Step/Skirt Performance Index Testing and Data Analysis

How to avoid common problems when measuring this important safety parameter, particularly with the PMT IMD-1 tool

by Ken Smith

It may not seem that long ago that "index" requirements became part of the *ASME A17.1 Safety Code for Elevators and Escalators*, but it has been almost 20 years since A17.1d-2000 became effective in January 2001, followed by A17.1-2000, which became effective in March 2002. Index testing of an escalator and any improvements required to meet the index were intended to reduce the probability of step/skirt entrapment on that unit. In the estimation of your author, the implementation of the index has been successful in reducing step/skirt entrapments. The following is an abbreviated version of the classes your author has taught for NAESA International about the Step/Skirt Performance Index. Plans are for your author's website, www.escalatorpro.com, to host the full presentation.

Background

In escalators, the motion of the step near the stationary skirt can cause objects on the step that contact the escalator skirt to get pulled into the gap between the step and skirt by the frictional force generated between the object and the skirt. The magnitude of the friction force is determined by the coefficient of friction between the object and skirt, and the force the object exerts against the skirt, perpendicular to the skirt. The harder something pushes against the skirt, the higher the frictional force. A17.1 has required the skirts be made from or treated with a friction-reducing material beginning with A17.1a-1982 until escalators produced under A17.1d-2000 and later, when the index requirements took effect. The requirement for treating the skirts with a friction-reducing material was removed from the maintenance section of the code in A17.1-2013.

The gap or clearance between the step and skirt also influences entrapment. First, there is the static gap, or the gap between the step and skirt on a stationary escalator. This is the gap that has been measured for years by mechanics and inspectors with a blade gage during annual inspections. Different escalators have varying required clearances, depending on their design. A17.1 has required limits for the static gap since at least its 1965 edition, until escalators produced under A17.1d-2000 and later, when the index requirements took effect, and "loaded gap" was introduced. It has also required skirt-obstruction devices since at least the 1971 edition.

As most people who have ridden an escalator have noticed, the step can also be shifted slightly from side to side. As a force is applied that shifts the step away from the skirt (in this case, an object being pulled into the gap), the gap between the step and skirt increases. In the industry, this shifting is commonly referred to as "step deadband." Skirt stiffness also influences the gap. As an object is pulled into the gap between the step and skirt, it is easy to see that the more flexible the skirt is, the easier it is for the object to enlarge the

Continued

Learning Objectives

After reading this article, you should have learned about:

- How the Step/Skirt Performance Index came to be a requirement
- The importance of the index
- How the index is calculated
- How to use the PMT IMD-1 to test the index
- How to analyze the results of the test

ELEVATOR WORLD EW ONLINE CONTINUING EDUCATION

Value: 1 contact hour (0.1 CEU)

This article is approved for Continuing Education by NAEC for CET® and NAESA International for QEI.

EW Continuing Education is currently approved in the following states: AL, AR, FL, GA, IL, IN, KY, MD, MO, MS, MT, OK, PA, VA, VT, WV and WI. Please check for specific course verification of approval at www.elevatorbooks.com.

gap between the step and skirt as it enters, and the easier it is to be pulled in. A17.1 has had skirt deflection requirements since at least the 1981 edition.

From this information, it is evident the code has been adding requirements that relate to the probability of entrapment for some time.

The Index

The Step/Skirt Performance Index was developed by Arthur D. Little (ADL), a consulting firm. The National Elevator Industry, Inc. retained ADL to develop a performance/safety standard to assess the potential for entrapment between the step and skirt. After much testing, factors relating to entrapment were identified:

- Coefficient of friction (μ) between an object (polycarbonate) and the skirt
- Initial (static) gap between the step and skirt
- Skirt stiffness
- Step deadband

The last three items were combined into what became the "loaded gap," the gap between the step and skirt when 25 lb is applied between the step and skirt. Based on the testing, the Step/Skirt Performance Index was created to measure the potential for entrapment. The lower the index, the lower the potential for entrapment. The index formula is:

$y = -3.77 + 2.37(\mu) + 9.3$ (loaded gap)

Index = $e^y/(e^y + 1)$

Physical Measurement Technologies (PMT) developed the IMD-1, a tool that would test the index and loaded-gap measurements.

Initially, beginning with the A17.1d-2000 addenda, escalators installed prior to the adoption of the addenda had to meet the following requirements:

- Index ≤ 0.15: no modifications required
- 0.15 ≤ Index ≤ 0.4: requires skirt deflectors
- Index > 0.4: not allowable

For escalators installed under the A17.1d-2000 addenda and later, the loaded gap replaced the static-gap measurement: loaded gap ≤ 0.2 in.

Older escalators still had to comply with the static-gap requirements at the time of their installation. Importantly, besides being in the escalator section of the code, the index requirements are also in the maintenance section (which is retroactive to older escalators).

The maximum allowable index was reduced in the A17.1a-2002 addenda:

- Index ≤ 0.15: no modifications required
- 0.15 ≤ Index ≤ 0.25: requires skirt deflectors
- Index > 0.25: not allowable
- Loaded gap ≤ 0.2 in.

The test comprises four subtests:

- Step 1 right
- Step 1 left
- Step 2 right
- Step 2 left

As one might expect, both the left and right sides of two steps are tested. If any of the results don't comply, the unit requires some type of repair to bring it into compliance.

Step/Skirt Performance Index Testing

The only tester currently on the market, of which your author is aware, is the PMT IMD-1. The tool is easy to use and quite reliable. However, even though it has been in the field for nearly 20 years, it is not always being used correctly. The tool is clamped to and aligned with the edge of a step. It measures the coefficient of friction between its replaceable polycarbonate friction face and the skirt, as well as the loaded gap. The index is calculated from these measurements. The tool can record this data and print a graph that displays the loaded gap, coefficient of friction and index. It can also be used in "real time mode" for escalator diagnostic purposes. The following assumes the reader has some familiarity with performing an index test.

When preparing to test an escalator, there are some things that need to be looked at to make sure the tool is not damaged during testing:

- Make sure there is no debris on the unit that could interfere with the test.
- Check the slide or stopping distance so that when the unit is stopped, the IMD-1 will not slide into the combteeth. (Some older escalators have very long slides.)
- Make sure the height of the skirt deflectors at each end will not contact the tool's sensor. Deflectors with plenty of clearance are shown in Figure 1.

Figure 1

When setting up the data collector to use the IMD-1 index tester, make sure either the EVA-625 or MMC-1 data recorder is configured so the run time is long enough for the tester to traverse the complete length of the escalator, or the tool will stop recording before the test is complete:

>"Configure"
>"Set Operations"
>"Set Record Time"
>Enter the appropriate record time

The *ASME A17.2 Guide for Inspection of Elevators, Escalators, and Moving Walks* requires the tests be performed in a certain manner:

- For an up unit: test in the up direction.
- For a down unit: test in the down direction.

- For a unit that runs in both directions: test in the down direction.
- Select a normal step for the first test.
- Select an unusual step for the second test that is at least eight steps away from the first step tested.
- Use a new polycarbonate friction face for each test.

It seems to your author that if there is an unusual step (one that is damaged, or shifts or rocks excessively), it should be repaired before performing the index test. The code intends the index results to be typical for that unit by testing a normal and unusual step. However, since most units have more than 80 steps, and only two are tested, the test won't find all the unit's issues relating to potential entrapment. The code also intends that the unit be tested in its normal operating condition; that means skirt lubricant shouldn't be applied just prior to the test.

Use "Record Event" mode to generate the code-required test and graph.

When setting up the tool, there are some important points to consider:

1) Position the tool consistently on the steps. It is good practice to locate the base (the part that clamps to the step) seven cleats or ribs from the edge of the step and 5 in. back from the step nose. This gives enough space to easily affix and zero the friction face and lets the friction face contact the same portion of the skirt for each test.
2) When stepping through the test menu, "Set ID #" appears. This is where the user enters the unit identifier. When entering the last digit (note arrow in Figure 2) and pressing the "Enter" button, make sure nothing is touching the friction face, as the friction force transducer is being calibrated at this point.
3) When "Set Distance to Zero" appears, the friction shoe must be pushed toward the sensor housing until *all four* silver studs contact the housing (Figure 3). Hold in this position and press the "Enter" button. At this point, the position (loaded gap) transducer is calibrated. If the user is not careful, the sensor will calibrate incorrectly, generating invalid loaded-gap measurements (sometimes negative), which will result in inaccurate index results. This step is sometimes difficult due to lighting, unit width and the location of the skirt deflectors.
4) After clamping the tool to the step, make sure to rotate the housing so the top surface (the one with the instructions on it) is parallel to the top of the inclined skirt, and lock it in place. Make sure to change it when testing the other side of the step.
5) Next, "Align Pointer" is displayed. This is another critical step, since loaded gap influences the index more than the coefficient of friction does. The IMD-1's pointer must be aligned evenly with the edge of the step (where the arrow is pointing in Figure 4). Make sure the edge detector, the "T"-shaped tool (an old, gold edge detector is shown in Figure 4) is pulled tight against the edge of the step and that the sensor housing is carefully slid toward the skirt until the IMD-1's pointer (circled in Figure 4) just touches the edge detector. Tighten the locking knobs on the IMD-1. It is good practice to recheck the setting after the knobs are tight to make sure.
6) Tighten the tool's spring (load). This may seem obvious, but it can be forgotten when in a hurry. A friend of your author's, who is an inspector, related, "During an inspection, the maintenance company technician was setting up the tool. I noticed he didn't tighten the spring. When I asked him about it, he stated that they never tighten the spring." If the spring is not tightened, the required 25-lb force will not be applied between the step and skirt. It gives a significantly better index and loaded-gap result, but it is also an invalid test. Inspectors should watch this closely.
7) A PMT pendant switch is a good tool to use to trigger the test. It allows the user to be a couple of steps away from the tool so he or she does not influence the test.
8) The technician should always start the unit before starting the test (at the beginning of the incline). On older units with across-the-line starters, the start will cause a spike in the results if the tool is triggered first. This sometimes causes a noncompliant index value. On newer units with soft starters, it doesn't make as much difference; however, there is still a transition from static to dynamic friction. It is also important to stop the test before the technician stops the escalator.
9) Repeat the process for the three remaining tests.

Continued

Figure 2

Figure 3

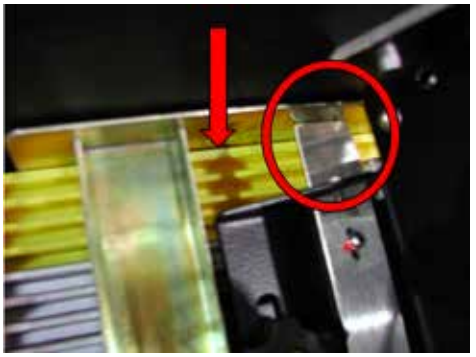
Figure 4

Real Time Mode

Real Time Mode can be used to find problems with steps, the track and skirts. It is useful to use this mode for testing the loaded gap at each end of the unit, as well. (Interestingly, your author has never seen the loaded gap measurements at each end of the unit turned in to the AHJ.) Select "Real Time Mode" from the menu. From the "Set Threshold Level" menu, select the index desired to be the maximum, and set up the tool as previously described. If or when the index exceeds the set threshold, the red LED pointed to in Figure 5 will light, identifying the location of a problem on the unit.

Figure 5

Loaded Gap: Real Time Mode Quick Check

The loaded gap can be verified with a blade gage if there is a question of tool setup. Just place the gage between the step and skirt as shown in Figure 6 when the IMD-1's spring is compressed. The blade gage should read a loaded gap very close to the one the tool reads. Using the blade gage in this manner is useful if the index test shows an unusually small loaded gap on an older escalator.

Figure 6

Analyzing the Test Results

A Properly Performed Test

Deciphering the graphical results is something not typically discussed. Most people just look at the maximum index values displayed in the bottom row of the graph to determine if the escalator is in compliance. Unfortunately, that is not enough.

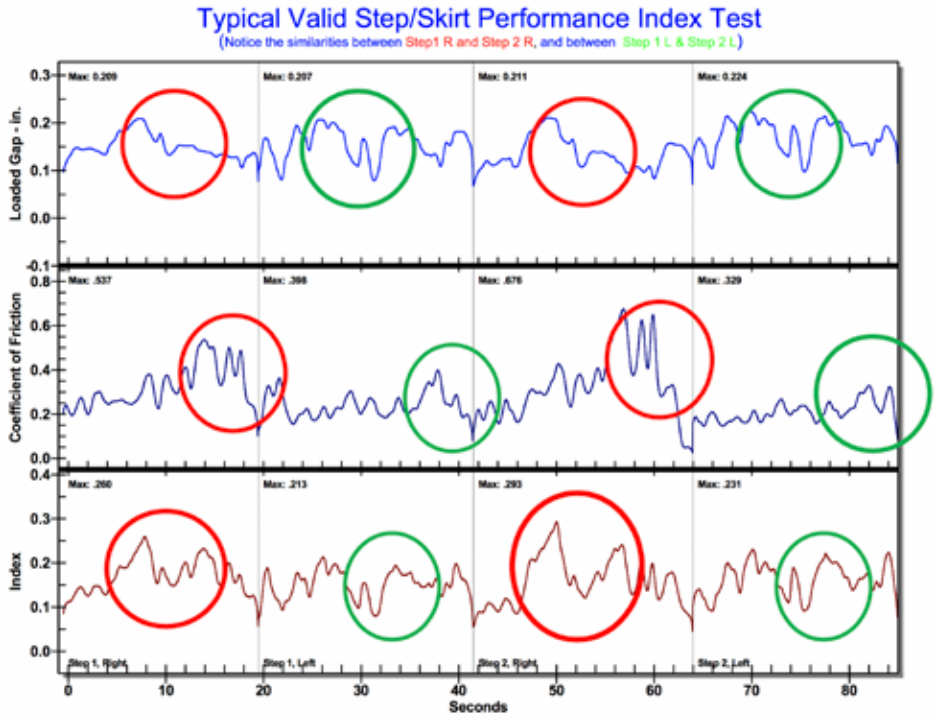

Figure 7

First, it is necessary to determine if the test was conducted properly. Without carefully witnessing or performing the test, one can never be 100% sure it was performed correctly. However, reviewing the results can reveal some errors.

In a properly performed index test (Figure 7), there should be similarities between the results of the right side (red) of both steps and the same between the left side (green) of both steps. The loaded gap is shown in the top row of Figure 7. There are similarities within each side (left and right) and color (red and green). If one of the tests is on a step with more deadband than the other, that graph will have higher loaded gap values, but the graphs should still look similar.

The second row of Figure 7 is coefficient of friction (μ). Again, the right side (red) shows similarities, as does the left side (green). If the tool is located on the step in a consistent manner as it should be, the friction face should be running in the same location on the skirt, and the coefficient of friction graphs should look similar. In testing with the IMD-1, your author has found that factory-coated low-friction skirts and skirts just treated with silicon or Teflon™ spray have μ @ 0.15 to 0.2. Older skirts or skirts that have not been treated in a while have μ @ 0.2 to 0.4, and dry stainless-steel skirts test around μ @ 0.4 to 0.6. Note that these are not lab test results, but general results from field testing.

The bottom row is the index. Again, if the test is performed correctly, there should be similarities between the tests on the right and between the tests on the left. Like the loaded gap, the values may differ, but the graphs should look similar.

A potential problem is older escalators that have too large a loaded gap for the IMD-1 to read. The tester will read a loaded gap up to approximately 3/8 in. An escalator with a loaded gap greater than 3/8 in. will display the gap as a straight line (Figure 8). Obviously, this escalator did not pass the index test. (Note that the index generated with this loaded-gap data will be lower than it actually is, since the escalator's loaded gap is greater than the tool will read.)

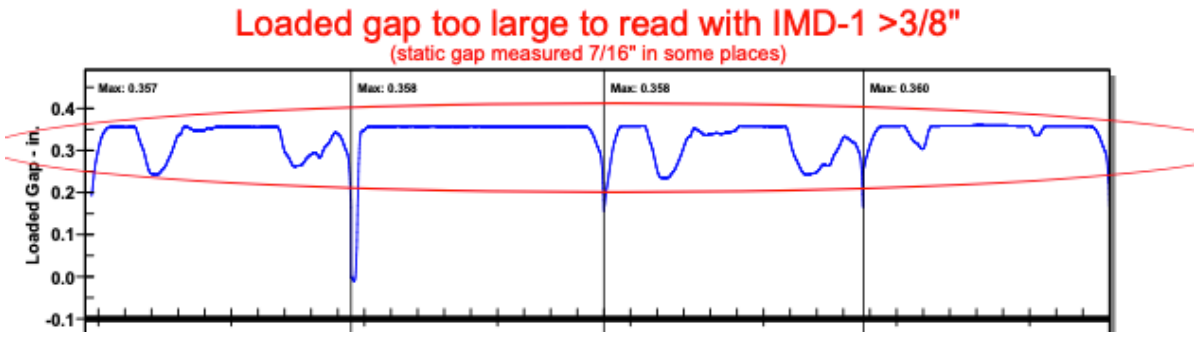

Figure 8

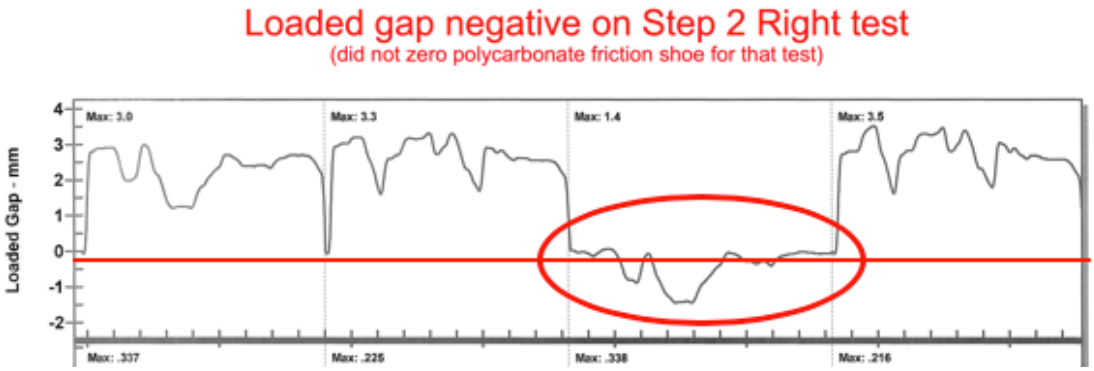

Figure 9

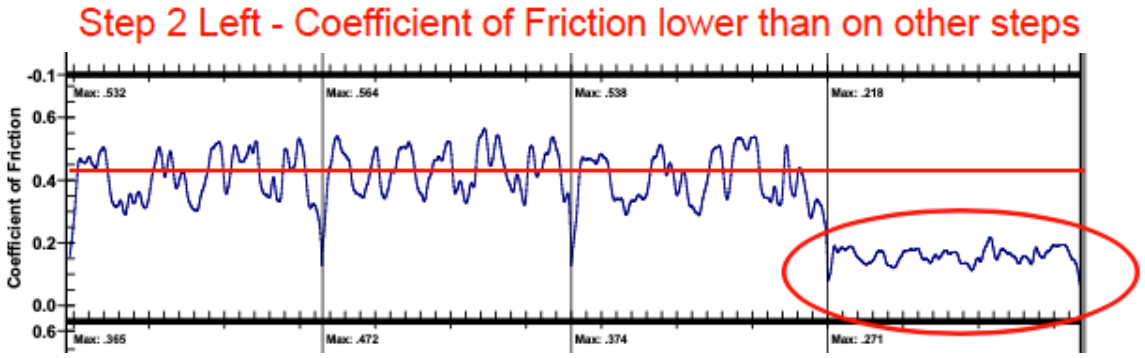

Figure 10

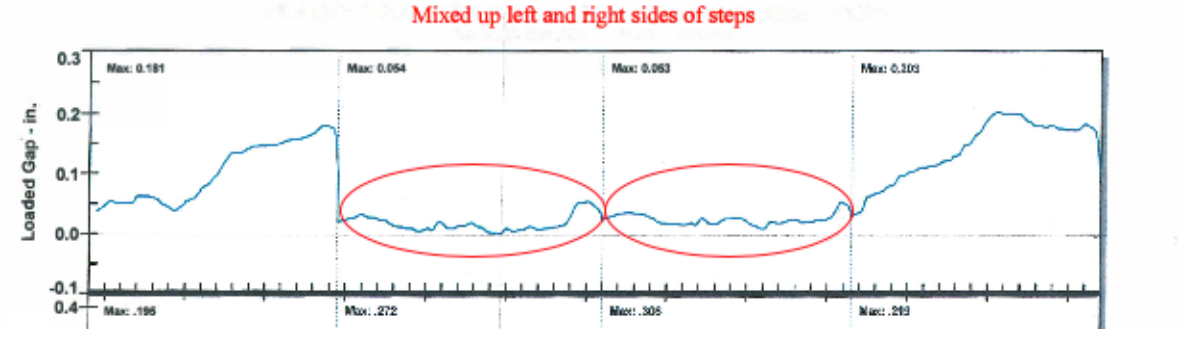

Figure 11

An Improperly Performed Test

Many index tests with negative loaded gaps (Figure 9) have been accepted by AHJs. A negative loaded gap indicates improper tool setup. Typically, the cause is that the friction face is not pressed in completely during "set distance to zero." Note that an index test with a negative loaded gap is invalid, and the unit will need to be retested.

Continued

Learning-Reinforcement Questions

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

- Should the escalator or the tool recording be started first? Why?
- What is the maximum allowable Loaded Gap on a unit installed under A17.1-2000?
- Do escalators installed under codes prior to A17.1d-2000 have to comply with the static step/skirt gap requirements, as well as the index?
- Does a lower index mean a lower or higher probability of entrapment? Why?
- According to A17.2, for an escalator that operates in both directions, which direction should the escalator be moving when the index test is performed? Why?

Often, a test is submitted with a portion of the graph dissimilar to the rest of it. For example, in Figure 10, μ for "Step 2 Left" is significantly less than that for "Step 1 Left." In this case, it is likely the polycarbonate friction face was not installed.

In Figure 11, left and right were mixed up during the test: the sides of one of the steps tested was entered as the right, when it was actually the left, and the same occurred with the other side. Interestingly, the circled loaded gaps on one side are almost zero, indicating improper tool setup (or steps that contact the skirt for most of the incline). Your author would want the escalator retested.

The improperly performed tests shown are among those your author was asked to review by various AHJs and inspectors. These are by no means all the things that can go wrong when testing an escalator but seem to be the most common. It is convenient to download the data to a laptop right after performing the test so if anything appears wrong, the test can be redone right away.

Summary

It is important to position the tool consistently and set up the tool properly. Make sure to start the unit before triggering the tool, and stop the tool before stopping the escalator. Download the data onsite to ensure valid tests. Make sure to check the loaded gap at each end if the code requires it for the escalator in question.

Ken Smith is a mechanical engineer specializing in the design, installation and maintenance of escalators and moving walks. Smith received his BS in Mechanical Engineering from the University of Iowa in 1985 and began his career with Montgomery Elevator in 1985 as a project engineer. In 1992, he went to Drives Inc. as Product Engineering manager, then returned to KONE in 2000 as manager of Engineering Services. He began working full time at his consulting firm, Ken Smith & Associates LLC, in 2003, and has more recently become a partner in eMCP, LLC. He holds patents in the U.S. and internationally. He is a member of the ASME A17 Escalator and Moving Walk and B29 Chain committees.

ELEVATOR WORLD

ONLINE
CONTINUING EDUCATION

ELEVATOR WORLD Continuing Education Assessment Examination Questions

- Read the article "**Step/Skirt Performance Index Testing and Data Analysis**" (p. __) 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 www.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®** and **NAESA International for QEI.**

1. In which edition of the American Society of Mechanical Engineers (ASME) code did the Step/Skirt Performance Index requirements first appear?
   a. A17.1-2000.
   b. A17.2-2000.
   c. A17.1-2002.
   d. A17.2-2002.

2. What is the maximum allowable index on a unit installed under A17.1-2000 that has skirt deflectors?
   a. 0.1.
   b. 0.2.
   c. 0.3.
   d. 0.4.

3. What is the maximum allowable index on a unit installed under A17.1a-2002 and later that has skirt deflectors?
   a. 0.15.
   b. 0.25.
   c. 0.35.
   d. 0.45.

4. What is the maximum allowable loaded gap on a unit installed under A17.1a-2002 and later?
   a. 0.1 in.
   b. 0.15 in.
   c. 0.2 in.
   d. 0.25 in.

5. What can be measured and/or displayed by the PMT IMD-1?
   a. Coefficient of friction, loaded gap and index.
   b. Coefficient of friction, loaded gap and skirt-lubrication level.
   c. Loaded gap, index and escalator maintenance schedule.
   d. Loaded gap, coefficient of friction and escalator maintenance schedule.

6. When ensuring the tester is not damaged during testing, which is *not* recommended to be performed before testing the escalator?
   a. Ensuring there is no interfering debris present
   b. Checking the slide or stopping distance.
   c. Ensuring no teeth of the combplate are broken or damaged.
   d. Making sure the skirt deflectors will not contact the tool's sensor.

7. How should the PMT IMD-1's pointer be aligned when "Align Pointer" is displayed?
   a. Even with the balustrade.
   b. Even with the tips of the combs.
   c. Even with the edge of the skirt.
   d. Even with the edge of the step.

8. It is important to tighten the PMT IMD-1's spring as part of a test. How much force does it apply as load?
   a. 10 lb.
   b. 15 lb.
   c. 20 lb.
   d. 25 lb.

9. What should occur if a test has a negative loaded gap in its results?
   a. The escalator should be taken out of service immediately.
   b. The test should be accepted by the AHJ.
   c. The test should be redone.
   d. The inspector's supervisor should be notified.

10. When should the skirts be lubricated?
    a. Immediately prior to testing.
    b. At its regular servicing interval.
    c. Skirts do not require lubrication.
    d. Upon installation and modernization only.

Continued

ELEVATOR WORLD Continuing Education Reporting Form

Article title: **"Step/Skirt Performance Index Testing and Data Analysis"** (EW, December 2019, p. __).

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. You can also take this test online at www.elevatorbooks.com.

Last name: _____

First name: _____ Middle initial:_____

CET®, CAT® or QEI number:_____

State License number:_____

Company name:_____

Address:_____ City:_____

State: _____ ZIP code:_____

Telephone:_____ Fax:_____

E-mail:_____

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

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?

hours: _____ minutes: _____

Circle correct answer.

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

Signature: _____

Payment options:

Check one:
- ❑ $35.00 – Non-subscriber course fee
- ❑ $29.75 – ELEVATOR WORLD subscriber course fee

Subscriber #: ___ ___ ___ ___ ___ ___
(Six-digit number on your print label or in your digital confirmation)

- ❑ Payment enclosed (check payable to Elevator World, Inc.)

Charge to my:
- ❑ VISA
- ❑ MasterCard
- ❑ American Express

Card number: _____

Expiration date: _____

Signature: _____

To receive your certificate of completion using the mail-in option, send the completed form with questions answered and payment information included to: Elevator World, Inc., P.O. Box 6507, Mobile, AL 36660.

To receive your certificate of completion online, visit www.elevatorbooks.com and follow the instructions provided for online testing.