

# Shock Absorbers and Rate Controls

ENIDINE

Shock Absorbers and Rate Controls



**ENIDINE**

 **LDA**  
Solutions for Life



**ITT**

ENGINEERED FOR LIFE

ITT Enidine provides quality energy absorption and vibration isolation products and services to a variety of heavy industries throughout the globe. These industries include; steel and aluminum rolling mills, manufacturers of mill equipment, gantry cranes, ship to shore cranes, overhead bridge crane manufacturers and automated stacker cranes. ITT is a diversified leading manufacturer of highly engineered critical components and customized technology solutions for growing industrial end-markets in energy infrastructure, electronics, aerospace and transportation.

Building on its heritage of innovation, ITT partners with its customers to deliver enduring solutions to the key industries that underpin our modern way of life. Founded in 1920, ITT is headquartered in White Plains, NY, with employees in more than fifteen countries and sales in more than 125 countries. The company generated pro forma 2010 revenues of approximately \$2 billion.

As part of our strategy to make the customer central to everything we do, our core technologies, engineering strength and global scale offers greater value for customers in terms of quality, cost and delivery.











Industry Leading  
Quality and Value –  
On Time Every Time



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With its world headquarters located in Orchard Park, New York, USA, **ITT ENIDINE Inc.** is a world leader in the design and manufacture of standard and custom energy absorption and vibration isolation product solutions within the Industrial, Aerospace, Defense, Marine and Rail markets. Product ranges include shock absorbers, gas springs, rate controls, air springs, wire rope isolators, heavy industry buffers and emergency stops. With facilities strategically located throughout the world and in partnership with our vast global network of distributors, Enidine Incorporated continues to strengthen its presence within marketplace.

Founded in 1966, ITT Enidine Incorporated now has close to 600 employees located throughout the globe in the United States, Germany, France, Japan, China and Korea. With a team of professionals in engineering, computer science, manufacturing, production and marketing our employees provide our customers the very best in service and application solutions.

***“ITT Enidine is widely recognized as the preferred source for energy absorption and vibration isolation products.”***

From Original Equipment Manufacturers (OEM) to aftermarket applications, ITT Enidine offers a unique combination of product selection, engineering excellence and technical support to meet even the toughest energy absorption application requirements.

Global Manufacturing and Sales Facilities offer our customers:

- **Highly Trained Distribution Network**
- **State-of-the Art Engineering Capabilities**
- **Custom Solution Development**
- **Customer Service Specialists**
- **Multiple Open Communication Channels**

If you are unsure whether one of our standard products meets your requirements, feel free to speak with one of our technical representatives **toll-free at 1-800-852-8508**, or contact us via **e-mail at [techsales@enidine.com](mailto:techsales@enidine.com)**.

### Products/Engineering/Technical Support

ITT Enidine continually strives to provide the widest selection of shock absorbers and rate control products in the global marketplace. Through constant evaluation and testing, we bring our customers the most cost effective products with more features, greater performance and improved ease of use.

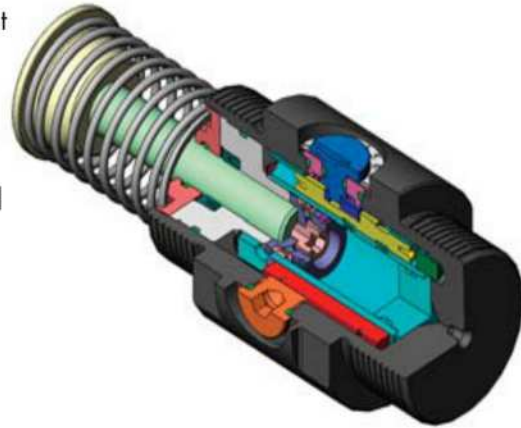


ITT Enidine engineers continue to monitor and influence trends in the motion control industry, allowing us to remain at the forefront of new energy absorption product development such as our new ECO Series shock absorbers and our new HDN Series shock Absorbers.

Our experienced engineering team has designed custom solutions for a wide variety of challenging applications, including automated warehousing systems and shock absorbers for hostile industrial environments such as glass manufacturing, among others. These custom application solutions have proven to be critical to our customers' success. Let ITT Enidine engineers do the same for you.



*Custom designs are not an exception at ITT Enidine, they are an integral part of our business. Should your requirements fit outside of our standard product range, Enidine engineers can assist in developing special finishes, components, hybrid technologies and new designs to ensure a "best-fit" product solution customized to your exact specifications.*



A talented engineering staff works to design and maintain the most efficient energy absorption product lines available today, using the latest engineering tools:

- **Solid Modeling**
- **3-D CAD Drawings**
- **3-D Solvable Support Technology**
- **Finite Element Analysis**
- **Complete Product Verification Testing Facility**

New product designs get to market fast because they can be fully developed in virtual environments before a prototype is ever built. This saves time and lets us optimize the best solution using real performance criteria.

## Global Service and Support

ITT Enidine offers its customers a global network of customer service staff technical sales personnel that are available to assist you with all of your application needs.

- Operating with lean manufacturing and cellular production, ITT Enidine produces higher quality custom and standard products with greater efficiency and within shorter lead times.
- An authorized Global Distribution Network is trained regularly by ITT Enidine staff on new products and services ensuring they are better able to serve you.
- **New Enisize sizing portal provides our customer with the necessary sizing and design tools. [www.enisize.com](http://www.enisize.com)**
- Global operations in United States, Germany, France, China, Japan and Korea.
- A comprehensive, website full of application information, technical data, sizing examples and information to assist in selecting the product that's right for you.

Our website also features a searchable worldwide distributor lookup to help facilitate fast, localized service. Contact us today for assistance with all of your application needs.



*Our global customer service and technical sales departments are available to assist you find the solution that's right for your application needs. Call us at 1.800.852.8508 or e-mail us at [industrialsales@enidine.com](mailto:industrialsales@enidine.com) and let us get started today.*

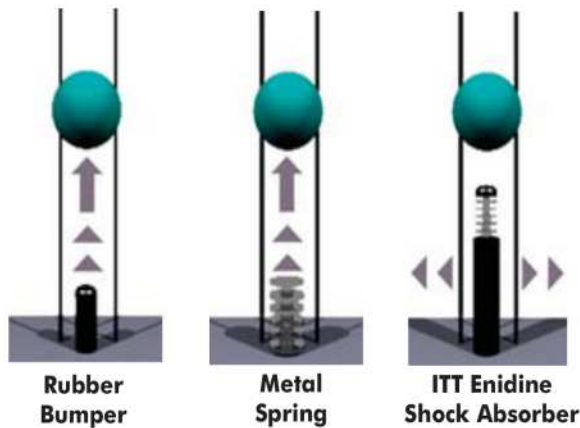


# Theory of Energy Absorption

ITT Enidine Inc.

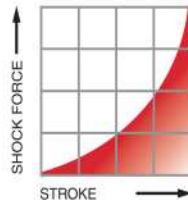
## Overview

As companies strive to increase productivity by operating machinery at higher speeds, often the results are increased noise, damage to machinery/products, and excessive vibration. At the same time, safety and machine reliability are decreased. A variety of products are commonly used to solve these problems. However, they vary greatly in effectiveness and operation. Typical products used include rubber bumpers, springs, cylinder cushions and shock absorbers. The following illustrations compare how the most common products perform:

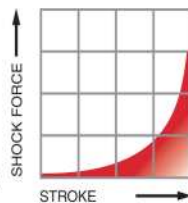


All moving objects possess kinetic energy. The amount of energy is dependent upon weight and velocity. A mechanical device that produces forces diametrically opposed to the direction of motion must be used to bring a moving object to rest.

**Rubber bumpers and springs**, although very inexpensive, have an undesirable recoil effect. Most of the energy absorbed by these at impact is actually stored. This stored energy is returned to the load, producing rebound and the potential for damage to the load or machinery. Rubber bumpers and springs initially provide low resisting force which increases with the stroke.



**Cylinder cushions** are limited in their range of operation. Most often they are not capable of absorbing energy generated by the system. By design, cushions have a relatively short stroke and operate at low pressures resulting in very low energy absorption. The remaining energy is transferred to the system, causing shock loading and vibration.



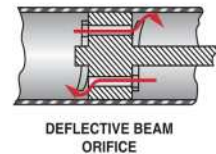
**Shock absorbers** provide controlled, predictable deceleration. These products work by converting kinetic energy to thermal energy. More specifically, motion applied to the piston of a hydraulic shock absorber pressurizes the fluid and forces it to flow through restricting orifices, causing the fluid to heat rapidly. The thermal energy is then transferred to the cylinder body and harmlessly dissipated to the atmosphere.

The advantages of using shock absorbers include:

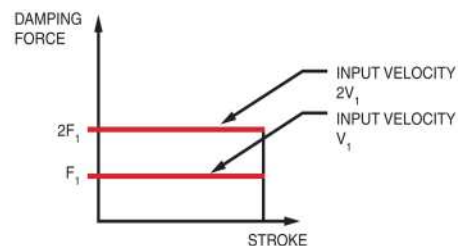
- 1. Longer Machine Life** – The use of shock absorbers significantly reduces shock and vibration to machinery. This eliminates machinery damage, reduces downtime and maintenance costs, while increasing machine life.
- 2. Higher Operating Speeds** – Machines can be operated at higher speeds because shock absorbers control or gently stop moving objects. Therefore, production rates can be increased.
- 3. Improved Production Quality** – Harmful side effects of motion, such as noise, vibration and damaging impacts, are moderated or eliminated so the quality of production is improved. Therefore, tolerances and fits are easier to maintain.
- 4. Safer Machinery Operation** – Shock absorbers protect machinery and equipment operators by offering predictable, reliable and controlled deceleration. They can also be designed to meet specified safety standards, when required.
- 5. Competitive Advantage** – Machines become more valuable because of increased productivity, longer life, lower maintenance costs and safer operation.

## Automotive vs. Industrial Shock Absorbers

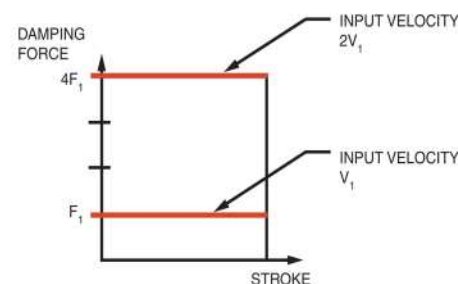
It is important to understand the differences that exist between the standard automotive-style shock absorber and the industrial shock absorber.



The automotive style employs the deflative beam and washer method of orificing. Industrial shock absorbers utilize single orifice, multi-orifice and metering pin configurations. The automotive type maintains a damping force which varies in direct proportion to the velocity of the piston, while the damping force in the industrial type varies in proportion to the square of the piston velocity. In addition, the damping force of the automotive type is independent of the stroke position while the damping force associated with the industrial type can be designed either dependent or independent of stroke position.



AUTOMOTIVE TYPE SHOCK ABSORBER



INDUSTRIAL TYPE SHOCK ABSORBER



Equally as important, automotive-style shock absorbers are designed to absorb only a specific amount of input energy. This means that, for any given geometric size of automotive shock absorber, it will have a limited amount of absorption capability compared to the industrial type.

This is explained by observing the structural design of the automotive type and the lower strength of materials commonly used. These materials can withstand the lower pressures commonly found in this type. The industrial shock absorber uses higher strength materials, enabling it to function at higher damping forces.

## Adjustment Techniques

A properly adjusted shock absorber safely dissipates energy, reducing damaging shock loads and noise levels. For optimum adjustment setting see useable adjustment setting graphs. Watching and "listening" to a shock absorber as it functions aids in proper adjustment.



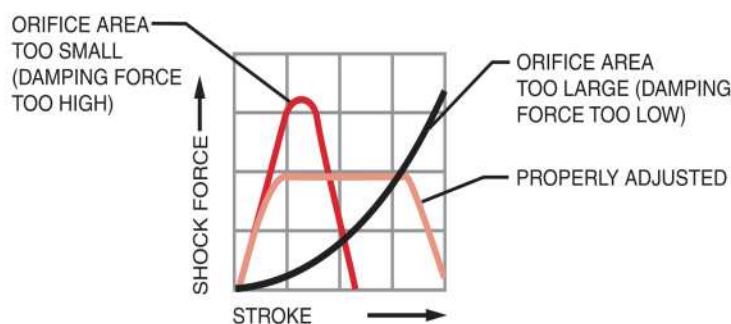
To correctly adjust a shock absorber, set the adjustment knob at zero (0) prior to system engagement. Cycle the mechanism and observe deceleration of the system.

If damping appears too soft (unit strokes with no visual deceleration and bangs at end of stroke), move indicator to next largest number. Adjustments must be made in gradual increments to avoid internal damage to the unit (e.g., adjust from 0 to 1, not 0 to 4).

Increase adjustment setting until smooth deceleration or control is achieved and negligible noise is heard when the system starts either to decelerate or comes to rest.

When abrupt deceleration occurs at the beginning of the stroke (banging at impact), the adjustment setting must be moved to a lower number to allow smooth deceleration.

If the shock absorber adjustment knob is set at the high end of the adjustment scale and abrupt deceleration occurs at the end of the stroke, a larger unit may be required.



## Shock Absorber Performance When Weight or Impact Velocity Vary

When conditions change from the original calculated data or actual input, a shock absorber's performance can be greatly affected, causing failure or degradation of performance. Variations in input conditions after a shock absorber has been installed can cause internal damage, or at the very least, can result in unwanted damping performance. Variations in weight or impact velocity can be seen by examining the following energy curves:

**Varying Impact Weight:** Increasing the impact weight (impact velocity remains unchanged), without reorificing or readjustment will result in increased damping force at the end of the stroke. Figure 1 depicts this undesirable bottoming peak force. This force is then transferred to the mounting structure and impacting load.

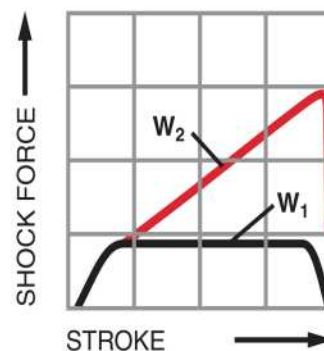


Figure 1

**Varying Impact Velocity:** Increasing impact velocity (weight remains the same) results in a radical change in the resultant shock force. Shock absorbers are velocity conscious products; therefore, the critical relationship to impact velocity must be carefully monitored. Figure 2 depicts the substantial change in shock force that occurs when the velocity is increased. Variations from original design data or errors in original data may cause damage to mounting structures and systems, or result in shock absorber failure if the shock force limits are exceeded.

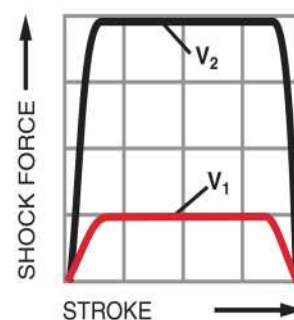


Figure 2



# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

## Overview

### SHOCK ABSORBER SIZING

Follow the next six steps to manually size Enidine shock absorbers:

**STEP 1:** Identify the following parameters. These must be known for all energy absorption calculations. Variations or additional information may be required in some cases.

- A. Weight of the load to be stopped (lbs.)(Kg).
- B. Velocity of the load upon impact with the shock absorber (in./sec.)(m/s).
- C. External (propelling) forces acting on the load (lbs.)(N), if any.
- D. Cyclic frequency at which the shock absorber will operate.
- E. Orientation of the application's motion (i.e. horizontal, vertical up, vertical down, inclined, rotary horizontal, rotary vertical up, rotary vertical down).

NOTE: For rotary applications, it is necessary to determine both the radius of gyration (K) and the mass moment of inertia (I). Both of these terms locate the mass of a rotating object with respect to the pivot point. It is also necessary to determine the angular velocity ( $\omega$ ) and the torque (T).

**STEP 2:** Calculate the kinetic energy of the moving object.

$$E_K = \frac{W}{772} \times V^2 \text{ (linear) or } E_K = \frac{1}{2} \omega^2 \text{ (rotary) or } E_K = \frac{1}{2} M V^2 \text{ (metric)}$$

(Note: 772 = 2 x acceleration due to gravity)

Utilizing the Product Locators for Shock Absorbers located at the beginning of each product family section, select a model, either adjustable or non-adjustable, with a greater energy per cycle capacity than the value just calculated.

**STEP 3:** Calculate the work energy input from any external (propelling) forces acting on the load, using the stroke of the model selected in Step 2.

$$E_W = F_D \times S \text{ (linear) or } E_W = \frac{T}{R_S} \times S \text{ (rotary)}$$

**Caution:** The propelling force must not exceed the maximum propelling force listed for the model chosen. If the propelling force is too high, select a larger model and recalculate the work energy.

**STEP 4:** Calculate the total energy per cycle  $E_T = E_K + E_W$

The model selected must have at least this much energy capacity. If not, select a model with greater energy capacity and return to Step 3.

**STEP 5:** Calculate the energy that must be absorbed per hour. Even though the shock absorber can absorb the energy in a single impact, it may not be able to dissipate the heat generated if the cycle rate is too high.

$$E_T C = E_T \times C$$

The model selected must have an energy per hour capacity greater than this calculated figure. If it is not greater, there are two options:

1. Choose another model that has more energy per hour capacity (because of larger diameter or stroke). Keep in mind that if the stroke changes, you must return to Step 3.
2. Use an Air/Oil Tank. The increased surface area of the tank and piping will increase the energy per hour capacity by 20 percent.

**STEP 6:** If you have selected an HP, PM, SPM, TK, or PRO Series model, refer to the sizing graph(s) in the appropriate series section to determine the required damping constant. If the point cannot be found in the sizing graph, you must select a larger model or choose a different series. Note that if the stroke changes, you must return to Step 3.

If you have selected an adjustable model (OEM, HP or HDA series), refer to the Useable Adjustment Setting Range graph for the chosen model. The impact velocity must fall within the limits shown on the graph.

### RATE CONTROL SIZING

Follow the next five steps to manually size ITT Enidine rate controls:

**STEP 1:** Identify the following parameters. These must be known for all rate control calculations. Variations or additional information may be required in some cases.

- A. Weight of the load to be controlled (lbs.)(Kg)
- B. Desired velocity of the load (in./sec.)(m/s)
- C. External (propelling) force acting on the load (lbs.)(N), if any.
- D. Cyclic frequency at which the rate control will operate.
- E. Orientation of the application's motion (i.e. horizontal, vertical up, vertical down, inclined, rotary horizontal, rotary vertical up, rotary vertical down.)
- F. Damping direction (i.e., tension [T], compression [C] or both [T and C].
- G. Required stroke (in.)(mm)

**STEP 2:** Calculate the propelling force at the rate control in each direction damping is required. (See sizing examples on page 6-12).

**CAUTION:** The propelling force in each direction must not exceed the maximum propelling force listed for the chosen model. If the propelling force is too high, select a larger model.

**STEP 3:** Calculate the total energy per cycle

$$E_T = E_W \text{ (tension) } + E_W \text{ (compression)}$$

$$E_W = F_D \times S$$

**STEP 4:** Calculate the total energy per hour

$$E_T C = E_T \times C$$

The model selected must have an energy per hour capacity greater than this calculated figure. If not, choose a model with a higher energy per hour capacity.

Compare the damping direction, stroke, propelling force, and total energy per hour to the values listed in the Rate Controls Engineering Data Charts (pages 97-106).

**STEP 5:** If you have selected a rate control, refer to the sizing graphs in the Rate Controls section to determine the required damping constant.

If you have selected an adjustable model (ADA), refer to the Useable Adjustment Setting Range graph for the chosen model. The desired velocity must fall within the limits shown on the graph.



# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

### Overview

### SYMBOLS

a = Acceleration (in./sec.<sup>2</sup>)(m/s<sup>2</sup>)  
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<sub>K</sub> = Kinetic energy (in-lbs.)(Nm)  
E<sub>T</sub> = Total energy per cycle  
(in-lbs.)(Nm/c), E<sub>K</sub> + E<sub>W</sub>  
E<sub>T</sub>C = Total energy to be absorbed per  
hour (in-lbs./hr)(Nm/hr)  
E<sub>W</sub> = Work or drive energy (in-lbs.)(Nm)  
F<sub>D</sub> = Propelling force (lbs.)(N)  
F<sub>P</sub> = Shock force (lbs.)(N)  
H = Height (in.)(m)  
Hp = Motor rating (hp)(kw)  
I = Mass moment of inertia  
(in-lbs./sec.<sup>2</sup>)(kgm<sup>2</sup>)  
K = Radius of gyration (in.)(m)  
L = Length (in.)(m)  
P = Operating pressure (psi)(bar)  
R<sub>S</sub> = Mounting distance from pivot point (in.)(m)  
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)

α = Angle of incline (degrees)  
θ = Start point from true vertical 0° (degrees)  
μ = Coefficient of friction  
∅ = Angle of rotation (degrees)  
ω = Angular velocity (radians/sec)

### USEFUL FORMULAS

#### 1. To Determine Shock Force

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

For PRO and PM Series only, use

$$F_P = \frac{E_T}{S \times .50}$$

#### 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)

$$V = \frac{2 \times D}{t}$$

#### 3. To Determine Propelling Force Generated by Electric Motor

$$F_D = \frac{19,800 \times \text{Hp}}{V} \quad F_D = \frac{3,000 \times \text{Hp}}{V} \quad (\text{metric})$$

#### 4. To Determine Propelling Force of Pneumatic or Hydraulic Cylinders

$$F_D = .7854 \times d^2 \times P \quad F_D = 0.07854 \times d^2 \times P \quad (\text{metric})$$

#### 5. Free Fall Applications

A. Find Velocity for a Free Falling Weight:  
 $V = \sqrt{772 \times H} \quad V = \sqrt{19.6 \times H} \quad (\text{metric})$

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

$$G = \frac{F_P - F_D}{W} \quad G = \frac{F_P - F_D}{\text{kg} \times 9.81} \quad (\text{metric})$$

B. To Determine the Approximate Stroke with a Given G Load (Conventional Damping Only)

$$S = \frac{E_K}{GW \times .85 - .15 F_D}$$

\*For PRO/PM and TK Models:

$$S = \frac{E_K}{GW \times .5 - .5 F_D}$$

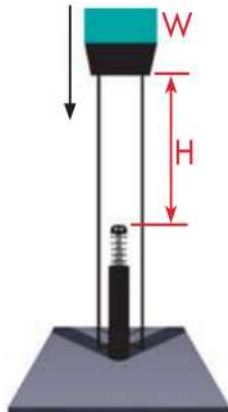
NOTE: Constants are printed in **bold**.

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 = 3,400 lbs.  
(H) Height = 20 in.  
(C) Cycles/Hr = 2

#### STEP 2: Calculate kinetic energy

$$E_K = W \times H$$

$$E_K = 3,400 \times 20 = 68,000 \text{ in-lbs.}$$

Assume Model OEM 4.0M x 6 is adequate (Page 31).

#### STEP 3: Calculate work energy

$$E_W = W \times S$$

$$E_W = 3,400 \times 6$$

$$E_W = 20,400 \text{ in-lbs.}$$

#### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W$$

$$E_T = 68,000 + 20,400$$

$$E_T = 88,400 \text{ in-lbs./c}$$

#### STEP 5: Calculate total energy per hour

$$E_{TC} = E_T \times C$$

$$E_{TC} = 88,400 \times 2$$

$$E_{TC} = 176,800 \text{ in-lbs./hr}$$

#### STEP 6: Calculate impact velocity and confirm selection

$$V = \sqrt{772 \times H}$$

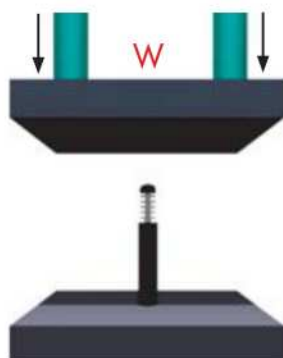
$$V = \sqrt{772 \times 20}$$

$$V = 124 \text{ in./sec.}$$

Model OEM 4.0M x 6 is adequate.

#### EXAMPLE 2:

##### Vertical Moving Load with Propelling Force Downward



#### STEP 1: Application Data

(W) Weight = 3,400 lbs.  
(V) Velocity = 80 in./sec.  
(d) Cylinder bore dia. = 4 in.  
(P) Pressure = 70 psi  
(C) Cycles/Hr = 200

#### STEP 2: Calculate kinetic energy

$$E_K = \frac{W}{772} \times V^2 = \frac{3,400}{772} \times 80^2$$

$$E_K = 28,187 \text{ in-lbs.}$$

Assume Model OEM 4.0M x 4 is adequate (Page 31).

#### STEP 3: Calculate work energy

$$F_D = [.7854 \times d^2 \times P] + W$$

$$F_D = [.7854 \times 4^2 \times 70] + 3,400$$

$$F_D = 4,280 \text{ lbs.}$$

$$E_W = F_D \times S$$

$$E_W = 4,280 \times 4$$

$$E_W = 17,120 \text{ in-lbs.}$$

#### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W$$

$$E_T = 28,187 + 17,120$$

$$E_T = 45,307 \text{ in-lbs./c}$$

#### STEP 5: Calculate total energy per hour

$$E_{TC} = E_T \times C$$

$$E_{TC} = 45,307 \times 200$$

$$E_{TC} = 9,061,400 \text{ in-lbs./hr}$$

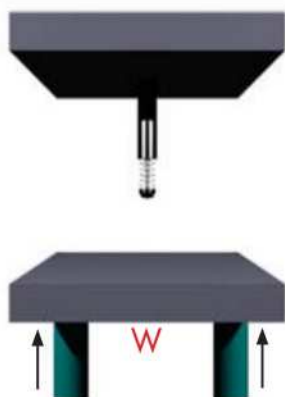
Model OEM 4.0M x 4 is adequate.



## Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

## Overview

**EXAMPLE 3:**Vertical Moving Load with  
Propelling Force Upward**STEP 1: Application Data**

(W) Weight = 3,400 lbs.  
 (V) Velocity = 80 in./sec.  
 (d) 2 Cylinders bore dia. = 6 in.  
 (P) Operating pressure = 70 psi  
 (C) Cycles/Hr = 200

**STEP 2: Calculate kinetic energy**

$$E_K = \frac{W}{772} \times V^2 = \frac{3,400}{772} \times 80^2$$

$$E_K = 28,187 \text{ in-lbs.}$$

Assume Model OEM 3.0M x 5 is  
adequate (Page 31).

**STEP 3: Calculate work energy**

$$F_D = 2 \times [.7854 \times d^2 \times P] - W$$

$$F_D = 2 \times [.7854 \times 6^2 \times 70] - 3,400$$

$$F_D = 558 \text{ lbs.}$$

$$E_W = F_D \times S$$

$$E_W = 558 \times 5$$

$$E_W = 2,790 \text{ in-lbs.}$$

**STEP 4: Calculate total energy per cycle**

$$E_T = E_K + E_W$$

$$E_T = 28,187 + 2,790$$

$$E_T = 30,977 \text{ in-lbs./c}$$

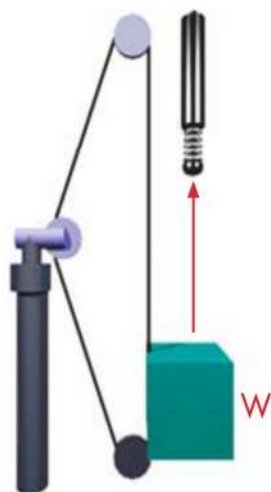
**STEP 5: Calculate total energy per hour**

$$E_{TC} = E_T \times C$$

$$E_{TC} = 30,977 \times 200$$

$$E_{TC} = 6,195,400 \text{ in-lbs./hr}$$

Model OEM 3.0M x 5 is adequate.

**EXAMPLE 4:**Vertical Moving Load with  
Propelling Force from Motor

(e.g., Load Moving Force Up)

**STEP 1: Application Data**

(W) Weight = 200 lbs.  
 (V) Velocity = 60 in./sec.  
 (Hp) Motor horsepower = 1.5 Hp  
 (C) Cycles/Hr = 100

**STEP 2: Calculate kinetic energy**

$$E_K = \frac{W}{772} \times V^2 = \frac{200}{772} \times 60^2$$

$$E_K = 933 \text{ in-lbs.}$$

**CASE A: UP****STEP 3: Calculate work energy**

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

$$F_D = \frac{19,800 \times 1.5}{60} - 200$$

$$F_D = 295 \text{ lbs.}$$

Assume Model OEM 1.25 x 2 is  
adequate (Page 24).

$$E_W = F_D \times S$$

$$E_W = 295 \times 2$$

$$E_W = 590 \text{ in-lbs.}$$

**STEP 4: Calculate total energy per cycle**

$$E_T = E_K + E_W$$

$$E_T = 933 + 590$$

$$E_T = 1,523 \text{ in-lbs./c}$$

**STEP 5: Calculate total energy per hour**

$$E_{TC} = E_T \times C$$

$$E_{TC} = 1,523 \times 100$$

$$E_{TC} = 152,300 \text{ in-lbs./hr}$$

Model OEM 1.25 x 2 is adequate.

**CASE B: DOWN****STEP 3: Calculate work energy**

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

$$F_D = \frac{19,800 \times 1.5}{60} + 200$$

$$F_D = 695 \text{ lbs.}$$

Assume Model OEMXT 2.0M x 2 is  
adequate (Page 29).

$$E_W = F_D \times S$$

$$E_W = 695 \times 2$$

$$E_W = 1,390 \text{ in-lbs.}$$

**STEP 4: Calculate total energy per cycle**

$$E_T = E_K + E_W$$

$$E_T = 933 + 1,390$$

$$E_T = 2,323 \text{ in-lbs./c}$$

**STEP 5: Calculate total energy per hour**

$$E_{TC} = E_T \times C$$

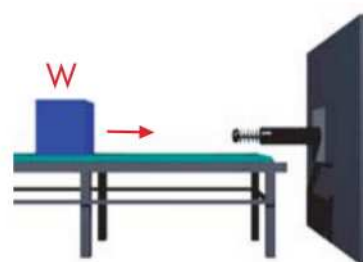
$$E_{TC} = 2,323 \times 100$$

$$E_{TC} = 232,300 \text{ in-lbs./hr}$$

Model OEMXT 2.0M x 2 is adequate.

**EXAMPLE 5:**

Horizontal Moving Load

**STEP 1: Application Data**

(W) Weight = 1,950 lbs.  
 (V) Velocity = 60 in./sec.  
 (C) Cycles/Hr = 200

**STEP 2: Calculate kinetic energy**

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

$$E_K = \frac{1,950}{772} \times 60^2$$

$$E_K = 9,093 \text{ in-lbs.}$$

Assume Model OEMXT 2.0M x 2 is  
adequate (Page 29).

**STEP 3: Calculate work energy: N/A****STEP 4: Calculate total energy per cycle**

$$E_T = E_K = 9,093 \text{ in-lbs./c}$$

**STEP 5: Calculate total energy per hour**

$$E_{TC} = E_T \times C$$

$$E_{TC} = 9,093 \times 200$$

$$E_{TC} = 1,818,600 \text{ in-lbs./hr}$$

Model OEMXT 2.0M x 2 is adequate.

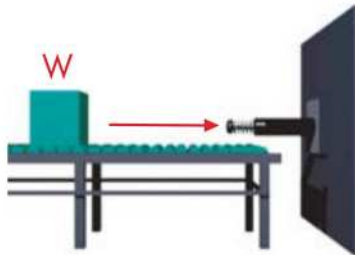


# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

### Overview

#### EXAMPLE 6: Horizontal Moving Load with Propelling Force



##### STEP 1: Application Data

(W) Weight = 1,950 lbs.  
(V) Velocity = 60 in./sec.  
(d) Cylinder bore dia. = 3 in.  
(P) Operating pressure = 70 psi  
(C) Cycles/Hr = 200

##### STEP 2: Calculate kinetic energy

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

$$E_K = \frac{1,950}{772} \times 60^2$$

$$E_K = 9,093 \text{ in-lbs.}$$

Assume Model OEMXT 2.0M x 2 is adequate (Page 29).

##### STEP 3: Calculate work energy

$$F_D = .7854 \times d^2 \times P$$

$$F_D = .7854 \times 3^2 \times 70$$

$$F_D = 495 \text{ lbs.}$$

$$E_W = F_D \times S$$

$$E_W = 495 \times 2$$

$$E_W = 990 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W$$

$$E_T = 9,093 + 990$$

$$E_T = 10,083 \text{ in-lbs./c}$$

##### STEP 5: Calculate total energy per hour

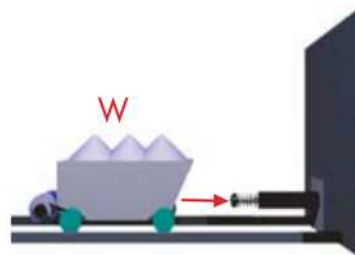
$$E_{TC} = E_T \times C$$

$$E_{TC} = 10,083 \times 200$$

$$E_{TC} = 2,016,600 \text{ in-lbs./hr}$$

Model OEMXT 2.0M x 2 is adequate.

#### EXAMPLE 7: Horizontal Moving Load, Motor Driven



##### STEP 1: Application Data

(W) Weight = 2,200 lbs.  
(V) Velocity = 60 in./sec.  
(Hp) Motor horsepower = 1.5 Hp  
(C) Cycles/Hr = 120

##### STEP 2: Calculate kinetic energy

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

$$E_K = \frac{2,200}{772} \times 60^2$$

$$E_K = 10,259 \text{ in-lbs}$$

Assume Model OEMXT 2.0M x 2 is adequate (Page 29).

##### STEP 3: Calculate work energy

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

$$F_D = \frac{19,800 \times 1.5}{60}$$

$$F_D = 495 \text{ lbs.}$$

$$E_W = F_D \times S$$

$$E_W = 495 \times 2$$

$$E_W = 990 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W$$

$$E_T = 10,259 + 990$$

$$E_T = 11,249 \text{ in-lbs./c}$$

##### STEP 5: Calculate total energy per hour

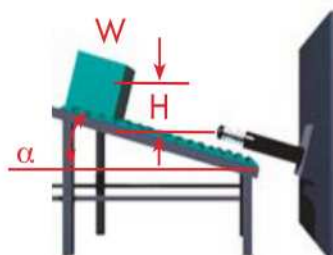
$$E_{TC} = E_T \times C$$

$$E_{TC} = 11,249 \times 120$$

$$E_{TC} = 1,349,880 \text{ in-lbs./hr}$$

Model OEMXT 2.0M x 2 is adequate.

#### EXAMPLE 8: Free Moving Load Down an Inclined Plane



##### STEP 1: Application Data

(W) Weight = 550 lbs.  
(H) Height = 8 in.  
(alpha) Angle of incline = 30°  
(C) Cycles/Hr = 250

##### STEP 2: Calculate kinetic energy

$$E_K = W \times H$$

$$E_K = 550 \times 8$$

$$E_K = 4,400 \text{ in-lbs.}$$

Assume Model OEMXT 1.5M x 3 is adequate (Page 27).

##### STEP 3: Calculate work energy

$$F_D = W \times \sin \alpha$$

$$F_D = 550 \times .5$$

$$F_D = 275 \text{ lbs.}$$

$$E_W = F_D \times S$$

$$E_W = 275 \times 3$$

$$E_W = 825 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W$$

$$E_T = 4,400 + 825$$

$$E_T = 5,225 \text{ in-lbs./c}$$

##### STEP 5: Calculate total energy per hour

$$E_{TC} = E_T \times C$$

$$E_{TC} = 5,225 \times 250$$

$$E_{TC} = 1,306,250 \text{ in-lbs./hr}$$

##### STEP 6: Calculate impact velocity and confirm selection

$$V = \sqrt{772 \times H}$$

$$V = \sqrt{772 \times 8} = 79 \text{ in./sec.}$$

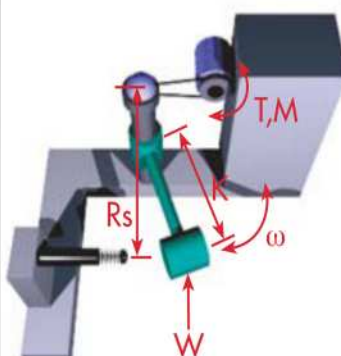
Model OEMXT 1.5M x 3 is adequate.

# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

### Overview

#### EXAMPLE 9: Horizontal Rotating Mass



##### STEP 1: Application Data

(W) Weight = 200 lbs.  
(ω) Angular velocity = 1.5 rad./sec.  
(T) Torque = 1,065 in-lbs.  
(K) Radius of gyration = 15 in.  
(R<sub>S</sub>) Mounting radius = 20 in.  
(C) Cycles/Hr = 120

##### STEP 2: Calculate kinetic energy

$$I = \frac{W}{386} \times K^2$$

$$I = \frac{200}{386} \times 15^2$$

$$I = 117 \text{ in-lbs./sec.}^2$$

$$E_K = \frac{I \times \omega^2}{2}$$

$$E_K = \frac{117 \times 1.5^2}{2}$$

$E_K = 132 \text{ in-lbs.}$   
Assume Model STH .5M is adequate  
(Page 40).

##### STEP 3 Calculate work energy

$$F_D = \frac{T}{R_S}$$

$$F_D = \frac{1,065}{20}$$

$$F_D = 53 \text{ lbs.}$$

$$E_W = F_D \times S$$

$$E_W = 53 \times .5$$

$$E_W = 27 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W$$

$$E_T = 132 + 27$$

$$E_T = 159 \text{ in-lbs./c}$$

##### STEP 5: Calculate total energy per hour

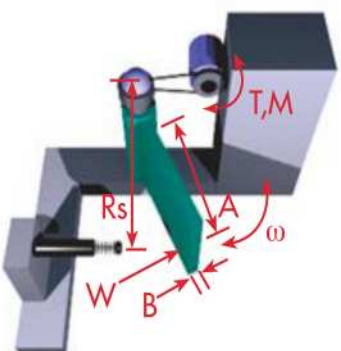
$$E_T C = E_T \times C$$

$$E_T C = 159 \times 120$$

$$E_T C = 19,080 \text{ in-lbs./hr}$$

Model STH .5M is adequate.

#### EXAMPLE 10: Horizontal Rotating Door



##### STEP 1: Application Data

(W) Weight = 50 lbs.  
(ω) Angular velocity = 2.5 rad./sec.  
(T) Torque = 100 in-lbs.  
(R<sub>S</sub>) Mounting radius = 20 in.  
(A) Width = 40 in.  
(B) Thickness = .5 in.  
(C) Cycles/Hr = 250

##### STEP 2: Calculate kinetic energy

$$K = .289 \times \sqrt{4 \times A^2 + B^2}$$

$$K = .289 \times \sqrt{4 \times 40^2 + .5^2}$$

$$K = 23.12$$

$$I = \frac{W}{386} \times K^2$$

$$I = \frac{50}{386} \times 23.12^2$$

$$I = 69 \text{ in-lbs./sec.}^2$$

$$E_K = \frac{I \times \omega^2}{2}$$

$$E_K = \frac{69 \times 2.5^2}{2}$$

$$E_K = 216 \text{ in-lbs.}$$

Assume Model OEM .5 is adequate  
(Page 21).

##### STEP 3: Calculate work energy

$$F_D = \frac{T}{R_S}$$

$$F_D = \frac{100}{20}$$

$$F_D = 5 \text{ lbs.}$$

$$E_W = F_D \times S = 5 \times .5 = 2.5 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 216 + 2.5 = 218.5 \text{ in-lbs./c}$$

##### STEP 5: Calculate total energy per hour

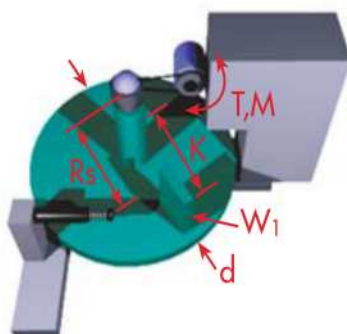
$$E_T C = E_T \times C = 218.5 \times 250 = 54,625 \text{ in-lbs./hr}$$

##### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 20 \times 2.5 = 50 \text{ in./sec.}$$

Model OEM .5 is adequate.

#### EXAMPLE 11: Horizontal Moving Load, Rotary Table Motor Driven with Additional Load Installed



##### STEP 1: Application Data

(W) Weight = 440 lbs.  
(W<sub>1</sub>) Installed load = 110 lbs.  
Rotational speed = 10 RPM  
(T) Torque = 2,200 in-lbs.  
Rotary table dia. = 20 in.  
(K<sub>Load</sub>) Radius of gyration = 8 in.  
(R<sub>S</sub>) Mounting radius = 8.86 in.  
(C) Cycles/Hr = 1  
(ω) Direction

##### Step 2: Calculate kinetic energy

To convert RPM to rad./sec., multiply by .1047

$$\omega = \text{RPM} \times .1047 = 10 \times .1047$$

$$= 1.047 \text{ rad./sec.}$$

$$I = \frac{W}{386} \times K^2$$

In this case, the mass moment of inertia of the table and the mass moment of inertia of the load on the table must be calculated.

$$K_{\text{Table}} = \text{Table Radius} \times .707$$

$$K_{\text{Table}} = 10 \times .707 = 7.07 \text{ in.}$$

$$I_{\text{Table}} = \frac{W}{386} \times K_{\text{Table}}^2$$

$$I_{\text{Table}} = \frac{440}{386} \times 7.07^2 = 57 \text{ in-lbs./sec.}^2$$

$$I_{\text{Load}} = \frac{W_1}{386} \times K_{\text{Load}}^2$$

$$I_{\text{Load}} = \frac{110}{386} \times 8^2 = 18 \text{ in-lbs./sec.}^2$$

$$E_K = \frac{(I_{\text{Table}} + I_{\text{Load}}) \times \omega^2}{2}$$

$$E_K = \frac{(57 + 18) \times 1.047^2}{2} = 41 \text{ in-lbs.}$$

Assume Model ECO 50 is adequate  
(Page 46).

##### STEP 3: Calculate work energy

$$F_D = \frac{T}{R_S} = \frac{2,200}{8.86} = 248 \text{ lbs.}$$

$$E_W = F_D \times S = 248 \times .875 = 217 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 41 + 217 = 258 \text{ in-lbs./c}$$

##### STEP 5: Calculate total energy per hour: not applicable, C = 1

##### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 8.86 \times 1.047 = 9 \text{ in./sec.}$$

From ECO Sizing Graph.  
Model ECO 50 is adequate.



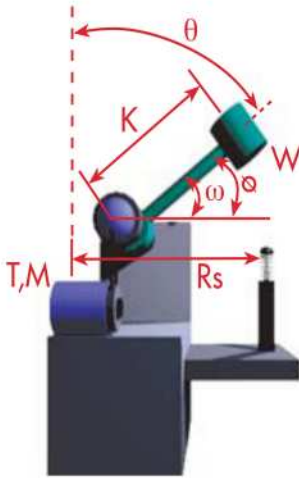
# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

### Overview

#### EXAMPLE 12:

**Vertical Motor Driven Rotating Arm with Attached Load**  
**CASE A-Load Aided by Gravity**



#### STEP 1: Application Data

(W) Weight = 110 lbs.  
 (ω) Angular velocity = 2 rad./sec.  
 (T) Torque = 3,100 in-lbs.  
 (θ) Starting point of load from true vertical = 20°  
 (Ø) Angle of rotation at impact = 30°  
 (K<sub>Load</sub>) Radius of gyration = 24 in.  
 (R<sub>S</sub>) Mounting radius = 16 in.  
 (C) Cycles/Hr = 1

#### STEP 2: Calculate kinetic energy

$$I = \frac{W}{386} \times K^2 = \frac{110}{386} \times 24^2$$

$$I = 164 \text{ in-lbs-sec}^2$$

$$E_K = \frac{I \times \omega^2}{2}$$

$$E_K = \frac{164 \times 2^2}{2}$$

$$E_K = 328 \text{ in-lbs.}$$

Assume Model OEM 1.0 is adequate  
 (Page 21).

#### CASE A

#### STEP 3: Calculate work energy

$$F_D = \frac{[T + (W \times K \times \sin(\theta + \phi))]}{R_S}$$

$$F_D = \frac{[3,100 + (110 \times 24 \times .77)]}{16}$$

$$F_D = 320.8 \text{ lbs.}$$

$$E_W = F_D \times S = 320.8 \times 1 = 320.8 \text{ in-lbs.}$$

#### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 328 + 320.8$$

$$E_T = 648.8 \text{ in-lbs./c}$$

#### STEP 5: Calculate total energy per hour: not applicable, C = 1

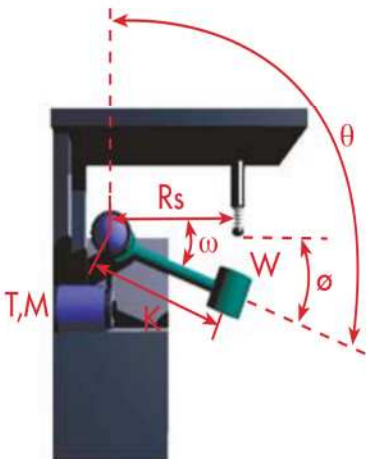
#### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 16 \times 2 = 32 \text{ in./sec.}$$

Model LROEM 1.0 is adequate.  
 Needed for higher calculated propelling force.

#### EXAMPLE 13:

**Vertical Motor Driven Rotating Arm with Attached Load**  
**CASE B-Load Opposing Gravity**



#### STEP 1: Application Data

(W) Weight = 110 lbs.  
 (ω) Angular velocity = 2 rad./sec.  
 (T) Torque = 3,100 in-lbs.  
 (θ) Starting point of load from true vertical = 30°  
 (Ø) Angle of rotation at impact = 150°  
 (K<sub>Load</sub>) Radius of gyration = 24 in.  
 (R<sub>S</sub>) Mounting radius = 16 in.  
 (C) Cycles/Hr = 1

#### STEP 2: Calculate kinetic energy

$$I = \frac{W}{386} \times K^2 = \frac{110}{386} \times 24^2$$

$$I = 164 \text{ in-lbs-sec}^2$$

$$E_K = \frac{I \times \omega^2}{2}$$

$$E_K = \frac{164 \times 2^2}{2}$$

$$E_K = 328 \text{ in-lbs.}$$

Assume Model OEM 1.0 is adequate  
 (Page 21).

#### CASE B

#### STEP 3: Calculate work energy

$$F_D = \frac{[T - (W \times K \times \sin(\theta - \phi))]}{R_S}$$

$$F_D = \frac{[3,100 - (110 \times 24 \times .77)]}{16}$$

$$E_W = F_D \times S = 67 \times 1 = 67 \text{ in-lbs.}$$

#### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 328 + 67$$

$$E_T = 394.7 \text{ in-lbs./c}$$

#### STEP 5: Calculate total energy per hour: not applicable, C = 1

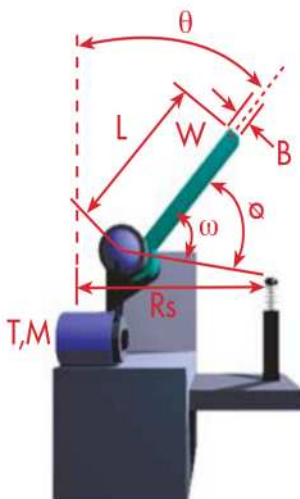
#### STEP 6: Calculate impact velocity and confirm selection.

$$V = R_S \times \omega = 16 \times 2 = 32 \text{ in./sec.}$$

Model OEM 1.0 is adequate.

#### EXAMPLE 14:

**Vertical Rotating Beam**



#### STEP 1: Application Data

(W) Weight = 540 lbs.  
 (ω) Angular velocity = 3.5 rad./sec.  
 (T) Torque = 250 in-lbs.  
 (θ) Starting point of load from true vertical = 20°  
 (Ø) Angle of rotation at impact = 50°  
 (R<sub>S</sub>) Mounting radius = 20 in.  
 (B) Thickness = 2.5 in.  
 (L) Length = 24 in.  
 (C) Cycles/Hr = 1

#### STEP 2: Calculate kinetic energy

$$K = .289 \times \sqrt{4 \times L^2 + B^2}$$

$$K = .289 \times \sqrt{4 \times 24^2 + 2.5^2} = 13.89$$

$$I = \frac{W}{386} \times K^2 = \frac{540}{386} \times 13.89^2$$

$$I = 270 \text{ in-lbs-sec}^2$$

$$E_K = \frac{I \times \omega^2}{2} = \frac{270 \times 3.5^2}{2} = 1,653 \text{ in-lbs.}$$

Assume Model OEM 1.5M x 2 is adequate (Page 27).

#### STEP 3: Calculate work energy

$$F_D = \frac{T + (W \times K \times \sin(\theta + \phi))}{R_S}$$

$$F_D = \frac{250 + (540 \times 13.89 \times \sin(20^\circ + 50^\circ))}{20}$$

$$F_D = 365 \text{ lbs.}$$

$$E_W = F_D \times S = 365 \times 2 = 730 \text{ in-lbs.}$$

#### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 1,653 + 730 = 2,383 \text{ in-lbs./c}$$

#### STEP 5: Calculate total energy per hour: not applicable, C = 1

#### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 20 \times 3.5 = 70 \text{ in./sec.}$$

Model OEM 1.5M x 2 is adequate.

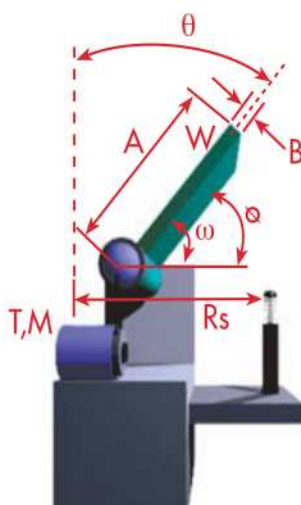


# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

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#### EXAMPLE 15: Vertical Rotating Lid



##### STEP 1: Application Data

- (W) Weight = 2,000 lbs.  
 (ω) Angular velocity = 2 rad./sec.  
 (Hp) Motor horsepower = .25 Hp  
 (θ) Starting point of load from true vertical = 30°  
 (φ) Angle of rotation at impact = 60°  
 (R<sub>S</sub>) Mounting radius = 30 in.  
 (A) Width = 60 in.  
 (B) Thickness = 1 in.  
 (C) Cycle/Hr = 1

##### STEP 2: Calculate kinetic energy

$$K = .289 \times \sqrt{4 \times A^2 + B^2}$$

$$K = .289 \times \sqrt{4 \times 60^2 + 1^2} = 34.68 \text{ in.}$$

$$I = \frac{W}{386} \times K^2 = \frac{2,000}{386} \times 34.68^2 \text{ in.}$$

$$I = 6,232 \text{ in-lbs./sec.}^2$$

$$E_K = \frac{I \times \omega^2}{2} = \frac{6,232 \times 2^2}{2}$$

$$E_K = 12,464 \text{ in-lbs.}$$

Assume Model OEM 3.0M x 2 is adequate (Page 31).

##### STEP 3: Calculate work energy

$$T = \frac{19,800 \times \text{Hp}}{\omega}$$

$$T = \frac{19,800 \times .25}{2} = 2,475 \text{ in-lbs.}$$

$$F_D = \frac{T + (W \times K \times \sin(\theta + \phi))}{R_S}$$

$$F_D = \frac{2,475 + (2,000 \times 34.68 \times \sin(30^\circ + 60^\circ))}{30}$$

$$F_D = 2,395 \text{ lbs.}$$

$$E_W = F_D \times S = 2,395 \times 2 = 4,790 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 12,464 + 4,790$$

$$= 17,254 \text{ in-lbs./c}$$

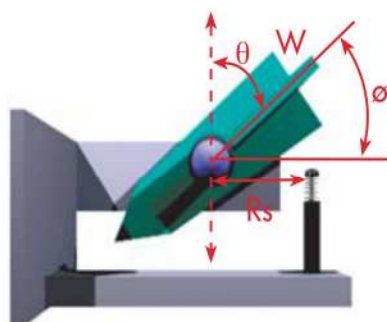
##### STEP 5: Calculate total energy per hour: not applicable, C = 1

##### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 30 \times 2 = 60 \text{ in./sec.}$$

Model OEM 3.0M x 2 is adequate.

#### EXAMPLE 16: Vertical Rotation with Known Inertia Aided by Gravity



##### STEP 1: Application Data

- (W) Weight = 220.5 lbs  
 (I) Known Inertia = 885 in-lbs/sec.<sup>2</sup>  
 (C/G) Center-of-Gravity = 12 in.  
 (θ) Starting point from true vertical = 60°  
 (φ) Angle of rotation at impact = 30°  
 (R<sub>S</sub>) Mounting radius = 10 in.  
 (C) Cycles/Hr = 1

##### STEP 2: Calculate kinetic energy

$$H = C/G \times [\cos(\theta) - \cos(\phi + \theta)]$$

$$H = 12 \times [\cos(60^\circ) - \cos(30^\circ + 60^\circ)]$$

$$E_K = W \times H$$

$$E_K = 220.5 \times 6$$

$$E_K = 1,323 \text{ in-lbs.}$$

##### STEP 3: Calculate work energy

$$F_D = (W \times C/G \times \sin(\theta + \phi)) / R_S$$

$$F_D = (220.5 \times 12 \times \sin(60^\circ + 30^\circ)) / 10$$

$$F_D = 264.6 \text{ lbs.}$$

$$E_W = F_D \times S = 264.6 \times 1 = 264.6 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 1,323 + 264.6$$

$$E_T = 1,587.6 \text{ in-lbs/cyc.}$$

##### STEP 5: Calculate total energy per hour: not applicable, C = 1

$$E_T C = E_T \times C$$

$$E_T C = 1,587.6 \times 1$$

$$E_T C = 1,587.6 \text{ in-lbs/hr.}$$

##### STEP 6: Calculate impact velocity and confirm selection

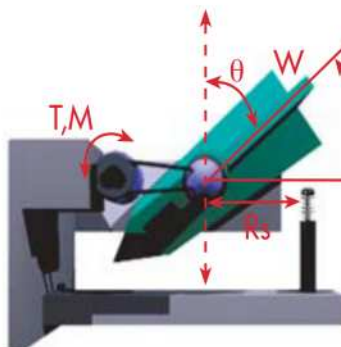
$$\omega = ((2 \times E_K) / I) 0.5$$

$$\omega = ((2 \times 1,323) / 885) 0.5 = 1.7$$

$$V = R_S \times \omega = 10 \times 1.7 = 17 \text{ in./sec.}$$

Model OEM 1.15 x 1 is adequate (Page 24).

#### EXAMPLE 17: Vertical Rotation with Known Inertia Aided by Gravity (w/Torque)



##### STEP 1: Application Data

- (W) Weight = 220.5 lbs  
 (ω) Angular Velocity = 2 rad/sec.  
 (T) Torque = 2,750 in-lbs.  
 (I) Known Inertia = 885 in-lbs/sec.<sup>2</sup>  
 (C/G) Center-of-Gravity = 12 in.  
 (θ) Starting point from true vertical = 60°  
 (φ) Angle of rotation at impact = 30°  
 (R<sub>S</sub>) Mounting radius = 10 in.  
 (C) Cycles/Hr = 100

##### STEP 2: Calculate kinetic energy

$$E_K = (I \times \omega^2) / 2$$

$$E_K = (885 \times 2^2) / 2$$

$$E_K = 1,770 \text{ in-lbs.}$$

##### STEP 3: Calculate work energy

$$F_D = [T - (W \times C/G \times \sin(\theta + \phi))] / R_S$$

$$F_D = [2,750 - (220.5 \times 12 \times \sin(60^\circ + 30^\circ))] / 10$$

$$F_D = 539.6 \text{ lbs.}$$

$$E_W = F_D \times S = 539.6 \times 1 = 539.6 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 1,770 + 539.6$$

$$E_T = 2,309.6 \text{ in-lbs/cyc.}$$

##### STEP 5: Calculate total energy per hour: not applicable, C = 1

$$E_T C = E_T \times C$$

$$E_T C = 2,309.6 \times 1$$

$$E_T C = 230,960 \text{ in-lbs/hr.}$$

##### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 10 \times 2 = 20 \text{ in./sec.}$$

Model OEM 1.15 x 1 is adequate (Page 24).



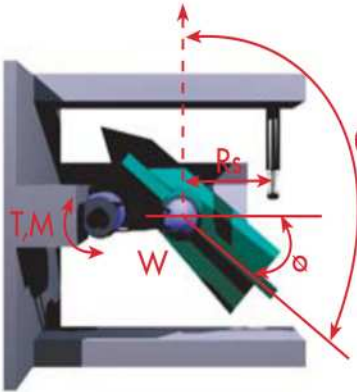
# Shock Absorber Sizing Examples

## Typical Shock Absorber Applications

### Overview

### Shock Absorber Sizing Examples

#### EXAMPLE 18: Vertical Rotation with Known Inertia Aided by Gravity (w/Torque)



##### STEP 1: Application Data

- (W) Weight = 220.5 lbs
- ( $\omega$ ) Angular Velocity = 2 rad./sec.
- (T) Torque = 2,750 in-lbs.
- (I) Known Inertia = 885 in-lbs./sec.<sup>2</sup>
- (C/G) Center-of-Gravity = 12 in.
- ( $\theta$ ) Starting point from true vertical = 120°
- ( $\emptyset$ ) Angle of rotation at impact = 30°
- (R<sub>S</sub>) Mounting radius = 10 in.
- (C) Cycles/Hr = 100

##### STEP 2: Calculate kinetic energy

$$E_K = (I \times \omega^2)/2$$

$$E_K = (885 \times 2^2)/2$$

$$E_K = 1,770 \text{ in-lbs.}$$

##### STEP 3: Calculate work energy

$$F_D = [T - (W \times C/G \times \sin(\theta - \emptyset))]/R_S$$

$$F_D = [2,750 - (220.5 \times 12 \times \sin(120^\circ - 30^\circ))]/10$$

$$F_D = 10.4 \text{ lbs.}$$

$$E_W = F_D \times S = 10.4 \times 1 = 10.4 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 1,770 + 10.4$$

$$E_T = 1,780.4 \text{ in-lbs./cyc.}$$

##### STEP 5: Calculate total energy per hour: not applicable, C=1

$$E_T C = E_T \times C$$

$$E_T C = 1,780.4 \times 100$$

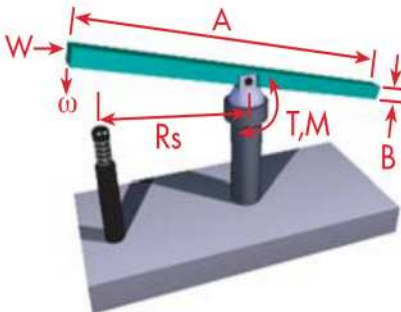
$$E_T C = 178,040 \text{ in-lbs./hr.}$$

##### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 10 \times 2 = 20 \text{ in./sec.}$$

Model OEMXT 1.5M x 1 is adequate (Page 27).

#### EXAMPLE 19: Vertical Rotation Pinned at Center (w/Torque)



##### STEP 1: Application Data

- (W) Weight = 220.5 lbs.
- ( $\omega$ ) Angular velocity = 2 rad./sec.
- (T) Torque = 2,750 in-lbs.
- (A) Length = 40 in.
- (R<sub>S</sub>) Mounting radius = 10 in.
- (B) Thickness = 2 in.
- (C) Cycles/Hr = 100

##### STEP 2: Calculate kinetic energy

$$K = .289 \times (A^2 + B^2)^{0.5}$$

$$K = .289 \times (40^2 + 2^2)^{0.5} = 11.6 \text{ in.}$$

$$I = (W/386) \times K^2$$

$$I = (220.5/386) \times 11.6^2 = 76.9 \text{ in-lb./sec}^2$$

$$E_K = (I \times \omega^2)/2$$

$$E_K = (76.9 \times 2^2)/2$$

$$E_K = 153.8 \text{ in-lbs.}$$

Assume Model OEM 1.0 is adequate (Page 21).

##### STEP 3: Calculate work energy

$$F_D = T/R_S$$

$$F_D = 2,750/10$$

$$F_D = 275 \text{ lbs.}$$

$$E_W = F_D \times S = 275 \times 1 = 275 \text{ in-lbs.}$$

##### STEP 4: Calculate total energy per cycle

$$E_T = E_K + E_W = 153.8 + 275$$

$$E_T = 428.8 \text{ in-lbs./cycle}$$

##### STEP 5: Calculate total energy per hour

$$E_T C = E_T \times C$$

$$E_T C = 428.8 \times 100$$

$$E_T C = 42,880 \text{ in-lbs./hr.}$$

##### STEP 6: Calculate impact velocity and confirm selection

$$V = R_S \times \omega = 10 \times 2 = 20 \text{ in./sec.}$$

Model OEM 1.0 is adequate.



# Shock Absorber Sizing Examples

## Typical Shock Absorber and Crane Applications

Calculations assume worst case scenario of 90% trolley weight over one rail.

Crane A		Per Buffer
Propelling Force Crane	lbs.	
Propelling Force Trolley	lbs.	
Weight of Crane ( $W_a$ )	lbs.	
Weight of Trolley ( $W_{ta}$ )	lbs.	
Crane Velocity ( $V_a$ )	in./sec.	
Trolley Velocity ( $V_{ta}$ )	in./sec.	

Crane B		Per Buffer
Propelling Force Crane	lbs.	
Propelling Force Trolley	lbs.	
Weight of Crane ( $W_b$ )	lbs.	
Weight of Trolley ( $W_{tb}$ )	lbs.	
Crane Velocity ( $V_b$ )	in./sec.	
Trolley Velocity ( $V_{tb}$ )	in./sec.	

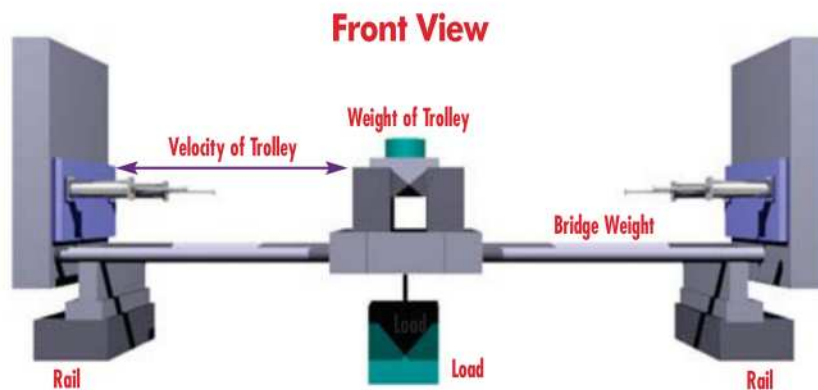
Crane C		Per Buffer
Propelling Force Crane	lbs.	
Propelling Force Trolley	lbs.	
Weight of Crane ( $W_c$ )	lbs.	
Weight of Trolley ( $W_{tc}$ )	lbs.	
Crane Velocity ( $V_c$ )	in./sec.	
Trolley Velocity ( $V_{tc}$ )	in./sec.	

### Please note:

Unless instructed otherwise, ITT Enidine will always calculate with:

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

## Overview



## Plan Views

### Application 1

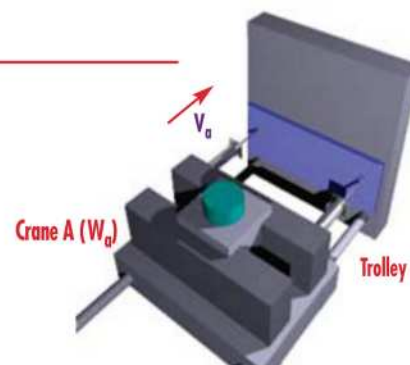
Crane A against Solid Stop

Velocity:

$$V_r = V_a$$

Impact weight per buffer:

$$W_d = \frac{W_a + (1.8) W_{ta}}{\text{Total Number of Shocks}}$$



### Application 2

Crane A against Crane B

Velocity:

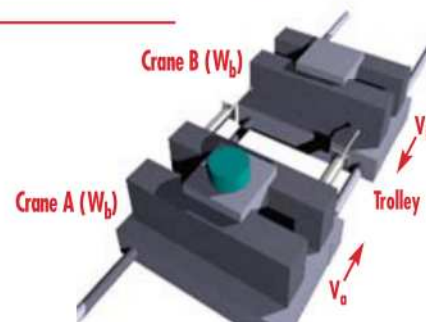
$$V_r = V_a + V_b$$

Impact weight per buffer:

$$W_1 = W_a + (1.8) W_{ta}$$

$$W_2 = W_b + (1.8) W_{tb}$$

$$W_d = \frac{W_1 W_2}{(W_1 + W_2)(\text{Total Number of Shocks})}$$



### Application 3

Crane B against Crane C

Velocity:

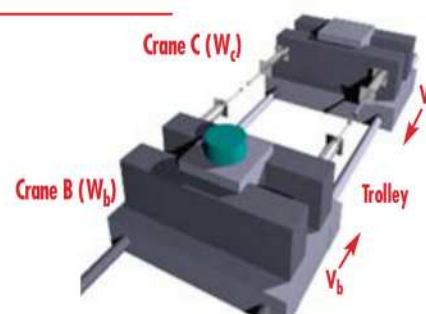
$$V_r = \frac{V_b + V_c}{2}$$

Impact weight per buffer:

$$W_1 = W_b + (1.8) W_{tb}$$

$$W_2 = W_c + (1.8) W_{tc}$$

$$W_d = \frac{2 W_1 W_2}{(W_1 + W_2)(\text{Number of Shocks Per Rail})}$$



### Application 4

Crane C against Solid Stop with Buffer

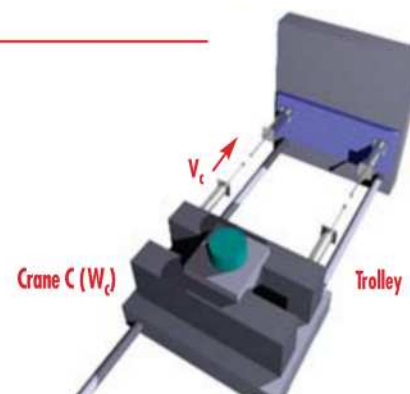
Velocity:

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

Impact weight per buffer:

$$W_1 = W_c + 1.8 (W_{tc})$$

$$W_d = \frac{2 W_1}{\text{Number of Shocks Per Rail}}$$





# Shock Absorber Sizing Examples

## Typical Shock Absorber and Crane Applications

### Overview

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.

### Calculation Example for Harbor Cranes as Application 1

Bridge Weight:	837,750 lbs.
Weight of Trolley:	99,200 lbs.
Crane Velocity:	60 in./sec.
Required Stroke:	24 in.
Trolley Velocity:	160 in./sec.
Required Stroke:	40 in.

### Given Values

$W_d = \frac{W_a + (1.8) W_t a}{\text{Total Number of Shocks}}$ $W_d = \frac{837,750 + (1.8)(99,200)}{2}$ $W_d = 508,155 \text{ lbs.}$	
--	--

### Determination of the Maximum Impact Weight $W_d$ per Buffer

$E_k = \frac{W_d}{772} \cdot V_i^2$ $E_k = \frac{508,155 \text{ lbs.}}{772} \cdot (60 \text{ in./sec.})^2$ $E_k = 2,369,635 \text{ in-lbs.}$ <p>Selecting for required 24-inch stroke:  <b>HD 5.0 x 24, maximum shock force ca. 116,159 lbs = <math>F_s = \frac{E_k}{s \cdot \eta}</math></b></p>	$V_i = V_a \text{ (Application 1)}$  $E_k = \text{Kinetic Energy}$  $\eta = \text{Efficiency}$
---	--

### Determine Size of Shock Absorber for Crane

$W_t = \text{Trolley Weight per Shock Absorber}$ $W_t = \frac{99,200 \text{ lbs.}}{2}$ $W_t = 49,600 \text{ lbs.}$ $E_k = \frac{W_t}{772} \cdot V_i^2$ $E_k = \frac{49,600 \text{ lbs.}}{772} \cdot (160 \text{ in./sec.})^2$ $E_k = 1,644,767 \text{ in-lbs.}$ <p>Selecting for required 40-inch stroke:  <b>HDN 4.0 x 40, maximum shock force ca. 48,376 lbs. = <math>F_s = \frac{E_k}{s \cdot \eta}</math></b></p>	
---	--

### Determine Size of Shock Absorber for Trolley

# Shock Absorber Sizing Examples

Typical Shock Absorber and Crane Applications

Overview

Application 1	Value
Buffer Distance H	ft.
Distance $X_1$	ft.
Distance $Y_1$	ft.
Distance $X_2$	ft.
Distance $Y_2$	ft.
Total Weight	lbs.
$W_{\max d}$	lbs.
$W_{\min d}$	lbs.
$W_{\max u}$	lbs.
$W_{\min u}$	lbs.



## Calculation Example Stacker Cranes

Please note that this example shows how to calculate the maximum impact weight on the upper and lower shock absorbers for a stacker crane.

Distance Between Buffers:	$H = 60 \text{ ft.}$	Given Values
Distance to C of G1 - Upper:	$X_1 = 45 \text{ ft.}$	
Distance to C of G1 - Lower:	$Y_1 = 15 \text{ ft.}$	
Distance to C of G2 - Upper:	$X_2 = 21 \text{ ft.}$	
Distance to C of G1 - Lower:	$Y_2 = 39 \text{ ft.}$	
Total Weight:	$W = 40,000 \text{ lbs.}$	Calculation for Lower Shock Absorbers
$W_{\max d} = \frac{X_1}{H} \cdot W$	$W_{\max d} = \frac{X_2}{H} \cdot W$	
$W_{\max d} = \frac{15 \text{ m}}{20 \text{ m}} \cdot 20 \text{ t}$	$W_{\max d} = \frac{21 \text{ ft.}}{60 \text{ ft.}} \cdot 40,000 \text{ lbs.}$	
$W_{\max d} = 15 \text{ t}$	$W_{\max d} = 14,000 \text{ lbs.}$	
$W_{\max d} = 5 \text{ t}$	$W_{\max d} = 26,000 \text{ lbs.}$	
Using the value for $W_{\max}$ obtained above, the kinetic energy can be calculated, and a shock absorber selected.		Shock Absorber Selection





Overhead Crane Applications



Cargo Crane Applications



Stacker Crane Applications



# Shock Absorber and Rate Controls Quick Selection Guide

## Typical Selections

## Technical Data

Use this **ITT Enidine Product Quick Selection Guide** to quickly locate potential shock absorber models most suited for your requirements. Models are organized in order of smallest to largest energy capacity per cycle within their respective product families.

### ITT Enidine Adjustable Shock Absorbers

Catalog No. (Model)	(S) Stroke (in.)	(E <sub>T</sub> ) Max. in.-lbs./cycle	(E <sub>T</sub> C) Max. in.-lbs./hour	Damping Type	Page No.
	1 in. = 25,4mm	1 in.-lb. = .11 Nm			
ECO OEM 0.1M (B)	0.28	62	120,000	D	21
ECO OEM .15M (B)	0.38	62	185,000	D	21
ECO OEM .25 (B)	0.38	62	195,000	D	21
ECO LROEM .25 (B)	0.38	62	195,000	D	21
ECO OEM .35 (B)	0.50	170	331,000	D	21
ECO LROEM .35 (B)	0.50	170	331,000	D	21
ECO OEM .5 (B)	0.50	275	311,000	D	21
ECO LROEM .5 (B)	0.50	275	311,000	D	21
ECO OEM 1.0 (B)	1.00	715	681,000	C	21
ECO LROEM 1.0 (B)	1.00	715	681,000	C	21
ECO OEM 1.15 X 1	1.00	1,900	737,000	C	24
ECO LROEM 1.15 X 1	1.00	1,900	737,000	C	24
ECO OEM 1.15 X 2	2.00	3,750	963,000	C	24
ECO LROEM 1.15 X 2	2.00	3,750	963,000	C	24
ECO OEM 1.25 x 1	1.00	1,900	886,000	C	24
ECO LROEM 1.25 x 1	1.00	1,900	886,000	C	24
ECO OEM 1.25 x 2	2.00	3,750	1,084,000	C	24
ECO LROEM 1.25 x 2	2.00	3,750	1,084,000	C	24
LROEMXT 3/4 x 1	1.00	3,750	1,120,000	C	27
OEMXT 3/4 x 1	1.00	3,750	1,120,000	C	27
LROEMXT 1.5M x 1	1.00	3,750	1,120,000	C	27
OEMXT 1.5M x 1	1.00	3,750	1,120,000	C	27
LROEMXT 3/4 x 2	2.00	7,500	1,475,000	C	27
OEMXT 3/4 x 2	2.00	7,500	1,475,000	C	27
LROEMXT 1.5M x 2	2.00	7,500	1,475,000	C	27
OEMXT 1.5M x 2	2.00	7,500	1,475,000	C	27
OEMXT 3/4 x 3	3.00	11,500	1,775,000	C	27
OEMXT 1.5M x 3	3.00	11,500	1,775,000	C	27
LROEMXT 1 1/8 x 1	1.00	6,000	2,000,000	C	27
LROEMXT 1 1/8 x 2	2.00	20,000	2,400,000	C	29
OEMXT 1 1/8 x 2	2.00	20,000	2,400,000	C	29
LROEMXT 2.0M x 2	2.00	20,000	2,400,000	C	29
OEMXT 2.0M x 2	2.00	20,000	2,400,000	C	29
OEM 3.0M x 2	2.00	20,000	3,290,000	C	31
OEMXT 1 1/8 x 4	4.00	40,000	3,200,000	C	29
OEMXT 2.0M x 4	4.00	40,000	3,200,000	C	29
OEM 4.0M x 2	2.00	34,000	13,300,000	C	31
OEM 3.0M x 3.5	3.50	35,000	5,770,000	C	31
OEMXT 1 1/8 x 6	6.00	60,000	3,730,000	C	29
OEMXT 2.0M x 6	6.00	60,000	3,730,000	C	29
OEM 3.0M x 5	5.00	50,000	8,260,000	C	31
OEM 3.0M x 6.5	6.50	65,000	10,750,000	C	31
OEM 4.0M x 4	4.00	68,000	16,000,000	C	31
OEM 4.0M x 6	6.00	102,000	18,600,000	C	31
OEM 4.0M x 8	8.00	136,000	21,300,000	C	31
OEM 4.0M x 10	10.00	170,000	24,000,000	C	31

Key for Damping Type:  
D – Dashpot  
C – Conventional

P – Progressive  
SC – Self-compensating

### ITT Enidine Non-Adjustable Shock Absorbers

Catalog No. (Model)	(S) Stroke (in.)	(E <sub>T</sub> ) Max. in.-lbs./cycle	(E <sub>T</sub> C) Max. in.-lbs./hour	Damping Type	Page No.
	1 in. = 25,4mm	1 in.-lb. = .11 Nm			
TK 6	0.25	9	31,863	D	39
TK 8	0.25	50	42,480	D	39
TK 21	0.25	20	36,000	D	40
ECO 8	0.25	35	55,000	SC	47
TK 10M	0.25	50	115,000	D	40
ECO 10	0.28	62	120,700	SC	47
ECO 15	0.41	106	275,000	SC	47
STH .25M	0.25	100	39,000	D	41
ECO 25	0.50	265	389,000	SC	47
ECOS 50	0.50	285	440,000	SC	47
ECO 50	0.88	550	523,000	SC	47
STH .5M	0.50	585	390,000	D	41
ECO 100	1.00	930	681,500	SC	47
ECO 110	1.56	1,860	743,500	P	50
ECO 120	1.00	1,640	743,000	SC	50
ECO 125	1.00	1,640	920,500	SC	50
PMXT 1525	1.00	3,250	1,120,000	SC	59
STH .75M	0.75	2,150	780,000	D	41
ECO 220	2.00	3,100	911,600	SC	50
ECO 225	2.00	3,100	1,124,000	SC	50
PMXT 1550	2.00	6,500	1,475,000	SC	59
STH 1.0M	1.00	4,400	1,300,000	D	41
PMXT 1575	3.00	10,000	1,775,000	SC	59
STH 1.0M x 2	2.00	8,800	2,100,000	D	41
PMXT 2050	2.00	16,500	2,400,000	SC	59
STH 1.5M x 1	1.00	10,200	2,200,000	D	41
PMXT 2100	4.00	33,000	3,200,000	SC	59
STH 1.5M x 2	2.00	20,400	3,200,000	D	41
PMXT 2150	6.00	50,000	3,730,000	SC	59

Key for Damping Type:  
D – Dashpot  
C – Conventional

P – Progressive  
SC – Self-compensating



# Shock Absorber and Rate Controls Quick Selection Guide

## Typical Selections

## Technical Data

Use this **ITT Enidine Product Quick Selection Guide** to quickly locate potential shock absorber models most suited for your requirements. Models are organized in order of smallest to largest energy capacity per cycle within their respective product families.

### ITT Enidine Heavy Duty Shock Absorbers

Catalog No. (Model)	(S) Stroke (in.)	(E <sub>T</sub> ) Min./Max. in.-lbs./cycle		Damping Type	Page No.
	1 in. = 25,4mm	1 in.-lb. = .11 Nm			
HDN 1.5 x (Stroke)	2-24	27,000	185,000	C, P, SC	66
HDN 2.0 x (Stroke)	10-56	212,000	680,000	C, P, SC	67
HDN 3.0 x (Stroke)	2-56	83,000	1,200,000	C, P, SC	68
HDA 3.0 x (Stroke)	2-12	40,000	240,000	C	71
HDN 3.5 x (Stroke)	2-48	112,500	1,800,000	C, P, SC	69
HDN 4.0 x (Stroke)	2-48	134,000	2,400,000	C, P, SC	70
HDA 4.0 x (Stroke)	2-10	120,000	600,000	C	72
HD 5.0 x (Stroke)	4-40	414,000	4,150,000	C, P, SC	74
HDA 5.0 x (Stroke)	4-12	327,000	1,000,000	C	74
HD 6.0 x (Stroke)	4-48	677,000	7,125,000	C, P, SC	75
HDA 6.0 x (Stroke)	4-12	540,000	1,625,000	C	75

Key for Damping Type:  
D – Dashpot  
C – Conventional

P – Progressive  
SC – Self-compensating

### ITT Enidine Heavy Industry Shock Absorbers

Catalog No. (Model)	(S) Stroke (in.)	(E <sub>T</sub> ) Min./Max. in.-lbs./cycle		Damping Type	Page No.
	1 in. = 25,4mm	1 in.-lb. = .11 Nm			
HI 50 x (Stroke)	2-4	26,500	55,000	C, P, SC	83
HI 85 x (Stroke)	2-4	60,000	120,000	C, P, SC	83
HI 100 x (Stroke)	2-32	88,000	1,150,000	C, P, SC	83
HI 120 x (Stroke)	4-40	283,000	2,301,000	C, P, SC	83
HI 130 x (Stroke)	10-32	885,000	2,400,000	C, P, SC	84
HI 150 x (Stroke)	5-40	548,000	4,500,000	C, P, SC	84

Key for Damping Type:  
D – Dashpot  
C – Conventional

P – Progressive  
SC – Self-compensating

### Jarret Shock Absorbers

Catalog No. (Model)	(S) Stroke (in.)	(E <sub>T</sub> ) Min./Max. in.-lbs./cycle		Damping Type	Page No.
	1 in. = 25,4mm	1 in.-lb. = .11 Nm			
BC1N	0.5-3	885,000	123,910	—	87
BC5	4-7	221,000	1,327,612	—	89
XLR	6-31.5	53,000	1,327,612	—	91
LR	16-51	885,000	8,850,746	—	93

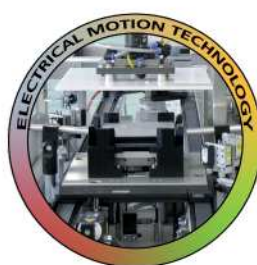
### ITT Enidine Adjustable Rate Controls

Catalog No. (Model)	(S) Stroke (in.)	(F <sub>p</sub> ) Max. Propelling Force		(E <sub>T</sub> C) Max. in.-lbs./hour	Page No.
	1 in. = 25,4mm	Tension lbs.	Compression lbs.	1 in.-lb. = .11 Nm	
ADA 505	2.00	450	450	650,000	101
ADA 510	4.00	450	375	850,000	101
ADA 515	6.00	450	300	1,050,000	101
ADA 520	8.00	450	200	1,250,000	101
ADA 525	10.00	450	125	1,450,000	101
ADA 705	2.00	2,500	2,500	1,100,000	101
ADA 710	4.00	2,500	2,500	1,400,000	102
ADA 715	6.00	2,500	2,500	1,800,000	102
ADA 720	8.00	2,500	2,500	2,100,000	102
ADA 725	10.00	2,500	2,500	2,500,000	102
ADA 730	12.00	2,500	2,500	2,800,000	102
ADA 735	14.00	2,500	2,500	3,200,000	102
ADA 740	16.00	2,500	2,500	3,500,000	103
ADA 745	18.00	2,500	2,000	3,900,000	103
ADA 750	20.00	2,500	1,700	4,200,000	103
ADA 755	22.00	2,500	1,400	4,600,000	103
ADA 760	24.00	2,500	1,200	4,900,000	103
ADA 765	26.00	2,500	1,000	5,300,000	103
ADA 770	28.00	2,500	900	5,600,000	103
ADA 775	30.00	2,500	800	6,000,000	103
ADA 780	32.00	2,500	700	6,300,000	103

### ITT Enidine Non-Adjustable Rate Controls

Catalog No. (Model)	(S) Stroke (in.)	(F <sub>p</sub> ) Max. Propelling Force		(E <sub>T</sub> C) Max. in.-lbs./hour	Page No.
	1 in. = 25,4mm	Tension lbs.	Compression lbs.	1 in.-lb. = .11 Nm	
DA 705	2.00	2,500	2,500	1,400,000	105
DA 710	4.00	2,500	2,500	1,700,000	105
DA 720	6.00	2,500	2,500	2,000,000	105
DA 720	8.00	2,500	2,500	2,300,000	105
DA 75 x 2	2.00	5,000	5,000	2,700,000	105
DA 75 x 4	4.00	5,000	5,000	3,100,000	105
DA 75 x 6	6.00	5,000	5,000	3,600,000	106
DA 75 x 8	8.00	5,000	5,000	4,100,000	106
DA 75 x 10	10.00	5,000	5,000	4,500,000	106
TB 100 x 4	4.00	10,000	10,000	4,400,000	106
TB 100 x 6	6.00	10,000	10,000	4,400,000	106





*We look forward to your application.*

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