ÇANKAYA UNIVERSITY

MECE 104
INTRODUCTION FLUID POWER

Burkay SARI

Fluid Power Definition
Advantages
Power Conversion
Usage
Fluid Power Basics
Pressure-Area-Flow Rate
Fluids & Selection
Pumps
Valves
Actuators
Accumulators
Tank & Filters

What is Fluid Power ?

Fluid Power is the technical expertise of the generation, control and transmission of Power with the pressurized fluids.

Fluid : A substance which has a definite mass and volume at a specific temperature and pressure.

Fluids used in industrial applications are liquids and gases.

Keep in mind !!

Liquids can be considered as incompressible and have the shape of the container.

Gases are compressible fluids, and spread throughout the container.

What is Fluid Power ?

Fluid Power can be analysed in two (2) categories

1- HYDRAULICS
(Fluid Power transferred with incompressible fluids such as Oil or Water)

2- PNEUMATIC
(Fluid Power transferred with compressible fluids such as Air or Inert Gases)

+

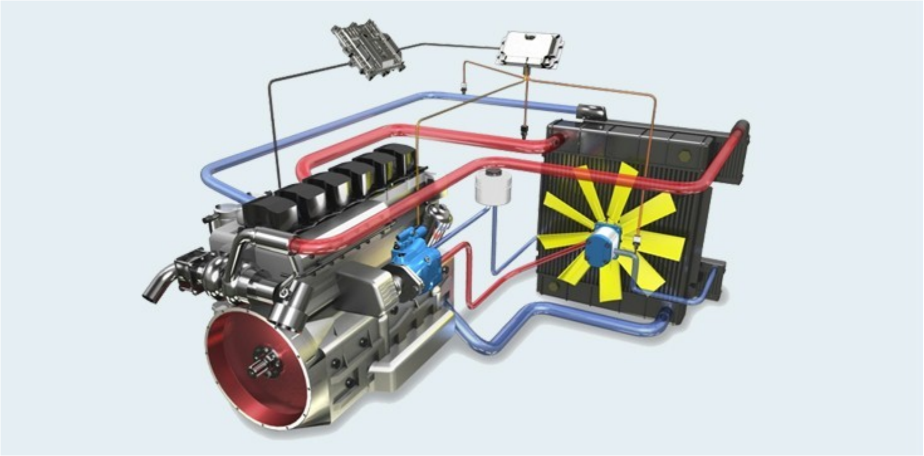
OR

+

Fluid Power

Hydrostatics, deals with the quasi static fluids

Example: Hydraulics can be considered as Hydrostatics



Hydrodynamics, Deals with the moving fluids

Example : Hydroelectrical Power Generation can be an example.

Power Transmission Types

Power Types	Advantages	Disadvantages
Mechanical	- Most Suitable when motion is transferred in short distance	-Limited speed change -System Wear an Maintenance,
Electrical	- Effective power transfer in long distances,	-Sophisticated and expensive systems, -Sensitive to working conditions; i.e. Temperature, dust,
Fluid	-Large power generation in small volumes, -Flexible and easy to apply, -Ease of Power generation and Precise Control,	- Hydraulic fluid behavior, leakage - Contamination sensitive, - Pneumatics have low force applications

ENERGY CONVERSION FLUID POWER SYSTEMS

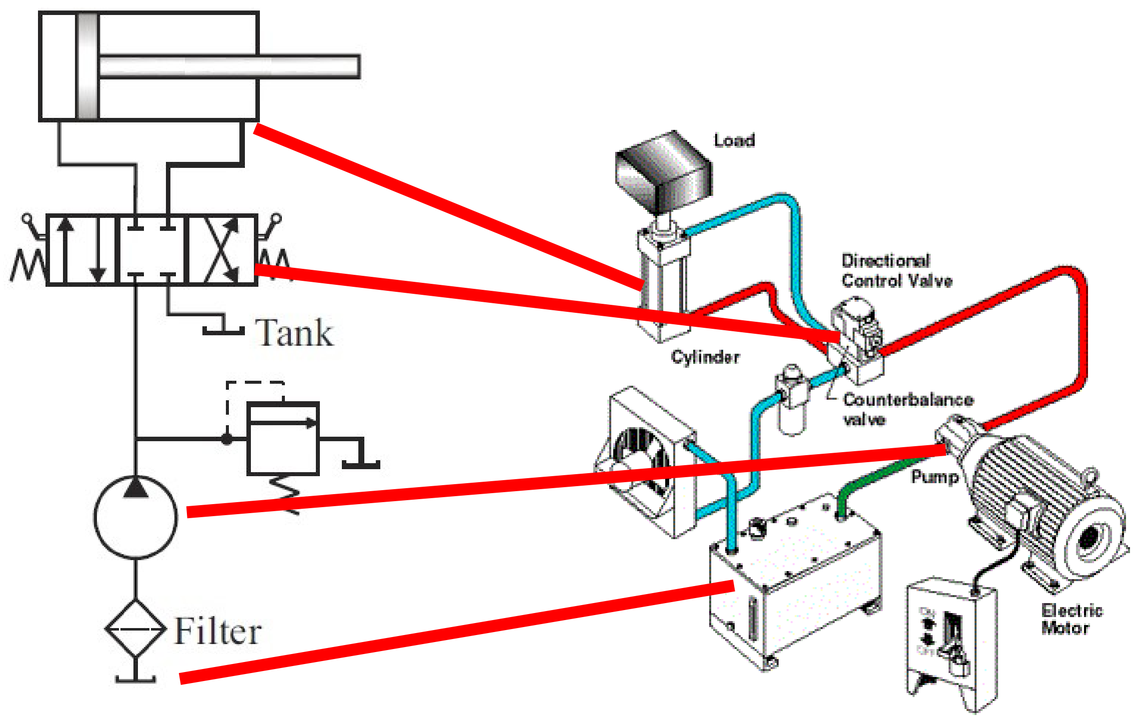
Power Source — Hydraulic Pump — Hydraulic Directional Control Valves — Hydraulic Actuator Cylinder/Motor — Work Done

Electrical / Combustion Energy — Mechanical Energy — Hydraulic Energy — Hydraulic Energy — Mechanical Energy

BASIC FLUID POWERED SYSTEM

Basic Components

- Energy Source (Motor)
- Hydraulic Pump
- Hydraulic Tank
- Hydraulic Relief Valve
- Hydraulic Cylinder
- Direction Control Valve



Fluid Power Applications

Mobile Applications	Machinery Applications			Factory Automation	Renewable Energies
Agricultural and Forestry Machinery	Architecture in Motion	Machine Tools (forming) and Presses	Rubber Processing	Assembly and Handling	Ocean Energy
Construction Machinery	Cement Industry	Marine	Shipyard Equipment	Automotive	Wind Energy
Material Handling	Chemical Industry	Materials Handling	Stage Technology	Machine Tools (cutting)	
On-Highway and Commercial Vehicles	Civil Engineering	Metallurgy	Sugar Industry	Packaging and Processing	
Aviation Applications	Energy Technology	Mineral Processing	Testing Technology	Printing and Converting	
Marine Applications	Engines	Mining	Transport Technology	Semiconductor and Electronics	
	Glass Making Machinery	Motion Simulation Technology	Tunnel Boring Machines	Solar	
	Horizontal and Utility Drilling	Offshore	Woodworking		
	Hydrodynamic Research	Oil and Gas land based			
		Plastic Machinery and Die Casting			
		Pulp and Paper Machinery			
		Recycling and Waste Handling			

Fluid Power Applications

Mobile Applications

- Agricultural and Forestry Machinery
- Construction Machinery
- Material Handling
- On-Highway and Commercial Vehicles
- Aviation Applications
- Marine Applications

Fluid Power Applications

Machinery Applications		
Architecture in Motion	Machine Tools (forming) and Presses	Rubber Processing
Cement Industry	Marine	Shipyard Equipment
Chemical Industry	Materials Handling	Stage Technology
Civil Engineering	Metallurgy	Sugar Industry
Dredging	Mineral Processing	Testing Technology
Energy Technology	Mining	Transport Technology
Engines	Motion Simulation Technology	Tunnel Boring Machines
Glass Making Machinery	Offshore	Woodworking
Horizontal and Utility Drilling	Oil and Gas land based	
Hydrodynamic Research	Plastic Machinery and Die Casting	
	Pulp and Paper Machinery	
	Recycling and Waste Handling	

Fluid Power Applications

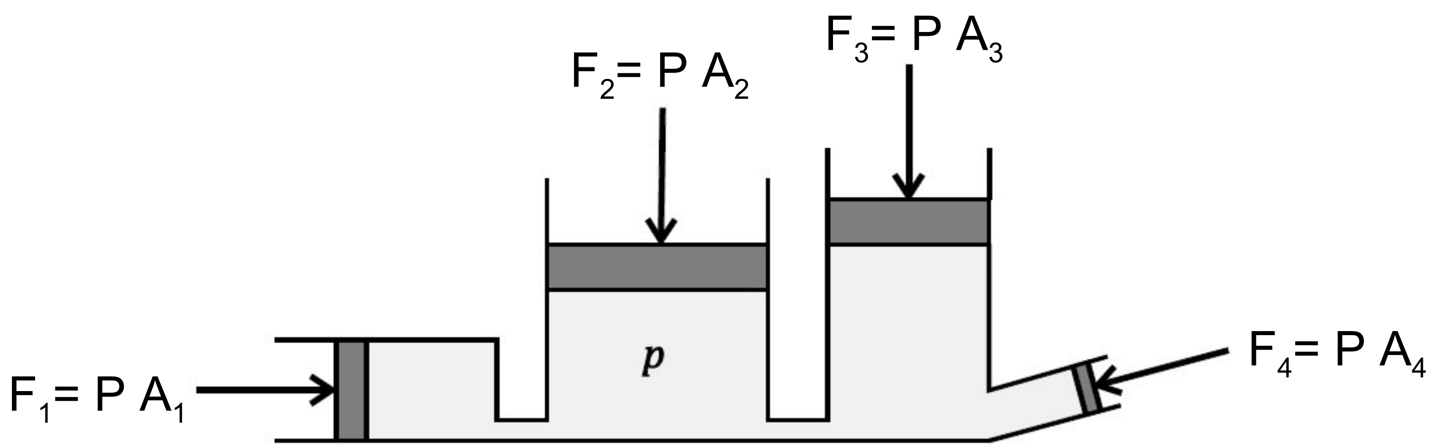
Factory Automation	Renewable Energies
Assembly and Handling	Ocean Energy
Automotive	Wind Energy
Machine Tools (cutting)	
Packaging and Processing	
Printing and Converting	
Semiconductor and Electronics	
Solar	

Pascal LAW

Pressure within a fluid at rest acts equally in all directions and at right angles to any surface on which it acts.

1- Conservation of Mass & Energy

2- Continuity



Units and Dimensions

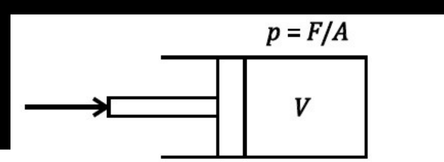
Force

$F = m\,a$

where,
F = in N (Newtons)
m = mass in kg (kilograms)
a = acceleration (m/s^2)

1 N = 1 kg m/ s^2

Cylinder Force Calculations
$F = P * A$
Where A is the area



Pressure
Pressure is force exerted per unit area in a direction that is normal to and towards the area
$P = F / A$

where,
P = Pressure in Pa or (N/m^2)
F = in N (Newtons)
A = Area (m^2)

Pressure Head (meters)
$P = \rho g h$
where,
ρ = density kg/m^3
g = gravitational acceleration m/s^2
h = depth below free surface

HYDRAULIC SYSTEM EQUIPMENTS

FLUIDS

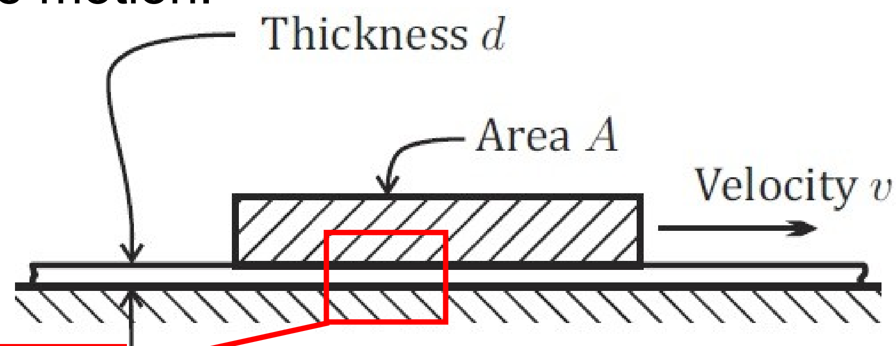
Viscosity

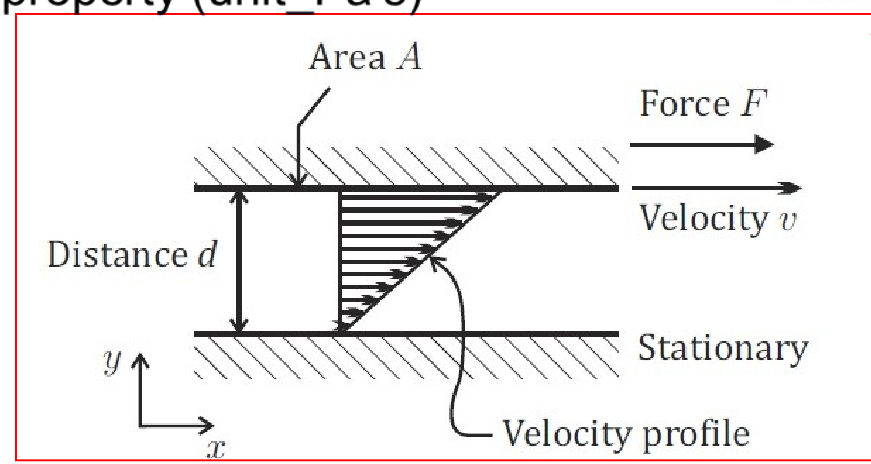
Viscosity is a property of a fluid, which quantifies how strongly that fluid resists relative motion.

$$F = \mu \frac{A\vartheta}{d}$$

Newtons Viscocity Equation

Where μ is absolute viscocity fluid property (unit_Pa s)





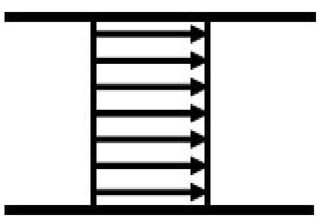
$$\gamma = \frac{\mu}{\rho}$$

Resim şu anda görüntülenemiyor.

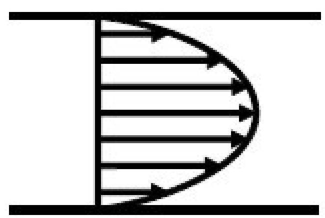
Pressure Losses in Pipes

Laminar & Turbulent Flow Definitions

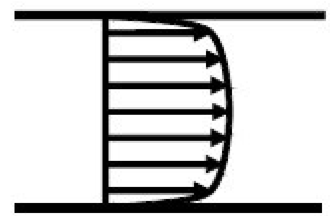
Due to the friction and the viscosity property of the fluid causes some flow patterns in the pipes



Uniform Flow



Laminar Flow

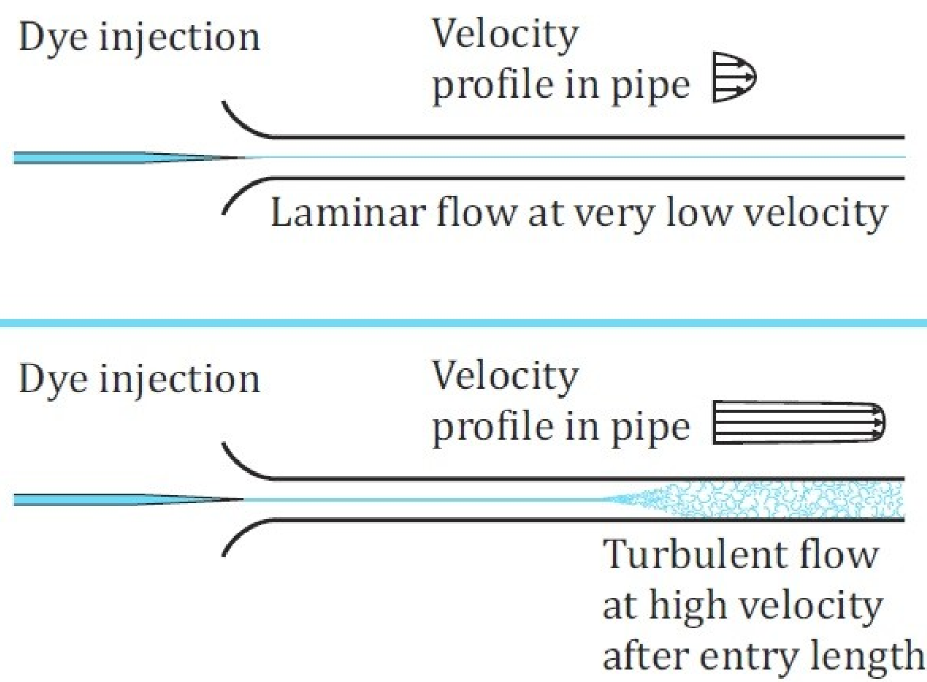


Turbulent Flow

Pressure Losses in Pipes

Turbulent Flow

Reynolds Experiment



Pressure Losses in Pipes

Reynolds Number

$$Re = \frac{\rho \vartheta d}{\mu} = \frac{\vartheta d}{\gamma}$$

Where,

Re , Reynolds Number, Unitless

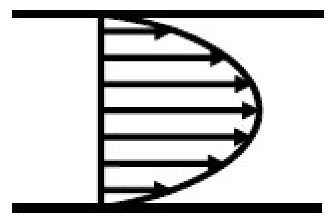
ρ, Density in kg/m^3,

ϑ, Velocity in m/s,

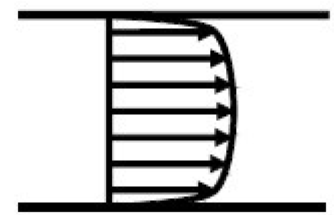
d, Diameter in m,

μ , Absolute Viscosity in Pa s

γ , Kinematic Viscosity in m^2 /s



Laminar Flow



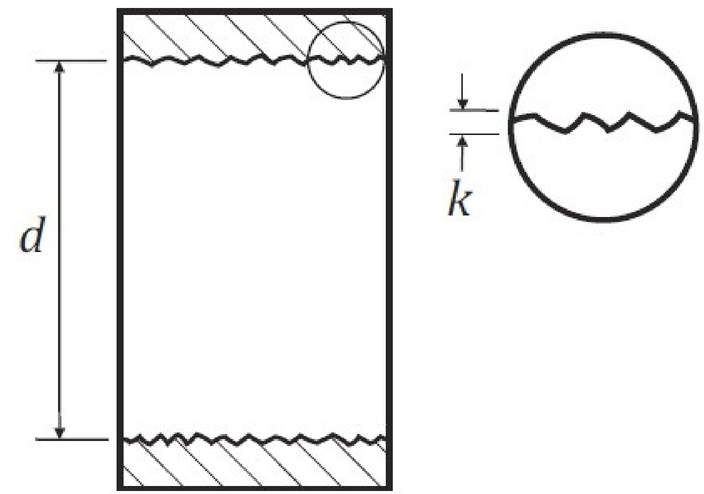
Turbulent Flow

Re < 2000	**Laminar Flow**
2000< Re<4000	**Both flow types possible**
Re> 4000	**Turbulent Flow**

Pressure Losses in Pipes

Darcy-Weisbach Equation

$$hf = \frac{4fL}{d}\frac{v^2}{2g}$$



Where,

hf, **head loss due to friction in meters**

f , **Friction Factor**

L , **Length of pipe in meters**

d , **Diameter in meters**

ϑ , **mean fluid velocity in m/s**

g , **acceleration due to gravity in m/s^2**

k , **Surface Roughness**

FLUID FUNCTIONS

Fluids must have some properties according to the system going to be used ,

-Correct Viscosity and High Viscosity Index,
-Suitable Chemical and Environmental properties, Non toxic,
-Should not react with the System Materials,
-Must Provide Lubrication,
-Fire Resistance,
-Foam Resistance,
-Low Density,
-Low Volatility,
-Large Bulk Modulus,
-Good Heat Transfer Capability,
-Inexpensible,
-Ease of supply,

FLUID SELECTION FOR APPLICATIONS

Applications	Suitable Fluids *	Max. Working Pressure	Working Temperature	Working Environment
Vehicles	1 • 2 • 3	250 bar	-40 to +60 °C	open & closed
Construction Machinery	1 • 2 • 3	315 bar	-40 to +60 °C	open & closed
Special Vehicles	1 • 2 • 3 • 4	250 bar	-40 to +60 °C	open & closed
Forestry Machines	1 • 2 • 3	250 bar	-40 to +50 °C	open & closed
Marine	1 • 2 • 3	315 bar	-60 to +60 °C	open & closed
Aerospace	1 • 2 • 5	210 (280) bar	-65 to +60 °C	open & closed
Material Handling, Conveyors	1 • 2 • 3 • 4	315 bar	-40 to +60 °C	open & closed
Machine Tools	1 • 2	200 bar	18 to 40 °C	open
Hydraulic Presses	1 • 2 • 3	630 bar	18 to 40 °C	generally open
Casting & Steel Production	1 • 2 • 4	315 bar	10 to 150 °C	open
Steel & Dam Applications	1 • 2 • 3	220 bar	-40 to +60 °C	open & closed
Power Plant	1 • 2 • 3 • 4	250 bar	-10 to +60 °C	generally open
Parforming Arts	1 • 2 • 3 • 4	160 bar	18 to 30 °C	generally open
Simulation and Testing Machines	1 • 2 • 3 • 4	1000 bar	18 to 150 °C	generally open
Mining	1 • 2 • 3 • 4	1000 bar	up to 60 °C	Closed & u.ground
Special Applications	2 • 3 • 4 • 5	250 (630) bar	-65 to 150 °C	open & closed

*) 1= Mineral Oil   2= Syntetic Oils   3= Enviromantal Friendly   4=Water, HFA, HFB   5=Special Oils

FLUID SELECTION FOR APPLICATIONS

Mineral yağ esaslı hidrolik yağ	WEC	Yanmaz akışkanlar	WEC	Çevredostu akışkanlar	WEC	Özel akışkanlar	WEC
DIN 51524, 1. bölüm Hidrolik yağ HL	2	Berrak su	0	Temel akışkan	·	Sentetik yağ	
Mineral yağ esaslı korozyona ve yaşlanmaya karşı katkı maddeleri içeren hidrolik akışkan		HFA tipleri (95/5)		Bitkisel yağlar (HTG) (Trigliserit)	0-1	(örneğin Poli-α olefin ve glikol)	
DIN 51524, 2. bölüm Hidrolik yağ HLP		HFA-E (emülsiyon)	3	Poli glikol (HPG)	0-1	Uçaklarda kullanılan akışkan	
HL tipi hidrolik yağ ile aynı özellikte, ancak ilave olarak sürtünme bölgelerinde aşınmaya karşı aktif katkı maddeli		HFA-M (mikro-emülsiyon)	3	Sentetik ester (HE)	0-1	Hadde yağı ile uyumlu akışkanlar	
DIN 51524, 2. bölüm Hidrolik yağ HLP-D		HFA-S (çözelti)	0-1			vs..	
HLP tipi hidrolik yağ ile aynı özellikte, ancak ilave olarak her biri aktif yayılma ve derterjan katkı maddeli, HLP yağlardan farklı olarak hava ve suyu ayrıştırmak gerekmez.		HFA-V (kalınlaştırılmış) % 80 H_2O + % 20 konsantre	~1				
DIN51524, 1. bölüm Hidrolik yağ HLP		HFB (yağ emilsiyonu içeren su) % 40 H_2O + % 60 mineral yağ	3				
HLP tipi yağ ile aynı özellikte, ancak ilave olarak viskozite / sıcaklık karakteristiğinin iyileştirilmesi için aktif katkı maddeli		HFC (su glikol) % 40 H_2O + % 60 glikol	0-1				
		HFD-R (fosfat ester)	1-(2)				
		HFD-U (diğer kombiasyonlar) (genelde poliester)	~1				

WEN
Suya zarar verme ka

WEC
Suya zarar verme sı

Açıklama

verirler

FLUID FUNCTIONS

Viscosity and High Viscosity Index,

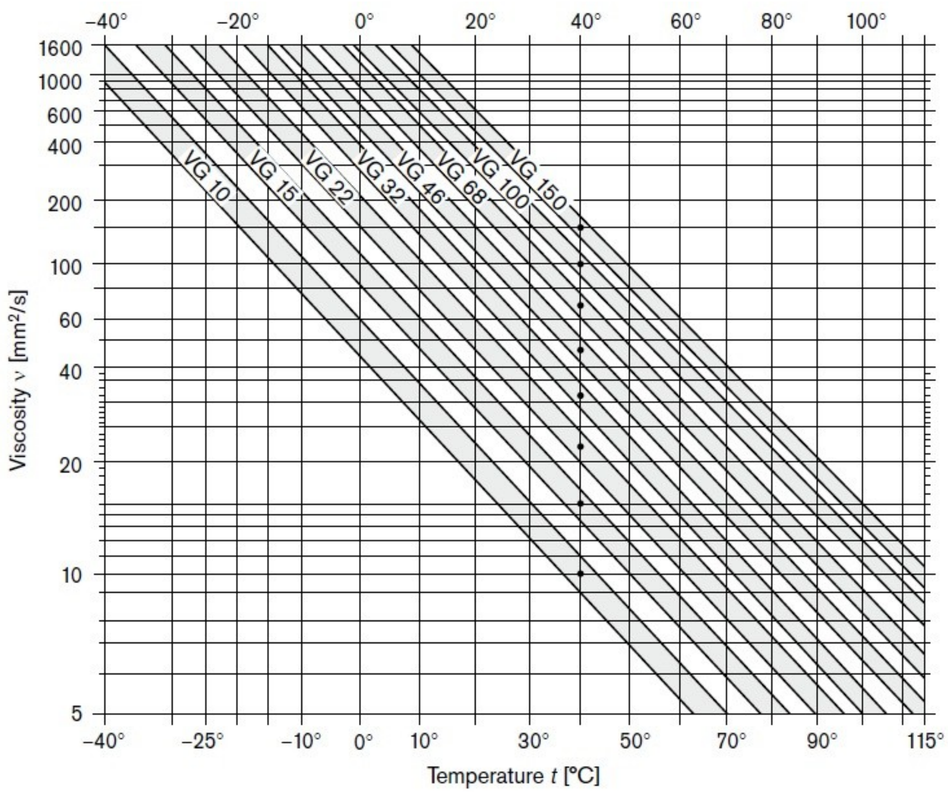
If the viscosity of a hydraulic fluid used is above the permitted operating viscosity, this will result in increased hydraulic-mechanical losses. In return, there will be lower internal leakage losses.

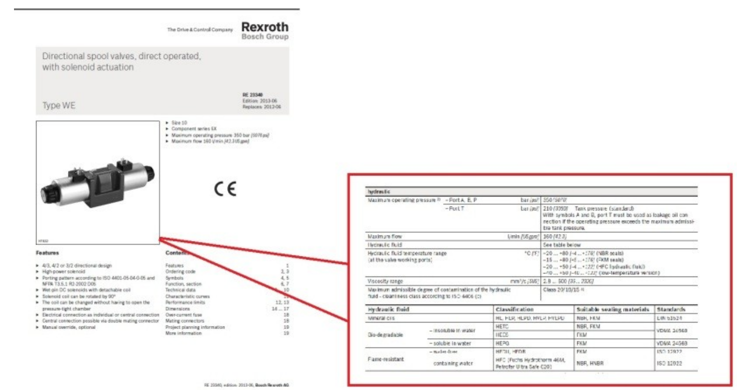
If the pressure level is lower, lubrication gaps may not be filled up, which can lead to increased wear. For hydraulic pumps, the permitted suction pressure may not be reached, which may lead to cavitation damage.

If the viscosity of a hydraulic fluid is below the permitted operating viscosity, increased leakage, wear, susceptibility to contamination and a shorter component life cycle will result.

FLUID FUNCTIONS

Viscosity – Temperature Effect





Hydraulic Oil must provide lubrication film thickness in System Temperature limits

FLUID FUNCTIONS

Viscosity – Temperature Considerations

Use only oils listed below or equivalent.
Do not mix different brand oil.

Service point	Kind of fluid	Capacity ℓ (U.S. gal)	Ambient temperature ℃(°F) -20 (-4), -10 (14), 0 (32), 10 (50), 20 (68), 30 (86), 40 (104)
Engine oil pan	Engine oil	14.2(3.8)	SAE 30 SAE 10W SAE 10W-30 SAE 15W-40
Transmission case		3.8(1.0)	
	Gear oil	5.0(1.3)	SAE 85W-140
		3)	NLGI NO.1 NLGI NO.2
		2×2) 5×4)	SAE 85W-90
		.6) .3)	ISO VG 32 ISO VG 46 ISO VG 68
		.5)	ASTM D975 NO.1 ASTM D975 NO.2
Fitting (Grease nipple)	Grease	As required	NLGI NO.1 NLGI NO.2
Radiator (Reservoir tank)	Mixture of antifreeze and water 50 : 50	35(9.2)	Ethylene glycol base permanent type

SAE : Society of Automotive Engineers
API : American Petroleum Institute
ISO : International Organization for Standardization
NLGI : National Lubricating Grease Institute
ASTM : American Society of Testing and Material

Service point	Kind of fluid	Capacity ℓ (U.S. gal)	Ambient temperature ℃(°F) -20 (-4), -10 (14), 0 (32), 10 (50), 20 (68), 30 (86), 40 (104)
Hydraulic tank	Hydraulic oil	Tank: 180(47.6) System: 270(71.3)	ISO VG 32 ISO VG 46 ISO VG 68

FLUID FUNCTIONS

Viscosity – Temperature Effect

The Drive & Control Company **Rexroth** Bosch Group

Directional spool valves, direct operated, with solenoid actuation

Type WE

RE 23340
Edition: 2013-06
Replaces: 2012-06

- Size 10
- Component series 5X
- Maximum operating pressure 350 bar *[5076 psi]*
- Maximum flow 160 l/min *[42.3 US gpm]*

CE

Features

- 4/3, 4/2 or 3/2 directional design
- High-power solenoid
- Porting pattern according to ISO 4401-05-04-0-05 and NFPA T3.5.1 R2-2002 D05
- Wet-pin DC solenoids with detachable coil
- Solenoid coil can be rotated by 90°
- The coil can be changed without having to open the pressure-tight chamber
- Electrical connection as individual or central connection
- Central connection possible via double mating connector
- Manual override, optional

Contents

RE 23340, edition: 2013-06, **Bosch Rexroth AG**

Technical data
(for applications outside these parameters, please consult us!)

general				
Weight			Individual connection	Central connection
	– Valve with one solenoid	kg *[lbs]*	3.6 *[7.9]*	3.5 *[7.7]*
	– Valve with two solenoids	kg *[lbs]*	4.4 *[9.7]*	4.3 *[9.5]*
Installation position			Any	
Ambient temperature range		°C *[°F]*	–30 … +50 *[–22 … +122]* (NBR seals) –20 … +50 *[–4 … +122]* (FKM seals)	
$MTTF_d$ values according to EN ISO 13849		Years	150 (for further details see data sheet 08012)	

hydraulic			
Maximum operating pressure	– Port A, B, P	bar *[psi]*	315 *[4569]*
	– Port T	bar *[psi]*	160 *[2320]* With symbols A and B, port T has to be used as leakage oil connection if the operating pressure exceeds the tank pressure.
Maximum flow		l/min *[US gpm]*	120 *[31.7]*
Flow cross-section (spool position 0)	– Symbol V	mm^2 *[$inch^2$]*	11 *[0.017]* (A/B to T); 10.3 *[0.016]* (P to A/B)
	– Symbol W	mm^2 *[$inch^2$]*	2.5 *[0.004]* (A/B to T)
	– Symbol Q	mm^2 *[$inch^2$]*	5.5 *[0.009]* (A/B to T)
Hydraulic fluid			See table below
Hydraulic fluid temperature range (at the valve operating ports)		°C *[°F]*	–30 … +80 *[–22 … +176]* (NBR seals) –20 … +80 *[–4 … +176]* (FKM seals)
Viscosity range		mm^2/s *[SUS]*	2.8 … 500 *[35 … 2320]*
Maximum admissible degree of contamination of the hydraulic fluid - cleanliness class according to ISO 4406 (c)			Class 20/18/15 [1)]

FLUID FUNCTIONS

Selected fluids must be environmental and application friendly,

NON-TOXIC,

FIRE RESISTANCE

APPLICATION FRENDINESS (FOOD INDUSTRY)

LOW DENSITY

LOW VOTALITY

INEXPENSİBLE,

Hydraulic fluids

Title	Hydraulic fluids based on mineral oils and related hydrocarbons	Environmentally acceptable hydraulic fluids	Fire-resistant, water-free hydraulic fluids	Fire-resistant, water-containing hydraulic fluids
Standard	DIN 51524	ISO 15380	ISO 12922	ISO 12922
Data sheets	RE 90220 RE 90220-01 (Market overview)	RE 90221 RE 90221-01 (Market overview)	RE 90222	RE 90223 (in preparation)
Classification	HL HLP HLPD HVLP HLPD and more	HEPG HEES partially saturated HEES saturated HEPR HETG	HFDR HFDU (ester base) HFDU (glycol base) and more	HFC HFB HFAE HFAS

FLUID CONSIDERATIONS

Selected fluid must also be considered in application suitability,

Wear protection capability

Tested as described in DIN 51524-2,-3 via test procedures "FZG gear test rig" (ISO 14635-1) and "Mechanical test in the vane pump" (ISO 20763).
But Not applicable ISO VG 32.

Aging Resistance

The way a hydraulic fluid ages depends on the thermal, chemical and mechanical stress to which it is subjected.

Reservoir temperature	Fluid life cycle
80 °C	100 %
90 °C	50 %
100 °C	25 %

Material compatibility

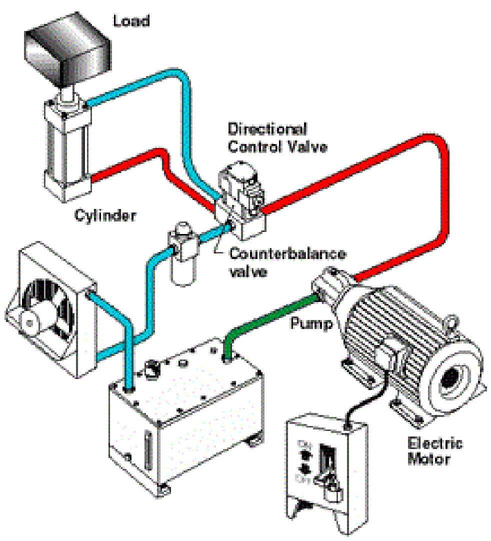
Classification	Incompatible with:
HLxx classifications	with EPDM seals
Zinc- and ash/free hydraulic fluids	with bronze-filled PTFE seals

HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)
- i- Gear
  - 1- External
  - 2- Internal
  - 3- External
- ii- Screw
- iii- Vane
  - 1- Balanced
  - 2-Unbalanced
- iv-Piston
  - 1- Radial
  - 2- Axial
    - -Bent Axis
    - -Swash Plate

B-Non-Positive Displacement
(Hydrodynamic)
- Centrfifugal (Impeller)
- Axial (Propeller)



HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

PUMP GENERAL CHARACTERISTICS

Type Of Pump			Pressure Capacity (bar)	Maximum Flow Rate (l/min)	Speed (rpm)	Viscosity (cS)	Approximate Efficiency
External Gear Pump			100-300	200	500-6000	40-80	% 80-90
Internal Gear Pumps			150-300	200	500-3000	40-80	% 80-90
Lobe Gear Pump			30-50	300			
Screw Pump			50-200	200	1000-3500	80-200	% 70-80
Vane Pumps	Fixed Displacement		100-200	300	500-3000	20-160	% 70-80
	Variable Displacement		40-160	125	500-2000	20-160	% 70-80
Piston Pumps	Radial		Up to 700	125	1000-3000	10-200	% 85-90
	Axial	Bent Axis	Up to 400	200	500-3000	20-50	% 85-90
		Swash Plate	150-400	200	1000-3000	30-50	% 85-90

PUMP SELECTING CRITERIAS FOR APPLICATIONS

CRITERIA	Type									
	DDP	İDP	OP	VP	TOPP	ÇOPP	EŞRPP	ESBRPP	EEPEPP	EDPEPP
Available Speed	1	2	2	2	3	3	2	2	2	2
Available Pressure	2	2	3	3	3	3	1	1	1	1
Viscosity	1	2	3	1	3	3	1	1	1	1
Noise Level	4	1	2	1	2	2	3	3	3	3
Product Life	3	2	2	1	1	1	2	2	2	2
Price	1	2	2	3	2	2	3	3	3	3

External Gear	=	DDP
Internal Gear Pump	=	İDP
Orbital Pump	=	OP
Screw Pump	=	VP
Unballanced Vane Pump	=	TOPP
Ballanced Vane Pump	=	ÇOPP
Radial Piston Pump	=	EŞRPP
Radial Eccentric Piston Pump	=	ESBRPP
Bent Axis Piston Pump	=	EEPEPP
Bent Axis Disk Piston Pump	=	EDPEPP

HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)

i- Gear

1- External

2- Internal

3- Lobe

ii- Screw

iii- Vane

1- Balanced

2-Unbalanced

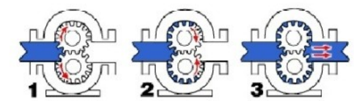
iv-Piston

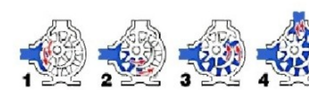
1- Radial

2- Axial

-Bent Axis

-Swash Plate





HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)

i- Gear

1- External

2- Internal

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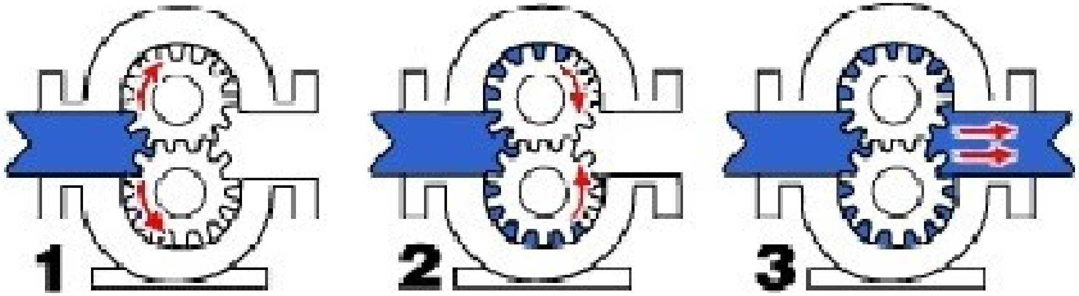
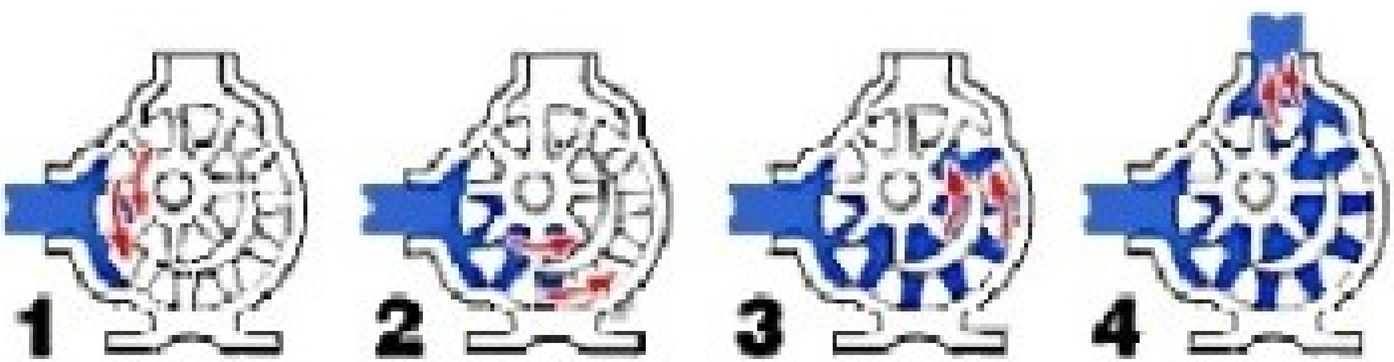


HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)

i- Gear
- 1- External
- 2- Internal
- 3- Lobe



HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

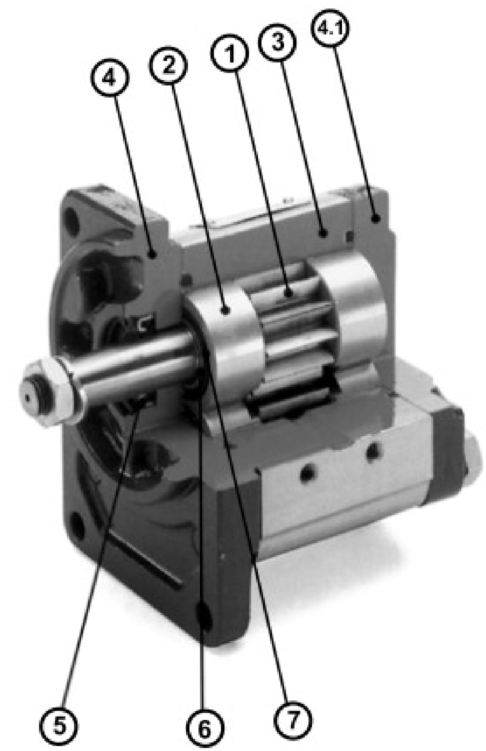
A-POSITIVE DISPLACEMENT
(Hydrostatic)

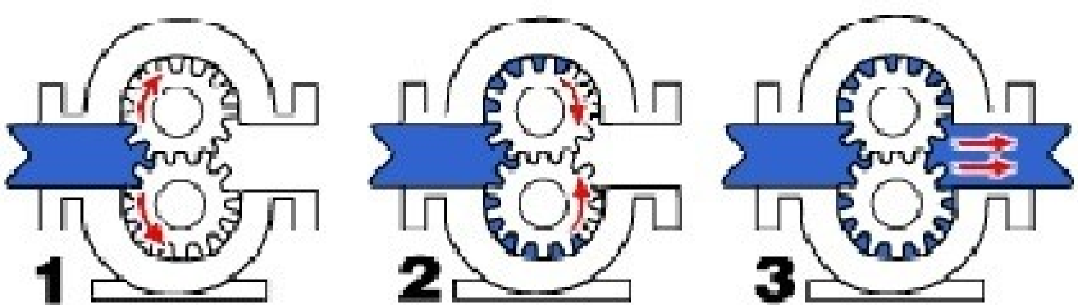
i- Gear
1- External
2- Internal
3- Lobe

GEAR PUMPS (External Gear Pumps)

V = m * z * b * h * pi
m= gear module
z= tooth #
b= tooth width
h= tooth height

① Gears
② Bearings
③ Extruded aluminium body
④ Covers
⑤ Shaft seal
⑥ Plain-bearing
⑦ Thrust pressure seal
⑧ Center coupling



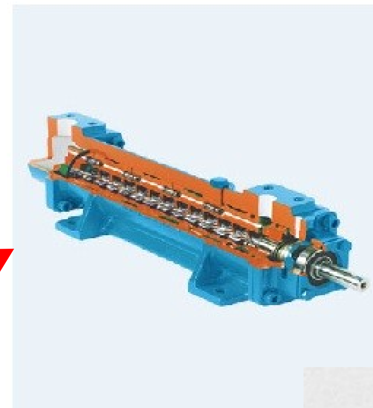


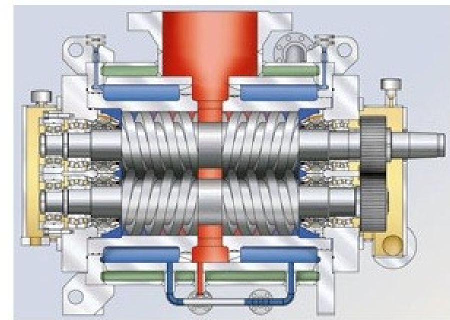
HYDRAULIC SYSTEM EQUIPMENTS

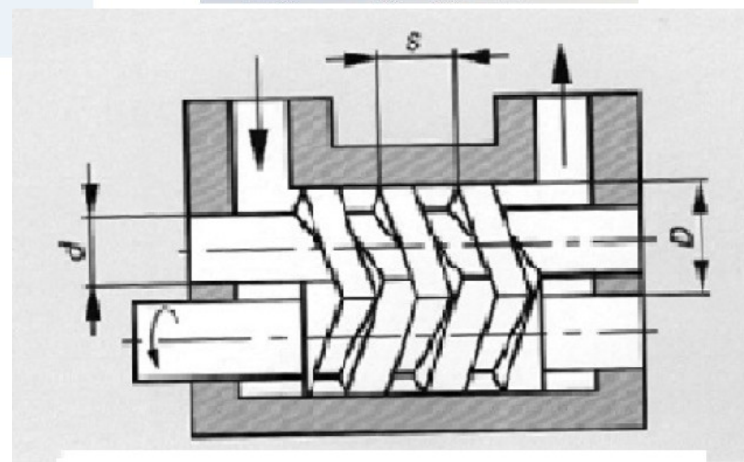
PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)

- i- Gear
  - 1- External
  - 2- Internal
  - 3- Lobe
- **ii- Screw**
- **iii- Vane**
  - **1- Balanced**
  - **2-Unbalanced**
- iv-Piston
  - 1- Radial
  - 2- Axial
    - -Bent Axis
    - -Swash Plate







$$V = \frac{\pi}{4}(D^2 - d^2) \cdot s - D^2\left(\frac{\alpha}{2} - \frac{\sin 2\alpha}{2}\right)s$$

$$\cos \alpha = \frac{D+d}{2D}$$

HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)
- i- Gear
  - 1- External
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  - 3- Lobe
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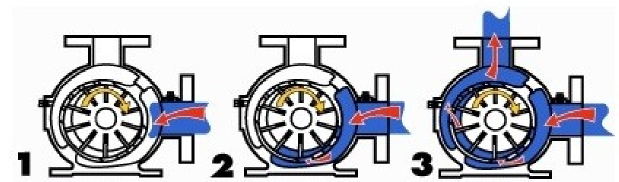
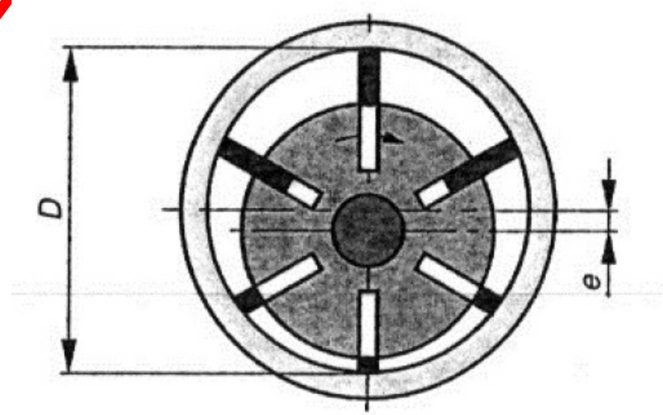
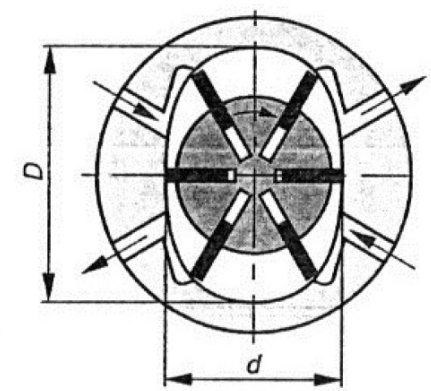




$$V = 2 \cdot \pi \cdot b \cdot e \cdot D$$

b = Width



$$V = \left(\frac{\pi \cdot (D^2 - d^2)}{4} \right) \cdot k \cdot b$$

b = Width

k = Displacement per /Stroke

HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)
- i- Gear
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  - 3- Lobe
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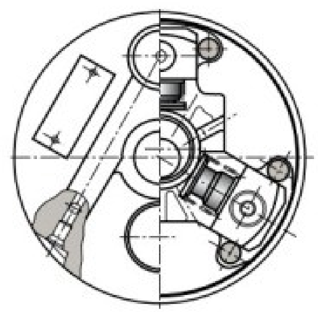
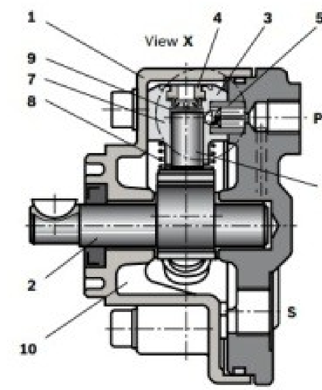
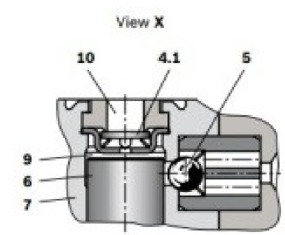
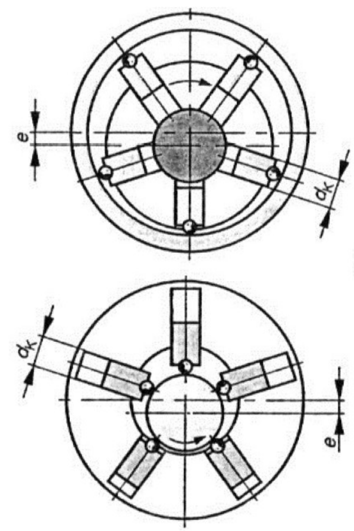
- **iv-Piston**
  - **1- Radial**
  - **2- Axial**
    - **-Bent Axis**
    - **-Swash Plate**









$$V = \frac{d_K^2 \cdot \pi}{4} \cdot 2e \cdot z$$

z = piston #

HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)

- i- Gear
  - 1- External
  - 2- Internal
  - 3- Lobe
- ii- Screw
- iii- Vane
  - 1- Balanced
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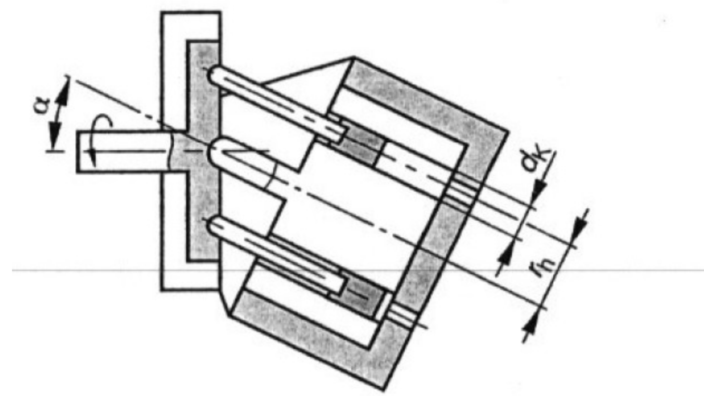
- **iv-Piston**
  - **1- Radial**
  - **2- Axial**
    - **-Bent Axis**
    - **-Swash Plate**



$$V = \frac{dk^2 \bullet \pi}{4} \bullet 2rh \bullet z \bullet \sin \alpha$$

z = piston #

HYDRAULIC SYSTEM EQUIPMENTS

PUMPS

A-POSITIVE DISPLACEMENT
(Hydrostatic)
- i- Gear
  - 1- External
  - 2- Internal
  - 3- Lobe
- ii- Screw
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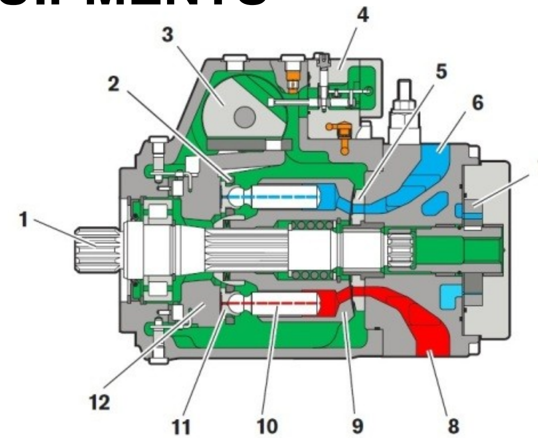
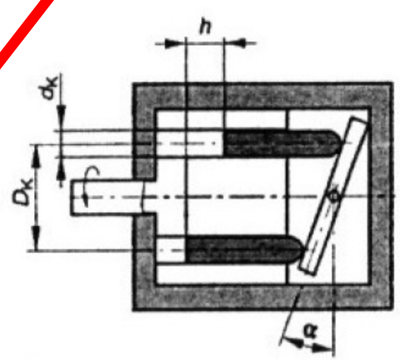
  - **2- Axial**
    - **-Bent Axis**
    - **-Swash Plate**



1 Drive shaft
2 Retaining plate
3 Stroke piston
4 Controller (using the EP as an example here)
5 Control plate
6 Low-pressure side
7 Auxiliary pump
8 High-pressure side
9 Cylinder
10 Piston
11 Slipper pad
12 Swashplate



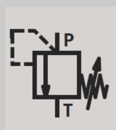
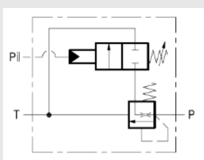
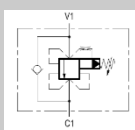
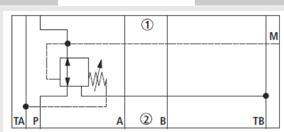
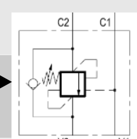
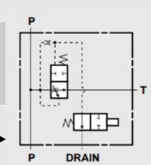
$$V = \frac{dk^2 \cdot \pi}{4} \cdot D_k \cdot \tan\alpha$$

HYDRAULIC SYSTEM EQUIPMENTS

VALVES

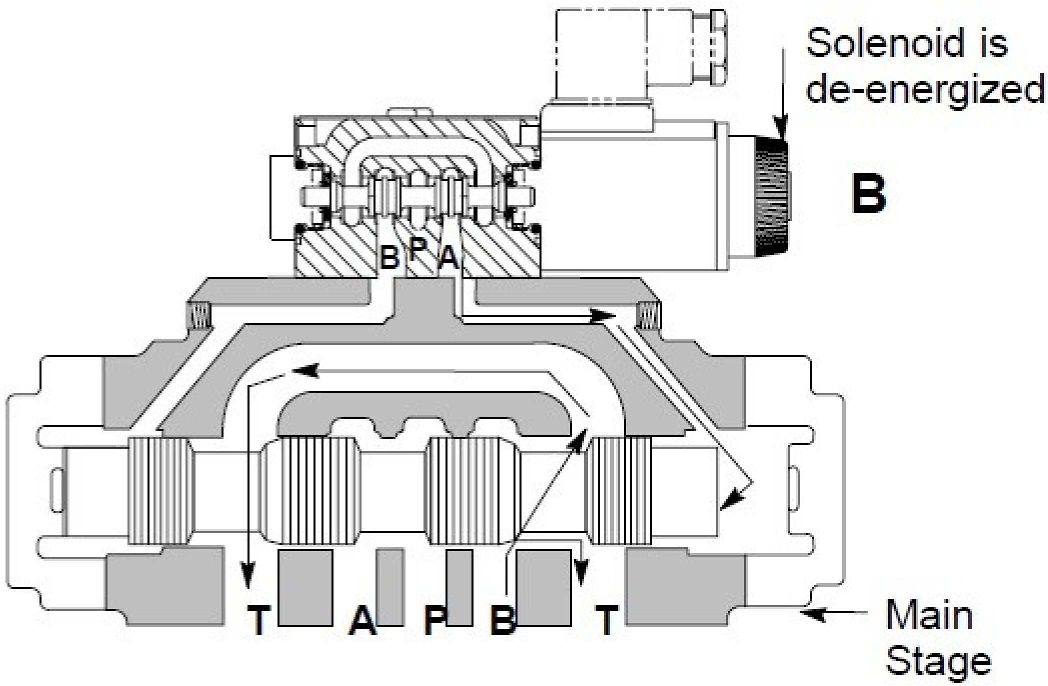
HYDRAULIC SYSTEM EQUIPMENTS_VALVES

Valve Types

Pressure Control		Direction Control		Flow Control
Relief Valve		Types -Ball -Puppet -Spool	Way -2/4 -4/3 -4/5	Uncompensated -Fixed Orifice -Variable Orifice,
Unloading Valve		Center Type -Open -Closed -Tandem	Actuation -Manual -Electric -Mechanical -Fluid (Pilot)	Pressure Compensated -Fixed Volume -Variable Volume
Sequence Valve				Deceleration Valve
Pressure Reducing Valve				Flow Divider -Adjustable -Priority -Demand Compensated
Counterbalance Valve	→			
Decompression Valve	→			

HYDRAULIC SYSTEM EQUIPMENTS_VALVES

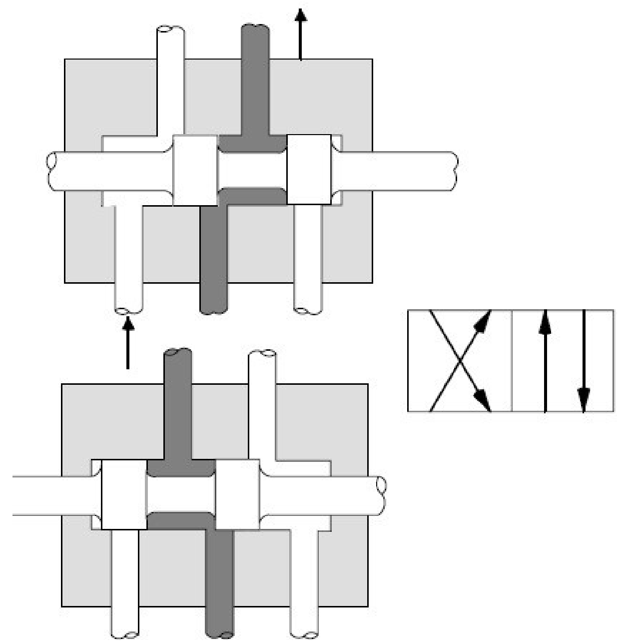
Directional Valve Types_ Pilot-Solenoid Operated



HYDRAULIC SYSTEM EQUIPMENTS_VALVES

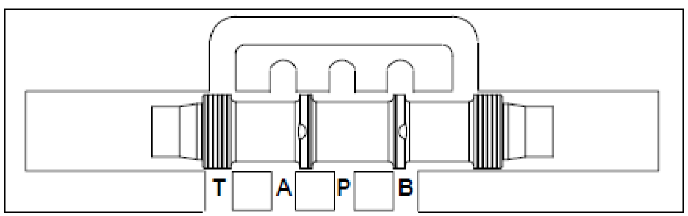
Directional Valve

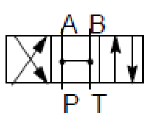
Simple 4 / 2



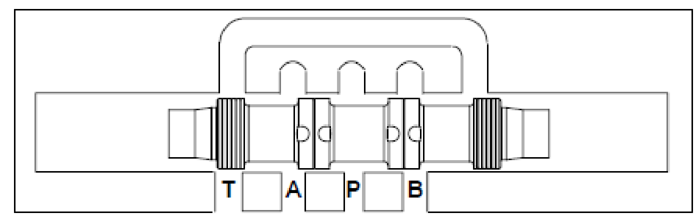
HYDRAULIC SYSTEM EQUIPMENTS_VALVES

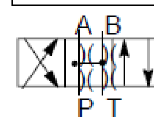
Directional Valve Types_ Open Center



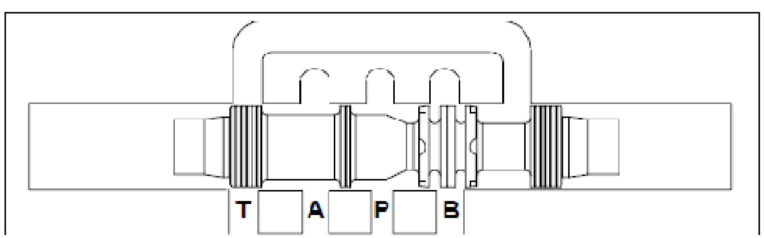


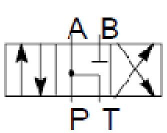
Open Center



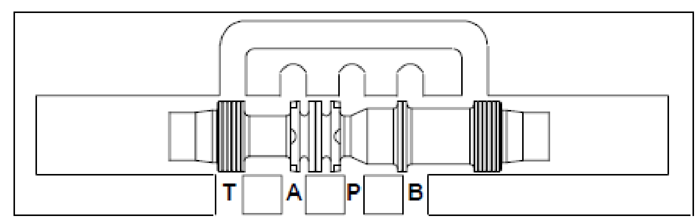


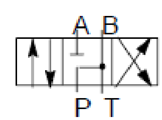
Open Center, Partial, All Ports





"B" Closed - Pressure Open to Tank through "A"





"A" Closed, Pressure Open to Tank through "B"

HYDRAULIC SYSTEM EQUIPMENTS

ACTUATORS

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Actuators (Cylinders)

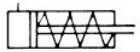
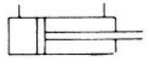
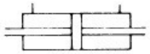
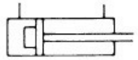
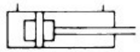
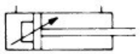
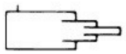
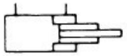
Actuators turns Hydraulic Power into Mechanical actuation,

Cylinders give **Linear**

Hydraulic Motors gives **Rotational**

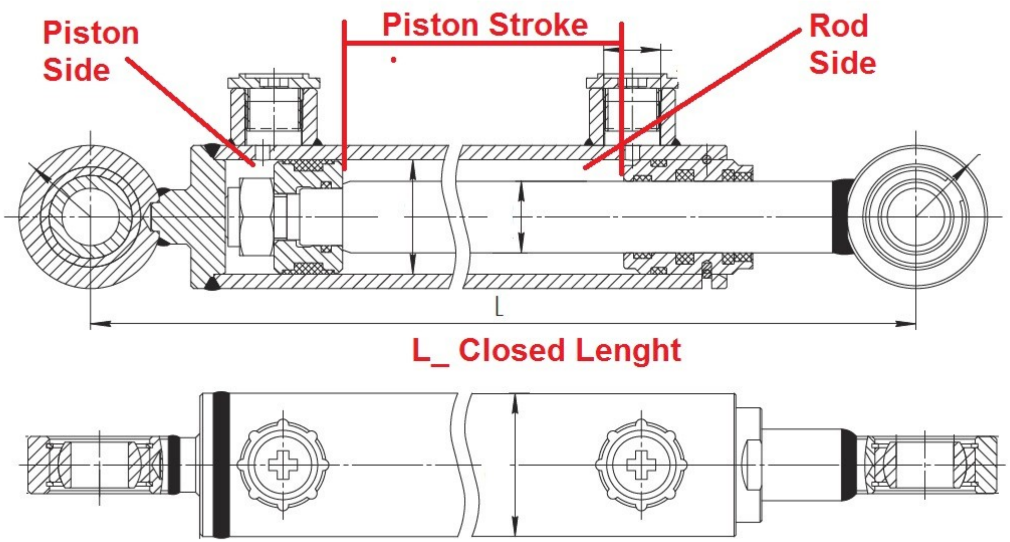
HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Actuators (Cylinders)
Hydraulic Symbols

CYLINDERS

Graphic symbol	Item	Description
	Single-acting cylinder	Return stroke by external force
		Return stroke through a spring
	Double-acting cylinder	Single rod
		Double rod
	Cylinder with fixed stroke end cushioning	Cushioning on one side
		Cushioning on both sides
	Cylinder with adjustable stroke end cushioning	Cushioning on one side
		Cushioning on both sides
	Telescopic cylinder	Single-acting
		Double-acting

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Actuators (Cylinders)

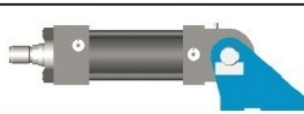
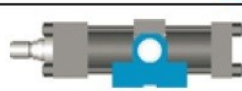
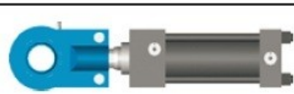
Cylinder Definitions

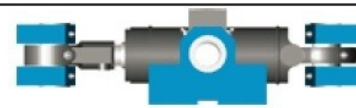
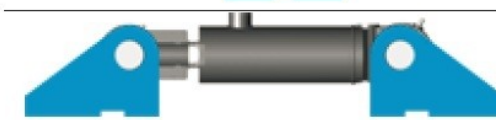
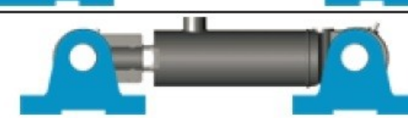


HYDRAULIC SYSTEM CIRCUIT ELEMENTS

Actuators (Cylinders)

Cylinder Typical Mounting Examples

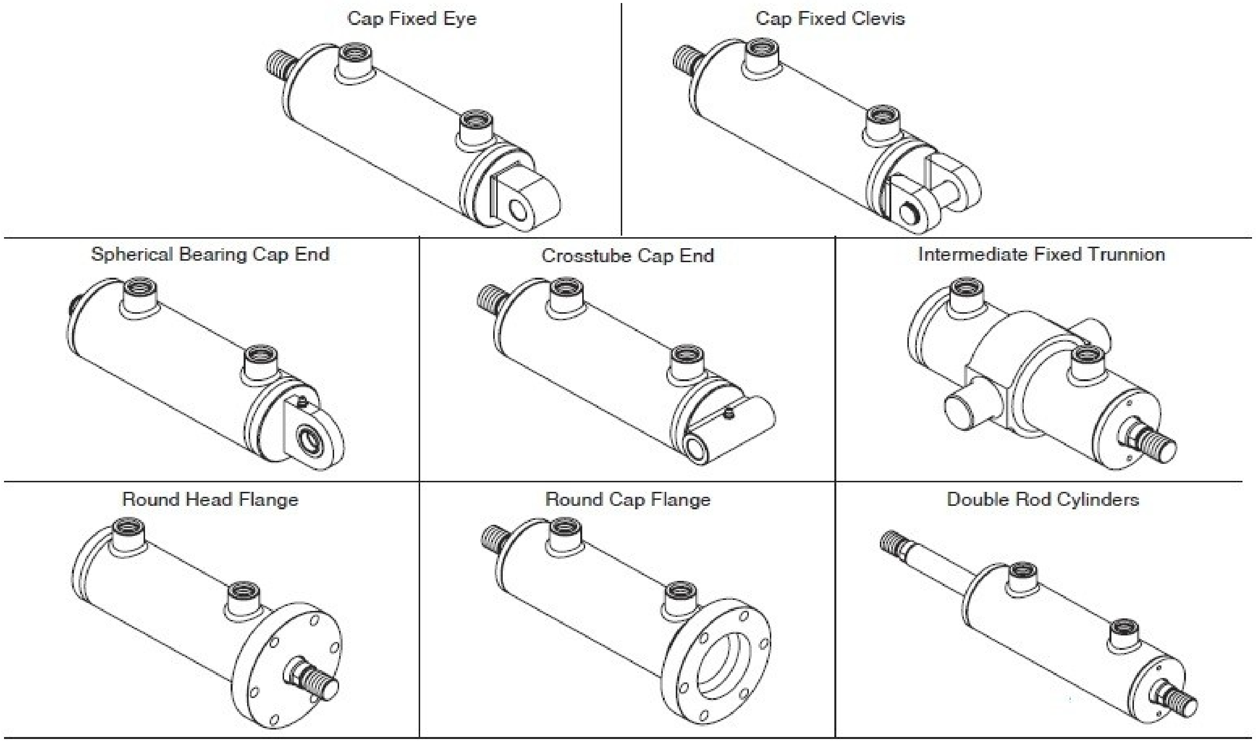
Assembly (symbolic representation)	Denomination / type
	Swivel head CGK ISO 12240-4
	Clevis bracket CLCC
	Fork clevis CCKA
	Eye bracket CLEA
	Clevis bracket (clampable) CLCB ISO 8133 DIN 24556
	Trunnion bracket CLTA
	Swivel head (clampable) CGKA ISO 8133 DIN 24555

Assembly (symbolic representation)	Denomination / type
	Swivel head CGKL ISO 12240-4
	Swivel head (clampable) CGKD ISO 8132
	Trunnion bracket CLTB ISO 8132
	Clevis bracket (clampable) CLCA ISO 8132 form B
	Clevis bracket (clampable) CLCD ISO 8132 form A

HYDRAULIC SYSTEM CIRCUIT ELEMENTS

Actuators (Cylinders)

Cylinder Typical Foot Mounting Types



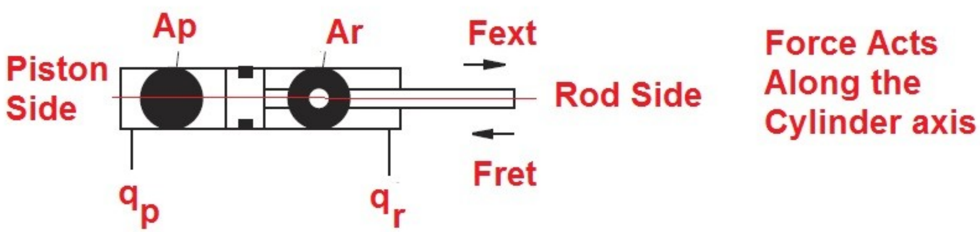
HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Actuators (Cylinders)
Force Relations

$$F_{ext} = \frac{P}{A_{piston}}$$

$$A_p = \pi \frac{D_p^2}{4}$$

$$F_{ret} = \frac{P}{A_r}$$

$$A_r = A_p - A_r = \pi \frac{(D_p^2 - D_r^2)}{4}$$



HYDRAULIC SYSTEM Actuators

Hydraulic Motors (Like Pumps)

→ Axial Piston Motors

→ External Gear Motors

→ Radial Piston Motors

HYDRAULIC SYSTEM Actuators

Hydraulic Motors

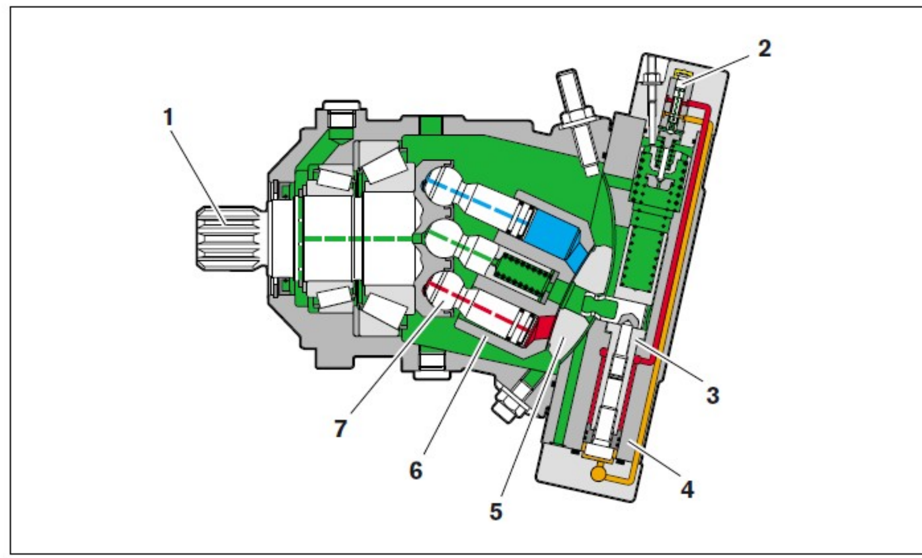
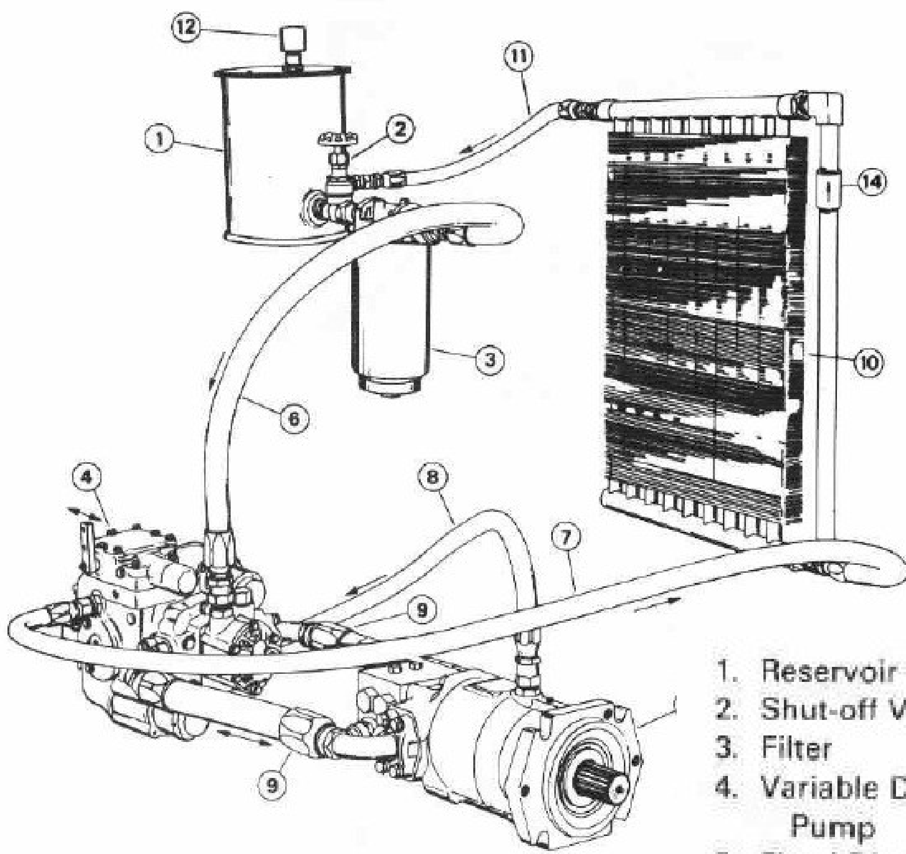


Fig. 2: Assembly of the A6VM

1	Drive shaft	**4**	Port plate	**7**	Piston
2	Control piston	**5**	Lens plate		
3	Stroke piston	**6**	Cylinder		

HYDRAULIC SYSTEM CIRCUITS

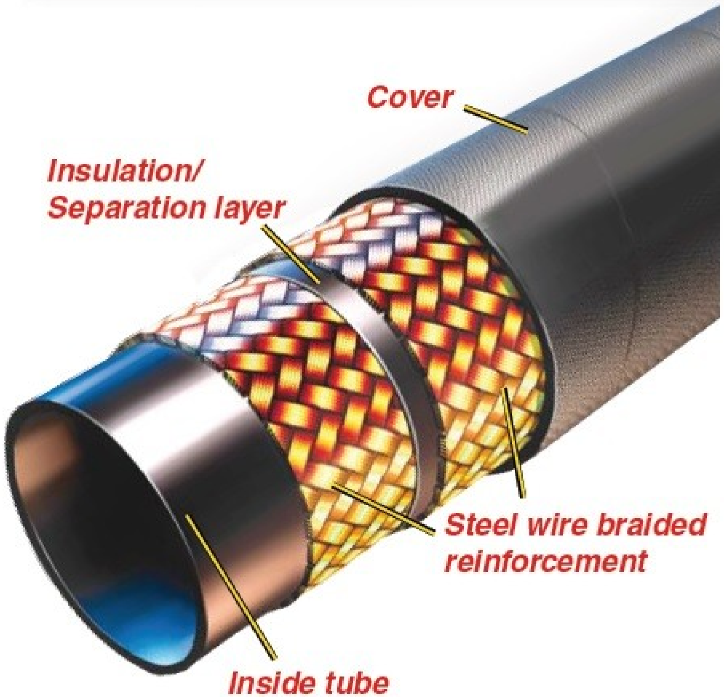


1. Reservoir
2. Shut-off Valve
3. Filter
4. Variable Displacement Pump
5. Fixed Displacement Motor
6. Inlet Line
7. Pump Case Drain Line
8. Motor Case Drain Line
9. High Pressure Lines
10. Heat Exchanger
11. Reservoir Return Line
12. Reservoir Fill Cap or Breather
14. Heat Exchanger By-pass Valve

HYDRAULIC SYSTEM EQUIPMENTS

HOSES

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
HOSES



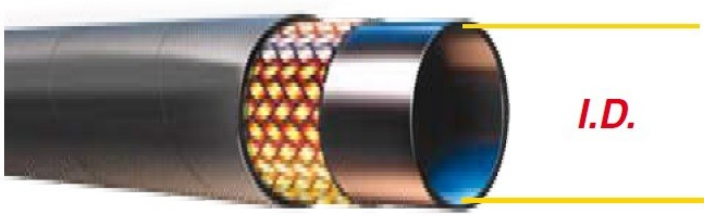
Hose

Typically a rubber hose is constructed of an extruded inside synthetic rubber tube that has the sole purpose to keep the conveyed fluid in the hose.
The elastomeric nature of rubber requires that a reinforcement layer be wound or braided around the tube in order to hold the internal pressure.
The reinforcement layer(s) are either textile or steel (or both).
To protect these inner layers of the hose from the ambient conditions, an outer synthetic rubber cover is extruded around the reinforcement.

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
HOSES

Hose Size

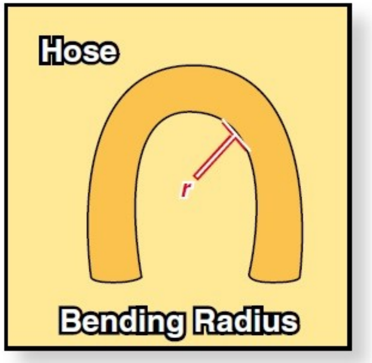
The power transmitted by means of a pressurised fluid varies with pressure and rate of flow.
The size of the components must be adequate to keep pressure drops to a minimum and avoid aging due to heat generation or excessive fluid velocity.
Parker uses the internationally recognised hose dash size as a measurement of the size of their hoses.
This size is a measurement of the inside tube of the hose – not the wall outer diameter.



Size		Inch		mm		DN
-6	⇒	6/16	⇒	6/16 * 25,4 = 9,525	⇒	10
⇩		⇩		⇩		⇩
-6		3/8		9,5		10

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
HOSES

Hose Bending Radius



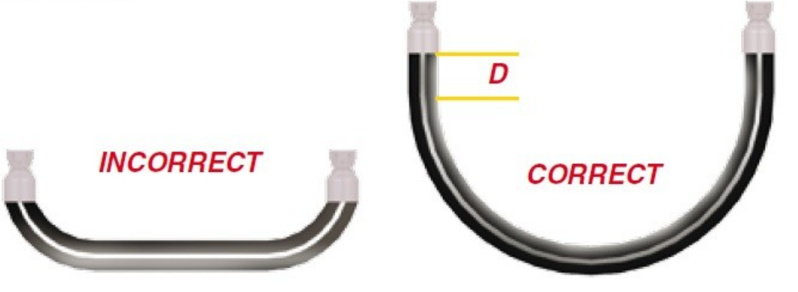
The minimum bend radius of a hose refers to the minimum radius that the hose may be bent through whilst operating at the maximum allowable published working pressure.

Bending radius is not a measurement or indicator of hose flexibility.

The catalogue specified values of bending radii are based on international or Parker specifications and have been proven through rigorous impulse testing of the hose assemblies.

Bending the hose below the minimum bending radius leads to loss of mechanical strength and hence possible hose failure.

A minimum straight length of 1,5 times the hose's outside diameter (D) shall be allowed between the hose fitting and the point at which the bend starts.

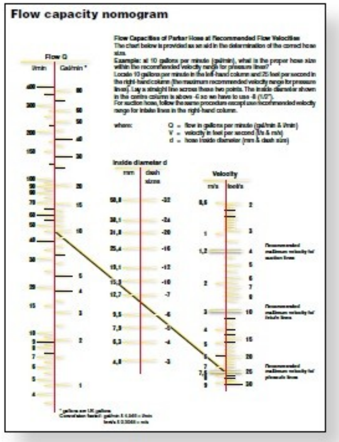


HYDRAULIC SYSTEM CIRCUIT ELEMENTS
HOSES

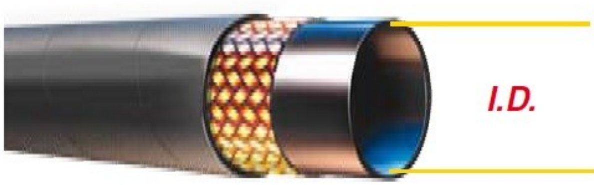
2 Size

The power transmitted by means of a pressurised fluid varies with pressure and rate of flow. The size of the components (hose and fittings) must be adequate to keep pressure drops to a minimum and avoid damage due to heat generation or excessive fluid velocity.

If the required size of hose is not already known, the **Hose Capacity Nomogram** , may assist.

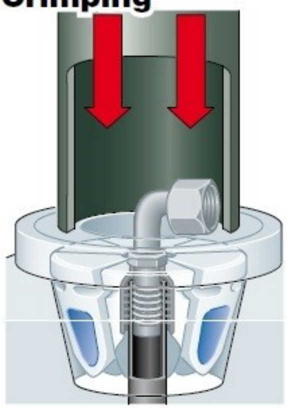


The size of standard hoses is specified by the inside diameter of the tube.

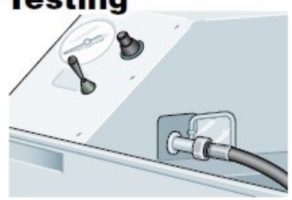


HYDRAULIC SYSTEM CIRCUIT ELEMENTS
HOSES

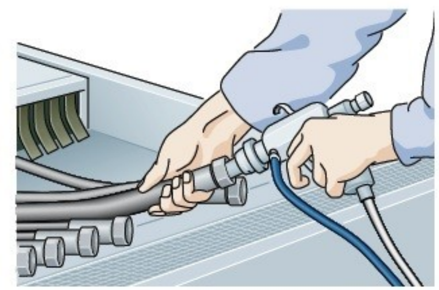
Crimping



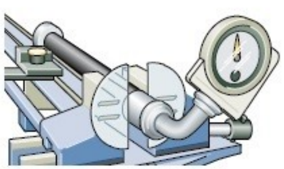
Testing



Cleaning

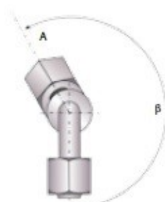


ISO 4406	NAS 1638	SAE 749	Cartridge
11/8	2		
12/9	3	0	
13/10	4	1	
14/11	5	2	
15/12	6	3	
16/13	7	4	3 µ
17/14	8	5	3 µ
18/15	9	6	3 µ
19/16	10		3 µ
20/17	11		
21/18	12		

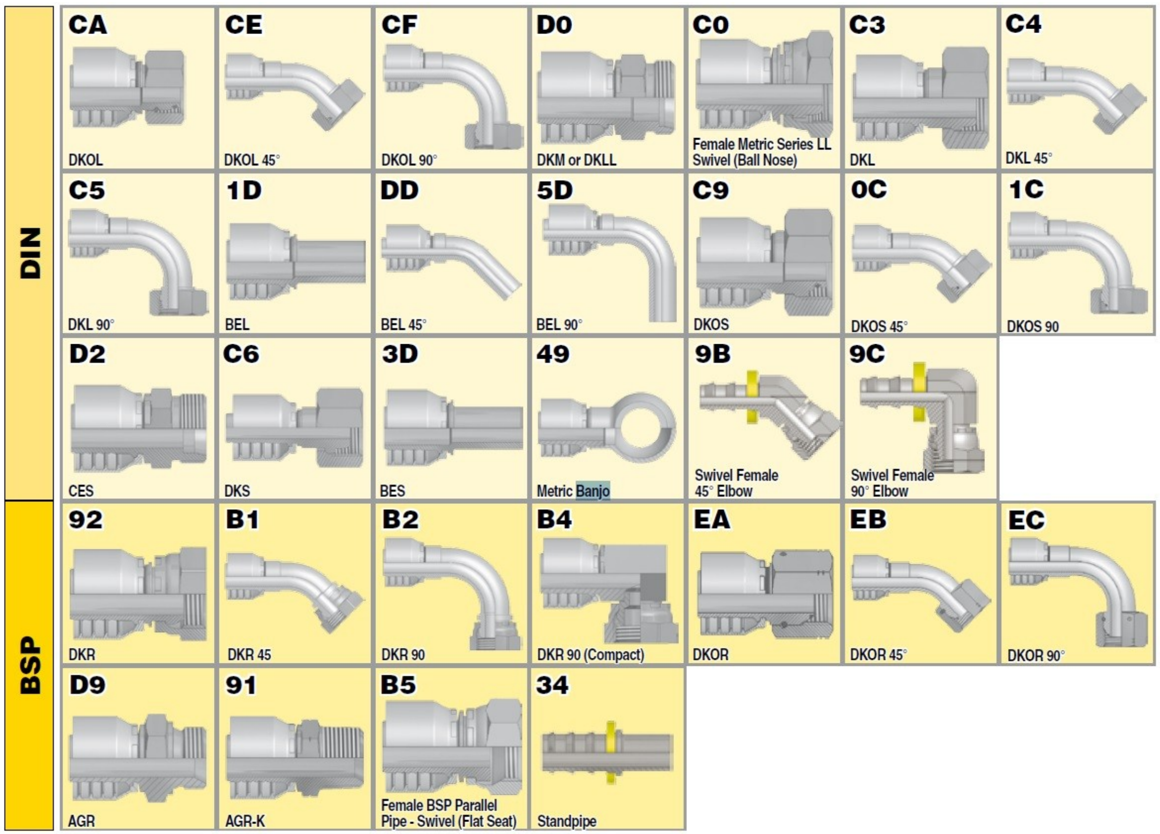


Angle setting

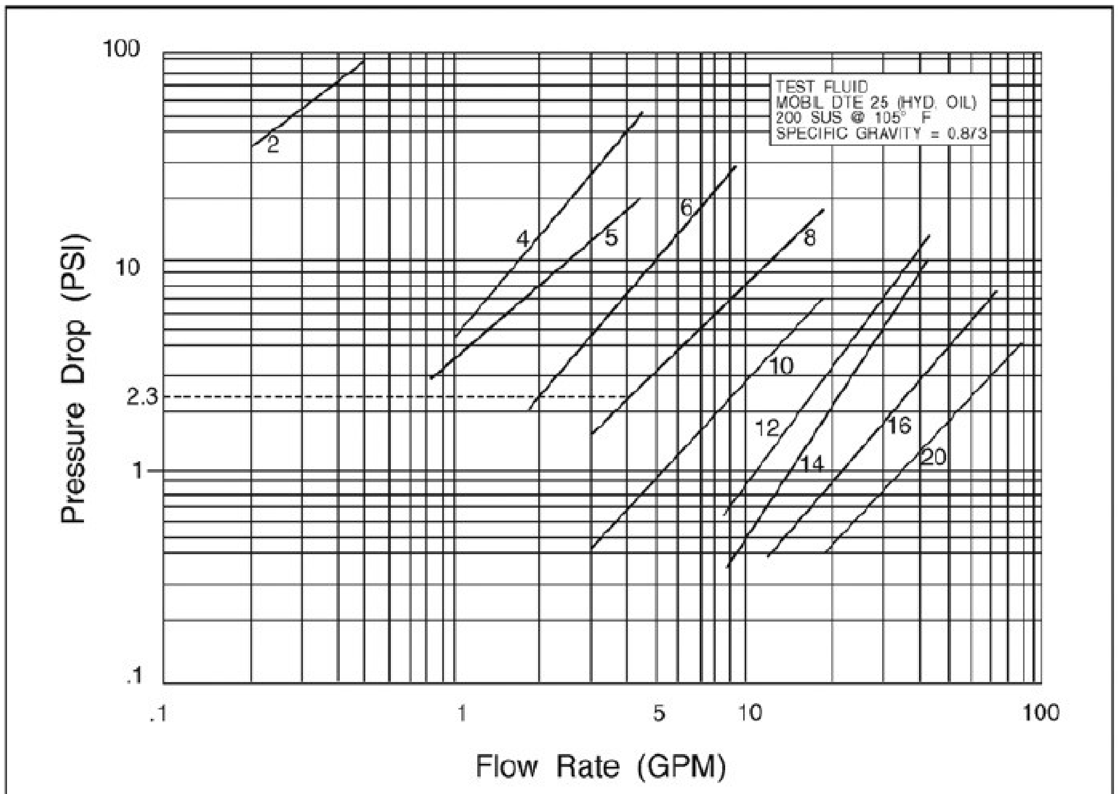
The displacement angle of a hose assembly is indicated only when two elbow fittings are assembled in a displaced way.
The angle always has to be indicated clockwise looking from the elbow fitting at the back to the one in the front.
Please also consider the natural bending of the hose.



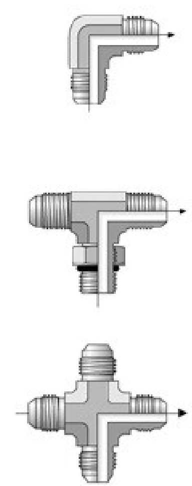
HYDRAULIC SYSTEM CIRCUIT ELEMENTS
HOSES



HYDRAULIC SYSTEM CIRCUIT ELEMENTS
FITTINGS-Pressure Drop



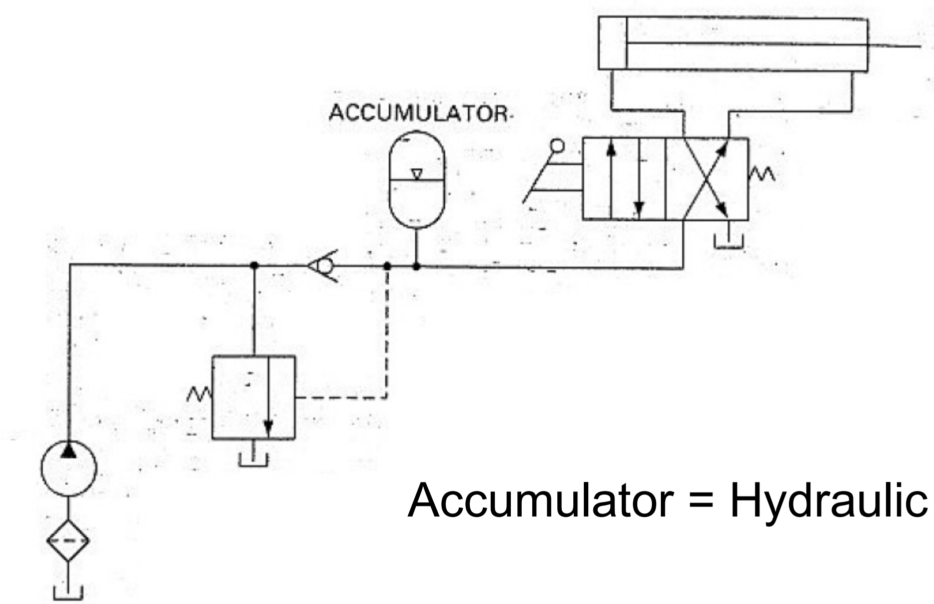
Examples:



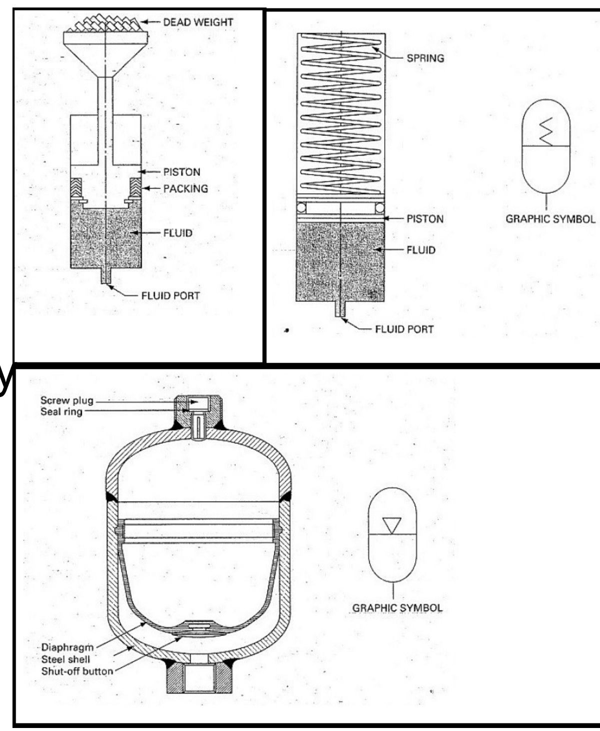
HYDRAULIC SYSTEM EQUIPMENTS

Accumulators

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Accumulator-Basic Accumulator Circuit



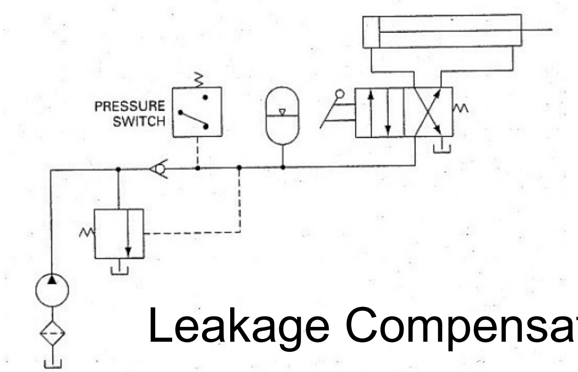
Accumulator = Hydraulic Battery



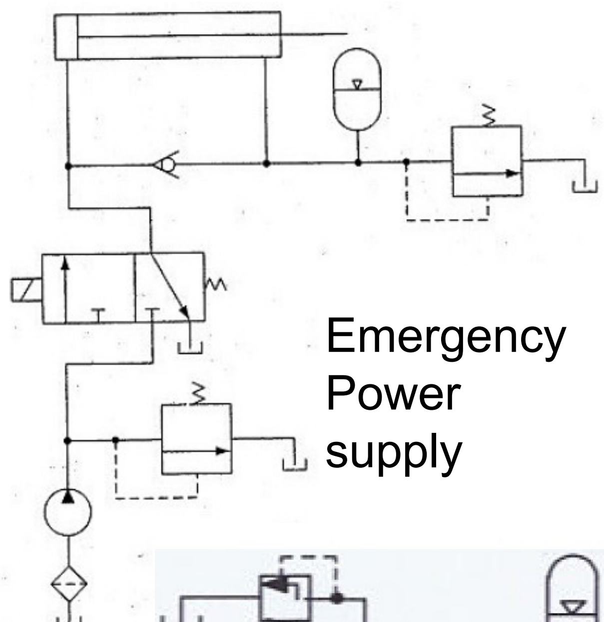
A hydraulic accumulator is a device which stores
hydraulic energy under pressure. There are three main types
- Dead Weight or Gravity Type
- Spring Loaded,
- Gas Loaded

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Accumulator-Accumulator Usage Purpose

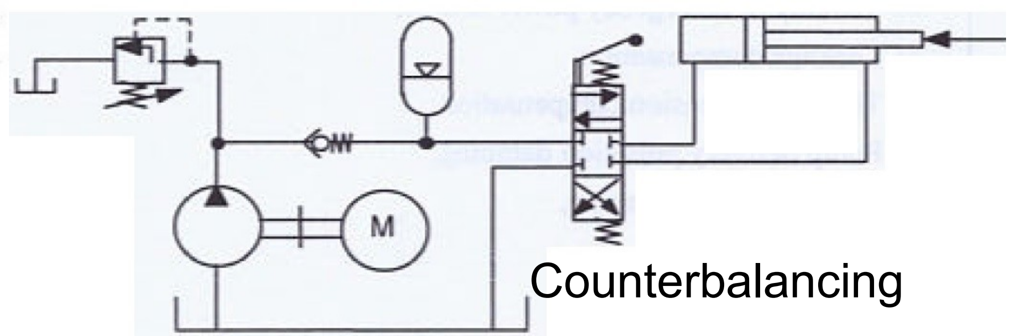
Accumulators are used for ;
- Fluid supply,
- Standby or emergency power source,
- Leakage Compensation,
- Thermal Expansion Compensation,
- Pump delivery pulsation damping,
- Pressure Surge Damping,
- Counterbalancing,



Leakage Compensation

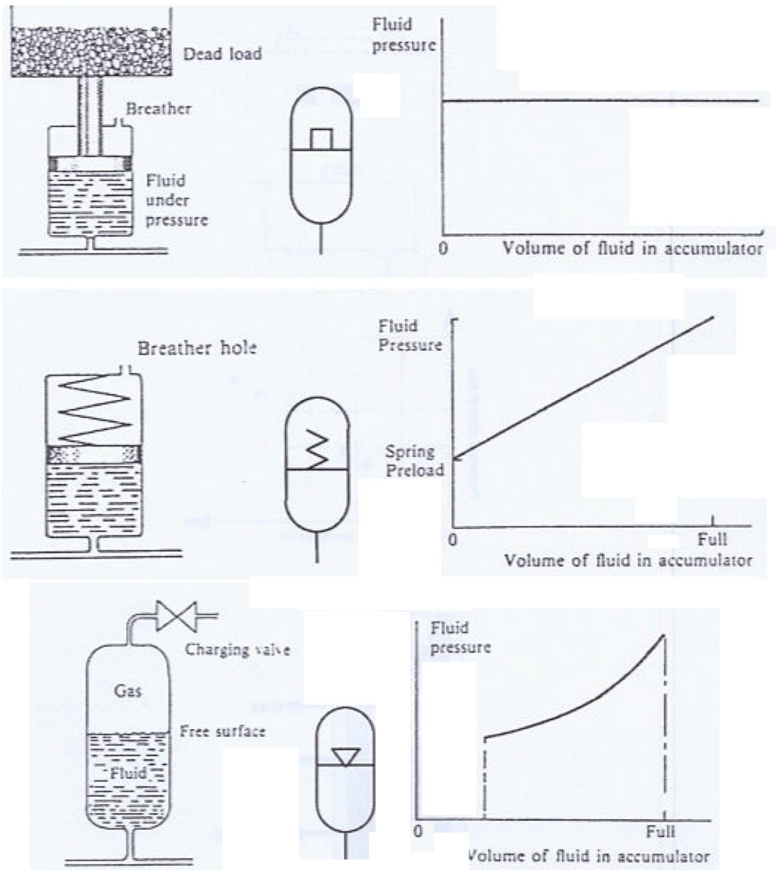


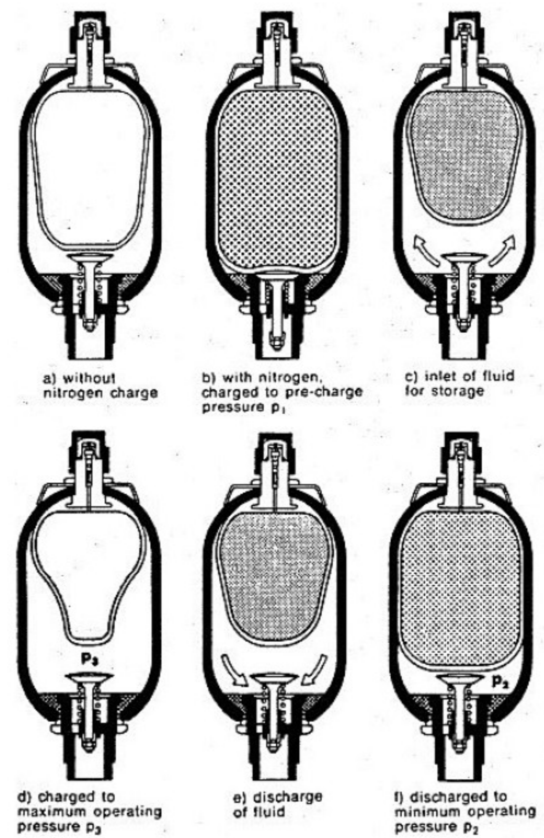
Emergency Power supply



Counterbalancing

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Accumulator- Accumulator Principle





HYDRAULIC SYSTEM EQUIPMENTS

Tank

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Hydraulic Reservoir

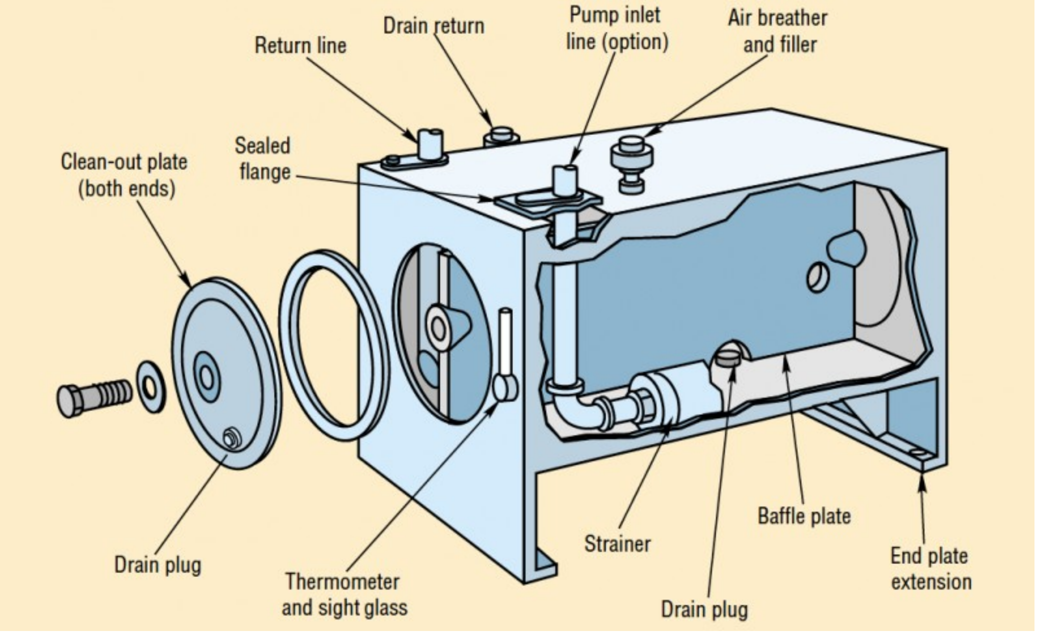
Approximate Volume = Pump Flow Rate X N

N= 1.5-2 for Mobile Application

N=3 for Industrial Applications

Temperature

Also Consider,
1-Service Hole ,
2-Breather ,
3-Return line-Suction Line Distance,
4-Level Gauge and Sight glass,
5-Strainer and Suction Height,
6-Filter Location,
7-Mounting,
8-Sealing,
9-Foam Suction Prevention,



HYDRAULIC SYSTEM EQUIPMENTS

Filters

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Filtration

Filtration Fact

Filter media ratings expressed as a Beta Ratio indicate a media's particle removal efficiency.

The Beta Ratio (also known as the filtration ratio) is a measure of the particle capture efficiency of a filter element. It is therefore a performance rating.

As an example of how a Beta Ratio is derived from a Multipass Test. Assume that 50,000 particles, 10 micrometres and larger, were counted upstream (before) of the test filter and 25 particles at that same size range were counted downstream (after) of the test filter. The corresponding Beta Ratio would equal 200, as seen in example 1.

The example would read "Beta ten equal to 200." Now, a Beta Ratio number alone means very little. It is a preliminary step to find a filter's particle capture efficiency. This efficiency, expressed as a percent, can be found by a simple equation. (Example 2)

$$\text{Efficiency}_x = \left(1 - \frac{1}{\beta}\right) 100$$

$$\text{Efficiency}_{10} = \left(1 - \frac{1}{200}\right) 100$$

$$= 99.5\%$$

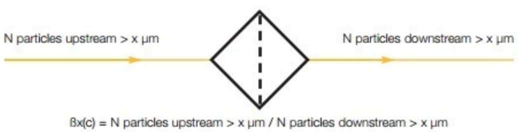
Example 1

$$\beta_x = \frac{\#\text{ of particles upstream}}{\#\text{ of particles downstream}}$$

"X" is at a specific particle size

$$\beta_{10}(c) = \frac{50{,}000}{25} = 200$$

Example 2



Beta Ratios / Efficiencies

Beta Ratio (at a given particle size)	Capture Efficiency (at same particle size)
1.01	1.0%
1.1	9.0%
1.5	33.3%
2.0	50.0%
5.0	80.0%
10.0	90.0%
20.0	95.0%
75.0	98.7%
100	99.0%
200	99.5%
1000	99.9%

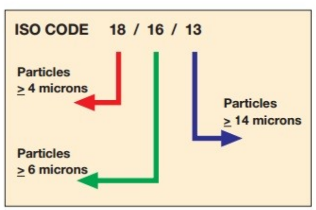
Beta Ratio

Upstream Particles: 100,000 > (x) microns

Downstream Particles			Beta Ratio (x)	Efficiency (x)
50,000	$\frac{100{,}000}{50{,}000}$	=	2	50.0%
5'000	$\frac{100{,}000}{5{,}000}$	=	20	95.0%
1,333	$\frac{100{,}000}{1{,}333}$	=	75	98.7%
1,000	$\frac{100{,}000}{1{,}000}$	=	100	99.0%
500	$\frac{100{,}000}{500}$	=	200	99.5%
100	$\frac{100{,}000}{100}$	=	1000	99.9%

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Filtration

ISO code number	Number of particles per ml	
	More than	Up to and including
22	20 000	40 000
21	10 000	20 000
20	5 000	10 000
19	2 500	5 000
18	1 300	2 500
17	640	1 300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
09	2.5	5
08	1.3	2.5
07	0.64	1.3



ISO Classification & Definition		
Range number	Micron	Actual Particle Count Range (per ml)
18	4+	1,300 - 2,500
16	6+	320 - 640
13	14+	40 - 80

The ISO codes 4, 6, 14 microns replace the 2 digit 5, 15 microns and 3 digit 2, 5, 15 microns in use prior to the introduction of ISO MTD. Their use continues and the results remain comparable with the 4, 6, 14 micron ISO codes.

ISO code numbers	Type of system	Typical components	Sensitivity
23 / 21 / 17	Low pressure systems with large clearances	Ram pumps	Low
20 / 18 / 15	Typical cleanliness of new hydraulic oil straight from the manufacturer. Low pressure heavy industrial systems or applications where long-life is not critical	Flow control valves Cylinders	Average
19 / 17 / 14	General machinery and mobile systems Medium pressure, medium capacity	Gear pumps/motors	Important
18 / 16 / 13	World Wide Fuel Charter cleanliness standard for diesel fuel delivered from the filling station nozzle. High quality reliable systems General machine requirements	Valve and piston pumps/motors Directional and pressure control valves	Very important
17 / 15 / 12	Highly sophisticated systems and hydrostatic transmissions	Proportional valves	Critical
16 / 14 / 11	Performance servo and high Pressure long-life systems e.g. Aircraft machine tools, etc.	Industrial servovalves	Critical
15 / 13 / 09	Silt sensitive control system with very high reliability Laboratory or aerospace	High performance servovalves	Super critical

NOTE: The three figures of the ISO code numbers represent ISO level contamination grades for particles of >4µm(c), >6µm(c) and >14µm(c) respectively.

HYDRAULIC SYSTEM CIRCUIT ELEMENTS
Filtration

Filter Types & Locations

- Air Filter
- Suction
- Pressure
- Return
- Off-line