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AEROSPACE RECOMMENDED PRACTICE

ARP 490A

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ELECTROHYDRAULIC FLOW-CONTROL SERVOVALVES

PART I

PART II

(To be published at a later date)

 Printed in U. S. A.

1. PURPOSE - This recommended practice is intended as a guide to aid in the specification and testing* of electrohydraulic flow-control servovalves.

2. SCOPE - The recommendations contained in this recommended practice are confined to the input and output characteristics of electrohydraulic flow-control servovalves. The information presented should be useful in standardizing the terminology, the specification of physical and performance parameters, and the test procedures used in conjunction with these components.

The recommendations do not restrict nor attempt to define the internal design characteristics of servovalves. As such, the material is equally applicable to servovalves having different internal functioning, different ratings, different physical size, etc. In certain instances, standards for valve design are recommended to increase component interchangeability, as, for example, pigtail color-coding, valve polarity, mounting bolt and fluid port locations.

The specifications contained herein should be adequate to describe electrohydraulic flow-control servovalves. Additional specifications may be necessary to define special requirements for specific control systems. Also, specialized test procedures may be necessary to measure servovalve performance in these unusual specification areas. These considerations are beyond the scope of this recommended practice.

3. RECOMMENDED ABBREVIATIONS

ac - alternating current
AR - amplitude ratio
cis - cubic inches per second
cps - cycles per second
db - decibels
dc - direct current
deg - degrees
emf - electromotive force
gpm - gallons per minute
hp - horsepower
ma - milliamperes
mw - milliwatts
PA - phase angle
psi - pounds per square inch

4. RECOMMENDED TERMINOLOGY

4.1 Servovalve, Electrohydraulic Flow-Control - An electrical input, flow-control valve, which is capable of continuous control.

4.1.1 Hydraulic Amplifier - A fluid valving device which acts as a power amplifier, such as a sliding spool, or a nozzle flapper, or a jet pipe with receivers.

*Testing section will be published at a later date.

4.1.2 Stage - A hydraulic amplifier used in a servovalve. Servovalves may be single-stage, two-stage, three-stage, etc.

4.1.3 Output Stage - The final stage of hydraulic amplification used in a servovalve.

4.1.4 Port - A fluid connection to the servovalve, e.g., supply port, return port, control port.

4.1.5 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.

4.1.6 Three-Way Valve - A multiorifice 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.

4.1.7 Four-Way Valve - A multiorifice 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. Reversed valve action opens supply to control port #2 and opens control port #1 to return.

4.2 Electrical Characteristics

4.2.1 Torque Motor - The electromechanical transducer commonly used in the input stages of servovalves.

4.2.2 Input Current - The current to the valve, expressed in ma, which commands control flow.

4.2.3 Rated Current - The specified input current of either polarity to produce rated flow, expressed in ma. Rated current must be specified for a particular coil connection (differential, series, or parallel), and does not include null bias current.

4.2.4 Quiescent Current - A 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.

4.2.5 Electrical Quiescent Power - The power dissipation required for differential operation when the current through each coil is equal and opposite in polarity.

4.2.6 Electrical Control Power - The power dissipation required for control of the valve. Control power is a maximum with full input signal, and is zero with zero-input signal. It is independent of the coil connection (series, 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.

4.2.7 Total Electrical Power - The sum of the instantaneous control power and the quiescent power, expressed in mw.

4.2.8 Coil Impedance - The complex ratio of coil voltage to coil current. It is important to note that the coil impedance may vary with signal frequency, amplitude, and other operating conditions due to back emf generated by the moving armature.

4.2.9 Coil Resistance - The dc resistance of each torque motor coil, expressed in ohms.

4.2.10 Polarity - The relationship between the direction of control flow and the direction of input current.

4.2.11 Dither - A low amplitude, relatively high frequency periodic electrical signal, sometimes superimposed on the servovalve input to improve system resolution. Dither is expressed by the dither frequency (cps) and the peak-to-peak dither current amplitude (ma).

4.3 Static Performance Characteristics

4.3.1 Control Flow - The flow through the valve control ports, expressed in cis or gpm. Control flow is referred to as No-Load Flow when there is zero load-pressure drop. Control flow is referred to as Loaded Flow when there is load-pressure drop. (See Paragraph 4.3.12, Load Pressure Drop.) Conventional test equipment normally measures no-load flow.

4.3.2 Rated Flow - The specified control flow corresponding to rated current and specified load pressure drop. Rated flow is normally specified as the no-load flow.

4.3.3 Flow Curve - The graphical representation of control flow versus input current. This is usually a continuous plot of a complete cycle between plus and minus rated current values. See Figure 1.

4.3.3.1 Normal Flow Curve - The locus of the midpoints of the complete cycle flow curve, which is the zero hysteresis flow curve. Usually valve hysteresis is sufficiently low, such that one side of the flow curve can be used for the normal flow curve. See Figure 2.

4.3.4 Flow Gain - The slope of the control flow versus input current curve in any specific operating region, expressed in cis/ma or gpm/ma. 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 3. Where this term is used without qualification, it is assumed to mean normal flow gain.

4.3.4.1 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. 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 4.

4.3.4.2 Rated Flow Gain - The ratio of rated flow to rated current, expressed in cis/ma or gpm/ma.

4.3.5 Flow Saturation Region - The region where flow gain decreases with increasing input current.

4.3.6 Flow Limit - The condition wherein control flow no longer increases with increasing input current. Flow limitation may be deliberately introduced within the servovalve.

4.3.7 Symmetry - The degree of equality between the normal flow gain of one polarity and that of the reversed polarity. Symmetry is measured as the difference in normal flow gain of each polarity, expressed as percent of the greater. See Figure 4.

4.3.8 Linearity - The degree to which the normal flow curve conforms to the normal flow gain line with other operational variables held constant. 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 4.

4.3.9 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. Hysteresis is normally specified as the maximum difference occurring in the flow curve throughout plus or minus rated current, and is expressed as percent of rated current. See Figure 1.

4.3.10 Threshold - The increment of input current required to produce a change in valve output, expressed as percent of rated current. Threshold is normally specified as the current increment required to revert from a condition of increasing output to a condition of decreasing output.

4.3.11 Internal Leakage - The total internal valve flow from pressure to return with zero control flow (usually measured with control ports blocked), expressed in cis or gpm. Leakage flow will vary with input current, generally being a maximum at the valve null (null leakage).

4.3.12 Load-Pressure Drop - The differential pressure between the control ports, expressed in psi. In conventional three-way servovalves, load-pressure drop may be expressed as an equation, wherein it is equated to the supply pressure, less return pressure, and less the pressure drop across the single active control orifice. ($P_s - P_r - P_o = P_l$).

4.3.13 Valve Pressure Drop - The sum of the differential pressures across the control orifices of the output stage, expressed in psi. Valve-pressure drop will equal the supply pressure minus the return pressure minus the load pressure drop.

4.3.14 Pressure Gain - The rate of change of load pressure drop with input current at zero control flow (control ports blocked), expressed in psi/ma. Pressure gain is usually specified as the average slope of the curve of load pressure drop versus current between $\pm 40\%$ of maximum load-pressure drop. See Figure 5.

4.3.15 Null Region - The region about null wherein effects of lap in the output stage predominate.

4.3.15.1 Null - The condition where the valve supplies zero control flow at zero load-pressure drop.

4.3.15.2 Null Pressure - The pressure existing at both control ports at null, expressed in psi.

4.3.15.3 Null Bias - The input current required to bring the valve to null, excluding the effects of valve hysteresis, expressed as percent of rated current.

4.3.15.4 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.

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

4.3.16.1 Zero Lap - The lap condition where there is no separation of the straight line extensions of the normal flow curve. See Figure 6A.

4.3.16.2 Overlap - The lap condition which results in a decreased slope of the normal flow curve in the null region. See Figure 6B.

4.3.16.3 Underlap - The lap condition which results in an increased slope of the normal flow curve in the null region. See Figure 6C.

4.4 Dynamic Performance Characteristics

4.4.1 Frequency Response - The complex ratio of flow-control flow to input current as the current is varied sinusoidally over a range of frequencies. 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.

4.4.2 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 cps). Amplitude ratio may be expressed in decibels where db = 20 $\log_{10}$ AR.

4.4.3 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 x frequency in cps x 360 degrees per cycle).

5. PROCUREMENT SPECIFICATIONS

5.1 Introduction - This section is intended to be a guide for the preparation of specifications covering electrohydraulic flow control servovalves. Certain background information is given to explain various considerations appropriate to such specification. This background material is presented in Section 5.2. Section 5.3 contains a sample specification for a standard servovalve. In both Sections 5.2 and 5.3 the subparagraph numbers in parentheses at the right margin form an independent numbering system which should be used for a servovalve specification. The format of this proposed specification is:

(1.) Scope
(2.) Reference Specifications
(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) Static
  - (3.2.3) Null
  - (3.2.4) Dynamic
- (3.3) Environmental Requirements

(4.) Quality Assurance Provisions
(5.) Preparation for Delivery
(6.) Notes

The specification information in Section 5.2 covers three common valve sizes, identified as Sizes I, II, and III. These three sizes correspond to three different ranges of flow

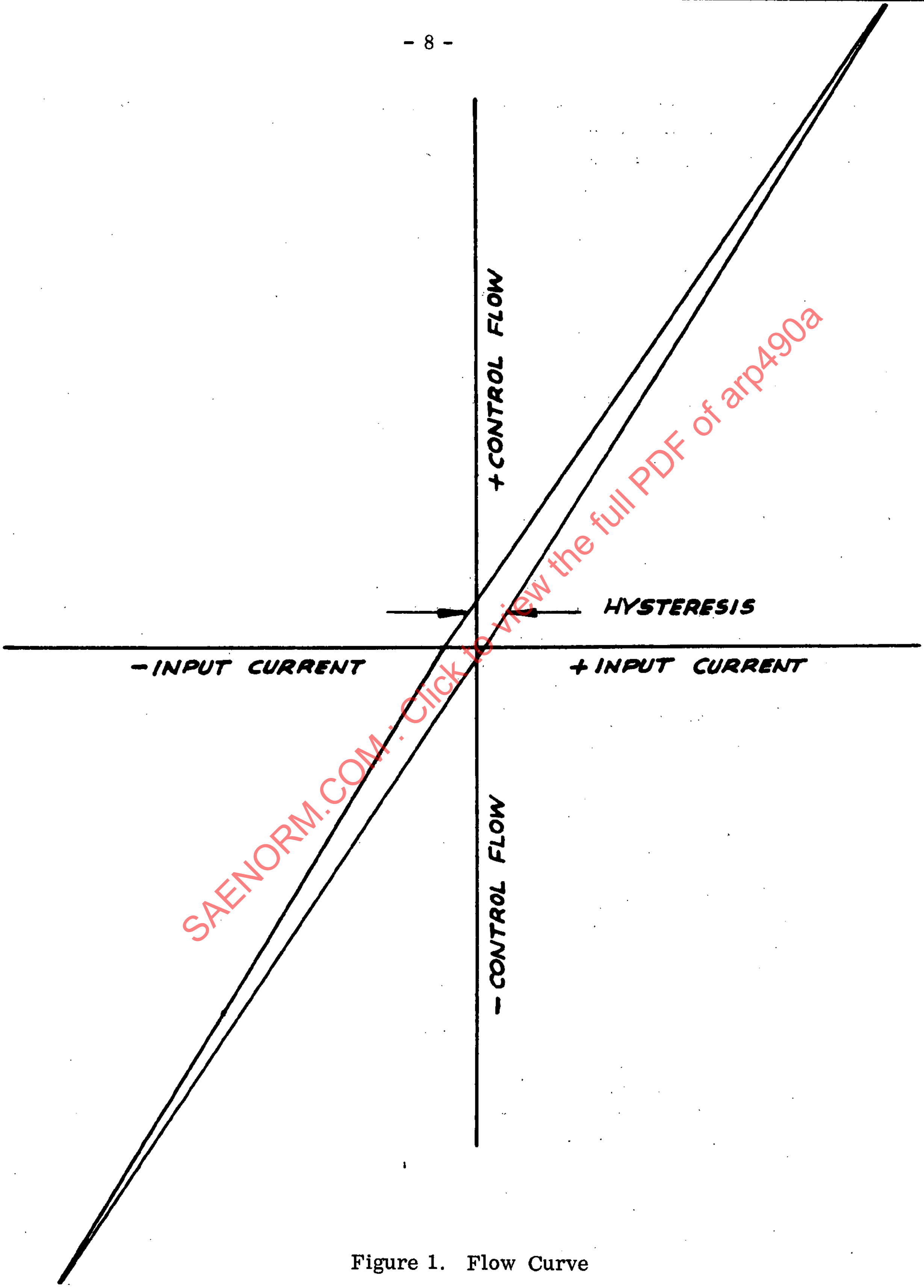


Figure 1. Flow Curve

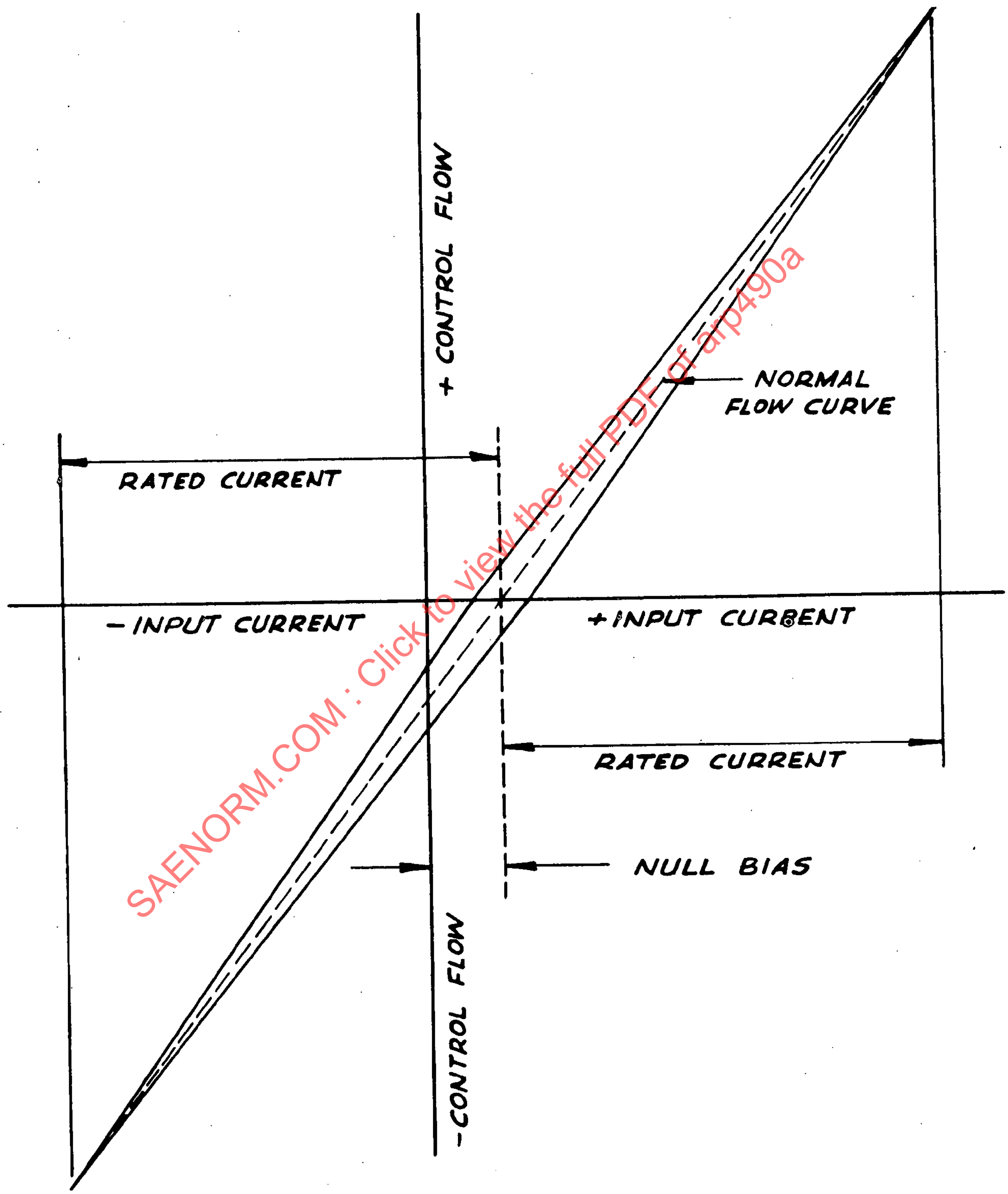


Figure 2. Normal Flow Curve

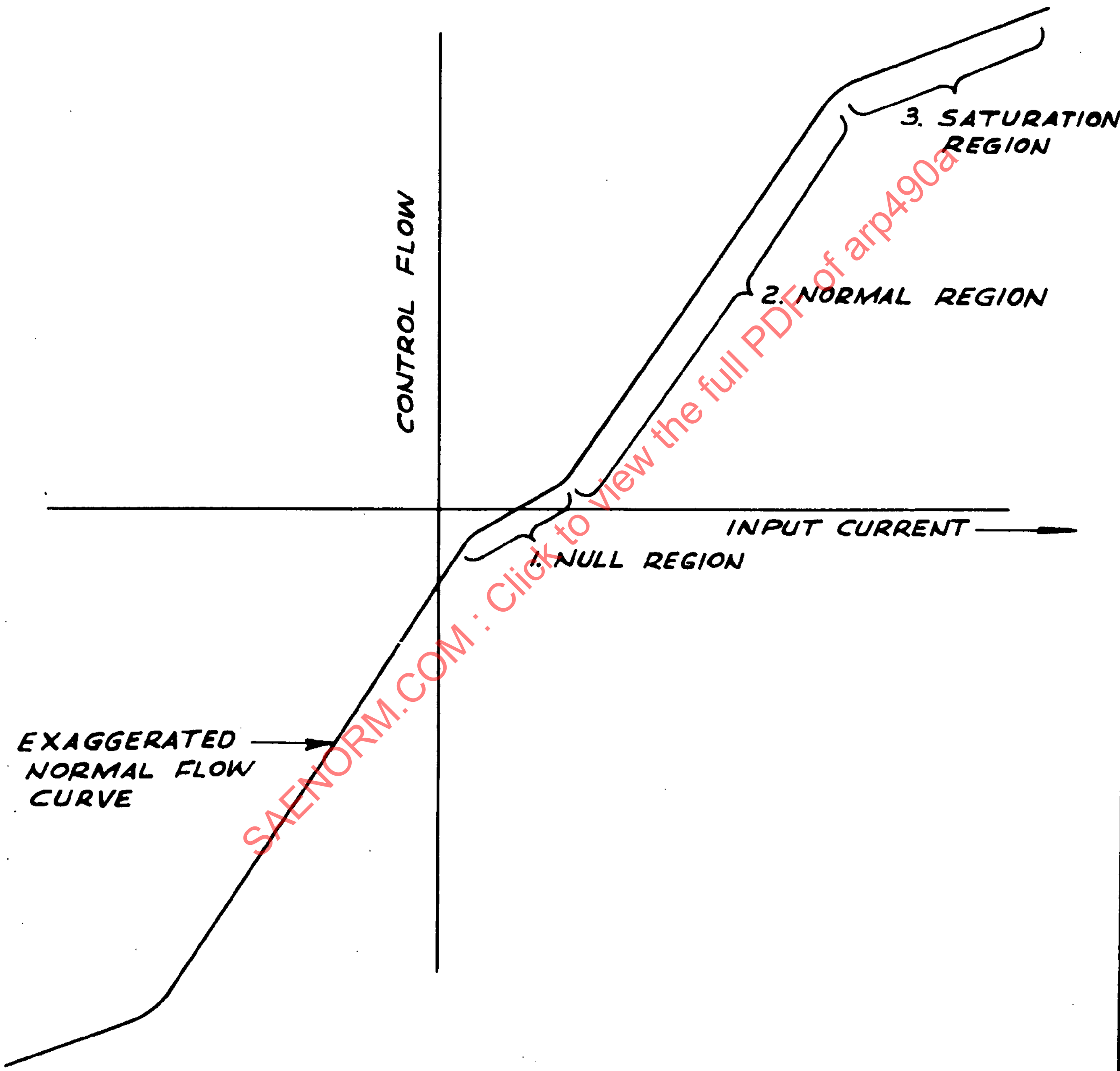


Figure 3. Operating Regions

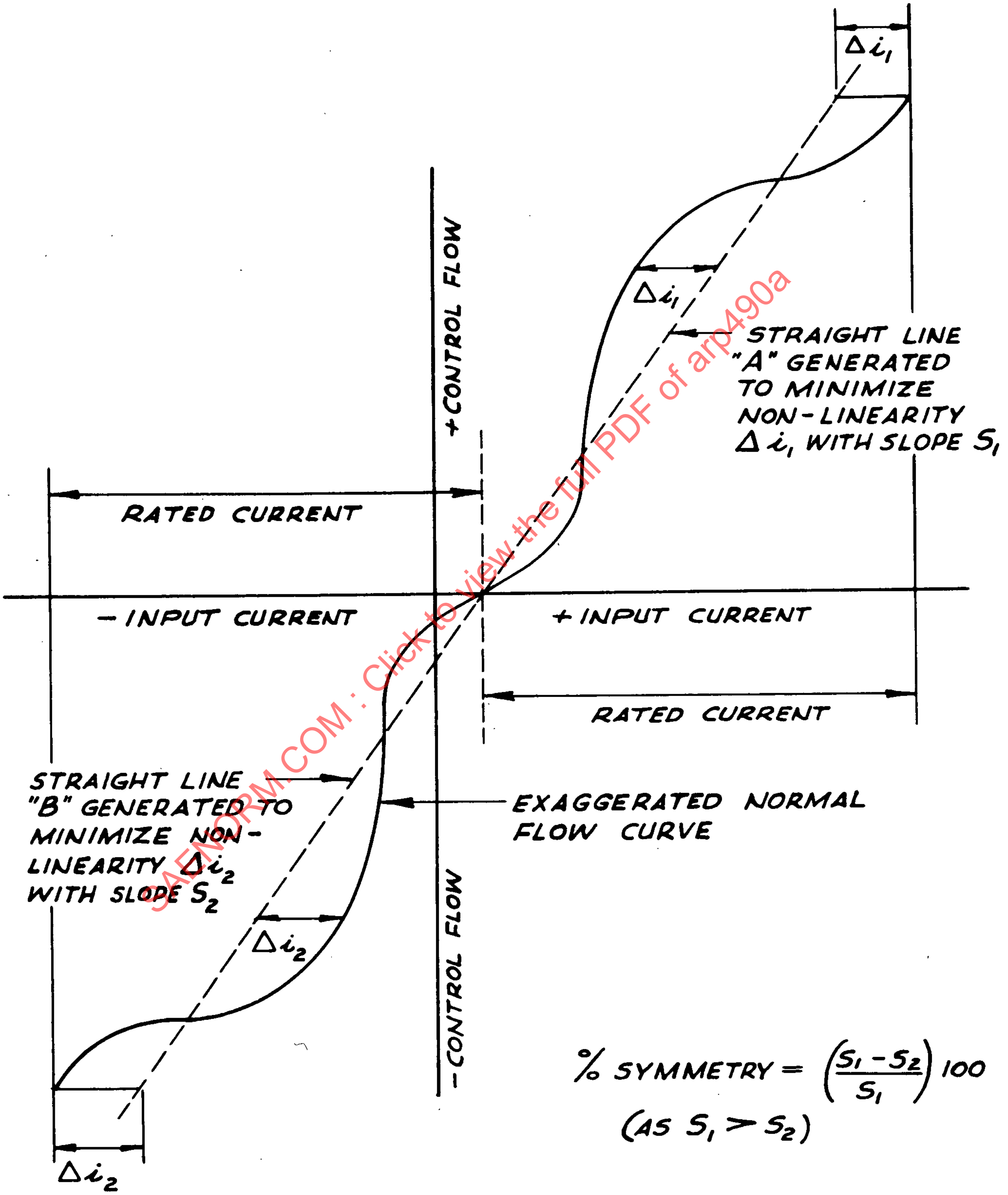


Figure 4. Linearity/Symmetry

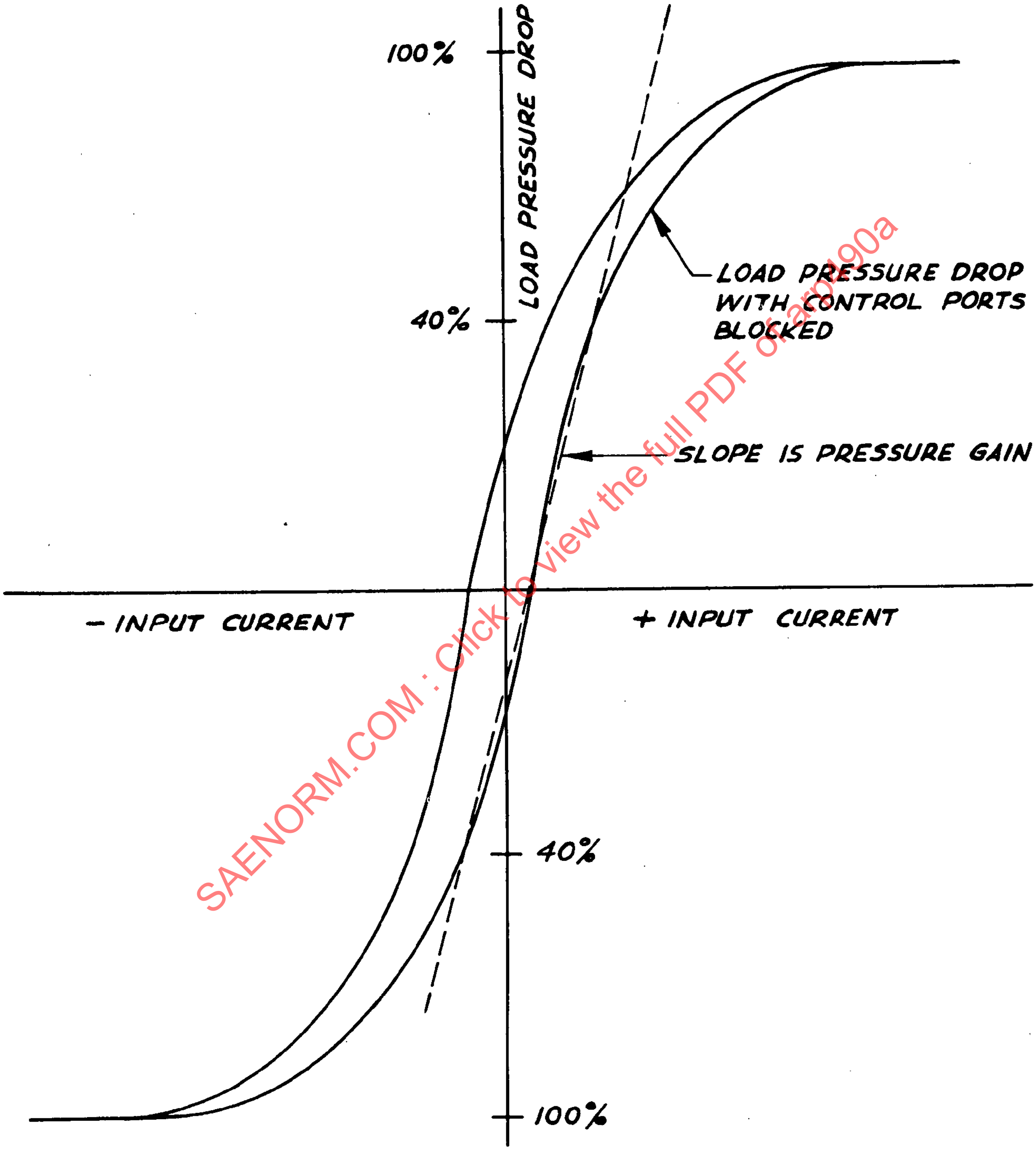


Figure 5. Pressure Gain

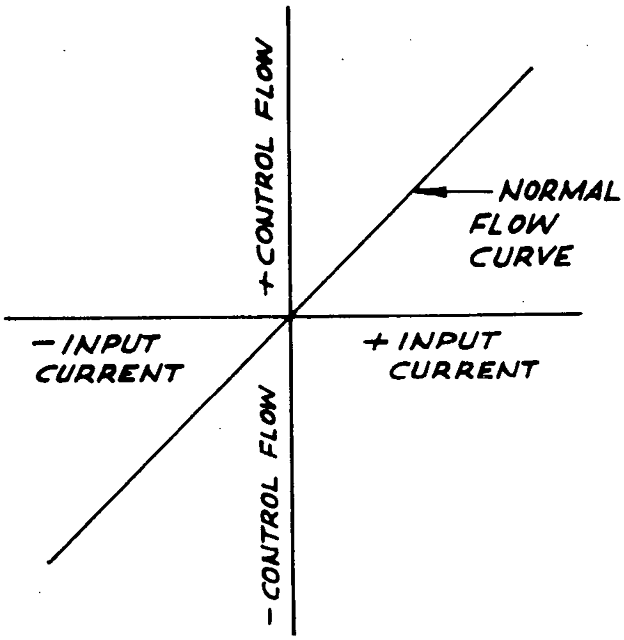


Figure 6A. Zero Lap

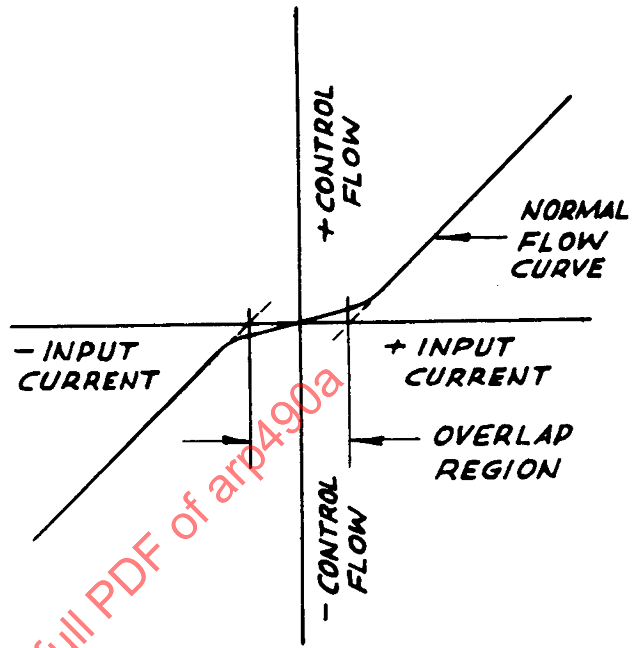


Figure 6B. Overlap

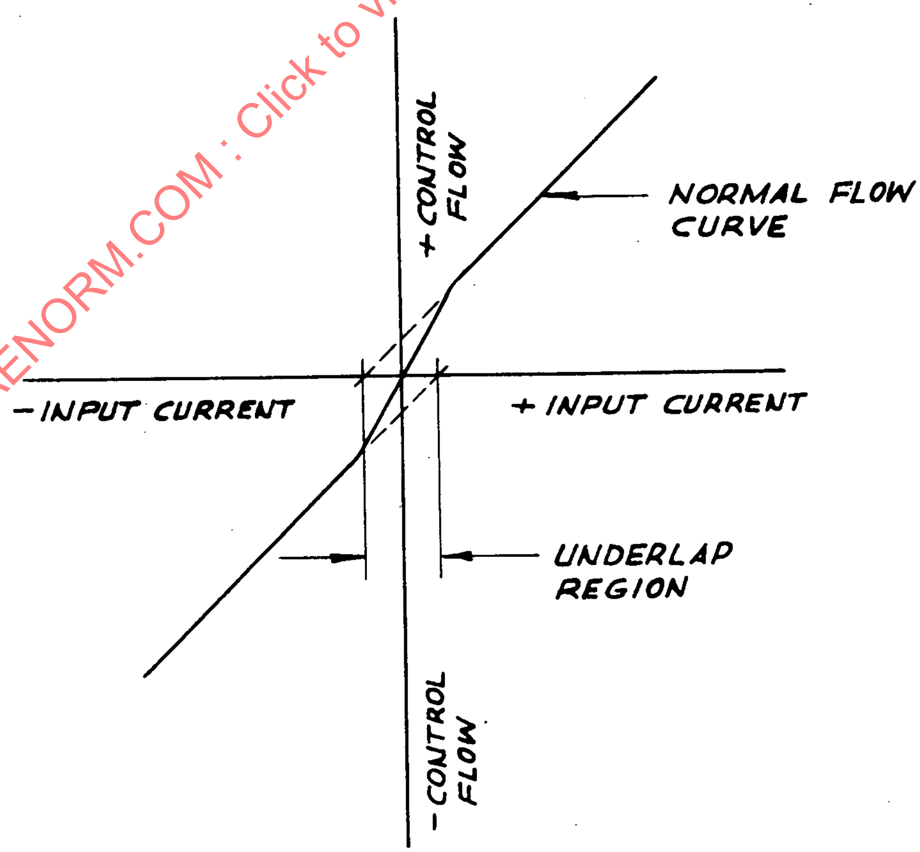


Figure 6C. Underlap

capacity based on MIL-H-5606 having approximate maximums at 3000 psi valve pressure drop of 2, 6, and 15 gpm, respectively. Design requirements which affect interchangeability are specified for the three valve sizes, including maximum envelope, mounting details, electrical input configuration, hydraulic output configuration, and polarity. It is recognized that other valve sizes are available. Much of the information given in this document will be applicable to these non-standard valve sizes.

The recommended specification limits included in Sections 5.2 and 5.3 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.

Reduction of the tolerances recommended in Sections 5.2 and 5.3 will generally affect 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 military control systems. However, it should be recognized that the requirements of many commercial control systems will be essentially the same.

5.2 Specification Considerations

5.2.1 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 (e.g., high temperature, high response, three-way, etc.).

5.2.2 Reference Specifications (2.)

Documents listed in this section shall include those specifications and/or drawings specifically referenced in the text of the specification. All referenced specifications shall 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: "The following documents of the issue in effect on the date of invitation for bids form part of this specification to the extent specified herein." Contractors' specifications and/or drawings shall be listed under the contractors' name and shall always be identified by the specific date of issue which is applicable.

The priority of any specified documents shall be clearly indicated to avoid misunderstanding. Some parts of applicable government documents may be incompatible with the particular application. In such cases, it should be noted whether these shall be disregarded or that approval to deviate from the requirements indicated shall be obtained.

5.2.3 Requirements (3.)

5.2.3.1 Design Requirements (3.1)

5.2.3.1.1 Mechanical (3.1.1)

5.2.3.1.1.1 Design Configurations (3.1.1.1)

A major difference 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 multistage servovalves. However, two-stage servovalves employing a spool type output stage and some form of frictionless variable orifice amplifier are used most extensively. Modern multistage 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.

5.2.3.1.1.2 Physical Description (3.1.1.2)

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

Envelope Drawing	Coil Connections
Mounting Details	Valve Polarity
Mating Electrical Connector	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:

Supply Port - P
Return Port - R
Control Port 1 - 1
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 7 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.

The recommended mounting and porting configurations and methods of dimensioning these areas are given in Figure 8. Only four-way port configurations are indicated; however, three-way servovalves should use the same basic mountings and dimensions except that control port 2 should be eliminated.

The flow capacity of commercially available servovalves most frequently employed may be classified broadly in terms of their respective port circle dimensions.

Size			Output Flow GPM (3000 psi valve pressure drop) with MIL-H-5606
I	A	.480 diamond	2
	B	.480 diameter	
II		.625 diameter	6
III		.780 diameter	15

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.

5.2.3.1.1.3 Identification (3.1.1.3)

An area on each servovalve should be available for the engravement or secure attachment of identifying information. MIL-P-6906 may be used as a guide. Identification as a minimum should include:

Manufacturer
Model Number (Supplier's Model or Part Number)
Serial Number

The following additional information may also be included:

Part Number (Customer)
Rated Pressure
Rated Current
Fluid

5.2.3.1.1.4 Materials (3.1.1.4)

Materials used should conform to all 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-STD-143 may be used as a guide in the selection of suitable materials.

5.2.3.1.1.5 Standard Parts (3.1.1.5)

Standard parts such as MS or AN should be used wherever they are suitable for the purpose.

5.2.3.1.1.6 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 MS 33540. Snap rings should not be used as retainers unless they are positively retained in their installed position.

5.2.3.1.1.7 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.

5.2.3.1.1.8 Seals (3.1.1.8)

When possible, seals, gaskets and packings should be of such composition and installation as to satisfy the requirements of all applicable military specifications and specified tests. If a specific seal compound is desired for certain fluid or environmental conditions, the specification for the compound should be included. The cure date of elastomeric seals within the servovalve should be clearly marked on the exterior of the valve housing.

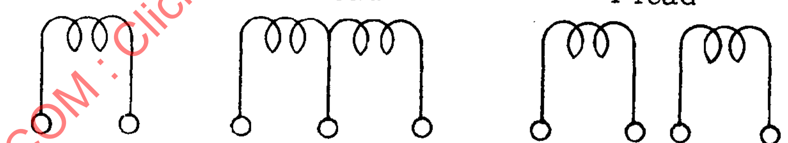
In servovalves it is normal to employ so-called "non-standard" packings and installations due to space limitations; these installations, while at times in conflict with certain military standards, have proven to be highly successful.

5.2.3.1.2 Electrical (3.1.2)

5.2.3.1.2.1 Coil Connections (3.1.2.1)

The external wiring configuration for the torque motor coils should be specified, together with the connector pin identification or pigtail color coding, as applicable. Recommended coil connections for single-ended, push-pull, and four-wire applications are shown below.

coil	2 lead	3 lead	4 lead
connector pins	B A	B A C	B A D C
external pigtail colors	green red	green red blue	green red yellow blue



5.2.3.1.2.2 Rated Current (3.1.2.2)

Rated current should be stated in ma for the particular coil connection specified in 5.2.3.1.2.1. Specifying rated current and resistance combinations less than those recommended by the manufacturer may require the servovalve to be designed with less than optimum electrical control power. In general, a very low value for rated current requires the use of extremely small magnet wire, with resultant reliability hazards; so it should be avoided if possible.

5.2.3.1.2.3 Quiescent Current (3.1.2.3)

If differential coil operation is specified, normal quiescent current values and polarity should be stated. Also, maximum anticipated quiescent current should be specified. If abnormal variations of quiescent current are anticipated, then the range of variation should be stated.

5.2.3.1.2.4 Insulation Resistance and Dielectric Strength (3.1.2.4)

Minimum insulation resistance of valve coils and leadout wires to valve body should be specified. It is recommended that this value be 50 megohms under room temperature and humidity conditions following a 15-second application of a dc potential equal to 1000 volts or five times the maximum anticipated coil voltage, whichever is less. Repeated applications of high voltage to the servovalve may eventually break down the coil insulation, so a maximum number of insulation resistance tests should be specified. The recommended number of tests is not more than four times on one servovalve.

5.2.3.1.2.5 Coil Resistance (3.1.2.5)

The dc resistance of the valve coil or coils should be specified. A ± 10% tolerance for individual coil resistance is recommended and the temperature (usually 68 F) at which resistance is measured should be stated. If more than one coil is required, it may be necessary to specify the resistance match of the coil pairs (usually within 10% of the nominal specified resistance).

5.2.3.1.2.6 Coil Impedance (3.1.2.6)

Coil impedance is a difficult parameter to measure accurately and normally will vary considerably from unit to unit. It is usually not specified where high output impedance servovalve driving amplifiers are used and the influence of valve complex impedance on servovalve input current is negligible. When impedance is specified, it is usually stated as a vector quantity, together with a tolerance. Since coil impedance will change considerably with slight variations in servovalve design, it is recommended that the individual servovalve manufacturers be consulted before this parameter is specified.

The apparent impedance of servovalve coils will be influenced markedly by operation of the torque motor. This influence is due to back emf's generated by the moving armature, so it will depend upon supply pressure, input current amplitude, and frequency. Therefore, the magnitude of each of these parameters should be included with a coil impedance specification.

The coil impedance presented to low frequencies is more pertinent for control system dynamic considerations than are measurements made with a conventional 1000 cps impedance bridge. Since servovalve coil impedance will vary with frequency, it is recommended that this parameter be specified and measured at a low frequency.

Usually 50 cps is chosen for specification purposes, as measurements at lower frequencies are subject to test equipment inaccuracies. Measurements at 60 cps should be avoided because of line frequency interaction, and frequencies above 60 cps are generally of less interest in electrohydraulic systems. At 50 cps the servovalve coil inductance will be considerably higher than at 1000 cps, which is the frequency at which coil inductance has been traditionally measured. Coil impedance presented to a carrier frequency demodulator (e.g., 400 cps, 800 cps, etc.) will vary from design to design and cannot be predicted from low frequency measurements.

5.2.3.1.3 Hydraulic (3.1.3)

5.2.3.1.3.1 Operating Pressures (3.1.3.1)

The system supply pressure should be specified together with the nominal return pressure.

5.2.3.1.3.2 Proof Pressure (3.1.3.2)

The servovalve should withstand, without evidence of external leakage (other than slight wetting insufficient to form a drop) or permanent performance degradation, the following proof pressures: 1.5 supply pressure applied for two minutes to ports P 1 and 2,with return open, followed by supply pressure applied simultaneously to all ports for two minutes. Normally, proof pressure tests are applied at room temperature for production acceptance tests and at maximum temperature during a qualification test. Proof pressure should be applied at a maximum rise rate of 25,000 psi/min.

5.2.3.1.3.3 Burst Pressure (3.1.3.3)

The servovalve should not rupture with burst pressures of 2.5 supply pressures on ports P 1 and 2 (applied at a maximum rise rate of 25,000 psi/min. and usually at room temperature) with return open, followed by 1.5 supply pressure applied simultaneously to all ports. The servovalve shall not be required to operate after this test.

5.2.3.1.3.4 Fluid (3.1.3.4)

The working fluid for the servovalve should be specified. The exposure to other fluids, such as preservative oil or alternate test fluids, should also be noted.

5.2.3.1.3.5 External Leakage (3.1.3.5)

Normally, the specification allows no external leakage, other than a slight wetting insufficient to form a drop, throughout all operational and environmental ranges.

5.2.3.1.3.6 Internal Leakage (3.1.3.6)

Internal leakage should be specified as the maximum flow from pressure to return under rated test conditions with zero control flow. Internal leakage can vary with input current, but is usually specified as a value not to be exceeded throughout the current range. If necessary, this parameter can be specified both at null and at rated signal with different maximum limits at the two points.

In general, servovalve first-stage leakage can be reduced, but at the expense of dynamic response. Also, the null leakage of the second stage will vary greatly with the lap condition. More overlap will reduce null leakage, but will make the valve susceptible to silting with a possible adverse effect on threshold and hysteresis.

Internal leakage is usually specified and measured with no externally applied dither. Dither will generally cause the servovalve to appear slightly underlapped, so the internal leakage normally increases as dither is applied.

5.2.3.2 Performance Requirements (3.2)

5.2.3.2.1 Rated Test Conditions (3.2.1)

Unless otherwise stated, all servovalve specifications apply to a set of standard test conditions as defined in this section. Any specification of performance over a range of conditions (i.e., over a range of temperatures, supply and return pressures, output loading, etc.) should be specified in Section 5.2.3.3. These environmental specifications are normally given as a maximum percentage variation of the particular parameter (flow gain, null, coil resistance, etc.) over the full specified range of each operating condition (valve pressure drop, temperature, etc.). If for some reason it is necessary to set the parameter tolerance at some non-standard test condition, or if some unusual environmental condition is expected, it should be so stated in this section. For example, if the valve is to be used primarily at elevated temperature, then it may be desirable to specify this temperature as a rated test condition. It should be noted that the normal tolerances given in Section 5.2.3.2 may not apply when the test conditions are non-standard.

The performance specifications given in Section 5.2.3.2 apply for operation of the servovalve under the following standard test conditions:

Fluid: (normally as specified in Paragraph 5.2.3.1.3.4)
Operating pressure: (Normally as specified in Paragraph 5.2.3.1.3.1)
Quiescent current: (Normally as specified in Paragraph 5.2.3.1.2.3)
Temperature: Normally 90 to 120 F fluid and 65 to 90 F ambient
Filtration: Conform with National Aerospace Standard 1638, Class 6 or better

5.2.3.2.2 Static (3.2.2)

5.2.3.2.2.1 Rated Flow (3.2.2.1)

Valve rated flow should be specified for the rated current and a particular load pressure drop. Rated flow is usually specified at no-load conditions since more accurate and more economical test methods can be employed. The tolerance for rated flow is generally ± 10%.

5.2.3.2.2.2 Linearity (3.2.2.2)

Linearity of the normal flow curve should be specified as a maximum per cent of rated current. Standard tolerance for this parameter is 7.5%. If significant flow gain non-linearities are anticipated for a particular application, linearity should be specified over the range where linear operation is desired. Linearity, therefore, may be specified to a point less than rated signal. If servovalve specifications require a radical deviation from zero lap, it is usually advantageous to redefine linearity according to the unique requirement of the particular application. These cases are not considered in this document.

5.2.3.2.2.3 Symmetry (3.2.2.3)

Symmetry of control flow on either side of null should be specified. Standard tolerance for this parameter is 10%. Intentional asymmetry can be specified, but this is a special requirement and is not considered in this document.

5.2.3.2.2.4 Hysteresis (3.2.2.4)

Hysteresis, as defined, includes threshold and electromagnetic effects. Therefore, hysteresis loop width is a function of input amplitude plus some constant value. Standard tolerance for this parameter is 5% of rated current.

When assessing the significance of this parameter, the effect of servovalve hysteresis on system positional accuracy should be considered. In most systems, the magnitude of this error is sufficiently small due to electrical feedback gain such that 5% servovalve hysteresis is acceptable.

Phase lag of the servovalve and of the test equipment increases the apparent hysteresis. Therefore, it is important to specify and measure servovalve hysteresis under essentially static conditions. Plots of a full hysteresis loop are usually run at less than 0.1 cps.

5.2.3.2.2.5 Threshold (3.2.2.5)

Threshold should be specified as a maximum percent of rated current and the normal value is 1.0%. In standard two-stage servovalves, this parameter is essentially a measure of the static friction of the moving elements in the second stage. Hydraulic oil contamination will generally increase the tendency of these parts to bind; therefore, it is important that this parameter be defined and tested according to a specified cleanliness standard. Electrical or externally applied mechanical dither is usually not included in the definition and test of this parameter.

In typical positional systems, high servovalve threshold can cause static errors or limit cycle oscillations. In both cases it is only threshold in the flow null region of the servovalve that is significant. Therefore, threshold specifications are considered to apply particularly to this region of servovalve operation. If desired, specifications can require threshold measurements at additional points, usually one on either side of null. It should be recognized that additional test points are more a check on servovalve quality than performance measurements which can be related directly to system operation.

5.2.3.2.2.6 Pressure Gain (3.2.2.6)

Pressure gain is a parameter that must be considered when determining the accuracy of a servovalve and actuator combination. Positional accuracy and static stiffness of the combination (amount of output deflection per unit of external load) are performance characteristics which relate to the servovalve pressure gain.

Pressure output of the servovalve is nonlinear with respect to input signal and saturation usually occurs at a small per cent of rated current. Therefore, this parameter is defined over a limited range about null, usually $\pm$ 40% of maximum load pressure drop. For a conventional four-way servovalve, maximum load pressure drop is equal to supply minus return pressure.

Pressure gain will normally exceed 20% of maximum load pressure drop for a change in signal input of 1% rated current.

5.2.3.2.2.7 Flow Limit (3.2.2.7)

Flow limit when specified is stated as a maximum flow which will not be exceeded for any servovalve input. Load pressure drop must be defined and is usually specified as zero. Flow limit is specified only when the application requires control of this parameter.

5.2.3.2.2.8 Control Flow versus Load Pressure Drop (3.2.2.8)

This characteristic is usually not included in servovalve specifications. When it is specified, it is generally not required as part of production acceptance tests since this characteristic is established by servovalve design and is not subject to change by parts tolerance variation. Moreover, the generation of a family of load-flow curves for each unit is generally impractical from an economic point of view.

This characteristic of servovalves can be utilized to relate a loaded-flow system requirement to the corresponding no-load flow specification. The no-load characteristics are preferable for specification parameters to facilitate servovalve testing. Correlation of loaded to unloaded flow is then established by special tests on a typical unit.

The specification can define the effect of varying load pressure on control flow for various constant input currents. Most servovalves present a constant orifice opening under these conditions so that increasing load pressure drop decreases the control flow by the square root relationship. For servovalves of this type, the specification can define a maximum deviation from the square root curve extending from no-load flow to zero flow (for varying load pressure drop) at a constant input current.

5.2.3.2.3 Null (3.2.3)

5.2.3.2.3.1 Lap (3.2.3.1)

Lap tolerances are independent of rated flow gain tolerances and establish the null pressure and the effective servovalve gain in the null region. When a nominal zero lap condition is specified, the tolerance extends toward underlap and overlap in equal amounts.

Normally, servovalves are considered to be closed center, minimum overlap flow control valves. If significant departure from the zero lap case is intended, then unusual specification methods not included in this document would be required. However, it is possible to modify servovalve performance by small changes in lap conditions. These changes usually amount to tolerance relocation and have the following general effects on servovalve performance.

Underlap is usually specified by allowing the lap tolerance to extend between zero lap and some maximum underlap. Flow gain will vary between 100% and 200% of nominal flow gain in the null region. Pressure gain is normally higher and tendencies to silt are less than for the overlap condition. Internal leakage of the servovalve at null increases as the underlap increases. Therefore, wear due to erosion of metering edges could be greater for the underlap case, and with mildly contaminated systems the internal leakage could increase more rapidly with time.

Overlap is usually specified by allowing the lap tolerance to extend between zero lap and some maximum overlap. Flow gain through the null region will be less than nominal gain, but will not go to zero due to clearance between the sliding member and its mating metering edge. Pressure gain will generally be lower and silting tendencies will be greater. Servovalve leakage at null will be low; effects of erosion wear will be less.

The total tolerance spread should be the same regardless of which lap condition is desired and is expressed in per cent of rated current. This value will be the allowable variation at zero flow of the extrapolated normal flow curve defining lap. The normal tolerances for lap are as follows:

Nominal zero lap	-	2.5% overlap to 2.5% underlap
Nominal underlap	-	0% overlap to 5% underlap
Nominal overlap	-	5% overlap to 0% underlap

5.2.3.2.3.2 Null Bias (3.2.3.2)

Many servovalve designs are available which have no external null adjustments. The servovalve null on these designs is set by the manufacturer and the maximum acceptable null bias should be specified. This parameter is usually set to within 2% of rated current under rated test conditions.

During the life of the servovalve, the null bias at rated test conditions may change from its original setting. This is usually attributed to a continuing stress relief of the critical assemblies in the servovalve and may be accelerated by the application of certain environments. As an example, a change in null bias at rated test conditions may occur as a result of the application of extreme temperature.

The long-term change in null bias is usually less than 3% of rated current from its original setting. Because of the practical problem of separating the effects of initial setting and subsequent change, the specification normally requires a null bias of 5% of rated current over the useful life of the servovalve. This parameter then includes the tolerance of initial setting and long-term variations.

5.2.3.2.3.3 Null Shift (3.2.3.3)

Null bias may change with the application of environments. Supply pressure, return pressure, and hydraulic oil temperature are three common variable environments and maximum allowable null shift for these environments is usually specified as a percent of rated current. When this parameter is specified, it should be defined as a maximum absolute value not to be exceeded throughout the required variation of the environment. Null shift may be specified for other environments if they are determined to be critical to system performance.

5.2.3.2.4 Dynamic (3.2.4)

5.2.3.2.4.1 Amplitude Ratio (3.2.4.1)

The dynamic transfer function of servovalves can generally be approximated by a second-order differential equation. However, since mathematical representation is approximate, the preferred method of specifying amplitude ratio is by defining graphical limits on a Bode plot. Usually, maximum and minimum limits are plotted through the frequency range of interest.

Servovalve frequency response will vary with fluid temperature, supply and return pressures, and input current amplitude. Therefore, predictions of servovalve response at extremes of these operating conditions are generally unreliable and should be measured on a prototype model if performance requirements are critical. Continuity of production is usually controlled by test at one particular set of operating conditions.

Servovalve dynamic response measured at large current amplitudes will saturate at higher frequencies due to limited output of the torque motor and intermediate stages. At low input current amplitude, servovalve threshold effects produce distorted waveforms. In either case, departure from sinusoidal waveforms can produce ambiguous and even meaningless response data. The recommended peak-to-peak amplitude of the input current for dynamic response testing is one-half the rated current (± 25% rated current).

Amplitude ratio is usually normalized to a reference frequency of 5 or 10 cps.

5.2.3.2.4.2 Phase Angle (3.2.4.2)

Phase angle should be specified on the same Bode plot as amplitude ratio. This parameter is usually specified as a curve of maximum allowable phase lags, in degrees, plotted through the frequency range of interest. The general comments and specification recommendations of the previous paragraph apply equally to phase angle definitions.

5.2.3.3 Environmental Requirements (3.3)

Standard servovalves for military applications are designed to meet certain specific environments and will perform their designed function fully in some and to a limited degree in others. It is important to be aware of the environments in which limited performance is to be expected and also the specific performance parameter most affected by a particular environment.

Some of the environments which are normally encountered by servovalves and the specific areas of performance which are affected are the following:

(1) Temperature - Servovalve performance, at various temperatures, will be greatly influenced by the viscosity of the fluid. As an example, only limited performance will be obtained below fluid temperatures of -20 F using MIL-H-5606 as the operating fluid. At -65 F fluid servovalve performance sufficient for system start capability should normally be expected. Servovalve pressure gain and null shift can be important at this temperature.

(2) Altitude - Normally, the only servovalve characteristics that are affected by altitude are insulation resistance and dielectric strength.

(3) Vibration, Acceleration and Shock - Normally, the only servovalve characteristics which are affected by these environments are null shift and structural integrity.

(4) Humidity, Salt Spray and Immersion - Normally, the only servovalve characteristics that are affected by these environments are insulation resistance, dielectric strength and integrity of protective finishes.

(5) Fluid Contamination - Dependent upon the degree of contamination, a servovalve may be expected to perform to specification for a limited period of time only. Care must be taken to be sure that the operating time desired and the contaminant level are compatible.

(6) Life - The performance of a servovalve is a function of many factors which, regardless of excellence of design, may reduce its life. These factors include extreme environments, fluid contamination and frequency and magnitude of electrical and pressure overloads. A servovalve is designed to perform many millions of cycles and should have a useful life exceeding 1000 hours. However, dependent upon the above factors, some degradation of performance is to be expected. In particular, high levels of fluid contamination will cause increases in internal leakage flow, increase nonlinearity through the null region, decrease pressure gain and will probably increase both hysteresis and threshold. The other factors mentioned will tend to cause similar changes in performance. It is, therefore, very important that proper consideration be given to any life test conducted in view of the probable differences between the actual operating conditions and those employed during life testing. Additionally, if severe operating conditions are imposed during an extensive life test, some allowance for degradation of performance must be made.

Servovalve performance is not normally affected by such environments as sunshine, sand and dust, rain and fungus. If exceptional environments, such as radiation or corrosive atmosphere, will be encountered in a particular application, then a special environmental requirement should be specified.

5.2.4 Quality Assurance Considerations (4.)

Quality assurance provisions are outlined to establish a means of test and inspection for a servovalve in order to assure that all critical design parameters of the valve have been met and are maintained. These tests may be required at either or both vendor and procuring agency facilities, or in combinations as specifically outlined in each test specification.

5.2.4.1 Quality Assurance General Requirements (4.1)

Information pertaining in general to test equipment, method of testing, or the inspection techniques may be outlined below to prevent redundant statements in the procedures. Where applicable, Government Control Documents should be included.

5.2.4.1.1 Classification of Tests (4.1.1)

The types of tests that are necessary to establish and maintain control on the servovalve design are generally described as:

Qualification Tests
Acceptance Tests
Reliability Tests

5.2.4.1.2 Calibration of Instrumentation (4.1.2)

All measuring and testing equipment must be maintained in a calibrated condition to provide the standards which are necessary to define servovalve operating characteristics. Tolerances in test measurements should be accounted for in defining the operating limits; therefore, it is imperative that these tolerances be held to a minimum. The standard test equipment used by servovalve manufacturers is usually scaled to obtain maximum readability and accuracy. If special test equipment is required, the method and equipment tolerances required should be specified.

5.2.4.1.3 General Test Notes (4.1.3)

These notes should define all conditions, values, and procedures that will be standard throughout the majority of the tests. Items such as quiescent current, fluid type, filtration required, and ambient and fluid temperatures are described. Caution notes for cleaning test manifolds, bleeding air from the system, and avoiding back flushing of the servovalve may be detailed.

5.2.4.2 Qualification Tests (4.2)

Qualification tests may be conducted on a sample group of units selected at random out of the first production valves from the manufacturer. These tests are normally conducted by the manufacturer per test procedures which are approved by the buying agency. These tests are conducted to demonstrate compliance with design and performance requirements, particularly throughout extremes of environments.

The number of units subjected to a Qualification Test and the particular tests will depend on the final system requirements, previous experience with a particular valve model, and other test information and statistics available from the manufacturer.

The following are normally included in a servovalve qualification test program:

- Preparation of Test Unit
- Proof Pressure Test
- Acceptance Tests
- Extreme Temperature Tests
- Life Test
- Burst Pressure Test
- Altitude Test
- Vibration Test
- Shock Test
- Humidity Test
- Salt Spray Test
- Immersion Test
- Contamination Test

All information pertaining to the maintenance of parts, procedures and data for these tests should be described. Such items as approvals required for the test procedure, rework and retest instructions in case of a failure, identification of the test parts, and the type and number of copies of final data required should be outlined.

5.2.4.3 Acceptance Test (4.3)

Acceptance tests are conducted on each unit delivered by the manufacturer. These tests prove conformance to design limits as established by the design specification. Testing is generally conducted on standard test equipment at ambient room temperature with the hydraulic fluid at normal operating temperature.

The following parameters are normally included in an acceptance test procedure:

Examination of Product
Coil Resistance
Insulation Resistance and Dielectric Strength
Proof Pressure
Polarity
Flow Gain
Linearity
Symmetry
Pressure Gain
Internal Leakage
Null Bias
Threshold
Hysteresis
Dynamic Performance

5.2.4.4 Reliability Tests (4.4)

Reliability tests may be conducted on a periodic or a sampling basis throughout the production run to assure that the required level of reliability is maintained. Reliability tests may also be run to establish confidence in a new design or where a unit has unusual operating conditions or environment. Tests of this nature usually define life expectancy by imposing a given number of typical operating cycles with or without extreme environmental conditions.

5.2.5 Preparation for Delivery (5.)

This section should specify all delivery requirements. Standard items usually noted include container requirements, interior packaging, package markings, and wrapping. Requirements that are somewhat unique to servovalves such as flushing and use of preservative fluids should also be included in this section.

5.2.6 Notes (6.)

Miscellaneous ordering data are specified in this paragraph. If a definition of terms is included in the specification, it should be presented in the notes.

5.3 Sample Specification - Servovalve, Electrohydraulic Flow-Control

5.3.1 Scope - This specification defines the requirements for a two-stage four-way electrohydraulic flow-control servovalve. In application, the servovalve will be used in a closed loop hydraulic actuation system for the control of position of an aerodynamic surface. Physically, the servovalve will be mounted directly upon a linear hydraulic actuator.

5.3.2 Reference Specifications - The following documents of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein. In the event of conflict between this specification and any referenced specification, standard, drawing or publication, the requirements of this specification shall govern.

Specifications:

Military

MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification for
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft and Ordnance
MIL-P-6909	Plates, Information and Identification
MIL-H-8775	Hydraulic System Components, Aircraft, General Specification for
MIL-Q-9858	Quality Program Requirements
MIL-P-25732	Packing, Preformed, Petroleum, Hydraulic Fluid Resistant, 275 F
MIL-H-25475	Hydraulic Systems, Missile, Design, Installation, Test, General Specification for

Standards

Military

MIL-STD-129	Marking for Shipment and Storage
MS20995	Wire, Lock
MS28775	Packing, Preformed, Hydraulic, 275 F
MS3106	Connector, Plug, Electric, Straight
MS33540	Safety Wiring, General Practices for

DIMS & WEIGHT	SIZE IA & IB	SIZE II	SIZE III
A	1.640	3.120	3.23
B	1.800	2.54	2.54
C	1.640	2.520	2.520
WEIGHT	.47 LB	1.0 LB	1.3 LB

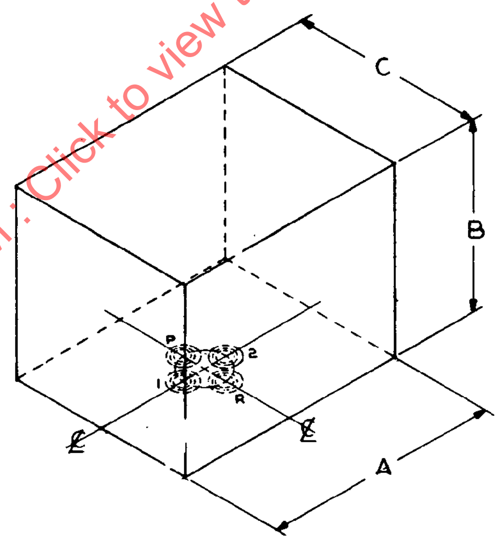
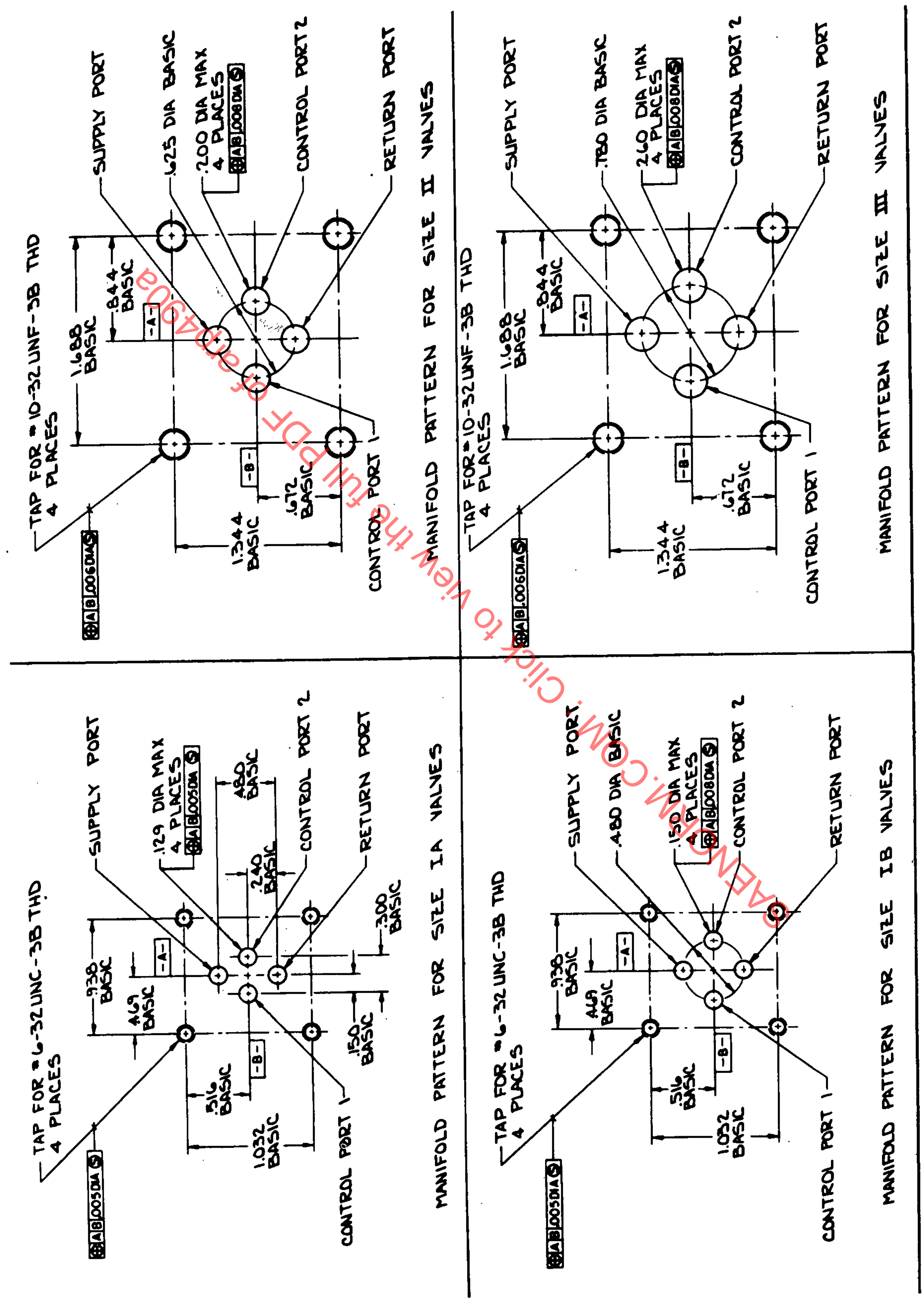


Figure 7



NOTES:
1. MANIFOLD SURFACE TO BE ⏥ .001 WITHIN ⅞ WITHIN PORT AREA.
SURFACE OF VALVE.

Figure 8

Drawings

XYZ Aircraft Corp.

0001 Servovalve, Electrohydraulic (rev. C)
Flow-Control, Specification Control

Other Publications

Air Force - Navy Aeronautical Bulletin

ANA Bulletin
No. 438 Age Control for Synthetic Rubber Parts

Society of Automotive Engineers, Aerospace Recommended Practices

ARP 490 Electrohydraulic Flow-Control Servovalves
ARP 598 Procedure for Determination of Particulate Contamination of Hydraulic Fluids by the Particle Count Method

National Aerospace Standard

NAS 1638 Cleanliness Requirements of Parts Used in Hydraulic Systems

5.3.3 Requirements (3.)

5.3.3.1 Design Requirements (3.1)

5.3.3.1.1 Mechanical (3.1.1)

5.3.3.1.1.1 Design Configuration (3.1.1.1)

5.3.3.1.1.1.1 Classification (3.1.1.1.1)

The servovalve shall be a two-stage, four-way electrohydraulic flow-control servovalve. It shall conform to the physical requirements of a size II servovalve, as defined in ARP 490 and the temperature requirements of a type II hydraulic system (-65 to +275 F) per MIL-H-8775.

5.3.3.1.1.1.2 External Null Adjustment (3.1.1.1.2)

The null shall be properly adjusted before delivery. If an external adjustment is used, it shall be sealed with an inspection stamp to permit detection of unauthorized adjustment.

5.3.3.1.1.1.3 Special Tools (3.1.1.1.3)

Installation and removal of the servovalve shall not require the use of special tools.

5.3.3.1.1.1.4 Internal Filtration (3.1.1.1.4)

The servovalve shall incorporate a first stage filter, if required to assure satisfactory performance with the system fluid.

5.3.3.1.1.2 Physical Description (3.1.1.2)

5.3.3.1.1.2.1 Envelope (3.1.1.2.1)

The servovalve envelope shall be held to a minimum, not exceeding that of specification control drawing 0001.

5.3.3.1.1.2.2 Mounting (3.1.1.2.2)

The servovalve shall be designed to mate with the manifold as specified on drawing 0001.

5.3.3.1.1.2.3 Electrical Connector (3.1.1.2.3)

The servovalve connector shall mate with a MS 3106-10SL-3S plug.

5.3.3.1.1.2.4 Weight (3.1.1.2.4)

The dry weight of the servovalve shall not exceed 1.0 lb.

5.3.3.1.1.3 Identification (3.1.1.3)

The servovalve shall include permanent identification showing:

Manufacturer's Name
Model Number
Serial Number

MIL-P-6906 may be used as a guide.

5.3.3.1.1.4 Materials (3.1.1.4)

All materials used in the manufacture of this servovalve shall be of suitable quality and type to assure compliance with the requirements of this specification.

5.3.3.1.1.5 Standard Parts (3.1.1.5)

Standard parts such as MS or AN should be used wherever they are suitable for the purpose.

5.3.3.1.1.6 Locking Devices (3.1.1.6)

All threaded parts shall be securely locked or safetied by safety wiring, self-locking nuts or other approved methods. Safety wire shall be applied in accordance with standard MS33540 and shall conform to MS20995.

5.3.3.1.1.7 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.

5.3.3.1.1.8 Seals (3.1.1.8)

All seals shall conform to MIL-P-25732 and MS28775, except where the use of nonstandard seal sizes is considered advantageous from a size and weight standpoint.

The servovalve shall be clearly marked with the date of assembly of the elastomers per ANA Bulletin No. 438.

5.3.3.1.2 Electrical (3.1.2)

5.3.3.1.2.1 Coil Connections (3.1.2.1)

The coil connection polarity and configuration shall be for differential operation as shown on specification control drawing 0001.

5.3.3.1.2.2 Rated Current (3.1.2.2)

The rated differential current is defined as the current, of either polarity, required to produce rated flow, and shall be 10 ma.

5.3.3.1.2.3 Quiescent Current (3.1.2.3)

The quiescent current shall be 6 to 10 ma per coil and shall be of the polarity shown on specification control drawing 0001.

5.3.3.1.2.4 Insulation Resistance and Dielectric Strength (3.1.2.4)

The insulation resistance between the coils and valve body shall be greater than 50 megohms following a 15 second application of 1000v dc. Testing shall be performed under room temperature and humidity conditions. This test shall not be applied more than 4 times during the life of a servovalve.

5.3.3.1.2.5 Coil Resistance (3.1.2.5)

The dc resistance of each coil shall be 1000 ± 100 ohms at 68 F. The resistance of the coil pairs shall be matched within 100 ohms.

5.3.3.1.3 Hydraulic (3.1.3)

5.3.3.1.3.1 Operating Pressures (3.1.3.1)

The system supply pressure shall be nominally 3000 psi. The actual supply pressure may vary between 2000 and 3100. Return pressure shall be less than 50 psi.

5.3.3.1.3.2 Proof Pressure (3.1.3.2)

The servovalve shall withstand without evidence of external leakage (other than slight wetting insufficient to form a drop) or permanent performance degradation, the following proof pressures: 1.5 times supply pressure applied for two minutes to ports P 1 and 2, with return open, followed by supply pressure applied simultaneously to all ports for two minutes. Proof pressure shall be applied at a maximum rise rate of 25,000 psi/min.

5.3.3.1.3.3 Burst Pressure (3.1.3.3)

The servovalve shall not rupture with burst pressures of 2.5 times supply pressure on ports P 1 and 2 (applied at room temperature and at a maximum rise rate of 25,000 psi/min), with return open, followed by 1.5 times supply pressure applied simultaneously to all ports. The servovalve shall not be required to operate after this test.

5.3.3.1.3.4 Fluid (3.1.3.4)

The working hydraulic fluid will be MIL-H-5606. System filtration will provide fluid meeting the following maximum contamination level (conforms to NAS 1638; Class 5):

Particle Size (Microns)	Count per 100 ml (per ARP 598)
5-15	8,000
15-25	1,425
25-50	253
50-100	45
over 100	8

5.3.3.1.3.5 External Leakage (3.1.3.5)

There shall be no evidence of external leakage, other than slight wetting insufficient to form a drop, throughout all operation and environmental ranges.

5.3.3.1.3.6 Internal Leakage (3.1.3.6)

The internal leakage of this servovalve, at rated test conditions, shall not exceed 0.20 gpm.

5.3.3.2 Performance Requirements (3.2)

5.3.3.2.1 Rated Test Conditions (3.2.1)

Unless otherwise specified, all servovalve performance requirements apply to a set of standard test conditions as defined below:

Fluid - As specified in paragraph (3.1.3.4)*
Operating Pressures - Supply pressure 3000 ± 50 psi
Return pressure 0 - 50 psi
Valve Pressure Drop - Nominally 3000 psi
Quiescent Current - 8 ma ± 0.1
Temperatures - Ambient 65 - 90 F
Fluid 90 - 120 F
Filtration - The fluid entering the servovalve shall conform to the maximum contamination level specified in paragraph (3.1.3.4)

5.3.3.2.2 Static Performance (3.2.2)

5.3.3.2.2.1 Rated Flow (3.2.2.1)

The rated flow shall be 3.0 gpm ± 10% at no-load conditions.

5.3.3.2.2.2 Linearity (3.2.2.2)

The linearity shall be a maximum of 7.5% of rated current.

5.3.3.2.2.3 Symmetry (3.2.2.3)

The control flow symmetry shall be a maximum of 10%.

5.3.3.2.2.4 Hysteresis (3.2.2.4)

The maximum hysteresis shall be 5% of rated current.

5.3.3.2.2.5 Threshold (3.2.2.5)

The maximum threshold shall be 1% of rated current.

5.3.3.2.2.6 Pressure Gain

The minimum load pressure gain shall be 30% of maximum load pressure drop for a change of signal input of 1% rated current.

*Paragraph references apply to the recommended sample specification number shown in parentheses in the righthand margin.