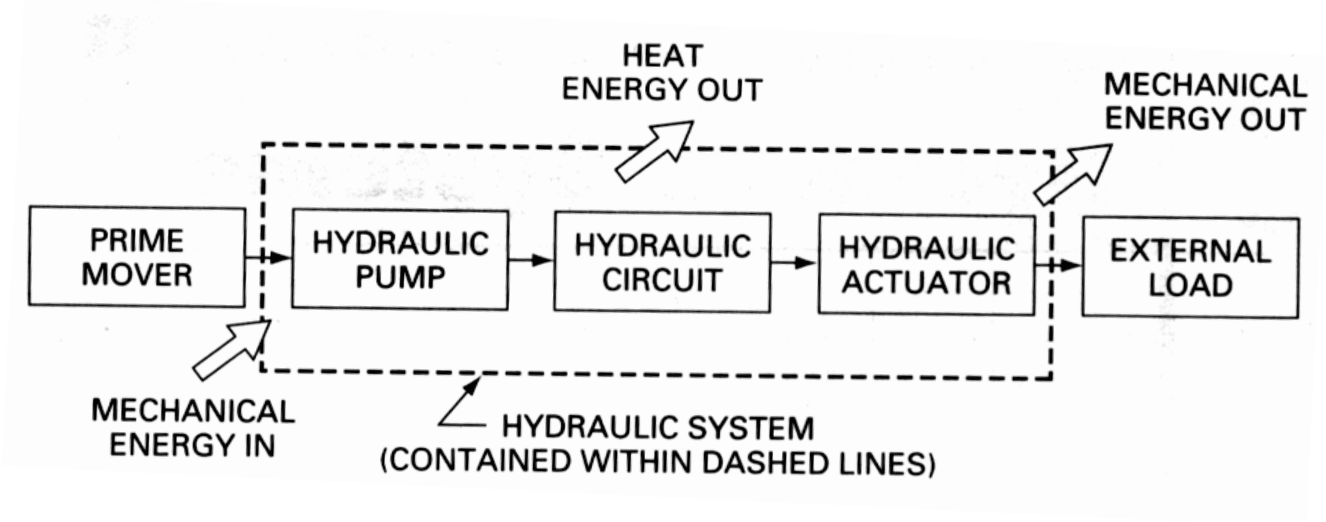
**Energy**
It is defined as the ability to PerformWork.




Block Diagram of Hydraulic System Showing Major Components
HowEnergy is transferred throughout a Hydraulic System.

ME = MechanicalEnergy. HE= Heat Energy.
InputME - Lost HE = OutputME

The Conservation of Energy Lawstates that Energy can be Neither CreatedNorDestroyed.

**Power** is defined as The Rate of doing Work or expending Energy

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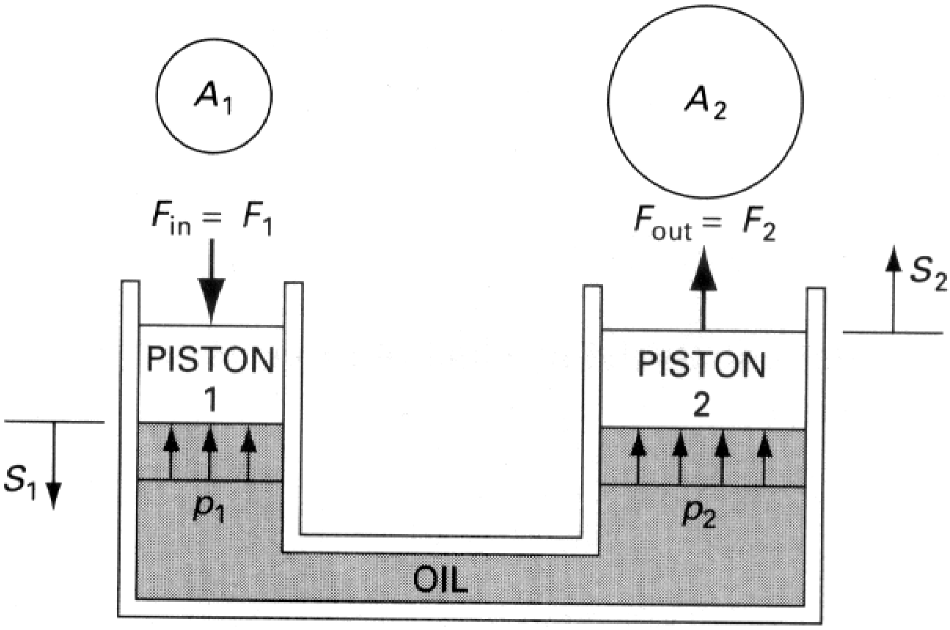
## Analysis of Simple Hydraulic Jack

Does a HydraulicJackproduce More Energy thanit receives?

Answer:Let'sAnalyzetheHydraulicJackillustrated below.




Operation of Simple Hydraulic Jack

By Pascal's Law, $p_1 = p_2$.

$$(F_1/A_1) = (F_2/A_2)$$

$$(F_2/F_1) = (A_2/A_1) \qquad (1)$$

A Force Multiplication occurs from the Input to the Output of the Jack if the Output Piston Area is greater than the Input Piston Area.

The cylindrical volume of oil displaced by the input piston equals the cylindrical volume displaced by the output piston:

$$V_1 = V_2$$

$$A_1S_1 = A_2S_2$$

$S_1$ = Downward movement of piston 1,
$S_2$ = Upward movement of piston 2.

$$(S_1/S_2) = (A_2/A_1) \qquad (2)$$

Combining Eq. (1) and (2) yields the corresponding relationship

$$(F_2/F_1) = (S_1/S_2)$$

$$F_1S_1 = F_2S_2 \qquad (3)$$

The Energy Input to the Hydraulic Jack equals the Energy Output from the Jack.

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**A Check Valve** allows flow to pass in Only One Direction
**The Bleed Valve** is a hand-operated valve, which, when opened, allows the Load to be lowered by Bleeding Oil from the Load Cylinder back to the Tank.

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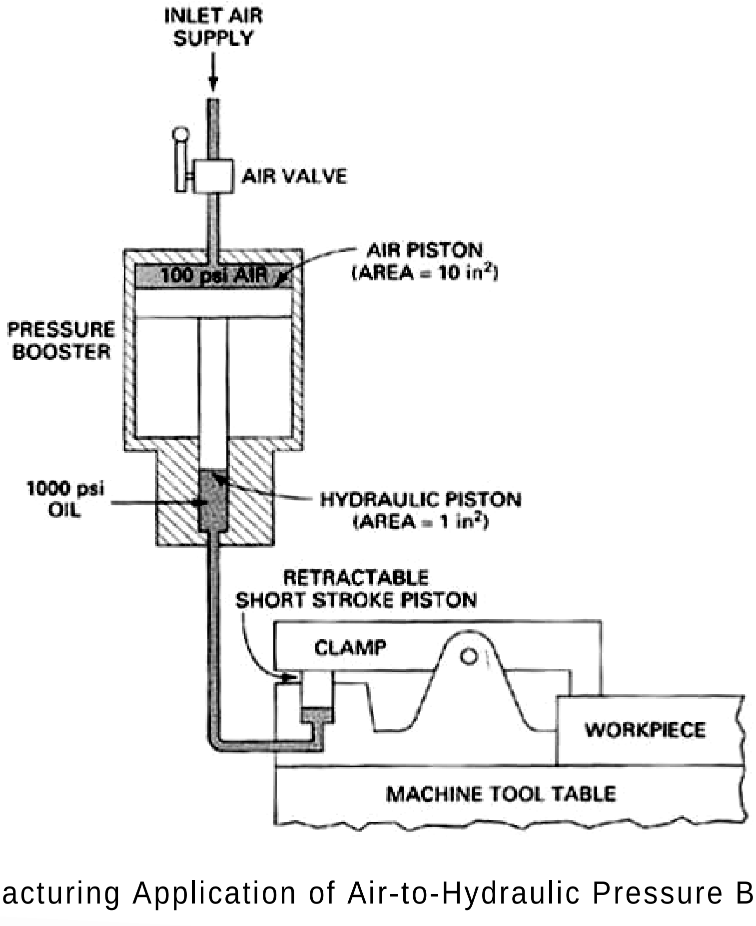


Manufacturing Application of Air-to-Hydraulic Pressure Booster

$$\text{pressure ratio} = \frac{\text{output oil pressure}}{\text{input air pressure}} = \frac{\text{area of air piston}}{\text{area of hydraulic piston}}$$

$$\text{pressure ratio} = \frac{1000 \text{ psi}}{100 \text{ psi}} = \frac{10 \text{ in}^2}{1 \text{ in}^2} = 10$$

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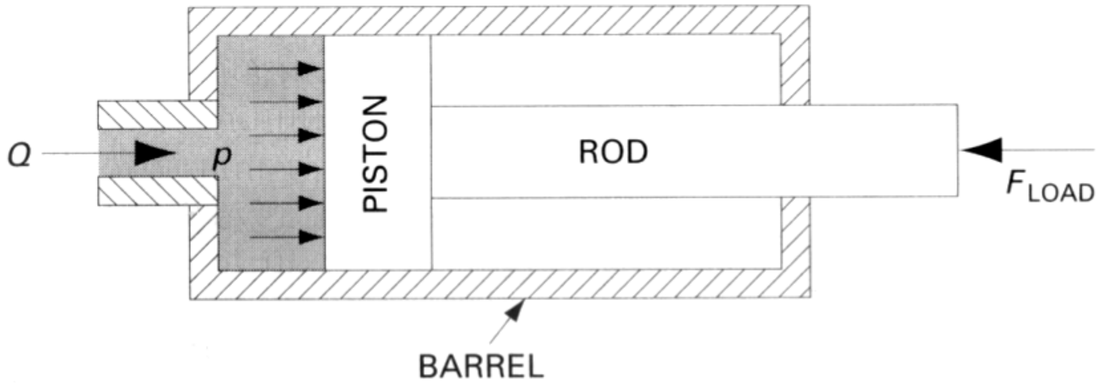
## Hydraulic Power

## Hydraulic Cylinder

The Power Delivered by a Hydraulic Fluid to A Load-driving Device such as a hydraulic Cylinder is called Hydraulic Power.




Cylinder Example for Determining Hydraulic Horsepower

Hydraulic Horsepower (HHP) The Horsepower delivered by the Fluid to the Cylinder
Output Horsepower (OHP) The Horsepower delivered by the Cylinder to the Load

Output Horsepower is always Less than Hydraulic Horsepower due to Friction and Leakage Losses. The Efficiency of any component is always Less than 100%.

This Pressure, p, acts on the Area of the piston A to produce the Force

$$pA = F_{load} \text{ then } A = F_{load}/p \qquad (4)$$

The Load is known from the Application, and The maximum allowable Pressure is established based on the Pump Design. Eq. (4) allows us to calculate the required Piston Area if the Friction between the Piston and Cylinder bore is Negligibly Small.

$$V_D(ft^3) = A(ft^2) \text{ X } S(ft)$$

The volumetric displacement $V_D$ & stroke S

If there is Negligibly Small Leakage between the Piston and Cylinder bore,

$$Q(ft^3/s) = V_D(ft^3)/t(s)$$

$$Q(ft^3/s) = A(ft^2) \text{ X } S(ft)/t(s)$$

$$Q(ft^3/s) = A(ft^2) \text{ X } v(ft/s)$$

$$\text{Energy} = (F)(S) = (pA)(S)$$

$$\text{Power} = \text{Energy/Time} = (pA)(S)/t = p(Av), \quad \text{Since } Q = Av,$$

Hydraulic Power $(ft.lb/s) = p(lb/ft^2) \text{ X } Q(ft^3/s)$

Recalling that 1 hp = 550 ft•lb/s,

$$\text{Hydraulic Horsepower} = HHP = p(lb/ft^2) \text{ X } Q(ft^3/s) \text{ X } 1 \text{ hp}/(550 \text{ ft.lb/s})$$

$$HHP = p(lb/ft^2) \text{ X } Q(ft^3/s)/550$$

Hydraulic Horsepower in Terms of psi andgpmUnits

Hydraulic Power = p x $Q$

$$= p\left(\frac{\text{lb}}{\text{in}^2}\right) \times Q\left(\frac{\text{gal}}{\text{min}}\right) \times \frac{231\ \text{in}^3}{1\ \text{gal}} \times \frac{1\ \text{min}}{60\ s} \times \frac{1\ \text{ft}}{12\ \text{in}} \times \frac{1\ \text{HP}}{550\ \text{ft} \cdot \text{lb/s}}$$

HHP = p(psi) X Q(gpm)/1714(5)

---

Power Analogy among Mechanical, Electrical, and Hydraulic systems:

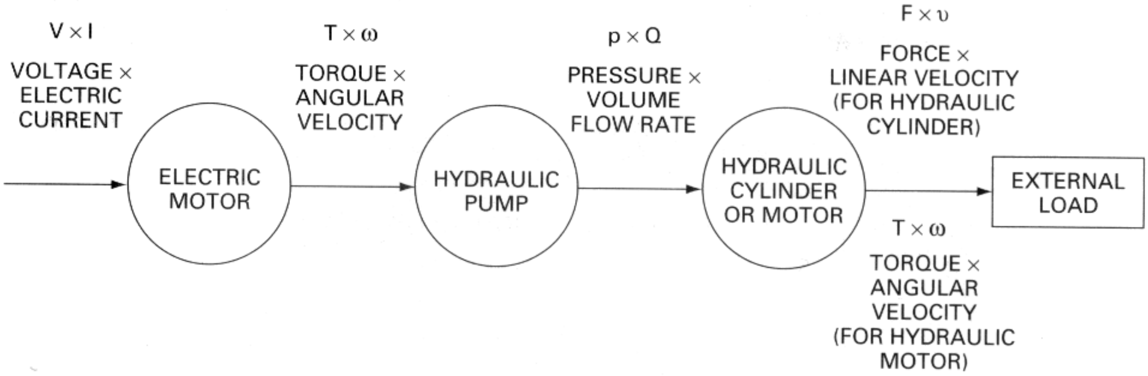
Mechanical Power = Force X Linear Velocity
= Torque X Angular Velocity

Electrical Power = Voltage X Electric Current

Hydraulic Power = Pressure X VolumeFlow Rate

AllThreeTypesof power (Mechanical, Electrical and Hydraulic)are involved in Hydraulic Systems.

1- An Electric Motor is used as thePrime Mover to drivethePump.
2- The PumpconvertstheMechanicalPower into HydraulicPower.
3- Hydraulic Cylinderor hydraulic Motortransforms.The HydraulicPower back intoMechanical Power to drivetheLoad.




Conversion of Power from Input Electrical to Mechanical to Hydraulic to Output Mechanical in a Hydraulic System.

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## ENERGY, POWER, AND FLOW RATE IN THE SI METRIC SYSTEM

**Energy**

1 J = 1 N x 1 m = 1 N.m

Energy (J) = F (N) X S (m)

**Power**

Power = Work/Time

1 W = 1 J/s = 1 N .m/s

Power = Work(N.m)/Time(s)

Hydraulic Power (W) = p(N/m$^2$) X Q(m$^3$/s)

1 HP =746 W = 0.746 kW.

p = γH, p = γ$H_P$.$H_P$=Pump Head

$H_P$ (m) = Pump HydraulicPower (W) / [У(N/m$^3$) X Q(m$^3$/s)]

The MotorHead can alsobe calculatedusingthe same equation,wheretheH$_P$termis replacedby H$_m$.

The PumpHydraulicPower is replacedby theMotorHydraulicPowerandQrepresentstheMotorflowrate.

Mechanical Output Power (Brake Power) delivered in a Hydraulic Motor:

$$\text{power(kW)} = \frac{T(\text{N}\cdot\text{m}) \times \omega(\text{rad/s})}{1000} = \frac{T(\text{N}\cdot\text{m}) \times N(\text{rpm})}{9550}$$

where T is torque and ω or N is angular Speed.

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## Flow Rate

Volume Flow rate within a pipeline equals the product of The Pipe cross-sectional Area and the Fluid Velocity:

$$Q(m^3/s) = A(m^2) \times v(m/s)$$

$$1\ m^3/s = 15{,}800\ gpm$$

Liters per second (Lps) or Liters per minute (Lpm)

$$1\ liter = 1\ L = 0.001\ m^3$$

$$Q(Lps) = Q(L/s) = 1000\ Q(m^3/s)$$

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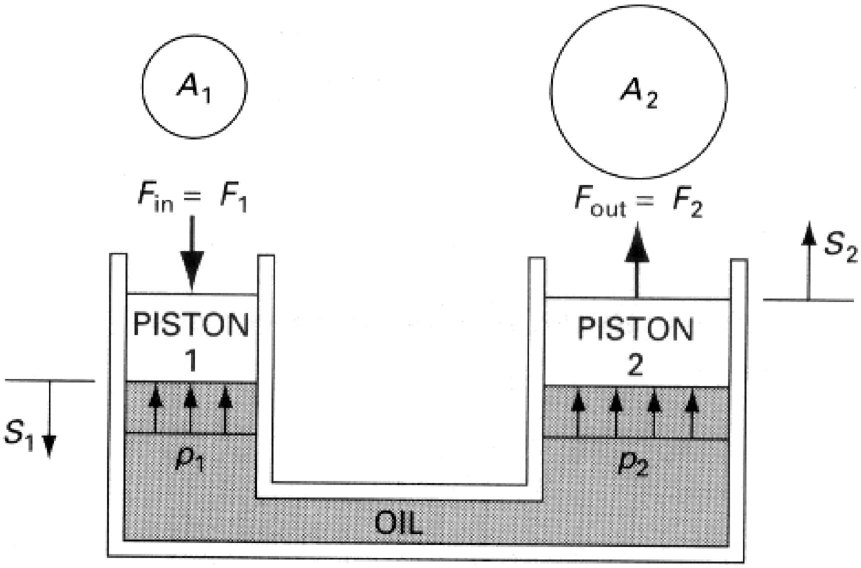
## Example




For the hydraulic jack of Figure 3-6 the following data are given:

$A_1 = 25\ cm^2 \qquad A_2 = 100\ cm^2$

$F_1 = 200\ N$

$S_1 = 5\ cm$

Determine

**a.** $F_2$

**b.** $S_2$

***Solution***

**a.** $$F_2 = \frac{A_2}{A_1} \times F_1 = \frac{100}{25} \times 200 = 800\ N$$

**b.** $$S_2 = \frac{A_1}{A_2} \times S_1 = \frac{25}{100} \times 5 = 1.25\ cm$$