



## Mondel

### ■ GENERAL FRICTION LAW

The coefficient of friction between two surfaces in contact is equal to the force required to overcome the friction divided by the reaction force between the two surfaces as shown in the following formula:

$$\mu = \frac{F}{R}$$

Where:  $\mu$  = Coefficient of Friction  
 F = Force required to overcome the Friction  
 R = Reaction force between the two surfaces

Therefore, the retarding torque of shoe brakes is a product of the effect of the torque spring pressure and the coefficient of friction of the lining material.

### ■ BRAKING TORQUE

- Brake torque is the force applied at the brake wheel to stop the motion of the moving equipment.
- Assuming the operating conditions for the equipment are constant, a brake having a retarding torque equal to the full load torque of the motor to which it is applied is usually satisfactory.

The torque can be determined from the following formula for both AC and DC motors:

$$T = \frac{5250 \times \text{HP} \times \text{SF}}{\text{RPM}}$$

Where: T = Brake Torque (Lb. Ft.)  
 5250 = Constant  
 HP = Motor Horse Power  
 RPM = Speed of Brake wheel  
 SF = Application Service Factor

It is assumed that the brake will work on a brake wheel mounted on the motor shaft.

- Depending upon the type of application, the brake torque selected may be greater or less than the full load motor torque. CMAA, OSHA and AISE-NEMA standards provide guidelines for the application of brakes to hoist, bridge and trolley drives.

### Bridge and Trolley Brakes: Application "SF" for Braking Torque

Application	Bridge		Trolley	
	AISE	CMAA	AISE	CMAA
Cab-operated crane with cab located on the bridge	--	100%	50%	50%
Cab-operated crane with cab located on the trolley	100%	75%	--	100%
Floor, remote and pulpit-operated cranes	100%	50%	50%	50%

### Hoist Brakes:

Standard	Basis for Selection of Brake Torque	Hoist Drive with Single Brake	
		With Control Braking (1)	With Mechanical Load Brake
CMAA	Motor Full Load Torque	125%	100%
OSHA	Torque Required to Hoist Rated Load	125%	100%
AISE		150%	150%

Standard	Basis for Selection of Brake Torque	Hoist Drive with Two Brakes (2)	
		Handling Hot Metal	Not Handling Hot Metal
CMAA	Motor Full Load Torque	100%	100%
OSHA	Torque Required to Hoist Rated Load	100%	100%
AISE		125%	100%

- 1) Control braking is eddy current, counter torque or dynamic lowering brake.
- 2) Service factor is for each brake.

Using full load motor torque as a guide does not satisfy all applications. The additional energy created by excessive brake operations or duty cycles must also be considered.

In some applications the braking torque may be determined by extreme operating conditions, such as high inertial loads, overhauling loads, excessive duty cycles, or where stopping time or distance have been specified.

- For high inertia applications or loads where a stop in a specified time or distance is involved, the average brake torque required to retard the total inertia can be determined from the following formula:

$$T_A = \frac{WK^2 \times \text{RPM}}{308 \times t}$$

Where:  $T_A$  = Brake Torque (Lb. Ft.)  
 $WK^2$  = Total inertia referred to Brake wheel (Lb. Ft<sup>2</sup>)  
 RPM = Speed of Brake wheel  
 308 = Constant  
 t = Stopping Time (Seconds)

- For applications where there is a descending load, the load driveback torque to overcome the overhauling load is determined by the following formula:

$$T_B = \frac{W \times V}{2 \times TT \times \text{RPM}}$$

Where:  $T_B$  = Overhauling Torque (Lb. Ft.)  
 W = Weight of Load (Lb.)  
 V = Linear Velocity of descending load (Ft./Min.)  
 2 TT = Constant  
 RPM = Speed of Brake Wheel



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Brake wheel speed (RPM) may be greater than the motor speed (overspeeding due to the gravity overhauling load) or may be reduced by electrically controlled dynamic braking.

- The total brake torque required to decelerate a descending load and to overcome the overhauling effect is the sum of the calculated torques above:

$$T_T = T_A + T_B$$

Where:

$$T_T = \text{Total Brake Torque (Lb. Ft.)}$$

During the stopping cycle a brake converts kinetic energy into thermal energy, or heat. This heat is absorbed almost entirely by the brake wheel alone. The brake must be large enough to absorb and dissipate the heat generated (thermal capacity) without exceeding the temperature limitations of the linings and brake wheel.

There are two categories of thermal capacity for a brake: The first is the maximum kinetic energy the brake can absorb in one stop, or an emergency stop. During this stop almost no heat is dissipated and the brake wheel must be allowed to cool before the next stop. The second is the heat dissipation capability of the brake when it is frequently cycled.

To achieve optimum brake performance, the total calculated energy in the system referred to the brake wheel (Ft. Lb.) should not exceed the maximum energy ratings (Ft. Lb.) shown in Table 1. This should take into account overhauling loads, inertia, duty cycle, type of drive, motor control system and speed of load referred to brake shaft.

- If dynamic or regenerative braking is used to reduce the brake wheel speed automatically before the brake is applied, a smaller brake may be selected to satisfy the lower "service" energy requirement. The size is then primarily determined by the one (emergency) stop capability of the brake as shown in Table 1.
- On applications where the brake is used for frequent stopping over a repeated duty cycle, the energy must be calculated for each part of the cycle (hoisting, lowering, etc.). The maximum brake duty is determined as follows:

$$\text{Cycles Per Hour} = \frac{\text{Maximum Energy Per Hour (Table 1)}}{\text{Total Energy Per Cycle}}$$

The energy generated in stopping the inertia of a rotating load (kinetic energy converted to heat by brake per hour) can be determined from the following formula:

$$KE_R = \frac{WK^2 \times RPM^2 \times N}{5875}$$

Where:

$KE_R$  = Kinetic Energy of Rotating Load (Ft.Lb./Hr.)

$WK^2$  = Total Inertia referred to Brake wheel (Lb. Ft.<sup>2</sup>)

RPM = Speed of Brake wheel

N = Number of Stops per Hour

5875 = Constant

**Brake Wheel Capacity Data (Table 1)**

Brake Wheel Size	Maximum Energy	
	Heat Dissipation per Hour for Frequent Stopping	Heat Absorption Capacity during one or Infrequent Stopping
Dia. Width	(1) Ft. Lb./Hour	(2) Ft. Lb
5" x 2 3/4"	730,000	80,300
8" x 3 1/4"	1,250,000	137,500
10" x 3 3/4"	2,300,000	253,000
13" x 5 3/4"	4,250,000	467,500
16" x 6 3/4"	6,200,000	682,000
19" x 8 3/4"	9,800,000	1,078,000
23" x 11 1/4"	14,600,000	1,606,000
30" x 14 1/4"	21,200,000	2,332,000

- Values given are for reasonably evenly spaced stops using a ductile-iron brake wheel with free air flow for cooling around outer surfaces, and approximately 300°F (150°C) brake wheel temperature with ambient temperature 68°F (20°C).
- The values are for one or infrequent stops per hour; the brake wheel must be allowed to cool to ambient temperature before the next stop.

- Brakes with extra shoe clearances and/or with wider shoes will result in higher energy figures. Also brakes with smaller shoe clearances and/or narrower shoe widths will reduce energy figures given in the table above.
- On bridge crane applications which have repetitive duty cycles, the brake absorbs repeated amounts of energy during successive stops. The hourly energy load for the equipment based on the duty cycle may be determined from the following formula:

$$KE_R = \frac{N}{232} ((WE) (VE)^2 + (WL) (VL)^2)$$

Where:

$KE_B$  = Kinetic Energy (Ft.Lb./Hr.)

N = Number of Stops per Hour

232 = Constant

WE = Unloaded Crane Weight (Tons)

WL = Loaded Crane Weight (Tons)

VE = Unloaded Crane Velocity (Ft./Min.)

VL = Loaded Crane Velocity (Ft./Min.)

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