Designation: E319 – 85(Reapproved 2008)

Standard Practice for the Evaluation of Single-Pan Mechanical Balances[1]

This standard is issued under the fixed designation E319; 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 balance performs two basic functions: (*1*) it compares an unknown load with one or more weights, and (*2*) it indicates the difference between the two loads for differences smaller than the smallest weights normally used on the balance. The test procedure given herein measures the precision with which the balance can compare the two loads, and the rates at which systematic errors may affect the observed difference.

1. Scope

1.1 This practice covers testing procedures for evaluating the performance of single-arm balances required by ASTM standards.

1.2 This practice is intended for but not limited to sensitivity ratios of 10^6 or better and on-scale ranges of 1000xd or more where d = reability either directly or by estimation.

1.3 This practice can also be applied to other single-pan balances with mechanical weight changing of different capacities or sensitivities with appropriate test loads and calibration weights.

NOTE 1—Mechanical balances of this type have largely been replaced by automatic electronic balances incorporating a variety of operational principles. Nevertheless, some single-pan mechanical balances are still manufactured and many older balances will remain in service for years to come. One type of automatic electronic balance, the so-called "hybrid," bears considerable similarity to single-pan mechanical balances of the null type. (**1**)[2]

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions*(1):

2.1.1 *accuracy*—the degree of agreement of the measurements with the true value of the magnitude of the quantity measured (**2**).

2.1.2 *correction for a weight*—the correction for the error in adjustment is:

$$Cr.W = A - N \tag{1}$$

where:

$Cr.W$ = correction for the error in adjustment to nominal value,
A = actual value of the weight, and
N = nominal value.

NOTE 2—In practice it is not possible to adjust weights exactly to their nominal values.

2.1.3 *correction for error in scale indication*— the correction for the scale indication, I, is:

$$Cr.I = A - I \tag{2}$$

NOTE 3—The correction for the scale is taken with reference to the measured value of a weight used as a test load during calibration of the on-scale range.

2.1.4 *index of precision*—the standard deviation, computed in any acceptable manner, for a collection of measurements involving a given pair of mass standards (**3**).

NOTE 4—The standard deviation is computed from the data provided by the instrument precision test (see Section 7) index of precision.

2.1.5 *null-type balance*—a balance which requires, as the final step in its operation, that the observer restore the angle of the balance beam to its original (or null) position. The least significant figures of the balance indication are obtained from this operation.

2.1.6 *optical-type balance*—in this type the least significant figures of the balance indication are related to the deflection angle of the beam from its original (or null) position. A scale placed on the moving beam is optically projected onto the (stationary) balance case to provide this indication.

[1] This practice is under the jurisdiction of ASTM Committee E41 on Laboratory Apparatusand is the direct responsibility of Subcommittee E41.06 on Weighing Devices.

Current edition approved Nov. 1, 2008. Published January 2009. Originally approved in 1968. Last previous edition approved in 2003 as E319 – 85 (2003). DOI: 10.1520/E0319-85R08.

[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

2.1.7 *precision*—the repeatability of the balance indication with the same load under essentially the same conditions.

NOTE 5—The more closely the measurements are grouped, the smaller the index of precision will be. The precision must be measured under environmental conditions that represent the conditions under which the balance is normally used.

2.1.8 *readability*—the value of the smallest decimal subdivision of a scale division in terms of mass units, that can be read, when the balance is read in the intended manner.

NOTE 6—The readability of a particular instrument is not a measure of its performance as a weighing device. The relationship between the numerical value obtained by reading devices and the ability of the operator to estimate the location of the reference device or index is important. It is possible to introduce a large number of readable subdivisions of the main scale divisions that would increase the "readability" as defined but if the reading device cannot be reset to the same numerical value when the beam is in an immovable condition, or when the load on the beam is a constant value, the readability becomes meaningless. Readability substantially less than 1 standard deviation as determined by repeated measurement with a given test weight is usually superfluous.

2.1.9 *scale division*—the smallest graduated interval subdivided either by estimation or with the aid of a vernier. Subdivisions which appear as divisions on the vernier are not considered to be scale divisions, but rather parts of scale divisions.

2.1.10 *sensitivity weight*—a small weight used to measure the "on-scale" deflection of the balance indicator.

NOTE 7—With single-pan balances the sensitivity weight should be equal to the value of the smallest built-in weight represented by the first step on the dial for the smallest weights.

2.1.11 *test load*—a load chosen to represent the sample load in the test procedure.

2.1.12 *value of the division*—the change in load required to change the balance indication by one scale division. The reciprocal of the sensitivity is its most useful function.

3. Summary of Practice

3.1 The accuracy of the direct-reading scale, the smallest weight of the set of built-in weights, and uniformity of sensitivity between the upper and lower halves of full-scale deflections are verified by preliminary tests.

3.2 Estimates of rate of change of the zero with time, rate of change in the value of the scale division with time, and a quantitative measure of the variability or random error are provided by short tests for precision and bias.

3.3 An overall test of the direct-reading capability is provided by tests of the built-in weights.

4. Significance and Use

4.1 *Monitoring Weighing Performance*—This practice provides results in the form of control charts which measure the weighing capability at the time of the test. A series of tests at appropriate intervals will monitor balance performance over a period of time. A marked change from expected performance may result from a variety of causes including: maladjustment, damage, dirt, foreign material, and thermal disturbances. If the test results are to indicate future performance, any disturbances that occur exterior to the balance must be brought under control (**2**).

4.2 *Acceptance Tests*—This practice may also be used as acceptance tests for new balances. For this purpose, the tests should be conducted under favorable, but not necessarily ideal, conditions. Since systematic error in the course of the zero and the course of the sensitivity may be caused by disturbances external to the balance, limits on these errors are not ordinarily prescribed in acceptance requirements.

5. Preparation of Apparatus

5.1 *Balance* (In all cases, the balance should be used in accordance with the manufacturer's instructions)*:*

5.1.1 The results obtained will depend on the environment. Select an area which is free of excessive vibration and air currents, where rapid changes in temperature and relative humidity will not be encountered, and where the floor is rigid enough to be free of a tilting effect on the balance indication. Place the balance on a sturdy bench. If the balance has been moved to a new location, permit it to come to thermal equilibrium for at least 1 h before performing the test, preferably several hours.

5.1.2 Inspect and test the balance to make sure that it is in proper mechanical order. Arrest and release the beam to make sure that readings are approximately repetitive. Observe the indication during arrest and release to ensure that there is no "kick" that would indicate that arrestment points might be out of adjustment. If necessary, have the balance adjusted by a competent balance technician.

5.1.3 Make a few trial measurements of the interval from zero to the full-scale indication.

5.2 *Reading the Balance*—The balance should be read in accordance with the instructions supplied by the manufacturer. Optical types should include the reading of verniers or micrometres. Null types should include the indication of the device for restoring to null including verniers or micrometres.

6. Preliminary Testing of Single-Arm Balances

6.1 *Summary of Method*—With single-pan balances the smallest built-in weight, indicated by the first step on the dial, is compared with a calibrated weight. The direct-reading scale is tested for agreement with the smallest built-in weight and the sensitivity is adjusted, if necessary, so that the indications of the scale are precise in terms of the calibrated weight. A "fifty-fifty" test verifies the accuracy of the midpoint at half-full scale. This test should be performed before proceeding to other tests. After the accuracy of adjustment of the smallest built-in weight is verified, this weight is used to test full-scale deflections. Tests are also made for the uniformity of deflection over the lower and upper halves of the full-scale deflection. The preliminary tests show either that the balance is operating properly, or that discrepancies indicate the presence of sources of error. Uncertainties of perhaps one millionth of the balance capacity may be caused by dirt or foreign material in the bearings, or by unskilled handling, while larger discrepancies may be caused by worn or damaged knife-edges or other sources such as electrostatic effects. Any necessary cleaning or servicing should be done at this point. If discrepancies continue, other possible sources of uncertainty should be studied. There is no point in proceeding with routine test procedures until acceptable results can be obtained with the preliminary tests.

NOTE 8—With null-type balances (including the hybrid) it is possible to use the flexure of a segment of metal, quartz, etc. as the main pivots instead of knife edges. A flexure pivot is by its nature free of problems of dirt. Flexures are also generally more robust than knives. The chief problem associated with flexures is that they act like springs and thus add a restoring force which may vary with time or temperature. This drawback can be minimized by careful design and all but eliminated by the use of servo-control in electronic balances.

6.2 *Materials:*

6.2.1 A watch or clock which indicates seconds,

6.2.2 Pencils for recording data,

6.2.3 Columnar data sheets (If balance performance will be monitored periodically, it may be useful to enter data directly into a personal computer which has been programmed for this task.),

6.2.4 A calibrated weight designated *S*1 which has the nominal value equal to the smallest interval on the dial-operated weights, and

6.2.5 Two weights of half of the nominal value of *S*1 designated (½)1 and (½)2. (These weights need not be calibrated but they should bear distinguishing marks, preferably one, and two dots.)

6.3 *Procedure*—Adjust the "no-load" readings to a point near the center of the vernier so that zero drift or other deviation will not cause a negative scale reading. Perform the preliminary tests, loading the pan and changing the dial settings according to the schedule in Table 1. Before releasing the beam, record the load on the pan and the dial setting so that the observation will be confined to the scale reading. Release the balance and observe the scale reading. Record the indication and verify the stability of the scale reading, then arrest the balance promptly.

6.4 *Calculations for Preliminary Tests:*

6.4.1 Compute *D*1, the value of the smallest built-in weight as follows:

$$D1 = [(a - b + f - e)/2] + S1 \quad (3)$$

where: *a, b, f*, and *e* are taken from Table 1, and *S*1 = calibrated value of test weight.

6.4.2 Compute *S*1 in scale divisions to verify the full-scale value on the direct-reading scale as follows:

$$S1 = (c - b + d - e)/2 \quad (4)$$

where *c, b, d*, and *e* are taken from Table 1. Adjust the balance sensitivity if necessary so that the full-scale reading equals *D*1.

6.4.3 Compute average scale difference, *A*, for lower 50 % of direct-reading scale as follows:

$$A = (g - f + j - k)/2 \quad (5)$$

6.4.4 Compute average scale difference, *B*, for upper 50 % of direct-reading scale as follows:

$$B = (h - g + i - j)/2 \quad (6)$$

A and *B* should agree within 3 standard deviations (see 7.5.3). Any discrepancy smaller than 3 standard deviations may be ascribed to uncertainty in the preliminary measurements and does not necessarily indicate a real change in the value of the scale divisions.

6.4.5 Inspect the no-load readings, *a, f*, and *k* for agreement or zero drift.

6.4.6 See Table 2 and Fig. 1 for examples of calculations and observation form.

7. Instrument Precision (4)

7.1 *Summary of Method:*

7.1.1 A set of four readings is repeated four times, or more, to obtain pairs of readings with identical loads:

7.1.1.1 A reading near zero,

7.1.1.2 A reading near the upper end of the scale,

7.1.1.3 A reading near the upper end of the scale with a test load plus a small weight, and

7.1.1.4 A reading near zero with the test load but with the small weight removed.

7.1.2 Readings are taken at a steady pace as rapidly as practicable, consistent with good practice, and the time is observed at the start of each set of observations and at the end of the test.

7.1.3 The balance indications are plotted on a graph to provide a visual presentation of errors. The zero readings are connected to show the course of the zero with time. The response of the balance to the small weight is plotted. The course of the sensitivity with time is represented by a plot of

TABLE 1 Schedule for Preliminary Tests of Single-Arm Balances

Observation	Time	Pan Load	Dial Setting	Scale Reading
a	Record the time	zero	0	...
b		$S1^A$	1	...
c		$S1^A$	0	...
d	Wait 30 s	$S1^A$	0	...
e		$S1^A$	1	...
f	Record the time	0	0	...
g		$(½)_1{}^B$	0	...
h	Add $(½)_2{}^B$	$(½)_1 + (½)_2{}^B$	0	...
i	Wait 30 s	$(½)_1 + (½)_2{}^B$	0	...
j	Remove $(½)_1{}^B$	$(½)_2{}^B$	0	...
k	Record the time	0	0	...

[A] S1 = calibrated weight of nominal value equal to the smallest dial-operated weight.
[B] $(½)_1$ and $(½)_2$ = weights of nominal value equal to ½ S1 (not necessarily calibrated but marked for identification).

TABLE 2 Example of Preliminary Test of Direct Reading Balance

Observer: John Doe — Date: (May 5)

Observation	Time	Load	Dial	Scale Reading
a	1:30 p.m.	0	0	6.4
b		*S*1	1	6.45
c		*S*1	0	1006.5
d	1:34 ½	*S*1	0	1006.5
e		*S*1	1	6.5
f		0	0	6.4
g	1:39	$(500\ mg)_1$	0	506.5
h		$(500\ mg)_1 + (500\ mg)_2$		1006.25
i		$(500\ mg)_1 + (500\ mg)_2$	0	1006.3
j		$(500\ mg)_2$	0	506.15
k		0	0	6.4

Calculations:

$$D1 = [(a - b + f - e)/2] + S1 = [(6.4 - 6.45 + 6.4 - 6.5)/2] + 1000 = 999.925$$

$$S1\ (= 1000.006\ \text{mg}) = [(c - b + d - e)/2] = [(1006.5 - 6.45 + 1006.5 - 6.5)/2] = 1000.025\ \text{scale divisions}$$

$$A = (g - f + j - k) = (506.5 - 6.4 + 506.15 - 6.4)/2 = 499.925$$

$$B = (h - g + i - j) = (1006.25 - 506.5 + 1006.3 - 506.15)/2 = 499.95$$

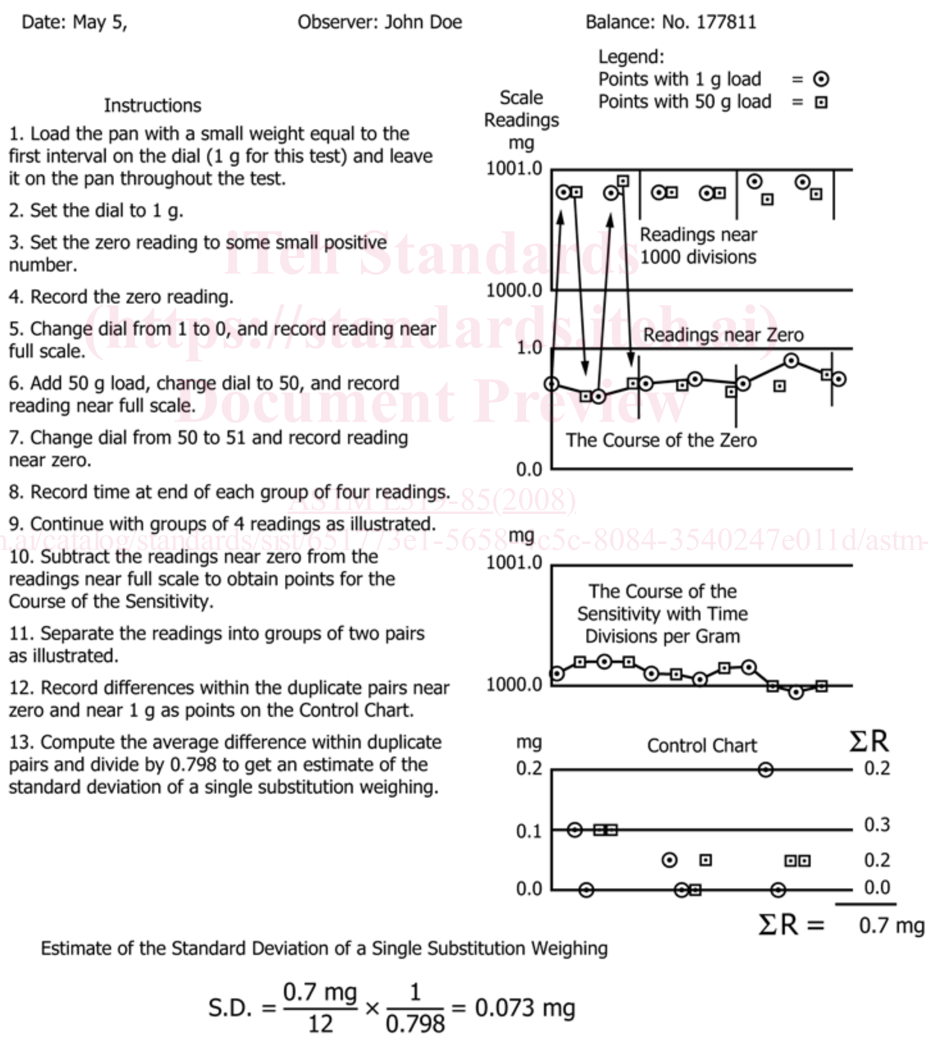

FIG. 1 Calculations and Observation Form for Test of Precision

the interval from zero to full-scale angular motion of the beam, or with balances having indication to a null point by a plot of an interval measured on the device for restoring the beam to a null indication.

7.1.4 A control chart formed by plotting the range within pairs provides a quick estimate of the standard deviation for a single reading. The precision of the balance is estimated by computations based on the range within pairs of observations.

7.2 *Materials*—The following materials are required:

7.2.1 A watch or clock which indicates seconds,

7.2.2 Pencils,

7.2.3 Cross-section paper, 20 lines/in. or 10 lines/cm (If balance performance will be monitored periodically, it may be useful to enter data directly into a personal computer which has been programmed for this task.),

7.2.4 One 50-g test load or other appropriate load (the correction to nominal value need not be determined),

7.2.5 A sensitivity weight (usually 1 or 0.1 g depending upon the type of balance) with the nominal value equal to one interval on the dial for the smallest internal weight. (The correction for this weight is not needed since the full-scale indication is compared directly with the smallest weight in the self-contained set of weights.)

7.3 *Preparation:*

7.3.1 Draw, in the upper left quarter of the sheet of graph paper, a horizontal base line for points near zero and a second horizontal base line for points near full scale (100 or 1000 divisions).

7.3.2 Time is represented in the horizontal direction. Space observations one square apart and record the time showing hour, minutes, and seconds at the start of each set of four readings and at the end of the test. The vertical axis represents change in balance indication. One square represents the smallest unit that is intended to be read or estimated. It is, however, proper to record one half a vernier division as half a square on the graph.

7.3.3 Refer to Fig. 2 for an example.

ASTM
Form No.
E1Sub31-1

Computation Form
for
Preliminary Test of Direct Reading Scale

Balance Identification
Maker: *John Doe Bal Co*
Serial No.: *223090*
Inventory No.: *MB-3*

Standard Weight Set
Designation: ____________

Sheet No. *1*
Test No. *M-21*
Observer.: *John Doe*
Room No.: *101-S*
Date: *May 5,*

Definitions:

D1 = Built-in weight removed by first interval, 0–1, of the dial for the smallest weights.

S1 = Standard weight of same nominal value as D1, usually 1 g, 100 mg, or 10 mg.

H_1, H_2, = Weights equal to half of D1, not necessarily calibrated. Show identification, distinguishing marks, and values for S1, and also identify and show values if known for H_1 and H_2.

S1= *100.006 mg*
H_1= *(50. mg)1*
H_2= *(50. mg)2*

OBSERVATIONS

Time	Load	Dial	Scale Reading
_____	0	0	*5.50* = a
	S1	1	*5.56* = b
	S1	0	*105.57* = c
(Wait 1/2 minute)			
	S1	0	*105.58* = d
	S1	1	*5.61* = e
_____	0	0	*5.61* = f
	H_1	0	*55.61* = g
	H_1+H_2	0	*105.63* = h
(Wait 1/2 minute)			
	H_1+H_2	0	*105.63* = i
	H_2	0	*55.64* = j
_____	0	0	*5.65* = k

COMPUTATIONS

D1 - S1		Mean
a-b = A	f-e = F	1/2 (A+F)
–0.06	*0.00*	*–0.03 mg*

Cr .S1 = *+0.006"*
Mean + Cr.S1 = Cr .D1 = *–0.024 mg*

Full Scale Indication

c–b = *100.01*
d–e = *99.97*
Mean = *99.99* in scale divisions.
D1 = *99.976* in mg
Note agreement between Mean and D1!

EQUALITY OF LOWER 50% and UPPER 50%

	Lower 50%	Upper 50%
g–f =	*50.00*	
h–g =		*50.02*
i–j =		*49.99*
j–k =	*49.99*	
Mean: Upper 50% =		*50.005*
Mean Lower 50% =	*49.995* =	(–) *49.995*
Upper 50% – Lower 50%		= *+ 0.01 mg = J*

Course of the Zero

a = *5.50* mg
f = *5.61* "
k = *5.65* "
Deviation within a, f, and k = *0.15* mg = Zero Shift

FIG. 2 Computation Form for Preliminary Test of Direct-Reading Scale

7.4 *Precision Test (Short Test Procedures)*—See Table 3 for summary of test. In the following procedure a 50-g test load is used as an example. Any other test load can be used with appropriate dial settings.

7.4.1 The 50-g weight and sensitivity weight equal to one step on the dial for the smallest weights shall have been in the balance case for at least 1 h. Load the pan with the sensitivity weight (1 or 0.1 g for most balances) and leave it on the pan for the entire series of observations. Close the door. Set the dial for the smallest weights to "1". Release the beam and adjust the zero to a reading in the range from +0.5 to 1 mg so that change in the zero will not take the indication off scale. Arrest the beam. After the door has been closed for at least 30 s, proceed with the following test cycle.

7.4.2 Record the time on the graph. Release the beam at the time recorded. When the beam comes to rest, observe the indication and record as a zero reading on the graph. Enclose the point within a small circle. Look again at the balance indication to verify the reading. Without observing the time, but working at a steady pace, continue with the sequence.

7.4.3 Arrest the beam, change the dial from "1" to "0", release the beam, read as soon as practicable, record one square to the right of the first point as a point near full scale (near an indication of "100" or "1000" divisions as the case may be), encircle this point, verify the reading, and arrest the beam.

7.4.4 Open the door and place the 50-g test load on the pan using weight forceps long enough so that your hand is not put inside the weighing chamber. Shut the door promptly, change the dial to the appropriate setting, that is "50" or "50.0" leaving the dial for the smallest weight at "0". Release the beam, read and record as a point near an indication of "100" or "1000" scale divisions, as the case may be. Enclose the point in a small square to indicate the 50-g load. Arrest and change the dial for the smallest weight from "0" to "1". Release, read and record as a point near zero enclosed in a small square, verify, and arrest the beam.

7.4.5 Open the door and remove the 50-g test load from the pan and place it on the floor of the balance case next to the pan where it will be most convenient to be picked up again. Close the door. Change the appropriate dial, that is the 10-g increment dial from "5" to" 0". Observe the time estimating a few seconds ahead to the time the balance will be released.

7.4.6 Repeat the observations as listed from 7.4.4 and 7.4.5 at least three times more to obtain four or more sets of four readings. Four sets of readings will provide the minimum number of observations required to treat the data by small sample statistics. A more reliable estimate of the standard deviation may be secured by using more sets of observations. If desired, additional data can be taken. The total number of sets of four readings must be an even number so that two adjacent sets can be paired to provide the difference between pairs of readings with identical loads. Fig. 2 shows the data and computations for six sets of four readings arranged so that all data and computations are on a single sheet of graph paper. Successive points are to be plotted one square apart, from left to right.

7.4.7 After completing the desired even number of sets of four readings, finish with a zero reading. This last reading will be used to complete the course of the zero with time. Record the time.

7.4.8 See 7.5 for calculations, and Fig. 2 for an example.

7.5 *Calculations*—See Fig. 1 for an example.

7.5.1 *The Course of the Zero*—Connect the points obtained by Step 1 of the test cycle to show the course of the zero with time.

7.5.2 *The Course of the Sensitivity*—Subtract the indications for the first observation from the second, and the fourth from the third, and plot to obtain the values of scale difference corresponding to the first step on the dial for the smallest weights. Connect these points to show the course of the sensitivity with time as illustrated in Fig. 1.

7.5.3 *Quick Estimate of the Standard Deviation(s)*—(**4**,**5**):

Average difference between pairs $= (2/\pi)s = 0.798s$

It then follows that s = average difference/0.798

The estimate computed in this manner may not agree with that computed by more sophisticated procedures if the collection of data is small. This, however, does not impair its usefulness since either value may differ from the long range estimate of the standard deviation computed on sufficiently large collections of data.

7.5.4 *Report on Balance Test—Identifying Data*—The balance should be identified by model and serial number. The observer, date, and location should be stated. Distinctive features of the balance should be listed.

7.5.5 *Systematic Error*—If there was a trend in the data, state an estimate of the rate of change with time in mass units per minute, or describe the change in the course of the zero. For direct reading balances, compare the full scale deflection with the first dialed interval.

7.5.6 *Random Error*—State the estimate of the standard deviation.

TABLE 3 Summary of Short Test of Precision—Single-Pan Constant-Load Balance

Record starting time on graph.

Step	Operation	Weight on Pan	Dial Setting	Observation		Record
1	Record time and release beam, read, record	1 g or 0.1 g	1 or 0.1	point near "0"	lb. at "0" time	near "0" line
2	Arrest beam, change dial, release beam, read, record, arrest beam	1 g or 0.1 g	0 or 0.0	point near 1000 or 100	lb. at time "1"	near "1000" or "100" line
3	Open door, place test load on pan, shut door, set dial, release beam, read, record	51 g or 50.1 g	50 or 50.0	point near 1000 or 100	at time "2"	near "1000" or "100" line
4	Arrest, change dial, release, read, record	51 g or 50.1 g	51 or 50.1	point near 0	at time "3"	near "0" line
5	Open door, remove 50-g weight, close door, change dial, close door, observe time	1 g or 0.1 g	1 or 0.1			

Repeat steps 1 to 5 four times for a total of at least 16 points recorded on the graph (see Fig. 2).
Finish with a zero reading (Step 1). Record the time.