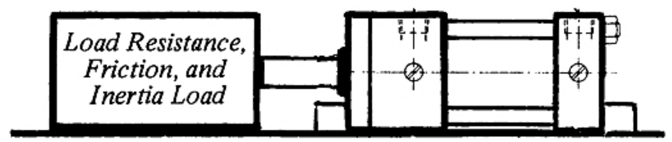
FLUID POWER Design Data Sheet-

Womack

Revised Sheet 4 – Womack Design Data File

FORCE REQUIRED TO ACCELERATE A LOAD



Cylinder Load Consists of Three Components

The load on a hydraulic cylinder (or motor) consists of these three components:

(1). Normal load resistance, where fluid power is converted into mechanical work exerted against the load.
(2). Friction resistance, where some of the fluid power is expended in overcoming friction.
(3). Inertia, where fluid power is needed to get a massive load into motion, sometimes very quickly.

As far as Items (1) and (2) are concerned, acceleration to final velocity would be instantaneous as soon as the fluid power is applied to the cylinder (or motor).

If the load has high inertia due to high mass, as in Item (3), then an ***additional*** amount of pressure must be supplied to accelerate the load from standstill to final velocity in a desired interval of time. This power due to extra pressure is carried as kinetic energy while the load is moving at a constant velocity, and may come back into the system as shock and heat when the load is stopped, unless it can be absorbed by the load in the form of work.

The purpose of this data sheet is to show how to calculate the extra pressure or torque needed in a hydraulic system to accelerate an inertia load, Item (3), from standstill to its final velocity in a given time, assuming the pressure needed for Items (1) and (2), the work load and the friction resistance has already been calculated or assumed.

Calculating for Inertia Load . . .

Before calculating the extra PSI needed to rapidly accelerate this vertically moving cylinder, the normal PSI needed to move the load at a constant speed must be calculated by the usual method: Load weight ÷ Piston Area. Allowance should also be made for friction in the ways or guides if significant.

Use the following formula to calculate the ***extra*** PSI for acceleration to a final velocity in a specified time:

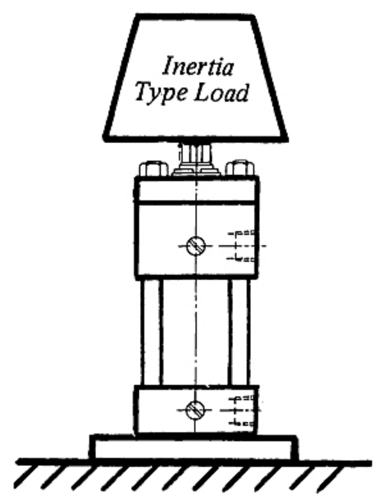
(a). **F= (V x W) ÷ (g x t) Lbs, in which:**

F is the accelerating force, in lbs, that will be needed.
V is the final velocity, in feet per second, starting from standstill.
W is the load weight, in lbs.
g is acceleration of gravity to convert weight into mass, always 32.16
t is the time, in seconds, during which acceleration will take place.

If the cylinder bore is known, the accelerating force for its piston can be found directly from the formula:

(b). **PSI = V x W ÷(A x g x t), in which:**

A is piston area in square inches. Other symbols are same as above.



PROBLEM DATA – VERTICAL CYLINDER WITH INERTIA LOAD	
Steady Load = 35,000 lbs.	Initial Velocity = 0; Final Velocity = 12 ft/sec.
Cylinder Bore = 4" (Piston Area = 12.57 sq.ins.)	Time Required to Accelerate = 2 Seconds.

Example of Inertia Calculation . . .

Use the problem data in the box to solve for the total PSI needed on the vertically moving cylinder not only to lift the given load, but to accelerate it to its final velocity in the specified time. Or to accelerate it from a lower to a higher velocity.

PSI for Steady Movement . . . 35,000 lbs. (load weight) ÷ 12.57 (piston area) = 2784 PSI needed to raise the load.

PSI for Acceleration . . . PSI = (12 x 35,000) ÷ (12.57 x 32.16 x 2) = 520 PSI.

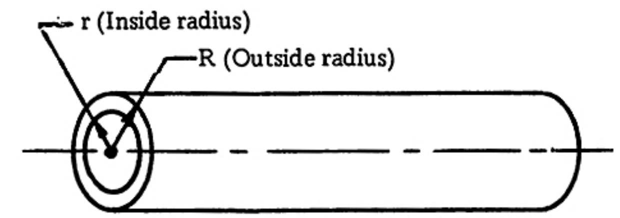
Total PSI . . . The cylinder must be provided with 2784 + 520 = 3304 PSI to meet all conditions of the problem.

Non-Inertia Loads . . .

No significant extra PSI is needed to accelerate work loads which consist almost entirely of frictional resistance and negligible mass.

MOMENT OF INERTIA OF ROTATING LOAD . . .

The moment of inertia, indicated with symbol J in the formulae in the opposite column, must be calculated before accelerating torque can be figured. Examples for three common shapes are shown here. Many other shapes are shown in machinery handbooks.

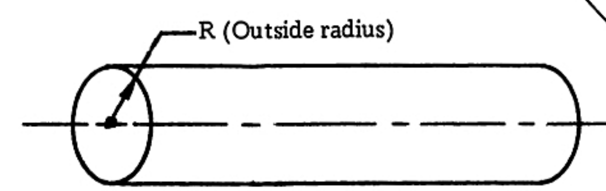


HOLLOW CYLINDER (Pipe) . . .

J (moment of inertia) of a pipe about an axis running lengthwise is:

J = W x (R² + r²) ÷ 2g Inch-Lbs-Secs², in which:

W is total weight of pipe in pounds
R is outside radius of pipe in inches
r is inside radius of pipe in inches
g is acceleration of gravity, always 32.16

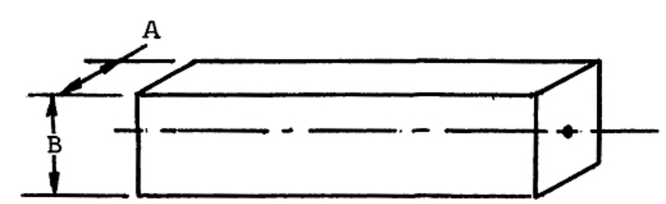


SOLID CYLINDER . . .

J (moment of inertia) of a solid cylinder about an axis running lengthwise is:

J = W x R² ÷ 2g Inch-Lbs-Secs², in which:

W is total weight of cylinder in pounds
R is outside radius of cylinder in inches
g is acceleration of gravity, always 32.16



PRISM . . .

J (moment of inertia) of a prism of uniform cross section about the axis shown is:

J = W x (A² + B²) ÷ 12g Inch-Lbs-Secs², in which:

W is total weight of prism in pounds
A and B are cross section dimensions in inches
g is acceleration of gravity, always 32.16

ROTATING LOADS – Driven With Hydraulic Motors

Centrifugal pipe casting in which a high mass must be rapidly accelerated to a high rotational speed, is a typical application where a significant amount of extra torque, in addition to that required to keep the pipe spinning at a constant speed, must be supplied by the hydraulic motor. Incidentally, most rotating loads driven at high speeds ***do*** require extra torque to get them up to speed in a reasonable time because of the very high kinetic energy contained in almost any rotating load driven at high speed.

The ***extra*** torque for acceleration can be calculated with this basic formula:

(c) **T=J x π x RPM ÷ 360 x t inch-lbs., in which:**

T is the extra torque in inch-lbs.
J is the moment of inertia of rotating load which must be calculated. See formula in box in opposite column.
π is always 3.14.
RPM is the change in velocity, revolutions per minute, from standstill to final velocity, or from a lower to a higher speed.
t is the time, in seconds, allowed for the acceleration.

After finding torque, T, the additional PSI on the hydraulic motor to produce this torque can be determined from catalog information on the particular motor used.

EXAMPLE OF PIPE SPINNING . . .

Find the torque required to accelerate a 500 lb. pipe from a standstill to 700 RPM in a time of 5 seconds. Pipe diameter is 10" O.D. x 7" I.D.

First, solve for the moment of inertia using the formula in the box in the other column.

J (moment of inertia) = 500 lbs x (5² + 3.5²) ÷ 2 x 32.16
J = 500 x (25 + 12.25) ÷ 64.32 = 289.6

Next, use this calculated value of J in Formula *(c)* above to determine torque required just for acceleration.

T = 289.6 x 3.14 x 700 ÷ 360 x 5 = 353.6 inch lbs.

Remember, this calculated value of torque is in addition to steady torque required to keep the pipe spinning at a constant RPM. Also remember that the GPM oil flow to the motor must be sufficient to produce the desired 700 RPM.

Acceleration From a Lower to a Higher Speed

When accelerating from a lower to a higher speed, subtract the difference between the two speeds and use this as RPM in the basic formula *(c)* at the top of this page.

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