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Standard Practice for Accelerated Polishing of Aggregates or Pavement Surfaces Using a Small-Wheel, Circular Track Polishing Machine[1]

This standard is issued under the fixed designation E 660; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

The Small-Wheel Circular Track Wear and Polishing Machine[2] is a device developed to rate aggregates and paving mixtures on their skid resistance after exposure to wearing and polishing. It is a small-diameter, circular track machine capable of accelerated wearing and polishing of pavement specimens. Correlation and comparison can be accomplished through the use of control specimens that are tested simultaneously with regular test specimens. Track capacity is twelve individual specimens per test run.

The actual wearing and polishing for bituminous pavement specimens and exposed aggregate specimens are provided by the action of four smooth pneumatic tires to eliminate, as much as possible, the variables associated with tire tread pattern effects. The wheels are adjusted for camber and for toe-out to provide scrubbing action for polishing without the aid of water or grinding compounds.

To provide accelerated wear sufficient to remove the top textured layer from portland-cement-concrete pavement specimens and to expose the coarse aggregate, as often encountered on worn pavements, that have been in use for substantial periods of time, the wear and polish procedure can be modified by use of steel wheels having studs mounted in the periphery. The procedure for concrete specimens consists of a period of operation with four smooth pneumatic tires to polish the as-built surface, followed by a period of accelerated wear using the steel wheels to expose the coarse aggregate, followed by a final polishing cycle using the four rubber tires again to polish the exposed aggregate.

1. Scope

1.1 This practice describes a laboratory procedure for estimating the extent to which aggregates or pavement surfaces are likely to polish when subjected to traffic. Specimens to be evaluated for polishing resistance are placed in a circular track and subjected to the wearing action of four small-diameter, pneumatic tires without use of abrasive or water. Terminal polish is achieved after approximately 8 h of exposure.

2. Referenced Documents

2.1 *ASTM Standards:*

C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory[3]

D 2240 Test Method for Rubber Property—Durometer Hardness[4]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[5]

E 274 Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire[6]

E 303 Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester[6]

E 707 Test Method for Skid Resistance of Paved Surfaces Using the North Carolina State University Variable-Speed Friction Tester[6]

3. Summary of Practices

3.1 The circular track is fitted with twelve specimen holders that can be adapted to specimens of various shapes and thicknesses, but when mounted in the track, form a continuous plane running surface for the polishing wheels. A complete set

[1] This practice is under the jurisdiction of ASTM Committee E-17 on Vehicle-Pavement Systems and is the direct responsibility of Subcommittee E 17.23 on Surface Characteristics Related to Tire-Pavement Slip Resistance.

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[2] Mullen, W. G., Whitfield, J. K., Gibson, D., and Matlock, T. L., "Implementation for Use of Variable Speed Friction Tester and Small Wheel Circular Track Wear and Polishing Machine," Highway Research Program Project ERSD 110-76-2, Final Report; Available from National Technical Information Service, Springfield, VA 22161.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] *Annual Book of ASTM Standards*, Vol 04.03.

of twelve specimens exposed to wear and polishing at the same time is counted as a round of testing. Usually specimens are tested in sets of three per variable per round of test with three control specimens of a standard surface included in each round to allow comparison between rounds of testing. It is recommended that each variable be repeated in three separate rounds, making a minimum of nine specimens per variable to obtain an average polishing curve.

3.2 To obtain a polishing curve, specimens are subjected to polishing action in the track until friction measurements show no substantial decrease in level with continued polishing effort. Measurements are recorded at the beginning of the test and periodically throughout the test cycle to establish the shape of the polishing curve. Usually 8 h of exposure on the track at 30 r/min or 7200 wheel passes per hour is sufficient to complete the polishing cycle for bituminous bound mixtures and exposed aggregate specimens. For portland-cement-concrete bound mixtures, it is recommended that a polish curve be obtained on the original textured surface followed by removal of the surface to expose the coarse aggregate using the steel-studded abrading wheels. A polishing curve is then obtained for the exposed aggregate surface.

3.3 Friction measurements can be obtained for bituminous plant mix type surfaces using the British Pendulum Tester in accordance with Test Method E 303. The British Pendulum Tester has been found to be ineffective in obtaining friction measurements on highly textured surfaces such as bituminous surface treatments and portland-cement-concrete surfaces. Therefore, it is recommended that the North Carolina State University Variable-Speed Friction Tester[2] be used in accordance with Test Method E 707 as the friction measurement device on highly textured surfaces. With the Variable Speed Friction Tester, speed gradients are obtainable in the laboratory.

3.4 Interpretation of the laboratory polishing curves for field application is not included as part of this practice.

4. Significance and Use

4.1 The use of laboratory obtained polishing curves and speed gradients on proposed aggregate combinations and pavement mixtures are helpful tools in predicting the polishing characteristics of these surfaces if placed in field service.

5. Apparatus

5.1 *Small-Wheel Circular Track*[2]—A power-driven device consisting of four equally spaced wheels, independently suspended, on each of which may be mounted a smooth-tread pneumatic tire, operating over a circular track that holds specimens to be polished (Fig. 1).

NOTE 1—Construction plans are published in the reference cited in footnote 2.

5.1.1 *Rotating Wheel Assembly*—Four individually mounted wheel assemblies, free rolling, attached to the central shaft. Tires are 11 × 6.00 × 5 nylon smooth no-pattern tread tires, 2-ply rating.[7] Each wheel may be individually adjusted for distance from center shaft, plane of rotation (camber), and toe-in or toe-out. Tire pressure is maintained at 20 psi (138 kPa) resulting in 13 psi (90 kPa) average contact pressure under normal 72-lbf (320-N) wheel loading. Each wheel assembly has a horizontal fender onto which weights may be fastened to increase the wheel loading. One pair of opposite wheels is toed-out 2° while the other pair of wheels is toed in 4° to produce an accelerated polishing action.

5.1.2 Drive mechanism for the vertical central shaft is an electric motor geared to rotate the shaft and wheel assembly at 30 ± 2 r/min or approximately 7200 wheel passes per hour.

5.1.3 The circular track is 36 in. (914 mm) in diameter to the center of the wheel travel path. There are spaces for individually mounting twelve equally spaced specimen holders to make up the track running surface. Specimen holders are clamped into place to the supporting frame when testing is in progress.

5.1.4 Specimen holders or track segments are metal plates supported by three adjustable, lockable bolts for mounting and leveling each specimen before and during testing as necessary.

5.1.4.1 Trapezoidal specimens sawed to size are mounted on the bottom plate of the specimen holder. No top plate is used.

[7] Available from Goodyear Tire and Rubber Co., Akron, OH 44316.

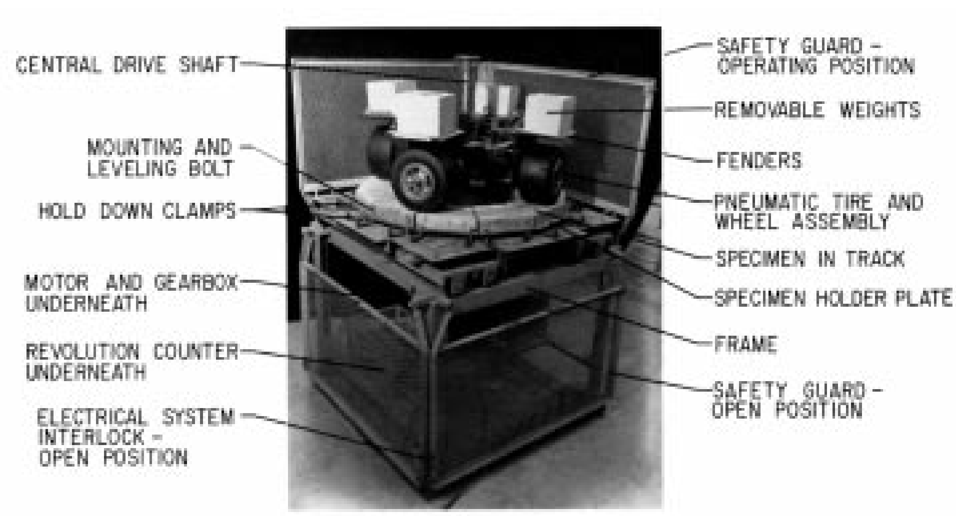

FIG. 1 NCSU Wear and Polishing Machine—Mark II

5.1.4.2 Circular specimens or cores at least 6 in. (152 mm) in diameter are mounted on the bottom plate of the specimen holder, and a top plate with the appropriate diameter circular hole is used to complete the track running surface between adjacent circular specimens.

5.1.4.3 Specimens are cemented to bottom plate using an epoxy glue or may be held in place by a clamping ring.

NOTE 2—Thermoplastic cements are unsatisfactory as they allow specimens to rotate or shift during the progress of the test.

5.2 *Electrical System*—The electrical system consists of three circuits.

5.2.1 The motor circuit is equipped with a slow-blow fuse to protect the motor in case of overheating or machine lockup.

5.2.2 The motor is controlled by a subtracting predetermined revolution counter.

5.2.3 The safety guards are interlocked so that the motor will not operate unless guards are in operating position.

5.3 *Studded Steel Abrading Wheel*—The steel abrading wheel, fabricated from 12-in. (305-mm) diameter steel tubing, is mounted by inflating a pneumatic tire inside. Socket-head cap screws, ¼– 20, used as studs, are arranged in 60 rows and spaced 1.125 in. (28.6 mm) apart within rows with each screw offset 0.375 in. (9.5 mm) from the one above. Two wheels are recommended. Abrading wheels can only be used on trapezoidal specimens where no top specimen holder plate is required (Fig. 2).

NOTE 3—Construction plans are published in the reference cited in footnote 2.

5.3.1 A fiber bristle brush is mounted behind one wheel to sweep the track surface when the abrading wheel is used (Fig. 2).

5.4 *Weights*—Weights of 50 lb (22.7 kg) may be added to wheel assembly aprons when portland-cement concrete is being tested.

5.5 *Friction-Measuring Device*—Any friction-measuring device that will operate to within the center 3.5 by 5.06-in. (89 by 129-mm) portion of a 6-in. (152-mm) diameter specimen would be suitable provided the measurement can be taken in the direction of traffic and the device can be taken into the field to be reasonably correlated with Test Method E 274 skid trailer measurements.

5.5.1 Friction measurements can be made on low macrotexture pavements or pavement samples using the British Pendulum Tester in Test Method E 303.

5.5.2 Friction measurements can be made on any pavements or pavement samples using the Variable Speed Friction Tester.[2] In addition, speed gradients may be obtained using this device.

5.6 *Molds*—Specimen molds may vary in size and shape depending upon aggregate, mixture, or surface to be tested.

5.6.1 *Bituminous Laboratory Specimen*—A 6-in. (152-mm) inside diameter mold is recommended for bituminous specimen compaction. The base should be detachable for specimen extraction. If static compaction in a compression machine is used, a 5.875-in. (149-mm) diameter compaction mold plunger should be provided.

5.6.2 *Concrete Laboratory Specimens*—Because of texturing, it is desirable to cast large concrete surfaces and to saw trapezoidal specimens. A steel plate and angle iron mold 7.75 by 28.0 by 2 in. (197 by 711 by 51 mm) deep will provide a slab from which three trapezoidal specimens can be sawed.

5.6.3 *Exposed Aggregate Laboratory Specimens*—A 6-in. (152-mm) inside diameter mold approximately 1.8 in. (46 mm) in height is recommended for exposed aggregate specimen preparation. The base should be detachable for specimen extraction.

5.6.4 *Cores and Thin Surfacings*—Thin or irregular back specimens may be built up with plaster of paris to suitable mounting thicknesses of 1 to 2 in. (25 to 50 mm) using rings cut from paper concrete cylinder molds.

6. Materials

6.1 *Laboratory-Made Bituminous Specimens*—It is recommended that a standard laboratory aggregate for manufacture of control specimens be stocked in sufficient quantity for approximately 1 year of operation, and that sufficient quantity

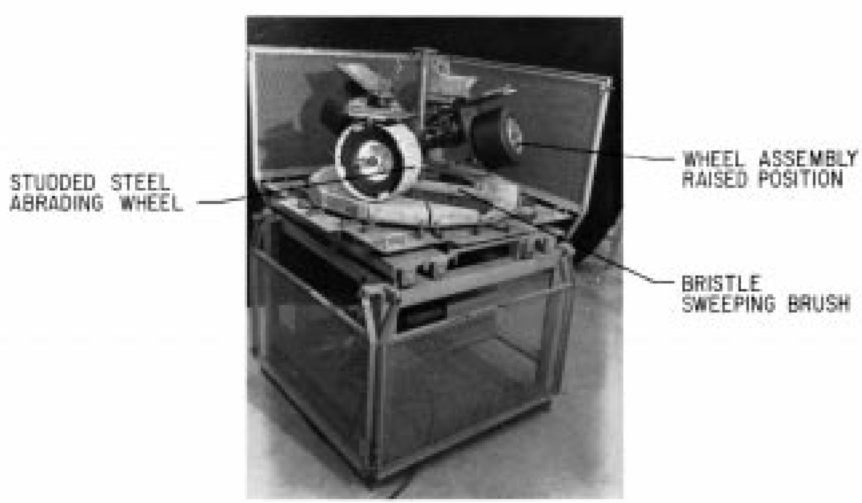

FIG. 2 Studded Steel-Abrading Wheels and Bristle Sweeping Brush

shall be retained for recalibration of a new supply before the original supply is exhausted.

6.2 *Laboratory-Made Portland Cement Concrete Specimens*—It is recommended that standard laboratory coarse and fine aggregates for manufacture of control specimens be stocked in sufficient quantity for approximately 1 year of operation and that sufficient quantity shall be retained for recalibration of a new supply before the original supply is exhausted.

6.3 *Laboratory-Made Exposed Aggregate Specimens*—It is recommended that standard laboratory coarse aggregate for the manufacture of control specimens be stocked in sufficient quantity for approximately one year of operation and that sufficient quantity shall be retained for recalibration of a new supply before the original supply is exhausted.

6.4 *Specimen Mounting Cement*—Commercially available epoxy cement or a clamping ring shall be used for mounting specimens.

7. Sampling

7.1 Not applicable, as sampling schemes may be varied to meet the needs of the user.

8. Test Specimens

8.1 *Bituminous Laboratory Specimens*—Use a minimum of three individual specimens to evaluate each aggregate or each pavement mixture design. Three rounds of three are recommended.

8.1.1 Prepare bituminous specimens using the aggregate gradation and asphalt cement content desired.

8.1.1.1 Mix preheated aggregates and asphalt using a mechanical laboratory mixer.

8.1.1.2 Preheat the mold assembly (5.5.1) to mixing temperature and place a filter paper in the bottom of the mold.

8.1.1.3 Distribute the mixture in the mold using a spatula, rodding around the mold sides and rodding and leveling the surface. Place filter paper over the mixture.

8.1.1.4 Place the compaction plunger in the mold and compact the specimen in a compression machine to 3000 psi (20.68 MPa) holding the load for 2 min.

NOTE 4—At pressures in excess of 3000 psi (20.68 MPa) some aggregate particles may be crushed, resulting in possible bias of the test results.

8.1.1.5 Remove the plunger, cool the mold and specimen to room temperature, and extract the specimen from the mold using a hydraulic press.

8.1.1.6 Mark the bottom surface as compacted as the test surface, and store the specimen prior to use on a flat surface.

8.1.2 *Portland Cement Concrete Specimens*:

8.1.2.1 Mold portland cement concrete specimens in the molds described in 5.6.2 in accordance with Practice C 192, except that texture shall be imparted to the top surface using the desired texturing medium when the surface is sufficiently stiffened to retain the texture.

8.1.2.2 Remove the molds and diamond-saw individual trapezoidal specimens from the slab between 24 to 48 h after molding.

8.1.2.3 Continue curing to 28 days in accordance with Practice C 192 or until time of test, whichever is sooner.

8.2 *Field Specimens*:

8.2.1 Obtain field specimens by coring with a 6-in. (152-mm) inside diameter diamond bit in a process using water lubrication.

8.2.2 Identify field cores, and store top surface down on a flat surface for transportation to the laboratory.

8.2.3 Reduce field specimens to approximately 1.5-in. (38-mm) thickness by wet diamond-sawing.

8.2.3.1 Lap the sawed face to remove major surface irregularities that would interfere with the mounting of the specimen.

8.2.4 Store prepared field cores top surface down on a flat surface prior to mounting and testing.

8.3 *Remolded Bituminous Specimens* (Note 5):

8.3.1 Heat cores to be remolded in the oven at mixing temperature until soft.

8.3.2 Separate the surface mixture from other layers of pavement using a spatula. Discard underlying layers.

8.3.3 Scrape away and discard the worn surface and the core drill cut or sawed surface.

8.3.4 Bring the remaining material to mixing temperature, mix mechanically, and mold into a specimen following the procedure in 8.1.1 through 8.1.1.5 (Note 6).

NOTE 5—If it is desired to estimate the original friction value of a bituminous mixture subjected to wear in the field, this is accomplished by remolding field cores after they have been run on the circular track to terminal polish.

NOTE 6—If there is insufficient material for a 1.5-in. (38-mm) thick specimen, two or more like cores may be combined, or a backing mixture of bituminous concrete may be placed on top of the remolded mixture in the step described in 8.1.1.3.

8.4 *Exposed Aggregate Specimens*:

8.4.1 Prepare 6 by 1.8-in. (152.4 by 45.7-mm) circular steel mold by painting bottom with retarder.

8.4.2 Hand-place aggregate particles (passing ½-in. (12.7-mm) sieve and retained on ⅜-in. (9.5-mm) sieve) with flat surface down for smooth surface and maximum aggregate exposure.

8.4.3 Carefully place cement grout over aggregate, vibrating as necessary.

8.4.4 Remove the specimens from the mold after 24-h cure under wet burlap.

8.4.5 Scrub mortar from surface of aggregate with a steel brush, exposing aggregate to be tested.

8.4.6 Cure specimens as required to develop strength prior to testing.

NOTE 7—This test measures only the polishing effects on aggregate microtexture. However, good correlation with field tests of actual mixture has been obtained in tests conducted by the Illinois Department of Transportation.

9. Calibration and Standardization

9.1 Use standard laboratory aggregates for test control.

9.1.1 Include at least two specimens made from the standard laboratory aggregates in every fourth twelve-specimen run of the circular track for comparison to a master curve (Note 8) previously established for the standard aggregate for a given gradation or mixture design.

NOTE 8—A master curve for the control aggregates can be obtained by averaging the friction values for 36 specimens (three runs of the track) exposed in the track to terminal polish.

9.1.2 Where aggregate evaluation alone for bituminous mixtures is desired, open-grade and size the mixture by separation into sizes and recombine as follows:

Sieve Size	Percentage Passing
½ in. (12.7 mm)	100
⅜ in. (9.5 mm)	95
No. 4 (4.75 mm)	43
No. 10 (2.00 mm)	10
No. 40 (425 µm)	4
No. 80 (180 µm)	3
No. 200 (75 µm)	2

9.1.3 Where mixture design or aggregate blend evaluation is desired, the mixture shall be as desired, and the control aggregate mixture shall be of the same gradation and cementing medium content for which a master curve was previously established. An alternative method of control may be the use of the aggregate gradation in 9.1.2 for all control specimens where bituminous mixtures are being evaluated.

NOTE 9—It is not recommended that portland cement concrete and bituminous concrete specimens be included in the same run of the circular track.

9.1.4 Compare the terminal hour exposure friction value for the average of the two control specimens from every fourth run to the previously established master curve. If the difference is greater than ± 3 whole number, friction data obtained during the last four runs may be suspect.

10. Specimen Mounting

10.1 Locate the specimens in the twelve circular track positions by use of random techniques.

10.1.1 Mount the cored specimens, if slightly undersized, touching the edge of the circular opening down traffic from the direction of travel of the wheel assembly.

10.2 Epoxy specimens to the mounting plates or hold in place with a clamping ring.

10.2.1 Cure epoxy in accordance with the manufacturer's instructions.

10.3 Adjust the specimens to be level and flush with the surface of the track using the three adjusting bolts so that the wheel assembly will travel without bumping.

11. Test Procedure for Bituminous Bound or Exposed Aggregate Specimens

11.1 Measure initial friction of mounted specimens.

NOTE 10—If aggregate only is to be evaluated in a bituminous mixture, using the aggregate gradation given in 9.1.2, surfaces of test and control specimens shall be cleaned of asphalt by thorough and careful wiping of surface with rags and solvent before initial friction values are measured.

11.2 Lower the wheel assembly to the track.

11.2.1 Adjust the tire air pressure to 20 psi (138 kPa).

11.2.2 Measure the temperature near the surface of track.

11.2.3 Set the revolution counter for the number of revolutions desired.

11.3 Set the wheel assembly in motion at 30 r/min.

11.4 Stop the wheel assembly for friction measurements at 1 and 2 h of machine time and at 2-h intervals thereafter until terminal exposure has been attained.

NOTE 11—Normal terminal polish is achieved after approximately 8 h of exposure. Interim readings may be eliminated if deemed unnecessary.

11.4.1 At each time interval, remove the track segments and measure the friction values for each specimen.

11.4.2 Monitor the tire pressure at 20 psi (138 kPa).

11.4.3 Monitor the air temperature near the surface of track.

11.4.4 Monitor the adjustment of specimens.

11.4.5 Monitor the condition of individual specimens for wear and raveling.

11.4.5.1 If a specimen is too worn or raveled to be measured for friction, discontinue measurement of that specimen and replace with a dummy plate for the remainder of the test exposure.

NOTE 12—If raveling of bituminous laboratory specimens becomes a problem, adjustments in asphalt content, substitution of a harder asphalt, more compaction or aging, or both, of specimens before testing may be effective in eliminating the problem.

11.4.6 Replace the track segments in machine.

11.4.7 Lower the wheels to the track surface.

11.4.8 Preset the revolution counter for the next test increment.

11.4.9 Set the wheel assembly in motion for next test increment.

12. Test Procedures for Portland-Cement Bound Specimens

12.1 It is recommended that a 50-lb (22.69-kg) weight be added to each wheel apron for the test exposure for portland-cement bound specimens.

12.2 Follow procedure for bituminous bound specimens in Section 11 to obtain the as-built polishing curve.

12.3 If the polishing curve for textureless, exposed, coarse aggregate concrete is desired, remove the texture using the studded wheel-abrading wheels in 5.3.

12.3.1 Replace two adjacent pneumatic tire-track wheels with two studded steel-abrading wheels. Remove the apron weights from these two wheels. Install the bristle brush to sweep the track surface (Fig. 2).

12.3.2 Expose the specimen to abrading action until texture is removed and coarse aggregate is exposed.

NOTE 13—For most portland cement concrete, 1.5 h of abrading exposure is sufficient.

12.4 Repeat the procedure in 12.1 and 12.3 to establish the polishing curve for exposed aggregate surface.

13. Report

13.1 The report shall include the following information as is appropriate to the needs of the user:

13.1.1 Full identification of specimens including aggregate source, gradation, and mixture design,

13.1.2 Field location, if cores, including lane and wheel path, contract identification, age, and traffic history, if available,

13.1.3 Friction values at start of test, for each time increment for individual test specimens, and for control specimens; and the average friction values for each set of test and control specimens,

13.1.4 Correction factors for friction values for average of the control specimens at terminal polish as determined by comparison to the master control curve,

13.1.5 Corrected average friction values for each set of test specimens,

13.1.6 Remarks about wear or raveling of specimens, if any, during progress of test,

13.1.7 Test temperature, and

13.1.8 Dates of testing.

14. Precision and Bias

14.1 Precision of specific measurements undertaken as part of this practice are included in referenced standards (Section 2) for those measurements.

14.2 The single operator multi-batch precision using Test Method E 303 as the measurement method to determine the BPN of low macrotexture portland cement concrete and bituminous concrete surfaces is found to be ±2.8 % (1S %) max, as defined in Practice E 177, over the BPN range of 40 to 70 numbers measured after 8 h of exposure on the small-wheel circular track. Multi-operator, multi-batch precision under the same conditions was found to be ±5.13 % (1S %) max.