*TB 9-6670-254-40

DEPARTMENT OF THE ARMY TECHNICAL BULLETIN

CALIBRATION PROCEDURE FOR WEIGHTS (MASS) (GENERAL)

Headquarters, Department of the Army, Washington, DC
13 September 2007

REPORTING OF ERRORS AND RECOMMENDING IMPROVEMENTS

You can improve this manual. If you find any mistakes or if you know of a way to improve these procedures, please let us know. Mail your letter or DA Form 2028 (Recommended Changes to Publications and Blank Forms) directly to: Commander, U.S. Army Aviation and Missile Command, ATTN: AMSAM-MMC-MA-NP, Redstone Arsenal, AL 35898-5000. A reply will be furnished to you. You may also send in your comments electronically to our E-mail address: 2028@redstone.army.mil or by fax 256-842-6546/DSN 788-6546. For the World Wide Web use: https://amcom2028.redstone.army.mil. Instructions for sending an electronic 2028 can be found at the back of this manual.

*This bulletin supersedes TB 9-6670-254-50, dated 1 November 1984, including all changes.

SECTION I
IDENTIFICATION AND DESCRIPTION

1. Test Instrument Identification. This bulletin provides instructions for the calibration of Weights (Mass) (General) from 1 mg up to 100 kg. NIST IR 6969, NIST SP 700-1, NIST Handbook 105-1, and ASTM E617-97 (2003) were used as the prime data sources in compiling these instructions. The equipment being calibrated will be referred to as the TI (test instrument) throughout this bulletin.

a. Model Variations. None.

b. Time and Technique. The time required for this calibration is approximately 20 minutes per weight, using the physical technique.

2. Forms, Records, and Reports

a. Forms, records, and reports required for calibration personnel at all levels are prescribed by TB 750-25.

b. Adjustments to be reported are designated (R) at the end of the sentence in which they appear. When adjustments are in tables, the (R) follows the designated adjustment. Report only those adjustments made and designated with (R).

3. Calibration Description. TI parameters and performance specifications which pertain to this calibration are listed in tables 1 and 2.

NOTE

Secondary Reference Laboratories are not equipped to calibrate Class 3 weights over the entire range while maintaining a four-to-one accuracy ratio.

NOTE

The transposition technique is no longer recommended by NIST and should only be used if the ballast weight required for the substitution technique cannot be assembled.

NOTE

NIST Class F tolerances have replaced the old NBS tolerances (P, Q and C) for field standard weights.

Table 1. NIST Class F Weight Tolerances

Metric		Avoirdupois			Apothecary		Grains	
TI (metric)	Tolerance	TI	Metric equivalent[1]	Tolerance	TI	Tolerance (mg)	TI	Tolerance (mg)
100 kg	10 g	200 lb	90.718474 kg	9.1 g	12 oz ap	70	10 000	70
50 kg	5 g	100 lb	45.359237 kg	4.5 g	10 oz ap	62	5 000	70
30 kg	3 g	50 lb	22.679619 kg	2.3 g	6 oz ap	37	3 000	39
25 kg	2.5 g	30 lb	11.339809 kg	1.4 g	5 oz ap	31	2 000	26
20 kg	2 g	25 lb	9.071847 kg	1.1 g	4 oz ap	25	1 000	13
10 kg	1 g	20 lb	6.803886 kg	910 mg	3 oz ap	19	500	6.5
5 kg	0.5 g	10 lb	4.535924 kg	450 mg	2 oz ap	12	300	3.9
3 kg	0.3 g	9.5 lb	4.309128 kg	430 mg	1 oz ap	6.2	200	2.6
2 kg	0.2 g	8 lb	3.628739 kg	363 mg	6 dr ap	4.7	100	1.6
1 kg	0.1 g	5 lb	2.267962 kg	230 mg	5 dr ap	3.9	50	1.3
500 g	70 mg	4 lb	1.814369 kg	181 mg	4 dr ap	3.1	30	1.1
300 g	60 mg	3 lb	1.360777 kg	140 mg	3 dr ap	2.3	20	0.98
200 g	40 mg	2 lb	907.185 g	91 mg	2 dr ap	1.7	10	0.78
100 g	20 mg	1 lb	453.592 g	70 mg	1 dr ap	1.4	5	0.63
50 g	10 mg	0.5 lb	226.796 g	45 mg	0.5 dr ap	1.1	3	0.53
30 g	6 mg	0.3 lb	136.078 g	27 mg	2 s ap	1.2	2	0.47
20 g	4 mg	0.2 lb	90.718 g	18 mg	1 s ap	0.98	1	0.38
10 g	2 mg	0.1 lb	45.359 g	9.1 mg	0.5 s ap	0.78	0.5	0.30
5 g	1.5 mg	0.05 lb	22.680 g	4.5 mg	- - -	- - -	0.3	0.26
3 g	1.3 mg	0.03 lb	13.608 g	2.7 mg	- - -	- - -	0.2	0.23
2 g	1.1 mg	0.02 lb	9.072 g	1.8 mg	- - -	- - -	0.1	0.18
1 g	0.9 mg	0.01 lb	4.536 g	1.5 mg	- - -	- - -	- - -	- - -
500 mg	0.72 mg	0.005 lb	2.268 g	1.2 mg	- - -	- - -	- - -	- - -
300 mg	0.61 mg	0.003 lb	1.361 g	0.99 mg	- - -	- - -	- - -	- - -
200 mg	0.54 mg	0.002 lb	907.18 mg	0.87 mg	- - -	- - -	- - -	- - -
100 mg	0.43 mg	0.001 lb	453.59 mg	0.70 mg	- - -	- - -	- - -	- - -
50 mg	0.35 mg	10 oz	283.50 g	57 mg	- - -	- - -	- - -	- - -
30 mg	0.30 mg	8 oz	226.80 g	45 mg	- - -	- - -	- - -	
20 mg	0.26 mg	4 oz	113.40 g	23 mg	- - -	- - -	- - -	- - -
10 mg	0.21 mg	2 oz	56.70 g	11 mg	- - -	- - -	- - -	- - -
5 mg	0.17 mg	1 oz	28.35 g	5.4 mg	- - -	- - -	- - -	- - -
3 mg	0.14 mg	1/2 oz	14.18 g	2.8 mg	- - -	- - -	- - -	- - -
2 mg	0.12 mg	1/4 oz	7.09 g	1.7 mg	- - -	- - -	- - -	- - -
1 mg	0.10 mg	1/8 oz	3.54 g	1.3 mg	- - -	- - -	- - -	- - -
- - -	- - -	1/16 oz	1.77 g	1.1 mg	- - -	- - -	- - -	- - -
- - -	- - -	1/32 oz	885.9 mg	0.87 mg	- - -	- - -	- - -	- - -
- - -	- - -	1/64 oz	443.0 mg	0.69 mg	- - -	- - -	- - -	- - -
- - -	- - -	1/128 oz	221.5 mg	0.56 mg	- - -	- - -	- - -	- - -

[1]Metric equivalent of avoirdupois weights shown for convenience. (1 pound mass = 453.59237 grams).

NOTE

ASTM E617-97 Class 3 and Class 7 have replaced the old NBS S-1 and T classifications respectively.

NOTE

To determine the tolerance of a non-metric TI, it must first be converted to metric. If TI value falls between those listed in table 2, use the lower tolerance.

Table 2. ASTM E 617-97 Weight Tolerances

TI (oz)	TI (lb)	TI metric	Tolerance ± mg (unless otherwise indicated)				
			Class 3	Class 4	Class 5	Class 6	Class 7
- - -		100 kg	---	2 g	5 g	10 g	15 g
- - -		50 kg	500	1 g	2.5 g	5 g	7.5 g
- - -	100	30 kg	300	600	1.5 g	3 g	4.5 g
- - -	- - -	25 kg	250	500	1.2 g	2.5 g	4.5 g
- - -	50	20 kg	200	400	1 g	2 g	3.8 g
- - -	30, 25[1]	10 kg	100	200	500	1 g	2.2 g
- - -	20	- - -	50[2]	100	250	500	1.4 g
- - -	- - -	5 kg	50	100	250	500	1.4 g
- - -	10	3 kg	30	60	150	300	1 g
- - -	APN 7916702[3]	- - -	- - -	- - -	- - -	- - -	9g
- - -	5	2 kg	20	40	100	200	750
- - -	3	1 kg	10	20	50	100	470
- - -	2	500 g	5	10	30	50	300
- - -	1	300 g	3[2]	6	20	30	210
10, 8[1]	0.5	200 g	2	4	15	20	160
5, 4[1]	0.3	100 g	1	2	9	10	100
2	0.2	50 g	0.60	1.2	5.6	7	44
- - -	0.1	30 g	0.45	0.9	4	5	44
1	0.05	20 g	0.35	0.7	3	3	33
1/2	0.03	10 g	0.25	0.5	2	2	21
1/4	0.02	5 g	0.18	0.36	1.3	2	13
1/8	0.01	3 g	0.15	0.3	0.95	2	9.4
1/16	0.005	2 g	0.13	0.26	0.75	2	7
1/32	0.003	1 g	0.10	0.2	0.5	2	4.5
- - -	0.002	500 mg	0.08	0.16	0.38	1	3
1/64	0.001	300 mg	0.07	0.14	0.3	1	2.2
1/128	0.0005	200 mg	0.06	0.12	0.26	1	1.8
- - -	- - -	100 mg	0.05	0.1	0.2	1	1.2
- - -	- - -	50 mg	0.042[2]	0.085	0.16	0.5	0.88
- - -	- - -	30 mg	0.038[2]	0.075	0.14	0.5	0.68
- - -	- - -	20 mg	0.035[2]	0.07	0.12	0.5	0.56
- - -	- - -	10 mg	0.030[2]	0.06	0.1	0.5	0.40
- - -	- - -	5 mg	0.028[2]	0.055	0.08	0.2	- - -
- - -	- - -	3 mg	0.026[2]	0.052	0.07	0.2	- - -
- - -	- - -	2 mg	0.025[2]	0.05	0.06	0.2	- --
- - -	- - -	1 mg	0.025[2]	0.05	0.05	0.1	- - -

[1]TI's listed together have the same tolerance (see note above).
[2]Cannot meet 4 to 1 accuracy ratio; set containing this weight must be calibrated at APSL.
[3]Special application 5 lb hanger assembly.

SECTION II
EQUIPMENT REQUIREMENTS

4. Equipment Required. Table 3 identifies the specific equipment to be used in this calibration procedure. This equipment is issued with Secondary Reference Calibration Standards Set NSN 4931-00-621-7878. Alternate items may be used by the calibrating activity when the equipment listed in table 3 is not available. The items selected must be verified to perform satisfactorily prior to use and must bear evidence of current calibration. The equipment must meet or exceed the minimum use specifications listed in table 3. The accuracies listed in table 3 provide a four-to-one ratio between the standard and TI. Where the four-to-one ratio cannot be met, the actual accuracy of the equipment selected is shown in parenthesis.

5. Accessories Required. The accessories required for this calibration are common usage accessories, issued as indicated in paragraph **4** above, and are not listed in this calibration procedure.

Table 3. Minimum Specifications of Equipment Required

Common name	Minimum use specifications	Manufacturer and model (part number)
BALANCE NO. 1	Range: 10 to 100 kg Readability: (10 mg)	HNU-Voland Model HCE100
BALANCE NO. 2	Range: 200 g to 5 kg Readability : (1mg)	Sartorius LC 5101S
BALANCE NO. 3	Range: 0.1 mg to 200 g Readability: (0.01 mg)	Mettler, Model AE200MC
WEIGHT NO. 1	Range: 50 lbs (1 each) Accuracy: APSL test report	(7909945)
WEIGHT NO. 2	Range: 20 lbs (1 each) Accuracy: APSL test report	(7910453)
WEIGHT SET NO. 1	Range: 0.001 to 0.5 lb 1 each 0.001, 0.005, 0.01, 0.05, 0.1, 0.5 lb) (2 each 0.002, 0.02, 0.2 lb) Accuracy: APSL test report	(7907377)
WEIGHT SET NO. 2	Range: 1 to 25 lbs (1 each 1, 5, 25 lbs) (2 each 2, 10 lbs) Accuracy: APSL test report	(7907378)
WEIGHT SET NO. 3	Range: 1/64 to 10 oz (1 each 1/32, 1/16, 1/8, 1/4, 1/2, 1, 2, 4, 5, 10 oz) (2 each 1/64 oz) Accuracy: APSL test report	(7909971)

Table 3. Minimum Specifications of Equipment Required - Continued

Common name	Minimum use specifications	Manufacturer and model (part number)
WEIGHT SET NO. 4	Range: 1 mg to 100 g (1 each 1, 2, 3, 5, 10, 20, 30, 50, 100 g) (1 each 1, 2, 3, 5, 10, 20, 30, 50, 100, 200, 300, 500 mg) Accuracy: APSL test report	(7907068)
WEIGHT SET NO. 5	Range: 100 g to 1 kg (1 each 100 g, 500 g, 1 kg) (2 each 200 g) Accuracy: APSL test report	(7907379)

SECTION III
CALIBRATION PROCESS

6. Preliminary Instructions

a. The instructions outlined in paragraphs **6** and **7** are preparatory to the calibration process. Personnel should become familiar with the entire bulletin before beginning the calibration.

b. Items of equipment used in this procedure are referenced within the text by common name as listed in table 3.

c. Unless otherwise specified, verify the result of each test and, whenever the test requirement is not met, take corrective action before continuing with the calibration. Adjustments required to calibrate the TI are included in this procedure. Additional maintenance information is contained in the manufacturer's manual for this TI, NIST Handbook 145 and 105-1.

7. Equipment Setup

a. Ensure that all balances to be used are visually clean, free of obvious vibration, direct sunlight, draft, and direct heat radiation.

b. Exercise balances properly and establish center rest point on balance prior to use.

c. Clean TI with methyl alcohol and allow ambient stabilization of 4 hours for weights 1 pound or less, and 12 hours for weights over 1 pound.

d. The balances used in this procedure are CNR items. They are used as comparators to compare the TI to a standard mass. The order (sequence) in which the weighings are performed is critical since it accounts for the zero drift (linear) of the balance.

e. Sensitivity is the response of a balance under load to an additional small weight. A sensitivity weight is used during weighings to calibrate the range of use of the balance, thereby correcting the inaccuracy of the balance indication. The sensitivity weight selected

should be at least four times the value of the mass difference between the TI and standard but less than half the digital range of the balance.

f. Several smaller standard weights (from table 3) may be summed to make up the required standard, however, try to minimize the total number of weights used in order to reduce the total uncertainty of the measurement.

g. NIST recommends that the substitution technique be performed when using a double-pan balance by placing a ballast weight on the right pan, while the standard and TI are substituted on the left pan (treat as a single pan). The ballast weight must be the same nominal value as the TI, can be made up of any available weights, and does not require calibration. The accuracy of the double substitution technique is limited only by the accuracy of the standard weights used and the reproducibility of the balance.

h. Balance no. 1 is to be used for TI's above 5 kg and may be used for oversized Class F and Class 7 TI's 300 g and above. Balance no. 2 is to be used for TI's between 200 g and 5 kg. Balance no. 3 is to be used for TI's 200 g and below.

8. Substitution Technique

a. Performance Check

(1) Empty balance pan(s) and zero appropriate balance.

NOTE

If balance no. 1 is to be used, then perform step (2), otherwise proceed to step (3).

CAUTION

Balance no. 1 must be arrested before placing or removing weights.

(2) Place ballast weight of the same nominal value as TI on right pan and perform the remaining steps on the left pan (treat like a single pan balance).

(3) Place standard weight (Std) of the same nominal value as TI on balance.

(4) Record balance indication on substitution worksheet (see table 4).

(5) Replace standard weight with TI and repeat step (4).

Table 4. Substitution Worksheet

Observation number	Load	Balance indications
0_1	Std	- - -
0_2	TI	- - -
0_3	TI + sw	- - -
0_4[1]	Std + sw	- - -

[1]Optional check that makes up the double substitution technique.

(6) Place sensitivity weight (sw) on balance pan and record indication.

NOTE

If TI is Class 3 or Class 4 then perform step (7) for double substitution, otherwise proceed to step (8).

(7) Replace TI with standard weight (sensitivity weight remains) and repeat step (4).

(8) Compute TI actual mass using the appropriate formula below:

Single Substitution:

$$A = B + K (0_2 - 0_1)$$

Double Substitution:

$$A = B + K \frac{(0_2 - 0_1) + (0_3 - 0_4)}{2}$$

Where: A = TI actual mass.
B = Conventional mass of standard weight from test report.
$K = \frac{sw}{(0_3 - 0_2)}$
sw = Conventional mass of sensitivity weight from test report.

Subscripts indicate the order of weighings.

EXAMPLE (Double Substitution):
TI nominal weight was 5 lbs or 2267.9619 g
Standard weight (Std) = 4.9999902 lbs or 2267.957405 g from APSL test report
Sensitivity weight (sw) = 0.100 g

0_1 = Std = 2267.945 g
0_2 = TI = 2267.949 g
0_3 = TI + sw = 2268.049 g
0_4 = Std + sw = 2268.046 g

$$A = B + \frac{sw}{0_3 - 0_2} \times \frac{(0_2 - 0_1) + (0_3 - 0_4)}{2}$$

$$A = 2267.957 + \frac{0.100}{(2268.049 - 2267.949\ g)} \times \frac{(2267.949 - 2267.945) + (2268.049 - 2268.046)}{2}$$

A = 2267.961 g = 4.9999893 lbs

(9) Determine difference between TI actual mass and nominal value. Difference will not exceed tolerance value listed in appropriate tolerance table. If tolerance is exceeded, perform **b** below (R).

(10) Repeat (2) through (9) above for each weight being calibrated, using tolerance listed in appropriate tolerance table.

b. Adjustments. Adjust weight, using appropriate procedure of paragraph **10** below.

9. Transposition Technique (Alternative Method)

NOTE

This technique should not be used to calibrate Class 3 TI.

a. Performance Check

CAUTION

Balance no. 1 must be arrested before placing or removing weights.

(1) Place TI on left pan of Balance no. 1.

(2) Place standard weight of the same nominal value as TI on right pan of balance.

(3) Allow balance to stabilize and record indication using worksheet similar to table 5.

NOTE

If balance oscillates, then take the average indication.

Table 5. Worksheet (Transposition)

Observation number	Load		Balance Indication
	Left pan	Right pan	
0_1	TI	Std	- - -
0_2	Std	TI	- - -
0_3	Std + sw	TI	- - -
0_4[1]	TI+ sw	Std	- - -

[1]Optional check that makes up the double transposition technique.

(4) Transpose TI and standard weight and repeat (3) above.

(5) Place sensitivity weight on left pan and repeat (3) above.

NOTE

If TI is Class 4, then perform step (6) for double transposition, otherwise proceed to step (7).

(6) Transpose TI and standard weight only (sensitivity weight remains on left pan) and repeat step (3) above.

(7) Compute TI actual mass, using the appropriate formula listed below:

Single Transposition:

$$A = B + K \frac{(0_1 - 0_2)}{2}$$

Double Transposition:

$$A = B + K \frac{(0_1 - 0_2) + (0_4 - 0_3)}{4}$$

Where: A = TI actual mass.
B = Conventional Mass of standard weight from test report.
$K = \frac{sw}{0_3 - 0_2}$
sw = Conventional mass of sensitivity weight from test report.

EXAMPLE:
The following example was taken from a special purpose weight calibration problem using the single transposition method with a large double pan balance.
Standard weight (Std) made by summing three standard weights was equal to 44.800 lbs, the approximate nominal value of the test weight. A sensitivity weight (sw) of 0.005 lb was chosen.

Observations: $0_1 = 0.125$
$0_2 = -0.25$ and
$0_3 = 0.3125$
Since:

$$A = B + \frac{sw}{0_3 - 0_2} \times \frac{(0_1 - 0_2)}{2}$$

Then

$$A = 44.800 + \frac{0.005}{0.3125 - (-0.25)} \times \frac{0.125 - (-0.250)}{2}$$

$A = 44.8000 + 0.0088 \times 0.1875$
$A = 44.800 + 0.0017 = 44.8017$
$A = 44.8017$ lbs.

(8) Determine difference between TI actual mass and nominal value. Difference will not exceed the tolerance table. If tolerance is exceeded, perform **b** below (R).

(9) Repeat (1) through (8) above for each weight being calibrated, using tolerance listed in appropriate tolerance table.

b. Adjustments. Adjust weight, using appropriate procedure of paragraph **10** below.

10. Weight Adjustments. Adjustments may be made where applicable, as follows:

a. Knob-Type Weights. Unscrew knob and remove excess weight from the cavity or from the threaded end of knob; to increase weight, add small weights to the cavity.

b. Sealer-Type Weights. Remove or add weight as necessary and reseal.

c. Round-Type Weights. Remove weight by drilling holes. Add weight by using solder or lead.

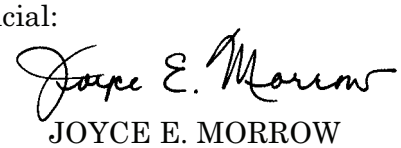
d. Flat-Thin Weights. Weight should be removed from edges of weights. No weight can be added.

11. Final Procedure. Annotate and affix DA label/form in accordance with TB 750-25.

By Order of the Secretary of the Army:

GEORGE W. CASEY, JR.
General, United States Army
Chief of Staff

Official:



JOYCE E. MORROW
Administrative Assistant to the
Secretary of the Army

0719701

Distribution:

To be distributed in accordance with STD IDS No. RLC-1500, 2 January 2003, requirements for calibration procedure TB 9-6670-254-40.

Instructions for Submitting an Electronic 2028

The following format must be used if submitting an electronic 2028. The subject line must be exactly the same and all fields must be included; however, only the following fields are mandatory: 1, 3, 4, 5, 6, 7, 8, 9, 10, 13, 15, 16, 17, and 27.

From: "Whomever" whomever@redstone.army.mil
To: <2028@redstone.army.mil

Subject: DA Form 2028

1. **From**: Joe Smith
2. Unit: home
3. **Address**: 4300 Park
4. **City**: Hometown
5. **St**: MO
6. **Zip**: 77777
7. **Date Sent**: 19-OCT –93
8. **Pub no:** 55-2840-229-23
9. **Pub Title**: TM
10. **Publication Date**: 04-JUL-85
11. Change Number: 7
12. Submitter Rank: MSG
13. **Submitter FName**: Joe
14. Submitter MName: T
15. **Submitter LName**: Smith
16. **Submitter Phone**: 123-123-1234
17. **Problem**: 1
18. Page: 2
19. Paragraph: 3
20. Line: 4
21. NSN: 5
22. Reference: 6
23. Figure: 7
24. Table: 8
25. Item: 9
26. Total: 123
27. **Text**

This is the text for the problem below line 27.