A Tale of Two Testing Methods, Part Three

The third and final part of this series focuses on test reports, data and the ways this testing method can improve elevator maintenance.

by Kevin Heling

Learning Objectives

After reading this article, you should be able to:

- ♦ The Henning ELVI 2 System takes CAT5 testing to an advanced level using instrumentation-based devices and engineering-derived and -proven methods of measuring and documenting stopping forces.
- ♦ ELVI 2 test reports incorporate measured values of velocity, acceleration/deceleration and specific loads (including required levels), which, in turn, are used in algorithms that directly and accurately measure system stopping capabilities. Nothing about this system involves "simulation." All results are based on direct measurements.
- ♦ You will see measures of force as gravity values and will learn and understand how much force (in g) is needed to effect safe stops of the elevator being tested.
- ♦ Measurement results will accurately and reliably show when repair or maintenance is needed. Additionally, measured values of some "passing" results will show that attention may be needed in the shorter term – i.e., before the next five-year test interval. Technician/mechanic experience and professional judgment add to this important work.
- ♦ Aspects of elevator system performance are revealed in this testing, which improves maintenance and ultimate safe operation of elevators that receive the benefit of this testing method. These advanced benefits are not possible using just test weights and observing stops.

Instrumentation-based and data-driven testing is highly professional and superior compared to simple observation-based Category 5 (CAT5) testing using weights. At a time when the elevator industry has active and growing discussions and initiatives about improving safety and maintenance, it is surprising that labor, AHJs and maintenance/service providers) have not quickly accepted the positive advantages of the ELVI 2 Testing Method. Better CAT5 testing was encouraged by a change in the "Safety Code" that came into place back in 2013.

In Part One of this three-part series, we covered the whats and whys of the Safety Code on CAT5 Testing and the technical objectives the writers of the Code laid out for a real advancement in elevator testing.

In Part Two, we clearly showed that the testing method using weights "is flawed, and, even worse, there is no assurance for us that testing was done correctly or even done at all." After more than 10 years of direct experience working with an available and broadly accepted "alternative" (better known as Instrumentation and data-based) CAT5 testing, we see that the old method, in many cases, is not "proving" safe emergency stops of elevators.

Part Three, this final phase of educating professionals in the industry (especially technicians doing CAT5 testing), now delves into reading and understanding all aspects of the test reports and the data, and learning the many ways this testing method reveals ways of improving the maintenance of elevators (primarily traction systems).

Elevator Machine Brake and Emergency Brake Test Results – Overview and Guide

Let's look at the elevator/lift brake test results shown in some accompanying graphics. These tests evaluate whether the machine brake and emergency brake systems meet safety requirements for dynamically stopping (most importantly and the most rigorous test); and holding an elevator car under various load conditions.

Graphic 1: Machine Brake Test Diagram

This overview/explanatory diagram shows the phases (graphically) of a machine brake test.

- ♦ Purple line: Vertical acceleration in g-forces
- ♦ Pink line: Speed in m/s

Value: 1 contact hour (0.1 CEU)

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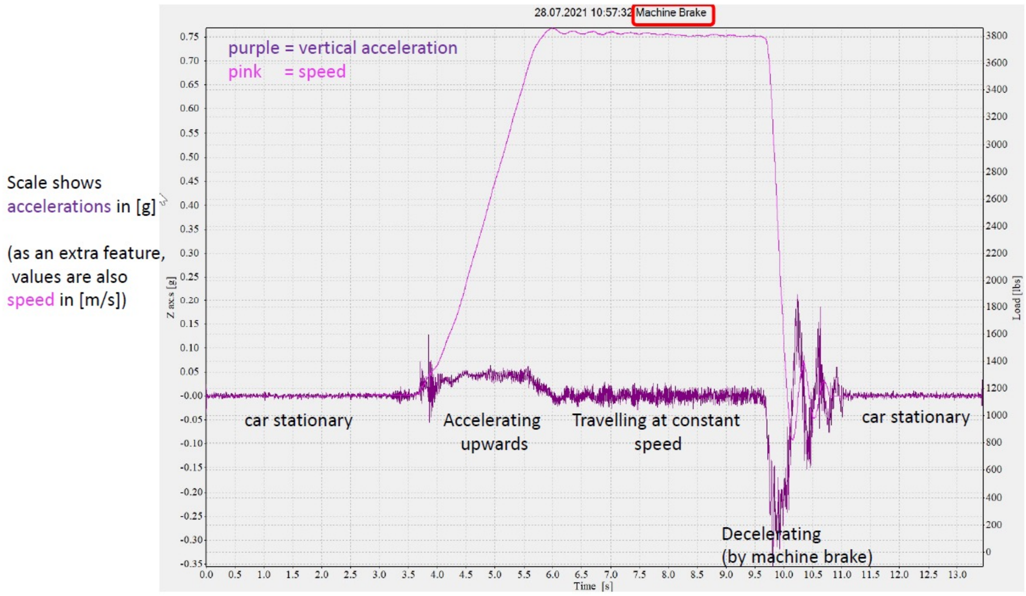
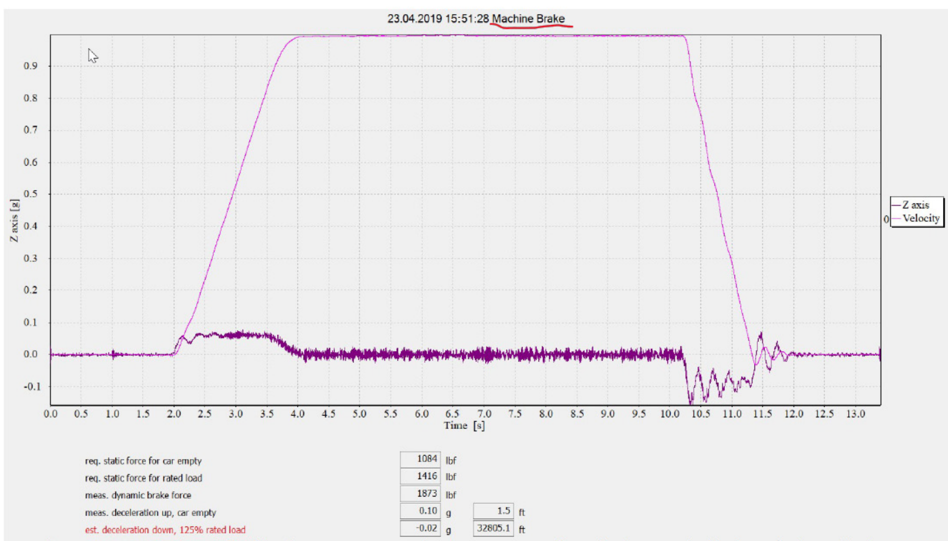


Graphic 1



Graphic 2

Close to passing, but failed brake test. Some adjustment to machine brake needed (adjust/tighten?) Also consider balance %

Phase breakdown (left to right):

1. Car stationary (0-3.5 s)
   - Both acceleration and speed near zero
   - Car sitting at rest position
2. Accelerating upwards (3.5-6.0 s)
   - Speed increases (pink line rises)
   - Positive acceleration spike visible (purple)
   - Motor brings car up to rated speed.
3. Traveling at constant speed (6.0-9.5 s)
   - Speed plateaus at ~0.75 m/s.
   - Acceleration returns to near-zero.
   - Steady-state operation
4. Decelerating by machine brake (from 9.5-11 s)
   - Speed decreases rapidly (pink line drops).
   - Large negative acceleration spikes (purple shows -0.20 to -0.30 g)
   - Brake engages and stops the car.
5. Car stationary (at 11.0+ s)
   - Both traces return to near-zero.
   - Car held in place by brake

Scale interpretation:

- The Y-axis shows accelerations in [g] where 1 g = 9.81 m/s^2.
- As noted: "As an extra feature, values are also speed in [m/s]."
- This allows both acceleration and velocity to be read from the same scale.

Normal vs. Excessive Deceleration:

- The spikes during braking show brief high deceleration (normal).
- If deceleration is too low, stopping distance becomes excessive.
- If deceleration is too high, passenger comfort suffers and mechanical stress increases.

Graphic 2: Machine Brake Test Failed Example

- Result: FAILED (though relatively close to passing)
- Graph shows two key traces:
  - Pink line (Velocity): Shows the speed of the elevator car

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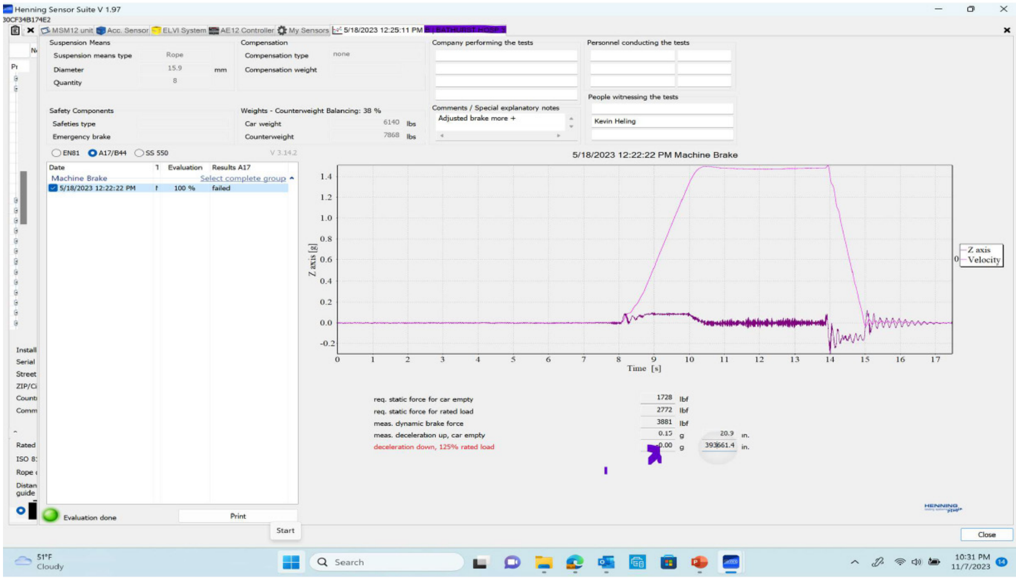

Graphic 3

- Purple line (Z axis acceleration): Shows vertical acceleration in g-forces
- Test Sequence:
  - 0-2 s: Car stationary at bottom
  - 2-4 s: Car accelerates upward (pink line rises).
  - 4-10 s: Car travels at constant speed (~1.0 m/s or peak velocity).
  - 10 s: Machine brake applied - car begins decelerating.
  - 10-12 s: Deceleration phase (pink line slopes downward)
  - 12+ s: Car comes to complete stop.

Key Measurements

Parameter	Value	Unit	Notes
Required static force (empty car)	1084	lbf	Force brake must hold when car is empty.
Required static force (rated load)	1416	lbf	Force brake must hold at rated capacity.
Measured dynamic brake force	1873	lbf	Actual braking force measured.
Measured deceleration (up, empty)	0.10	g	Deceleration achieved (empty car going up).
Calculated deceleration (down, 125% load)	-0.02	g	CRITICAL FAILURE

Why This Test Failed

ASME A17.1/B44 Code requires there must be deceleration. Negative g means car is not decelerating.

What the numbers mean:

- The brake can generate 1873 lbf of stopping force.
- This is adequate for an empty car going up (0.10 g deceleration).
- However, when the car is overloaded (125% capacity) and traveling down, gravity assists the car's downward motion; dynamic test of the brake is the most demanding test. If it fails, static tests mean nothing.
- The brake cannot overcome this additional force.
- Result: Unsafe and not Code compliant

Recommended Actions

- Adjust/tighten the machine brake to increase braking force.
- Check/consider Car/CWT balance percentage to ensure adequate balance. Balance affects brake performance.
- Re-test after adjustments to assure there is main brake deceleration – prove Code requirement is met.

Graphic 3: Machine Brake Test; Second Test After Adjustment

Result: FAILED

- Suspension type: Rope
- Rope diameter: 15.9 mm (5/8 in.)
- Quantity: Eight ropes
- Compensation type: None
- Car weight: 6140 lb
- Counterweight: 7868 lb
- Counterweight balancing: 38%
- Witness: Kevin Heling
- Comments: "Adjusted brake more ++"

Key Measurements

Parameter	Value	Unit
Required static force (empty car)	1728	lbf
Required static force (rated load)	2772	lbf
Measured dynamic brake force	3881	lbf
Measured deceleration (up, empty)	0.15	g
Est. deceleration (down, 125% load)	-0.00	g
Braking distance	Not stopping	

Why This Test Failed

Despite adjustments noted in comments ("Adjusted brake more ++"), the test still failed:

- The dynamic brake force (3881 lbf) is higher than the previous.
- Measured deceleration for downward travel with 125% load is -0.00 g – not decelerating.
- Brake still cannot generate stopping force for worst-case scenario (overloaded car traveling down).

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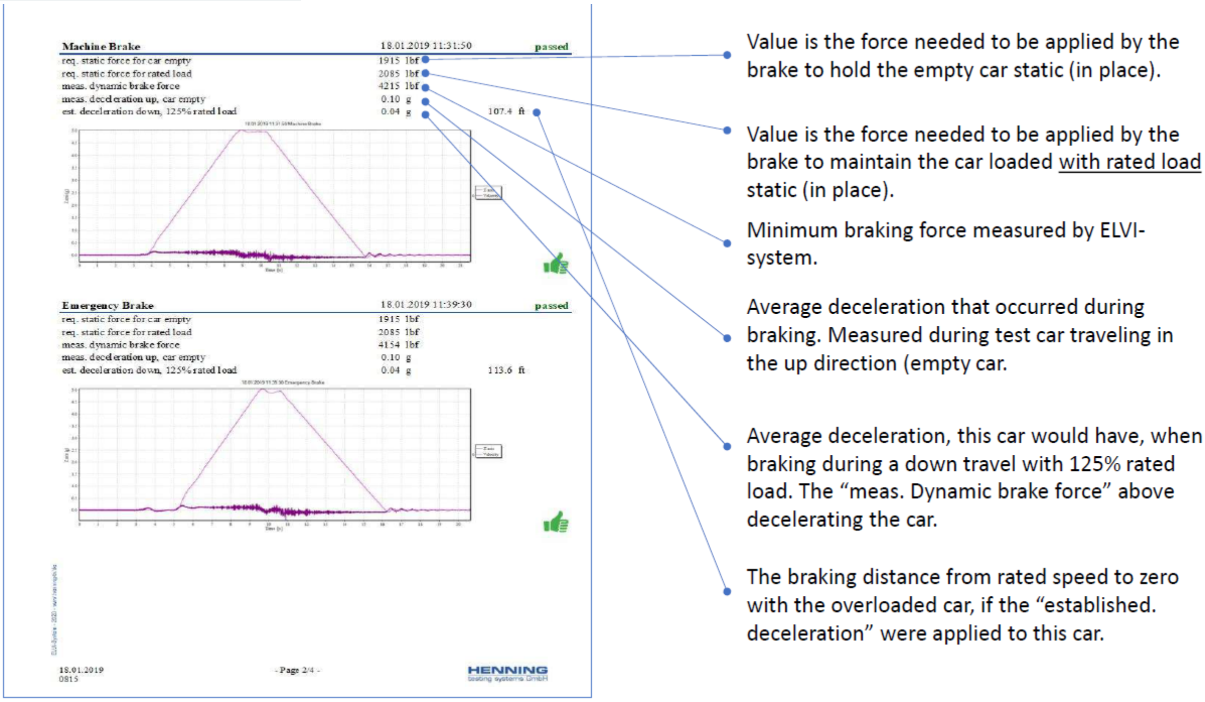

Graphic 4

- Interestingly, if balance percentage were increased, results potentially might have measured as passing.
- Maintenance provider determined after these tests that further adjustments (to brake solenoid) would risk a catastrophic failure of the brake. The next step was a brake rebuild and evaluation of system balance.

Graphic 4: Test Results Summary With Terminology

The document shows machine brake and emergency brake results side-by-side with explanations of measurements. We can see that the measurements and following results are the same for machine brakes and emergency brakes.

Machine Brake Test Results

Date/Time: Date of test documented

Result: PASSED ✓

Key Measurements

Parameter	Value	Unit
Required static force (empty car)	1915	lbf
Required static force (rated load)	2085	lbf
Measured dynamic brake force	4215	lbf
Measured deceleration (up, empty)	0.10	g
Calculated deceleration (down, 125% rated load)	0.04	g
Braking distance	107.4	ft

Test PASSED because:

- Established deceleration (0.04 g) is positive.
- Braking distance (107.4 ft) OK; though in most installations a decelerating car like this will reach the pit and buffer (presumably traveling at less than the rated speed of the buffer).
- Brake force (4215 lbf) exceeds requirements.

Emergency Brake Test Results

Date/Time: January 18, 2019, at 11:39:30

Key Measurements

Parameter	Value	Unit
Required static force (empty car)	1935	Lbf
Required static force (rated load)	2085	Lbf
Measured dynamic brake force	4154	Lbf
Measured deceleration (up, empty)	0.10	G
Calculated deceleration (down, 125% rated load)	0.04	G
Braking distance	113.6	Ft

Measurement Definitions (Right Side)

The document includes helpful explanations:

1. "Required static force for car empty"
   - Force the brake must apply to hold an empty car stationary
   - Prevents car from moving due to imbalanced counterweight
2. "Required static force for rated load"
   - Force needed to hold a fully loaded car in place
   - Accounts for rated capacity plus counterweight imbalance
3. "Measured dynamic brake force"
   - Minimum braking force measured during the test
   - Must exceed static requirements with safety margin
4. "Measured deceleration up, car empty"
   - Actual deceleration achieved during upward test run
   - Measured with empty car for consistency
5. "Calculated deceleration down, 125% rated load"
   - MOST CRITICAL VALUE
   - Adjusts deceleration to worst-case scenario
   - 125% overload + downward travel + gravity assistance
   - Must be positive to pass
   - Used to calculate braking distance
6. "Braking distance"

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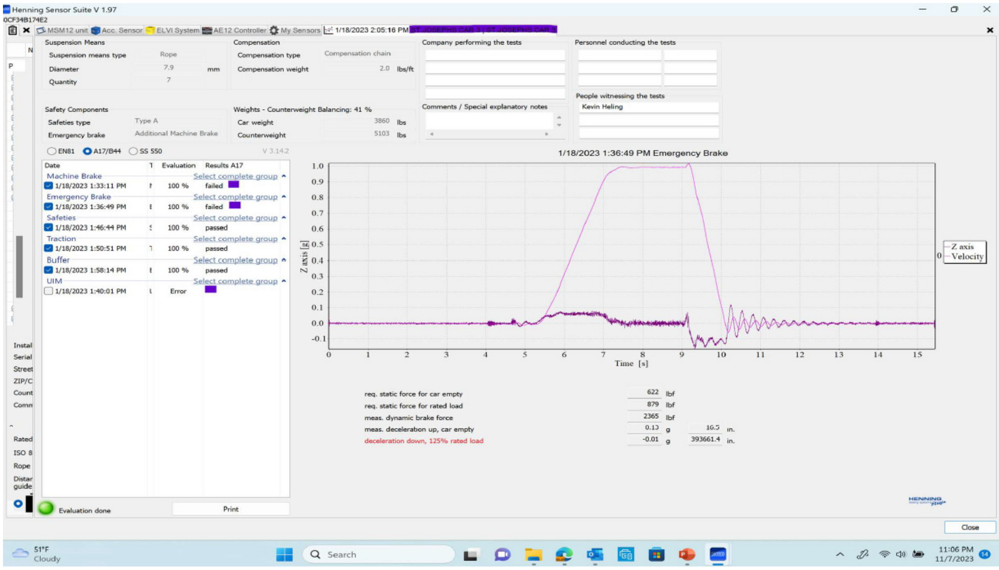

Graphic 5

- Distance car would travel from rated speed to complete stop
- Based on measured actual deceleration
- Within acceptable limits for the building/shaft and the elevator system buffer, if needed

Why These Tests Passed

Both brakes demonstrated:

- Enough dynamic braking force for this car/CW balancing and rated load(>4000 lbf)
- Positive deceleration in worst-case scenario (i.e. 0.04 g)
- Reasonable stopping distances, speed not expected to exceed the system rated speed
- Forces well above minimum requirements

Understanding Test Failures vs. Passes

Critical Success Factors

For a brake test to PASS:

- Dynamic brake force must exceed static force requirements.
- Deceleration with 125% load traveling down must be positive.
- All values shown in black (not red) on the report

Common reasons for FAILURE:

- Brake adjustment too loose - insufficient clamping force
- Worn brake pads or shoes, reducing friction
- Contaminated brake surfaces (oil, grease, debris)
- Improper counterweight balancing

The Physics Behind the Test

Why downward travel with overload is critical:

- Gravity acts downward with force = mass × 9.81 m/s^2.
- With 125% load, gravitational force is at maximum (125% is the highest Code-allowed overload).
- Counterweight provides upward force but is designed for 100% load.
- Brake must overcome: (125% load weight) - (counterweight) + friction losses.
- If brake force insufficient, car continues accelerating downward.
- Result: negative deceleration value = failure

Safety Implications

Brake tests ensure:

- Passenger safety during normal stops
- Emergency stopping capability if controls fail
- Ability to hold car stationary at any floor
- Protection against uncontrolled descent
- Compliance with elevator safety codes (ASME A17.1, EN 81, etc.)

Conclusion

These report samples demonstrate a thorough testing process for elevator brake (main and auxiliary/emergency) systems. Tests examine both machine brakes (normal operation) and emergency brakes (safety systems) under worst-case loading conditions. The difference between passing and failing usually comes down to proper adjustment and maintenance of brake components, but the system balance percentage may also be a factor.

Key takeaway: A positive deceleration value for the "125% rated load, downward travel" scenario is essential for test passage required by Code and, more importantly, for safe elevator operation.

Emergency Brake Testing Analysis: Two Examples

The attached documents present two emergency brake test results. Here's an analysis of each test scenario:

Graphic 5: Emergency Brake Example 1 - Failed Test (1/18/2023 1:36:49 PM)

This test was conducted on a rope suspension system with seven 8-mm diameter ropes. This elevator has:

- Car weight: 3860 lb
- Counterweight: 5103 lb
- Counterweight balancing: 41%

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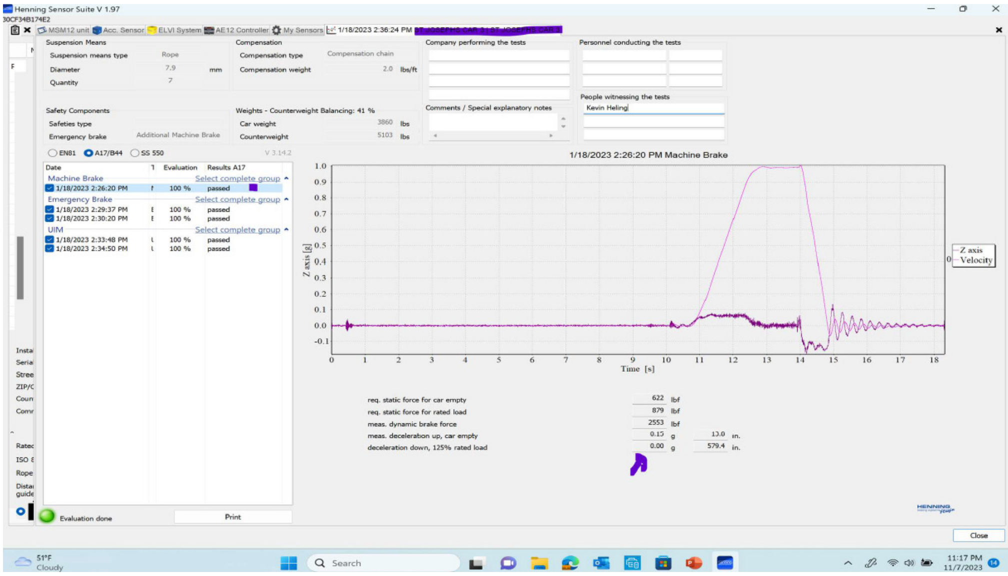
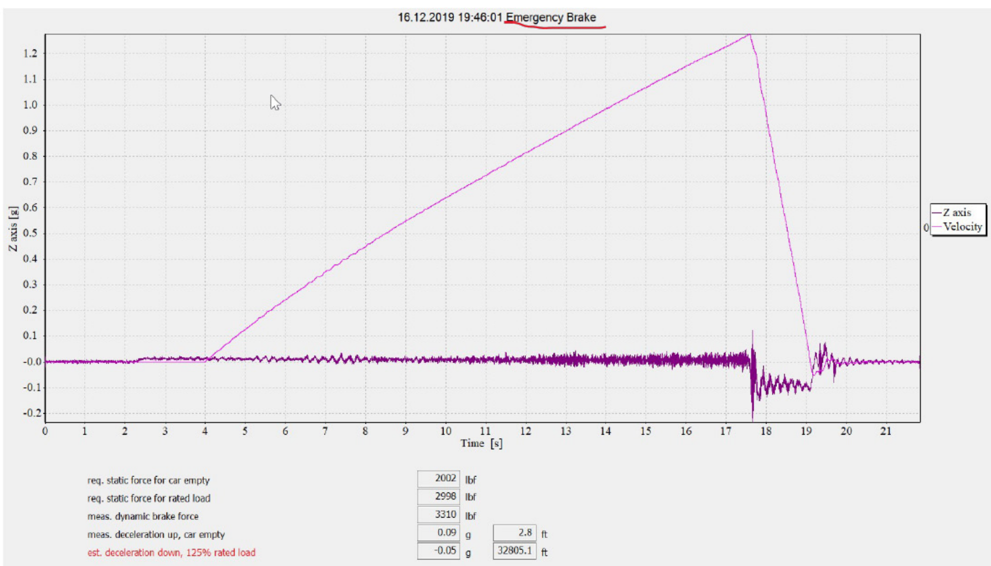


Graphic 6



Graphic 7

Failed emergency brake test...if rope brake, repair may involve changing brake pads, or burn in...Or look at balance %

The graph displays Z-axis acceleration and velocity over approximately 15 s. The test shows a rapid deceleration event around the 9-s mark, where the velocity sharply drops from about 0.9 m/s to negative values before stabilizing. Key measurements include:

- Required static force (car empty): 622 lbf
- Required static force (rated load): 879 lbf
- Measured dynamic brake force: 2365 lbf
- Measured deceleration up (car empty): 0.13 g equal to a stopping distance of 16.5 in.
- Deceleration down (125% rated load): -0.01 g (shown in red, indicating a failure)

Graphic 6: Emergency Brake Example 2 - Passed Test (1/18/2023 2:26:20 PM)

This test uses the same elevator configuration as Example 1. The velocity profile shows a smooth acceleration up to approximately 1.0 m/s around the 12-s mark, followed by a controlled deceleration back to baseline around the 14-s mark. Test results indicate:

- Required static force (car empty): 622 lbf
- Required static force (rated load): 879 lbf
- Measured dynamic brake force: 2553 lbf
- Measured deceleration up (car empty): 0.15 g equal to a stopping distance of 13.8 in.
- Deceleration down (125% rated load): 0.00 g equal to a stopping distance of 579.4 in.

All evaluation steps for this machine brake test show “100% passed” status, indicating successful performance.

Graphic 7: Emergency Brake Example 3 - Failed Test With Special Notes (16.12.2019 19:46:01)

This earlier test shows a clear failure scenario. The velocity graph shows steady acceleration reaching approximately 1.25 m/s over 18 s, followed by an abrupt deceleration around the 19-s mark. Test measurements show:

- Required static force (car empty): 2002 lbf

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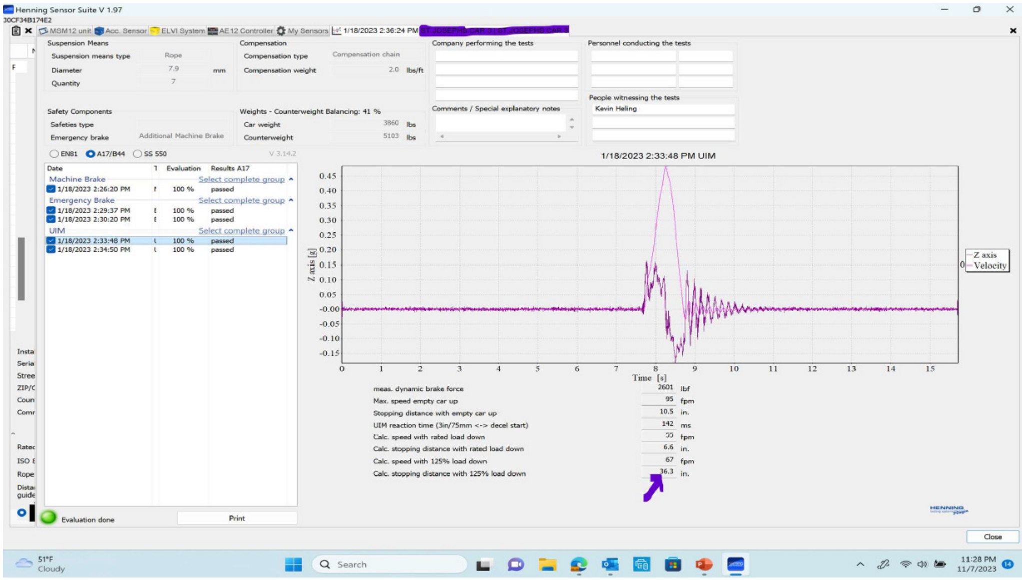

Graphic 8

- Required static force (rated load): 2998 lbf
- Measured dynamic brake force: 3310 lbf
- Measured deceleration up (car empty): 0.09 g equal to a stopping distance of 2.8 ft
- Established deceleration down (125% rated load): -0.05 g (shown in red)

The document includes a critical note: "Failed emergency brake test ... if rope brake, repair may involve changing brake pads or burn in ... or look at balance %."

This annotation suggests that the failure may be related to brake pad wear or improper brake conditioning, or possibly an issue with the counterweight balance percentage. The technician's note provides troubleshooting guidance for addressing the failure.

These three tests illustrate the importance of comprehensive elevator CAT5 testing. Two of the three emergency brake tests failed, showing inadequate deceleration performance under the critical 125% rated load condition. The successful machine brake test demonstrates that, when functioning properly, the system can achieve appropriate deceleration values. The special notes on the third test provide valuable insight into potential remediation strategies, including brake pad replacement, brake burn-in procedures or balance adjustment.

Unintended Car Movement (UIM) Testing: Test Example

The attached document shows UIM test results from the Henning Sensor Suite V 1.97 software conducted on January 18, 2023, on this elevator system. Detailed analysis of the test process:

System Configuration (Same for Both Tests)

Elevator being tested has the following general specifications:

- Suspension means type: Rope
- Diameter: 8 mm
- Quantity: Seven ropes
- Compensation type: Compensation chain
- Compensation weight: 2.0 lb/ft
- Car weight: 3860 lb
- Counterweight: 5103 lb
- Counterweight balancing: 41%
- Safety components: Type A safeties, additional machine brake

Testing shows a complete evaluation sequence with all components tested "100% and passed":

- Machine brake, emergency brake, safeties
- And UIM (the focus of these tests)

Graphic 8 UIM Example (1/18/2023 2:33:48 PM)

Test measures UIM system response to UIM in the up direction.

The velocity graph (Z-axis, left axis) shows approximately 8 s of baseline operation near zero velocity, followed by upward movement (test initiated and car allowed to drift) around the 8-s mark. Car reaches peak velocity of approximately 0.45 m/s before UIM system activates, causing deceleration. Subsequent oscillations show the car settling after e-stop, with decreasing amplitude until stabilizing around the 11-s mark.

Key Test Measurements:

- Measured dynamic brake force: 2601 lbf (measured during test of emergency brake)
- Maximum speed (empty car up): 95 ft/min
- Stopping distance with empty car up: 10.5 in.
- UIM reaction time (3in/75mm <-> decal start): 142 ms (milliseconds)
- Calculated speed with rated load down: 55 fpm
- Calculated stopping distance with rated load down: 6.6 in.
- Calculated speed with 125% load down: 67 fpm
- Calculated stopping distance with 125% load down: 36.3 in. (highlighted in purple)

Test Result: PASSED

The test/graph shows the UIM system can detect and stop unintended upward movement within Code-defined

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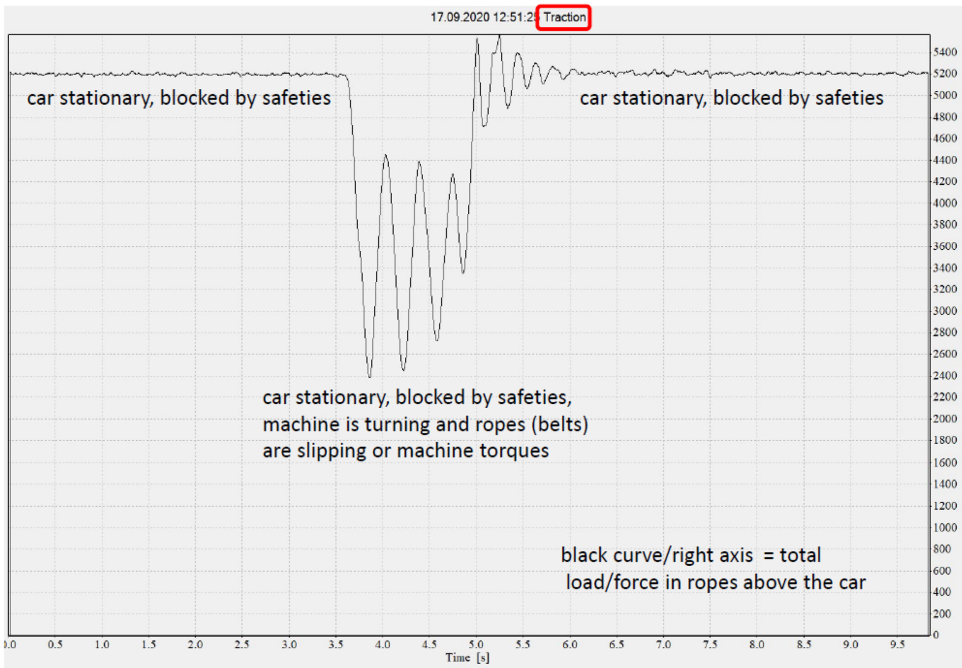

Graphic 9

parameters. The reaction time of 142 ms shows rapid detection and engagement of the secondary brake mechanism.

An identical second test was conducted just 62 s after the first test, testing the same UIM functionality; showing us both consistency and repeatability of results.

- Measured dynamic brake force: 2601 lbf (identical as it's taken from the passing e-brake test)
- Maximum speed (empty car up): 97 fpm (2 fpm higher)
- Stopping distance with empty car up: 10.7 in. (0.2 in. more)
- UIM reaction time (3 in./75 mm <-> decal start): 147 ms (5 ms slower)
- Calculated speed with rated load down: 57 fpm vs 55 fpm
- Calculated stopping distance with rated load down: 6.8 in. vs. 6.6 in.
- Calculated speed with 125% load down: 70 fpm vs 67 fpm
- Calculated stopping distance with 125% load down: 38.8 in. vs 36.3 (highlighted in purple)

Tests demonstrate excellent consistency and repeatability.

Understanding UIM Testing

UIM testing is critical for elevator safety, as it verifies the system's ability to detect and stop unintended car movement that could occur due to:

- Brake failure
- Controller or drive malfunction
- Mechanical issues such as unacceptable overbalance
- Rope/belt slippage

The test measures several key parameters:

- Reaction Time: System detecting movement and begins stopping (both tests showed ~145 ms average)
- Stopping Distance: How far the car travels before coming to a complete stop; Code requirement is maximum 48 in. (corresponds to the Code-defined dimension of the shear apron, aka toe guard).
- Maximum Speed: The peak velocity reached during the unintended movement event
- Brake Force: The force applied to arrest the movement; tested and verified in the emergency brake test

The values for rated load and 125% load scenarios are direct calculations from empty car test results, allowing technicians/engineers to verify safety margins without physically loading the car during testing.

This UIM test method is representative of other tests seen with this system. It demonstrates a properly functioning safety system with excellent repeatability. Minor variations between the tests (within 2-5%) fall well within acceptable tolerances and confirm reliability of the UIM safety mechanism. The rapid reaction times (under 150 ms) and short stopping distances (around 10-11 in. for empty car) indicate a responsive safety system that would effectively protect passengers in the event of an UIM event.

Elevator Traction Test Results – Overview and Guide

Graphic 9: Traction Test Basic Graph

This document provides a detailed explanation of how to interpret traction test graphs, making it an essential reference for understanding test results.

The black curve on the right axis represents the total load/force in the ropes (or belts) above the car, measured in lbf. The y-axis scale ranges from 0 to approximately 5400 lbf.

The graph is divided into three distinct phases across the 10-s time span:

1. Phase 1 (0-3.5 s): "Car stationary, blocked by safeties"
   - The load curve shows a steady baseline around 5200 lbf.
   - This represents the static condition before the traction test begins.
   - The car is held securely by the safety mechanisms.

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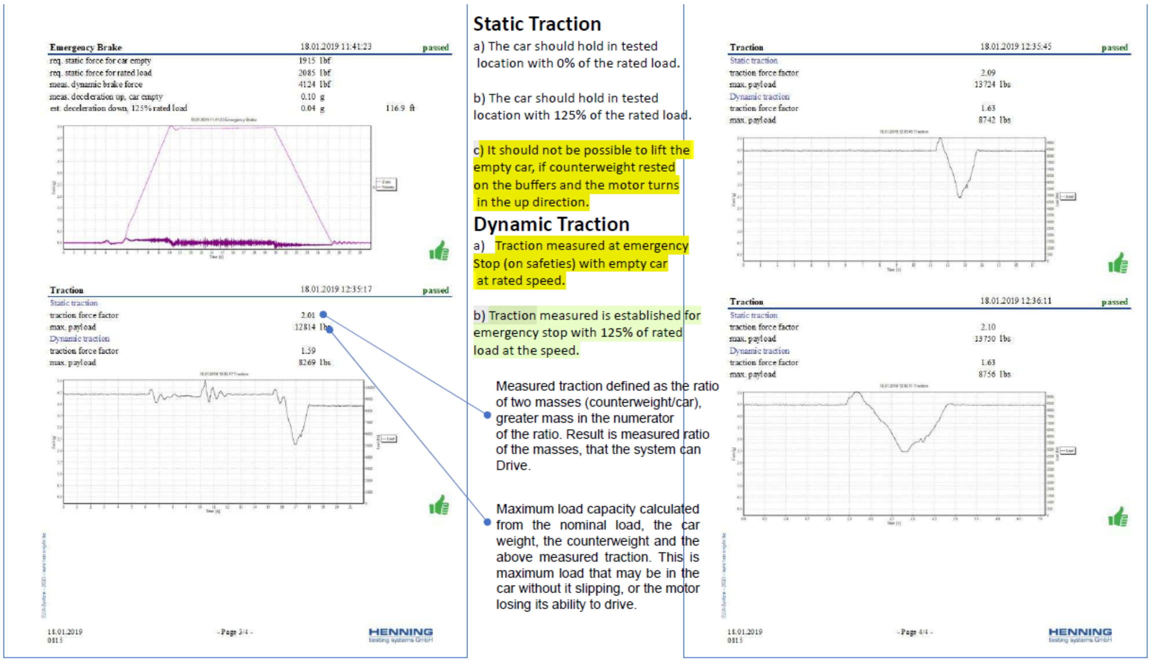

Graphic 10

2. Phase 2 (3.5-6.0 s): "Car stationary, blocked by safeties, machine is turning and ropes (belts) are slipping or machine torques."

- The load curve shows dramatic oscillations dropping as low as 2,400 lbf.
- Multiple peaks and valleys indicate dynamic events.
- The motor is attempting to move the car while safeties prevent motion.
- The fluctuations demonstrate either rope/belt slippage over the sheave or the motor torquing against the locked system.
- This is the critical measurement phase – traction limits are identified.

3. Phase 3 (6.0-10.0 s): "Car stationary, blocked by safeties"

- The load curve returns to steady-state around 5,200 lbf.
- Some minor oscillations persist briefly before stabilizing.
- The test has concluded, and the system returns to static conditions.

Key Testing Principle:

This test demonstrates the fundamental traction testing methodology: With the car locked in place by the safeties, the drive motor attempts to move the system. The resulting force variations in the suspension ropes/belts reveal the maximum traction available before slippage occurs. The minimum load values during the oscillation phase indicate the point at which the drive system loses its grip and can no longer transfer force effectively through the ropes or belts to the sheave.

Understanding these load fluctuations is essential for determining safe operating parameters. The difference between the static baseline load and the minimum dynamic load during the test reveals the system's traction margin. If this margin is insufficient, the elevator could experience dangerous slippage during normal or emergency operation, particularly under heavy load conditions.

Graphic 10: Traction Testing Measures and Procedures

This document presents the complete framework for evaluating elevator traction capabilities, including both static and dynamic testing requirements, along with four actual test results conducted in 2019.

Static Traction Testing Requirements:

- The car must hold its position at the tested location with 0% rated load (empty car test).
- The car must hold its position at the tested location with 125% rated load (overload condition test).
- A critical safety verification (highlighted in yellow): It should not be possible to lift the empty car when the counterweight is resting on the buffers and the motor turns in the upward direction. This test ensures the system cannot create dangerous uncontrolled ascent conditions.

Dynamic Traction Testing Requirements:

Amount of traction available during emergency stop (on safeties) with an empty car traveling at rated speed.

Understanding Measured Traction:

The document defines measured traction as the ratio of two masses (counterweight to car), with the greater mass placed in the numerator. This ratio represents the system's ability to drive and control the elevator under various load conditions.

Maximum Load Capacity Calculation:

The maximum load capacity is calculated using the nominal load, car weight, counterweight and the measured traction values. This represents the maximum safe load that can be placed in the car without rope/belt slippage or loss of motor drive capability.

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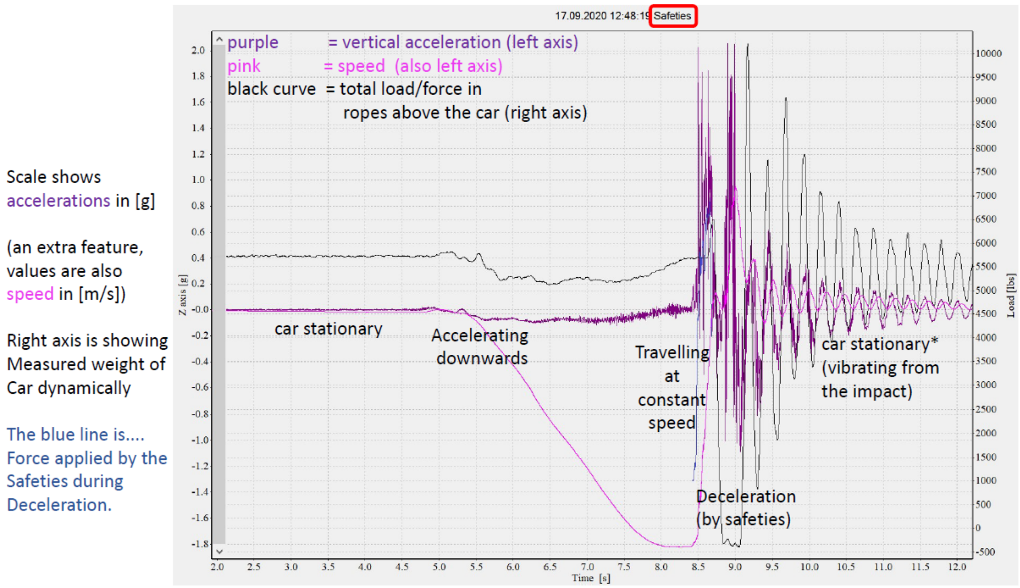

Graphic 11

Traction Testing Measures and Procedures

The document shows four test graphs:

1. Emergency Brake Test (11:41:23) - Measured as "passed"
   - Required static forces: 1915 lbf (empty), 2,085 lbf (rated load)
   - Measured dynamic brake force: 4,124 lbf
   - Deceleration measurements at 116.9 ft
2. Traction Test (12:35:17) - Measured as "passed"
   - Static traction force factor: 2.61
   - Maximum payload: 12,814 lb
   - Dynamic traction force factor: 1.59
   - Maximum payload: 8269 lb
3. Traction Test (12:35:45) - Measured as "passed"
   - Static traction force factor: 2.09
   - Maximum payload: 11,724 lb
4. Traction Test (12:36:11) - Measured as "passed"
   - Static traction force factor: 2.10
   - Maximum payload: 11,750 lb
   - Dynamic traction force factor: 1.63
   - Maximum payload: 8756 lb

The graphs show the dynamic load measurements over time with characteristic dips indicating the points where traction is tested under static conditions.

Together, these documents provide a complete picture of elevator traction testing. The first document establishes the testing requirements and shows multiple successful test results with calculated traction factors and maximum payload capacities. The second document explains how to interpret the dynamic force measurements during the critical testing phase when the motor attempts to drive against locked safeties. This testing methodology ensures that elevator systems maintain adequate traction under all operating conditions, preventing dangerous slippage that could lead to uncontrolled car movement or inability to stop safely.

Static Traction Testing:

The car must hold its position with 0% rated load. The car must also hold its position with 125% rated load. A critical safety check: It should not be possible to lift the empty car when the counterweight is resting on the buffers and the motor turns in the up direction (highlighted in yellow as a key safety requirement).

Dynamic Traction Testing:

The traction amount during emergency stop (on safeties) with an empty car at rated speed is calculated from the static traction. Traction is directly calculated for emergency stops with 125% rated load at rated speed. The document includes four test result graphs from January 18, 2019, showing both Emergency Brake and Traction tests. Key measurements include Emergency Brake test (11:41:23): Shows deceleration data with measurements at 116.9 ft. Traction test results showing force factors ranging from 1.59 to 2.61; multiple tests illustrate effective repeatability of testing process. Maximum payloads calculated at 8269 lb and 8742 lb for different test conditions. The measured traction is defined as the ratio of two masses (counterweight/car), with the greater mass in the numerator. This ratio determines the system's drive capability and helps calculate the maximum load capacity based on nominal load, car weight, counterweight and measured traction values.

Elevator Safety Testing: Comprehensive Analysis of Safeties Performance

These attached documents provide detailed information about elevator safety (safeties) testing procedures and some specific test case examples.

Graphic 11: Safeties Test Basic Graph Details (September 17, 2020)

This document provides a detailed explanation of how to read and interpret safeties test graphs, making it an excellent reference for understanding the previous test results.

Graph Components Explained:

- Purple line = vertical acceleration (left axis, measured in g-forces)
- Pink line = speed (also left axis, measured in m/s)

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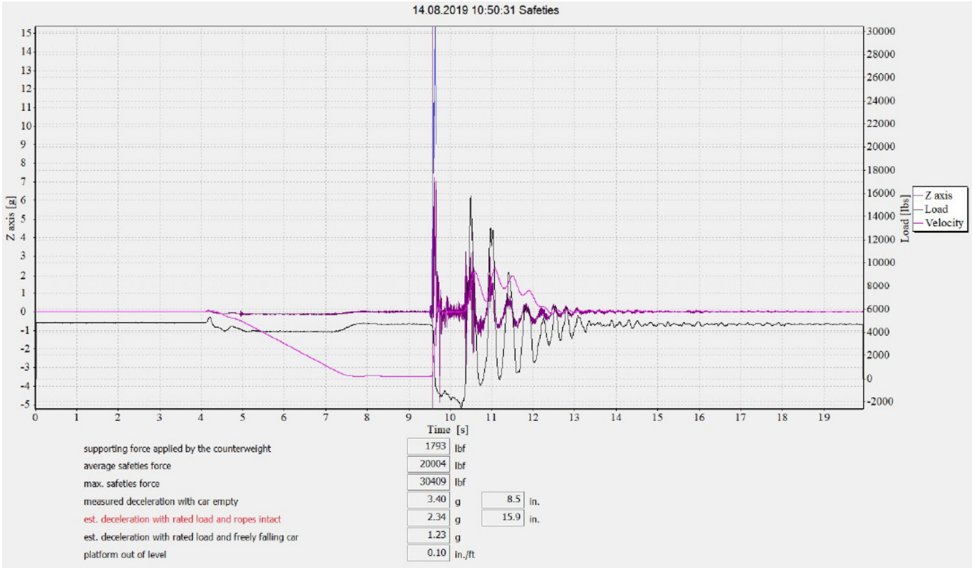


Graphic 12

Safeties, stopping far too harshly, need to be adjusted, decrease stopping force, to provide a lower decel rate

- Black curve = total load/force in ropes above the car (right axis, measured in lb)
- Blue line = force applied by the safeties during deceleration

Test Phases Identified:

- Car stationary — baseline readings before test begins
- Accelerating downward — car begins free-fall or controlled descent
- Traveling at constant speed — steady-state velocity reached
- Deceleration (by safeties) — safety engagement point showing dramatic changes in all measurements
- Car stationary* — post-engagement phase with visible vibrations from impact

The annotated graph shows healthy oscillations following safety engagement, indicating proper energy dissipation. The load curve spikes dramatically during deceleration, demonstrating the dynamic forces experienced during safety activation. This visual guide helps technicians identify normal versus problematic safety engagement patterns.

Graphic 12: Excessive Deceleration - Safeties Test Example (14.08.2019)

This test demonstrates a safety system that stops too harshly and requires adjustment to decrease (or soften) the stopping force.

We see a dramatic deceleration event around the 10-s mark, with the Z-axis measurements reaching up to 15 g. The velocity profile shows extremely violent oscillations following the safety engagement, indicating an overly aggressive braking action.

Critical Test Results:

- Supporting force applied by counterweight: 1,793 lbf
- Average safeties force: 20,004 lbf
- Maximum safeties force: 30,409 lbf
- Measured deceleration with car empty: 3.40 g and a related stopping distance of 8.5 in.
- Established deceleration with rated load and ropes intact: 2.34 g at 15.9 in. (shown in red)
- Established deceleration with rated load and freely falling car: 1.23 g
- Platform out of level: 0.10 in./ft

Technician's Note: "Safeties, stopping far too harshly, need to be adjusted, decrease stopping force, to provide a lower decel rate."

The excessive 2.34 g deceleration rate significantly exceeds acceptable comfort and safety standards. The violent oscillations visible in the graph indicate potential passenger injury risk and mechanical stress on the system.

Graphic 13: Insufficient Deceleration - Failed Safeties Test (03.12.2019)

This test shows the opposite problem: a safety system with insufficient stopping force that failed the test.

The graph displays a much gentler deceleration profile around the 25-s mark. The velocity decreases from approximately 0.5 m/s to a stop, but the deceleration is too gradual. The load measurements show inadequate braking force.

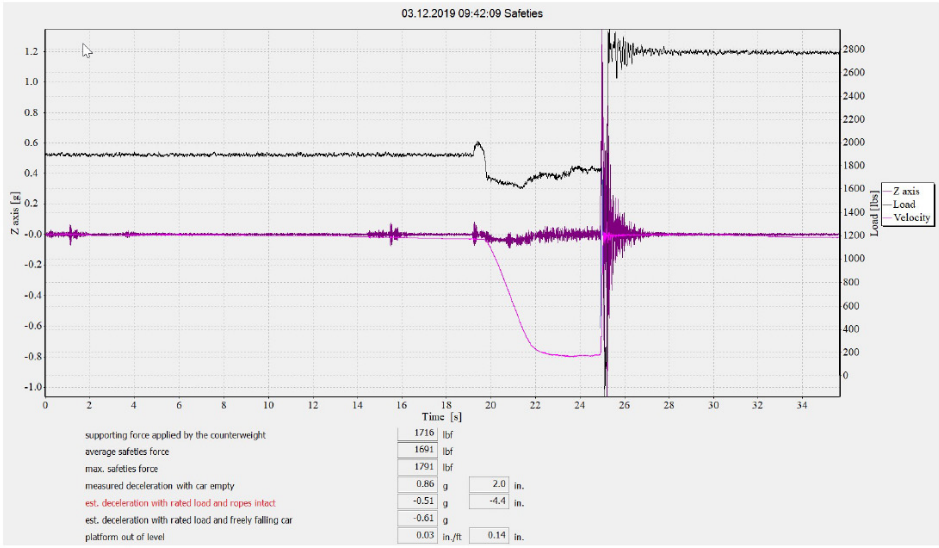
Critical Test Results:

- Supporting force applied by counterweight: 1,716 lbf
- Average safeties force: 1,691 lbf
- Maximum safeties force: 1,791 lbf
- Measured deceleration with car empty: 0.86 g at 2.0 in.
- Established deceleration with rated load and ropes intact: -0.51 g at -4.4 in. (shown in red, indicating failure)
- Direct calculated deceleration with rated load and freely falling car: -0.61 g
- Platform out of level: 0.03 in./ft at 0.14 in.

Technician's Note: "Failed Safeties test, need to be adjusted, stronger stopping force, provide a higher decel rate."

The negative deceleration values and extremely low safety forces (1,691-1,791 lbf compared to the previous test's 20,004-

Continued



Graphic 13

Failed Safeties test, need to be adjusted, stronger stopping force, to provide a higher decel rate

30,409 lbf) indicate the safeties are not gripping adequately. This creates a dangerous condition where the car would continue to fall rather than stop effectively.

Summary

These three documents illustrate the critical importance of proper safety system calibration in elevator installations. Actual test results demonstrate the range between excessive force (2.34 g causing harsh stops) and insufficient force (-0.51 g causing test failure). Proper adjustment of safety mechanisms ensures passenger safety while maintaining acceptable comfort levels during an emergency stop.

Buffer Test Graph: Basic Graph – Graphic 14

This document serves as a detailed reference guide for understanding and interpreting elevator buffer test graphs generated by the Henning Sensor Suite software.

Purple Line = Vertical Acceleration

- Represents the acceleration forces experienced during the test
- Measured on the left axis in g-forces (gravitational acceleration units)
- Critical for assessing passenger safety and buffer performance

Pink Line = Speed/Velocity

- Shows the car's velocity throughout the test
- Also measured on the left axis in meters per second (m/s)
- Traces the complete motion profile from descent through buffer impact to rest

Left Axis Scale Features: The document notes an important dual-purpose feature: "Scale shows accelerations in [g] (as a hidden feature, values are also speed in [m/s])." This means the numerical values on the left axis serve double duty, representing both acceleration in g-forces and velocity in meters per second, allowing both traces to be overlaid on the same scale.

Five Phases of Buffer Testing

The annotated graph identifies five operational phases during a buffer test:

Phase 1: Car Stationary (Initial) - 6.0 to 7.5 s

- Both velocity and acceleration traces hover near zero.
- Pink line at 0 m/s indicates no movement.
- Purple line at 0 g indicates no acceleration.
- Baseline conditions established before test begins.
- Right axis shows static car weight around 3500 lb.

Phase 2: Accelerating Downwards - 7.5 to 10.0 s

- Pink velocity line drops progressively from 0 to approximately -1.8 m/s
- Negative values indicate downward direction.
- Smooth, steady acceleration curve shows controlled descent.
- Car gains speed under gravity, simulating a free-fall or controlled descent scenario.
- The controlled nature of this acceleration phase suggests brake release or controlled drive.

Phase 3: Traveling at Constant Speed - 10.0 to 12.5 s

- Pink velocity line plateaus at approximately -1.8 m/s.
- Represents steady-state descent velocity
- Brief duration indicates this is a transitional phase before buffer impact.
- Purple acceleration line remains relatively stable near 0 g (indicating constant velocity).
- Right axis weight reading remains steady around 3500 lb.

Phase 4: Decelerating (by buffer) - 12.5 to 14.5 s

This is the critical measurement phase where buffer performance is evaluated. The deceleration phase shows dramatic changes in all measured parameters:

Velocity Changes (Pink Line):

- Rapid transition from -1.8 m/s to 0 m/s
- Steep slope indicates high deceleration rate.
- Complete stop achieved within approximately 1.5 s.

Acceleration Spikes (Purple Line):

- Multiple sharp peaks reaching approximately +3.0 g

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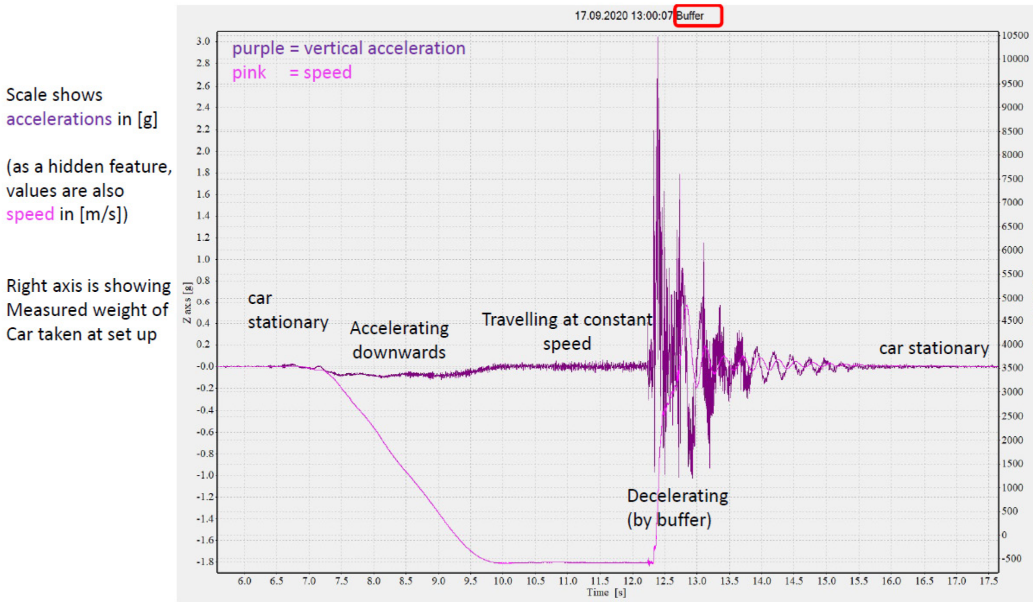

Graphic 14

- First major spike: ~2.8-3.0 g (initial buffer compression)
- Second peak: ~1.8 g (first rebound)
- Third peak: ~1.2 g (second rebound)
- Fourth peak: ~0.5 g (third rebound)
- Oscillating pattern shows buffer compression and rebound cycles.
- Each successive peak is lower than the previous, demonstrating effective damping.

Dynamic Weight Changes (Right Axis):

- Weight measurements fluctuate during impact.
- Peak loads correspond to maximum buffer compression.
- Dynamic forces significantly exceed static weight during deceleration.

Buffer Performance Characteristics: The multiple oscillations reveal the buffer's mechanical properties:

- Initial high-g spike represents maximum compression force.
- Subsequent rebounds show elastic energy storage and release.
- Progressive amplitude reduction demonstrates damping effectiveness.
- Pattern indicates a spring-type buffer with hydraulic or friction damping.

Phase 5: Car Stationary (Final) - 14.5 to 17.5 s

- Pink velocity line returns to 0 m/s and remains stable.
- Purple acceleration line shows diminishing oscillations around 0 g.
- Minor vibrations visible as the system settles.
- Car rests on compressed buffer.
- Right axis shows return to static weight conditions with some residual oscillation.
- Gradual stabilization confirms energy has been fully dissipated.

Key Technical Insights

Dual-Purpose Left Axis: The annotation "as a hidden feature, values are also speed in [m/s]" is particularly important for users. This clever design choice allows both the acceleration trace (purple) and velocity trace (pink) to share the same axis scale. At any given point:

- If reading the purple line: interpret values as g-forces.
- If reading the pink line: interpret the same numerical values as m/s.

Buffer Performance Evaluation: The graph demonstrates several critical buffer performance metrics:

- Peak Deceleration: Maximum g-force experienced (approximately 3.0 g)
- Damping Ratio: Rate at which oscillations decrease (visible in successive peak reduction)
- Stopping Distance: Can be calculated from the velocity profile
- Energy Absorption: Total kinetic energy dissipated during deceleration phase

Safety Considerations: The deceleration values shown (peak ~3.0 g) represent important safety thresholds:

- Sustained forces above 2.5 g for more than 40 ms can cause passenger discomfort or injury.
- Brief spikes (ms) are generally acceptable.
- The oscillating pattern shown is preferable to a single sustained high-g deceleration.
- Multiple smaller peaks distribute the deceleration forces over time.

This reference helps technicians:

- Identify normal vs. abnormal buffer behavior
- Recognize when buffers need adjustment or replacement
- Understand the relationship between velocity, acceleration and force
- Diagnose buffer problems from test data patterns

Expected vs. Problematic Patterns:

Normal Buffer Operation (as shown):

- Smooth acceleration phase
- Multiple damped oscillations during deceleration
- Progressive reduction in oscillation amplitude
- Complete energy dissipation within 2-3 s

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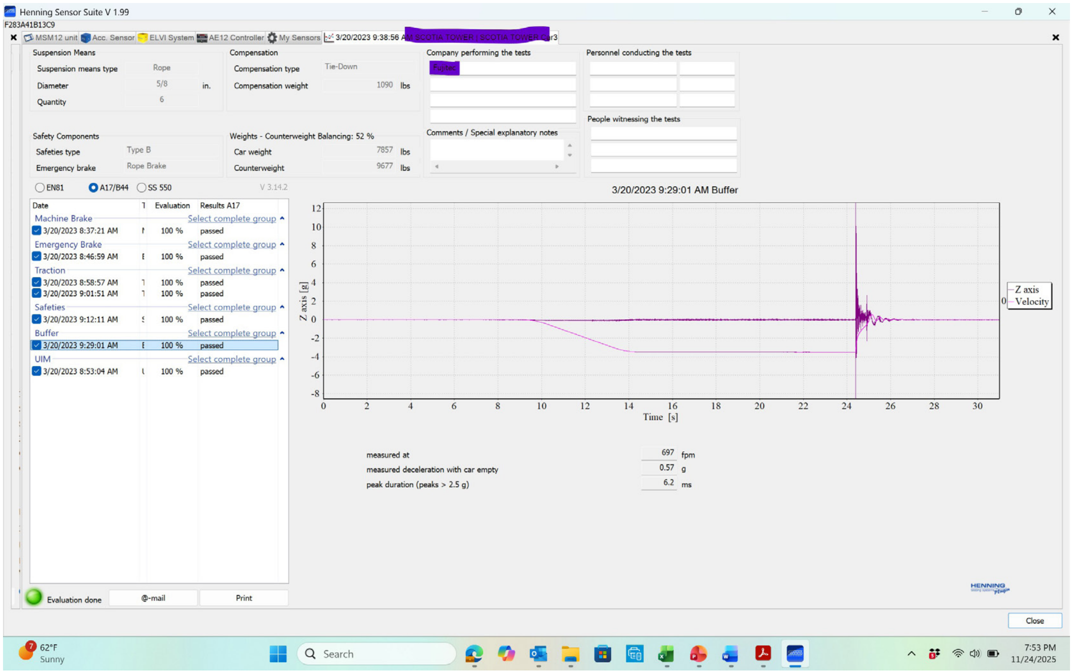

Graphic 15

Problematic Patterns (not shown, but identifiable by deviation):

- Insufficient deceleration (car doesn't stop quickly enough)
- Excessive deceleration (sustained high g-forces)
- Poor damping (oscillations don't decrease)
- Asymmetric response (uneven force distribution)

This buffer test interpretation guide provides essential knowledge for understanding elevator testing results. The clearly labeled five-phase progression shows the complete buffer test sequence from stationary start through controlled descent, buffer impact and final rest. The dual-axis system efficiently displays velocity, acceleration and dynamic weight data simultaneously, while the annotated phases help technicians quickly identify each stage of the test. The example shown demonstrates proper buffer function with controlled deceleration, effective damping and safe g-force levels, serving as a benchmark for evaluating actual test results. Understanding these patterns is crucial for ensuring elevator safety systems meet regulatory requirements and protect passengers in emergency stopping scenarios.

Buffer Test: March 20, 2023 - Complete Analysis Graphics 15 and 16 (Showing Zoom Capability)

This document presents a comprehensive buffer test conducted on March 20, 2023, at 9:29:01 a.m. using the Henning Sensor Suite V 1.99 software. The test was part of a complete Category 5 safety evaluation that achieved 100% passing marks across all required components.

Basic Example Elevator System Configuration

Suspension Means:

- Type: Rope
- Diameter: 5/8 in.
- Quantity: Six ropes

Compensation System:

- Type: Tie-Down
- Compensation weight: 1090 lb

Weight Distribution:

- Car weight: 7857 lb
- Counterweight: 9677 lb
- Counterweight balancing: 52%

Safety Components:

- Safeties type: Type B
- Emergency brake: Rope Brake
- Testing standard: A17/B44
- Software version: V 3.14.2

Company Information:

- Company performing the tests: [Redacted in purple bar]
- Personnel conducting/witnessing tests: Listed, not relevant in detail

Example Test: Buffer Measurements and Results

1. Measured at: 697 ft/min
   - This is the impact velocity when the car struck the buffer.
   - Equivalent to approximately 3.5 m/s (700 ft/min) or 7.8 mph
   - Represents a controlled emergency descent speed
2. Measured deceleration with car empty: 0.57 g
   - This is the average deceleration force experienced during buffer engagement.
   - Measured in gravitational acceleration units (g-forces)
   - 0.57 g is well below injury thresholds and provides comfortable stopping.
   - Significantly lower than the 2.5 g sustained force limit for passenger safety

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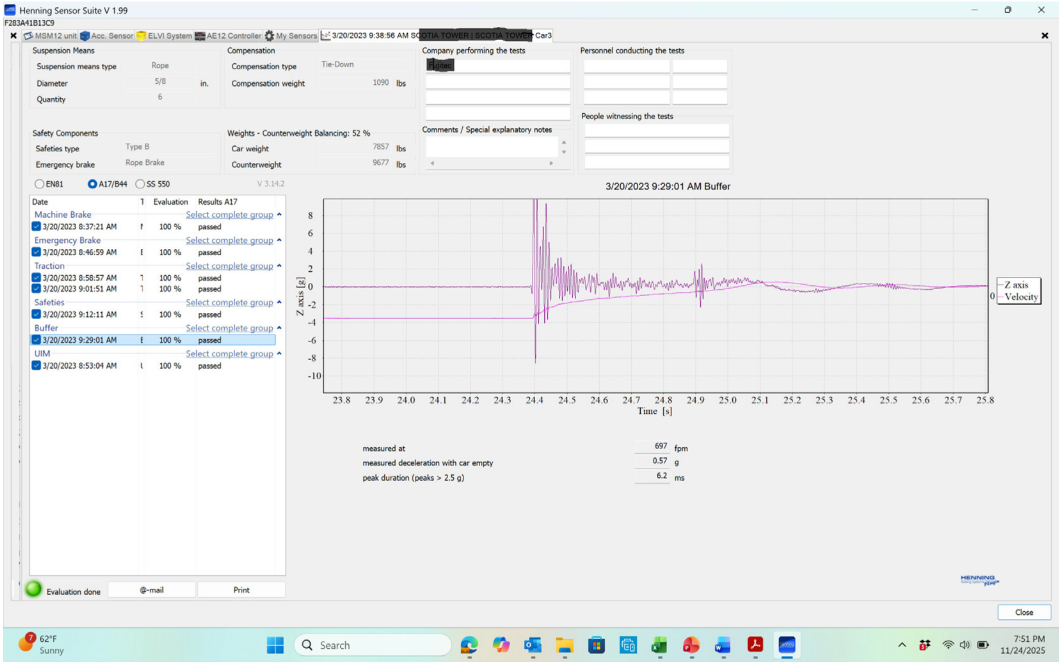

Graphic 16

3. Peak duration (peaks > 2.5 g): 6.2 ms

- Measures how long deceleration forces exceeded 2.5 g.
- Only 6.2 ms indicates very brief high-force spikes.
- Brief duration means no sustained high-g exposure.
- Well within acceptable safety parameters

Test Result: PASSED ✓

All three measured parameters fall within acceptable ranges, confirming proper buffer performance and passenger safety compliance.

Analysis and Safety Evaluation

Deceleration Assessment:

The measured 0.57 g average deceleration represents excellent buffer performance. To put this in perspective:

- 1.0 g = normal gravity (standing still)
- 0.57 g = approximately 57% of gravity's force
- Comparable to moderate braking in a car
- Well below discomfort thresholds (typically 2.0-2.5 g sustained)
- Far below injury thresholds (4.0+ g sustained)

Peak Force Duration:

The 6.2 ms peak duration (forces > 2.5 g) is exceptionally brief:

- 0.0062 s of elevated force
- Too short for human perception as a distinct event
- No risk of passenger injury from such brief spikes
- Indicates excellent buffer damping characteristics
- According to the Code, peaks above 2.5 g are just allowed for less than 40 ms.

Impact Velocity:

The 697 ft/min impact speed represents:

- A realistic emergency descent scenario
- Sufficient velocity to properly test buffer capacity
- Controlled enough to ensure equipment safety during testing
- Standard test velocity for this class of elevator

Based on the test results, the buffer demonstrates:

Energy Absorption:

- Successfully dissipated the kinetic energy of a 7857 lb car traveling at 697 ft/min
- Total kinetic energy absorbed = ½ × mass × velocity^2
- Smooth deceleration curve indicates progressive energy absorption.
- No evidence of bottoming out or insufficient capacity

Damping Effectiveness:

- Low average deceleration (0.57 g) indicates good damping.
- Brief peak duration (6.2 ms) shows effective force distribution.
- Oscillations visible in graph decay quickly.
- No sustained high-force events

Structural Integrity:

- Buffer maintained position throughout test.
- No signs of failure or excessive compression
- Proper rebound characteristics (visible in oscillation pattern)
- System returned to service-ready condition post-test.

Code Compliance:

The test results demonstrate compliance with ASME A17.1/CSA B44 Safety Code requirements:

- Buffer engaged at appropriate velocity.
- Deceleration forces within permitted ranges
- Peak force duration within acceptable limits
- All evaluation criteria marked as "passed."

Continued

Safety Margins:

The system shows excellent safety margins:

- ♦ Average deceleration is only 23% of the 2.5 g sustained limit.
- ♦ Peak durations are measured in milliseconds rather than seconds.
- ♦ Multiple redundant safety systems all passed testing.
- ♦ Buffer performance exceeds minimum requirements.

System Integration

Complete Safety System:

The buffer test is the sixth component in a comprehensive seven-part safety evaluation:

- ♦ Machine Brake – Primary stopping system
- ♦ Emergency Brake – Secondary stopping system
- ♦ UIM protection
- ♦ Traction (two tests) – Rope grip and drive capability
- ♦ Safeties – Emergency grip mechanisms
- ♦ Buffer – Final line of defense (this test)

All systems achieved 100% passing marks, indicating a fully compliant and well-maintained elevator installation.

Operational Sequence:

In normal operation:

- ♦ Machine brake provides primary stopping.
- ♦ Emergency brake serves as backup.
- ♦ Safeties engage if overspeed occurs.
- ♦ Buffer provides final protection if all else fails.

The successful buffer test confirms this last line of defense functions properly, though it should rarely (if ever) be needed during normal elevator operation.

Test Outcome:

The March 20, 2023, buffer test successfully demonstrated:

- ♦ Proper buffer engagement at 697 ft/min impact velocity
- ♦ Safe deceleration profile averaging 0.57 g
- ♦ Minimal peak force duration of only 6.2 ms
- ♦ Complete compliance with safety standards
- ♦ Integration with overall safety system

The elevator's buffer system, as well as other existing system components that tested passing, are:

- ♦ Functioning as designed
- ♦ Providing appropriate passenger protection
- ♦ Meeting all regulatory requirements
- ♦ Properly maintained and service-ready
- ♦ Part of a fully compliant safety system

Operational Clearance:

Based on these examples and ultimate passing test results of all components, an elevator system may be approved for continued service, providing confidence that in the unlikely event of an emergency requiring various kinds of stops, including an emergency, passengers would be protected by controlled deceleration forces that have been measured and are demonstrably within ASME A17.1/B44 Code defined safety limits.

Kevin Heling founded Elevator Technical & Training Associates (etta) in September of 2022 after almost 40 years with technical and management positions as a supplier to the elevator industry. As the sole owner and principal of etta, he provides consulting in areas within his elevator component expertise (including elevator traveling cables and electrical components, steel wire ropes and other suspension means and some installation and testing tools). Training services focus specifically on Category 5 testing, the value and technical process of instrumentation and data-based Cat 5 testing. "Alternative testing" was first introduced in the Safety Code for Elevators and Escalators (ASME A17.1-2013/CSA B44-13). Heling is actively involved with ASME A17 Code Committees and is a member of the Board of Certification for NAESA International. He also recently became a business partner with the founder of RCW Canada, an elevator component distributor based in Pickering (Toronto), Ontario, Canada.

Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at elevatorbooks.com or on p. 118 of this issue.

- ♦ Review and make sure you know the Learning Reinforcement questions in Part 2. How does a checklist (as used in the full-load test process) assure that the test has been done correctly? Or, even done at all? How can a digitally documented report help to ensure an elevator will be operating safely after testing?
- ♦ How effective do you think a digitally documented report with data showing measured stopping forces will be if there needs to be an accident investigation conducted sometime after when the elevator had its CAT5 test?
- ♦ Why is it important to take a current accurate measurement of a traction elevator's system masses? Remember that algorithms have been developed using the Physics principle of F=ma.
- ♦ How important is it to carefully follow the ELVI 2 System testing process? Exact time to trigger Start and Stop of each test? Knowing and following the process for handling and using the testing system is best learned through hands on training and experience and carefully following instructions described and pictured on the Control Device (UCD).
- ♦ Do you know how to reference and read velocity graphs? Acceleration/deceleration measurements? Force measurements?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Read the article **"A Tale of Two Testing Methods, Part Three"** (EW, May 2026, p. 80) and study the learning-reinforcement questions at the end of the article.

- To receive **one hour (0.1 CEU)** of continuing-education credit, answer the assessment examination questions found below online at elevatorbooks.com or fill out the ELEVATOR WORLD Continuing Education reporting form found overleaf and submit by mail with payment.
- Approved for Continuing Education by **NAEC for CET®, CAT® and QEI.**

1. Which of the following are reasons UIM or uncontrolled motion (UIM/UCM) could occur?
   a) Controller or drive malfunction
   b) Mechanical issue related to unacceptable CWT overbalance
   c) Brake failure or traction slip
   d) All of the above

2. Which of the following closely agrees with proper traction testing?
   a) This may be a difficult and complicated test to conduct with the ELVI 2 System.
   b) Static Traction measurement is more important than Dynamic Traction measurement.
   c) Traction is a dynamic ratio; it helps determine the systems' drive capability based on nominal load, car weight, weight of CWT and measured traction values.
   d) Static Testing means the car holds its position with 125% rated load only.

3. The article points out that instrumentation and data-based CAT5 testing is an important improvement over the simple load-based method. Which of these do NOT logically support that position?
   a) We have a long-established method (that means that it is proven and reliable).
   b) Some labor people and heads of AHJs are against it.
   c) Taking measurements using accurate and calibrated instruments and determining force is always better than a simple observational test.
   d) Specific results – data in a report – can be used to determine need for near-term or longer-term maintenance needs.
   e) a) and b) above

4. Which of the following is the best answer about Emergency Brake testing?
   a) Testing the emergency (auxiliary brake) is ONLY necessary to evaluate UIM/UCM.
   b) Testing e-brakes reveals cases where adjustments or brake re-builds are necessary and/or the stopping force may be affected by a wrong overload balance.
   c) The pink line in an e-brake test graph represents deceleration in g (gravity).
   d) If deceleration is too low (or soft), the stop will be harsh.

5. The article describes an actual experience where the machine brake test was repeated two times after a first CAT5 brake test. What was the issue?
   a) Brake spring tensions were adjusted (tightened) three times, but PASS was still not achieved on the stopping force. There was risk of burning out the brake solenoid if adjusted further. Brake re-build scheduled.
   b) In this example, it was noted that there was grease or some similar contaminant on the sheave or the brake pads.
   c) Weight of the CWT (counterbalance %) was significantly low.
   d) The last measured deceleration was -0.00; which was determined to be okay.

6. Select correct statements about machine and emergency brakes.
   a) Tests must measure more than any positive deceleration; must see a complete physical stop on all elevators tested to achieve a PASS.
   b) CAT5 tests of brakes (machine and auxiliary) is good if the stopping force is greater than 1 g.
   c) If there is positive deceleration down at 100% load, it is a passing test according to the Code.
   d) Positive stopping force validated at 125% load – deceleration is above +0.00 and below 1.0 g; this is a PASS according to the Code.

7. What is measured during a buffer test?
   a) The buffer compresses fully and returns within 30 s.
   b) Velocity at impact, average deceleration and peak force duration
   c) Injury threshold is >5.0 g sustained.
   d) Discomfort threshold typically begins at 1.5 g.

8. Measurements during Safeties testing include:
   a) Pink line in graph is speed (left axis) in m/s.
   b) Black curve shows dynamic total load/force in ropes above the car (right axis) measured in pounds (or kg).
   c) Blue line is the force applied by Safeties during deceleration.
   d) All of the above

9. What qualifies as a PASS or important consideration during Safeties testing?
   a) Car running at inspection speed stops in 6 in.
   b) Safeties stopping too harshly need to be adjusted to increase the stopping force.
   c) Safeties do not have insufficient stopping force or excessive stopping force (according to Safety Type and established Code), and the Platform is not out of level (measured <.30 in./ft).
   d) Deceleration with rated load and freely falling car has positive g.

10. Which of the following ELVI 2 tests must directly measure dynamic load on the ropes above the car during the test?
   a) Main Brake and Emergency (auxiliary) Brake
   b) Traction and Safeties tests
   c) Buffer Test and Traction Test
   d) Safeties Test and Main Brake Test only

ELEVATOR WORLD Continuing Education Reporting Form

Article title: **"A Tale of Two Testing Methods, Part Three"** (EW, May 2026, p. 80)

Continuing-education credit: This article will earn you one contact hour (0.1 CEU) of elevator-industry continuing-education credit.

Directions: Select one answer for each question in the exam. Completely circle the appropriate letter. A minimum score of 80% is required to earn credit.

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This article is rated for one contact hour of continuing-education credit. Certification regulations require that we verify actual study time with all program participants. Please answer the below question.

How many hours did you spend reading the article and studying the learning-reinforcement questions?

1.	a	b	c	d	e	6.	a	b	c	d	e
2.	a	b	c	d	e	7.	a	b	c	d	e
3.	a	b	c	d	e	8.	a	b	c	d	e
4.	a	b	c	d	e	9.	a	b	c	d	e
5.	a	b	c	d	e	10.	a	b	c	d	e

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