be the only port to which flow is applied.) All other ports except vents are to be fully blocked. These impedance characteristics for the load resistor shall be taken exactly as prescribed in test method 1001. The range of pressures shall include those that will be experienced by the load attached to the device under test. The impedance characteristic data shall be presented with the data generated by this test method.

The specific circuit for each of the tests can be found in the appropriate basic test method (1001 through 1005). However, rather than using the blocked loads as per the basic test method specifications, individual ports in the device under test may be loaded by any of the three options given above. The loads which are actually used shall be given along with the data generated by this test method.

4. SUMMARY. In addition to the information specified in 4.6, the following information shall be specified:

(a) The data may be presented as unreduced data in the same form as that used for the data for the corresponding blocked load test, or the dependent variable data may be shown as the deviation from the blocked load test data in decibels or as a percentage deviation from the blocked load test data as a function of the independent variable.

(b) When a "short form" of this sensitivity data may be presented, it shall be presented as the maximum deviation from the blocked load test data in decibels or in percent. Thus, this short form data is a single number describing the greatest change in each particular characteristic, such as the supply characteristic, caused by change from blocked load and uniform load on specified ports.

METHOD 1100

SWITCHING TIME

1. PURPOSE. This method establishes the means of determining the switching time for certain digital devices. Switching time is not defined in MIL-STD-1306.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Switching time (t_s). The total elapsed time from the first discernible change in the input until the output has reached 90 percent of its final value.

1.1.2 Propagation delay time (t_{pd}). The time measured to a specified level of the output from a corresponding level of the input. The levels are specified in terms of percent of final value.

1.1.3 Rise time (t_r). The time of transition of the output signal from 10 percent to 90 percent of its final high value.

1.1.4 Fall time (t_f). The time of transition of the output signal from 90 percent to 10 percent of its initial high value.

2. APPARATUS.

2.1 Timing equipment. A dual trace time base oscilloscope with memory capability is a reliable means of accomplishing time measurement to fractions of milliseconds.

2.2 Pressure instrumentation. The pressure transducers at the input and output should be similar with respect to volume and frequency response. The accuracy and frequency response shall be specified in the applicable procurement document.

2.3 Driving signal. A low impedance wall attachment amplifier operable over a wide range of supply pressures can provide a realistic driving signal similar to what would be encountered in circuit use. However, to determine with certainty the shortest possible transient times of the device under test, a constant flow source is required. Small devices can be driven by large ones for this purpose. To test a large device with relatively low input impedance, an electromechanical square wave generator will be more satisfactory. Unless otherwise specified, test data on transient characteristics shall include an output characteristic curve of the driving source used in the test.

3. PROCEDURE. The test circuit and instruments shall be connected as shown in Figure 1100-1. Line lengths must be kept short since each inch of line length requires roughly .1 milliseconds of transport time.

3.1 Measurement of t_{pd}. Propagation delay time can be measured between any two corresponding points of the input and output. Figure 1100-2 shows t_{pd} measured from the application of the input to the first discernible change in the output. It may also be taken between the 50 percent values of the input and the output. Other corresponding points of the signals may be more appropriate for a particular case.

3.2 Measurement of t_r and t_f. The rise transition time at the output shall be measured from the 10 percent point to the 90 percent point. The fall transition time shall be measured from the 90 percent point to the 10 percent point. Figure 1100-3 shows typical transition time characteristics.

The propagation delay time and the transition times should be measured with the power supply pressure of the device under test set to its nominal value or midpoint of a design range. The driving signal should exceed the switching pressure of the device under test by at least 100 percent. To simulate normal operating conditions as closely as possible, the resistance of the load should be equivalent to the resistance of the control nozzle of an identical device. The process should be repeated with at least two other power supply pressures, one above and one below nominal.

3.3 Switching time. The sum of the propagation delay time and the rise (or fall) time closely approximates the switching time and will be acceptable unless otherwise specified.

4. SUMMARY. The following details shall be specified:

(a) t_{pd} as shown in Figure 1100-2 or as otherwise specified in the applicable procurement document.

(b) t_r and t_f at nominal P_s and minimum during signal.

(c) t_r and t_f at P_s above and below nominal P_s, or as specified by the applicable procurement document.

(d) Ambient conditions at time and place of testing.

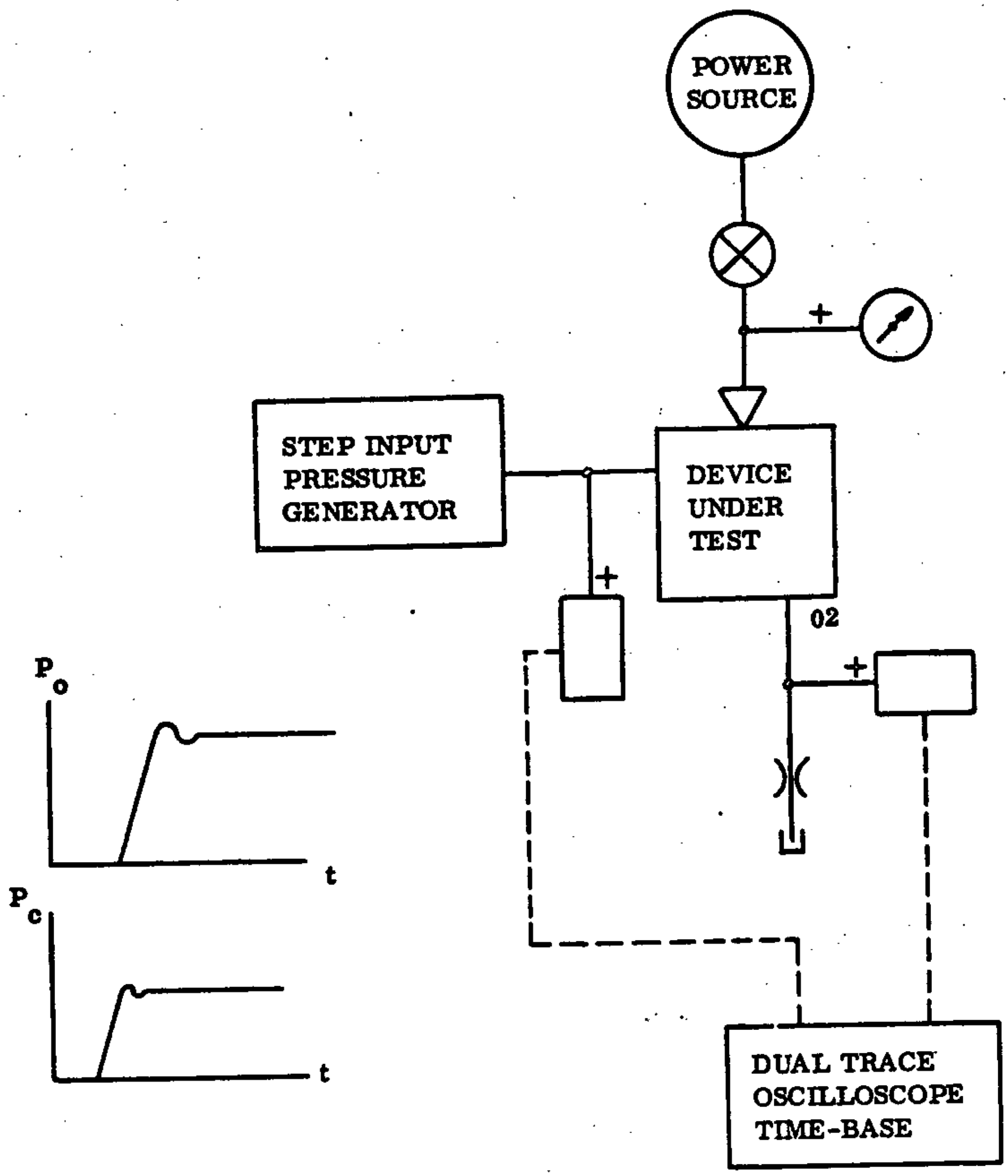


FIGURE 1100-1

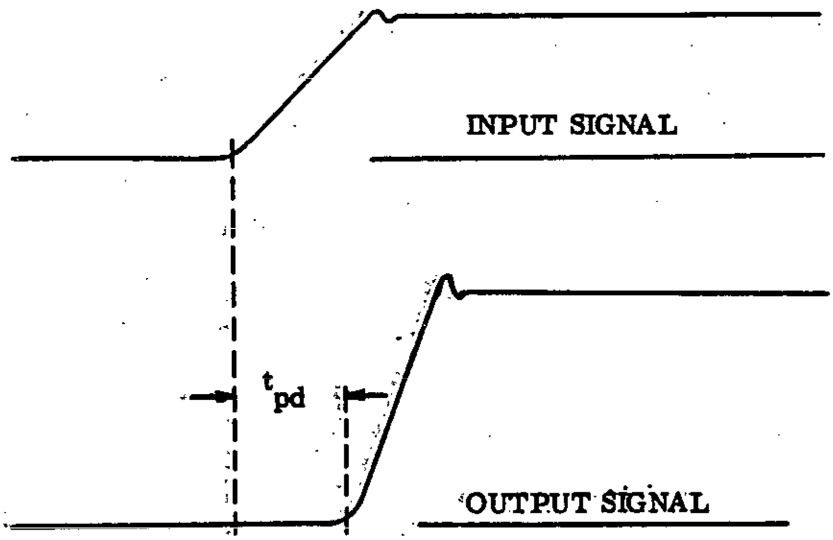


FIGURE 1100-2 PROPAGATION DELAY

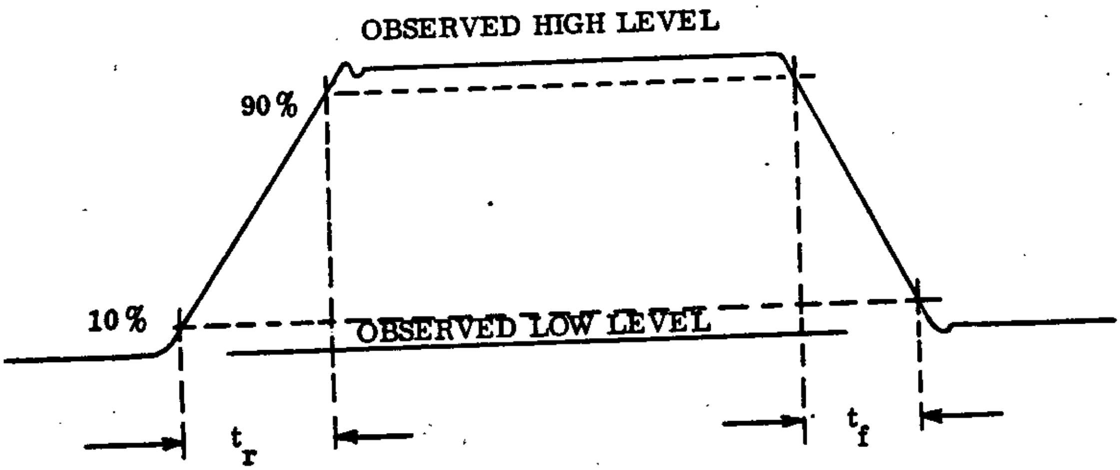


FIGURE 1100-3 RISE TIME AND FALL TIME

METHOD 2001

POWER SUPPLY, QUIESCENT INPUT AND QUIESCENT OUTPUT CHARACTERISTICS

1. PURPOSE. This method establishes the means for measuring power supply, quiescent input and quiescent output characteristics for low frequency, pneumatic use (generally under 25 Hz).

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Balanced amplifier. A differential amplifier whose impedance at each input terminal is identical over a specified range of (a) quiescent input pressures, (b) supply pressures, (c) balanced load impedances. If under these conditions output gage pressure and flow are within 5 percent of their average values when the differential input pressure and flow are zero, then the amplifier is balanced.

1.1.2 Input bias pressure. That differential pressure which must be applied to the control ports of a differential input amplifier to force the output differential pressure to zero, when loaded with matched passive impedances of specified value. Supply pressure, P_S, and quiescent input pressure, P_{CO}, must be specified.

1.1.3 Input bias flow. The input bias flow is the difference between the flows entering the control port of a differential input amplifier required to force the output differential pressure to zero when loaded with matched passive impedances of specified value.

2. APPARATUS. The apparatus shall consist of regulators, valves and restrictors capable of delivering sufficient flow to establish a maximum useful supply and quiescent input pressure for the element under test. The extent to which the investigation is automated affects the circuit design and thus the choice of some elements in the circuit. Figure 2001-1 is a complete but rudimentary circuit for measuring supply and quiescent characteristics. Figure 2001-2 is a circuit for using controller driven valves and automatic data reducing and recording equipments.

2.1 Pressure sensors. The pressure sensor (gage, manometer or whatever) should be connected to lines through expansion tanks. This is done to reduce the speed of the fluid so that the reading obtained represents total pressure.

2.2 Flow sensors. Flow meters of very low impedance must be used at the outputs. If the pressure drop through the flow meter is large, the accuracy of the calculations is affected. For the case of the control and power supply, if connected as shown in Figure 2001-1, the pressure drop through the flow meter becomes negligible as the line pressure at that point becomes larger. Care must be taken not to exceed the rated pressure of the flow meter.

3. PROCEDURE.

3.1 Power supply characteristics. The power supply characteristics are a plot of the power supply flow values, varying as the power pressure is varied from zero to maximum design pressure. Load impedance and quiescent input pressures and flows can affect the power supply characteristics so that the conditions under which these measurements are taken must be specified. Alternately, several curves taken with different combinations of input pressures and output impedances may be included.

Referring to Figure 2001-1, the power valve should be adjusted to several different settings (at least five) with inputs and outputs closed. Evidence of possible load sensitivity may occur during these readings as the power supply pressure is increased. If the amplifier is unstable, reduce output impedance to maximum value for which stability occurs.

Repeat the test with input valves open and output impedance reduced to minimum, plotting points on the same graph as above, connecting them to form smooth curves.

Repeat the test once more with input quiescent pressures maintained at 10 percent (or other appropriate percentage) of P_s, plotting the points on the same graph as before so that the curves can be compared. Typical curves are shown in Figure 2001-3.

If the curves overlie, then the power supply characteristics are essentially insensitive to loading and input conditions. If the curves do not overlie, each curve should be plainly identified.

If the process is automated, Figure 2001-2 is a basic test circuit. Valves must be opened and closed slowly to minimize transient effects.

3.2 Quiescent input characteristics. The quiescent input characteristics are a plot of input quiescent flow values varying as the input quiescent pressures are varied from zero to maximum design value or beyond if an operational maximum value is to be determined. Frequently, power supply condition can affect the quiescent input characteristics. Less often, the input characteristics are affected by load impedance. To illustrate these effects or their absence, quiescent input characteristics should be taken at two different supply pressures, running each under zero and maximum load impedance conditions. Plot these four characteristics on a single graph. See Figure 2001-4.

3.3 Quiescent output characteristics. The quiescent output characteristics are a plot of output flow values varying as output pressure is varied by means of changing the load impedance, all while the differential input pressure is held constant (zero, for the case of a balanced amplifier). Referring to Figure 2001-1, the power supply pressure is set to its minimum value. The quiescent input pressure is set to 10 percent of P_s. The output pressure and flow(both fixed by the load impedance) are recorded as a point on the graph. Without changing the load impedance, other points are generated with increasing P_s and P_{co} values. The process is repeated for three or four load impedance settings and the points are connected with lines of constant power supply pressure as shown in Figure 2001-5.

4. SUMMARY. The graphs generated in the above tests are necessary for only one side of the amplifier if it is balanced. In addition to the data described above, the barometric pressure and ambient temperature must be shown.

	Yes	No
Balanced?		
Operable with blocked load?		

Present the power supply characteristics as shown in Figure 2001-3. Particular points on the power supply curve can (should) be specifically labeled. For example, if, during the course of this and other tests, it is noticed that a particular point or range of points on the power supply characteristic yields a superior S/N ratio, this point or range should be indicated and so labeled on the power supply curve.

If the curves overlie, indicate the range of input and the loading conditions under which the data were taken.

Present the quiescent input characteristics as they are shown in Figure 2001-4. If the curves overlie, indicate the various input and loading conditions under which the data were taken.

Present the quiescent output characteristics as they are shown in Figure 2001-5. Two additional curves would be appropriate. With the P_s set to a nominal value (say, case c in Figure 2001-5), present curves for $P_{co}/P_s = .05$ and $P_{co}/P_s = .25$ respectively.

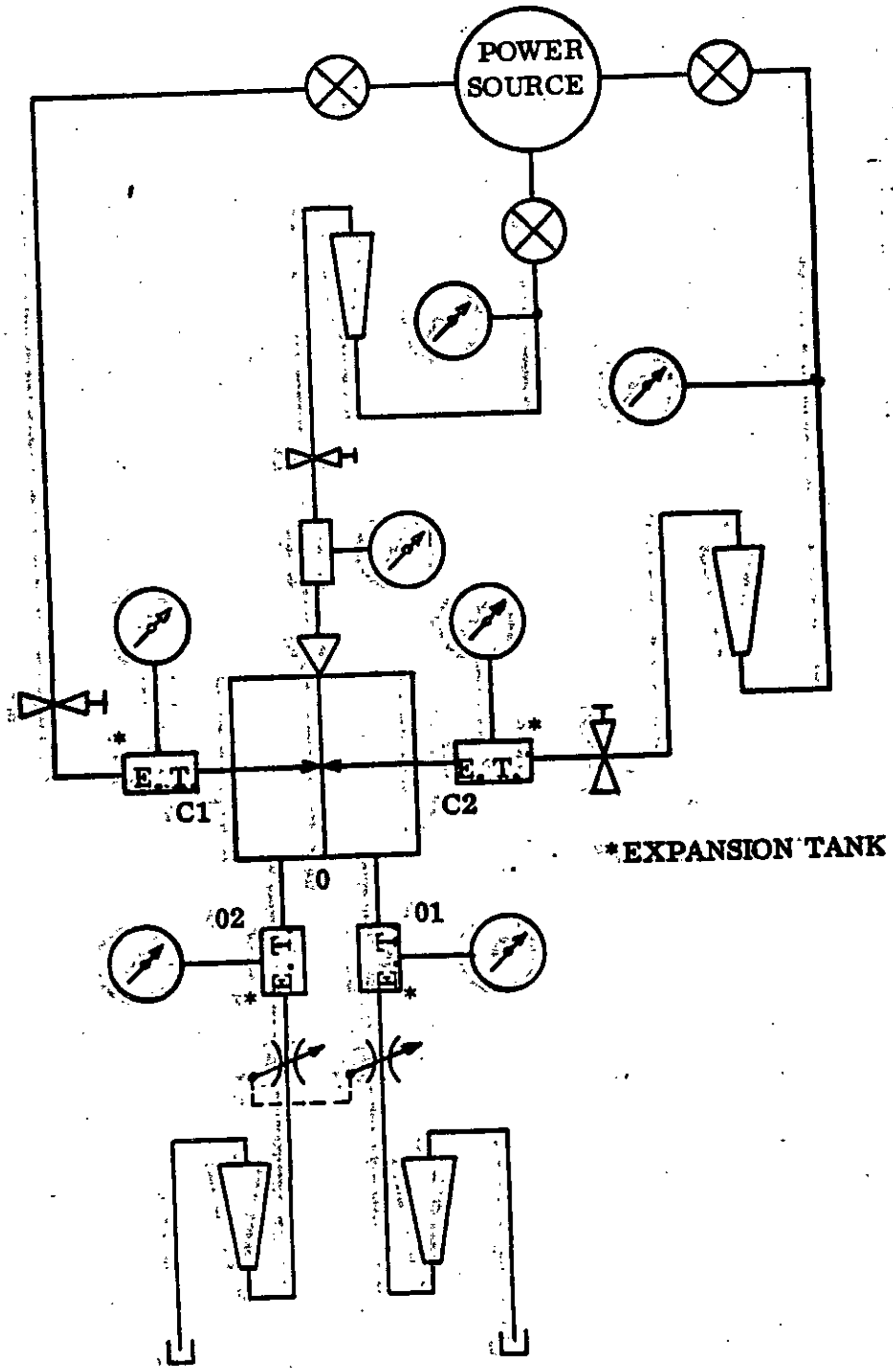


FIGURE 2001-1 POWER SUPPLY, QUIESCENT INPUT AND QUIESCENT OUTPUT TEST CIRCUIT

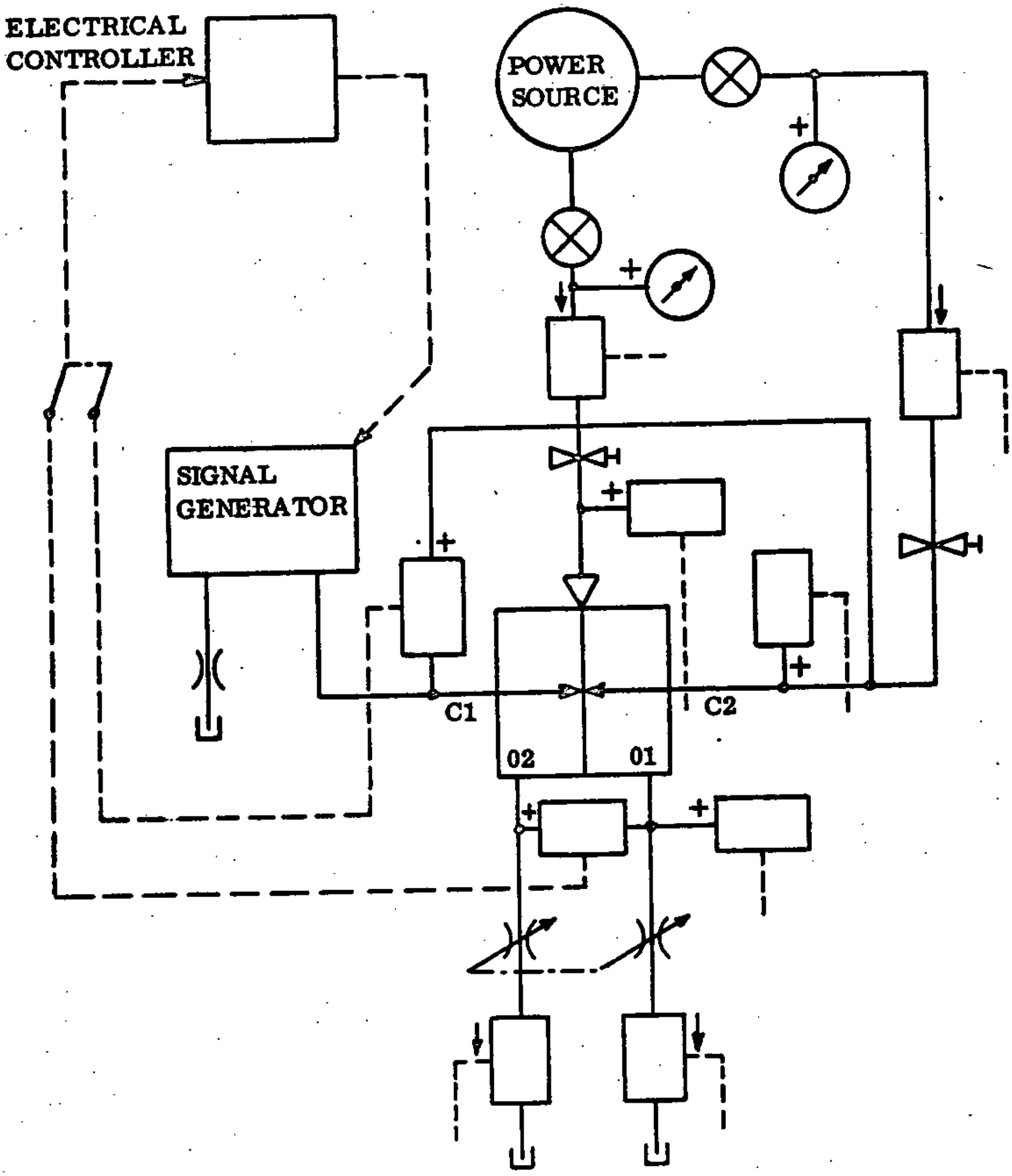


FIGURE 2001-2 POWER SUPPLY, QUIESCENT INPUT AND QUIESCENT OUTPUT TEST CIRCUIT USING AUTOMATED EQUIPMENT

Curve	Input	Z_1
△	Blocked	Zero
▢	Open	Zero
○	10% P_s	Zero
●	10% P_s	Max (or blocked)

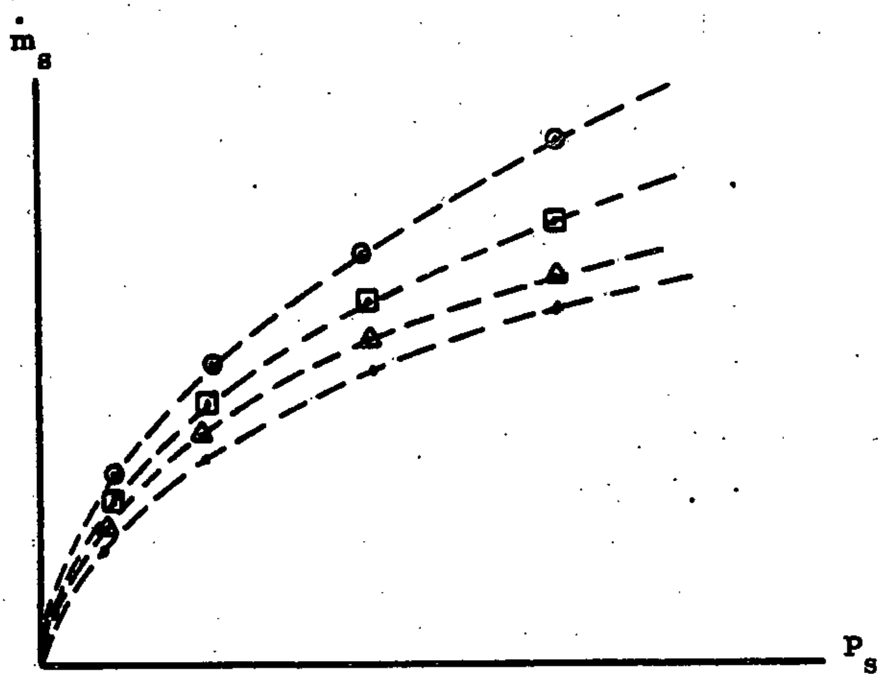


FIGURE 2001-3 POWER SUPPLY CHARACTERISTICS

Curve	P_s	Z_1
⊡	Min	Zero
•	Min	Max (or blocked)
⊙	Max	Zero
▲	Max	Max (or blocked)

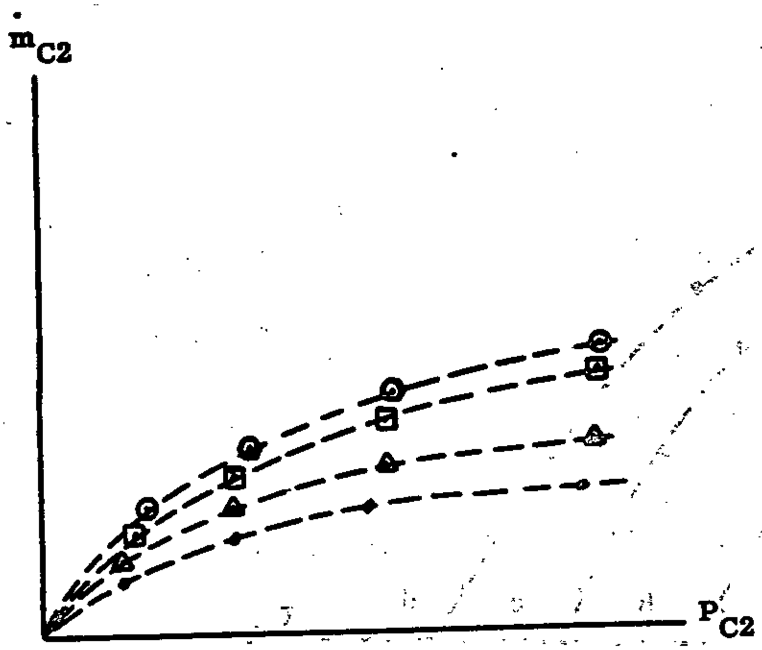


FIGURE 2001-4 QUIESCENT INPUT CHARACTERISTICS, PORT C2

$P_{co}/P_s = .10$

Curve	P_s
a	1
b	4
c	10
d	20

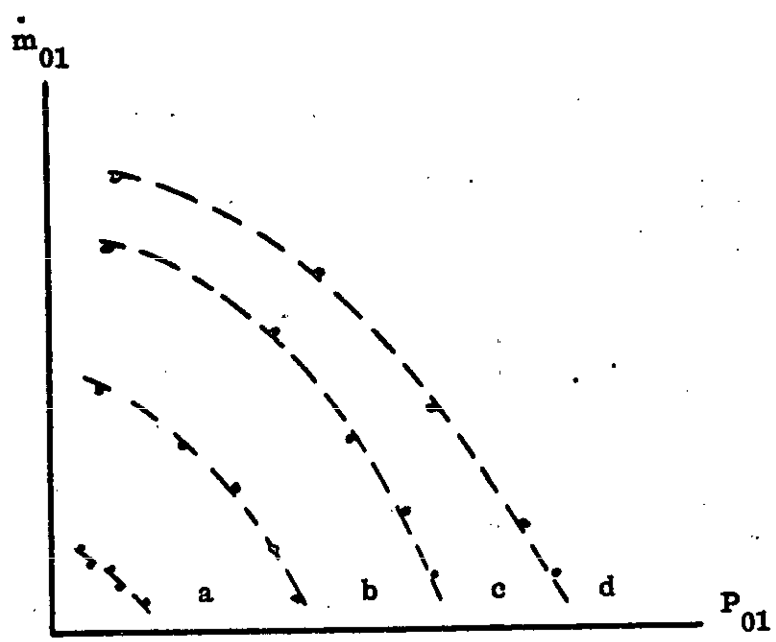


FIGURE 2001-5 QUIESCENT OUTPUT CHARACTERISTICS, PORT 01

METHOD 2002

DIFFERENTIAL INPUT AND OUTPUT CHARACTERISTICS, AND PRESSURE TRANSFER CURVES

1. PURPOSE. This method establishes the means for measuring the differential input and output characteristics. While these characteristics supply the necessary information to compute pressure gain, an alternate more direct way of determining pressure gain comprises a part of this method.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Sign convention. When $P_{C1} > P_{C2}$ the control differential pressure is considered to be positive. Similarly, when $P_{O1} > P_{O2}$ the output differential pressure is considered to be positive.

1.1.2 Nominal supply pressure. The mid point of the range of supply pressures at which an amplifier is designed to be operated.

2. APPARATUS. The apparatus shall consist of regulators, valves, and restriction capable of delivering sufficient flow to establish differential input signals that will drive the output to saturation. The extent to which the testing is automated has considerable effect on the circuit design and thus the choice of some elements in the circuit.

Figure 2002-1 is a complete but rudimentary circuit. If the amplifier is balanced, then the characteristics for one side can be considered valid for the other. Thus, flow readings can be taken on one side only as indicated by Figure 2002-1.

Figure 2002-2 is a circuit utilizing electronic transducers and automatic data reducing and plotting equipment.

2.1 Pressure sensors. The pressure sensors are connected to the lines through expansion tanks so that the reading obtained represents total pressure. Considerable forethought should be given to the size of the tanks. They must be large enough so that the velocity of the fluid is slowed to a negligible magnitude. But volumes are capacitances and they can make the measuring process very cumbersome. For automated test circuits, the size of the expansion tanks and line lengths to pressure sensors must be minimized. The voltage to the valve controllers must be varied slowly so that those transient effects induced by unavoidable volumes are minimized.

2.2 Flow sensors. The output flow meter should be chosen for lowest possible impedance. The impedance of the input flow meter can be made negligible by inserting it into a line of highest practicable pressure consistent with the range and pressure rating of the instrument. The circuit in Figure 2002-1 permits the use of high pressures at the flow meter locations.

2.3 Load impedance. Load impedances should be identical, since in normal operation it is assumed that differential proportional amplifier outputs will be subjected to similar load impedance under quiescent and small signal conditions. A set of five matched pairs of laminar flow resistors can be prepared by making minute length adjustment in capillary tubing. These should be sized so that they admit flows from 10 to 80 percent of the anticipated saturated flow recovery at the output ports of the amplifier to be tested. This involves cut-and-try approximations. A more direct means providing more flexibility involves two valves with similar characteristics for a like number of turns from closed position. These should be mounted rigidly so that they can be geared together. This installation now provides matched output impedances with variability available by turning a single dial.

Matched variable resistors can also be purchased if ranges of pressure and flow are specified.

3. PROCEDURE. The input and output characteristics can be taken simultaneously by taking a number of readings at various settings. The methods vary considerably depending on the extent to which the test is automated.

Referring to Figure 2002-1, set the power supply pressure to nominal value. Set the quiescent input pressures to 10 percent P_s.

The first set of readings is taken with the output lines open to atmosphere (zero load impedance). Pressure and flow readings are taken at C1 and C2 for the quiescent input conditions and recorded on a graph of appropriate scale (this point should lie on the quiescent input curve of Figure 2001-4). The output pressure and flow readings are taken and the point recorded on a graph. The scales of these graphs should be similar, since superposition of these curves reveals the first adjustment necessary to stage one amplifier with another.

Then set C1 pressure to 11 percent P_s and C2 pressure to 9 percent (or 10-1/2 percent P_s and 9-1/2 percent P_s if smaller increments are desired) and make another set of readings, recording the points on the appropriate graph. Continue until C1 is at 15 percent P_s and C2 is at 5 percent P_s.

This completes the positive P_{cd} readings. Now make pressure settings at C1 at 9 percent and C2 at 11 percent P_s, taking readings at each setting until C1 is at 5 percent P_s and C2 is at 15 percent P_s. This completes the negative Pcd readings and the entire set of readings at zero load impedance.

The next set of readings is made in an identical manner with the load impedances increased so that the output pressures are about 10 or 15 percent of P_s. The input pressures and flow should be checked at each input setting but need be recorded only if they differ by more than 10 percent from those of the first set (indicating load sensitivity).

Subsequent sets of readings are taken at three or four more load impedance settings and the points connected by line of constant P_{cd}. The curves generated are typically like those shown in Figure 2002-3.

Figure 2002-4 shows the input differential characteristics for a specific P_s and P_{co}.

The process described above is repeated with the same P_s, but with P_{co} at less than 10 percent P_s and again with P_{co} greater than 10 percent P_s. This will yield two more graphs like that of Figure 2002-3. The input differential curves for the second and third sets can be plotted on the same graph as was the first set, as shown in Figure 2002-5.

Two more sets, one with a P_s above the nominal, the other with P_s below the nominal, each with P_{co}/P_s at 10 percent will give a representative description of the amplifier.

These curves can be generated in a fraction of the time required for the above description if the process is carried out with electronic transducers and plotting equipment. Such a process is implied by the test circuit shown in Figure 2002-2.

In this method each output curve is plotted directly for a constant input signal, by varying the load impedance from zero to blocked (or to the maximum value for which stable operation is possible). The error signal for the input controller is the input controller is the differential input signal, so that the burden of maintaining a precise input signal is taken from the investigator.

The input data should be taken from these settings and the input flows should be monitored as the output impedance is varied to determine load sensitivity, if it exists.

The process should be repeated to produce the five sets of characteristics needed for a complete static analysis of the amplifier.

3.1 Transfer curve. A direct automated procedure for plotting pressure gain is available with the circuit of Figure 2002-2 by simply plotting output differential pressure vs input differential pressure. An integrator input to the controller can help to generate a uniformly time-varying fluidic input signal to the amplifier. The curves generated in this fashion are more specialized, in that they represent a single load impedance and P_{co}/P_s combination, where the five sets of curves allow all combinations of impedance to be considered with a sampling of three different P_{co}/P_s ratios and three different P_s values. The direct transfer curves have the obvious advantage of quick assessment of linear range and saturation values.

4. SUMMARY.

4.1 Output characteristics. Present five sets of output characteristics as follows:

(a) P_s at nominal, P_{co}/P_s at nominal (10 percent).

(b) P_s at nominal, P_{co}/P_s below nominal.

(c) P_s at nominal, P_{co}/P_s above nominal.

(d) P_s above nominal, P_{co}/P_s at nominal.

(e) P_s below nominal, P_{co}/P_s at nominal.

4.2 Input characteristics. Present five input characteristics on three graphs as follows:

(a) P_s at nominal with three input characteristics for P_s/P_{co} at nominal, above nominal, and below nominal, respectively.

(b) P_s above nominal, P_{co}/P_s at nominal.

(c) P_s below nominal, P_{co}/P_s at nominal.

4.3 Pressure transfer characteristics. Present one or more transfer curves as requested by the applicable procurement document. Specify load impedance P_s and P_{co}/P_s.

4.4 General information.

4.4.1 Ambient temperature and barometric pressure.

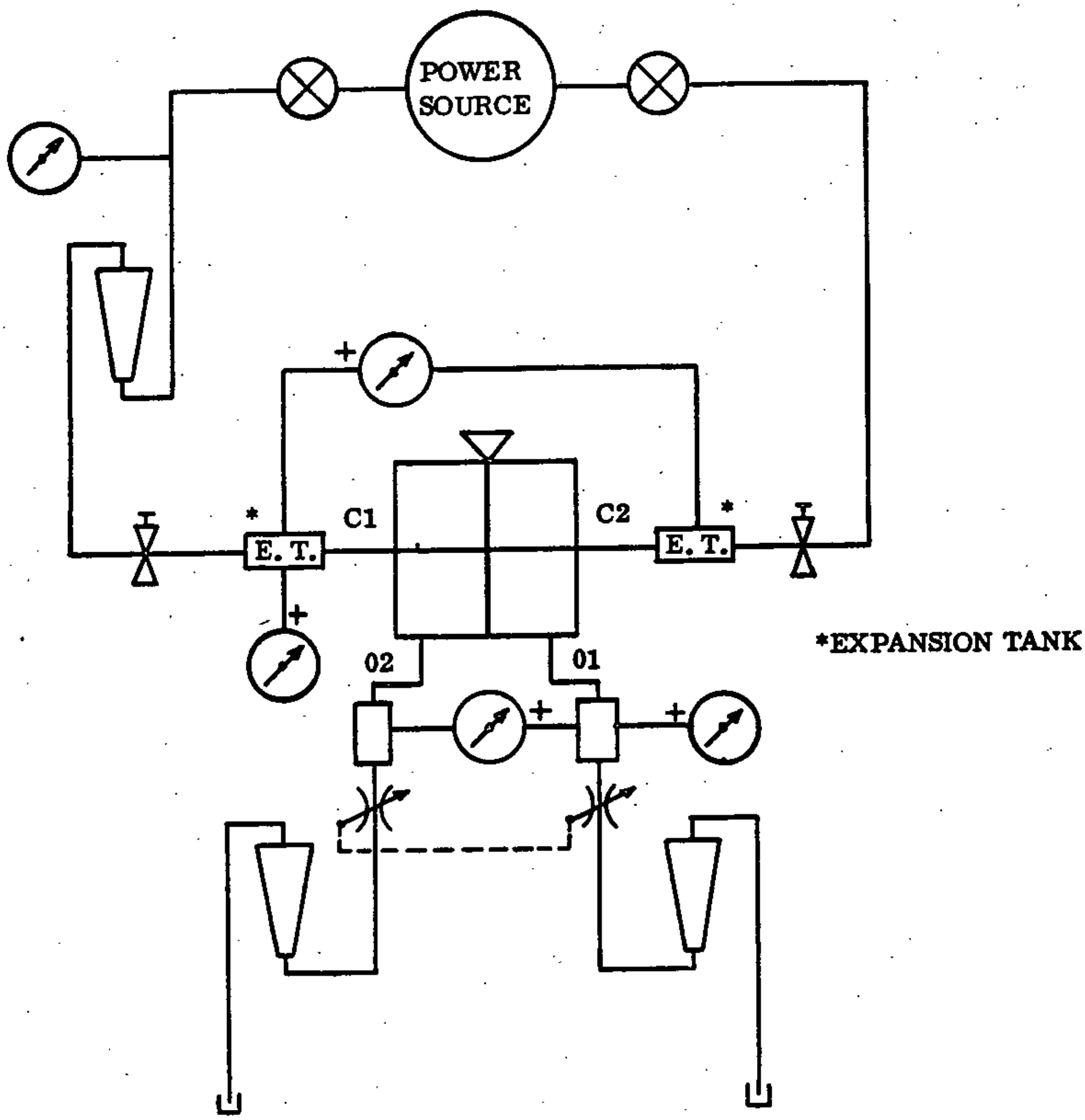


FIGURE 2002-1 TEST CIRCUIT FOR MEASURING DIFFERENTIAL INPUT AND DIFFERENTIAL OUTPUT CHARACTERISTICS

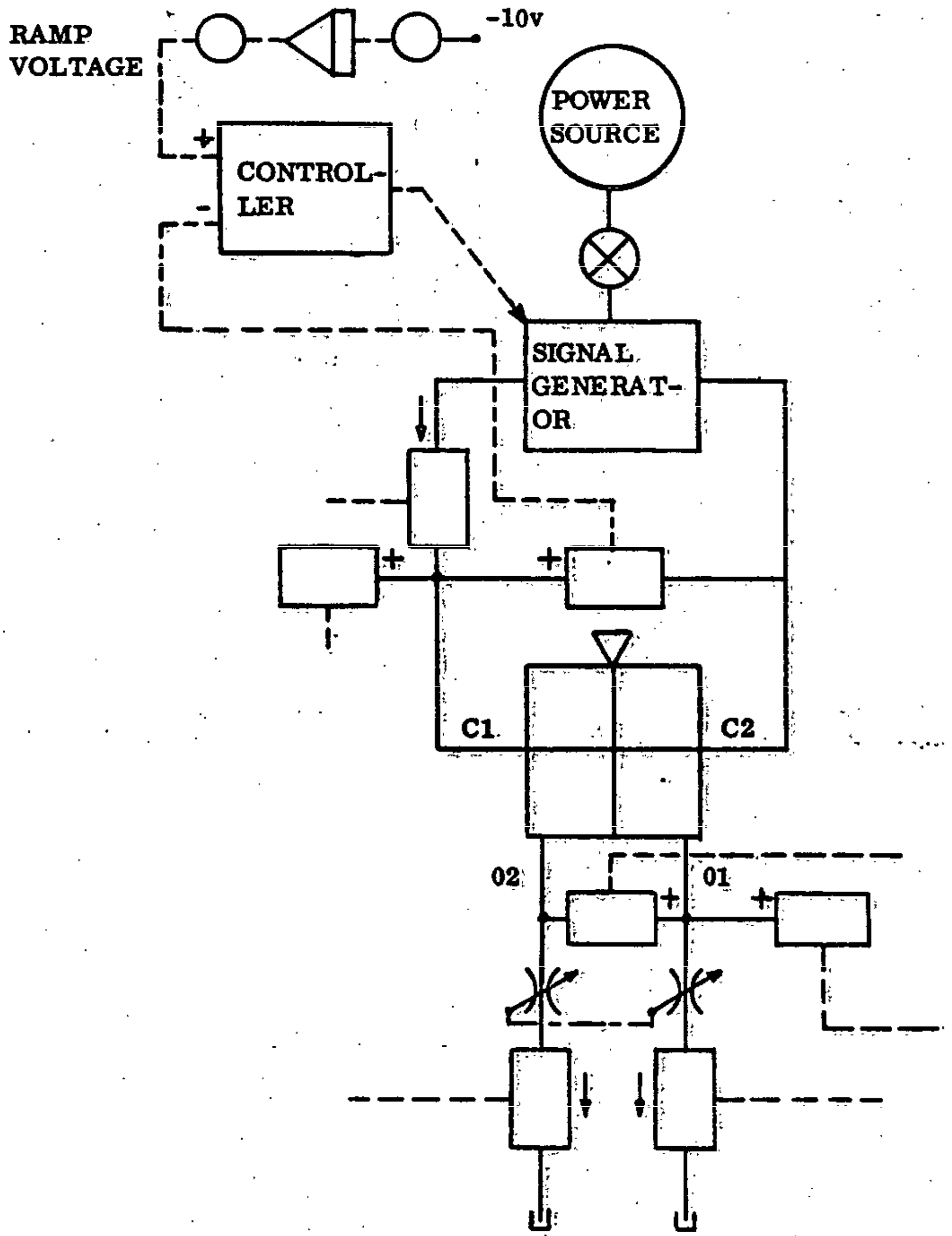
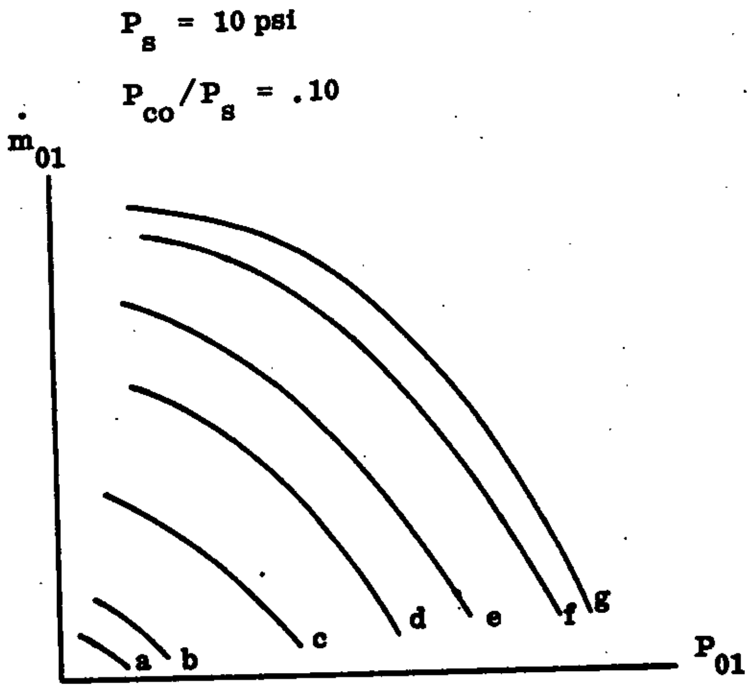


FIGURE 2002-2 AUTOMATED TEST CIRCUIT FOR MEASURING DIFFERENTIAL CHARACTERISTICS AND PRESSURE TRANSFER CHARACTERISTICS



Curve	P_{cd}
a	$-10\%\ P_s$
b	$-\ 8\%\ P_s$
c	$-\ 4\%\ P_s$
d	0
e	$+\ 4\%\ P_s$
f	$+\ 8\%\ P_s$
g	$+10\%\ P_s$

FIGURE 2002-3 DIFFERENTIAL OUTPUT CHARACTERISTICS

P_s / P_{co} = Nominal (10% P_s)

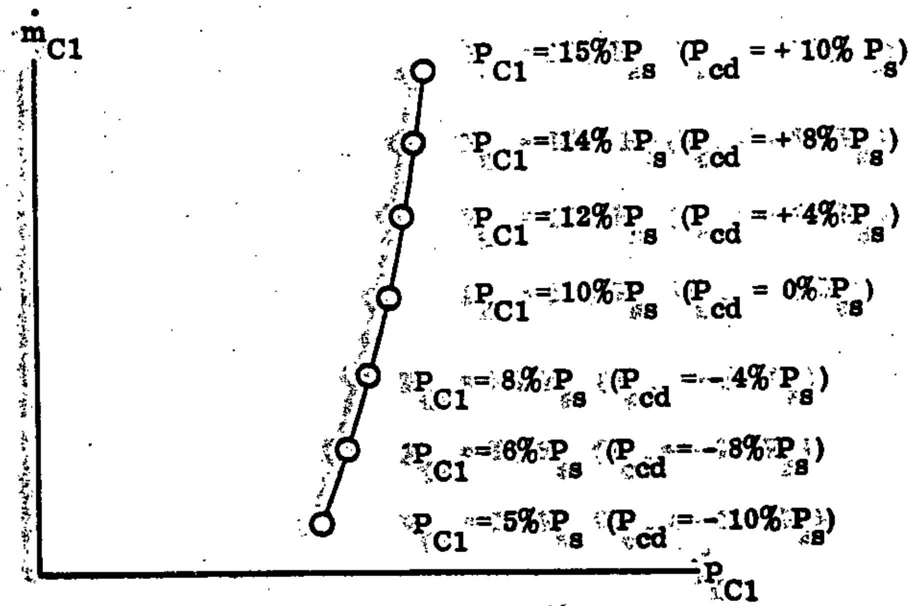


FIGURE 2002-4. DIFFERENTIAL INPUT CHARACTERISTIC, PORT C1

P_s = Constant Z_1 = Constant

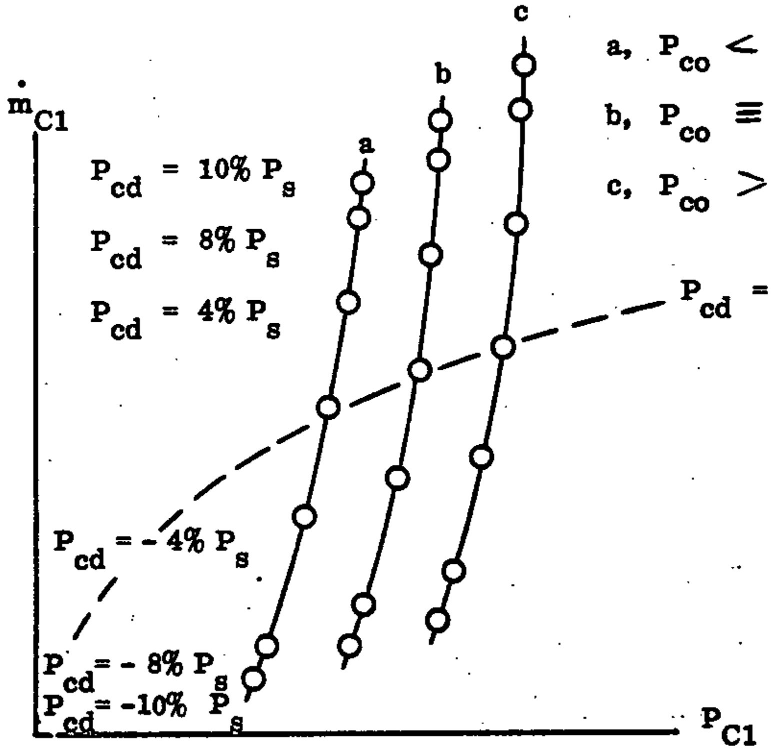


FIGURE 2002-5 DIFFERENTIAL INPUT CHARACTERISTIC, PORT C1

METHOD 2003

DYNAMIC TESTING

1. PURPOSE. This method establishes the means of determining the frequency response and transport time delay of a flueric differential proportional amplifier. The method is applicable for pneumatic operation at frequencies up to 25 Hz (the power spectrum for analog flueric devices).

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Dynamic gain. The ratio of the amplitude of the sinusoidal output (response) signal to the amplitude of the sinusoidal input (stimulus) signal for a specified frequency (or range of frequencies).

1.1.2 Phase angle. The number of degrees by which the sinusoidal output differs from the sinusoidal input for a specified frequency (or range of frequencies).

2. APPARATUS. The test circuit is shown in Figure 2003.

2.1 Transducers. The pressure transducers must be of minimum volume, since volumes introduce capacitive effects into the circuit which would affect the data obtained. In this connection, line lengths should be minimized throughout the circuit.

2.2 Signal generator. The signal generator must have an adjustable output null level and be easily interfaced with an electronic controller. If the input transducer voltage is the error signal to the controller, the balance of the output of the signal generator will be dependent on the similarity of the impedance of each of the input ports of the amplifier.

The signal generator should maintain a reasonably constant output over the range of frequencies of interest.

2.3 Display media. An oscilloscope of high sensitivity with two beams, common time base and with XY plotting capability serves as a practical means for monitoring input and output data. Alternately, a time-base recorder with an overall frequency response at least four times higher than that anticipated for the item under test can be used, although data reduction takes somewhat longer.

3. PROCEDURE.

3.1 Frequency response. Make five runs through the frequency response tests as follows:

(a) P_s at nominal, P_{co}/P_s at nominal

(b) P_s at nominal, P_{co}/P_s above nominal

(c) P_s at nominal, P_{co}/P_s below nominal

(d) P_s above nominal, P_{co}/P_s at nominal

(e) P_s below nominal, P_{co}/P_s at nominal

It is assumed that the "nominal" pressures above are those for which the amplifier was designed and are the same as those of Method 2002 (for a given test item). The amplitude of the signal generator output must be checked at each frequency setting to be sure that it is maintained constant. When the size of the excursion is decided upon, check it at maximum frequency to be sure that amplitude can be maintained through the frequency range anticipated for the test.

3.2 Transport time delay. A step input is used for this test. Essentially the same test circuit as was used for the frequency response tests can be used for this test, except that the square wave signal generator must be substituted. Transport time as defined in MIL-STD-1306 can be determined most conveniently by a two-trace oscilloscope with memory. The display can be photographed directly, or the results can be tabulated. Use the same set of pressures as listed in 3.2.

4. SUMMARY.

4.1 Frequency response. Present the five sets of frequency response test data on separate Bode plots, indicating the P_s, P_{co}/P_s, and load impedance.

4.2 Transport time delay. Present photographs of the displays of the five transport time delay tests. Alternately, the data can be tabulated identifying the appropriate P_s, P_{co}/P_s, and Z_{load} with each measured quantity.

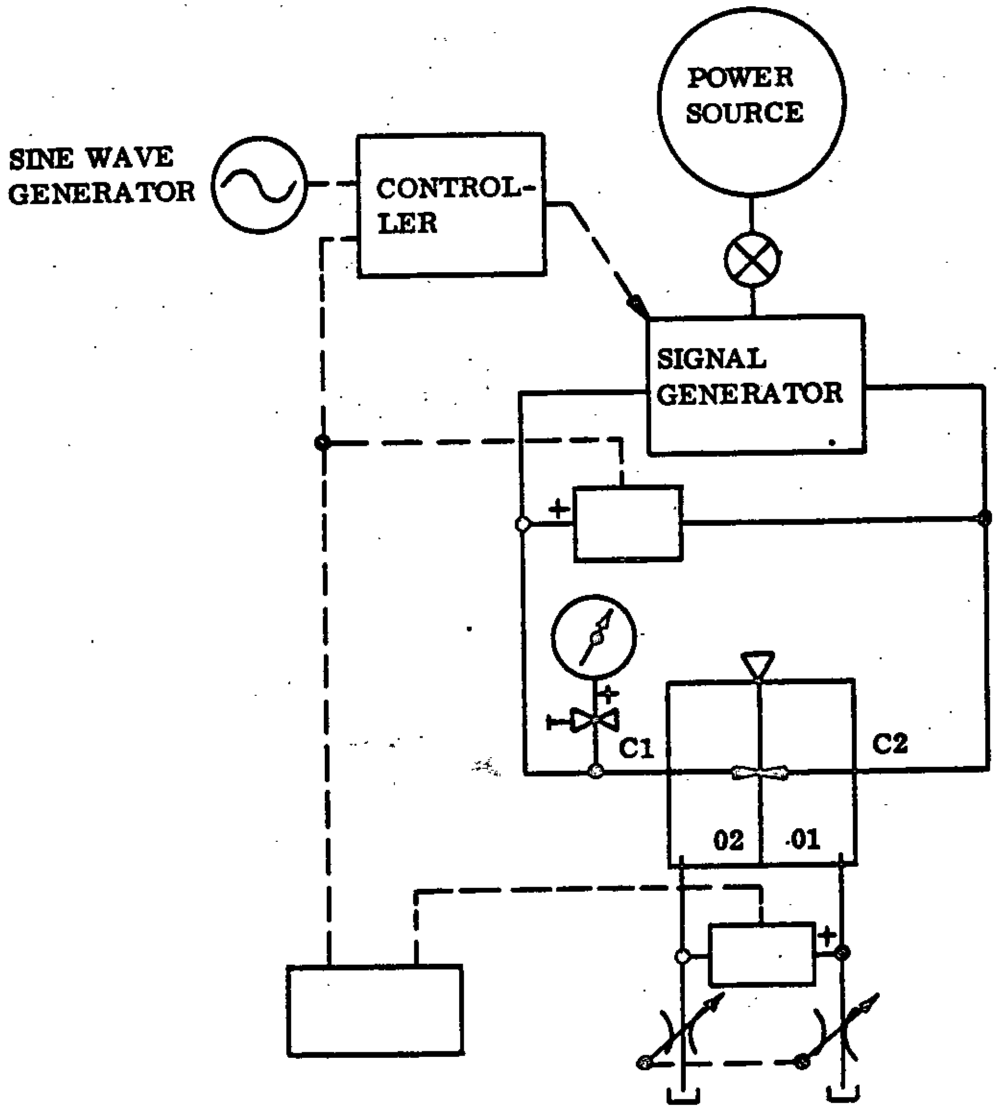


FIGURE 2003 TEST CIRCUIT FOR FREQUENCY RESPONSE AND TIME DELAY MEASUREMENTS

METHOD 2004

SIGNAL TO NOISE RATIO FOR PROPORTIONAL AMPLIFIERS

1. PURPOSE. This method establishes a means of determining signal to noise ratio for proportional amplifiers.

The signal-to-noise ratio (S/N) for a fluidic element is the ratio of the maximum-output-signal to the output-noise. Ideally, noise should be described as a spectrum showing noise amplitude vs. frequency. As a practical minimum, the value for noise used is meaningful only if the passband of the measurement system (the fluidic device, the load on the fluidic device, and the instrumentation) is provided.

Values of S/N are most frequently given in terms of the peak-to-peak or RMS amplitude characteristic of the noise. A peak-to-peak determination involves estimating the actual peak-to-peak extreme of the noise waveform as displayed on an oscilloscope or level recorder over a suitable sampling interval. The peak-to-peak S/N value $(S/N)_p$ is then the maximum output range of the device divided by the peak-to-peak noise measured.

An RMS determination requires the use of a true RMS measurement instrument, including provision for averaging (filtering) the fluctuating RMS value when significant noise content is present below the natural frequency of the meter movement. The RMS (S/N) value $(S/N)_R$ is defined as the maximum useful RMS output signal possible for the device, divided by the RMS noise measured. For the general case, the maximum output signal is taken as the saturation value and the noise is taken as the maximum noise amplitude measured at saturated output. The maximum RMS output signal for proportional devices is defined as the peak-to-peak maximum output (i.e., the maximum linear range) divided by $2\sqrt{2}$ (i.e., the RMS value of the largest possible output sine wave).

Selection of peak or RMS values of noise depends upon the intended use of the data, the character of the noise, and the time and facilities available for the test. The RMS method is generally preferred since (1) the RMS value tends to be a more stable and unambiguous indicator of a random signal, (2) a meter is more convenient to read than a trace on an oscilloscope or recording, and (3) methods exist for analysis (e.g., instrument noise can be subtracted). The peak-to-peak method, though perhaps not as precise, affords the convenience of directly indicating the amount of the useful output range of the device that will be influenced by the noise signal. Only a common oscilloscope may be required to establish approximate amplitude values for comparative purposes. It should be emphasized that for any noise measurement the passband of the measurement system must be provided. The data will be most useful if a spectrum of data over the frequency range of intended usage is provided.

2. APPARATUS. Figure 2004 shows a test circuit for obtaining RMS noise data from a fluidic element. In the circuit of Figure 2004, a differential proportional amplifier is illustrated as a typical device under test. Since the output noise of concern is the differential output, a pressure transducer is attached to each output port and the difference signal is obtained with the electronic differential amplifier. Generally, high-response transducers are used and connecting tubing is kept to minimum lengths to result in high response from the fluidic circuit. The noise signal usually is fed through a lowpass filter and then to the true-RMS meter. The lowpass filter is optional but provides the capability to obtain noise data as a function of passband. If the lowpass filter cut-off frequency is set significantly below the response of the fluidic element and load (including transducers), for example, the lowpass filter determines measurement system response, and noise data as a function of passband are readily obtained.

3. PROCEDURE. The device should be operated at conditions which are used to obtain the transfer curve of Method 2002, 3.1. Unless otherwise specified, these should be nominal P_s, P_{co}/P_s, and load impedance equal to that of one control nozzle. The contractor may choose these conditions to produce the optimum S/N ratio. MIL-STD-1306 specifies that noise be measured at saturation. In some cases it may be desirable to include additional noise measurements where substantial operation is anticipated. These measurements would be made with the control port pressures set for selected output levels in the desired range of operation. As a minimum for analog devices, the noise should be measured at saturation and null conditions; (i.e., control port pressures at values corresponding to zero output signal).

3.1 Maximum RMS signal. The maximum peak-to-peak output signal first is obtained from a steady-state transfer curve (see MIL-STD-1306, Definition of "Saturation" and Figure 13). This signal divided by $2\sqrt{2}$ defines the maximum RMS sinusoidal signal.

3.2 RMS noise. The noise value as read from the RMS meter may require engineering judgment to result in an "average" value since low frequency content in the noise can make the meter fluctuate. Justification for this value should include limits of meter fluctuation. A measurement system response value must accompany all noise values. Response is defined as the frequency corresponding to the 3db-down point.

Typically the first test will be that with the lowpass filter "open", i.e., the cutoff frequency would be set significantly above the fluidic element (with load) response. A frequency-response measurement of the element with load will be necessary to determine the 3 db-down point and thus define the passband. Noise readings then can be made with the cutoff frequency of the lowpass filter set at frequencies significantly lower than the response of the element so that the passband of the system now conveniently is determined by the filter.

4. SUMMARY. The following quantities shall be specified.

4.1 S/N calculation. The RMS signal (3.1) divided by the RMS noise (3.2) provides the S/N value.

4.2 Reporting of data. Present a curve of S/N vs passband of the measurement system (fluidic element, transducers and lowpass filter). Alternately a listing of S/N values and corresponding response values for the measurement system may be given.

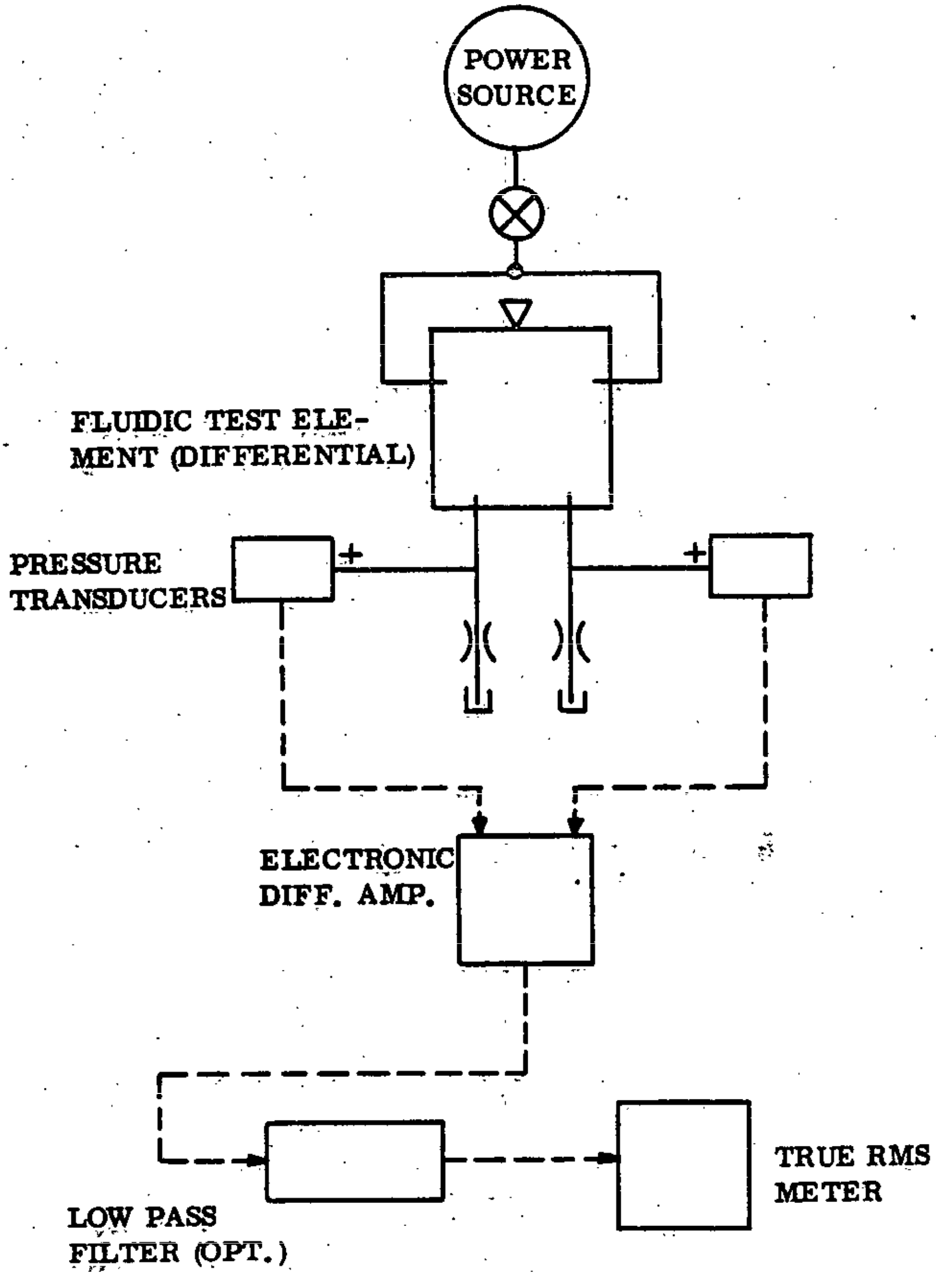


FIGURE 2004. TEST CIRCUIT FOR NOISE MEASUREMENTS

METHOD 3001

EVALUATION OF A FLUIDIC OPERATIONAL AMPLIFIER

1. PURPOSE. This method specifies tests and procedures to determine power requirements, quiescent input characteristics, transfer characteristics, time delay, and frequency response of a fluidic operational amplifier.

2. APPARATUS.

2.1 Pressure regulators. The control port pressure regulators must be capable of maintaining constant pressure through a range of zero to 70 percent of the specified power supply pressure, or as specified in the applicable procurement document. The power supply pressure regulator must maintain constant pressure, ±5 percent, at the specified supply pressure through flow variations encountered as P_{co} is varied from zero to 50 percent P_s.

2.2 Pressure sensors. The pressure sensors should be connected to the lines through expansion tanks for those tests where considerable line velocity is expected (such as the output lines with relatively low load impedance, for example). Frequency response tests should be conducted without expansion tanks, but with the transducers teed directly from the shortest practicable lines. Pressure transducers should have identical frequency responses of greater than 100 Hz or as specified in the applicable procurement document.

2.3 Flow sensors. A flow meter of appropriate range and low impedance should be used to measure the power flow. The flow sensors at the control ports must be of very low range.

3. PROCEDURE.

3.1 Power requirements and quiescent input characteristics. The circuit should be connected as shown in Figure 3001-1 (a). Only one control port is shown with flow being measured. With a flow measuring instrument at each control port, all data can be taken in a single test run.

The power supply pressure should be set to design pressure, or as specified in the applicable procurement document. With P_{co} set to zero gage pressure, increase this pressure slowly, or in suitable increments if discreet supply flow data readings are being taken, until P_{co} = 60 percent P_s, or as specified in the applicable procurement document. While increasing P_{co}, P_s should be monitored to ensure that it remains constant.

Repeat procedure with output blocked.

3.2 Pressure transfer characteristics. Differential pressure transfer characteristics should be measured for each pair of input ports, C_1 and C_2; C_3 and C_4; etc.

The circuit should be connected as shown in Figure 3001-2 (a). Output loads are defined as follows:

a. 1 nozzle load - An orifice whose resistance is equal to the resistance of a control nozzle of the device under test.

b. 2 nozzle load - An orifice whose resistance is equivalent to the resistance of two control nozzles of the device under test when connected in parallel.

c. No load - Infinite resistance (blocked load). Since these loads are used in pairs, their resistance values must be similar; within 5 percent of each other, or within limits specified in the applicable procurement document.

The loads specified above are defined in terms of the "average" point resistance of the control nozzles when P_{co} = 30 percent P_s (see Figure 3001-1(c).

The power supply pressure should be set at design pressure, or as specified in the applicable procurement document. The quiescent input pressure, P_{co}, should be set at design level or as specified in the applicable procurement document.

Differential input signals should be applied so that $P_{c1} + P_{c2} / 2 = P_{co}$. The differential pressure input should be increased until $|P_{cd}| = 2|P_{co}|$, or as specified in the applicable procurement document. Data should be taken, recording P_{cd} and P_{od} for each P_{cd} increment.

The procedure is carried out under each of the loading conditions of (a), (b) and (c) above.

If the amplifier has more than one pair of control ports, the three test runs are conducted for each pair of control ports with the unused control ports set to P_{co}.

Finally, to verify summing capability, the three test runs are conducted with input signals applied to all pairs of control ports simultaneously.

3.3 Frequency response. The operational amplifier can be evaluated for frequency response with equipments as described in Method 2003, Dynamic Testing.

The procedure is the same as that described in 3.1 of Method 2003 except that P_s and P_{co}/P_s are specified at particular values (design values, or as specified in the applicable procurement document), and the load impedance is fixed at 1-nozzle load (or as specified by the applicable procurement document). One frequency response test is required for each pair of control ports, the unused control ports set at P_{co}.

3.4 Time delay. The procedure described in Method 2003, 3.2 is applicable for an operational amplifier. One test is required for each pair of control ports. P_s, P_{co}/P_s and load impedance shall be as specified in Section 3.3 above. Input amplitude should be of a size to drive the output to 50 percent (±5 percent) saturation.

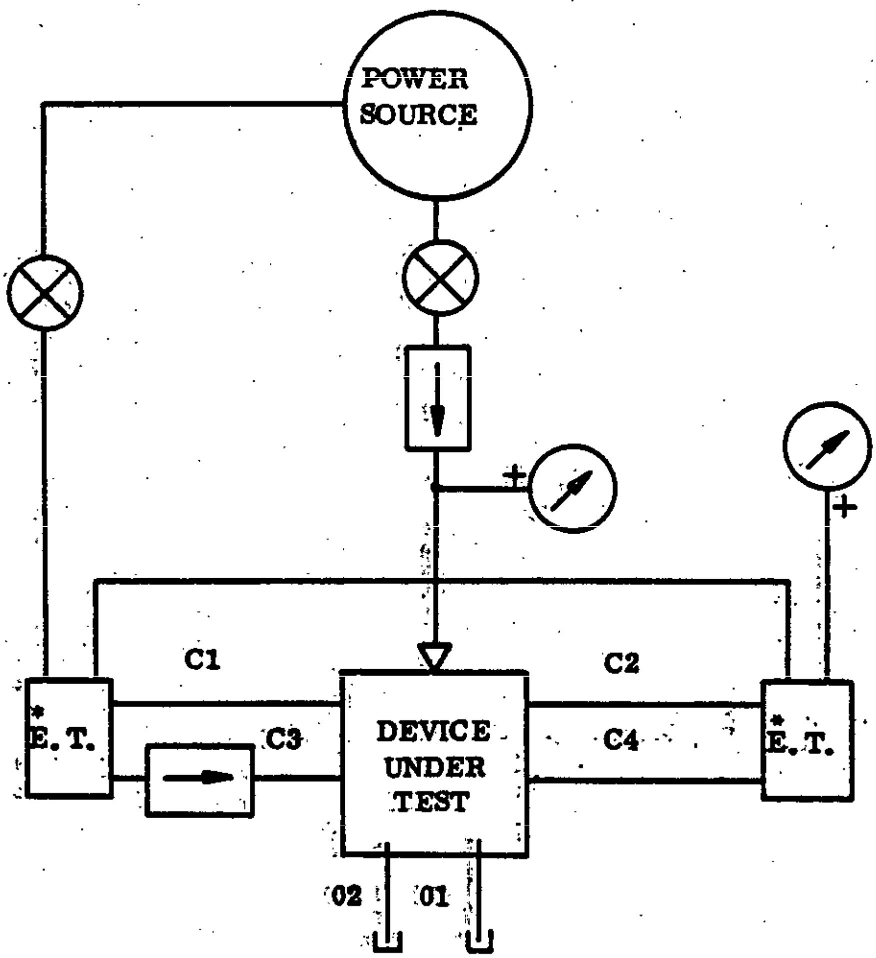
4. SUMMARY.

4.1 Power requirements and quiescent input characteristics. Present curves as shown in Figures 3001-1 (b) and (c), specifying P_s. Curves on both graphs may overlie.

4.2 Pressure transfer characteristics. Present one graph, as shown in Figure 3001-2 (b), for each pair of control ports, and one graphs for the sum of all pairs of control ports. Specify P_s and P_{co}/P_s on each graph. Identify the curves by output loading condition.

4.3 Frequency response. Present a separate Bode plot for each test (i.e., for each pair of control ports). Specify P_s, P_{co}/P_s, load impedance, and input signal amplitude.

4.4 Time delay. Present a photograph of the display of each time delay (one for each pair of control ports). Alternately, the data can be tabulated, identifying the appropriate P_s, P_{co}/P_s, load impedance and input amplitude.



*EXPANSION TANK

FIGURE 3001-1 (a)

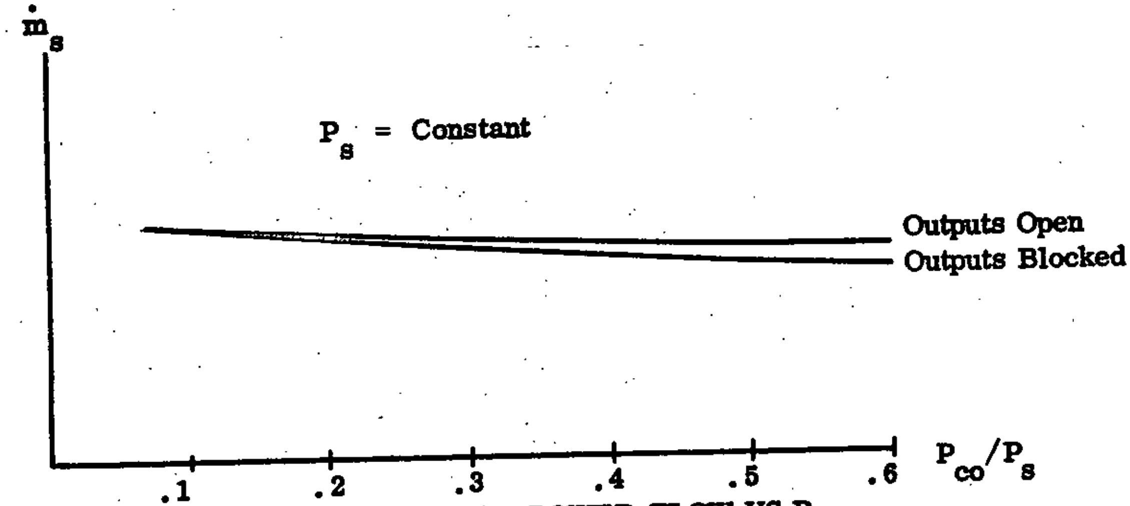


FIGURE 3001-1 (b) POWER FLOW VS P_{co}
(ALL CONTROL PORTS AT COMMON PRESSURE)

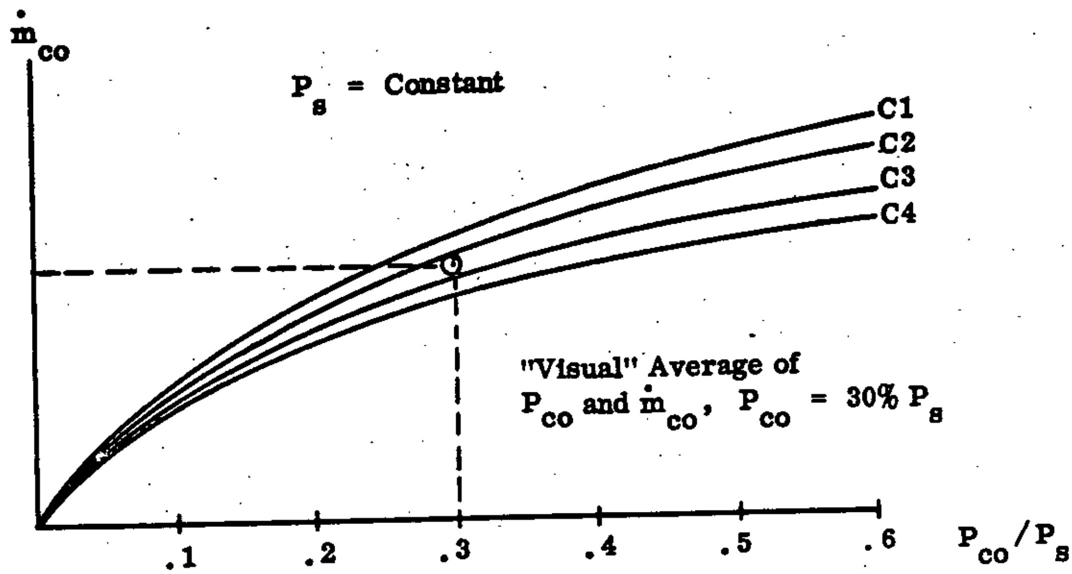


FIGURE 3001-1 (c) $\dot{m}_{co}$ vs P_{co}/P_s

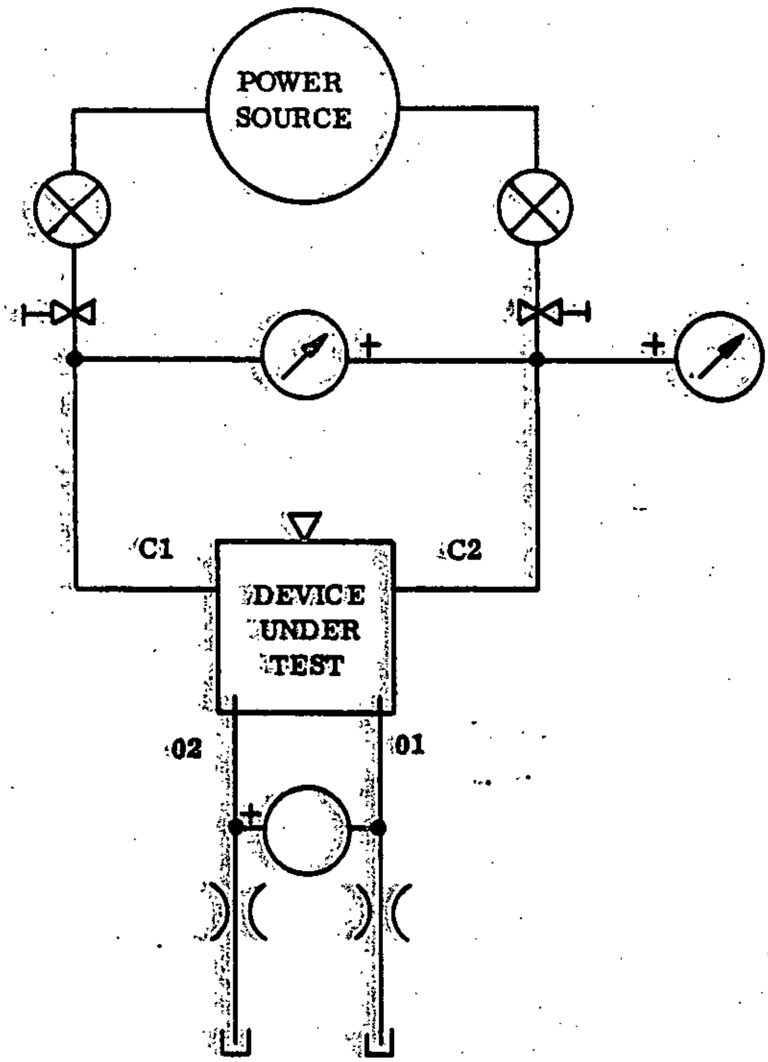


FIGURE 3001-2 (a)

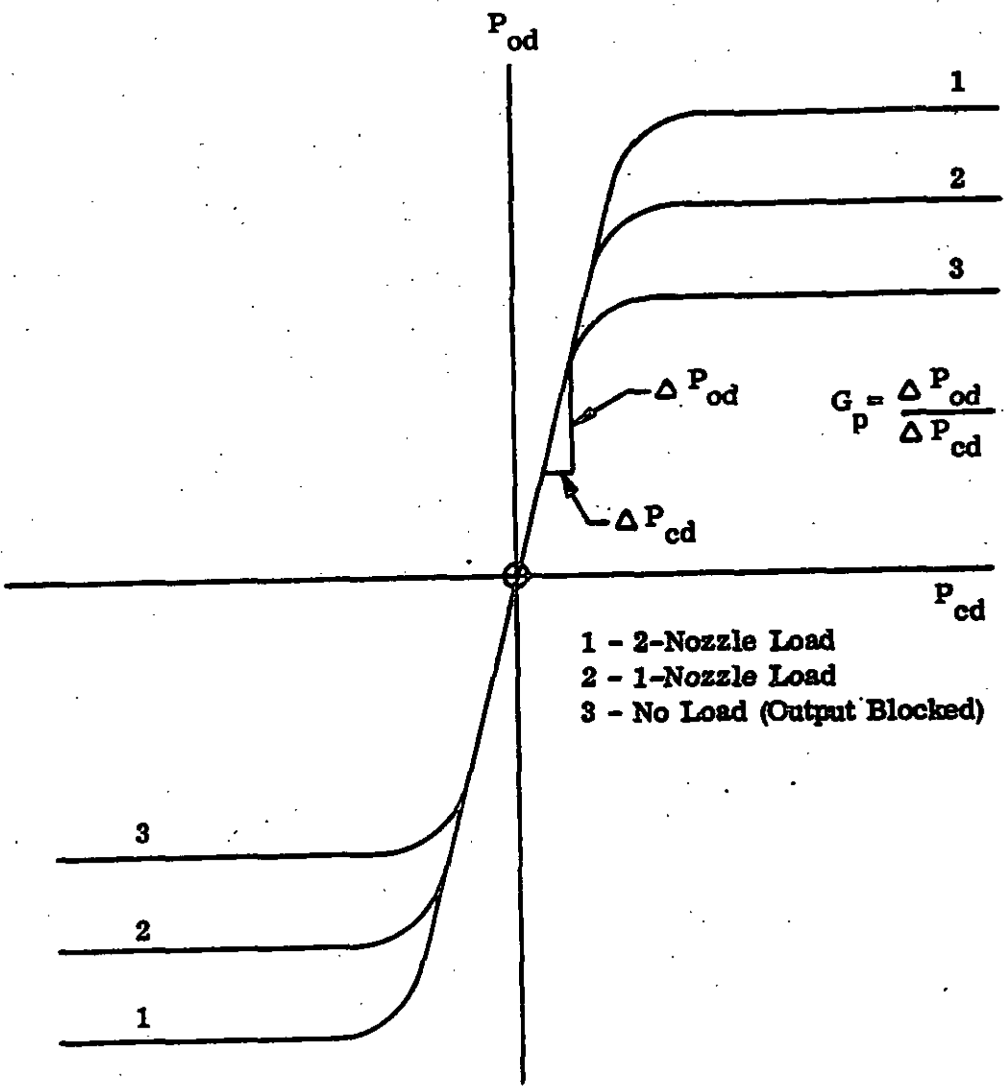


FIGURE 3001-2 (b)

METHOD 4001

ELECTROMECHANICAL SIGNAL GENERATOR OUTPUT CHARACTERISTICS

1. PURPOSE. This method establishes the means for measuring the output quantities of an electromechanical signal generator. The generator has two output ports and can be operated either differentially or singlesided.

1.1 Definitions. The following definitions shall apply for the purpose of this test method.

1.1.1 Nominal power supply pressure (P_s nom.). The nominal power supply pressure is the power supply pressure for which the generator was designed. If the generator was designed to be operable through a range of pressures, then the nominal power supply pressure is the midpoint of this range.

1.1.2 Input bias voltage (V_{ib}). That voltage which must be applied at the input to force the quiescent output flows from either side to identical values when loaded with identical resistors.

For single output operation, the input bias voltage is that voltage necessary to force the output pressure and flow to specified quiescent levels when load and power supply conditions are specified.

2. APPARATUS. The output ports of the signal generator must be connected to identical resistive loads. Matched pairs of resistors, not necessarily linear, provide a convenient means for loading the outputs. Alternately, a pair of needle valves, whose characteristics are identical at like settings (numbers of turns from closed position, for example), can be geared together to provide the output ports with identical resistive loads. If matched pairs are used, they should cover a wide range of resistance. At least four pairs are needed.

3. PROCEDURE. With the circuit connected as shown in Figure 4001-1 and the supply pressure set to nominal value, apply voltages in increments so that at least seven readings of output pressure and flow are taken. (The middle reading should be taken when the output pressure and flow are identical, that is, at quiescent value or where the input voltage is set to V_{ib} as defined in 1.1.2 of this method.) Then with a different set of resistors at the outputs, the process should be repeated. The data points should be recorded on graph paper to an appropriate scale as shown in Figure 4001-2. When the process has been repeated for each set of resistors, the points of constant voltage should be connected as shown in Figure 4001-3. Both output characteristics can be recorded at the same time. The sign convention for the input quantity is arbitrary. For example, Figure

4001-3 shows typical characteristics for the right output and the curves above V_{ib} were taken as positive input quantities. On the graph for the companion left output data (not shown), the curves below V_{ib} would be labeled positive since the output quantities rise and fall in opposition to each other.

4. SUMMARY.

4.1 Output characteristics. The above procedure is repeated for each output at two other supply pressure settings; one above and one below nominal power supply pressure as defined in para. 1.1.1 of this test method.

The description of the load resistors used for the test should be in the form of pressure-flow characteristics or as specified by the applicable procurement document.

4.2 Transfer curves. The applicable procurement document may specify transfer curves, for example, differential output pressure as a continuous function of input voltage at a specific power supply pressure and loaded with specific values of resistance. A typical curve of this type is shown in Figure 4001-4.

4.3 Ambient data.

(a) Barometer

(b) Temperature

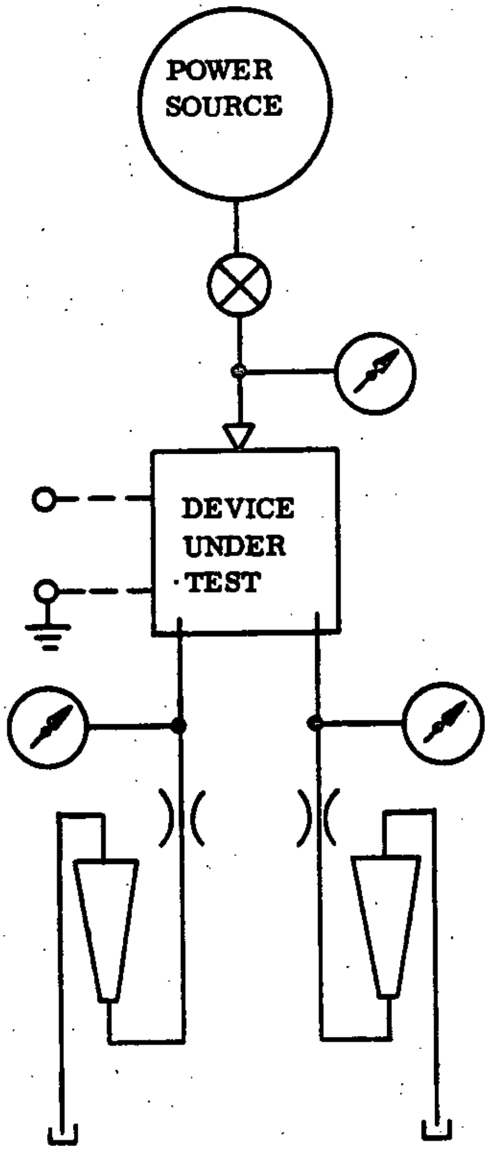


FIGURE 4001-1

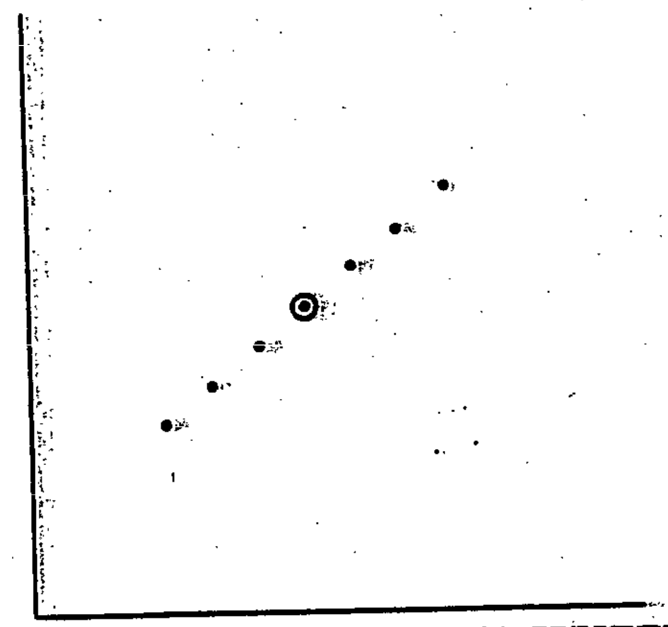


FIGURE 4001-2

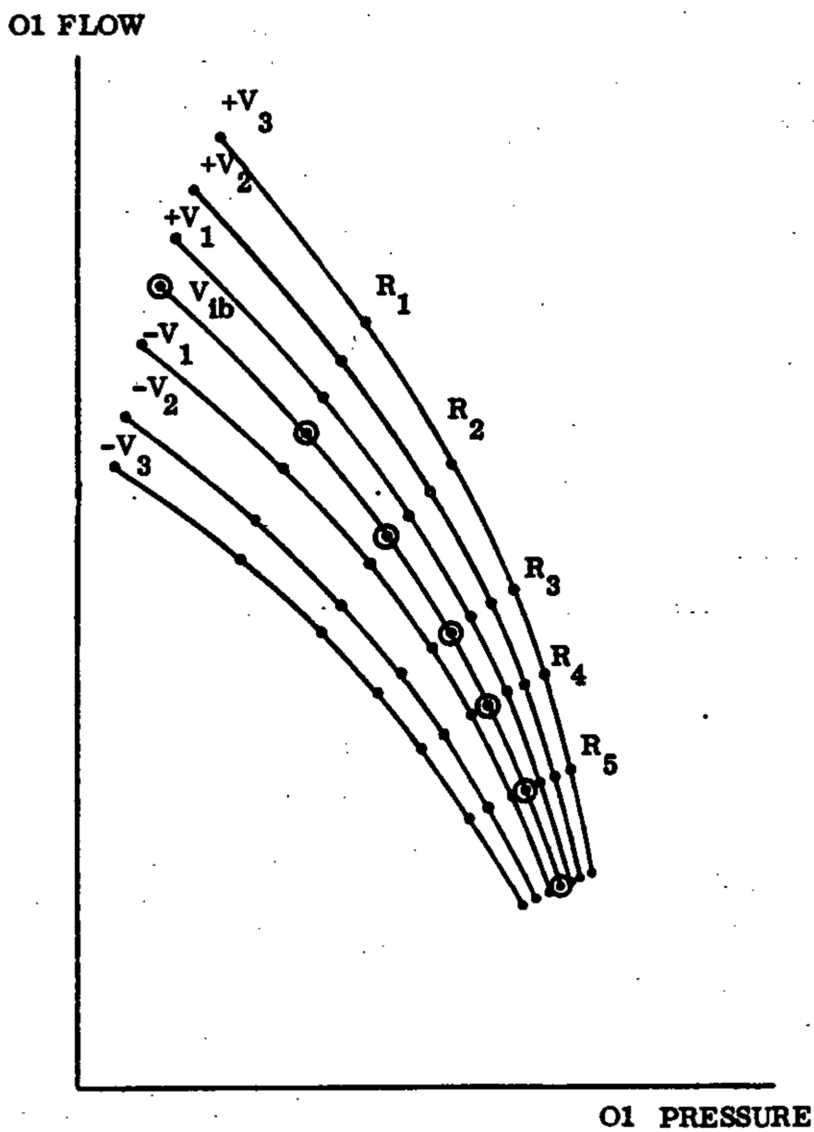


FIGURE 4001-3

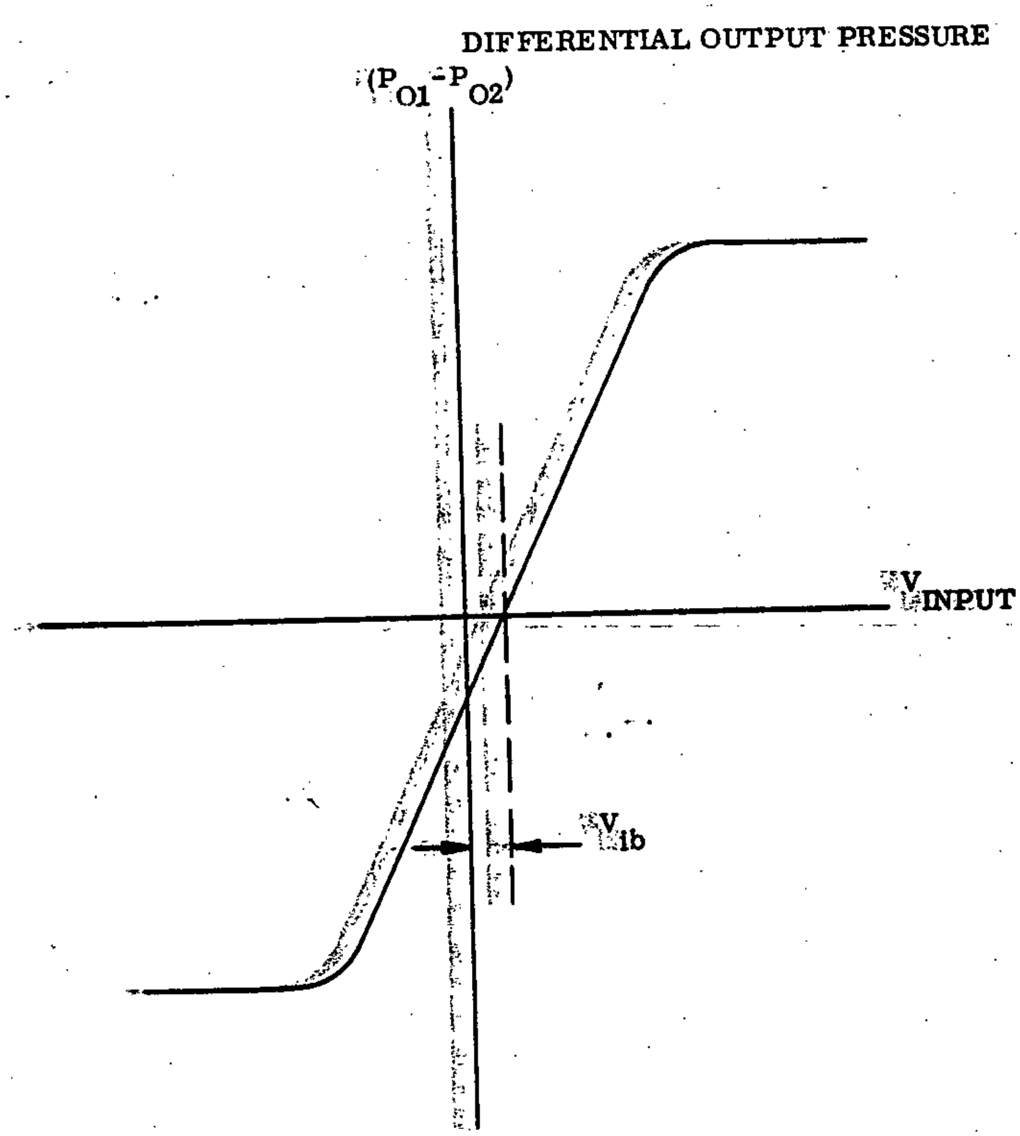


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FIGURE 4001-4

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL	OMB Approval No. 22-R255

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