

## SOP 34

### Standard Operating Procedure<sup>1</sup> for the Selection and Use of Sensitivity Weights and Tare Weights in Weighing Procedures

#### 1 Introduction

Mass calibration procedures are based on comparing the unknown mass,  $X$ , to a standard mass,  $S$ , utilizing the balance as a comparator. This comparison relies on the accuracy of balance indications. When balance indications are not accurate enough for precision mass calibrations, and they drift with time, appropriate procedural adjustments are required. Drift can often be assumed to be linear over a short period. Concerns over balance inaccuracy and drift result in two possible causes of errors in mass determination procedures. Inaccuracy of the balance indications can be corrected by incorporating a sensitivity weight in the procedure that calibrates the range of use of the optical scale (mechanical balances) or of the digital indications (electronic balances). Errors due to drift can be minimized by using the correct comparison method, selecting a suitable sensitivity weight, and by consistent timing within the procedure. The proper selection of procedures (GMP 12), the adherence to those procedures, and equal time intervals between weighing operations will allow the measured difference between  $X$  and  $S$  to be corrected for inaccuracy of the balance indications and for balance drift.

Mass comparison procedures rely on the unknown and standard masses to be nominally equal. When the mass standards are not near to each other, tare weights need to be used to bring them closer together. Tare weights in this case function as additional mass standards and are essentially be treated as additional mass standards in summation.

##### 1.1 Purpose

The following practice will guide you through the process of selecting and using a correct sensitivity weight and/or tare weight(s) for mass determination procedures.

##### 1.2 Prerequisites

1.2.1 Valid calibration certificates with appropriate values and sufficiently small uncertainties must be available for all the sensitivity weights and tare weights used in a calibration. All mass standards must have demonstrated metrological traceability to the international system of units (SI), which may be through a National Metrology Institute such as NIST.

1.2.2 Verify that weight-handling equipment is available and in good operational condition.

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<sup>1</sup> This SOP was formerly Good Measurement Practice 14 (2003, 2012) and provides the procedure and general guidelines for the use of tare weights and sensitivity weights.

- 1.2.3 Verify that the operator is familiar with the design and the operation of the balances and familiar with weighing procedures.

### 1.3 Safety

- 1.3.1 Handling of large or small weights can represent a hazard to either the weights or personnel if the weights are dropped.

## 2 Methodology

### 2.1 Summary

A sensitivity weight is selected to calibrate the balance over the range to be used in the measurement procedure. Minimizing the difference in mass values between  $X$  and  $S$  is critical when choosing an appropriate sensitivity weight. Therefore, tare weights may be necessary whenever the difference in mass values is significant. Minimizing the difference between  $X$  and  $S$  works to our benefit since the range of the measurements is minimized and reduces potential errors that can be introduced by nonlinearity or span inaccuracies of the balance as well as bringing the mass standards within range on mass comparators with limited weighing ranges.

### 2.2 Apparatus

Clean forceps to handle the weights, or gloves to be worn if the weights are to be moved by hand.

### 2.3 Procedure for selection

- 2.3.1 Conduct preliminary measurements to determine the approximate mass value for the difference between the standard and the unknown ( $X - S$ ).

- 2.3.2 Define the range of use for the balance to be used:

- 2.3.2.1 Equal arm – number of scale divisions

- 2.3.2.2 Mechanical – optical scale

- 2.3.2.3 Combination (Electro-mechanical) and Comparators – digital indications

- 2.3.2.4 Fully electronic – capacity

- 2.3.3 Determine the need for tare weights if the difference between  $X$  and  $S$  exceeds the values shown in Table 1, considering the impact of potential errors based on comparison with calibration uncertainties.

**Table 1. Recommended maximum difference between  $X$  and  $S$ .**

Balance	$(X - S)$
Equal arm	balance each other within one division on the scale
Mechanical	1/10 of the optical scale or the applicable tolerance depending on weight class and suitability <sup>a</sup>
Combination Electro-mechanical and Comparator	
Fully electronic	

<sup>a</sup>Evaluate the impact of potential errors on the uncertainty.

2.3.4 Select tare weights, if necessary, making sure that the difference between  $X$  and  $S$ , with the appropriate tare weights, is generally less than the values shown in Table 1. If weights are of equal nominal value and all are within applicable tolerances, the need for tare weights is rare. Tare weights or multiple standards in summation are often required for unequal nominal values.

2.3.5 Select a sensitivity weight within the ranges give according to Table 2. Round the estimated mass of the sensitivity weight to the nearest convenient standard nominal mass (1-2-3-5).

**Table 2. Selection of Sensitivity Weight.**

Balance	Procedures	Sensitivity Weight (Criteria should be met by the selected sensitivity weight.)
Equal Arm	SOP 3, 5, 6, 7, 8, 28	change turning points by about 20 %
Mechanical	SOP 4, 5, 7, 28 SOP 8	$\geq 4$ times $(X - S)$ <sup>a</sup> ; $\leq \frac{1}{2}$ optical scale, usually $\approx \frac{1}{4}$ optical scale
Combination Electro-mechanical and Comparator	SOP 4, 5, 7, 8, 28	$\geq 4$ times $(X - S)$ ; $\leq \frac{1}{2}$ digital range
Fully Electronic	SOP 4, 5, 7, 28 SOP 8	$\geq 4$ times $(X - S)$ ; $\geq 2$ times the applicable tolerance; $\leq 0.5$ % capacity

<sup>a</sup>4 times the difference between  $X$  and  $S$  is required to avoid flagged errors in the output report when using the NIST Mass Code.

- 2.3.6 A sensitivity weight is not required if using an electronic mass comparator or fully electronic balance that has been evaluated (with supporting data and documented analysis available), and which has ongoing periodic validation (e.g., prior to each use) to determine that the balance has sufficient accuracy, resolution, repeatability, and stability so that no advantage is gained by using a sensitivity weight. For example, any possible errors must be less than the last digit retained in the expanded uncertainty. Monitoring is required to verify metrological traceability. See calculations and uncertainties noted in Section 3.

## 2.4 Using sensitivity weights

- 2.4.1 The sensitivity weight is incorporated into the mass procedures to ensure that the mass differences determined with the optical scale, or electronic range, have valid accuracy and traceability. The sensitivity weight calibrates the range of use of the balance used for making the mass determinations. Using a sensitivity weight provides us with a sensitivity value in terms of mass units per division. If the sensitivity is not constant with time, temperature and load, its variation must be included in the mass correction and in the uncertainty. What follows is a generic equation for the sensitivity correction factor. Equations are modified in each SOP when buoyancy corrections are performed.

$$\text{sensitivity} = \frac{\text{mass units}}{\text{divisions}} = \frac{M_{sw}}{\text{deflection}} \quad \text{Eqn. (1)}$$

where  $M_{sw}$  represents the mass of the sensitivity weight.

## 3 Calculations

- 3.1 See each mass SOP for calculation of sensitivity as it is included in the procedure. Examples of sensitivity accuracy evaluation include the following:
- 3.1.1 SOP 8 – The error in sensitivity must be less than 2 percent of the balance reading. That is, the sensitivity factor portion of the mass calculation must be between 0.98 and 1.02 mass units per division when the sensitivity is equal to 1 (or 980 to 1020 if sensitivity is equal to 1000).
- 3.1.2 Comparison SOPs – The potential systematic error due to sensitivity inaccuracies may be calculated by determining the average observed deflection of a sensitivity weight divided by the mass of the sensitivity weight and multiplied by the average or maximum difference between  $X$  and  $S$ , from the following equation:

$$\text{Potential sensitivity error} = \left| \frac{\text{Observed deflection} - M_{sw}}{M_{sw}} \right| \times \text{Average max } d \quad \text{Eqn. (2)}$$

The applicable tolerance may be substituted for the average maximum difference between  $X$  and  $S$ ,  $d$ .

#### 4 Uncertainty

- 4.1 Sensitivity errors that may be incorporated in SOP 8 where sensitivity is assessed but not included in the calculations need to be evaluated and included as an uncorrected systematic error in the uncertainty (treated as a rectangular distribution), according to this approach and to instructions in SOP 8.
- 4.2 The uncertainty of the sensitivity weight may be treated in the same way as the difference between the observed deflection and mass of the sensitivity weight in the equation given in 3.1.2 to determine significance.

$$\text{Potential sensitivity uncertainty} = \left| \frac{u_{sw}}{M_{sw}} \right| \times \text{Average max } d \quad \text{Eqn. (3)}$$

Again, the applicable tolerance may be substituted for the average maximum difference,  $d$ . The uncertainty of the sensitivity weight is generally relatively small and insignificant. However, it does no harm to incorporate it in uncertainty calculations when spreadsheets are set up to handle all of the data which will account for possible larger uncertainties on sensitivity weights.

The resulting systematic errors that are calculated in Section 3.1.2 that are evaluated and not corrected as a part of the procedure may be treated as a rectangular distribution in combination with all other sources of uncertainty. Note: An alternative equation such as C.6.4.2, from OIML R111 may be used as well.

- 4.3 Uncertainties associated with all tare weights are treated as if multiple standards are used in summation and evaluated accordingly (See SOP 29 for references to dependencies).

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