Caliper brakes: among the most tried and true braking technologies in industrial use. Designed to clamp onto both sides of discs or flat rails, these specialized brakes create friction that exerts a braking force on the disc attached to the rotating shaft, or on a rail or fin in linear motion applications. Caliper brakes are well suited for a range of industrial uses, such as construction machinery, material handling equipment, metalworking machinery, automated assembly machines, and other heavy equipment.

Brakes can be either hydraulically or pneumatically released. Pneumatic systems (using air) are widely used in manufacturing to operate at low power and pressures, whereas hydraulic systems (using fluids) are used where greater amounts of power and pressure are required.

The decision to use one brake style over the other is determined by the application’s torque requirement, system cost, working environment, and safety.

### Determining required torque
The amount of torque — a function of the brake’s clamping force and the working radius of a disc in rotary applications — needed to stop or hold the load is the most important factor when choosing a caliper brake. Typically, spring-engaged, air-released (pneumatic) brakes are used for stopping and holding in moderate torque range applications, while spring-engaged, hydraulically-released brakes are used when higher torque is needed.

In linear motion applications, a caliper brake clamp force value is used to determine the time and distance needed to perform a full stop. Other brake considerations include the disc diameter, disc heat sink capacity, and friction facing life. (Examples later in this article illustrate the steps necessary to arrive at these values.)

#### Hydraulics versus pneumatics

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pneumatic</th>
<th>Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life</td>
<td>Up to 10 years</td>
<td>Up to 15 years</td>
</tr>
<tr>
<td>Initial cost, brake</td>
<td>Approx. 50% hydraulic brake cost</td>
<td>High</td>
</tr>
<tr>
<td>Energy cost</td>
<td>Medium</td>
<td>Higher</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Low cost repairs</td>
<td>Expensive replacement costs</td>
</tr>
<tr>
<td>Noise</td>
<td>Quiet — compressor normally remote</td>
<td>Loud — power unit nearby</td>
</tr>
<tr>
<td>Temperature limit</td>
<td>Above freezing</td>
<td>Sub-zero</td>
</tr>
<tr>
<td>Wet conditions</td>
<td>Seal protection to IP67</td>
<td>Underwater compatible</td>
</tr>
<tr>
<td>Clamp force</td>
<td>2,560 lb</td>
<td>3,143 lb</td>
</tr>
<tr>
<td>Broken hoses</td>
<td>Clean; hose whip is dangerous</td>
<td>Dirty, messy</td>
</tr>
<tr>
<td>Controls cost</td>
<td>Lower, less complicated</td>
<td>Higher, more components</td>
</tr>
<tr>
<td>Pressure, maximum</td>
<td>80 to 100 psi</td>
<td>1,000 to 5,000 psi</td>
</tr>
<tr>
<td>Release pressure</td>
<td>72 psi</td>
<td>250 psi</td>
</tr>
<tr>
<td>Friction-facing area</td>
<td>15.70 sq. in.</td>
<td>30.96 sq. in.</td>
</tr>
<tr>
<td>Facing life</td>
<td>628 hp-hours</td>
<td>1,238 hp-hours</td>
</tr>
<tr>
<td>Safety</td>
<td>Non-sparking</td>
<td>Flammable</td>
</tr>
<tr>
<td>Actuation method</td>
<td>Air or nitrogen are compressible</td>
<td>Oil not compressible</td>
</tr>
<tr>
<td>Control system</td>
<td>Open, exhausts air to atmosphere</td>
<td>Closed, recirculates oil</td>
</tr>
<tr>
<td>System flexibility</td>
<td>Easy to modify and change</td>
<td>Not easy to expand</td>
</tr>
<tr>
<td>Disc diameter</td>
<td>18 in.</td>
<td>14 in.</td>
</tr>
<tr>
<td>Disc thickness</td>
<td>0.50 in.</td>
<td>1.0 in.</td>
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<td>Disc inertia</td>
<td>10 lb-ft$^2$</td>
<td>7 lb-ft$^2$</td>
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### Cost comparison
While hydraulic systems accommodate greater torque...
Brakes

Caliper brakes: Basic model and working radii

Examples of working radii of various disc diameters

<table>
<thead>
<tr>
<th>Disc diameter</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>24</th>
</tr>
</thead>
</table>

Pressure ranges and safety factors

Despite these environmental drawbacks, hydraulic systems are able to develop extreme high pressures that produce much higher forces in actuated components than their pneumatic counterparts. Hydraulic fluids are not compressible, so hydraulic systems offer exceptionally smooth motion of actuated components because there is no “bounce” due to fluid compressing and expanding, as is typical of pneumatic systems.

Spring-engaged, air-released caliper brakes

Along with lower cost and environmental advantages, spring-engaged, air-released caliper brakes can include several features designed for ease of use and increased accuracy: Rectangular friction facings provide reliable clamping on a rail; quick-release facing shoe pins can facilitate fast brake shoe removal from the actuator arms for simple replacement of the friction pad. Interchangeable actuator locations may be mounted on either side of the brake, delivering increased flexibility, and oil-free bearing at all pivot points reduce maintenance requirements. Adjustment screws are also available for maintaining the facing gap in vertical shaft applications, and a built-in manual release mechanism allows safe and easy maintenance.

Typical specifications of spring-engaged, air-released caliper brakes are as follows:
- Spring hold-off chamber area = 23.758 sq. in.
- Air pressure needed to fully compress the spring = 70 psi
- Spring force = Area x spring pressure = 23.758 (70) = 1,663 lb
- Caliper mechanical advantage = 2.04
- Design coefficient of friction = 0.35

Spring-engaged, hydraulically released caliper brakes

As mentioned, spring-engaged, hydraulically released caliper brakes are typically selected for applications with greater torque requirements or applications that require braking between actuator movements. While a variety of options are available, a brake should be selected with features to simplify setup and enhance performance.

For example, a large friction-facing area lowers facing pressure to provide long friction-facing life. A nested spring design minimizes spring force loss and allows the braking torque to be modified based on specific application requirements. Large orifice ports provide for fast actuation and reliable operation — even in temperatures as low as -30° F. This provides a significant environmental advantage compared to traditional pneumatically-actuated brakes and clutches, which require a minimum operating range of 32° F. Additionally, spring-engaged, hydraulically released caliper brakes can offer some of the same features as air-released brakes, including quick-release shoe pins, adjustment screws, oil-free bearings at pivot points, interchange-able actuator locations, and a manual release accessory.

Typical specifications of spring-engaged, hydraulically released caliper brakes are as follows:
- Spring hold-off chamber area = 9.62 sq. in.
- Air pressure needed to fully compress the spring = 250 psi
- Spring force = Area x spring pressure = 2(0.33) = 2,692 lb
- Caliper mechanical advantage = 2.04
- Design coefficient of friction = 0.35

Application example: Air and hydraulically actuated brakes

Calculate the torque needed to stop a mill roll in 7 sec for the following conditions:
- Roll radius \( d = 2.083 \) ft
- Spring force \( F_l = 2,405 \) lb
- Caliper mechanical advantage = 2.04
- Design coefficient of friction = 0.35

Application example: Caliper brakes clamping on a rail

Determine the deceleration rate \( A \) in \( \text{ft/sec}^2 \) ...

\[ A = \frac{V^2}{2S}, \]

Where \( V \) = Velocity, \( \text{ft/sec} \)
\( S \) = Required stopping distance, \( \text{ft} \)

Then calculate the linear force \( F_l \)

\[ F_l = \frac{WA}{32.16}, \]

Where \( W \) = Weight of the load and acceleration due to gravity = 32.16 \( \text{ft/sec}^2 \)

Finally, calculate the clamping force \( F_c \) needed to stop the load in the distance required.

\[ F_c = \frac{F_l}{2(0.35)}, \]

Where \( F_c \) = linear force
\( 0.35 = \) Design coefficient of friction ... And the coefficient is multiplied by two, to account for two caliper sides.

What is the clamping force needed to stop a 1,200-lb load in 4 in. that is traveling at 70 ips?

Velocity: 70 ips = 70/12 = 5.8 \( \text{ft/sec} \)
4-in. stopping distance = 0.333 ft

\[ A = \frac{5.8^2}{2(0.333)} = 50.5 \text{ ft/sec}^2 \]

\[ F_l = \frac{1,200 \times 50.5}{32.16} = 1,885 \text{ lb} \]

\[ F_c = \frac{1,885}{2(0.35)} = 2,692 \text{ lb clamping force} \]

For this example, a spring-engaged, air-released brake, with a clamp force of 2,550 lb, has rectangular shoes that are suitable for clamping onto a 0.5-in. thick mill, but will allow a slightly longer stopping distance than specified. In contrast, the spring-engaged, hydraulically released brake, with a clamp force of 3,143 lb, stops the load in a shorter distance than specified — but the arced shoes must be replaced with the rectangular shoes from the air-released brake.
Roll weight \( w = 4,410 \text{ lb} \)
- Deceleration rate = 4.92 ft/sec^2
- Speed = To be calculated
- Line speed = 1,969 fpm
- Stop time \( t \) = To be calculated

1. **Calculate speed.**

\[
\text{Speed} = \frac{\text{Line speed}}{\text{Roll diameter} \times \pi} = \frac{1,969}{4,166 \times 3.1416} = 150 \text{ rpm}
\]

2. **Calculate inertia.**

\[
WK^2 = 4,410 \left( \frac{2.083^2}{2} \right) = 9,567 \text{ lb - ft}^2
\]

3. **Calculate the stop time.**

\[
t = \frac{\text{Line speed}}{\text{Max. deceleration rate}} = \frac{32.81}{4.92} = 7 \text{ sec}
\]

4. **Calculate the torque needed to stop the roll in 7 sec.**

\[
\tau = 0.39 \left( \frac{WK^2}{t} \right) \times \text{rpm}
\]

\[
\tau = 0.039 \times (9.567) \times 150 = 8,000 \text{ in. - lb}
\]

Applying a service factor of 1.50 gives a final torque = 1.50 \times 8,000 = 12,000 \text{ in.-lb}.

5. **Compare torque generated by different brakes and discs.**

- For a spring-engaged, air-released brake and 18-in. diameter \times 0.50-in. thick disc:
  - Clamp force = 2,550 lb
  - 18-in. disc working radius = 7.625 in.

\[
\text{Torque } \tau = 2,550 (0.35) \times 2(7.625) = 13,610 \text{ in.-lb}
\]

- For a spring-engaged, hydraulically-released brake and 14-in. diameter \times 1.00-in. thick disc:
  - Clamp force = 3,143 lb
  - 14-in. disc working radius = 5.562 in.

\[
\text{Torque } \tau = 3,143 (0.35) \times 2(5.562) = 12,237 \text{ in.-lb}
\]

6. **Verify the kinetic energy output per cycle.**

\[
Ec = 0.00017 (WK^2) \text{ rpm}^2
\]

For the load energy of our example, \( Ec = 0.00017(9.567) \times 150^2 = 36,598 \text{ ft-lb} \).

7. **Determine the total system inertia associated with each disc.**

- 14-in. disc: 36,594 + 7 = 36,601 \text{ lb-ft}^2
- 18-in. disc: 36,594 + 10 = 36,604 \text{ lb-ft}^2

**Final factors: Life and thermal capacity**

Friction facing life is the maximum number of cycles based on horsepower hours (hp hr) value of the friction facing.

Horsepower hours of a friction facing is the usable amount of facing material in cubic inches divided by the material’s wear rate:

\[
\text{Life} = \frac{\text{hp hr} \times 33,000 \times 60}{Ec}
\]

For air-actuated brakes:

\[
\text{Life} = \frac{1,243,440,000}{36,601} = 33,972 \text{ cycles}
\]

Hydraulically actuated brakes:

\[
\text{Life} = \frac{2,451,240,000}{36,605} = 66,965 \text{ cycles}
\]

A brake disc’s thermal horsepower capacity is partially determined by velocity \( V \) in fps and continuous heat dissipation \( Q \):

\[
V = \frac{0.262 \times D \times N}{60}
\]

and \( Q = k_1 \times t_a \times A \)

Where \( N = \text{Disc rpm} \)
\( k_1 = 0.00063 \sqrt{V} \)
\( t_a = \text{Allowable temperature rise from ambient, use } 320^\circ F \)

\( A = \text{Contact area of the friction disc} = 0.7854(D^2 - d^2) \)

\( D = \text{Outside diameter of contact area} \)

\( d = \text{Inside diameter of contact area} \)

**Final considerations**

In the rotary application we explored, both brake-actuator types perform the stop. The decision of which style to use can be determined by other factors previously described, including the environment, physical space for the brake and disc, and overall system cost.

If the machine is located inside a building where an air supply is readily available and the temperature is stable, the logical choice is the air-engaged unit. For outdoor use, at temperatures below freezing, two types of brake actuation methods are possible — hydraulic or nitrogen. Nitrogen is commonly used to replace air in many types of applications. Nitrogen is a colorless, odorless, tasteless gas, constituting 78.08% of air by volume, which remains stable at any temperature. The moisture content in compressed nitrogen is very low compared to the moisture content in compressed air. Less moisture (oxygen) means dryer components and less oxidation (rust).

For more information, visit nexen-group.com or call (800) 843-7445.