Shock Absorber Sizing Examples

Typical Shock Absorber Applications

SYMBOLS

- a = Acceleration (in./sec.^{2})(mls^2)
- A = Width (in.)(m)
- B = Thickness (in.)(m)
- C = Number of cycles per hour
- d = Cylinder bore diameter (in.)(mm)
- D = Distance (in.)(m)
- E_K = Kinetic energy (in-lbs.)(Nm)
- E_T = Total energy per cycle (in-lbs./c)(Nm/c), $E_K + E_W$
- E_TC = Total energy to be absorbed per hour (in-lbs./hr)(Nm/hr)
- E_W = Work or drive energy (in-lbs.)(Nm)
- F_D = Propelling force (lbs.)(N)
- F_P = Shock force (lbs.)(N)
- H = Height (in.)(m)
- Hp = Motor rating (hp)(kw)
- L = Length (in.)(m)
- P = Operating pressure (psi)(bar)
- S = Stroke of shock absorber (in.)(m)
- t = Time (sec.)
- T = Torque (in-lbs.)(Nm)
- V = Impact velocity (in./sec.)(m/s)
- W = Weight (lbs.)(Kg)

USEFUL FORMULAS

1. To Determine Shock Force

$$F_P = \frac{E_T}{S \times \mathbf{.85}}$$

2. To Determine Impact Velocity

A. If there is no acceleration (V is constant) (e.g., load being pushed by hydraulic cylinder or motor driven.) $V = \frac{D}{t}$

B. If there is acceleration. (e.g., load being pushed by air cylinder) $V = \frac{\mathbf{2} \times D}{t}$

3. To Determine Propelling Force Generated by Electric Motor

$F_D = \frac{\mathbf{19{,}800} \times Hp}{V}$ $F_D = \frac{\mathbf{30\ 000} \times Hp}{V}$ (metric)

4. To Determine Propelling Force of Pneumatic or Hydraulic Cylinders

$F_D = \mathbf{.7854} \times d^2 \times P$ $F_D = \mathbf{0{,}07854} \times d^2 \times P$ (metric)

5. Free Fall Applications

A. Find Velocity for a Free Falling Weight:
$V = \sqrt{\mathbf{772} \times H}$ $V = \sqrt{19{,}6 \times H}$ (metric)

B. Kinetic Energy of Free Falling Weight:
$E_K = W \times H$

6. Deceleration and G Load

A. To Determine Approximate G Load with a Given Stroke
$G = \frac{F_P - F_D}{W}$ $G = \frac{F_P - F_D}{kg \times 9{,}81}$ (metric)

B. To Determine the Approximate Stroke with a Given G Load (Conventional Damping Only)
$$S = \frac{E_K}{GW\ .85 - .15\ F_D}$$

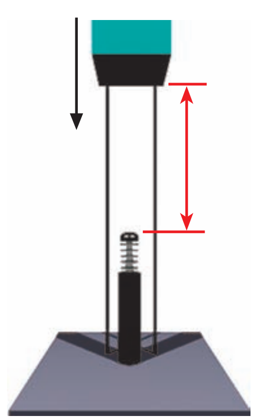
NOTE: Constants are printed in **bold**.

The following examples are shown using Imperial formulas and units of measure.

Shock Absorbers

EXAMPLE 1:

Vertical Free Falling Weight



STEP 1: Application Data
(W) Weight = 5,000 lbs.
(H) Height = 20 in.
(C) Cycles/Hr = 2

STEP 2: Calculate kinetic energy
$E_K = W \times H$
$E_K = 5{,}000 \times 20 = 100{,}000$ in-lbs.

Assume Model HD 2.0 x 10 is adequate (Page 15).

STEP 3: Calculate work energy
$E_W = W \times S$
$E_W = 5{,}000 \times 10$
$E_W = 50{,}000$ in-lbs.

STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W$
$E_T = 100{,}000 + 50{,}000$
$E_T = 150{,}000$ in-lbs./c

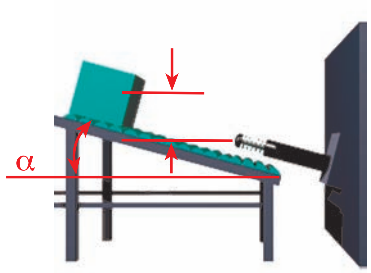
STEP 5: Calculate total energy per hour
$E_TC = E_T \times C$
$E_TC = 150{,}000 \times 2$
$E_TC = 300{,}000$ in-lbs./hr

STEP 6: Calculate impact velocity and confirm selection
$V = \sqrt{\mathbf{772} \times H}$
$V = \sqrt{\mathbf{772} \times 20}$
$V = 124$ in./sec.

Model HD 2.0 x 10 is adequate.

EXAMPLE 2:

Free Moving Load Down an Inclined Plane



STEP 1: Application Data
(W) Weight = 2,000 lbs.
(H) Height = 8 in.
(α) Angle of incline = 30°
(C) Cycles/Hr = 60

STEP 2: Calculate kinetic energy
$E_K = W \times H$
$E_K = 2{,}000 \times 8$
$E_K = 16{,}000$ in-lbs.

Assume Model HD 1.5 x 2 is adequate (Page 13).

STEP 3: Calculate work energy
$F_D = W \times \sin \alpha$
$F_D = 2{,}000 \times .5$
$F_D = 1{,}000$ lbs.
$E_W = F_D \times S$
$E_W = 1{,}000 \times 2$
$E_W = 2{,}000$ in-lbs.

STEP 4: Calculate total energy per cycle
$E_T = E_K + E_W$
$E_T = 16{,}000 + 2{,}000$
$E_T = 18{,}000$ in-lbs./c

STEP 5: Calculate total energy per hour
$E_TC = E_T \times C$
$E_TC = 18{,}000 \times 60$
$E_TC = 1{,}080{,}000$ in-lbs./hr

STEP 6: Calculate impact velocity and confirm selection
$V = \sqrt{\mathbf{772} \times H}$
$V = \sqrt{\mathbf{772} \times 8} = 79$ in./sec.

Model HD 1.5 x 2 is adequate.

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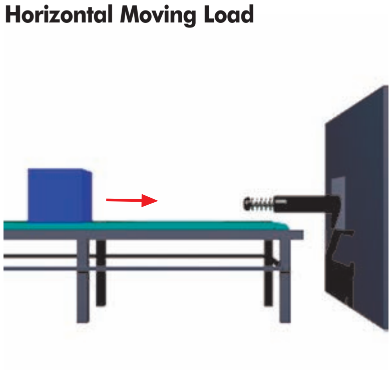
EXAMPLE 3:
Horizontal Moving Load



STEP 1: Application Data
(W) Weight = 20,000 lbs.
(V) Velocity = 20 in./sec.
(C) Cycles/Hr = 4

STEP 2: Calculate kinetic energy

$E_K = \frac{W}{772} \times V^2$

$E_K = \frac{20,000}{772} \times 20^2$

$E_K = 10,364$ in-lbs.

Assume Model HD 1.5 x 2 is adequate (Page 13).

If there is no additional drive force proceed to step 4 and $E_w = 0$. If the application is driven by a cylinder, proceed to step 3a. If the application is driven by a motor proceed to step 3b.

STEP 3a: Calculate work energy:
(d) Cylinder bore diamter = 6 in.
(P) Cylinder pressure = 80 psi
$F_D = .7854 \times d^2 \times P$
$F_D = .7854 \times 6^2 \times 80$ psi
$F_D = 2,262$ lbs.

$E_w = F_D \times S$
$E_w = 2,262 \times 2$
$E_w = 4,524$ in-lbs.

STEP 3b: Calculate work energy:
(Hp) Motor Horsepower = 5 Hp

$F_D = \frac{19,800 \times Hp}{V}$

$F_D = \frac{19,800 \times 5}{20}$

$F_D = 4,950$ in-lbs.

$E_w = F_D \times S$
$E_w = 4,950 \times 2$
$E_w = 9,900$ in-lbs.

STEP 4: Calculate total energy per cycle
Note: Using Calculations from 3a
$E_T = E_K + E_w$
$E_T = 10,364 + 4,524$
$E_T = 14,888$ in-lbs.

STEP 5: Calculate total energy per hour
$E_TC = E_T \times C$
$E_TC = 14,888 \times 4$
$E_TC = 59,552$ in-lbs./hr

Model HD 1.5 x 2 is adequate.

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Shock Absorber Sizing Examples
Typical Shock Absorber and Crane Applications

Crane A		Per Buffer
Propelling Force Crane	lbs.	
Propelling Force Trolley	lbs.	
Weight of Crane	lbs.	
Weight of Trolley	lbs.	
Distance X_{min}	in.	
Distance X_{max}	in.	
Distance Y_{min}	in.	
Distance Y_{max}	in.	
Crane Velocity	in./sec.	
Trolley Velocity	in./sec.	

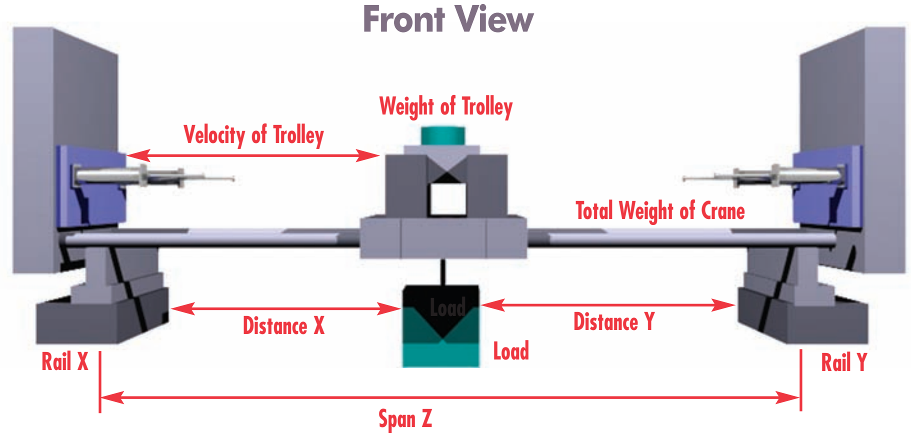
Crane B		Per Buffer
Propelling Force Crane	lbs.	
Propelling Force Trolley	lbs.	
Weight of Crane	lbs.	
Weight of Trolley	lbs.	
Distance X_{min}	in.	
Distance X_{max}	in.	
Distance Y_{min}	in.	
Distance Y_{max}	in.	
Crane Velocity	in./sec.	
Trolley Velocity	in./sec.	

Crane C		Per Buffer
Propelling Force Crane	lbs.	
Propelling Force Trolley	lbs.	
Weight of Crane	lbs.	
Weight of Trolley	lbs.	
Distance X_{min}	in.	
Distance X_{max}	in.	
Distance Y_{min}	in.	
Distance Y_{max}	in.	
Crane Velocity	in./sec.	
Trolley Velocity	in./sec.	

Please note:
Unless instructed otherwise, Enidine will always calculate with:

- 100% velocity v, and
- 100% propelling force F_D

Front View



Plan Views

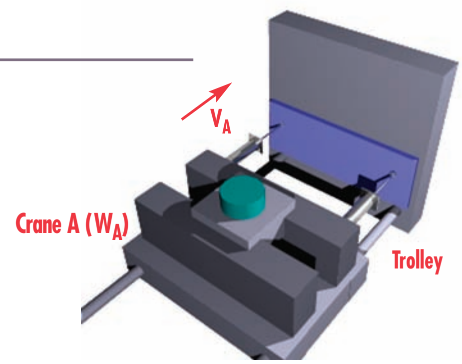
Application 1
Crane A against Solid Stop

Velocity:

$$V_r = V_A$$

Impact weight per buffer:

$$W_D = \frac{W}{2}$$



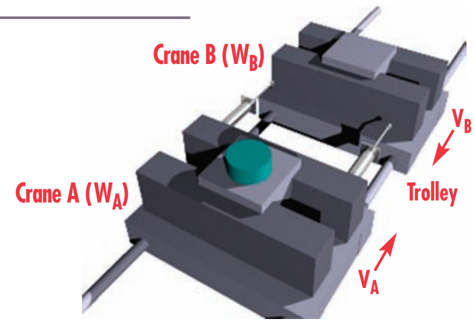
Application 2
Crane A against Crane B

Velocity:

$$V_r = V_A + V_B$$

Impact weight per buffer:

$$W_D = \frac{W_A \bullet W_B}{W_A + W_B} \div 2$$



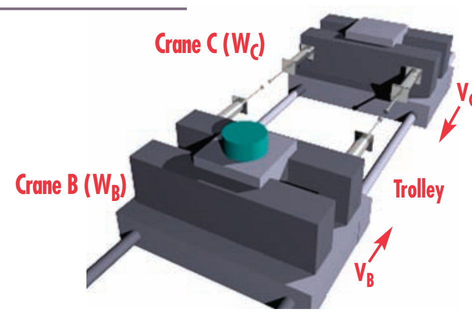
Application 3
Crane B against Crane C

Velocity:

$$V_r = \frac{V_B + V_C}{2}$$

Impact weight per buffer:

$$W_D = \frac{W_B \bullet W_C}{W_B + W_C}$$



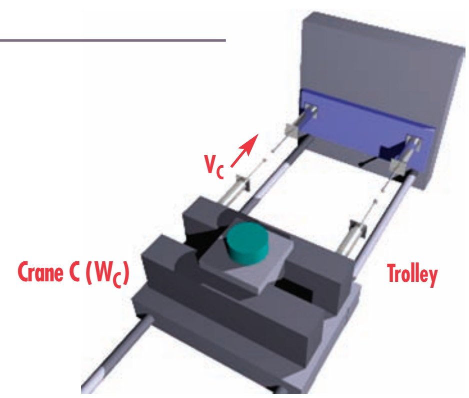
Application 4
Crane C against Solid Stop with Buffer

Velocity:

$$V_r = \frac{V_C}{2}$$

Impact weight per buffer:

$$W_D = W_C$$



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Calculation Example for Harbor Cranes as Application 1

Please note that this example is not based on any particular standard. The slung load can swing freely, and is therefore not taken into account in the calculation.

Given Values

Total Weight of Crane:	**837,750 lbs.**
Weight of Trolley:	**99,200 lbs.**
Span:	**z = 3,940 in.**
Trolley Impact Distance:	**x = 3,540 in.**
Crane Velocity:	V_{Crane} **= 60 in./sec.**
Required Stroke:	**24 in.**
Trolley Velocity:	$V_{Trolley}$ **= 160 in./sec.**
Required Stroke:	**40 in.**

Determination of the Maximum Impact Weight W_{Dmax} per Buffer

$$\text{Bridge Weight per Rail} = \frac{\text{crane weight}_{total} - \text{trolley weight}}{2}$$

$$\text{Bridge Weight per Rail} = \frac{837{,}750 \text{ lbs.} - 99{,}200 \text{ lbs.}}{2} = 369{,}275 \text{ lbs.}$$

$$W_{Dmax} = \text{Bridge Weight per Rail} + \text{Trolley Weight in Impact Position}$$

$$W_{Dmax} = 369{,}275 \text{ lbs.} + \frac{(99{,}200 \text{ lbs.} \bullet 3{,}540 \text{ in.})}{3{,}940 \text{ in.}}$$

$$\mathbf{W_{Dmax} = 458{,}404 \text{ lbs.}}$$

Determine Size of Shock Absorber for Crane

$$E_K = \frac{W_{Dmax}}{772} \bullet V_r^2$$

$$E_K = \frac{458{,}404 \text{ lbs.}}{772} \bullet (60 \text{ in./sec.})^2$$

$$\mathbf{E_K = 2{,}137{,}635 \text{ in-lbs.}}$$

$V_r = V_A$ Application 1

E_K = Kinetic Energy

η = Efficiency

Selecting for required 24-inch stroke:
HD 5.0 x 24, maximum shock force ca. 104,786 lbs = $F_s = \frac{E_K}{s \bullet \eta}$

Determine Size of Shock Absorber for Trolley

W_D = Trolley Weight per Shock Absorber

$$W_D = \frac{99{,}200 \text{ lbs.}}{2}$$

$$\mathbf{W_D = 49{,}600 \text{ lbs.}}$$

$$E_K = \frac{W_D}{772} \bullet V_r^2$$

$V_r = V_A$ Application 1

$$E_K = \frac{49{,}600 \text{ lbs.}}{772} \bullet (160 \text{ in./sec.})^2$$

$$\mathbf{E_K = 1{,}644{,}767 \text{ in-lbs.}}$$

Selecting for required 40-inch stroke:
HD 4.0 x 40, maximum shock force ca. 48,376 lbs. = $F_s = \frac{E_K}{s \bullet \eta}$