1. SCOPE

1.1 This method covers the procedures to operate, calibrate, and maintain a California-type profilograph.

1.2 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. APPARATUS

2.1 Profilograph, California-type, constructed with a metal frame with about 25 ft. (7.62 m) between the front and rear wheel assembly supports, and allowing field calibration using vertical deflection standards. Each wheel assembly consists of six averaging rubber-tired wheels arranged so the center of the frame represents the mean evaluation of the road surface between the wheel assemblies. For consistent graph recording, maintain air pressure in the profile wheel to the manufacturer's specification. Motive power may be manual or a small propulsion unit attached to the center assembly.

2.2 Profilogram, scaled with 1 in. equal to 25 ft. (25.4 mm = 7.62 m.) longitudinally and 1 in. (25.4 mm) equal to 1 in. (25.4 mm) (full scale) vertically.

2.3 Profile index scale, transparent plastic scale 1.70 in. x 21.12 in. (43.2 mm x 536.4 mm) representing a scaled pavement length of 0.1 mi. (0.16 km). The center of the scale must be a 0.2 in. (5.08 mm) opaque 'blanking' band that extends the length of the scale. On both sides of this band are lines scribed 0.1 in. (2.54 mm) apart, parallel to the centerline of the scale, serving as a scale to measure deviations of the profilogram above and below the blanking band.

2.4 Bump template, rectangular transparent plastic guide with a scribed line 1 in. (25.4 mm) long with a hole about 0.0625 in. (1.59 mm) in diameter at both ends. This line represents a scaled distance of 25ft. (7.62 m) on the profilogram. A slot 0.0625 in. (1.59 mm) wide, parallel to the scribed line, and of equal length, spaced 0.3 in. (7.62 mm) (or other value shown on the plans) from the line (as shown in Figure 1) is cut into the guide.

2.5 Tools, to adjust profilograph as described in the manufacturer's instructions.
2.6 Miscellaneous materials, including an engineering scale marked in tenths of an inch, a calculator, recorder chart paper, and pencils.

Example Showing Method of Deriving Profile Index From Profilograms

Figure 1—Example Showing Method of Deriving Profile Index from Profilograms

3. APPROVAL OF PROFILOGRAPH EQUIPMENT

3.1 The Department’s Design Division approves the manual and automated models of profilographs for use in this test method.

3.2 Approved manual models include:
- McCracken Manual Profilograph

3.3 Approved automated models include:
- Cox Automated Profilograph
- Ames Automated Profilograph
- McCracken Automated Profilograph.

3.4 The filter settings from the approved automated profilograph should read, “The approved data filter is a third order Butterworth with a 2.0 foot cutoff.”

3.5 All automated model test results must correlate to those generated by a manual 12-wheel McCracken California-type profilograph, the Department standard, to within a Profile
Index (P.I.) of 1 for pavement surfaces up to 15 P.I. roughness. They must also demonstrate a repeatability level, after three tests, with a standard deviation of no more than 1 P.I., when testing pavements up to 15 P.I. in roughness. Approved units must allow field calibration using vertical deflection standards and provide a verifiable method of horizontal calibration.

3.6 Automated models must meet all of the standards for manual models including vertical and horizontal calibration, 0.2 in. (5.08 mm) blanking band, and a 0.3 in. (7.62 mm) bump template over 25 ft. (7.62 m). Provide a method that assures that the data filters, cut-off frequencies, and vertical and horizontal transducers are not tampered with after calibration.

3.7 All profilograms (manual or automated) should use the 2.0-inch blanking to produce the resultant Profile Index (PI).

3.8 Department-approved manual profilogram automated data reduction systems include ProScan, Devore Systems, Inc.

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4. ASSEMBLY

4.1 Certain profilographs can be taken apart and transported in sections on a trailer. Assemble according to the manufacturer’s instructions.

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5. CALIBRATION STANDARDS

5.1 Horizontal:

5.1.1 The horizontal or longitudinal calibration standard is a straight roadway test section at least 500 ft. (152.4 m) long, measured accurately to within 1 ft. (.30 m), or 0.2% of the length.

5.2 Vertical:

5.2.1 The vertical deflection standards are flat plates of known thicknesses.

5.2.2 These plates should be of such thickness and number to permit testing the recorder at known deflections of 0.2, 0.3, 0.4, 0.5, 1.0, and 1.5 in. (5.08, 7.62, 10.16, 12.70, 25.4, and 38.1 mm) as a minimum.

5.2.3 The standards must be accurate to within 0.01 in. (0.254 mm) and must be at least 3 x 6 in. (76.2 x 152.4 mm) in size.
6. CALIBRATING THE PROFILOGRAPH

6.1 Frequency of Calibration:

6.1.1 Perform horizontal and vertical calibration verification of the profilograph prior to use on each project, at least weekly during use, and when the Engineer determines verification is necessary.

6.1.2 Additionally, verify vertical calibration again after each reassembly of the profilograph.

6.1.3 Check the air pressure of the profile wheel at least daily.

6.1.4 Maintain a log kept with the profilograph to provide a calibration history.

6.2 Horizontal Calibration:

6.2.1 Perform horizontal calibration by pushing the profilograph over a measured test section at least 500 ft. (152.4 m) long.

6.2.2 Determine the scale factor by dividing the length of this test section in feet (meters) by the length of the recording on the chart, measured to the nearest 0.05 in. (1.27 mm).

6.2.3 This factor must be 25.0 with a tolerance of 0.2 (0.8%).

6.2.4 If the factor is out of tolerance, adjust the chart drive mechanism and/or profile tire according to the manufacturer's instructions to bring the calibration within tolerance.

6.3 Vertical Calibration:

6.3.1 Perform vertical calibration on a flat level area using flat plates of known thicknesses.

6.3.2 Elevate the profile wheel and place a vertical calibration plate or plates under the wheel. The first plate or plates for this test must have a total thickness of 0.2 in. (5.08 mm). The bottom plate must seat firmly so that it cannot flex, rock, or tilt.

6.3.3 Lower the wheel onto the plate and mark the recorder pen deflection.

6.3.4 Elevate the wheel again and insert another plate on top of any already under the wheel. This plate is normally 0.1 in. (2.54 mm) thick.

6.3.5 Mark recorder pen deflection.

6.3.6 Repeat this procedure until, as a minimum, deflection points are marked at 0.2, 0.3, 0.4, 0.5, 1.0, and 1.5 in. (5.08, 7.62, 10.16, 12.7, 25.4, and 38.1 mm) above the level surface.

6.3.7 Reverse this process, by removing plates from the top of the stack and marking each deflection.
6.3.7.1 The pen must return to the original beginning point for the calibration, normally at 0.2 in. (5.08 mm) above the pavement.

6.3.7.2 Adjust chart deviations in excess of 0.03 in. (0.76 mm) according to the manufacturer's instructions.

7. PROCEDURE

7.1 Prior to recording the profile, clean the roadway path of all loose material.

7.2 When recording a profile, push or propel the profilograph at a speed no greater than a walk, about 3 mph (4.83 km/h). Too fast a speed will produce a profilogram containing excessive ‘spikes’ that will be difficult to evaluate.

7.3 After assembly and checking, and immediately prior to taking each profile, set the recorder pen and all counters to zero, on a flat surface.

7.4 When taking the profile, place frequent reference marks on the profilogram with the operator reference pen to identify locations when analyzing the profilogram. Suggested reference mark is every 200 ft. (60 m).

7.5 Operate profilograph according to the manufacturer's instructions.

7.6 Make profilograms on longitudinal lines as required by the specifications. These lines are normally in the wheel paths of the pavement lane. Pavement wider than 12 ft. (3.66 m) may have profiles taken near each longitudinal joint and each wheel path. Areas out of tolerance may require additional profiles.

7.7 Begin the 0.1 mi. (0.16 km) sections at the beginning of daily operation. The sections must all be 0.1 mi. (0.16 km) sections with the exception of the last section in the daily production. The last section can be longer or shorter than 0.1 mi. (0.16 km) but less than 0.2 mi. (0.32 km).

8. EVALUATION

8.1 Manual evaluation of profilograms, as described below, is the standard evaluation method. Automated evaluation must match manually evaluated results from the standard profilograph to within 1 P.I. for pavement roughnesses up to 15 P.I.

8.2 An important aspect of profilogram evaluation is the identification of 'spikes' that are not counted as pavement roughness. Refer to the following definitions:

8.2.1 Scallop—Scallop is a vertical projection above or below the blanking band.

8.2.2 Spike—Spike is a scallop with a width of less than 0.08 in. (2.03 mm) (less than 2 ft. [0.61 m] on the roadway).
9. PROFILE INDEX

9.1 Preparing Profilogram:

9.1.1 Trace through the approximate center of the spikes on any profilogram, using a fine point pen. (Suggested colors would be blue or black ink for the original profilogram trace and red ink for the manual tracing.)

9.1.2 Outline any scallop that is not a spike as close as possible to the original trace recorded on the profilogram. Use a different color ink than that used during the original profilogram recording.

9.1.3 Mark off the 0.1 mi. (0.16 km) segments on the profilogram using a profile index scale 21.12 in. (536.45 mm) long. The outside (horizontal) edges of the scale must be clearly marked on the profilogram after each scale placement has been determined.

9.1.4 If repositioning the P.I. scale is necessary within each 0.1 mi. (0.16 km) segment, mark the outside edges of the scale on the profilogram to indicate the repositioning.

9.2 Evaluating the Profilogram:

9.2.1 Place the plastic profile index scale over the recorder chart profile so the blanking band covers as much of the profile as possible. The scallops above and below the blanking band can usually but not always be approximately balanced (See Figure 1).

9.2.2 The recorded profile may drift or move from the usual horizontal position, particularly when using the profilograph on super-elevated curves. When this happens, break the 0.1 mi. (0.16 km) section into short subsections, then shift the scale so the blanking band covers as much of the profile as possible within each short subsection, as shown in the upper part of Figure 2.

9.2.3 Determine the total vertical deviation for each section by measuring the manual tracing of each scallop to find its maximum extent above or below the blanking band and summing these values. (Figure 1 illustrates this process.)

9.2.4 Measure each scallop to the nearest 0.05 in. (1.27 mm) (Half the distance between the P.I. scale lines). Write this deviation above the scallop on the profilogram. For scallops with multiple peaks, as shown in Figure 1, (D), count only the highest peak.

9.2.5 Record the sum of vertical deviations for each section on the profilogram. Scale the last profilogram section of the day's production, when it is less or greater than 0.1 mi. (0.16 km), to determine its length.
10. **CALCULATIONS**

10.1 Calculate the Profile Index (P.I.) in excess of the 0.2 in. (5.08 mm) blanking band. Find the P.I. for any section by summing the total vertical deviation in inches (millimeters), for each 0.10 mi. (0.16 km), for each wheel path in the travel lane, and averaging the two values.

11. **DETERMINING HIGH POINTS AND DEPRESSIONS**

11.1 Place the bump template so the two holes at each end of the 1 in. (25.4 mm) scribed line lie on the profilogram trace at the base of each high point or depression.

11.2 If the base of the bump or depression is 25 ft. (7.62 m) or less, place the scribed line across the low points, as shown in the lower part of Figure 2. These base lines do not have to be horizontal. In no case must this base line be greater than 25 ft. (7.62 m) or 1 in. (25.4 mm) on the template.

11.3 When the base of a bump or depression tracing exceeds 1 in. (25.4 mm) on the template, draw the base line so the 1 in. (25.4 mm) line begins and ends on the manual tracing of the scallop, as shown in Figure 2.

11.4 With the template in place as described, use a sharp pencil to mark a line 0.3 in. (7.62 mm) (or other value shown on the plans) from the base line as illustrated in
Figure 2. Any part of the peak projecting above this mark represents a bump above the specified limit. This bump may be located on the pavement by using the operator's reference marks placed on the profilogram.

11.5 Mark these bumps on the profilogram and note in the final report summary.

12. DAILY AVERSAGE PAY FACTOR

12.1 When required by the specifications, obtain the Daily Average Pay Factor by averaging all pay factors of equivalent 0.1 mi. (0.16 km) sections of a pavement placed during a given day. The following example illustrates the calculation of Daily Average Pay Factor:

<table>
<thead>
<tr>
<th>Section Length (miles)</th>
<th>Section Profile Index</th>
<th>Section Pay Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 (0.16)</td>
<td>06.75</td>
<td>1.01</td>
</tr>
<tr>
<td>0.1 (0.16)</td>
<td>12.25</td>
<td>0.94</td>
</tr>
<tr>
<td>0.1 (0.16)</td>
<td>10.00</td>
<td>1.00</td>
</tr>
<tr>
<td>300 ft. (91.44 m)=0.057</td>
<td>06.50</td>
<td>1.01</td>
</tr>
</tbody>
</table>

\[
\text{Daily Average Pay Factor} = \frac{3.96}{4} = 0.99
\]

13. DETERMINING PAY ADJUSTMENT

13.1 When the pay adjustment is a dollar sum for each 0.1 mi (0.16 km) section, based on the P.I., correct the pay adjustment sum for sections that are shorter than 0.1 mi (0.16 km), as shown in the following example.

<table>
<thead>
<tr>
<th>Section Length Mile/Kilometer</th>
<th>Average P.I.</th>
<th>Pay Adjustment $</th>
<th>Corrected Pay Adjustment, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 (0.16)</td>
<td>5.0</td>
<td>+35</td>
<td>+35</td>
</tr>
<tr>
<td>0.1 (0.16)</td>
<td>7.8</td>
<td>-35</td>
<td>-35</td>
</tr>
<tr>
<td>0.1 (0.16)</td>
<td>4.8</td>
<td>+35</td>
<td>+35</td>
</tr>
<tr>
<td>0.057 (.092)</td>
<td>4.9</td>
<td>+35</td>
<td>$35 \times .057/.01 = 19.95$</td>
</tr>
</tbody>
</table>
14. REPORTING

14.1 The Engineer must receive each profilogram and a report showing:

- project and control numbers
- exact location and length in miles (kilometers) of the profilogram
- summary of each profile index
- average profile index
- date
- name of operator
- name of the evaluator of the profilogram.