14.0 BALANCES AND UNCERTAINTY IN WEIGHTS AND MEASURES

14.1 Balances

14.1.1 Equipment and Quality Control

14.1.1.1 The TBI FCU uses a variety of electronic balances to determine the weight of submitted samples. All balances in use shall have weekly performance verifications also referred to as checks. Certified NIST-traceable weights that satisfy the criteria for a CRM will be used to conduct these checks. A performance check log sheet will be also be maintained in a location near each balance.

14.1.1.2 The accepted accuracy ranges for each type of balance used are listed below.

Acceptable Accuracy Ranges

Balance Type	Accuracy Range
Top loading (dual range)	± 0.01 grams or ± 0.1 grams
Pound	± 0.1 pounds

14.1.1.3 The analyst will conduct performance checks using the static weighing procedure. Static weighing is defined in Chapter 3.

14.1.1.4 If a balance performance check falls outside of the acceptable range, then an auto-calibration program inherent to the balance will be performed. After the program has completed, the performance check will be repeated. Balances that fail the repeated performance check will be removed from service, and the unit supervisor will be notified.

14.1.1.5 The analyst will routinely use the balance located at his or her workstation. However, if another balance is used, the analyst must ensure that the balance is current on performance checks and document the identity of the balance in the case record.

14.1.1.6 New balances received by the TBI FCU must be performance checked by qualified personnel using the existing performance criteria before being placed into service.

14.1.1.7 All balance sheets are located in the Lab Documentation folder in Ensur.

14.1.1.8 Refer to the Quality Assurance chapter of the Forensic Chemistry Manual for balance and weight certification, storage, and transport policies.

14.1.2 Balance operation

- Ensure that the balance is powered on, level, and clean.
- Performance check the balance if needed.
- Tare the balance. If weigh paper, a weigh boat, or another type of container is used, tare the balance after placing the container on the pan.
- Place the sample on the tared container and record the weight (dynamic weighing)

OR

- Remove the container, place the sample in the container, and record the weight (static weighing)
- Remove the sample from the balance pan.
- Dispose of the weighing container, or clean the container if it is not disposable.
- Clean the balance pan as necessary.

Refer to balance logbook or the Ensur document control system for more detailed operating instructions.

14.2 Uncertainty in Weights and Measures

14.2.1 The measurement of uncertainty of the balances will be three (3) times the readability of the balance. This uncertainty measurement will give the TBI FCU a confidence level of 99.7% for mass determinations. Refer to the Balance Measurement of Uncertainty Logbook for additional information.

14.2.2 Measurement of uncertainty will be calculated once per calendar year.

14.2.3 Uncertainty calculations – Single Dynamic weighing events

Since dynamic weighing events count as one weighing event, the measurement of uncertainty will be reported as follows:

Example 1: The reading from the balance is 1.23 grams, and the readability is 0.01 grams. The measurement of uncertainty would be 1.23 ± 0.03 grams.

Example 2: The reading from the balance is 450.2 grams, and the readability is 0.1 grams. The measurement of uncertainty would be 450.2 ± 0.3 grams.

14.2.4 Uncertainty calculations – Single Static weighing events

Static weighing events count as two weighing events. The equation to calculate measurement of uncertainty for a single measurement is defined in Equation 1.

Equation 1

$$U = \sqrt{N(W) * (U_b)^2}$$

U = Total uncertainty

N = Number of measurements

W = Weighing type (static or dynamic)

- When using dynamic weighing: W = 1
- When using static weighing: W = 2

U_b = Uncertainty of balance

Example 3: The static weighing event reading from the balance is 1.23 grams. Uncertainty will be calculated as follows.

$$\sqrt{1(2) * (0.03^2)}$$

U = ± 0.042 grams

U = ± 0.04 grams (conventionally rounded to two significant figures)

14.2.5 Uncertainty calculations – Multiple weighing events

Equation 1 can be also be applied to calculate the uncertainty (U) for multiple weights using the same balance and the same type of weighing events.

Example 4: The same balance was used to obtain the weight for five bags using dynamic weighing events. The uncertainty for the balance in this range for a single measurement is 0.03 grams. The table below shows the weights of the substances in the five bags using this balance.

Example 4 Table

Bag #	Weight (g)
1	0.56
2	0.62
3	0.73
4	1.35
5	0.32

$\sqrt{5(1) * (0.03^2)}$

U = ± 0.067 grams

U = ±0.07 grams (conventionally rounded to two significant figures)

Example 5: Using the same information as in example 4 the following calculation demonstrates how to use this equation for five static weighing events.

$\sqrt{5(2) * (0.03^2)}$

U = ± 0.094 grams

U = ±0.09 grams (conventionally rounded to two significant figures)

14.2.6 Uncertainty calculations – Multiple measurements on the same balance with multiple readabilities

Equation 2 can be applied to calculate the uncertainty (U) for multiple weights using the same balance but with different readabilities.   .

Equation 2

$$U = \sqrt{N_{gram}(W)(U_{gram})^2 + N_{gram}(W)(U_{gram})^2}$$

Example 6: Uncertainty calculation for same balance with one or more readabilities (dual range balances) using dynamic weighing events

Example 6Table

Bag #	Weight (g)
1	9.56
2	2.54
3	3.07
4	451.1
5	350.9
6	300.1

$\sqrt{3(1)(0.03)^2 + 3\ (1)(0.3)^2}$

$\sqrt{3(0.0009) + 3(0.09})$

$\sqrt{0.0027 + 0.27}$

$\sqrt{0.2727}$

U = ± 0.522 grams

U = ± 0.52 grams (conventionally rounded to two significant figures)

Example 7: Using the same information as in example six, the following calculation demonstrates how to use this equation for six static weighing events.

$\sqrt{3(2)(0.03)^2 + 3(2)(0.3)^2}$

$\sqrt{6(0.0009) + 6(0.09})$

$\sqrt{0.0054 + 0.54}$

$\sqrt{0.5454}$

U = ± 0.739 grams

U = ± 0.74 grams (conventionally rounded to two significant figures)

14.2.7 Uncertainty calculations – Multiple measurements with two or more balances with multiple readabilities

Equation 3

$$U = \sqrt{N_{gram}(W)(U_{gram})^2 + N_{pound}(W)(U_{pound})^2}$$

Example 8: A submission came into the laboratory that consisted of 3 plastic bags and 3 compressed blocks containing material that was visually consistent. Due to the different size of the containers, it is recommended that the analyst make separate exhibits. However, if this is not possible, then the following will be applied.

Table B1 (gram balance)

Bag #	Weight (g)
1	11.02
2	15.31
3	30.75

Table B2 (pound balance)

Bag #	Weight (lbs)
4	2.0
5	5.1
6	11.3

$\sqrt{3(1)(0.03 \div 454)^2 + 3(1)(0.3)^2}$

*Note that the gram uncertainty must be converted to pounds

$\sqrt{3(0.0000660793)^2 + 3(0.3)^2}$

The gram balance becomes insignificant when compared to the pound balance

$\sqrt{0.0000000131 + 0.27}$

U = ± 0.5196152549 pound (pound & gram balance)

U = ± 0.5196152423 pound (pound balance only)

U = ± 0.52 pound

Example 9: Using the same information as in example eight, the following calculation demonstrates how to use this equation for these static weighing events.

$\sqrt{3(2)(0.03 \div 454)^2 + 3(2)(0.3)^2}$

$\sqrt{6(0.0000660793)^2 + 6(0.3)^2}$

$\sqrt{0.0000000262 + 0.54}$

U = ± 0.7348469258 pound (pound & gram balance)

U = ± 0.7348469228 pound (pound balance only)

U = ± 0.73 pound

The uncertainty of the gram balance becomes insignificant and contributes a negligible amount to the total uncertainty.

14.2. Uncertainty calculations – Multiple measurements on the same balance with different weighing events

If a case requires a combination of static and dynamic weighing events on the same balance, the analyst will need to calculate the total number of weighing events (W) for calculating uncertainty

Example 10: An analyst used the same balance to obtain the weight of two bags. One weighing event was static and read 4.99 grams. The other event was dynamic and read 0.07 grams.

In this example, the following equation would be used to account for the combined events.

Equation 4

$$U = \sqrt{[(N_d(W_d) + N_s(W_s)] * (U_b)^2}$$

U = Total uncertainty

N = Number of measurements (N_d is dynamic and N_s is static)

W = Weighing type (W_d is dynamic and W_s is static)

- When using dynamic weighing: *W* = 1
- When using static weighing: *W* = 2

U_b = Uncertainty of balance

$$\sqrt{[1(1) + 1(2)] * (0.03)^2}$$

$$\sqrt{3(0.0009)}$$

$$\sqrt{(0.0027)}$$

U = ± 0.052 grams

U = ± 0.05 grams (conventionally rounded to two significant figures)

14.3 Volumetric Measurements

The TBI FCU will not report drug volumes or an associated measurement of uncertainty since the TCA §39-17-417 has weight penalty enhancements instead of volumes. Refer to the Reporting chapter for liquid reporting requirements.

14.4 Documentation and Reporting Guidelines

14.4.1 Given the various scenarios of drug cases, the analyst must clearly document in his or her case notes how the measurements were made so that uncertainty may be calculated.

14.4.2 All weighing events will have the type of weighing process (static versus dynamic) documented in the casefile.

14.4.3 Uncertainties will be calculated and reported when the measurement **and** the uncertainty range would place the exhibit either above or below a weight threshold limit as defined in the TCA §39-17-417. Refer to the Reporting chapter for the proper remarks.

14.4.4 The number of decimal places in the calculated uncertainty will match the number of decimal places in the reported measurement.

14.4.5 Conventional rounding rules will be applied to the uncertainty when calculated values exceed the appropriate number of decimal places.

14.5 References

1. Eurachem. *Quantifying Uncertainty in Analytical Measurement.* Third Edition. 2012
2. NIST. Recommended guide for Determining and Reporting Uncertainties for Balances and Scales. January 2002.
3. SWGDRUG. Measurement Uncertainty for Weight Determinations in Seized Drug Analysis Supplemental Document SD-3. July 2011.