



AEROSPACE RECOMMENDED PRACTICE

ARP490™**REV. G**Issued 1958-07
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Superseding ARP490F

(R) Electrohydraulic Servovalves

RATIONALE

The document has been revised to:

- Clarify definition of terms and align them with the illustrations given in figures.
- Update document references.
- Correct multiple typographical errors introduced during previous revisions.
- Include some technical updates.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides definitions and background information regarding the physical performance and testing of electrohydraulic flow control and pressure control servovalves. This ARP also provides extensive guidance for the preparation of procurement specifications and for functional testing.

NOTE: An example of a procurement specification is provided as Appendix A.

1.1 Field of Application

This ARP is applicable to electrohydraulic servovalves that are used in fluid power systems in all types of commercial and military flight vehicles.

Although the primary focus of this ARP is on four-way servovalves, three-way servovalves are discussed to a limited extent.

1.2 Limitations

The requirements that are contained in ARP490 are confined to the interface definition and the input/output characteristics of electrohydraulic servovalves.

This ARP does not restrict or attempt to define the internal characteristics of servovalves. As such, the recommendations are equally applicable to valves having different internal functioning, different ratings, different physical size, and valves used with different fluids. In certain instances, standards for valve design are recommended for the purpose of interchangeability; for example, as valve polarity, mounting bolt, and fluid port locations.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR810	Degradation Limits of Hydrocarbon-Based Hydraulic Fluids, MIL-PRF-5606, MIL-PRF-83282, and MIL-PRF-87257 Used in Hydraulic Test Stands
ARP1231	Gland Design, Elastomeric O-Ring Seals, General Considerations
ARP1383	Aerospace - Impulse Testing of Hydraulic Components
ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
ARP5941	Aerospace Fluid Power - Contamination Sensitivity - Considerations for Establishing Test Procedures for Flight Control Actuators
AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
AS4059	Aerospace Fluid Power - Contamination Classification for Hydraulic Fluids
AS4941	Aerospace - General Requirements for Commercial Aircraft Hydraulic Components
AS8775	Hydraulic System Components, Aircraft and Missiles, General Specification for

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ANSI/NCSL Z540.3 Requirements for the Calibration of Measuring and Test Equipment

2.1.3 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

ASME Y14.5 Dimensioning and Tolerancing

2.1.4 NAS Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NASM33540 Safety Wiring, Safety Cabling, Cotter Pinning, General Practices for

2.1.5 NASA Publications

NASA Technical Services, NASA STI Program STI Support Services, Mail Stop 148, NASA Langley Research Center, Hampton, VA 23681-2199, 757-864-9658, Fax: 757-864-6500, <http://ntrs.nasa.gov/>.

NASA-STD-8729.1 Planning, Developing and Managing an Effective Reliability and Maintainability (R&M) Program

2.1.6 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

RTCA DO-160 Environmental Conditions and Test Procedures for Airborne Equipment

2.1.7 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-HDBK-1587 Materials and Process Requirements for Air Force Weapon Systems

MIL-PRF-83282 Hydraulic Fluid, Fire Resistant Synthetic Hydrocarbon Base, Aircraft, Metric, NATO Code Number H-537

MIL-PRF-87257 Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft & Missile

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

MIL-STD-889 Dissimilar Metals

2.2 Definitions

Refer to ARP4386 for general hydraulic and actuation terms that are used in this document.

NOTE: The following definitions describe recommended terminology for electrohydraulic flow-control servovalves. Specific terminology that is only applicable to pressure-control servovalves can be found in Appendix B.

2.2.1 General

SERVOVALVE, ELECTROHYDRAULIC FLOW-CONTROL: An electrical input, flow-control valve, which is capable of continuous control.

NOTE: The output stage flow is a direct function of the input current.

HYDRAULIC AMPLIFIER: A device which acts as a power amplifier, such as a sliding spool, or a nozzle flapper, or a jet pipe with receivers.

STAGE: A hydraulic amplifier used in a servovalve.

NOTE: Servovalves may be single-stage, two-stage, three-stage, etc. (see 3.2.3.1.1.1).

OUTPUT STAGE: The final stage of hydraulic amplification used in a servovalve.

PORT: A fluid connection to the servovalve; for example, supply port, return port, control port.

TWO-WAY VALVE: An orifice flow-control component with supply and one control port arranged so that action is in one direction only, from supply to control port.

THREE-WAY VALVE: A multi-orifice flow-control component with supply, return and one control port arranged so that valve action in one direction opens supply to control port and reversed valve action opens the control port to return.

FOUR-WAY VALVE: A multi-orifice flow-control component with supply, return, and two control ports arranged so that the valve action in one direction opens supply to control port #1 and opens control port #2 to return.

NOTE: Reversed valve action opens supply to control port #2 and opens control port #1 to return.

2.2.2 Electrical Characteristics

TORQUE MOTOR: The electromechanical drive commonly used in the input stages of servovalves.

INPUT CURRENT: The current to the valve, expressed in mA, which commands control flow.

RATED CURRENT: The specified input current, expressed in mA, of either polarity to produce rated flow.

NOTE: The particular coil connection (differential, series, individual, or parallel) must be specified in conjunction with the rated current. Rated current does not include null bias current.

QUIESCENT CURRENT: The DC current that is present in each valve coil when using a differential coil connection, the polarity of the current in the coils being in opposition such that no electrical control power exists.

ELECTRICAL QUIESCENT POWER: The power dissipation required for differential operation when the current through each coil is equal and opposite in polarity.

ELECTRICAL CONTROL POWER: The power dissipation required for control of the valve.

NOTE: Control power is a maximum with full input signal, and is zero with zero-input signal. It is independent of the coil connection (series, individual, parallel, or differential) for any conventional two-coil operation. For differential operation, the control power is the power consumed in excess of the electrical quiescent power. This power increase is a result of the differential current change.

TOTAL ELECTRICAL POWER: The sum of the instantaneous electrical control power and the electrical quiescent power, expressed in mW.

COIL IMPEDANCE: The complex ratio of coil voltage to coil current.

NOTE: It is important to note that the coil impedance may vary with signal frequency, signal amplitude, and other operating conditions due to back EMF generated by the moving armature. The coil impedance is usually described in terms of impedance amplitude and phase angle plotted against the input signal frequency. An example of such a plot is shown in Figure 1.

COIL RESISTANCE: The DC resistance of each torque motor coil, expressed in Ω .

POLARITY: The relationship between the direction of control flow and the direction of input current.

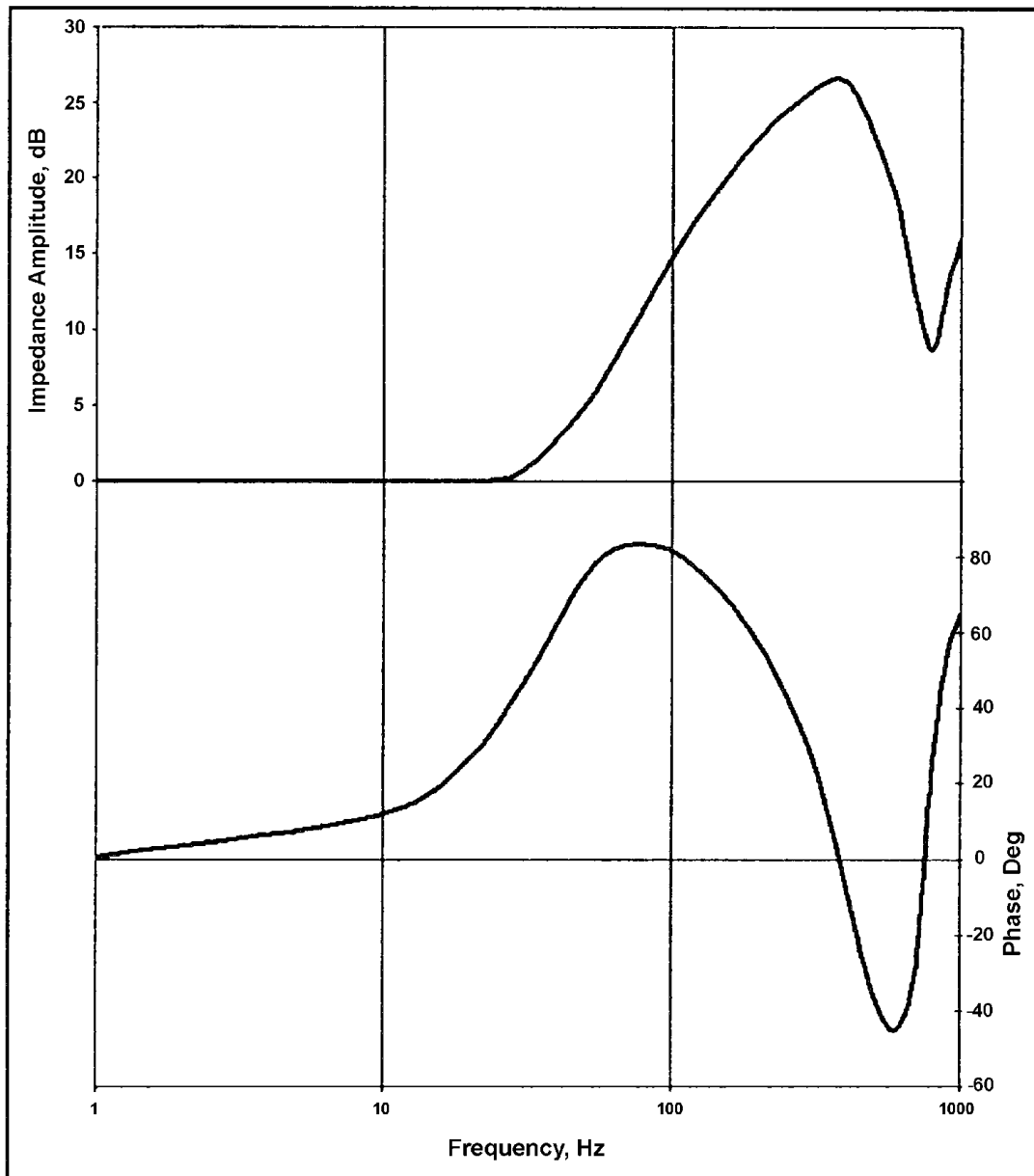


Figure 1 - Coil impedance amplitude and phase angle

DITHER: A low amplitude, relatively high frequency periodic electrical signal, sometimes superimposed on the servovalve input to reduce threshold.

NOTE: Dither is expressed by the dither frequency (Hz) and the peak-to-peak dither current amplitude (mA).

2.2.3 Steady State Characteristics

CONTROL FLOW: The flow through the valve control ports, expressed in cis or gpm (L/min).

NOTE: Control flow is referred to as no-load flow when there is zero load-pressure drop or as loaded flow when there is load-pressure drop. (See 2.2.3.) Conventional test equipment normally measures no-load flow.

RATED FLOW: The specified control flow corresponding to rated current and for a specified total valve pressure drop (net supply pressure minus load pressure).

NOTE: Rated flow is normally specified as the no-load flow.

FLOW CURVE: The graphical representation of control flow versus input current.

NOTE: This is usually a continuous plot of a complete cycle between plus and minus rated current values of no-load flow (see Figure 2).

NORMAL FLOW CURVE: The locus of the midpoints of the complete cycle flow curve, which is the zero hysteresis flow curve.

NOTE: Where valve hysteresis is sufficiently low, one side of the flow curve can usually be used for the normal flow curve (see Figure 3).

FLOW GAIN: The slope of the control flow versus input current curve in any specific operating region, expressed in cis/mA or gpm/mA (L/min/mA).

NOTE: Three operating regions are usually significant with flow-control servovalves: (1) the null region, (2) the region of normal flow control, and (3) the region where flow saturation effects may occur (see Figure 4). Where this term is used without qualification, it is assumed to mean normal flow gain.

NORMAL FLOW GAIN: The slope of a straight line drawn from the zero flow point of the normal flow curve, throughout the range of rated current of one polarity, and drawn to minimize deviations of the normal flow curve from the straight line.

NOTE: Flow gain may vary with the polarity of the input, with the magnitude of load differential pressure and with changes in operating conditions (see Figure 5).

RATED FLOW GAIN: The ratio of rated flow to rated current, expressed in cis/mA or gpm/mA (L/min/mA).

FLOW SATURATION REGION: The region where flow gain decreases with increasing input current.

FLOW LIMIT: The condition where control flow no longer increases with increasing input current.

NOTE: Flow limitation may be deliberately introduced within the servovalve.

SYMMETRY: The degree of equality between the normal flow gain of one polarity and that of the reversed polarity.

NOTE: Symmetry is measured as the difference in normal flow gain of each polarity, expressed as a percent of the greater (see Figure 5 and 4.4.3.3).

LINEARITY: The degree to which the normal flow curve conforms to the normal flow gain line with other operational variables held constant.

NOTE: Linearity is measured as the maximum deviation of the normal flow curve from the normal flow gain line, expressed as percent of rated current (see Figure 5).

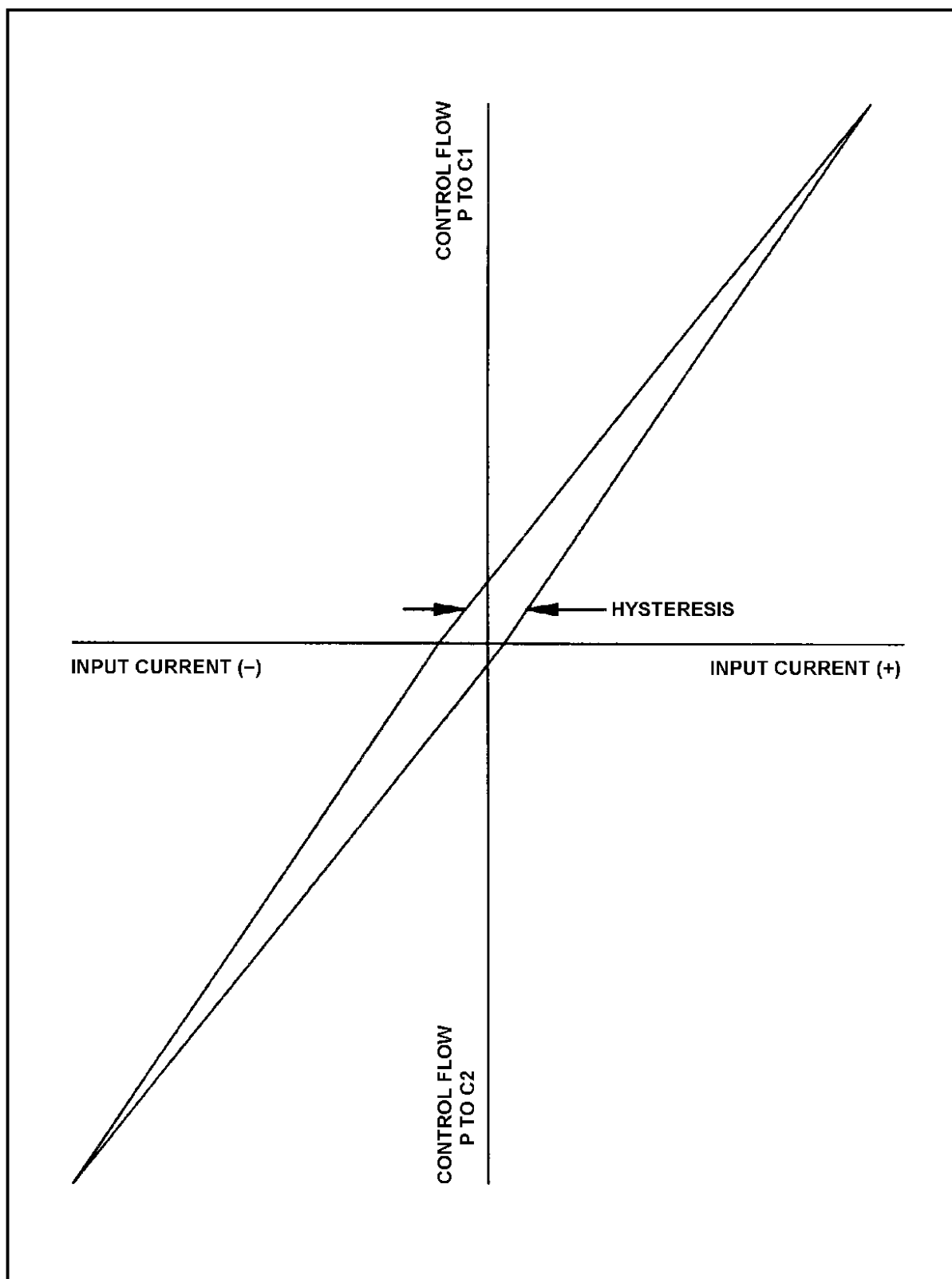


Figure 2 - Flow curve

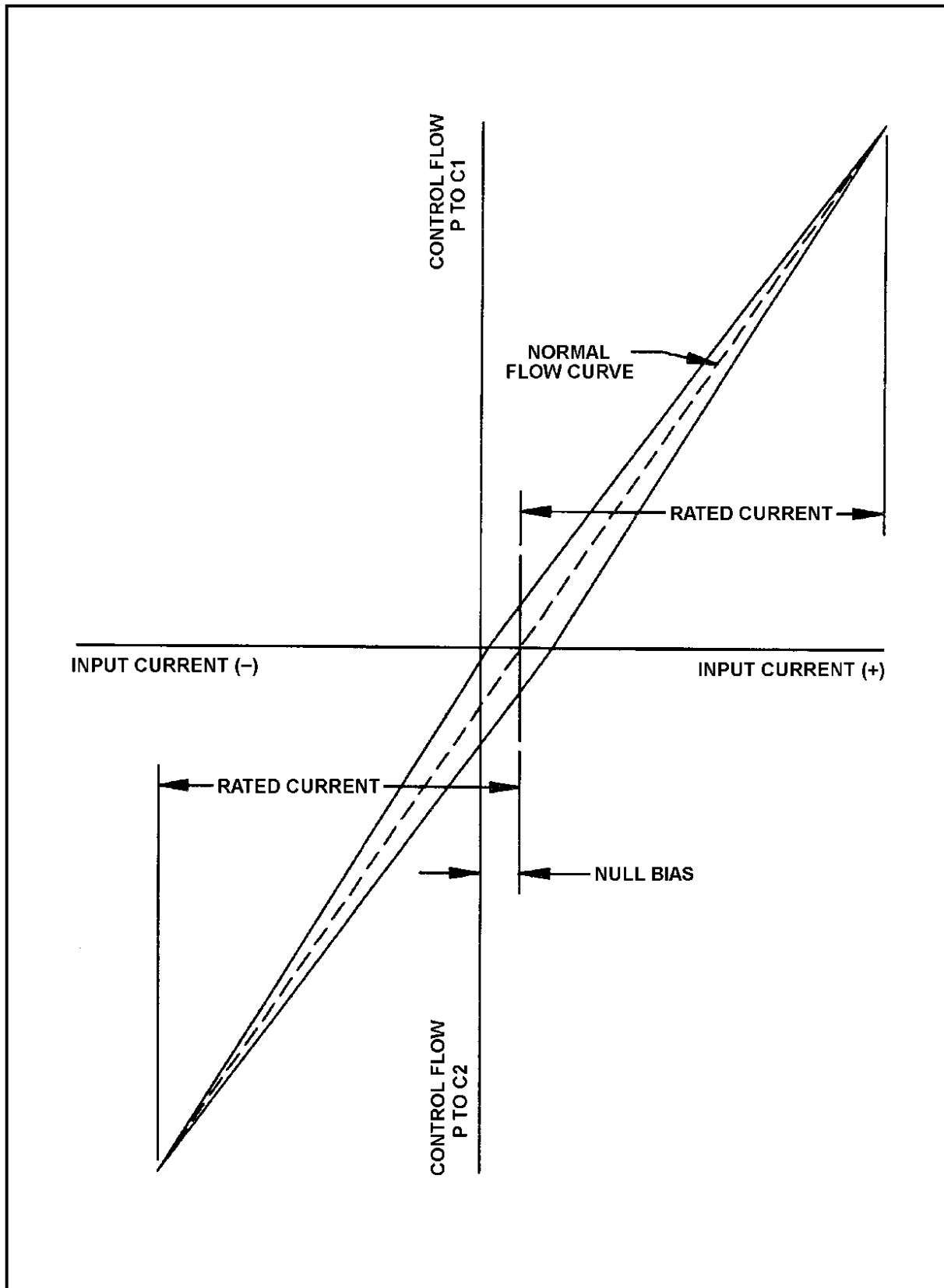


Figure 3 - Normal flow curve

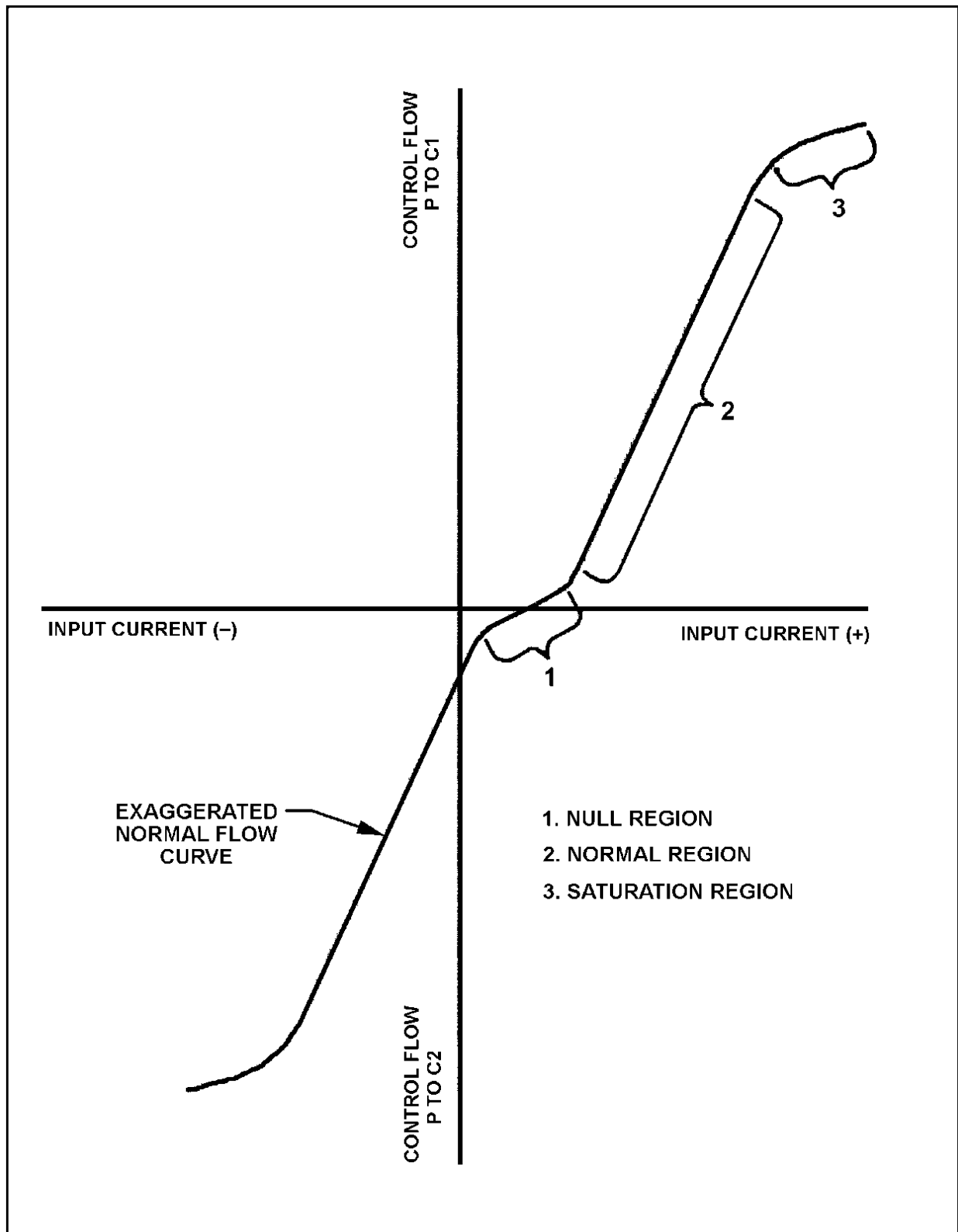


Figure 4 - Operating regions

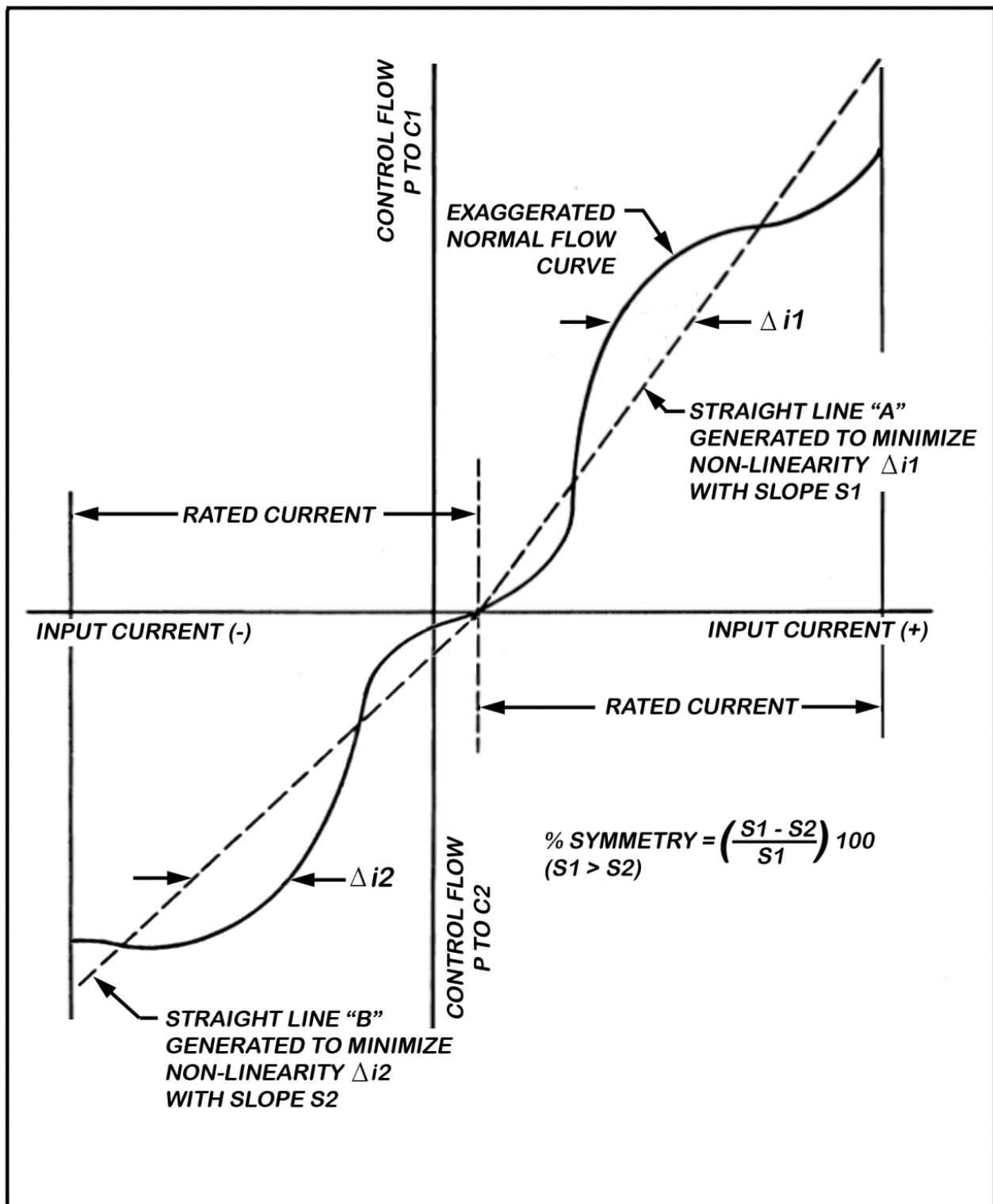


Figure 5 - Linearity/symmetry

HYSTERESIS: The difference in the valve input currents required to produce the same valve output during a single cycle of valve input current when cycled at a rate below that at which dynamic effects are important.

NOTE: Hysteresis is normally specified as the maximum difference occurring in the flow curve throughout plus or minus rated current, and is expressed as a percent of rated current (see Figure 2).

THRESHOLD: The smallest increment of input current which will produce a change in valve output, expressed as percent of rated current.

NOTE: Threshold is normally specified as the current increment required to revert from a condition of increasing output to a condition of decreasing output, when current is changed at a rate below that at which dynamic effects are important.

INTERNAL LEAKAGE: The total internal valve flow from pressure to return with zero control flow (usually measured with control ports blocked and with the specified supply and return pressure), expressed in cis or gpm (L/min).

NOTE: Leakage flow will vary with input current, generally being a maximum at the valve null (null leakage).

LOAD-PRESSURE DROP: The differential pressure between the control ports, expressed in psi (kPa).

NOTE: In conventional three-way servovalves, load-pressure drop (PI) may be expressed as an equation, where it is equated to the supply pressure (Ps), less return pressure (Pr), and less the pressure drop across the single active control orifice (Po). ($P_s - P_r - P_o = P_i$.)

VALVE PRESSURE DROP: The sum of the differential pressures across the control orifices of the output stage, expressed in psi (kPa).

NOTE: Valve pressure drop will equal the supply pressure minus the return pressure minus the load pressure drop.

PRESSURE GAIN: The rate of change of load pressure drop with input current at zero control flow (control ports blocked), expressed in psi/mA (kPa/mA).

NOTE: Pressure gain is usually specified as the average slope of the curve of load pressure drop versus current between 40% of maximum load-pressure drop (see Figure 6).

NULL REGION: The region about null where effects of lap in the output stage predominate.

NULL: The condition where the valve supplies zero control flow at zero load-pressure drop.

NULL PRESSURE: The pressure existing at both control ports at null, expressed in psi (kPa).

NULL REGION PRESSURE: The variation of control ports pressure in the region near null with the control ports interconnected (no-load flow), expressed in psi (kPa).

NULL BIAS: The input current required to bring the valve to null, excluding the effects of valve hysteresis, expressed as a percent of rated current.

NULL SHIFT: A change in null bias, expressed as percent of rated current. Null shift may occur with changes in supply pressure, temperature, and other operating conditions.

LAP: In a sliding spool valve, the relative axial position relationship between the fixed and movable flow-metering edges with the spool at null.

NOTE: For a servovalve, lap is measured as the total separation at zero flow of straight line extensions of the nearly straight portions of the normal flow curve, drawn separately for each polarity, expressed as percent of rated current.

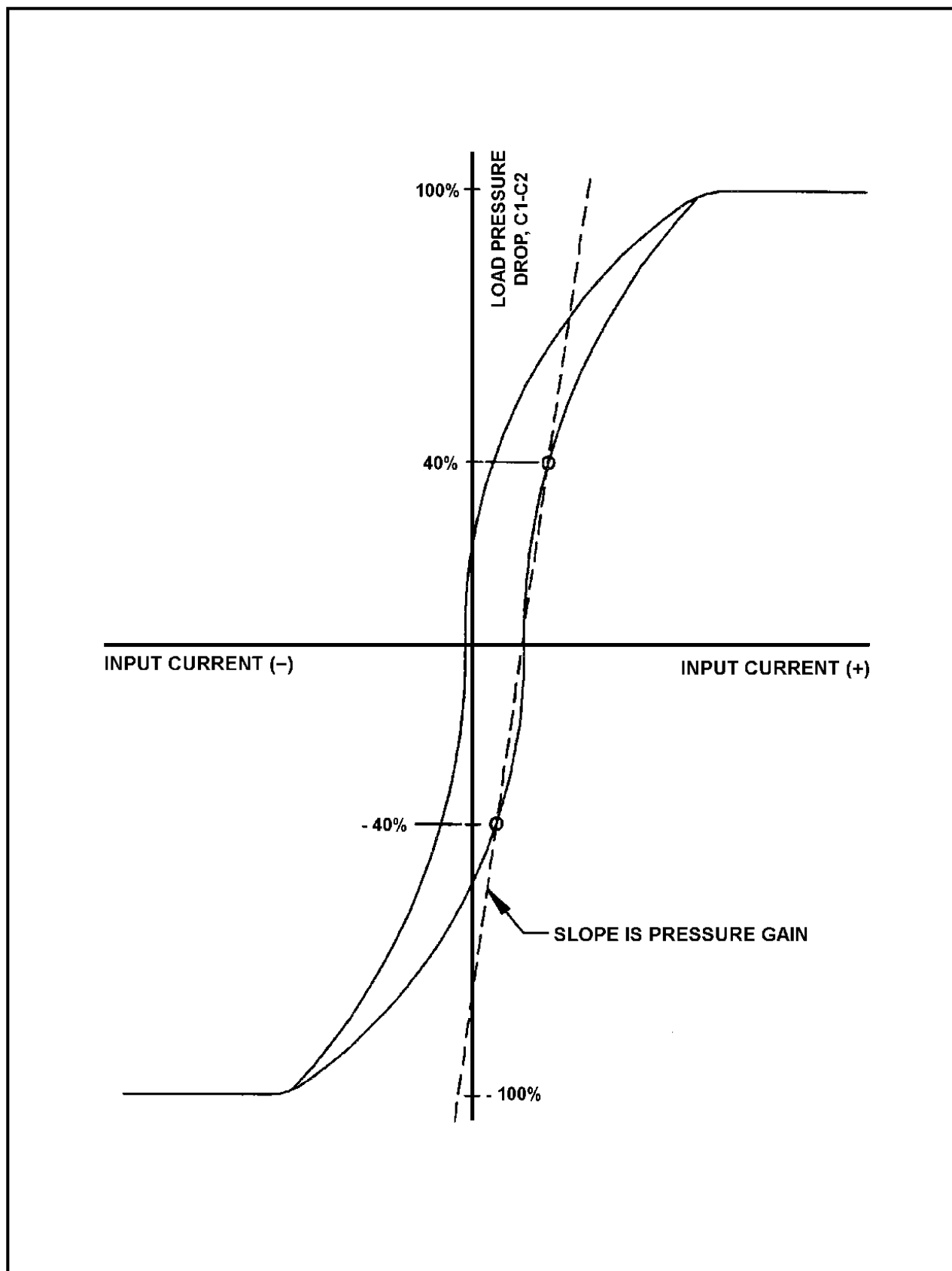


Figure 6 - Pressure gain

ZERO LAP: The lap condition where there is no separation of the straight line extensions of the normal flow curve (see detail A in Figure 7).

OVERLAP: The lap condition which results in a decreased slope of the normal flow curve in the null region (see detail B in Figure 7).

UNDERLAP: The lap condition which results in an increased slope of the normal flow curve in the null region (see detail C in Figure 7).

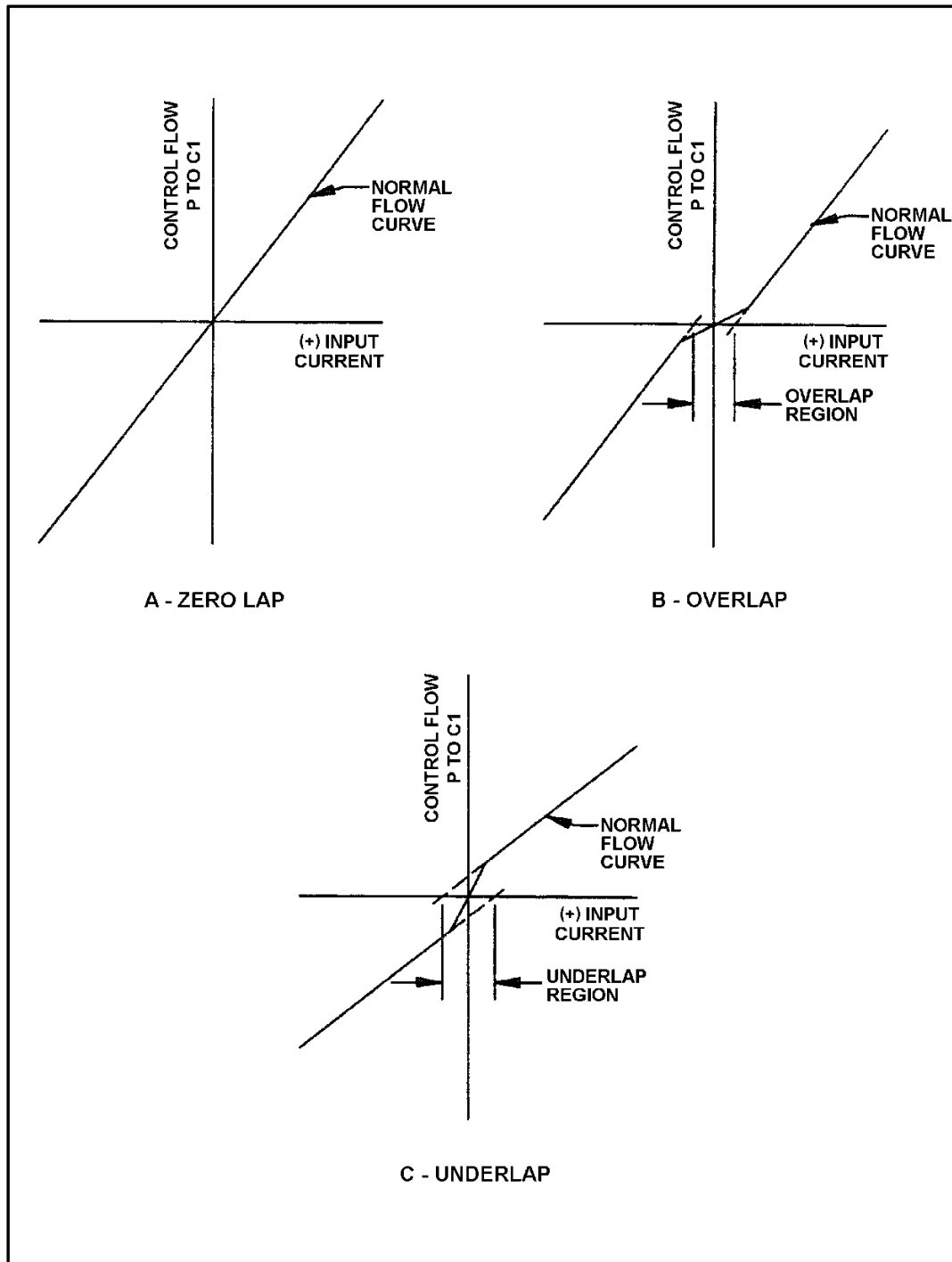


Figure 7 - Lap definitions

2.2.4 Dynamic Performance Characteristics

FREQUENCY RESPONSE: The complex ratio of control flow to input current as the current is varied sinusoidally over a range of frequencies.

NOTE: Frequency response is normally measured with constant input current amplitude and zero load pressure drop, expressed as amplitude ratio, and phase angle. Valve frequency response may vary with the input-current amplitude, temperature, supply pressure, and other operating conditions.

AMPLITUDE RATIO: The ratio of the control-flow amplitude to the input-current amplitude at a particular frequency divided by the same ratio at the same input-current amplitude at a specified low frequency (usually 5 or 10 Hz).

NOTE: Amplitude ratio may be expressed in decibels where $\text{dB} = 20 \log_{10}(\text{AR})$.

PHASE LAG: The instantaneous time separation between the input current and the corresponding control-flow variation, measured at a specified frequency and expressed in degrees (time separation in seconds * frequency in Hz * 360 degrees per cycle).

BODE DIAGRAM: A graphical depiction of servovalve frequency response, wherein phase lag and logarithmic amplitude ratio (usually expressed in dB) are plotted versus input signal frequency using logarithmic scale (see Figure A2).

2.3 Symbols and Abbreviations

Symbols and abbreviations used in this ARP are as listed below:

AC	alternating current
AR	amplitude ratio
°C	degrees Celsius
cis	cubic inches per second
dB	decibel
DC	direct current
EMF	electromotive force
°F	degrees Fahrenheit
gpm	gallons per minute
Hz	hertz
kg	kilogram
kPa	kilopascal
L	liter
M	mega (prefix)
m	meter
mA	milliampere
mL	milliliter

PA	phase angle
psi	pounds per square inch
Ω	ohm
μ	micro (prefix)

3. PROCUREMENT SPECIFICATIONS

3.1 Introduction

This section is intended to be a guide for the preparation of specifications covering electrohydraulic flow control servovalves. Certain background information is presented in 3.2 to explain various considerations appropriate to such specifications. Supplementing this section is Appendix A, where a sample specification for a typical servovalve can be found.

3.1.1 Numbering System

The following numbering system is recommended for the organization of servovalve specifications. The numbers in parentheses to the right of each paragraph title in 3.2 correlate with this numbering system. The sample specification of Appendix A follows this system also.

- (1.) Scope
- (2.) Reference Documents
- (3.) Requirements
 - (3.1) Design Requirements
 - (3.1.1) Mechanical
 - (3.1.2) Electrical
 - (3.1.3) Hydraulic
 - (3.2) Performance Requirements
 - (3.2.1) Rated Test Conditions
 - (3.2.2) Steady State
 - (3.2.3) Null
 - (3.2.4) Dynamic
 - (3.3) Environmental Requirements
- (4.) Quality Assurance Provisions
- (5.) Preparation for Delivery
- (6.) Notes

3.1.2 Valve Sizes

The specification information in 3.2 covers four common valve sizes, identified as Sizes I, II, III, and IV. Design requirements which affect interchangeability are specified for all four sizes, including maximum envelope, mounting details, electrical input configuration, hydraulic output configuration, and polarity. It is recognized that other valve sizes are commonly used. The information provided in this section is general enough to be applicable to most of these cases also.

3.1.3 Valve Variants

The recommended specification limits included in 3.2 and Appendix A are consistent with the requirements of most systems and can be met with reliable servovalve designs of proven producibility. It is important to understand and appreciate that compromises can be made in the specification of a flow-control servovalve. Specific performance parameters can often be improved by relaxing other performance requirements. For example, frequency response can normally be improved by allowing increased internal leakage. Likewise, valve internal leakage can be reduced by allowing overlap, but this will cause reduced valve flow gain in the null region.

3.1.4 Tolerances

Any reduction of the tolerances recommended in 3.2 and Appendix A will generally affect the producibility of the servovalve. Moreover, particularly close parameter control can often require a design that reduces the basic component reliability. Therefore, improvements over the recommended specifications should be carefully related to system performance requirements before closer parameter control is arbitrarily imposed.

In general, the specification information is directed towards servovalves for use in aircraft control systems. However, it should be recognized that the requirements of many other control systems will be essentially the same.

3.2 Specification Considerations

3.2.1 Scope (1.)

The introductory paragraph of the servovalve specification should identify specifically the type of component. It is often helpful if a brief description of the application can be included in the introductory paragraph, together with any additional information which describes broadly the servovalve requirements. Any unusual design or performance requirements could be cited to indicate the general nature of the hardware to be procured by the specification (for example, high temperature, high response, three-way, etc.).

3.2.2 Reference Documents (2.)

Documents listed in this section should include those specifications or drawings, or both, specifically referenced in the text of the specification. All referenced specifications should be applicable only to the extent specified in the text of the servovalve specification. Military specifications, standards, publications, etc., shall be listed by number and complete title, preceded by a statement as follows: "Unless otherwise specified in the solicitation, the applicable issue of documents shall be the issue in effect on the date of solicitation for bids." Contractors' specifications or drawings, or both, should be listed under the contractors' name and should always be identified by the specific date of issue which is applicable.

3.2.3 Requirements (3.)

3.2.3.1 Design Requirements (3.1)

3.2.3.1.1 Mechanical (3.1.1)

3.2.3.1.1.1 Design Configurations (3.1.1.1)

A major design variable in flow-control servovalves lies in the utilization of the electrical control power. When this control power is applied to a torque motor directly controlling the output stage, it is termed a single-stage servovalve.

Servovalves employing one or more hydraulic amplifiers interposed between the output stage and the torque motor are termed two, three, etc., stage valves as applicable. For certain applications, sliding spool type hydraulic amplifiers are used for both single- and multi-stage servovalves. However, two-stage servovalves employing a spool type output stage and some form of frictionless variable orifice amplifier are used most extensively.

Modern multi-stage servovalves often employ some form of feedback from the output stage spool to the torque motor. This configuration is analogous to negative feedback systems employed in certain electronic amplifiers and has similar advantages.

3.2.3.1.1.2 Physical Description (3.1.1.2)

The installation requirements for the servovalve should be specified. Those requirements are normally referenced in a specification control drawing and include:

- a. Envelope drawing
- b. Coil connections
- c. Mounting details
- d. Valve polarity
- e. Mating electrical connector
- f. Dry weight

The servovalve port connections should be legibly marked. Suitable locating pins may be provided to prevent incorrect connection of servovalve and manifold. The following identification of servovalve ports is recommended:

- a. Supply Port: P
- b. Return Port: R
- c. Control Port 1: 1
- d. Control Port 2: 2

The envelope given normally represents the installation space for the servovalve. It should indicate maximum dimensions and specify the location and dimensions of electrical connectors or other critical areas if applicable.

The outline dimensions given in Figure 8 are furnished as a guide in the selection of servovalves. The cube-type envelopes shown reflect conditions which can be met within the industry. No allowance for electrical connectors has been made. Departure from the maximum dimensions shown can often be obtained in certain areas in order to meet more exacting space limitations.

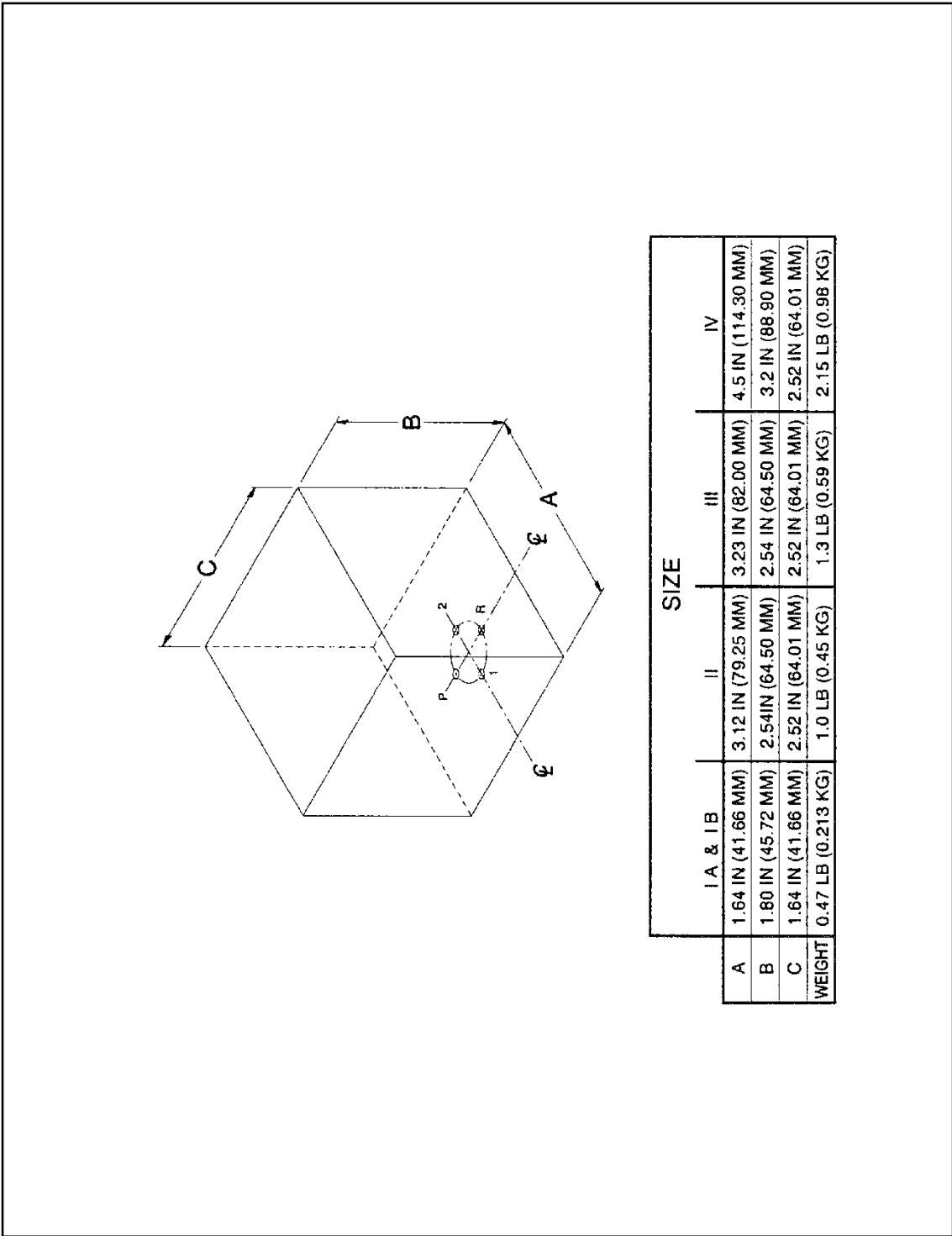


Figure 8 - Standard envelopes

The recommended mounting and porting configurations and methods of dimensioning these areas are given in Figure 9. Only four-way port configurations are indicated; however, three-way servo-valves should use the same basic mountings and dimensions except that one control port should be eliminated.

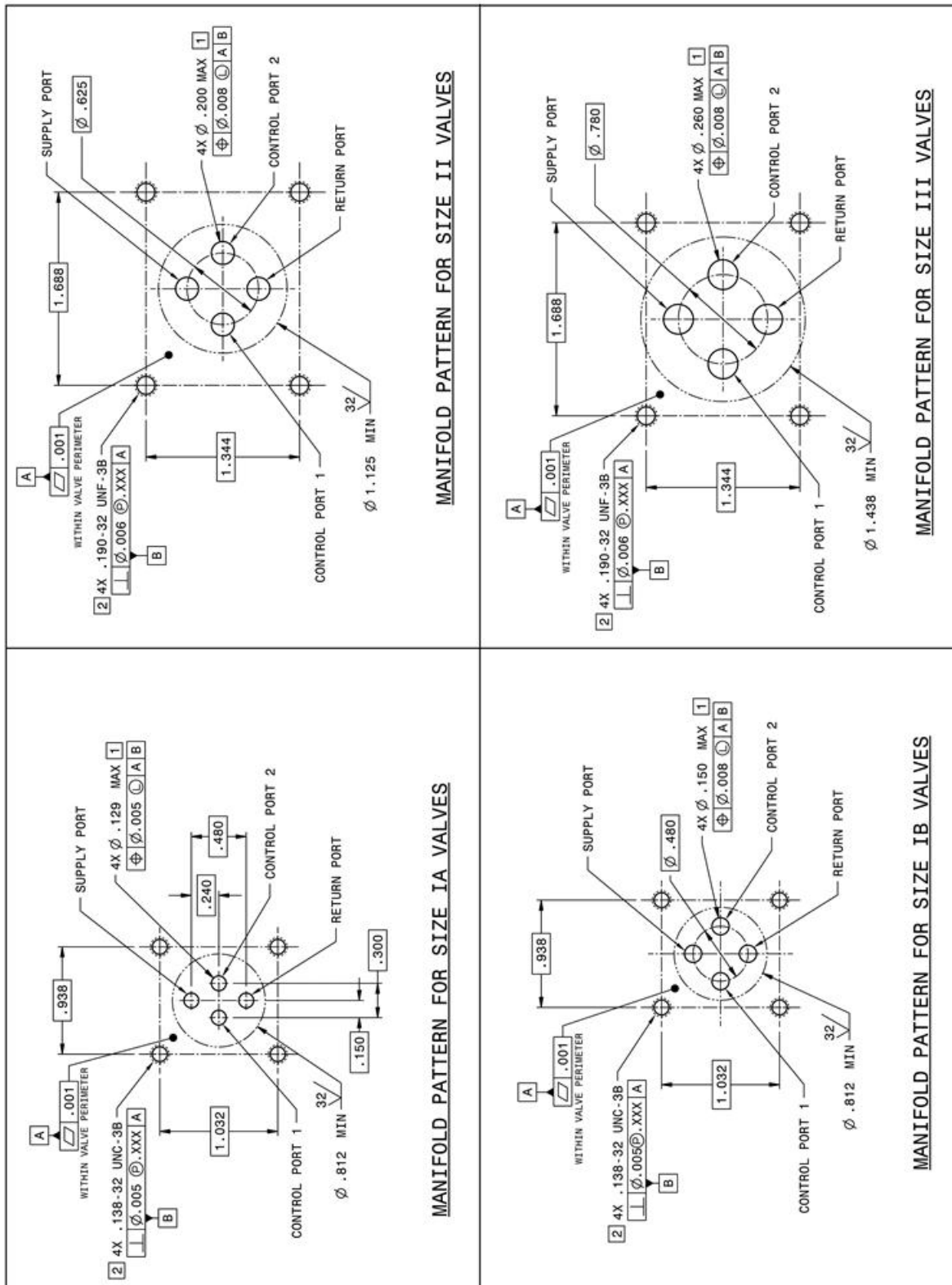


Figure 9 - Standard mounting interfaces

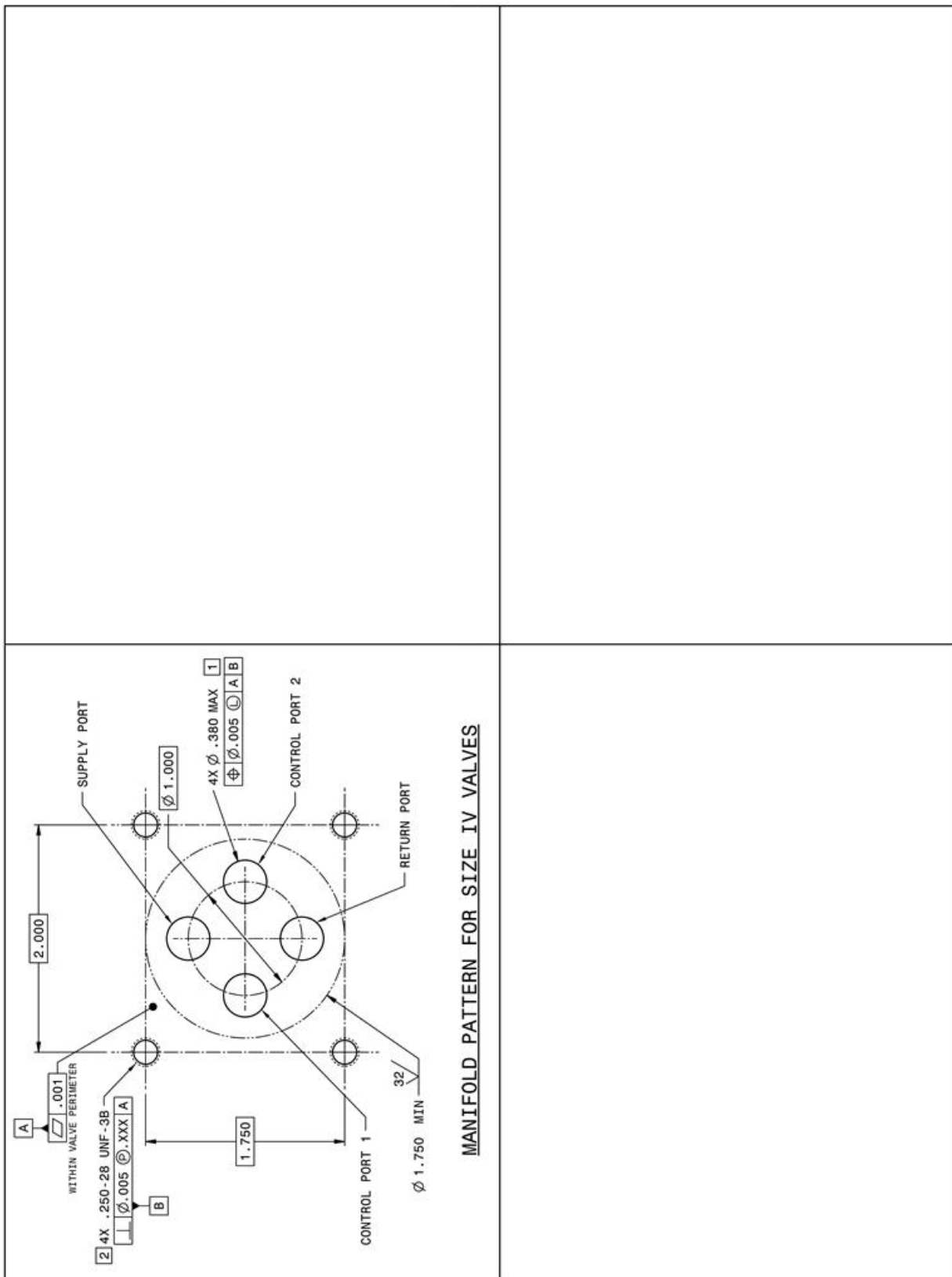


Figure 9 - Standard mounting interfaces (continued)

The flow capacity of commercially available servovalves most frequently employed may be classified broadly in terms of their respective port pattern dimensions as shown in Table 1.

It is not essential that these maximum ratings be rigidly followed since the allowable pressure drop within the servovalve at maximum required flow, or interchangeability requirements, often dictate the mounting configuration to be employed.

Table 1 - Rated flows for standard valve sizes

	Size	Flow ¹ gpm (L/min)
IA	0.480 x 0.300 inch (12.19 x 7.62 mm)	2 (7.5)
IB	Ø 0.480 inch (Ø 12.19 mm)	2 (7.5)
II	Ø 0.625 inch (Ø 15.88 mm)	6 (22.5)
III	Ø 0.780 inch (Ø 19.81 mm)	15 (57)
IV	Ø 1.000 inch (Ø 25.40 mm)	30 (113.4)

¹ Maximum no-load flow at 3000 psid (20690 kPa) using MIL-PRF-83282 fluid at 100 °F (38 °C). For alternate fluids and pressures, the applicable maximum flow can be estimated as:

$$Q' = (Q/6210) \times (P/\rho)^{1/2} \text{ (English units)} \quad (\text{Eq. 1})$$

$$Q' = (Q/4.98) \times (P/\rho)^{1/2} \text{ (metric units)}$$

where:

Q = Maximum flow, per the preceding table

Q' = New maximum flow

P = Valve pressure drop, psid (kPa)

ρ = Fluid mass density, lbf x s²/inch⁴ (kg/m³)

3.2.3.1.1.3 Identification (3.1.1.3)

An area on each servovalve should be available for engraving or secure attachment of identifying information. The identification of a servovalve as a minimum should include:

- Manufacturer
- Model number (supplier's model or part number)
- Serial number

Additional information may also be included, such as the following:

- Part number (customer)
- Rated pressure
- Rated current
- Fluid
- Contract number
- Assembly date

3.2.3.1.1.4 Materials (3.1.1.4)

Materials used should conform to all the applicable specifications and specified environments.

Fluid or environmental conditions, etc., often require special precautions to be taken regarding the selection of compatible materials to minimize the effects of chemical or electrical reaction, fungus growth, etc. Where applicable, these conditions should be specified. MIL-HDBK-1587 and MIL-STD-889 may be used as a guide in the selection of suitable materials.

3.2.3.1.1.5 Standard Parts (3.1.1.5)

Parts to industry and military standards, such as AS, MA, NAS, MS, or AN, should be used wherever they are suitable for the purpose.

3.2.3.1.1.6 Locking Devices (3.1.1.6)

All threaded parts should be securely locked or safetied by safety-wiring, self-locking nuts, or other approved methods. Safety-wire should be applied in accordance with standard NASM33540. Snap rings should not be used as retainers unless they are positively retained in their installed position.

3.2.3.1.1.7 Structural Strength (3.1.1.7)

All component parts of the servovalve should have sufficient strength to withstand all loads or combinations of loads resulting from hydraulic pressure, temperature, actuation, and torque loads imposed during installation and operation under rated conditions.

3.2.3.1.1.8 Seals (3.1.1.8)

Seals should be of such composition and dimensions so as to satisfy the standardization and operating requirements of the applicable specifications. If a specific seal compound is desired for certain fluid or environmental conditions, the specification for the compound should be included.

In aerospace servovalves, it is often necessary to utilize nonstandard seals because of space and weight constraints. Therefore, while the use of standard size seals is desirable, the specification should permit the use of nonstandard seals when the concurrence of the procuring activity is obtained.

Further, to assure adequate seal squeeze under the worst possible combinations of seal size, gland size, seal stretch, and gland eccentricities, the design of any nonstandard seal installations should follow the recommendations put forth in ARP1231.

3.2.3.1.2 Electrical (3.1.2)

3.2.3.1.2.1 Coil Connections (3.1.2.1)

The wiring configuration for the torque motor coils should be specified, together with the connector pin identification or lead wire color coding, as applicable. Recommended coil connections for two-, three-, or four-pin (wire) applications are shown in Figure 10.