INTRODUCTION

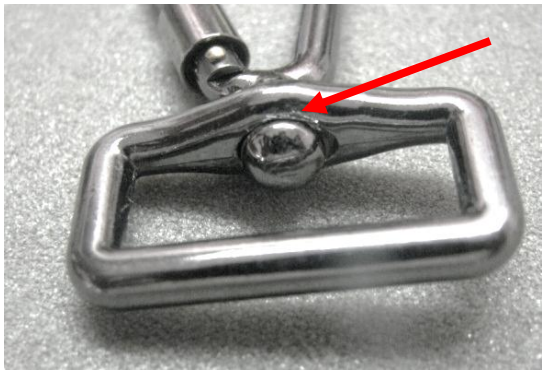
360° Product Testing performed destructive durability testing of three identical swivel test articles made of CR-2 Zinc as pictured at right. Also pictured at right is the typical ... application for these swivels (omitted).

Tests performed

- **Test 1:** Rotate swivel ... full turns with ... lbs. of weight applied.
- **Test 2:** Apply the force equivalent to ... lbs. dropping ...' performed over ... cycles.

Test results follow:

Test 1: Rotate swivel ... full turns with ... lbs. of weight applied.



Test Setup:

A custom rotary test fixture was fabricated that anchored the top clip using a metallic banding. While a secondary metallic banding rotated on an approximately two feet diameter circular path. This allowed the tested specimen to be anchored in the middle, while the secondary band rotated the clip. While rotating, a static ... lbs. load was suspended from the swivel via the blue strap shown in the center image above.

Rotation speed was set and measured, and then the time under test was used to closely estimate the total number of rotation cycles. Three swivels (pictured above left) were tested sequentially; each swivel being rotated at ~200 cycles per minute for ... minutes. The slight intermittent off-vertical orientation of the rotating swivel accelerated the localized rubbing on one side of the rotating head for a single sample as pointed to by the red arrow (above right).

All swivels passed the ... revolution requirement without failure. The only observable degradation observed was a very slight shaving on the third sample (pictured with red arrow on the preceding page). This wear did not appear to degrade the performance of the part.

Sample 1: PASS
Sample 2: PASS
Sample 3: PASS

Test 2: A pneumatic cylinder will apply the force equivalent to ... lbs. dropping ...' performed over ... cycles.

Background Math:

The total energy developed by dropping a ... pound mass by ... is 14.0 ft-lbs. (19.0 N-m).

Energy derivation (customary units):
Freefall velocity = (2 * Gravity * Height)
Velocity = (2 * 32.174 ft/sec² * 2 ft) = 11.34 ft/sec

Potential Energy = Kinetic Energy
Mass*Gravity*Height / Gc = ½ * Mass * Velocity² / Gc
(7 lbm)*(32.2 ft/sec²) * (2 ft) / (32.2 lbm-ft/lbf-sec²)
= ½ * (7 lbm) * (11.34 ft/sec)^2 / (32.2 lbm-ft/lbf-sec²)

14.0 ft-lbf = 14.0 ft-lbf (within rounding differences)

Energy derivation (metric units):
Freefall velocity = (2 * Gravity * Height)
Velocity = (2 * 9.8 m/sec² * 0.61 m) = 3.46 m/sec

Potential Energy = Kinetic Energy
Mass*Gravity*Height / Gc = ½ * Mass * Velocity² / Gc
(3.18 kg)*(9.8 m/sec²) * (0.61 m) / (1 N/N)
= ½ * (3.18 kg) * (3.46 m/sec)^2 / (1 N/N)

19.0 N-m = 19.0 N-m (within rounding differences)

The impact force is calculated using the deceleration of the mass upon impact from the maximum velocity calculated above to zero velocity over a very short period of time.

Force = Mass / Gc * (V1 – V2) / (∆t)

A shorter deceleration time creates a higher impact force. A typical deceleration time of 25 milliseconds is assumed as typical for this application.

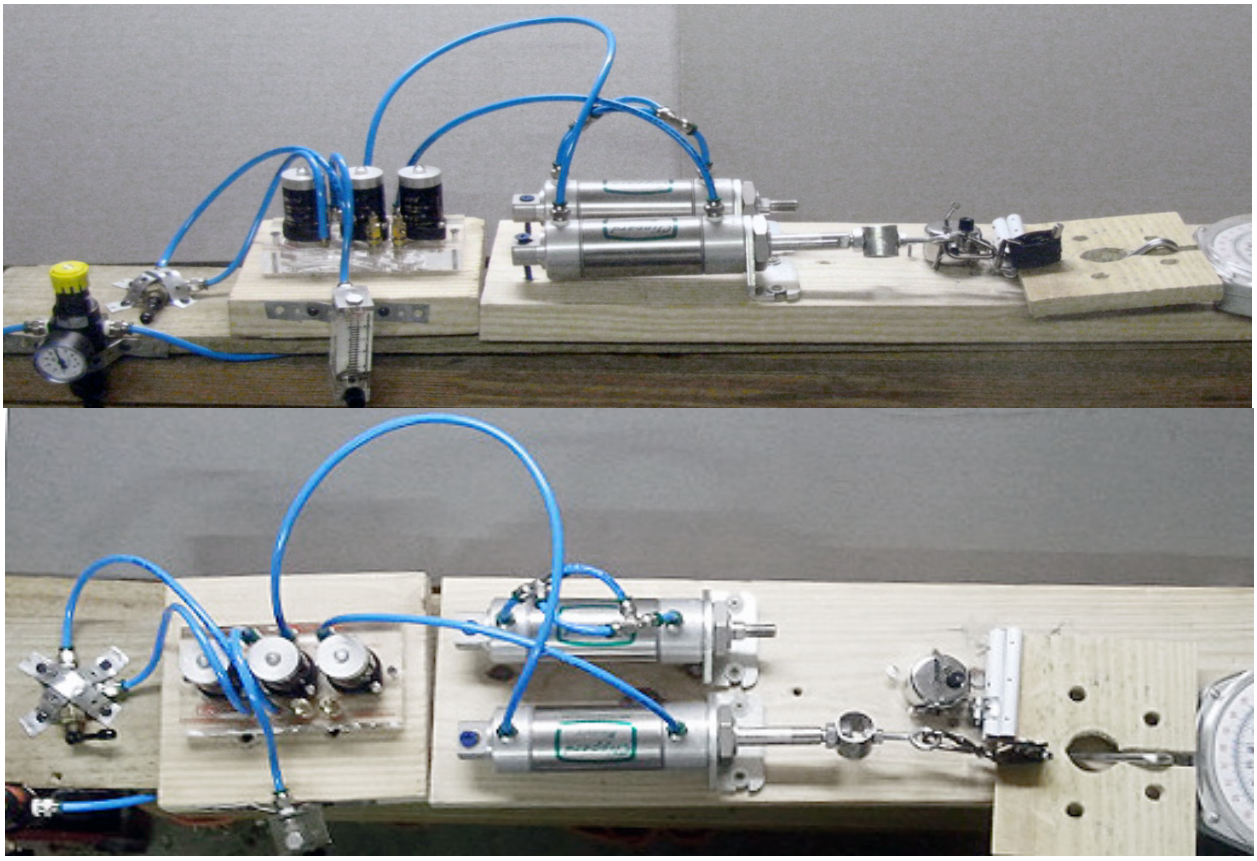
Force = (7 lbm) / (32.2 lbm-ft/lbf-sec²) * (11.34 ft/sec – 0 ft/sec) / (0.025 sec) = 98.7 lbf

Physical Benchmark Test:

Several drops of a ... pound mass from ... were observed and peaked on the measurement scales at approximately ... lbs. This testing validates the assumed deceleration time (25 ms) in the above force calculation.

Test Setup:

A specialized pneumatic actuator test jig was used to cycle repetitive horizontal strokes that pull against the swivel, and later the swivel suspended with Nylon webbing. The swivel is attached to an anchored force scale and the air pressure was adjusted to achieve the target force.



The initial force testing began at higher force values with limited cycles.

Sample	Force (lbs.)	Cycles to Failure	Status
1	omitted	omitted	Broken
2			Broken
3			Broken
4			Broken
5			Broken

In the initial test setup, the scale hook did contact the swivel's rectangular region and the swivel did not benefit from nylon strap dampening; thus, tests of samples 2 - 5 should not be considered strongly predictive of product performance. However, the test of sample #1 does likely represent a break force for the swivel with or without a nylon strap as the product broke with a single stroke.

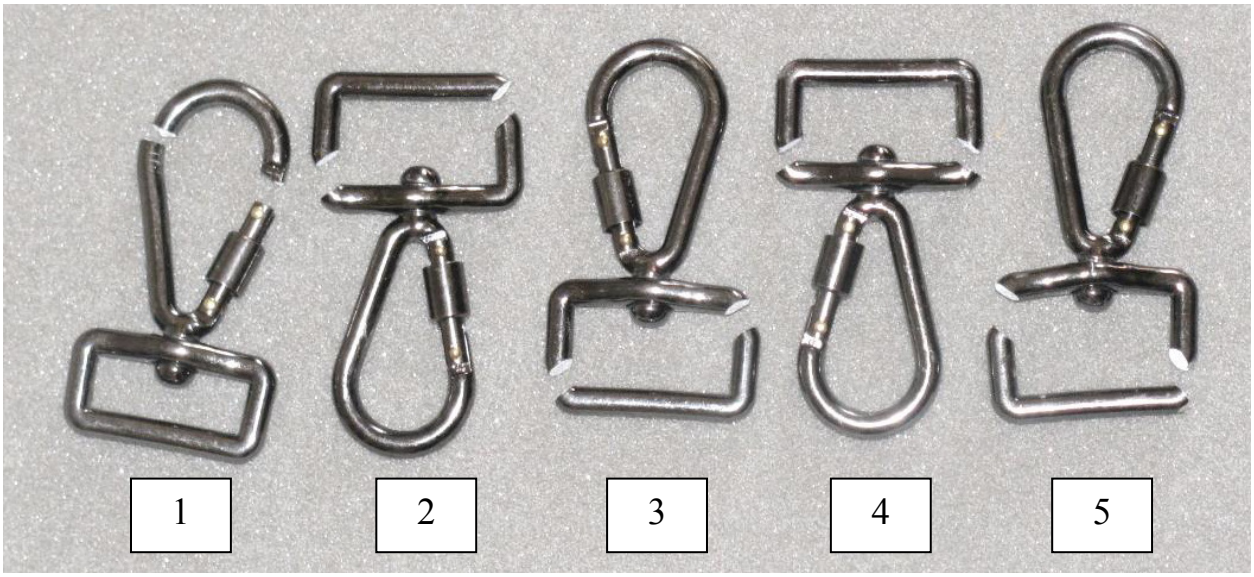


Figure 1: Failed Swivel Samples by Test Article Number

Swivel testing was then conducted with the supplied nylon strap to provide a more uniform force loading to the upper mounting loop of the product, and to better emulate the product's application.

The 6th sample (right) was tested at approximately ... lbs. and failed at ...cycles.

The 7th sample (below) completed ... cycles; however during the testing... lbs. Upon retesting at ... lbs., sample #7 it broke at ... cycles.

The 8th sample (right) completed ... cycles before breaking in an unusual mode. The cross-bar holding the spindle broke in the middle. Additionally, the corners of the rectangular section for holding the strap also broke.

The 9th and 10th (below) samples completed ... cycles without breaking. However, the 9th sample was run at an approximate force of ... lbs. The 10th sample at ... lbs.

Using the formulas and assumptions from the **Background Math** section above provides the following summary of impact forces for similar dropped weights:

Mass (lbs)	Distance (ft)	Impact Force (lbs)
omitted	omitted	56.42
		63.47
		70.52
		77.57
		84.62
		91.67
		98.73
		105.78
		112.83
		119.88
		126.93

... product samples passed the desired ... cycles at an impact force of approximately ... lbs. According to the summary table at left, the success impact force is an equivalent drop of a ... lbs. mass from ...

The 11th sample (right) broke at ... cycles with an approximate load of ... lbs. Similar to the sample #8's failure, sample #11 broke both at the corners of the strap rectangular region and at the spindle connection.

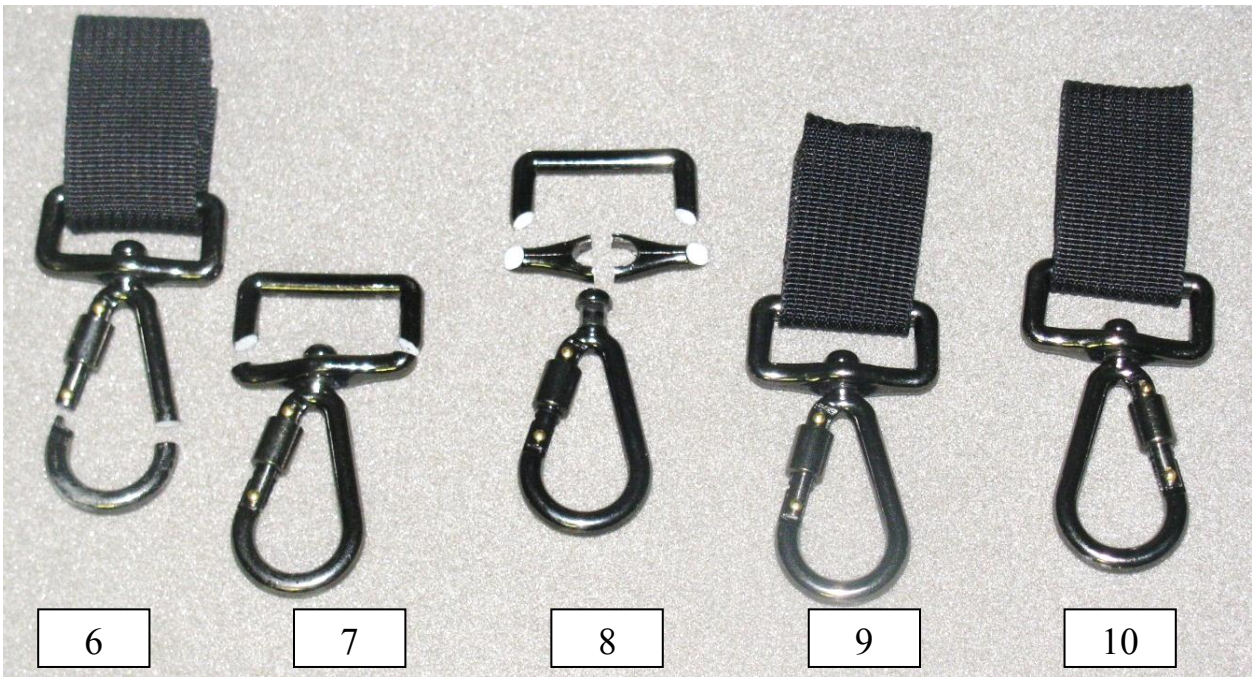


Figure 2: Failed Swivel Samples by Test Article Number

Sample	Force (lbs)	Cycles to Failure	Status
6	Omitted	Omitted	Broken
7			*Broken*
8			Broken
9			Passed
10			Passed
11			Broken