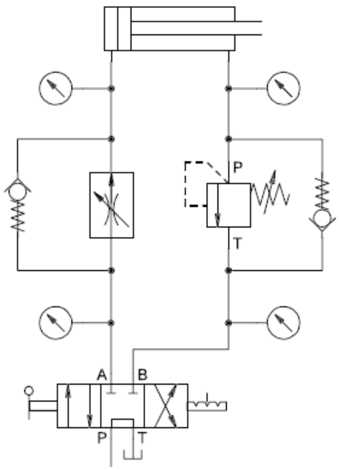
بسم الله الرحمن الرحيم

Hydraulic & Pneumatic Circuits



Tanta University

Faculty of Engineering
Mechanical power Engineering Dept.

Lecture (8)
on

Design of Hydraulic Systems

By

Dr. Emad M. Saad
Industrial Engineering Dept.
Faculty of Engineering
Fayoum University

2014 - 2015

Design Principles

- Principle 1. Liquids have no shape of their own and flow to acquire the shape of their container
- Principle 2. Liquids can be considered incompressible at pressures used in hydraulic systems
- Principle 3. Liquids transmit pressure equally in all directions.
- Principle 4. The flow rate of oil from a non-positive pump depends on the speed of the pump and on the system pressure.
- Principle 5. The flow rate of oil from a positive displacement pump varies proportionally with pump speed but is virtually independent of system pressure.
- Principle 6. Any flow of liquid through a pipe or orifice is accompanied by a reduction in liquid pressure.

Design Considerations

- Safety of Operation
  - Pressure and Temperature ratings
  - Interlocks for sequential operations
  - Emergency shutdown features
  - Power failure locks
  - Operation speed
  - Environment conditions

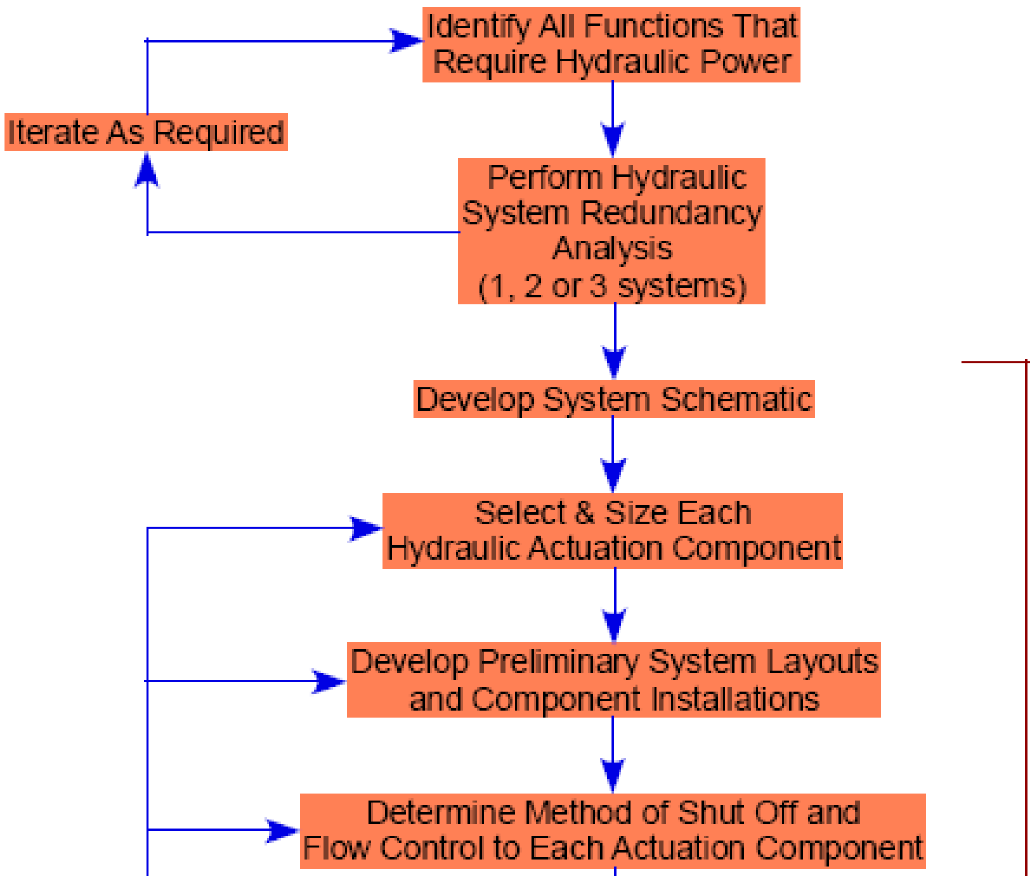
Design Considerations

- Meet functional requirements
  - Meet required performance specification
  - Life expectancy same as machine
  - Facilitate good maintenance practice
  - Compatibility with electrical and mechanical components
  - Withstand operational hazards

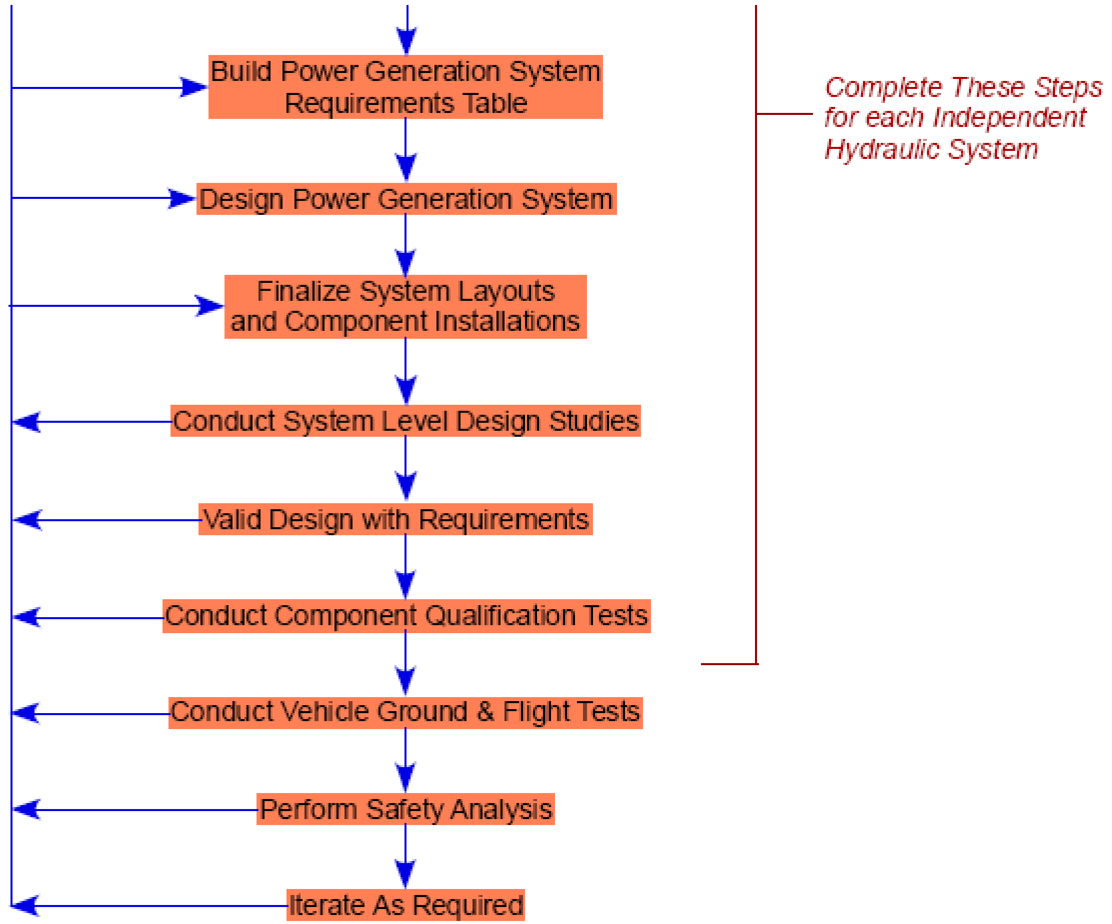
Design Considerations

- **Efficiency of Operation**
  - Keep system Simple, Safe and Functional
  - Access to parts need repair or adjustment
  - Design to keep min operational cost
  - Design to prevent and remove contamination.

Design Procedures



Design Procedures

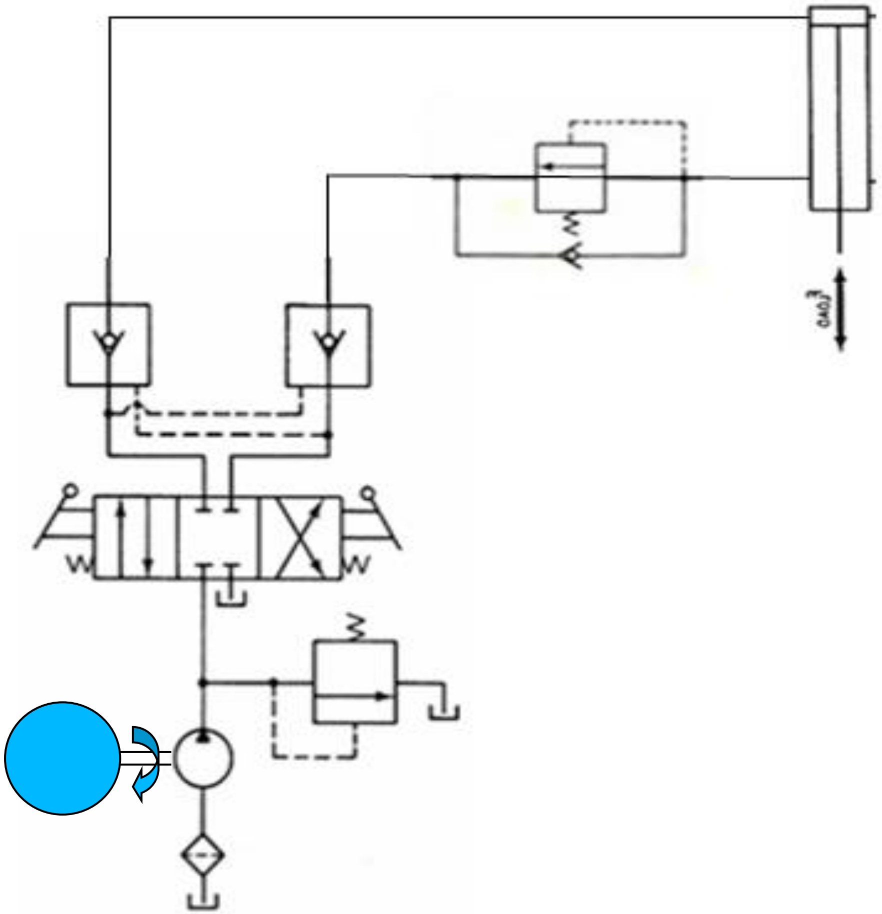


SIMPLE PRESS CIRCUIT

What are the specification of the job?

- Load to be Lifted – 1000 Kg.
- Load Travel Distance (Stroke Length) – 50 cm
- Time Required to Reach Distance – 10 cm/sec.

SIMPLE PRESS CIRCUIT



SIMPLE PRESS CIRCUIT

What Size of Cylinder Needed?

- Which Side Load to be Lifted (Piston or Rod side)
- Select the working Pressure (50 to 80 bar approx.)
- Calculate the Area of cylinder $A = F / P$
- Select Standard Bore and Rod size

SIMPLE PRESS CIRCUIT

○ Cylinder Selection Reasoning

- ➢ **Large Diameter Cylinder**
  - Operates at Low Pressure
  - Require Bigger pump for Speed
- ➢ **Smaller Diameter Cylinder**
  - Operates at High Pressure
  - Small Bigger pump give Speed
- ➢ **Cylinder Selected = 10 cm Bore**

SIMPLE PRESS CIRCUIT

- **What Capacity Pump is Needed?**
  - Maximum Cylinder Speed Required
  - Flow Rate =(Cyl. Area x Stroke / Time)
  - Next Standard Pump selected.
  - Cubic Centimeter per revolution

- **What Capacity of Electric Motor Needed?**
  - Calculate Power Required to Run Pump
  - Power KW =(LPM x Pressure) / 600
  - Motor Speed = (LPM / CC Per Rev. of pump)
  - Consider the Efficiency of Pump
  - Shaft Size, Type of Electric Source.

SIMPLE PRESS CIRCUIT

- **What Size of reservoir Should be used?**

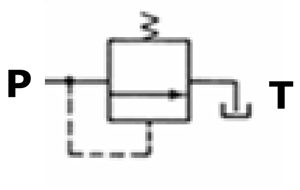
- Basically 4 to 5 times of Pump Capacity. (L × B × H)
- Deciding the Length and width Based on
  - ✓ Availability Space
  - ✓ Allowing free Heat Dissipation
  - ✓ Mounting Accessories (Example -Manifold, Filter, Field piping etc.)

- **Filler Breather**
- **Suction Strainer,**
- **Return line filter**

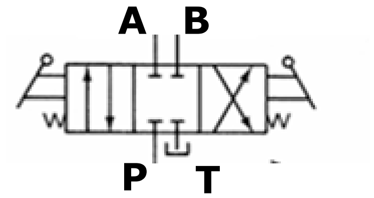
- These are all Selected 2 to 3 times of Pump Capacity.

SIMPLE PRESS CIRCUIT

- ## Valve Selection
  - Relief Valve
    - ✓ Pressure Range
    - ✓ Flow Handling capacity (1.5 times of Pump flow)

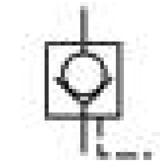


- ## Direction Control Valve
  - Based On Function
  - Flow Handling capacity (Max. Speed of Cylinder)

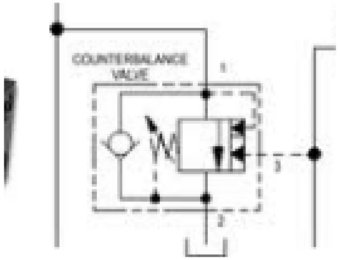


SIMPLE PRESS CIRCUIT

- **Pilot operated Check Valve**
  - Based On Following Function
    - ✓ Holding the Cylinder at intermittent stop
    - ✓ Power Failure condition (Ensuring safety)
    - ✓ To avoid the leakages Through DCV,



- **Counter Balance Valve**
  - Based On Following Function
    - ✓ To avoid sudden acceleration of load towards Gravity.



SIMPLE PRESS CIRCUIT

- **Tubing Size (I.D) Selection**
  - Suction Line
    - ✓ Velocity = 0.5 to 1 m/sec.
  - Pressure Line
    - ✓ Velocity = 3.0 to 5 m/sec.
  - Return Line
    - ✓ Velocity = 1.0 to 2 m/sec.
- Area = Q / V
- Area = ((pi) x d^2) / 4 m^2
- d = $\sqrt{(4 \times Area) / (pi)}$ m
- Wall thickness selected based line pressure

SIMPLE PRESS CIRCUIT

○ Tube Wall Thickness (t) Selection

Design Pressure Formula (LAME'S)

$$P = S\left(\frac{D^2 - d^2}{D^2 + d^2}\right) \quad \text{where:}$$

D = Outside diameter of tube, in
d = Inside diameter of tube (D-2T), in
P = Recommended design pressure, psi
S = Allowable stress for design factor of 4, psi
T = Tube wall thickness, in.

Table U9 — Design Pressure Formula

For thin wall tubes ($D/T \geq 10$) the following formula may be Used: **$P = 2ST/D$**

SIMPLE PRESS CIRCUIT

- **Tube Wall Thickness (*t*) Selection**

Material and Type	Allowable Design Stress fo Design Factor of 4 at 72°F	Tube Specification
Steel C-1010	12,500 PSI	SAE J356, J524, J525
Steel C-1021	15,000 PSI	SAE J2435, J2467
Steel, High Strength Low Alloy (HSLA)	18,000 PSI	SAE J2613, J2614
Stainless Steel 304 & 316	18,800 PSI	ASTM A213, A249, A269
Alloy Steel C-4130	18,800 PSI	ASTM A519
Copper, K or Y	6,000 PSI	SAE J528, ASTM B75
Aluminum 6061-T6	10,500 PSI	ASTM B210
Monel, 400	17,500 PSI	ASTM B165

SIMPLE PRESS CIRCUIT

○ Tube Wall Thickness (*t*) Selection

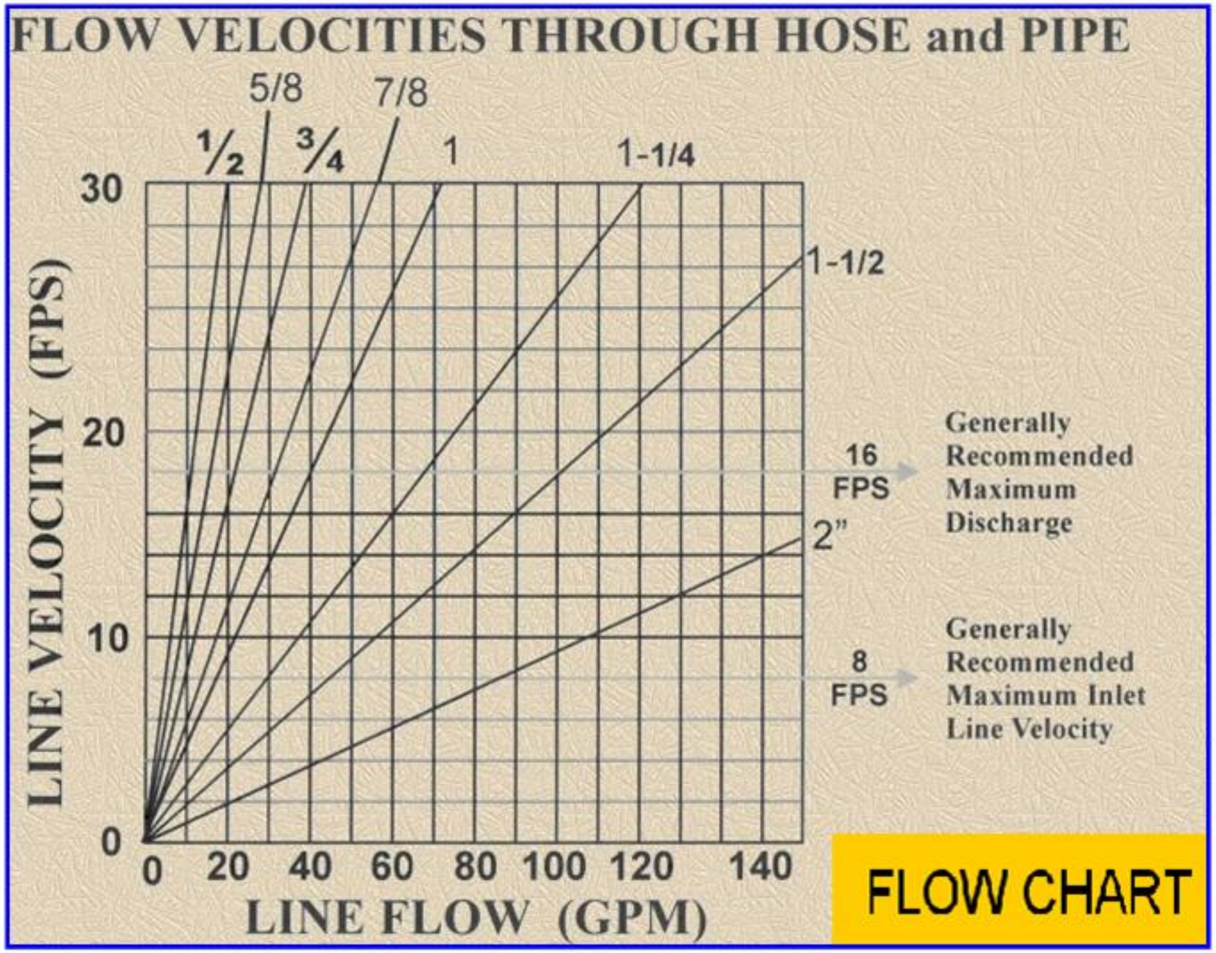
BASED ON FLOW RATE

Maximum Flow Rate LPM*	Recommended Flow Diameter in Millimeters		
	Pressure Lines	Return Lines	Suction Lines
1	1.670	2.640	4.180
2	2.362	3.734	5.911
3	2.893	4.573	7.240
4	3.340	5.280	8.360
5	3.734	5.903	9.347
6	4.091	6.467	10.239
7	4.418	6.985	11.059
8	4.723	7.467	11.823
9	5.010	7.920	12.540
10	5.281	8.348	13.218
12	5.785	9.145	14.480
14	6.249	9.878	15.640
16	6.680	10.560	16.720
18	7.085	11.201	17.734
20	7.468	11.806	18.694
22	7.833	12.383	19.606
24	8.181	12.933	20.478
26	8.515	13.461	21.314
28	8.837	13.970	22.118
30	9.147	14.460	22.895
32	9.447	14.934	23.646
34	9.738	15.394	24.373
36	10.020	15.840	25.080
38	10.295	16.274	25.767
40	10.562	16.697	26.437
45	11.203	17.710	28.040
50	11.809	18.668	29.557

BASED ON DESIGN PRESSURE

Metric Tubes				
			Design Pressure (Bar)	
Tube O.D. (mm)	Wall Thick. (mm)	Tube I.D. (mm)	Steel Low-Carbon St. 37-4	Stainless Steel 1.4571
4	0.5	3.0	313	256
4	0.75	2.5	409	366
4	1.0	2.0	522	465
5	0.8	3.5	376	301
5	1.0	3.0	432	386
6	0.75	4.5	333	256
6	1.0	4.0	389	330
6	1.5	3.0	549	465
6	2.0	2.0	692	585
6	2.25	1.5	757	639
8	1.0	6.0	333	256
8	1.5	5.0	431	366
8	2.0	4.0	549	465
8	2.5	3.0	658	556
10	1.0	8.0	282	209
10	1.5	7.0	373	301
10	2.0	6.0	478	386
10	2.5	5.0	576	465
10	3.0	4.0	666	539
12	1.0	10.0	235	177
12	1.5	9.0	353	256
12	2.0	8.0	409	330
12	2.5	7.0	495	400
12	3.0	6.0	576	465
12	3.5	5.0	651	527
14	1.0	12.0	201	153
14	1.5	11.0	302	223
14	2.0	10.0	403	289

SIMPLE PRESS CIRCUIT



Thank you