" INSPECTION AND APPROVAL OF HYDRAULIC DRIVE MACHINERY"

PREPARED FOR:

1987 MOVABLE BRIDGE SYMPOSIUM

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The expanded use of Industrial Hydraulics for movable bridge drive machinery has prompted a need for new bridge inspection techniques. Proper administration of this equipment has three standard phases that it must go through; initial shop drawing approval, construction inspection, and yearly performance inspection. Since the use of industrial hydraulic equipment is relatively new for bridges, all of these steps create new challenges for bridge engineers. This paper investigates the current state of different code requirements and how they apply to the inspection/approval process for hydraulic drive machinery.

ASSHTO code requirements have been a major influence in new drive machinery design. At this time, these requirements are under revision to better utilize current hydraulic technologies. Until this revision is completed there are proposed changes available from AASHTO which are acceptable for immediate use. Becoming familiar with AASHTO requirements is the first order of business.

Once you are familiar with AASHTO you will notice that several references are made to J.I.C. (Joint Industry Council), NFPA (National Fluid Power Association), ISO (International Standards Institute). This is not done with the expressed purpose of confusing the issue. Upon investigation you will find that most references are made to J.I.C. hydraulic standards. A copy of the current J.I.C. standards has been attached for your reference.

Understanding Fluid Power Graphical Symbols is an essential criteria for proper review. In the design and review stages detailed symbols are often used to show the intricacies of component function. These can sometimes be simplified for field inspection. A copy of the detailed and simplified symbols has been attached for your reference.

Now that you have the basic understanding of the necessary design requirements the inspection review process may begin. The proper documentation is always important. In order to do a proper job at any level you must first have a few recommended documents.

A.) Complete Hydraulic Schematic
B.) Power Unit Layout Drawing
C.) Cross Referenced Bill of Materials
D.) Piping Layout
E.) Catalog Cut Information
F.) Theory of Operation

Checking to make sure that a system will meet specific requirements is different for shop drawing review than it is for field inspection. At the time of shop drawing review the engineer must evaluate each component for pressure rating, flow rating, pressure drop, and a host of other criteria. Most importantly, will the components all work together as a smooth system. Not all hydraulic components function the same between different manufacturers.

Field inspection requires much more than just checking components for model number compliance, the engineer should check actual flows, pressures, and schematic compliance. Moreover, a working knowledge of piping practices and materials is in order.

Yearly inspection is yet another set of criteria for the inspection engineer. Due to the fact that few hydraulic drive machinery standards exist, the engineer must decide what is important to inspect. When no inspection criteria is given for a particular bridge, the field inspector should meet with the designer of the bridge to better understand what to look for. Once this has been established, it becomes a matter of simple inspection practices. Comparative analysis from one inspection to another should provide adequate information to identify any major problems.

This outline is provided as a guidelines for the symposium session. Please refer to the detailed minutes of the session for particular details on subjects of interest.

J I C
JOINT INDUSTRIAL COUNCIL
HYDRAULIC STANDARDS
for Industrial Equipment
and General Purpose Machine Tools
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FOREWORD

Users and suppliers of industrial equipment, as well as the component manufacturers, have long recognized that the safety of personnel and uninterrupted production are of cardinal importance to the economic growth of industry. The application of hydraulic mobility and control in a reliably proven manner necessitated the establishment of a standard more than 20 years ago. This is the latest revision of that standard.

This revision has been written as a General Purpose Hydraulic Standard and has been extended, where noted, to Mass Production Equipment as well as to the type of engineering considered desirable. This Standard is basic in nature; that is, it does not contain any requirements specific to any one industry, company, division, or plant.

All JIC Standards are advisory only. Their use in industry or trade is entirely voluntary.

The JIC assumes no liability for any patent infringements or asserted patent infringement which may result from the use of this standard.

Comments or requests for information regarding JIC activities or interpretation of the JIC Standards should be addressed to the Secretary of the Joint Industrial Council, 7901 Westpark Drive, McLean, VA 22101.

Proposals to change this JIC Hydraulic Standard are considered in the Joint Industrial Council meetings held at intervals for this purpose. Future revisions will include application requirements for those fields that become so closely associated with the hydraulic science as to be deemed a part thereof. No additions, revisions, or deletions shall be made hereto when reproduced as the JIC Hydraulic Standard for Industrial Equipment.

H1 General

H1.1 PURPOSE. The purpose of this Standard is to provide basic guidance for the application of hydraulic apparatus to industrial equipment to promote:

(1) Safety to personnel.
(2) Uninterrupted production.
(3) Long life of equipment.
(4) Ease and low cost of maintenance.

This Standard is intended as a reference and guide for detailed specifications and designs for industrial equipment utilizing hydraulic components or equipment. It is not intended to limit or inhibit advancement in hydraulic or mechanical engineering.

H1.2 SCOPE. This Standard applies to all hydraulic applications on industrial equipment. The term industrial equipment, referred to in this Joint Industrial Council (JIC) Hydraulic Standard, is any equipment hydraulically actuated or controlled, used in, or necessary for manufacturing processes and assembly.

H1.3 ADOPTED DOCUMENTS. To avoid duplication of effort and conflict in direction, Standards developed by other technical organizations have been adopted by reference as part of this JIC Standard. See Appendix D (page 26) for a bibliography of these Standards and their source of supply.

H1.4 DUAL PURPOSE STANDARD. This revision of the JIC Hydraulic Standard for Industrial Equipment is a dual purpose Standard. It is written as a General Purpose Standard and extended, where noted, to Mass Production Equipment.

■ Indicates a specific requirement for JIC Mass Production Equipment only.

Mass Production Equipment is single and/or special purpose equipment for continuous manufacturing processing and assembly.

H1.5 SPECIFIC REQUIREMENT VERSION. Where the purchaser specifies conformance to this JIC Standard and fails to specify either the General Purpose or the Mass Production version, the General Purpose Hydraulic Standard shall be deemed acceptable.

H1.6 TYPE OF REQUIREMENTS. Mandatory requirements of this Standard are distinguished by use of the word "shall."

Recommendations in this Standard are distinguished by use of the word "should."

▲ Indicates type of engineering desirable in new developments and reengineering of equipment.

H1.7 DEVIATIONS. Deviation from this Standard shall be agreed to in writing by the purchaser and supplier. Deviation(s) by the purchaser shall be specified on his purchase inquiry, or on the Hydraulic Equipment Data Form, and be confirmed on the supplier's quotation. Deviation(s) by the supplier shall be listed as "JIC Deviation by **(firm name)**" on supplier's quotation, and be confirmed on the purchase order. Deviation(s) shall pertain to specific paragraphs of this Standard, shall apply to the order in question and not to future orders, and shall not be considered as permanent amendments to this Standard.

H1.8 DEFINITIONS. Definitions of the terms used in this Standard are those given in the ANS B93.2-1965, Glossary of Terms for Fluid Power.

■ **H1.9 DATA FORM**

■ **H1.9.1 Data Form Use.** A sample Hydraulic Equipment Data Form is provided in Appendix E (pages 31, 32). This Data Form or a similar document should be used by the purchaser to provide the supplier with information required for the proper and specific hydraulic application to mass production industrial equipment. Where a Data Form or similar document is used by the purchaser, it shall be confirmed on the supplier's quotation.

■ **H1.9.2 Data Form Content.** The purchaser of mass production equipment should clearly indicate on this Data Form or similar document:

(1) To which version of this Standard, supplement(s), and/or other standard(s), if any, he requires conformance.
(2) Unusual operating conditions, environmental conditions not otherwise provided for, and required deviation(s) from this Standard as special requirements.
(3) Unique and other special requirements not covered in part (2) of this paragraph.
(4) Reference to applicable state and local codes.
(5) His equipment preference and the order of preference.

■ **H1.9.3 Omitted Information.** Where the purchaser of mass production equipment does not indicate on the Data Form or similar document:

(1) Conformance to any particular standard, the supplier's standard shall be acceptable.
(2) His equipment preference, the supplier's choice of equipment shall be acceptable.
(3) The order of equipment preference, the supplier's choice from the purchaser's preferred equipment list shall be acceptable.

■ **H1.9.4 Data Form Revision.** Where a Hydraulic Equipment Data Form or similar document is used and later agreements between the purchaser and supplier negate data in the existing data document, the purchaser shall issue a corrected Hydraulic Equipment Data Form or similar data document, marked revised and the revision dated. The revised Data Form or similar document shall be confirmed by the supplier.

H1.10 DRAWINGS

H1.10.1 Graphical Diagram. ANS Y32.10-1967, Graphic Symbols for Fluid Power Diagrams, shall be used for graphical (circuit) diagrams and to indicate component function. In final graphical diagrams, full symbols, not a simplified form, shall be used for multiple flow path directional valves. Information conveyed on the arrangement of the graphical diagrams shall be in accordance with ANS Y14.17-1966, Drafting Standards for Fluid Power Diagrams, and shall include the following:

(1) Identification of all hydraulic equipment by name, catalog number, serial or design number, and the manufacturer's name.
(2) Size of piping lines (outside diameter and wall thickness of tubing; size and schedule of pipe).
(3) Diameter of each cylinder piston and rod, length of stroke, and the estimated force required for the intended service.
(4) The displacement per rpm or minute and the torque rating of each hydraulic motor.
(5) The delivery in gpm and the direction rotation of each pump.
(6) The horsepower, rpm, and type of each pump drive.
(7) Operating pressure for the intended service and maximum pump-rated pressure.
(8) Quantity, capacity, and type strainers and filters.
(9) Reservoir capacity.
(10) Recommended fluid type and viscosity range.
(11) Time sequence chart, e.g., time range of cycle exclusive of loading.
(12) Data or text, or both, showing operations performed including the function(s) of the related electrical and mechanical controls and actuating equipment. Ref. Appendix A (page 27).

H1.10.2 Floor Layout. Where the installation consists of two or more separated equipment assemblies, the supplier shall provide the purchaser with a flor plan layout specifying dimensional relationships.

H1.10.3 Piping Layout. Where requested on the purchaser's inquiry and confirmed on the supplier's quotation, a piping layout shall be furnished by the supplier. Photographs which clearly show the piping arrangement and assembly may be substituted by agreement. (Ref. H.11.2)

H1.11 DATA TO SUPPLIER

H1.11.1 Scope of Data to Supplier. The purchaser shall specify on his inquiry, and the supplier shall confirm on his quotation, all the information necessary for proper application and uninterrupted production. Such information shall include:

(1) Any unusual operating conditions.
(2) Special requirements and unusual environmental conditions.
(3) Required deviations from this Standard.
(4) Reference to applicable state and local codes.

H1.11.2 Altitude. Altitude of installations above 3300 feet (1 kilometer) shall be specified on the purchaser's inquiry or on the Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

H1.11.3 Ambient Temperature. The ambient temperature range of the installation area shall be specified on the purchaser's inquiry or the Hydraulic Equipment Data Form, and shall be confirmed on the supplier's quotation.

H1.12 DATA TO PURCHASER

H1.12.1 Preliminary Data. The supplier shall submit for approval preliminary data in a form that is in accordance with ANS Y32.10-1967, Graphic Symbols for Fluid Power Diagrams, and ANS Y14.17-1966, Drafting Standards for Fluid Power Diagrams.

H1.12.2 Final Data. Final diagrams, drawings, and texts, including the maintenance data, shall conform to the equipment shipped and be forwarded to the purchaser not later than the time of equipment delivery. Final graphical (circuit) diagram(s) shall clearly show all fluid conductors within circuit manifolds accommodating two or more manifold mounted components. Where requested on the purchase order or the Hydraulic Equipment Data Form, final diagrams and drawings shall be on reproducible material.

H1.12.3 Field Changes. Where field changes are made by the supplier, the changes shall be recorded by the supplier and copies, or reproducible copies of the corrected drawings, shall be provided to the purchaser in accordance with the agreement between the purchaser and supplier, or where requested by the purchaser, on the Hydraulic Equipment Data Form or similar document.

Where the drawings bear the purchaser's title block, and are in the purchaser's possession, the supplier shall clearly report all field changes to the purchaser in writing. The purchaser shall be responsible for recording such reported changes on the drawing.

H1.12.4 Maintenance Data. The supplier shall provide the purchaser with maintenance data for all hydraulic equipment that clearly:

(1) Describes start-up and shut-down procedures where improper procedures could cause damage to the equipment.
(2) Describes adjustment procedures.
(3) Indicates external lubrication points and the type of lubricant required.
(4) Identifies seals and packings by the component manufacturer's part number.
(6) States service procedures for unique assemblies.
(7) Locates fluid level indicators, fill points, drains, filters, strainers, magnets, etc., that require regularly scheduled maintenance.

(8) Lists the serial number of each special cylinder or ▲ rotary actuator. This information should also appear on the graphical (circuit) diagram.

▲ Where parts in the hydraulic components are commercially available and manufactured to an established standard *that provides for uniform coding, further* identification as provided by the standard's code should be given.

▲ **H1.13 PROCUREMENT OF EQUIPMENT.** The supplier should procure components which use commercially available parts (key and keyways, bearings, packings, seals, lock rings, plugs, etc.) and part configuration (shaft and spline sizes, port sizes, mountings, interface patterns, etc.) that are manufactured to established standards and that provide for uniform coding.

■ *For mass production equipment,* approval shall be obtained by the supplier before components are procured. After approval by the purchaser, deviation(s) by the supplier shall have the purchaser's approval in writing.

H1.14 SAFETY (Ref. H13)

H1.14.1 Fail-Safe Concept. Hydraulic circuits shall be designed and components selected, applied, mounted, and adjusted to safely provide uninterrupted operation and extended life, and be fail safe. Circuits shall:

(1) Operate within *the component manufacturer's specifications.*
(2) Be protected against overpressure.
(3) Be so designed and applied that surge pressure, overpressure, and loss of pressure do not cause hazard or damage to the equipment. (Ref. H13.1)

▲ **H1.14.2 Service with Safety.** Hydraulic components attached to the industrial equipment shall be so located that they can be safely serviced.

H1.14.3 Inclined Ladders. Where personnel are required to carry heavy or bulky equipment to perform regularly scheduled maintenance on elevated hydraulic equipment at a level or 6 or more feet (1.83 meters) above the working floor, an inclined ladder or other suitable inclined means of access should be used. (Ref. H13.12)

H1.14.4 Elevated Platform. Where elevated walkways and platforms are required for access and servicing hydraulic equipment, they shall comply with ANS A12.1-1967, Safety Requirements for Floor and Wall Openings, Railings, and Toe Boards. (Ref. H13.13)

H1.15 ACCESSIBILITY. Hydraulic equipment and piping shall be accessible and so mounted as not to interfere with the adjustment of maintenance of the equipment.

H1.16 IDENTIFICATION

H1.16.1 Manufacturer's Information Plates. The following information shall be permanently indicated on each hydraulic component:

(1) The manufacturer's name and address.
(2) The manufacturer's part or *model designation and* data necessary to facilitate servicing.
(3) Where applicable, other data required by this Standard. (Ref. H2.2.3, H7.7.3, H9.5, H9.6)

H1.16.2 Component Identification. Hydraulic components *shall be plainly and permanently identified* with the same identification assigned to them in the graphical diagram. The manufacturer's original information plate shall not be used for this purpose.

H1.16.3 Port Identification. Component ports, including *pilot* ports, shall be plainly and permanently identified and the same identification shown on the graphical digram. Where port identification is not provided on the component or differs from the manufacturer's original, the identification shall then be plainly and permanently shown on an attached tag.

H1.16.4 *Valve Operator Identification.* *Valve operators* shall be plainly and permanently identified with the same identification assigned them in the graphical diagram, including the operator function(s). Solenoid operators shall have the same identification in the graphical diagram and the installation as assigned them in the electrical diagram.

H1.16.5 Identification of Internal Devices. Cartridge type and other functional devices (orifice plugs and passages, shuttle valves, check valves, etc.) located within a manifold, mounting plate, pad, or fitting shall be identified adjacent to their access openings. Where access openings are located under a component or components, identification shall be adjacent to the component and as close to the access opening as practical, and the identification marked "Concealed."

H1.16.6 Location of Identification. *Component identification,* other than the manufacturer's original information plate, shall be shown on a tag or plate permanently mounted on the installation adjacent to, not on, the component, accessory, or device.

H1.16.7 Control Station Nameplates. *A nameplate* shall be provided for each control station component and shall be located where it can be easily read by the equipment operator. The nameplate information shall be pertinent and easily interpreted, providing positive identification of the control component and its function (Ref. H13.2)

H1.17 FLUIDS

H1.17.1 Compatibility of Fluids. Fluid(s) used shall be compatible with the hydraulic components and shall be in accordance with the recommendations of the component manufacturer(s).

H1.17.2 Type of Fluid. The supplier shall provide the purchaser with the fluid specifications, including type, as recommended by the pump manufacturer.

▲ **H1.17.3 Fire Hazard.** Where flame, heated surfaces, or other ignition sources adjacent to a hydraulic circuit could be a fire hazard, the hydraulic fluid should be sufficiently fire resistant to prevent fire or explosion in the event of a major failure. Shielding or other isolation means may be used to prevent the fluid from reaching the ignition source under predictable failure conditions.

H1.17.4 Fire-Resistant Fluids. Where fire-resistant fluid(s) is (are) required, the type(s) shall be specified on the purchaser's inquiry or Hydraulic Equipment Data Form, and be confirmed on *the supplier's* quotation.

▲ **H1.17.5 Separated Fluid Systems.** Hydraulic and lubrication systems should be separated. Fluid from the hydraulic system should not be used to *lubricate ways, slides, exposed surfaces, and/or mechanisms* not integral with hydraulic components. Where separation is impractical, the following conditions shall exist:

(1) Unit Pressure shall be compatible with the intended service.
(2) Adequate means shall be provided to remove contamination from the fluid.
(3) Both the hydraulic and lubrication systems shall be capable of performing their required functions with the common fluid specified.
(4) Complete hydraulic and lubrication information shall be stated on the graphical hydraulic diagram.

■ Hydraulic and lubrication systems on mass production equipment may be combined only where agreed to in writing by the purchaser.

H1.18 SYSTEM TEMPERATURES

H1.18.1 Heat Generation. *Hydraulic circuits shall be* designed and applied as to minimize generation of undesirable heat.

H1.18.2 Operating Temperatures. Under conditions of continuous operation, the pump inlet temperature of the fluid should be 100° F (38° C) to 120° F (49° C), but shall not exceed 130° F (55° C).

The pump inlet temperature of water-base fluids shall not exceed 120° F (49° C).

H1.18.3 Low Temperature Control. Where temperatures lower than 100° F (38° C) are required, the maximum allowable temperature shall be specified on the purchaser's inquiry or Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

H1.18.4 Differential Temperature Control. Where the application requires the equipment to operate within a specific range of differential temperatures, the minimum and maximum temperatures shall be specified on the graphical (circuit) diagram and the required controls agreed to in writing by the purchaser and the supplier.

H1.19 FINAL TESTS

H1.19.1 Noise Limit. Hydraulic systems on industrial equipment shall not raise the sound pressure level of the equipment, at the time of installation, above those specified by applicable codes and standards.

H1.19.2 Leakage. There shall be no external leakage from the hydraulic system at the time of purchaser's acceptance.

H1.19.3 *Performance Tests.* *The hydraulic system(s)* on industrial equipment shall be completely performance tested to determine conformance with this Standard and the purchaser's specifications.

H1.20 PREPARATION FOR SHIPMENT

H1.20.1 Identification of Piping. Where construction of the equipment requires shipping or moving in sections, *removed piping runs and their corresponding* terminal ports and/or connectors shall be identically identified.

H1.20.2 Packaging of Piping. Removed piping runs shall be packaged in a manner that protects them from damage and distortion and preserves their identification during moving and shipping.

H1.20.3 Sealing of Openings. Exposed openings in hydraulic equipment shall be sealed and male threads shall be sleeved during moving and shipping.

H2 Circuit Controls

H2.1 DEFINITION OF CONTROLS

H2.1.1 Manual Controls. Manual control is any control actuated by the operator. (Ref. ANS B93.2-1965, Glossary of Terms for Fluid Power)

H2.2 PROTECTION

H2.2.1 Overpressure Protection. Internal and/or external overpressure protection shall be provided on the discharge side of each pump, except centrifugal types, and ahead of any positive shutoff valve and/or flow restriction. Overpressure protection shall be adequate for the intended service.

H2.2.2 Tamper-Resistant Protection. Where a hazard *or damage may result if operating* pressures are exceeded, tamper-resistant (e.g., internal positive stop, nonadjustable, etc.) overpressure protection shall be provided.

H2.2.3 Safe Working Range of Adjustable Controls. Pressure and flow control components shall be constructed in a manner that prevents adjustment outside their safe working range. The manufacturer's information plate on pressure control components shall be marked to indicate their minimum and maximum pressure limits.

H2.2.4 Adjustment of Controls. Adjustments on flow control and pressure control components, *except where tamper-resistant, shall be accessible.*

H2.2.5 Securing Adjustable Component Settings. Provision shall be made for securing the individual settings of adjustable components. (Ref. H8.2)

H2.2.6 Locking of Adjustable Component Settings. Where requested on the purchaser's inquiry or the Hydraulic Equipment Data Form and confirmed on the supplier's quotation, means for locking the enclosure(s) or compartment(s) in which flow control and pressure control component are mounted, or for locking their individual settings, shall be provided. (Ref. H8.3)

H2.2.7 Loss of Working Pressure. Where loss of working pressure could cause a hazard, loss of accuracy or damage to the equipment, means shall be provided to prevent operation under this condition.

H2.2.8 *Control Media Failure.* *Hydraulic devices* controlled electrically, pneumatically, and/or hydraulically shall be selected and applied so that failure of the control media does not cause a hazard or damage to the equipment. (Ref. H13.7)

H2.2.9 Control of Multiple Devices. Where there is more than one automatically and/or manually controlled device on the industrial equipment and where failure of any of these devices could cause a hazard or damage to the equipment, protective interlocks shall be provided. Where practical, these interlocks should interrupt all operations, but not release any locating pin, index drive engagement, latch, or clamping device, provided such interruption does not cause hazard or damage to the equipment or work in process.

H2.2.10 *Pump* Stoppage Interlock. Where more than one pump is used in the industrial equipment application, interlocks shall be provided so that stoppage of one pump will not cause a hazard or damage *to the equipment.*

H2.2.11 Pump Sequence Interlock. Where the operation of a pump in improper sequence could cause a hazard, damage to the equipment, or to the work in process, interlocks *shall* be provided to ensure operation of the pumps in proper sequence.

H2.2.12 Pumps in Series. Where pumps other than centrifugal type are applied in series, pressure protection shall be provided to prevent any one pump being damaged from overloading.

H2.3 PUMPS IN PARALLEL. Where pumps are connected in parallel:

(1) Primarily for standby operation of mass production equipment, valving to isolate each pump assembly while the other(s) is (are) still in operation shall be provided.

(2) As a multiple installation on mass production equipment, valving to isolate each pump assembly while the other(s) is (are) still in operation should be provided.

(3) Are unidirectional, and externally connected, means *should be provided in the discharge line of each* pump assembly to prevent reverse flow of the fluid.

H2.4 MANUAL CONTROLS

H2.4.1 Control Station Nameplates. A nameplate shall be provided for each control station component in accordance with H1.1.7 of this Standard.

H2.4.2 Emergency Controls (Ref. H8.11.1, H8.11.2, H13.3)

H2.4.2.1 Emergency Stop and Return Control. All industrial equipment shall incorporate an emergency stop or return control.

H2.4.2.2 Emergency Stop and Return Control Features. Emergency stop and return controls:

(1) Shall be readily accessible from the operator's working position.
(2) *Shall not release any locating pin, index drive* engagement, latch, lock, or clamping device.
(3) Shall operate immediately.
(4) Shall be independent and unaffected by the adjustments of other controls or flow restrictions.
▲ (5) Should provide a blocking valve upstream in the supply line of the servo valve(s) for emergency stop.
(6) Shall not require energizing any control element.
(7) Shall not require operation of more than one manual control for all emergency functions.
(8) Shall not create an additional hazard.

H2.4.2.3 Duplicate Emergency Controls. Duplicate emergency controls shall be provided at each operator station.

H2.4.2.4 Cycle Restart. The equipment cycle may be manually restarted after an emergency operation, provided resumption does not create a hazard or cause damage to the equipment or to the work in process. Where restarting the cycle is not feasible, manual controls shall be provided for returning the actuators affected by the emergency stop to their cycle start or other preset position.

▲ **H2.4.3 Manual Control Levers.** Manually actuated levers should move in the same direction as the resulting motion of the related equipment element. (Ref. H13.6)

H2.4.4 Required Setup Controls. Where equipment is controlled automatically, manual controls shall be provided to independently position actuators for changeover and setup. (Ref. H8.11.10)

H2.4.5 Two-Hand Control. Where pinch points and other movement hazards are exposed to the operating personnel, two-hand manual controls shall be provided for each operator, which:

(1) Require maintained actuation of each control throughout the equipment cycle or until the point in the cycle is reached where the hazard ceases.
(2) Are so located and guarded that operation by means other than both hands is prevented.
(3) Are so designed that the equipment cannot be operated unless both manual controls at each control station are released between cycles. (Ref. H13.4)

H2.4.6 Location of Manual Controls. (Ref. H13.5) The location and mounting of manual controls shall:

(1) Place the controls within reach of the equipment operator from his normal working position(s).
(2) Not require the operator to reach past rotating or moving equipment elements or work in process to operate the controls.
(3) Not interfere with the equipment operator's required working movements.
(4) *Protect the controls from external damage.*
(5) Prevent inadvertent operation of the controls.
(6) Provide adequate protection where controls are in high temperature or corrosive atmospheres.
(7) Provide easy accessibility for maintenance.
(8) Not use hydraulic piping for support.

H2.5 AUTOMATIC CONTROLS

H2.5.1 Location of Automatic Controls. The location mounting of automatic controls:

(1) Shall be on a panel or circuit manifold adjacent to the related power unit, unless size, function, or piping method requires alternate location.
(2) Shall be a minimum of 24 inches (0.60 meter) or a maximum of 72 inches (1.83 meters) above the working floor, unless size, function, or piping method requires alternate location.
(3) Shall provide accessibility for adjustment and maintenance of the controls without interfering with adjacent equipment.
(4) Shall provide adequate protection of the controls where they are in high temperature or corrosive atmospheres.
(5) Shall provide adequate protection of the controls from malfunction and damage that could be caused by work in process, waste materials, contaminants, and stock moving.
▲ (6) Should not use hydraulic pipe for support. (Ref. H8.5)

■ **H2.5.2 Cycle Time.** On mass production equipment, load variations and changes in fluid temperature shall not cause variations in cycle time inconsistent with the required service, provided voltage, frequency, and manual operations do not change.

H2.5.3 Surge Pressures. Circuits shall be designed, constructed, and adjusted to minimize surge pressures. The hydraulic components shall withstand existing surge pressures. (Ref. H8.6, H11.3, H11.4, H13.1)

H2.5.4 Sequence Control

H2.5.4.1 Sequence by Position. Where a sequence *malfunction could cause a hazard or damage* to the equipment or to the work in process, sequencing shall be governed by mechanically actuated fluid power valves, limit switches, or other position-sensing devices.

H2.5.4.2 Sequencing by Pressure Sensing and by Time Lapse. Where a sequence malfunction cannot cause a hazard or damage to the equipment or to the work in process, sequencing from pressure sensing and/or time lapse measuring may be used.

H2.5.5 Uncontrolled Movement. The circuit shall be designed to prevent uncontrolled movement and improper sequencing of the hydraulic actuators during all phases of the equipment cycle, including pump idling, starting, and stopping. (Ref. H13.8)

H2.5.6 Feed Controls

H2.5.6.1 Constant Feed Rates. Circuits requiring constant feed rates shall maintain consistent flow rates for the service intended, independent of reverse force and intermittent loads, and should be independent of fluid temperature fluctuations.

▲ **H2.5.6.2 Minimum Feed Volume.** The minimum constant feed rate without feedback should provide not less than 6 cubic inches (98 cubic centimeters) per minute fluid flow through the governing flow control.

H2.5.6.3 Traverse to Feed Transition. In changing from rapid traverse to feed, the starting position of the fed rate shall be consistent and satisfactory for the intended service and shall be fail-safe.

■ On mass production equipment where the starting position of the feed rate is fixed, shifting from rapid traverse to feed shall be by direct cam operation of the selecting valve. The feed position of the selecting valve shall be maintained.

H2.5.6.4 Trip Devices. On general purpose equipment, feed and cycle limiting trip devices shall be adjustable.

■ Feed limiting and cycle limiting trip devices used on mass production equipment shall be so arranged that feed distance(s) can be set and secured. After feed distance(s) is (are) preset, the limiting trip device assembly shall be adjustable as an assembly.

▲ **H2.5.7 Positive-Position Stops.** Positive-position stops should be so designed that the dwell time is not affected when the positive-position stops are reset.

H2.6 CIRCUIT RELATIONSHIPS

H2.6.1 Multiple Actuators. Circuits on industrial equipment having two or more moving elements, heads, slides, actuators, and/or combinations thereof shall be designed to ensure operation in the proper sequence regardless of load variations.

▲ **H2.6.2 Flow Proportionment.** Proportionment of flows for supply purposes should be by nonadjustable or lockable components that maintain consistent flow rates or by continuous positive displacement, independent of reverse force and intermittent loads.

▲ **H2.6.3 Simultaneous Operation.** Where a common fluid source is used for simultaneous motion of two or more actuators, means should be provided for reasonable proportionment of the fluid to assure intended motion of each actuator.

H2.7 SERVO CONTROLLED CIRCUITS

H2.7.1 Servo Valve Location. The servo valve shall be mounted as close to the related actuator as practical to minimize the contained volume between the valve and the actuator. (Ref. H8.4.2)

H2.7.2 Servo Valve Access. Servo valves shall be readily removable without disturbing piping or other equipment elements.

▲ **H2.7.3 Electrohydraulic Servo Valve Features.** Electrical connections to electrically operated servo valves should utilize plug-in oil-tight connectors. (Ref. H8.9.2)

▲ **H2.7.4 Emergency Blocking Valve.** A blocking valve should be used upstream in the supply line to the servo valve(s) for emergency stop. (Ref. H2.4.2, H8.11.2, H13.3)

▲ **H2.7.5 Fluid Loss Prevention.** Means should be provided in both the supply and return lines of a servo valve to automatically prevent fluid draining from the valve, the related piping, and actuator when the system is off. (Ref. H8.11.3)

▲ **H2.7.6 Protection Against Inertia Loads.** Crossover overpressure protection should be used between a servo valve and its related actuator where high inertia loads are reflected to the actuator. (Ref. H8.11.4)

H2.7.7 Filter Type and Location. Full flow filtration shall be used in the supply line preceding a servo valve. (Ref. H7.5.1)

H2.7.8 Filter Rating. Filter and air breather ratings shall be compatible with the servo valve(s) used. (Ref. H7.5.2)

▲ **H2.7.9 Fluid Sampling.** A means of obtaining a representative fluid sample without disturbing piping should be provided to permit periodic measurement of the fluid cleanliness level. (Ref. H11.22.4)

H2.7.10 Flushing. Flushing valves or flushing plates shall be utilized during the initial start-up. Flushing of the system shall continue until the required cleanliness level is obtained before installation of the servo valves. This procedure should also be used whenever the hydraulic system is opened or the cleanliness level exceeds the recommended standard.

H2.8 ENCLOSURES AND COMPARTMENTS

H2.8.1 Definition of Compartment. A compartment is a space within the base, frame, or column of the equipment. (Ref. ANS B93.2-1965, Glossary of Terms for Fluid Power)

H2.8.2 Definition of Enclosure. An enclosure is a housing for components. (Ref. ANS B93.2-1965, Glossary of Terms for Fluid Power)

H2.8.3 Materials. Enclosures, enclosure doors, and compartment doors for housing automatic controls shall be sheet steel not thinner than 14 MSG (1.88 mm), or approved equivalent.

H2.8.4 Types of Doors. Enclosures or compartments shall have hinged doors that swing horizontally or shall have self-supporting sliding doors.

H2.8.5 Fasteners for Doors. Doors shall be held closed with mechanical fasteners of the captive type that requires hand tools to open or shall be provided with a key lock. (Ref. H2.2.6)

H2.8.6 Maintenance Access. The size of compartments and enclosures, and the arrangement of the control devices within, shall provide adequate room for maintenance.

H3 Cylinders

H3.1 CYLINDER SPECIFICATIONS. The mounting dimensions, rod sizes, and bore sizes of commercially available cylinders shall conform to ANS B93.8-1968, Bore and Rod Size Configuration and Combinations, and to ANS B93.3-1968, Cylinder Bore and Piston Rod Sizes for Fluid Power Cylinders.

■ Where a preference of cylinders exists for mass production equipment, the preference shall be specified on the purchaser's inquiry or the Hydraulic Equipment Data Form.

H3.2 CYLINDER ALIGNMENT. The alignment of rigidly mounted cylinders with dependent slides and other guided equipment elements shall apply no side or radial load to the piston rod or ram.

H3.3 NONRIGID MOUNTNIGS. Cylinders with nonrigid mounting(s) shall be applied in accordance with the manufacturer's specifications, including stroke length, loading, and use of stop tubes.

H3.4 CYLINDER SERVICING. The design of the actuated equipment shall:

(1) Provide accessibility for cylinder servicing.
(2) Permit replacement of continuous ring piston rod packings and seals in the cylinder.

H3.5 CYLINDER REPLACEMENT. Cylinders that are not an integral part of the equipment shall be replaceable.

H3.6 REQUIRED CUSHIONS. Where a cylinder head is used as a positive-position stop, the stop head shall incorporate an adjustable cushion or an external deceleration control shall be provided to minimize detrimental mechanical impact.

H3.7 CYLINDER SEAL AND SEALING DEVICE

H3.7.1 Seal Requirements. Cylinder seal requirements not specifically covered in the following paragraphs shall be in accordance with Section H12 of this Standard.

H3.7.2 Cylinder Seals. Seals that do not leak under working conditions within the intended service range:

(1) Shall be used for cylinder end sealing.
(2) Other than that required for lubrication, shall be used for piston rod sealing.

▲ **H3.7.3 Piston Rod Seal Replacement.** Piston rod seal assemblies should be replaceable without cylinder disassembly.

H3.7.4 Dual Piston Rod Seals. Cylinders with dual piston rod seals shall:

(1) Be specified on the purchaser's inquiry or the Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

(2) Have an external provision for draining the interseal fluid collection.

H3.7.5 Piston Rings. Where the sealing devices used on a cylinder piston:

(1) Are metallic, they shall be of the step-cut type or shall provide equivalent performance.

▲ (2) *Can tolerate no* leakage other than that required for lubrication, they should be an elastomeric type and material.

H3.8 PISTON RODS

H3.8.1. Piston Rod Size. The piston rod size, including its thread, shoulder, and column strengths, shall be adequate for the service intended.

H3.8.2 Piston and Rod Assembly. Pistons shall be positively locked to the piston rod.

H3.8.3 Piston Rod Hardness. Piston rod material and hardness shall be such as to minimize scoring.

▲ **H3.8.4 Protection of Piston Rods.** Piston rods should be adequately protected from damage by corrosion *and abrasion by detrimental materials.*

H3.9 AIR ENTRAPMENT

H3.9.1 Fluid Input Location. Flow of fluid into nonrotating cylinders should be at the extreme top of the bores to prevent entrapment of air.

H3.9.2 Purging of Air. Cylinders which may not utilize *their full stroke shall have provision for purging* entrapped air.

H3.9.3 Air Bleed Accessibility. External provisions for purging entrapped air from cylinders shall be accessible.

H4 Rotary Fluid Motors (continuous rotation)

H4.1 FLUID MOTOR DATA

H4.1.1 Motor Data. A data sheet, catalog, or listing that is in accordance with ANS Y14.17-1966, Drafting Standards for Fluid Power Diagrams, giving information on minimum and maximum rpm, pressure range, volumetric displacement, torque or horsepower output, and the viscosity range of each rotary fluid motor shall be provided.

H4.1.2 Duplicate Information. Where a rotary motor manufacturer's information plate is not readily visible, a plate with duplicate information shall be installed in a readily visible location as closely adjacent to the component as is practical.

The manufacturer's original information plate shall not be removed.

H4.1.3 Direction of Motor Rotation. Where reverse rotation of a unidirectional fluid motor application could cause a hazard or damage to the equipment, the direction of shaft rotation shall be clearly indicated on the motor or the driven assembly and be clearly visible, and the direction of fluid flow to the related motor ports shall be clearly indicated on the graphical diagram.

H4.2 FLUID MOTOR MOUNTINGS

H4.2.1 Accessibility of Rotary Motors. Rotary fluid motors, and assemblies that include rotary fluid motors, shall be readily accessible for servicing.

H4.2.2 Protection of Rotary Motors. Rotary fluid motors shall either be mounted where they are protected from damage or suitable guarding shall be provided.

H4.2.3 Rigid Mountings. The mounting of rotary fluid motors to or on their driven mechanism assemblies shall be sufficiently rigid so as to prevent misalignment due to work load, temperature variations, and/or maximum torque transmission.

H4.2.4 Direct-Coupled Fluid Motors. Direct-coupled rotary fluid motors shall be mounted to their driven mechanism assemblies in a manner that assures alignment.

H4.3 SHAFT COUPLINGS

H4.3.1 Power Transmission. Shaft couplings shall be adequate to transmit the rated torque of the rotary fluid motor, including any required braking operation.

H4.3.2 Flexible Couplings. Where flexible couplings are used with a rotary fluid motor, the couplings shall be readily accessible.

▫ On mass production equipment, flexible couplings used between shafts shall be of a type approved by the purchaser. The type of coupling(s) should be specified on the purchaser's inquiry or the Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

H4.4 INSTALLATION OF FLUID MOTORS

H4.4.1 RPM of Rotary Motors. The operating rpm or range of rpm of each rotary fluid motor application shall be within the minimum and maximum limits of the manufacturer's specifications for the intended service. The starting and stall torques, the effect of load variations, and the kinetic energy of the moving load *shall be considered in the application of rotary fluid* motors.

H4.4.2 Compatibility with the Fluid. Rotary fluid motors shall be compatible with the fluid used.

H4.4.3 Motor Drains. The size, location, termination, and configuration of the piping for required rotary fluid motor drains shall be in accordance with the component manufacturer's specifications and shall be piped separately without restriction to the reservoir or to a vented collecting manifold. (Ref. H11.12)

H4.4.4 Prefill of Motor Housings. Where the manufacturer's specifications require prefilling rotary fluid motor housings with fluid prior to start-up, a readily accessible means for prefilling shall be provided and shall be so located to assure no entrapment of air in the housing.

H5 Pumps

H5.1 PUMP DATA

H5.1.1 Information and Specifications. A data sheet, catalog, or listing that is in accordance with ANS Y14.17-1966, Drafting Standards for Fluid Power Diagrams, stating information on rpm, pressure range, volumetric output, horsepower requirements, and the fluid viscosity range shall be provided for hydraulic pumps.

H5.1.2 Duplicate Information. Where the pump manufacturer's information plate is not readily visible, a plate with duplicate information shall be installed in a readily visible location.

The manufacturer's original information plate shall not be removed from the pump.

H5.1.3 Direction of Rotation. The direction of rotation shall be clearly indicated on each pump and shall be readily visible.

H5.2 PUMP MOUNTINGS

H5.2.1 Pump Location. Pumps and subassemblies that include a pump shall:
(1) Be readily accessible for maintenance.
(2) Be mounted where they are protected from damage.
(3) Not be mounted inside of a reservoir.

H5.2.2 Rigid Mounting. The pump and drive motor mounting shall be sufficiently rigid to prevent misalignment due to work load, temperature variations, and/or rated torque transmission.

H5.2.3 Direct-Coupled Pumps. Direct-coupled pumps shall be securely mounted in a manner that assures alignment.

▲ **H5.3 PUMP AND DRIVE MOTOR TYPES.** On mass production equipment, standard single-end shaft, foot mounted electric motors, and hydraulic pumps should be used.

H5.4 COUPLINGS OF PUMPS TO DRIVE MOTORS

5.4.1 Power Transmission. Shaft couplings shall have adequate capacity to transmit the power required.

H5.4.2 Flexible Couplings. A flexible coupling shall be used between the pump and drive motor shafts.

■ On mass production equipment, flexible couplings of a type approved by the purchaser shall be used between the pump and drive motor shafts. The type of flexible coupling should be specified on the purchaser's inquiry or Hydraulic Equipment Data Form, and shall be confirmed on the supplier's quotation.

H5.4.3 Safety Guards. A detachable safety guard shall be fastened over exposed couplings and rotating shafts.

H5.5 INSTALLATION OF PUMPS

H5.5.1 RPM of Pumps. The pump operating rpm shall not exceed the manufacturer's specifications for the service intended.

■ On mass production equipment where the purchaser requires pump rpm other than that recommended by the manufacturer, the required rpm shall be specified on the purchaser's inquiry or Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

H5.5.2 Pump Inlet Piping. Pump inlet piping shall be in accordance with the pump manufacturer's specifications. (Ref. H11.6)

H5.5.3 Compatibility with the Fluid. Pumps shall be compatible with the fluid used.

H5.5.4 Pump Drains. The size, location, termination, and configuration of the piping for required pump drains shall be in accordance with the component manufacturer's specifications and shall be piped separately without restriction to the reservoir or vented collecting manifold. (Ref. H11.12)

H5.5.5 Prefill of Pump Housings. Where the manufacturer's specifications require prefilling pump housings with fluid prior to start-up, a readily accessible means of prefilling shall be provided and shall be so located to assure no entrapment of air in the housing.

H5.5.6 Pump Priming. Where the pump start-up discharges against a blocked passage, provision shall be made in the pump discharge line, ahead of the blocking component, for purging air from the pump chambers. Purging shall terminate automatically when the pump primes.

H6 Fluid Reservoirs

H6.1 LIMITATIONS OF THIS STANDARD. This Standard applies to integral and nonintegral reservoirs; it does not apply to sealed or pressurized reservoirs.

H6.2 NONINTEGRAL RESERVOIRS. Nonintegral fluid reservoirs shall be in accordance with NFPA standard T3.16.2, Nonintegral Industrial Fluid Power Hydraulic Reservoirs.

■ **H6.3 INTEGRAL RESERVOIRS.** Integral reservoirs on mass production equipment may be used only by specific agreement between the purchaser and the supplier and should be in accordance with NFPA standard T3.16.2, where practical.

H6.4 ELEVATED RESERVOIRS

■ **H6.4.1. Elevated Reservoir Filling.** Where the reservoir top for mass production equipment is elevated to a height of more than 4 feet (1.22 meters) above floor level, manual or automatic means for filling from the floor level shall be provided.

H6.4.2 Elevated Reservoir Fluid Level. Elevated reservoirs shall be equipped with a fluid level indicator that can be easily read from the working floor level.

H6.5 MULTIPLE RESERVOIRS. Adequate and effective means shall be provided to control the reservoir fluid levels where two or more separated reservoirs are used with a common hydraulic circuit.

H7 Filtration and Fluid Conditioning

H7.1 REMOVAL OF CONTAMINANTS. Filtration shall be provided to remove detrimental material from the hydraulic fluid. The degree of filtration shall be consistent with the service intended.

▲ **H7.2 FULL-FLOW FILTRATION.** Full-flow filtration should be used to ensure maximum fluid exposure to the filtering element.

H7.3 PROPORTIONAL FILTRATION. Where proportional filtration is used, the flow capacity shall be sufficient to filter all the hydraulic fluid in the circuit within a maximum period of four hours.

■ **H7.4 SPECIFIC TYPE OF FILTER.** Where a specific type of filter is required on mass production equipment, the type shall be specified on the purchaser's inquiry or the Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

H7.5 FILTRATION FOR SERVO CONTROLS

H7.5.1 Filter Type and Location. Full-flow filtration shall be used in the supply line preceding a servo valve. (Ref. H2.7.7)

H7.5.2 Filter Rating. The filter and breather rating shall be compatible with the servo valve(s) used. (Ref. H2.7.8)

H7.6 FILTER PRESSURES

H7.6.1 Pressure Drop. Provision shall be made for limiting the maximum pressure drop across the filter element to the manufacturer's specification.

H7.6.2 Housing Pressure. The filter housing pressure shall not exceed the manufacturer's specification.

H7.7 FILTER SERVICING

H7.7.1 Construction and Installation. The filter construction and the filter installation shall permit changing of the filter element without disturbing the piping. Filters shall be readily accessible for servicing.

▲ **H7.7.2 Condition Indicator.** A means should be provided to indicate when the filter needs servicing.

■ On mass production equipment, a means shall be provided to indicate when the filter needs servicing.

H7.7.3 Element Identification. The filter element identification number shall be permanently displayed on the filter housing. (Ref. H1.16.1)

■ **H7.7.4 Servicing Without Shutdown.** On mass production equipment, means shall be provided to change filter elements without stopping the equipment.

H7.8 SUCTION FILTERS (STRAINERS)

H7.8.1 Submerged Suction Filters. Suction filters (strainers) used below the fluid level shall be adequately sized to permit optimum service life.

▲ At the maximum flow required, the maximum pressure drop across a suction filter (strainer) installed below the fluid level should not be greater than ½ psi clean.

▲ At the maximum flow required using fire-resistant fluids, the maximum pressure drop across a suction filter (strainer) installed below the fluid level should not be greater than ¼ psi with the filter in the new and clean condition.

H7.8.2 Suction Filters Above the Fluid Level. Suction filters (strainers) used above the fluid level shall have flow capacities conforming to the recommendations or specifications of the pump manufacturer.

▲ **H7.8.3 Suction Filter Condition Indicator.** Where a suction filter (strainer) is used, means should be provided to indicate when the suction filter needs servicing.

H7.8.4 Servicing Without Draining Reservoir. Where a *suction filter is used below the fluid level, pro*vision shall be made for element removal and servicing without draining the reservoir.

▲ **H7.8.5 Servicing Without Shutdown.** Where suction ■ filters (strainers) are used on mass production equipment, means for servicing the filter element(s) without stopping the equipment should be provided.

H7.8.6 Self-Cleaning Suction Filters. Self-cleaning suction filters (strainers) shall be automatically actuated.

H7.9 MAGNETS

▲ **H7.9.1 Capacity of Magnets.** Magnets of sufficient quantity and strength to remove ferrous particles from the circulating reservoir fluid should be provided.

▲ **H7.9.2 Location of Magnets.** Where magnets are used, they should be located in the return side of the reservoir near a baffle opening.

H7.9.3 Servicing of Magnets. Magnet assembly installations shall be readily accessible and exclude *entry of contaminants during servicing.*

H8 Valving

▲ **H8.1 PRESSURE CHECKING PROVISIONS.** Pressure control valves should have provisions for gauge checking the governed pressure.

H8.2 SECURING ADJUSTABLE VALVE SETTINGS. Provision shall be made for securing the individual settings of adjustable valves. (Ref. H2.2.5)

■ **H8.3 LOCKING OF ADJUSTABLE VALVE SETTINGS.** Where requested on the purchaser's inquiry or the Hydraulic Equipment Data Form and confirmed on the supplier's quotation, means shall be provided for locking the enclosure(s) or compartment(s) in which flow control and pressure control valves are mounted, or for locking their individual settings. (Ref. H2.2.6)

H8.4 VALVE LOCATIONS

H8.4.1 Panel Mounting. Valves and other automatic controls shall be mounted on a panel or circuit manifold adjacent to the related power unit, unless the size, function, or piping method requires an alternate location. (Ref. H2.5.1)

H8.4.2 Servo Valve Location. Where a servo valve is used, it shall be mounted as close to the related actuator as practical so as to minimize the contained volume between the valve and the actuator. (Ref. H2.7-1)

H8.4.3 Valves Above Fluid Level. Valves shall be located above the high fluid of the reservoir except where proper functioning requires otherwise.

▲ **H8.5 VALVE SUPPORT.** Piping should not be used to support valves. (Ref. H2.5.1)

H8.6 DETRIMENTAL SURGES. The operation of valves shall not produce detrimental hydraulic surges. (Ref. H2.5.3, H11.3, H11.4, H13.1)

H8.7 EXTERNAL DRAINS. Where the application of a valve requires an external drain, the drain shall be piped to the reservoir or a vented collecting manifold. (Ref. H11.12.1)

H8.8 MANIFOLD MOUNTED VALVES

H8.8.1 Mounting Face Seals. Sealing devices that seal with pressure shall be used in the interface mounting of manifold valves.

▲ **H8.8.2 Valve Locating Pins.** Manifold mounted valves should have locating pins.

H8.8.3 Interface Hole Patterns. The interface pattern of manifold mounted valves shall conform to ANS B93.7-1968, Dimension for Mounting Surfaces of Sub-Plate Type Hydraulic Fluid Power Valves.

H8.9 ELECTRICALLY OPERATED VALVES

H8.9.1 Solenoid Valve Features. Solenoid valves shall have:

(1) Sealed solenoid enclosures that prevent entrance of contaminants.
(2) Adequate internal space to accommodate 6 inch (15.2 centimeter) taped leads of No. 14 AWG wire. (Ref. JIC EGP-1-1967 and EMP-1-1967)
(3) Ring type connectors on the wire leads. (Ref. JIC EGP-1-1967 and AMP-1-1967)
(4) Threaded electrical conduit connections (NPSM).
(5) Captive type fasteners to secure covers.
(6) Suitable means to prevent loss of covers.
(7) Manual overrides which can be operated without removing solenoid covers or enclosures, but which cannot be operated accidentally.
(8) Suitable means to prevent electrical operation of the valve when a solenoid cover or enclosure is removed.

▲ **H8.9.2 Electrohydraulic Servo Valve Features.** Electrical connections to electrically operated servo valves should utilize plug-in oil-tight connectors. (Ref. H2.7.3)

H8.9.3 Destructive Hammering. Solenoid and hydraulically operated valves shall be selected and installed to eliminate destructive hammering of the solenoids and spools.

H8.10 VALVE SERVICING

H8.10.1 Accessibility. Valves shall be accessible for adjustment and servicing.

▲ **H8.10.2 Valve Replacement.** Manifold mounted valves should be used to permit removal and replacement without disturbing the fluid lines.

H8.11 VALVE APPLICATION

- **H8.1.1 Emergency Functions.** Valves used for emergency functions shall operate immediately and shall not require energizing any control element. (Ref. H2.4.2.2)

▲ **H8.11.2 Emergency Blocking Valve.** A blocking valve should be used upstream in the supply line to the servo valve for emergency stop. (Ref. H2.4.2 2. H2.7.4, H13.3)

▲ **H8.11.3 Fluid Loss Prevention.** Means should be provided in both the supply and return lines of a servo valve to automatically prevent fluid draining from the valve, the related piping, and actuator when the system is off. (Ref. H2.7.5)

▲ **H8.11.4 Protection Against Inertia Loads.** Crossover overpressure protection should be used between a servo valve and its related actuator where high inertia loads are reflected to the actuator. (Ref. H2.7.6)

H8.11.5 Gravitational Effect. The effect of gravity on the main elements of a valve shall be considered in mounting any valve to assure fail-safe conditions.

H8.11.6 Counterbalancing. On vertical and inclined equipment slides, rams, and other similar equipment elements, means shall be provided to prevent their rapid drop. This is a requirement in the absence of counterweighting, not a substitute for, or an addition to, counterweighting. (Ref. H13.9)

H8.11.7 Multiple Flow Path Valves

▲ **H8.11.7.1 Spool-Type Valves.** Spool-type valves with multiple flow paths should be mounted with the main spool of the valve in a horizontal plane to prevent uncontrolled movement and hazard.

H8.11.7.2 Spring Returned Valves. Where the mounting position of a spring returned valve with multiple flow paths places the main element of the valve in a vertical plane, the spring force applied on the main element should be in a downward direction. Circuits shall use this returned position of a spring returned multiple flow path valve as the fail-safe condition.

H8.11.8 Detented Valves. Two-position, no-spring, spool-type valves shall have their spool position mechanically maintained by detents or equivalent means.

H8.11.9 Required Two-Position Valves. Two-position; no-spring valves shall be used for operating locating pins, index engagement or clamping mechanisms, or any actuators requiring the maintenance of their position during start-up, stopping, or in the event of elcetrical failure. (Ref. H8.11.8)

H8.11.10 Independent Control of Actuators. Where actuators are automatically controlled, manual controls shall be provided to independently position actuators to the preset timing or start cycle locations and to changeover and setup locations. (Ref. H2.4.4)

H9 Accumulators

H9.1 ACCUMULATOR CONSTRUCTION. The accumulator shall be constructed to conform to ASME Revision 1 Section 8, Code for Unfired Pressure Vessels.

H9.2 RELIEVING FOR DISASSEMBLY. Means shall be provided for safely relieving accumulator gas and liquid pressure prior to accumulator disassembly.

H9.3 AIR BLEEDING. Circuits that include accumulators shall be so arranged that all the air can be bled from the hydraulic circuit.

H9.4 ACCUMULATOR SAFETY (Ref. H13.10)

H9.4.1 Automatic Vent. Hydraulic circuits incorporating accumulators shall automatically vent the accumulator liquid pressure or shall positively isolate the accumulator when the equipment is shut off. Isolation shall prevent uncontrolled movement of the actuators in case manual overrides on associated equipment are operated.

H9.4.2 Pressure Isolation. Where deviation is agreed to or a circuit application utilizes accumulator liquid pressure isolation only (not vented) when equipment is shut off, complete information for proper servicing shall be given on or near the accumulator in a visible location. The information shall include the statement "CAUTION — PRESSURIZED VESSEL." Duplicate information shall be provided on the graphical diagram.

H9.4.3. Discharge Rate. Accumulator discharge rates shall be restricted to the demands of the intended service.

H9.4.4 Charging Medium. Gas accumulators shall be charged with nitrogen or an inert gas.

H9.5 ACCUMULATOR IDENTIFICATION PLATES. The following information shall be permanently indicated on the identification plate of each hydraulic accumulator.

(1) Manufacturer's name and address.
(2) Manufacturer's model number.
(3) Manufacturer's serial number, if any.
(4) Rated Maximum working pressure.
(5) Fluid capacity.
(6) Charging medium.
(7) Precharge pressure.
(8) CAUTION — PRESSURIZED VESSEL.

H9.6 IDENTIFICATION OF CHARGING MEDIUM. The charging medium and precharge pressure shall be inscribed on the accumulator nameplate by the supplier at time of installation. (Ref. H9.5 6, 7).

H9.7 ACCUMULATOR SERVICING. Accumulators shall be readily accessible for removal and servicing.

H10 Heat Exchangers

H10.1 APPLICATION. The use and application of heat exchangers shall be subject to approval by the purchaser.

H10.2 UNUSUAL TEMPERATURE. Any unusual temperature that affects the equipment operation shall be specified on purchaser's inquiry or Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation. The supplier should include the ambient temperature effect in determining the necessity for (and sizing of) heat exchangers.

H10.5 USE OF THERMAL CONTROLS. Where the use of heat exchangers is approved, automatic thermal controls shall be used as required to maintain the operating temperature range of the hydraulic fluid.

H10.6 DIAGRAM DATA. The make, type, pipe size, capacity, and rates of fluid flow shall be clearly indicated on the graphical diagram.

H11 Piping, Fittings, and Fluid Passages

H11.1 PIPING DEFINITIONS

H11.1.1 Piping. Piping includes all pipe, tubing, hose, and fittings. (Ref. ANS B93-1965, Glossary of Terms for Fluid Power)

H11.1.2 Passage. A passage is any machined or fluid-conducting path which lies within or passes through a component. (Ref. ANS B93.2-1965, Glossary of Terms for Fluid Power). Passages include all conductors other than piping.

H11.2 PIPING LAYOUT. Where requested on the purchaser's inquiry and confirmed on the supplier's quotation, a piping layout shall be furnished by the supplier. Photographs may be substituted by agreement. (Ref. H1.10.3)

H11.3 WALL STRENGTH OF PIPING. Piping shall have adequate wall strength to withstand additional pressure above that of the intended service, including the surge pressure rise rate and frequency developed when cycling the equipment. (Ref. H2.5.3, H8.6, H11.4)

Use of operating pressures above 2500 psi (172.4 bars) and the selection of piping materials shall be by written agreement between purchaser and supplier.

H11.4 SURGE SUPPRESSION. Pressure surges shall be minimized at their source. Protective devices shall be provided in the circuit(s) to protect piping and fittings from hydraulic impact. (Ref. H2.5.3, H8.6, H11.3)

H11.5 AREA OF PIPING. Piping shall have sufficient cross sectional area to prevent cavitation, excessive power losses, and the generation of excessive heat.

H11.6 PUMP INLET PIPING. Pump inlet piping shall be in accordance with the pump manufacturer's specification. (Ref. H5.5.2)

H11.7 FLUID VELOCITY IN PIPING. The fluid velocities through piping:

(1) Shall not create undue temperature rise, pressure drop, or shock load on the equipment.

(2) Should not exceed 15 feet (4.5 meters) per second.

Where velocities exceeding 15 feet (4.5 meters) per second are required, the hydraulic equipment shall be compatible.

Where a maximum velocity of less than 15 feet (4.5 meters) per second is desired on mass production equipment, the desired velocity shall be specified on the purchaser's inquiry or the Hydraulic Equipment Data Form and shall be confirmed on the supplier's quotation.

H11.8 PIPING RUNS

H11.8.1 Continuous Tubing Runs. Exclusive of terminal connectors and adapters, tubing runs shall be integral and continuous from one device or component to another.

H11.8.2 Tube Branching. Tube branching should occur at terminal connectors and/or adapters that are securely anchored to a terminal device or component.

H11.8.3 Number of Fittings. Piping runs fabricated of welded or threaded joints should contain a minimum number of fittings and bends.

Couplings shall be used only where necessary for length and assembly.

H11.9 PIPING ACROSS ACCESS WAYS. Piping runs across access wals shall no tinterfere with the normal use of the access way and should be located either below or well above the floor level and shall be in accordance with purchaser's requirements. These piping runs shall be readily accessible, rigidly supported, and, where necessary, protected against external damage.

H11.10 PIPING BETWEEN ASSEMBLIES. Where the equipment is constructed of separated assemblies, a rigidly mounted bulkhead type terminal device or terminal manifold shall be used to support the piping runs and shall provide connection for each end of the piping spans between assemblies.

H11.11 PIPING LOCATIONS. The location of piping shall not interfere with the adjustment, repair, or replacement of components or the industrial equipment elements, nor shall it subjet the piping to wear or damage from the work in process, the normal operation of the equipment, or the performance of normal maintenance.

H11.12 EXTERNAL DRAINS. Components with external drains shall be drained to the reservoir through separate piping runs or through a vented collecting manifold. (Ref. H4.4.3, H5.4.4, H8.7)

H11.13 FOREIGN MATTER IN PIPING. Piping, fittings, and fluid passages, including cored and drilled holes, shall be free of detrimental foreign matter (scale, burrs, etc., that may be dislodged to cause malfunction or restrict flow).

H11.14 PIPING CONNECTIONS

H11.14.1 Fitting Materials. Unless compatibility or pressure requirements necessitate alternate materials, steel fittings shall be used.

H11.14.2 Stepped Passages. Fittings with stepped-up or restricting stepped-down passages are not recommended.

H11.14.3 Orifice Fittings. The size, function, location, and identification of orifices within fittings shall be shown on the graphical diagram. (Ref. ANS Y14.17-1966, Drafting Standards for Fluid Power Diagrams) Fittings with orifices shall be permanently identified with the same identification shown on the graphical diagram in accordance with section H1.16 of this Standard. (Ref. H1.16.5, H1.16.6)

H11.14.4 Soldered Connections. Soft solder connections shall not be used.

H11.14.5 Sealing Flanged Connections. Flanged connections shall use sealing devices that seal with pressure.

H11.14.6 High Pressure Connections. Pipe used in service above 2500 psi (172.4 bars shall have welded or brazed joints.

H11.15 TUBE FITTINGS

H11.15.1 Straight Thread Fittings. Straight thread pressure sealing fittings should be used for circuit construction. Straight thread pressure sealing fittings shall conform to ANS B116.1-1968, Specifications for Straight Thread Hydraulic Ports.

H11.15.2 Flare Fittings. Where flared type tubing fittings are used, construction of the tube (i.e., tube end of the connector body, nut, and sleeve where a part of the fitting) shall be 37° from the center line. (Ref. SAE J514b, Hydraulic Tube Fittings)

H11.16 TUBING

H11.16.1 Steel Tubing Specifications. Seamless steel tubing used in circuit construction shall conform to ANS B93.11-1969, Seamless Low Carbon Hydraulic Line Tubing.

Welded steel tubing used in circuit construction shall conform to ANS B93.4-1969, Electric Resistance Welded, Mandrel Drawn Hydraulic Line Tubing.

Steel tubing used in circuit construction shall be applied in accordance with Appendix B (page 27) of this Standard.

H11.16.2 Plastic Tubing. Use of plastic tubing in circuit construction shall be by written agreement between the purchaser and the supplier.

H11.16.3 Tubing Sizes. Tubing sizes used in circuit construction for pilot and power transmission lines shall be ¼", ⅜", ½", ⅝", used for special lines, such as air bleed-offs, capillary tubes, restrictive flows, shall be specified on the graphical diagram.

H11.17 PIPE JOINTS

H11.17.1 Taper Pipe Threads. Where used, taper pipe threads for circuit connections shall conform to ANS B2.2-1968, Dryseal Pipe Threads.

H11.17.2 Distortion from Pipe Threads. The assembly of taper threaded pipe and fittings to components shall not distort the component housings so as to cause excessive internal leakage or malfunction.

H11.18 PIPE SPECIFICATIONS. Pipe used in circuit construction shall conform to the requirements of ASTM A-106, Grade B, Pipe Specifications or ASTM A53-B, Type F or Type S, Pipe Specifications. Ref. Appendix C, (pages 28, 29).

H11.19 FLEXIBLE LINES

H11.19.1 Flexible Line Use. Flexible hose, swing joints, or similar devices:

(1) Shall be used between moving elements of the equipment.

▲ (2) Should be avoided on stationary *equipment* elements, except where these components provide a *functional purpose* (adjustment of movable devices, interchange of similar equipment, etc.).

Flexible hose may be used to suppress the transmission of mechanical vibration and/or noise.

▲ **H11.19.2 Flexible Hose Safety Factor.** Flexible hose used in circuits where the working pressures exceed 250 psi (17.2 bars) should have a minimum factor of safety of 4:1. (Ref. H11.20.4)

H11.19.3 Flexible Hose Installations. Installations of flexible hose *shall:*

(1) Have vertical termination at the hose, ends, or the hose shall be *adequately supported where* end terminations are other than vertical.

(2) *Have only sufficient* length to avoid sharp flexing and straining of the hose during the equipment operation.

(3) Minimize torsional deflection of the hose.

(4) Be located or protected to minimize abrasive rubbing of the hose wall.

H11.19.4 Flexible Hose Replacement. Flexible hose *should be replaceable without* disturbing adjacent equipment and/or piping connections. (Ref. *H11.21*)

H11.20 PIPING SUPPORTS

H11.20.1 Support Requirements. *Piping shall be* securely supported to prevent its movement and *minimize its vibration.*

H11.20.2 Support Installations. Piping support shall not be welded to the piping, nor shall the contact of the supports with the outside of the piping damage it.

▲ **H11.20.3 Spacing of Piping Supports.** The maximum length of piping between supports should not exceed the distances specified in Table 1.

TABLE 1

Tubing outside Diameter in Inches	Pipe, Nominal Size	Length between Supports in Feet
¼, ⅜	⅛, ¼	3
½, ⅝, ¾, ⅞, 1	⅜, ½, ¾	5
1¼ *and larger*	1 and larger	7

H11.20.4 Flexible Hose Failure. Flexible hose shall be restrained or confined where its failure would constitute a hazard. (Ref. H13.11)

H11.21 ACCESSIBILITY OF PIPING

H11.21.1 Accessibility of *Piping Connections.* *Connec*tins of flexible lines, fabricated pipe, and *tubing runs shall be* accessible.

▲ **H11.21.2 Clearances in Fitting Clusters.** Where flexible *lines* and/or piping runs terminate in a fitting cluster, clearances should permit securing each threaded joint without disturbing adjacent piping or equipment.

H11.21.3 Removal of Piping Runs. Flexible lines, fabricated *pipe, and tubing runs shall* be removable without disturbing the terminal components.

H11.22 TEST LOCATIONS

H11.22.1 Test Ports in Piping. An accessible test port shall be provided in the piping where a pressure *governing component* is not so equipped.

▲ **H11.22.2 Test Feed Pressures.** An accessible test port *should* be provided between each feed producing actuator and its governing flow control.

▪ **H11.22.3 Multipressure Test Stations.** Where multiple pressures are used on mass production equipment, a multiple port test station with one gauge and selector valve or push-to-read valves *shall be pro*vided to permit checking any pressure without interrupting or *stopping the operation of the* equipment. Multiple port test stations shall be shown on the graphical *diagram* and each test position shall be identified.

▲ **H11.22.4 Fluid Sampling.** Where servo devices are used, means of obtaining a representative fluid sample without disturbing piping should be provided to permit periodic measurement of the fluid cleanliness level. (Ref. H2.7.9)

H11.22.5 Test Port Indicating. Test ports located in the circuit piping *shall be shown on the graphi*cal diagram.

H11.23 FLUID CONDUCTING MANIFOLDS

H11.23.1 Manifold Definition. A manifold is a conductor which provides multiple connection ports. (ANS B93.2-1965, Glossary of Terms for Fluid Power)

H11.23.2 Mounting Manifold. A mounting manifold is a subbase for attachment and support of an individual component and *it provides terminal* connection of piping runs.

HH.23.3 Junction Manifold. *Junction manifolds* provide both branching and terminal connection *of* piping runs.

H11.23.4 Terminal Manifold. Terminal manifolds are used at intermediate locations, providing support and terminal connection of piping runs too short for continuous runs, or are used to provide predetermined locations for piping *disassembly in sep*arated equipment assemblies.

H11.23.5 Circuit Manifold. Circuit *manifolds make* more efficient use of space by providing for *attachment and support* of manifold mounted components, and are used for channeling fluid through internal conductors in a manner prescribed by the graphical diagram.

H11.23.5.1 Circuitry within Manifolds. Circuitry encompassed by circuit manifolds shall be plainly indicated on the graphical diagram. Where boundary *lines or boundary envelopes are* used for this purpose, the boundary indicated shall not include *any symbol* of a component not mounted on or within the circuit manifold.

H11.23.5.2 Identification on Circuit Manifolds. All ports, solenoids, and components mounted on or within circuit manifolds shall be permanently identified in accordance with the *provisions of this* Standard (Ref. H1.16) and shall correspond with the *graphical diagram. Orifice plugs and* passages and devices within the manifold shall be identified adjacent to their access openings. When access openings are located under a component or components, identification shall be adjacent to the component and as close to access opening as practical *and the* identification shall be marked "Concealed."

▲ **H11.23.5.3 Internal Devices.** *Hydraulic devices (such* as cartridge type valves, checks, etc.) *should not* be located within a circuit manifold unless it is impractical to locate them externally. Internal devices should be accessible without disturbing other components and shall not require manifold disassembly. (Ref. H1.16.5)

▲ **H11.23.5.4 Manifold Assemblies.** Large circuit manifolds should be assembled from finished and ported sections for ease of manufacture and replacement.

H11.23.5.5 Manifold Interface Seals. Interface seals used in assembled manifolds shall be of a type that seals with pressure.

H11.23.6 Manifold Distortion. Circuit manifolds shall not distort under operating pressures and temperatures so as to cause component malfunction.

H11.23.7 Manifold Materials. Manifold material shall be compatible with the fluid used.

H11.23.8 Flow Capacity of Manifold Conductors. Flow capacity of manifold conductors shall equal that for correspondence piping.

H11.23.9 Handling Provisions. Manifolds and manifold assemblies weighing more than forty (40) pounds shall have provision for lifting the manifold with attached components.

H11.23.10 Support of Manifolds. Manifolds shall be rigidly and securely attached to the equipment; supports shall be independent of piping.

H12 Seals and Sealing Devices

▲**H12.1 SEALING PRINCIPLES.** Sealing devices for hydraulic circuits should be of the pressure sealing type.

H12.2 SEALING MATERIALS. Sealing device materials shall:

(1) Not be adversely affected by the hydraulic fluid.
(2) Be of compatible materials where adjacent contact materials are metals.
(3) Be of an elastomeric material where no leakage other than that required for lubrication can be tolerated, e.g., for reciprocating and rotating elements.

H12.3 SEAL QUANTITY. Seals shall be adequate in size and in number for the service intended.

▲**H12.4 AVAILABILITY.** Packings, seals, and sealing devices used in hydraulic circuit should be commercially available.

H12.5 SEAL REPLACEMENT. Where continuous ring packings and seals are used, the component and the actuated equipment designs shall facilitate servicing and replacement of seals and packings.

H12.6 SEAL GLAND CLEARANCES. Clearances in seal glands shall prevent extrusion of the sealing material(s).

H12.7 ADJUSTABLE SEAL GLANDS. Where seal glands are adjustable, seal and packing gland chambers shall be so designed that they cannot be adjusted beyond their functional limits.

H13 Safety

This section is concerned with the safety aspects of applying hydraulic power and its control to industrial equipment. Included are the safety related requirements from other sections of this Standard which have been repeated below primarily for those interested in this important phase of hydraulic application.

H13.1 SAFE CIRCUITRY. Hydraulic circuits shall be designed and components selected, applied, mounted, and adjusted to safely provide uninterrupted operation, extended life, and shall be fail-safe. Circuits shall:

(1) Operate within the component manufacturer's specifications.
(2) Be protected against overpressure.
(3) Be so designed and applied that surge pressure, overpressure, and loss of pressure do not cause hazard or damage to the equipment. (Ref. H1.14.1)
(4) Be so designed and constructed that components attached to the industrial equipment are located where they can be safely serviced. (Ref. H1.14.2)

H13.2 CONTROL STATION NAMEPLATES. A nameplate shall be provided for each control station component and shall be located where it can be easily read by the equipment operator. The nameplate information shall be pertinent and easily interpreted, providing positive identification of the control component and its function. (Ref. H1.16.7)

H13.3 EMERGENCY STOP AND RETURN CONTROLS. All industrial equipment shall incorporate an emergency stop or return control. Duplicate emergency controls shall be provided at each operator station. Emergency stop and return controls:

(1) Shall be readily accessible from the operator's working position.
(2) Shall not release any locating pin, index drive engagement, latch, lock, or clamping device.
(3) hall operate immediately.
(4) Shall be independent and unaffected by the adjustments of other controls or flow restrictions.
▲(5) Should provide a blocking valve upstream in the supply line of the servo valve(s) for emergency stop.
(6) Shall not require energizing any control element.
(7) Shall not require operation of more than one manual control for all emergency functions.
(8) Shall not create an additional hazard. (Ref. H2.4.2)

H13.4 TWO-HAND CONTROL. Where pinch points and other movement hazards are exposed to the operating personnel, two-hand manual controls shall be provided each operator, which:

(1) Require maintained actuation of each control throughout the equipment cycle or until the point in the cycle is reached where the hazard ceases.
(2) Are so located and guarded that operation by means other than both hands is prevented.
(3) Are so designed that the equipment canunot be operated unless both manual controls at each control station are released between cycles. (Ref. H2.4.5)

H13.5 LOCATION OF MANUAL CONTROLS. The location and mounting of manual controls shall:

(1) Place the controls within reach of the equipment operator from his normal working position(s).
(2) Not require the operator to reach past rotating or moving equipment elements or work in process to operate the controls.
(3) Not interfere with the equipment operator's required working movements. (Ref. H2.4.6)

H13.6 MANUAL CONTROL LEVERS. Manually actuated levers should move in the same direction as the resulting motion of the related equipment element. (Ref. H2.4.3)

H13.7 CONTROL MEDIA FAILURE. Hydraulic devices controlled electrically, pneumatically, and/or hydraulically shall be selected and so applied that failure of the control media does not cause a hazard or damage to the equipment. (Ref. H2.2.8)

H13.8 UNCONTROLLED MOVEMENT. The circuits shall be designed to prevent uncontrolled movement and improper sequencing of the hydraulic actuators during all phases of the equipment cycle, including pump idling, starting, and stopping. (Ref. H2.5.5)

H13.9 COUNTERBALANCING. On vertical and inclined equipment slides, rams, and other similar equipment elements, means shall be provided to prevent their rapid drop. (Ref. H8.11.6)

H13.10 ACCUMULATOR SAFETY (Ref. H9.4)

H13.10.1 Automatic Vent. Hydraulic circuits incorporating accumulators shall automatically vent the accumulator when the equipment is shut off. Isolation shall prevent uncontrolled movement of the actuators in case manual overrides on associated equipment are operated.

H13.10.2 Pressure Isolation. Where deviation is agreed to or a circuit application utilizes accumulator liquid pressure isolation only (not vented) when the equipment is shut off, complete information for proper servicing shall be given on or near the accumulator in a visible location. The information shall include the statement: CAUTION — PRESSURIZED VESSEL. Duplicate information shall be provided on the graphical diagram.

H13.10.3 Discharge Rate. Accumulator discharge rates shall be restricted to the demands of the intended service.

H13.10.4 Charging Medium. Gas accumulators shall be charged with nitrogen or an inert gas.

H13.11 FLEXIBLE HOSE FAILURE. Flexible hose shall be restrained or confined where its failure would constitute a hazard. (Ref. H11.20.4)

H13.12 INCLINED LADDERS. Where personnel are required to carry heavy or bulky equipment to perform regularly scheduled maintenance on elevated hydraulic equipment at a level of 6 or more feet (1.83 meters) above the working floor, an inclined ladder or other suitable inclined means of access should be used. (Ref. H1.14.3)

H13.13 ELEVATED PLATFORMS. Where elevated walkways and platforms are required for access and servicing hydraulic equipment, they shall comply with ANS A12.1-1967, Safety Requirements for Floor and Wall Opening, Railing, and Toe Boards. (Ref. H1.14.4)

APPENDIX D

Standard Reference Documents

Joint Industrial Council (JIC)
7901 Westpark Drive
McLean, VA 22101

EMP 1-1967 Electrical Standard for Mass Production Equipment
EGP 1-1967 Electrical Standard for General Purpose Equipment

National Fluid Power Association (NFPA)
Post Office Box 49
Thiensville, Wisconsin 53092

T3.8.67.2 Size Designation and General and Physical Requirements of Fluid Power Connectors and Closures.
T3.8.67.3 Procedure for Testing Fluid Power Steel Connectors and Closures.
T3.16.2 Recommended Standard for Nonintegral Fluid Power Hydraulic Reservoirs

Society of Automotive Engineers (SAE)
485 Lexington Avenue
New York, New York 10017

J-514b Hydraulic Tube Fittings

American Society of Mechanical Engineers (ASME)
345 East 47th Street
New York, New York 10017

Revision 1, Section 8, Code for Unfired Pressure Vessels

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, Pennsylvania 19103

A-53 Grade B, Type F and type S Welded and Seamless Steel Pipe
A-106 Grade B, Seamless Carbon Steel Pipe for High Temperature Service

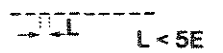
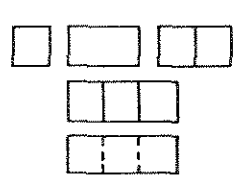
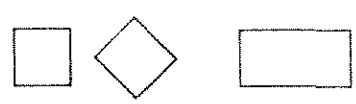
American National Standards Institute (ANSI)
1430 Broadway
New York, New York 10018

A12.1-1967 Floor & Wall Openings, Railings & Toe Boards - Safety Requirements
B2.1-1968 Pipe Threads (Except Dryseal)
B2.2-1968 Dryseal Pipe Threads
B93.1-1964 Seamless Low Carbon Hydraulic Line Tubing
B93.2-1965 Glossary of Terms for Fluid Power
B93.3-1968 Cylinder Bore and Piston Rod Sizes for Fluid Power Cylinders
B93.4-1969 ERW Hydraulic Line Tubing
B93.7-1968 Mounting Surfaces of Sub-Plate Hydraulic Valves
B93.8-1968 Bore and Rod Size Configuration and Combinations
B93.11-1969 Seamless Low Carbon Steel Hydraulic Line Tubing
B116.1-1968 Specifications for Straight Thread Hydraulic Ports
Y14.17-1966 American Drafting Standards of Fluid Power Diagrams
Y32.10-1967 Graphic Symbols for Fluid Power Diagrams

FLUID POWER GRAPHICAL SYMBOLS

IMPORTANT

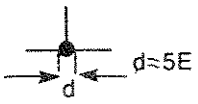
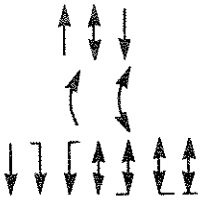
Previous editions of the Lighting Reference Handbook, have carried the Fluid Power Graphical Symbols as arrived at by the American National Standards Institute. The International Standards Organization, has published symbols upon which world wide agreement has been reached. Unfortunately many of the symbols carried in the American National Standards Institute standards have yet to be agreed upon by the International Standards Organization. The publisher, in an attempt to help the user of this publication in the transitional period, has published both sets of standards. The left-hand columns on these pages reflect the International Standards Organization specification for graphical symbols. The right-hand columns are the existing A.N.S.I. 1967 symbols that are roughly equivalent to the I.S.O. symbols. Where voids exist in either column the publisher was unable to find an approximate equivalent. The user in all cases should use the I.S.O. symbols where possible. If this is not possible the publisher suggests use of the A.N.S.I. symbols since these are in use and will probably be in use for quite some time in the future.

	Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".			Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.
	Description	*** Application**	**Symbol**	
5.1	Basic symbols			
5.1.1 5.1.1.1	*Line:* - continuous	flow lines		2.4.1 ——————— Solid Line (Main line conductor, outline, and shaft)
5.1.1.2	- long dashes			2.4.2 — — — — — Dash Line (Pilot line for control)
5.1.1.3	- short dashes			2.4.3 – – – – – – – – Dotted Line (Drain line)
5.1.1.4	- double	Mechanical connections (shafts, levers, piston-rods)		
5.1.1.5	- *long chain thin* (optional use)	Enclosure for several components assembled in one unit		2.4.4 ——— – ——— – ——— Center Line (Enclosure outline)
5.1.2	Circle semi-circle			2.5 Basic symbols may be shown any suitable size. Size may be varied for emphasis or clarity. Relative sizes should be maintained (as in the following example)
5.1.2.1		As a rule, energy conversion units (pump, compressor, motor)		2.5.1 Circle and Semi-Circle 
5.1.2.2		Measuring instruments		
5.1.2.3		Non-return valve, rotary connection, etc.		2.5.1.1 *Large and small circles may be used to* signify that one component is the "main" and the other the auxiliary
5.1.2.4		Mechanical link, roller, etc.		
5.1.2.5		Semi-rotary actuator		
5.1.3	Square, rectangle	As a rule, control valves (valve) except for non-return valves		2.5.4 Square Rectangle 
5.1.4	Diamond	Conditioning apparatus (filter, separator, lubricator, heat exchanger)		5. FLUID CONDITIONERS  *Devices which control the physical characteristics* of the fluid.

FLUID POWER GRAPHICAL SYMBOLS

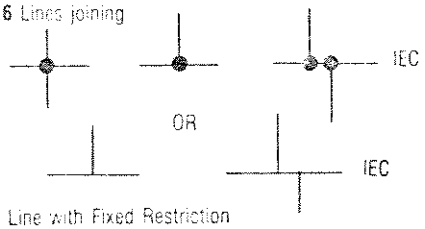
Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".

Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Application	Symbol
5.1.5	Miscellaneous symbols		
5.1.5.1		Flow line connection	
5.1.5.2		Spring	
5.1.5.3 5.1.5.3.1		Restriction: - affected by viscosity	
5.1.5.3.2		- unaffected by viscosity	
5.2	Functional symbols	The direction of flow and the nature of the fluid	
5.2.1 5.2.1.1 5.2.1.2	Triangle: - solid - in outline only	Hydraulic flow Pneumatic flow or exhaust to atmosphere	
5.2.2 5.2.2.1 5.2.2.2 5.2.2.3	Arrow	Indication of: - direction - direction of rotation - path and direction of flow through valves For regulating apparatus as in 7.4 both representations with or without a tail to the end of the arrow are used without distinction. As a general rule the line perpendicular to the head of the arrow indicates that when the arrow moves the interior path always remains connected to the corresponding exterior path.	

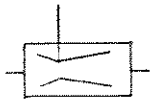
2.4.5 Lines crossing (The intersection is not necessarily at 90° angle)

2.4.6 Lines joining

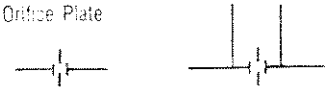


3.7 Line with Fixed Restriction

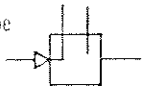
9.2 Sensing
9.2.1 Venturi



9.2.2 Orifice Plate

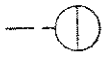


9.2.3 Pitot Tube

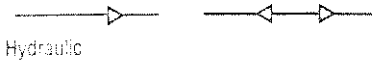


9.2.4 Nozzle

9.3.2 Float Switch



3.5 Flow, Direction of
3.5.1 Pneumatic



3.5.2 Hydraulic

2.5.3 Arrow

2.13 Rotating shafts are symbolized by an arrow which indicates direction of rotation (assume arrow on near side of shaft).

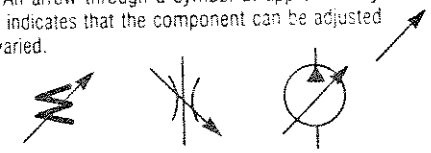
FLUID POWER GRAPHICAL SYMBOLS

Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".

Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Application	Symbol
5.2.3	Sloping arrow	Indication of the possibility of regulation or of a progressive variability.	
6.1	Pumps and compressors	To convert mechanical energy into hydraulic or pneumatic energy	
6.1.1	Fixed capacity hydraulic pump:		
6.1.1.1	- with one direction of flow		
6.1.1.2	- with two directions of flow		
		Use of the equipment or explanation of the symbol	
6.1.2	Variable capacity hydraulic pump:	The symbol is a combination of 6.1.1.1 and 5.2.3 (sloping arrow)	
6.1.2.1	- with one direction of flow		
6.1.2.2	- with two directions of flow	The symbol is a combination of 6.1.1.2 and 5.2.3 (sloping arrow)	

2.9 An arrow through a symbol at approximately 45° indicates that the component can be adjusted or varied.



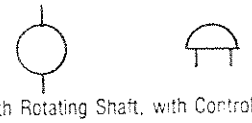
2.10 An arrow parallel to the short side of a symbol, within the symbol, indicates that the component is pressure compensated.

2.11 A line terminating in a dot to represent a thermometer is the symbol for temperature cause or effect.

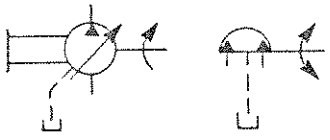
8. ROTARY DEVICES

8.1 Basic Symbol

8.1.1 With Ports



8.1.2 With Rotating Shaft, with Control, and with Drain



8.2 Hydraulic Pump

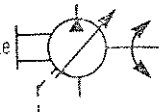
8.2.1 Fixed Displacement

8.2.1.1 Unidirectional

8.2.1.2 Bidirectional

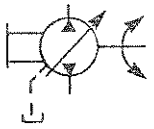
8.2.2.1 Unidirectional

Simplified 

Complete 

8.2.2.2 Bidirectional

Simplified 

Complete 

FLUID POWER GRAPHICAL SYMBOLS

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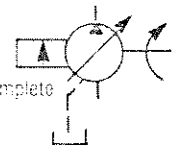
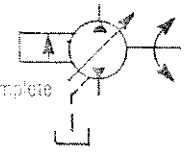
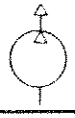
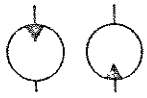
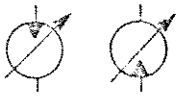
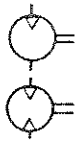
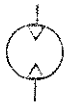
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol	
				8.2. Variable Displacement, Pressure Compensated 8.2.3.1 Unidirectional Simplified  Complete  8.2.3.2 Bidirectional Simplified  Complete 
6.1.3	Fixed capacity compressor (always one direction of flow)			8.5 Pump, Pneumatic 8.5.1 Compressor, Fixed Displacement 
				8.5.2 Vacuum Pump, Fixed Displacement 
6.2	Motors	To convert hydraulic or pneumatic energy into rotary mechanical energy		8.3 Hydraulic Motor 8.3.1 Fixed Displacement 
6.2.1 6.2.1.1 6.2.1.2	Fixed capacity hydraulic motor: - with one direction of flow - with two directions of flow			8.3.1.2 Bidirectional 
6.2.2 6.2.2.1 6.2.2.2	Variable capacity hydraulic motor: - with one direction of flow - with two directions of flow	The symbol is a combination of 6.2.1.1 and 5.2.3 (sloping arrow) The symbol is a combination of 6.2.1.2 and 5.2.3 (sloping arrow)		8.3.2 Variable Displacement 8.3.2.1 Unidirectional  8.3.2.2 Bidirectional 
6.2.3 6.2.3.1 6.2.3.2	Fixed capacity pneumatic motor: - with one direction of flow - with two directions of flow			8.6 Motor, Pneumatic 8.6.1 Unidirectional  8.6.2 Bidirectional 
6.2.4 6.2.4.1 6.2.4.2	Variable capacity pneumatic motor: - with one direction of flow - with two directions of flow	The symbol is a combination of 6.2.3.1 and 5.2.3 (sloping arrow) The symbol is a combination of 6.2.3.2 and 5.2.3 (sloping arrow)		

FLUID POWER GRAPHICAL SYMBOLS

Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".

Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol
6.2.5	Oscillating motor:		
6.2.5.1	- hydraulic		
6.2.5.2	- pneumatic		
6.3	Pump/motor units	Unit with two functions, either as pump or as rotary motor.	
6.3.1	Fixed capacity pump/motor unit		
6.3.1.1	- with reversal of the direction of flow.	Functioning as pump or motor according to direction of flow.	
6.3.1.2	- with one single direction of flow	Functioning as pump or motor without change or as a motor.	
6.3.1.3	- with two directions of flow	Functioning as pump or motor with either direction of flow.	
6.3.2	Variable capacity pump/motor unit:		
6.3.2.1	- with reversal of the direction of flow	The symbol is a combination of 6.3.1.1 and 5.2.3 (sloping arrow)	
6.3.2.2	- with one single direction of flow	The symbol is a combination of 6.3.1.2 and 5.2.3 (sloping arrow)	
6.3.2.3	- with two directions of flow	The symbol is a combination of 6.3.1.3 and 5.2.3 (sloping arrow)	
6.4	Variable speed drive units	Torque converter. Pump and/or motor are of variable capacity. Remote drives, see 12.2.	

8.7 Oscillator
8.7.1 Hydraulic

8.7.2 Pneumatic

8.4 Pump-Motor, Hydraulic
8.4.1 Operating in one direction as a pump. Operating in the other direction as a motor.

8.4.1.1 Complete Symbol 8.4.1.2 Simplified Symbol

8.4.2 Operating one direction of flow as either a pump or as a motor.

8.4.2.1 Complete Symbol 8.4.2.2 Simplified Symbol

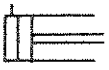
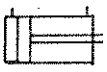
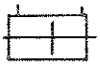
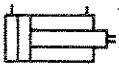
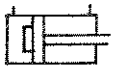
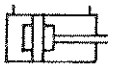
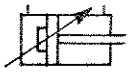
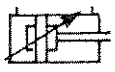
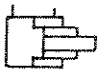
8.4.3 Operating in both directions of flow either as a pump or as a motor. (Variable displacement, pressure compensated shown.)

8.4.3.1 Complete Symbol 8.4.3.2 Simplified Symbol

FLUID POWER GRAPHICAL SYMBOLS

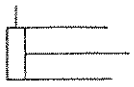
Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".

Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol	
6.5	Cylinders	Equipment to convert hydraulic or pneumatic energy into linear energy		
6.5.1	Single acting Cylinder	Cylinder in which the fluid pressure always acts in one and the same direction (on the forward stroke).	Detailed	Simplified
6.5.1.1	- returned by an unspecified force.	General symbol when the method of return is not specified.		
6.5.1.2	-returned by spring	Combination of the general symbol 6.5.1.1 and 5.1.5.2 (spring)		
6.5.2	Double acting cylinder:	Cylinder in which the fluid fluid pressure operates alternately in both directions (forward and backward strokes)		
6.5.2.1	- with single piston rod			
6.5.2.2.	- with double-ended ended piston rod			
6.5.3	Differential cylinder	The action is dependent on the difference between the effective areas on each side of the piston		
6.5.4	Cylinder with cushion:			
6.5.4.1	- with single fixed cushion	Cylinder incorporating fixed cushion acting in one direction only		
6.5.4.2	- with double fixed cushion	Cylinder with fixed cushion acting in both directions		
6.5.4.3	- with single adjustable cushion	The symbol is a combination of 6.5.4.1 and 5.2.3 (sloping arrow)		
6.5.4.4	- with double adjustable cushion	The symbol is a combination of 6.5.4.2 and 5.2.3 (sloping arrow)		
6.5.5	**Telescopic cylinder:**			
6.5.5.1	- single acting	The fluid pressure always acts in one and the same direction (on the forward stroke).		
6.5.5.2	- double acting	The fluid pressure operates alternately in both directions (forward and backward strokes),		

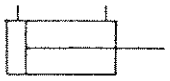
6.1 Cylinders, Hydraulic & Pneumatic

6.1.1 Single Acting

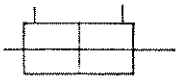


6.1.2 Double Acting

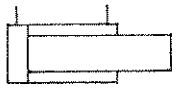
6.1.2.1 Single End Rod



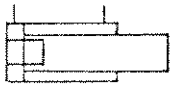
6.1.2.2 Double End Rod



6.1.2.5 Use these symbols when diameter of rod compared to diameter of bore is significant to circuit function.

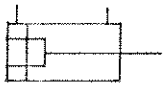


(Non-Cushion)

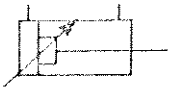


(Cushion, Advance & Retract)

6.1.2.3 Fixed Cushion, Advance & Retract



6.1.2.4 Adjustable Cushion, Advance Only



FLUID POWER GRAPHICAL SYMBOLS

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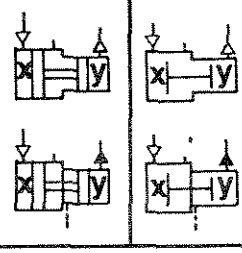
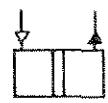
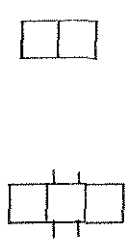
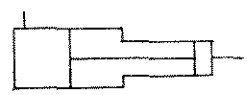
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

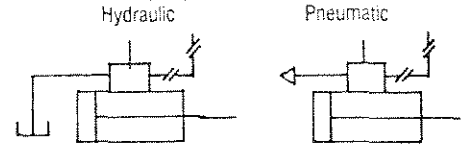
	Description	Use of the equipment or explanation of the symbol	Symbol	
			Detailed	Simplified
6.6	Pressure intensifiers:	Equipment transforming a pressure x into a higher *pressure y*		
6.6.1	- for one type of fluid	E.g. a pneumatic pressure x is transformed into a higher pneumatic pressure y.		
6.6.2	- for two types *of fluid*	E.g. a pneumatic pressure x is transformed into a higher hydraulic pressure y.		
6.7	*Air-oil actuator*	Equipment transforming a pneumatic pressure into a substantially equal hydraulic pressure or vice versa.		
7	**CONTROL VALVES**			
7.1	Method of representation of valves (except 7.3 and 7.6)	Made up of one or more squares 5.1.3 and arrows In circuit diagrams hydraulic and pneumatic units are normally shown in the unoperated condition.		
7.1.1	One single square	Indicates unit for controlling flow or pressure, having in operation an infinite number *of possible* positions between its end positions so as to vary the conditions of flow across one or more of its ports, thus ensuring the chosen pressure and/or flow with regard to the operating conditions of the circuit.		
7.1.2	Two or more squares	Indicates a directional control valve having as many *distinct positions as there* are squares. The pipe connections are normally represented as connected to the box representing the unoperated condition (see 7.1). The operating positions *are deduced by imagining* the boxes to be displaced so that the pipe connections correspond with the ports of the box in question.		

6.2 Pressure Intensifier



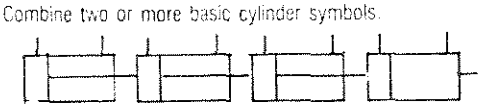
6.3 Servo Positioner (Simplified)

Hydraulic Pneumatic

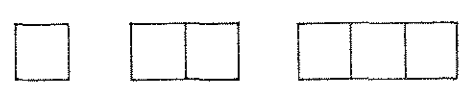


6.4 Discrete Positioner

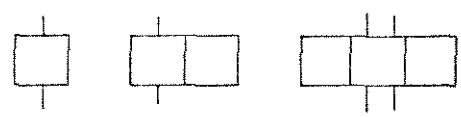
Combine two or more basic cylinder symbols.



10.4 Envelopes



10.5 Ports



FLUID POWER GRAPHICAL SYMBOLS

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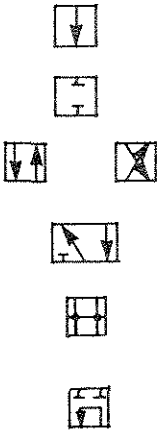
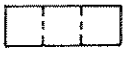
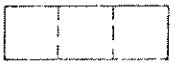
	Description	**Use of the equipment *or explanation of* the symbol**	***Symbol***	
7.1.3	Simplified symbol for valves in cases of multiple repetition.	The number refers to a note on the diagram in which the symbol for the valve is given in full		
7.2	Directional control valves	Units providing for the opening (fully or restricted) or the closing of one or more flow paths (represented by several squares).		
7.2.1	Flow paths:	Square containing interior lines		**10.6** Ports Internally Blocked Symbol System 10.1 — Symbol System 10.2 
7.2.1.1	- one flow path			
7.2.1.2	- two closed ports			
7.2.1.3	- two flow paths			
7.2.1.4	- two flow paths and one closed port			**10.7** Flow Paths, Internally Open (Symbol Systems 10.1 & 10.2) Symbol System 10.1 — Symbol System 10.2 
7.2.1.5	- two flow paths with cross connection			
7.2.1.6	- one flow path in a by-pass position, two closed ports.			
7.2.2	Non-throttling directional control valve.	The unit provides distinct circuit conditions each depicted by a square.		
7.2.2.1		Basic symbol for 2-position directional control valve		
7.2.2.2		Basic symbol for 3-position directional control valve		**10.11.4** Two-Position Snap Action with Transition. As the valve element shifts from one position to the other, it passes through an intermediate position. If it is essential to circuit function to symbolize this "in transit" condition, it can be shown in the center position, enclosed by dashed lines.
7.2.2.3		A transitory but significant condition between two distinct positions is optionally *represented by a square with* dashed ends. A basic symbol for a directional control valve with two distinct positions and one transitory intermediate condition.		 Typical Transition Symbol 
7.2.2.4		Designation: The first figure in the designation shows the number of ports, (excluding pilot ports) and the second figure the number of distinct positions.		

FLUID POWER GRAPHICAL SYMBOLS

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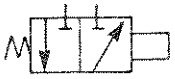
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol
7.2.2.5	Directional control valve 2/2:	Directional control valve with 2 ports and 2 distinct positions	
7.2.2.5.1	- with manual control		
7.2.2.5.2	- controlled by pressure operating against a return spring (e.g. on air unloading valve)		
7.2.2.6	Directional control valve 3/2:	Directional control valve with 3 ports and 2 distinct positions	
7.2.2.6.1	- controlled by pressure in both directions.		
7.2.2.6.2	- controlled by solenoid with return spring	Indicating an intermediate condition (see 7.2.2.3)	

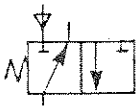
10.9.5.1 Two-Position
Normally Closed

Normally Open

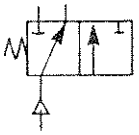
10.10 Three-Way Valves
10.10.1 Two-Position
10.10.1.1 Normally Open



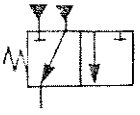
10.10.1.2 Normally Closed



10.10.1.3 Distributor (Pressure is distributed first to one port, then the other)

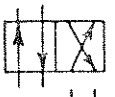


10.10.1.4 Two-Pressure

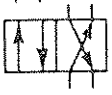


7.7 Pilot Pressure
7.7.1 Remote Supply

10.11 Four-Way Valves
10.11.1 Two-Position

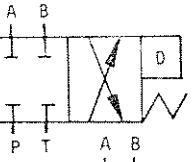


Normal

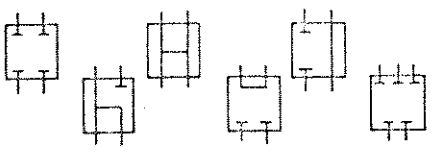


Actuated

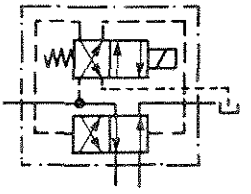
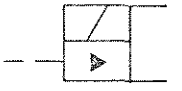
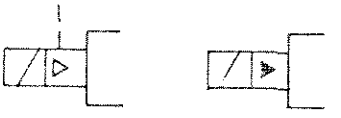
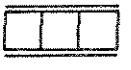
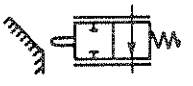
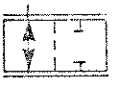
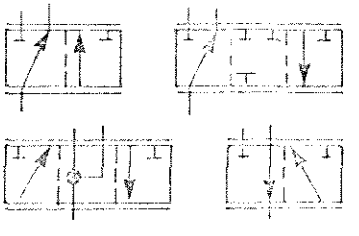
10.11.2 Three-Position



10.11.3 Typical Flow Paths for Center Condition of Three-Position Valves



FLUID POWER GRAPHICAL SYMBOLS

	Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".			Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.
	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	
7.2.2.7	Directional control valve 4/2:	Directional control valve with 4 ports and 2 distinct positions	Detailed 	
7.2.2.7.1	- controlled by pressure in both directions by means of a pilot valve (with a single solenoid and spring return)		Simplified 	7.8.1 Solenoid or Pilot External Pilot Supply 
7.2.2.8	Directional control valve 5/2:	Directional control with 5 ports and 2 distinct positions		Internal Pilot Supply and Exhaust 
7.2.2.8.1	- controlled by pressure in both directions			7.8.2 Solenoid and Pilot 
7.2.3	Throttling directional control	The unit has 2 extreme positions and an infinite number of intermediate conditions with varying degrees of throttling. All symbols have parallel lines along the length of the boxes. For valves with mechanical feedback, see 9.3		10.3 Multiple envelope valves capable of infinite positioning between certain limits are symbolized as in 10.2 above with the addition of horizontal bars which are drawn parallel to the envelope. The horizontal bars are the clues to the infinite positioning function possessed by the valve represented.
7.2.3.1		Showing the extreme positions		10.8 Flow Paths, Internally Open (Symbol System 10.3)
7.2.3.2		Showing the extreme positions and a central (neutral) position		
7.2.3.3	- with 2 ports (one throttling orifice)	For example: Tracer valve plunger operated against a return spring		
7.2.3.4	- with 3 ports (two throttling	For example: Directional control valve controlled by pressure against a return spring		10.14 Infinite Positioning Three-Way Valves 

FLUID POWER GRAPHICAL SYMBOLS

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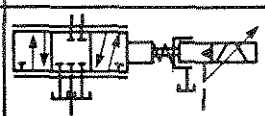
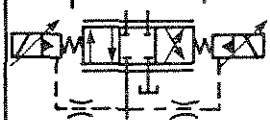
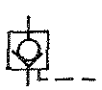
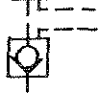
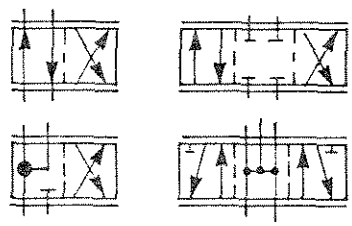
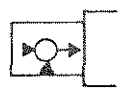
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol
7.2.3.5	- with 4 ports (four throttling orfices)	For example: Tracer valve, plunger operated against a return spring	
7.2.4	Electro-hydraulic servo valve: Electro-pneumatic servo valve:	A unit which accepts an analogue electrical signal and provides a similar analogue fluid power output	
7.2.4.1	- single stage	- *with direct operation*	
7.2.4.2	- two stage with mechanical feedback	- with indirect pilot operation	
7.2.4.3	- two stage with hydraulic feedback	- with indirect pilot operation	
7.3	Non-return valves, shuttle valve, rapid exhaust valve	Valves which allow free flow in one direction only	
7.3.1 7.3.1.1	Non-return valve: - free	Opens if the inlet pressure is higher than the outlet pressure	
7.3.1.2	- spring loaded	Opens if the inlet pressure is greater than the outlet pressure plus the spring pressure	
7.3.1.3	- pilot controlled	As in 7.3.1.1 but by pilot control it is possible to prevent:	
7.3.1.3.1		- closing of the valve	
7.3.1.3.2		- opening of the valve	
7.3.1.4	- with restriction	*Unit allowing free flow in* one direction but restricted flow in the other	

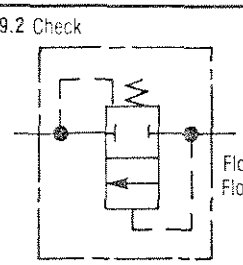
10.15 *Infinite Positioning Four-Way Valves*



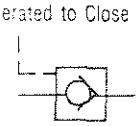
7.10 *Servo*
(This symbol contains representation for energy input, command input, and resultant output.)



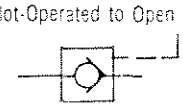
10.9.2 Check



10.9.4 Check, Pilot-Operated to Close



10.9.3 Check, Pilot-Operated to Open



FLUID POWER GRAPHICAL SYMBOLS

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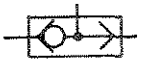
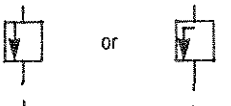
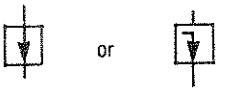
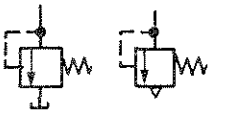
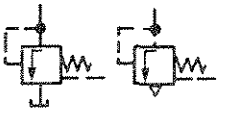
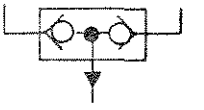
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

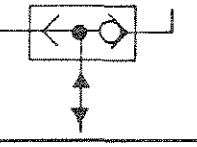
	Description	Use of the equipment or explanation of the symbol	Symbol
7.3.2	Shuttle valve	The inlet port connected to the higher pressure is automatically connected to the outlet port while the other inlet port is closed.	
7.3.3	Rapid exhaust valve	When the inlet port is unloaded the outlet port is freely exhausted	
7.4	Pressure control valves	Units ensuring the control of pressure. Represented by one single square as in 7.1.1 with one arrow (the tail to the arrow may be placed at the end of the arrow. For interior controlling conditions, see 9.2.4.3	
7.4.1	Pressure control valve:	General symbols	
7.4.1.1	- 1 throttling orifice normally closed		
7.4.1.2	- 1 throttling orifice normally open		
7.4.1.3	- 2 throttling orifices, normally closed		
7.4.2	Pressure relief valve (safety valve)	Inlet pressure is controlled by opening the exhaust port to the reservoir or to atmosphere against an opposing force (for example a spring)	
7.4.2.1	- with remote pilot control	The pressure at the inlet port is limited as in 7.4.2 or to that corresponding to the setting of a pilot control	

10.10.2 Double Check Valve. Double check valves can be built with and without 'cross bleed.' Such valves with two poppets do not usually allow pressure to momentarily 'cross bleed' to return during transition. Valves with one poppet may allow 'cross bleed' as these symbols illustrate.

10.10.2.1 Without Cross Bleed (One-Way Flow)

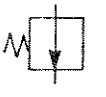


10.10.2.2 With Cross Bleed (Reverse Flow Permitted)



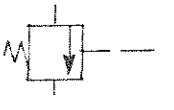
10.9.5.2 Normally Open
10.9.5.2 Infinite Position
Normally Closed Complete

Normally Open

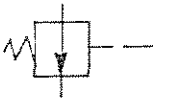


10.12 Infinite Positioning (Between Open & Closed)

10.12.1 Normally Closed

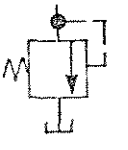


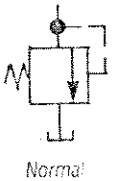
10.12.2 Normally Open



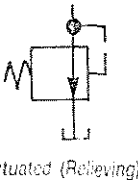
10.13.1 Pressure Relief

Simplified Symbol Denotes



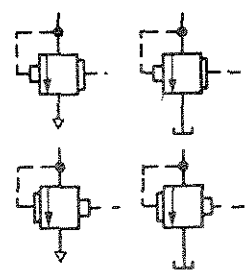
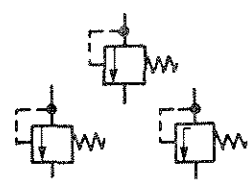
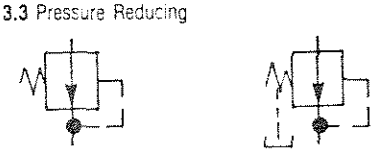
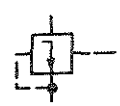
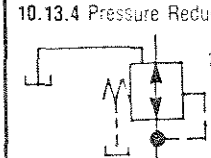
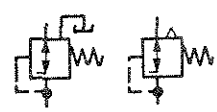
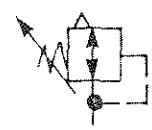
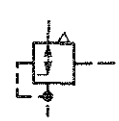
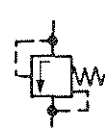
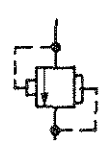


Normal



Actuated (Relieving)

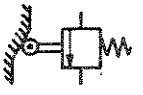
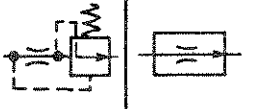
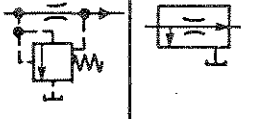
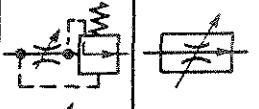
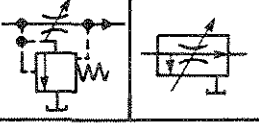
FLUID POWER GRAPHICAL SYMBOLS

	Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".			Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.
	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	
7.4.3	Proportional pressure relief	Inlet pressure is limited to a value proportional to the pilot pressure (see 9.2.4.1.3)		
7.4.4	Sequence valve	When the inlet pressure overcomes the opposing force of the spring, the valve opens permitting flow from the outlet port		10.13.2 Sequence 
7.4.5	Pressure regulator or reducing valve (reducer of pressure):	A unit which, with a variable inlet pressure, gives gives substantially constant *output pressure* provided that the inlet pressure remains higher than the required outlet pressure.		10.13.3 Pressure Reducing 
7.4.5.1	- without relief port			
7.4.5.2	- without relief port with *remote control*	As in 7.4.5.1 but the outlet *pressure is dependent* on the control pressure		10.13.4 Pressure Reducing and Relieving 
7.4.5.3	- with relief port			10.13.5 Airline Pressure Regulator (Adjustable, Relieving) 
7.4.5.4	- *with relief port*, with remote control	As in 7.4.5.3 but the outlet pressure is dependent on the control pressure		
7.4.6	Differential pressure regulator	The outlet pressure is reduced by a fixed amount with respect to the inlet *pressure*		
7.4.7	Proportional pressure regulator	The outlet pressure is reduced by a fixed ratio with respect to the inlet pressure (see 9.2.4.1.3)		

FLUID POWER GRAPHICAL SYMBOLS

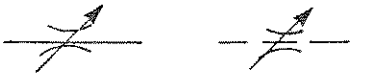
Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".

Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

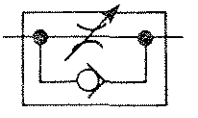
	Description	Use of the equipment or explanation of the symbol	Symbol
7.5	Flow control valves	Units ensuring control of flow. Excepting 7.5.3 positions and method of representation as 7.4	
7.5.1	Throttle valve:	Simplified symbol (Does not indicate the control method or the state of the valve)	
7.5.1	- with manual control	Detailed symbol (indicates the control method or the state of the valve)	
7.5.1.2	- with mechanical control against a return spring (braking valve)		
7.5.2	Flow control valve:	Variations in inlet pressure do not affect the rate of flow	Detailed / Simplified
7.5.2.1	- with fixed output		
7.5.2.2	- with fixed output and relief port to reservoir	As 7.5.2.1 but with relief for excess flow	
7.5.2.3	- with variable output	As 7.5.2.1 but with arrow 5.2.3 added to the symbol of restriction	
7.5.2.4	- with variable output and relief port to reservoir	As 7.5.2.3 but with relief for excess flow	
7.5.3	Flow dividing valve	The flow is divided into two flows in a fixed ratio substantially independent of pressure variations	
7.6	Shut-off valve	Simplified symbol	

10.16 Flow Control Valves

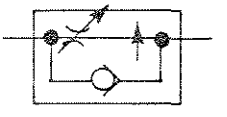
10.16.1 Adjustable, Non-Compensated (Flow control in each direction)



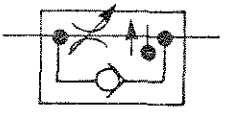
10.16.2 Adjustable with Bypass
Flow is controlled to the right
Flow to the left bypasses control.



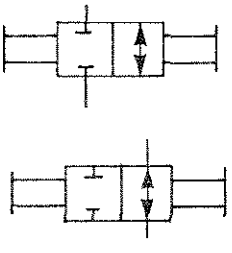
10.16.3 Adjustable and Pressure Compensated with Bypass



10.16.4 Adjustable, Temperature & Pressure Compensated



10.9 Two-Way Valves (2 Ported Valves)
10.9.1 On-Off (Manual Shut-Off)



Simplified

FLUID POWER GRAPHICAL SYMBOLS

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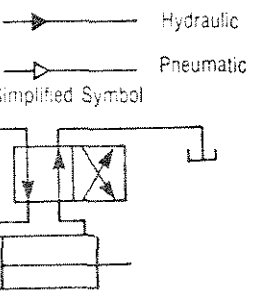
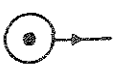
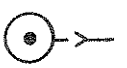
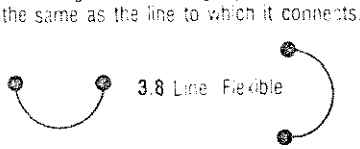
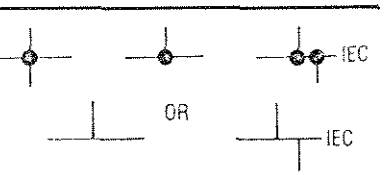
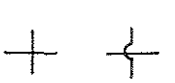
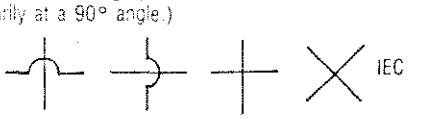
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol	
8	**ENERGY TRANSMISSION AND CONDITIONING**			4.4 Energy Source (Pump, Compressor, Accumulator, etc.) This symbol may be used to represent a fluid power source which may be a pump, compressor, or another associated system.
8.1	Sources of energy			
8.1.1	Pressure source	Simplified general symbol		
8.1.1.1	Hydraulic pressure source	Symbols to be used when the nature of the source should be indicated		
8.1.1.2	Pneumatic pressure source			
8.1.2	Electric motor	Symbol 113 in IEC Publication 117.2		8.8 Motors, Engines 8.8.1 Electric Motor 
8.1.3	Heat engine			8.8.2 Heat Engine (Internal Combustion Engine, Steam) 
8.2	Flow lines and connections			
8.2.1	Flow line:			
8.2.1.1	- working line, return line and feed line			3.1 Line, Working (main)
8.2.1.2	- pilot control line			3.2 Line, Pilot (for control)
8.2.1.3	- drain or bleed line			3.3 Line, Liquid Drain
8.2.1.4	- flexible pipe	Flexible hose, usually *connecting moving parts*		3.4 Line, sensing, etc. such as gauge lines shall be drawn the same as the line to which it connects. 
8.2.1.5	- electric line			
8.2.2	Pipeline junction			2.4.6 Lines joining 
8.2.3	Crossed pipelines	Not connected		2.4.5 Lines crossing (The intersection is not necessarily at a 90° angle.) 

FLUID POWER GRAPHICAL SYMBOLS

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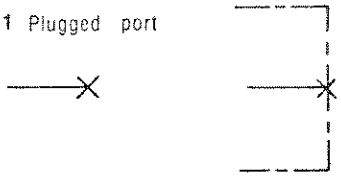
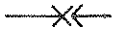
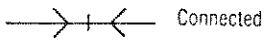
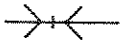
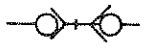
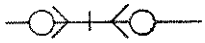
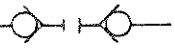
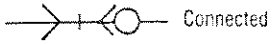
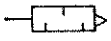
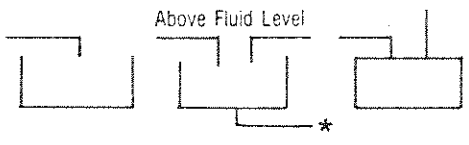
	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	
8.2.4	Air bleed			
8.2.5	Exhaust port:			3.6.1 Plain orifice, unconnectable 
8.2.5.1	- plain with no provision for connection			
8.2.5.2	- threaded for connection			3.6.2 Connectable orifice (E.G. Thread) by Internal Return 
8.2.6	Power take-off:	On equipment or lines, for energy take-off or measurement		3.9.1 Plugged port 
8.2.6.1	- plugged			
8.2.6.2	- with take-off line			
8.2.7	Quick-acting coupling:			3.10 Quick Disconnect 3.10.1 Without Checks  Connected  Disconnected
8.2.7.1	- connected, without mechanically opened non-return valve			3.10.2 With Two Checks
8.2.7.2	- connected, with mechanically opened non-return valves			Connected  Disconnected 
8.2.7.3	- uncoupled, with open end			3.10.3 With One Check
8.2.7.4	- uncoupled, closed by free non-return valve (see 7.3.1.1)			 Connected  Disconnected
8.2.8	Rotary connection:	Line junction allowing angular movement in service		3.11 Rotating Coupling
8.2.8.1	- one way			
8.2.8.2	- three way			
8.2.9	Silencer			9.3.3 Muffler 
8.3	Reservoirs			
8.3.1	Reservoir open to atmosphere:			4.1 Reservoir  Vented Pressurized
8.3.1.1	- with inlet pipe above fluid level			4.1.1 Reservoir with Connecting Lines  Above Fluid Level *

FLUID POWER GRAPHICAL SYMBOLS

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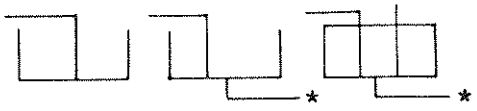
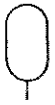
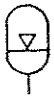
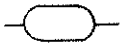
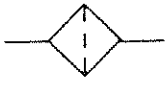
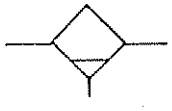
	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	
8.3.1.2	- with inlet pipe below fluid level			Below Fluid Level  *Show line entering or leaving below reservoir only when such bottom connection is essential to circuit function. 4.1.2 Simplified symbol. The symbols are  used as part of a complete circuit. They are analogous to the ground symbol of electrical diagrams  IEC Several such symbols may be used in one diagram to represent the same reservoir. 4.1.2.1 Below Fluid Level  4.1.2.2 Above Fluid Level (The return line is drawn to terminate at the upright legs of the tank symbol. 4.1.2.3 Vented Manifold 
8.3.1.3	- with a header line			
8.3.2	Pressurized reservoir			
8.4	Accumulators	The fluid is maintained under pressure by a spring weight or compressed gas (air, nitrogen, etc.)		4.2 Accumulator  4.2.2 Accumulator, Gas Charged  4.2.1 Accumulator, Spring Loaded  4.2.3 Accumulator, Weighted  4.3 Receiver, for Air or other Gases 
8.5	Filters, water traps, lubricators and miscellaneous apparatus			
8.5.1	Filter or strainer			5.2 Filter—Strainer 
8.5.2	Water trap:			5.3 Separator 5.3.1 With Manual Drain  5.3.2 With Automatic Drain 
8.5.2.1	- with manual control			
8.5.2.2	- automatically drained			

FLUID POWER GRAPHICAL SYMBOLS

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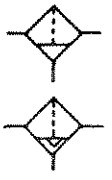
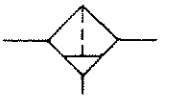
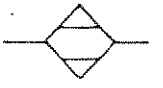
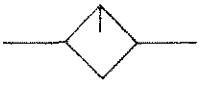
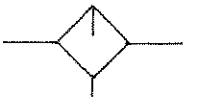
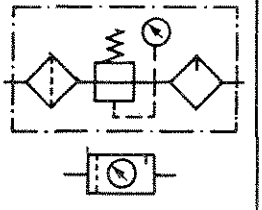
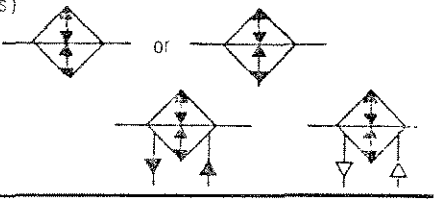
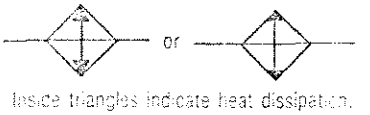
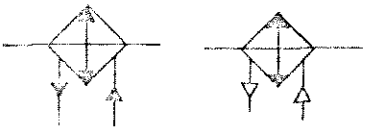
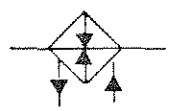
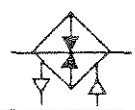
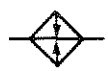
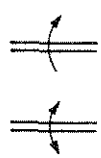
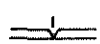
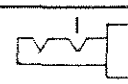
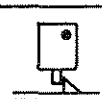
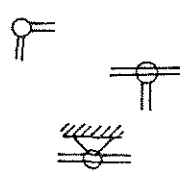
	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	
8.5.3	Filter with water trap:			5.4 Filter-Separator 5.4.1 With Manual Drain  5.4.2 With Automatic Drain 
8.5.3.1	- with manual control	Combination of 8.5.1 and 8.5.2.1		
8.5.3.2	- automatically drained	Combination of 8.5.1 and 8.5.2.2		
8.5.4	Air dryer	A unit drying air (for example by chemical means)		5.5 Dessicater (Chemical Dryer) 
8.5.5	Lubricator	Small quantities of oil are added to the air passing through the unit in order to lubricate equipment receiving the air		5.6.1 Less Drain  5.6.2 With Manual Drain 
8.5.6	Conditioning unit	Consisting of filter, pressure regulator, pressure gauge and lubricator		
8.5.6.1		- Detailed symbol		
8.5.6.2		- Simplified symbol		
8.6	Heat exchangers	Apparatus for heating or cooling the circulating fluid		
8.6.1	Temperature Controller	The fluid temperature is maintained between two predetermined values. The arrows indicate that heat may be either introduced or dissipated		5.1.3 Temperature Controller—(The temperature is to be maintained between two predetermined limits) 
8.6.2	Cooler	The arrows in the diamond indicate the extraction of heat		5.1.2 Cooler
8.6.2.1		- without representation of the flow lines of the coolant		
8.6.2.2		- indicating the flow lines of the coolant		Inside triangles indicate heat dissipation.  (Corners may be filled in to represent triangles.)

FLUID POWER GRAPHICAL SYMBOLS

	Graphic symbols shown below (left hand columns only) are in accordance with ISO 1219-1976 (E/F), "Fluid Power systems and components—graphic symbols".			Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.
	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	**5.1.1** Heater Inside triangles indicate the introduction of heat.  Outside triangles show the heating medium is liquid.  Outside triangles show the heating medium is gaseous. 
8.6.3	Heater	The arrows in the diamond indicate the introduction of *heat*		
9	**CONTROL MECHANISMS**			
9.1	Mechanical components			
9.1.1 9.1.1.1 9.1.1.2	Rotating shaft: - in one direction - in either direction	The arrow indicates rotation		*2.13 Rotating shafts are symbolized by an arrow* which indicates direction of rotation (assume arrow on near side of shaft). 
9.1.2	Detent	A device for maintaining a given position		7.4 Detent  (Show a notch for each detent in the actual component being symbolized. A short line indicates which detent is in use. Detent may be positioned on symbol for drafting convenience.)
9.1.3	Locking device	The symbol for unlocking control is inserted in the square		
9.1.4	Over-centre device	Prevents the mechanism *stopping in a dead centre* position		
9.1.5 9.1.5.1 9.1.5.2 9.1.5.3	Pivoting devices - simple - with traversing lever - with fixed fulcrum			
9.2	Control methods	The symbols representing control methods are incorporated in the symbol of the controlled apparatus to which they should be adjacent. For apparatus with *several sqares the actuation* of the control makes effective the square adjacent to it.		

FLUID POWER GRAPHICAL SYMBOLS

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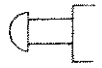
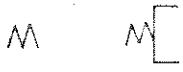
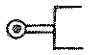
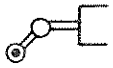
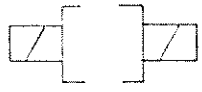
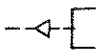
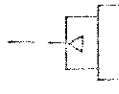
Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol	7.2 Manual (Use as general symbol without indication of specific type: i.e., foot, hand, leg, arm)
9.2.1	Muscular control:	General symbol (without indication of control type)		
9.2.1.1	- by push button			7.2.1 Push Button  7.2.2 Lever 
9.2.1.2	- by lever			
9.2.1.3	- by pedal			7.2.3 Pedal or Treadle 
9.2.2	Mechanical control			7.1 Spring 
9.2.2.1	- by plunger or tracer			
9.2.2.2	- by spring			7.3 Mechanical 
9.2.2.3	- by roller			
9.2.2.4	- by roller, operating in one direction only			7.5 Pressure Compensated 
9.2.3	Electrical control			7.6 Electrical 7.6.1 Solenoid (Single Winding) 
9.2.3.1	- by solenoid:			
9.2.3.1.1		- with 1 winding		
9.2.3.1.2		- with 2 windings operating in opposite directions		
9.2.3.1.3		- with 2 windings operating in a variable way progressively, operating in opposite direction		7.6.2 Reversing Motor
9.2.3.2	- by electric motor			
9.2.4	Control by application or release of pressure			7.7.2 Internal Supply
9.2.4.1	Direct acting control:			
9.2.4.1.1	- by application of pressure			7.7.3 Actuation By Released Pressure
9.2.4.1.2	- by release of pressure			 
9.2.4.1.3	- by different control areas	In the symbol the larger rectangle represents the larger control area, i.e. the priority phase		Remote Exhaust Internal Return

FLUID POWER GRAPHICAL SYMBOLS

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Approx. equiv. symbol (ANSI Y32.10-1967) as it appeared in 4th Edition of the Lightning Reference Handbook.

	Description	Use of the equipment or explanation of the symbol	Symbol
9.2.4.2	Indirect control, pilot actuated:	General symbol for pilot directional control valve	
9.2.4.2.1	- by application of pressure		
9.2.4.2.2	- by release of pressure		
9.2.4.3	Interior control paths	The control paths are inside the unit	
9.2.5	Combined control:		
9.2.5.1	- by solenoid and pilot directional valve	The pilot directional valve is actuated by the solenoid	
9.2.5.2	- by solenoid or pilot directional valve	Either may actuate the control independently	
9.3	Mechanical feedback	The mechanical connection of a control apparatus moving part to a controlled apparatus moving part is represented by the symbol 5.1.1.4 which joins the two parts connected. (For examples see 11.1.2 and 12.1.1)	1) 2) 1) Controlled apparatus 2) Control apparatus

7.7.4 Pilot Controlled, Spring Centered

Simplified Symbol

Complete symbol

7.7.5 Pilot Differential

Simplified Symbol Complete Symbol

7.8 Solenoid Pilot

7.8.1 Solenoid or Pilot

External Pilot Supply

Internal Pilot Supply and Exhaust

7.8.2 Solenoid and Pilot

7.9 Thermal—A mechanical device responding to thermal change.

7.9.1 Local Sensing

7.9.2 With Bulb for Remote Sensing

7.11 Composite Actuators (and, or and/or)

Basic — One signal only causes the device to operate.

FLUID POWER GRAPHICAL SYMBOLS

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	Description	**Use of the equipment or explanation of the symbol**	**Symbol**	And — One signal and a second signal both cause the device to operate. Or — One signal or the other signal causes the device to operate. And/Or — The solenoid and the pilot or the manual override alone causes the device to operate. The solenoid and the pilot or the manual override and the pilot. The solenoid and the pilot or a manual override and the pilot. or a manual override alone
10	**SUPPLEMENTARY EQUIPMENT**			
10.1	Measuring instruments			
10.1.1 10.1.1.1	Pressure measurement: - pressure gauge	The point on the circle at which the connection joins *the symbol is immaterial*		9.1 Indicating and Recording 9.1.1 Pressure
10.1.2 10.1.2.1	Temperature measurement: - Thermometer	The point on the circle at which the connection joins the symbol is immaterial.		9.1.2 Temperature
10.1.3 10.1.3.1 10.1.3.2	Measurement of flow: - Flow meter - Intergrating flow meter			9.1.3 Flow Meter 9.1.3.1 Flow Rate 9.1.3.2 Totalizing
10.2	Other apparatus			
10.2.1	Pressure electric switch			9.3.1 Pressure Switch