Accuracy Calculator explanation.

There are two Accuracy Calculator sheets: NTEP Class III and Precision. Each of the two sheets has two calculators, so a total of four calculators are available.

The calculators provide a tool for estimating the percentage of accuracy for an applied load on a particular scale. One calculator on each sheet has scale specifications preloaded so the user can select from a list, the second calculator on each sheet is “free” and the user can populate the scale performance specifications or the actual performance test data.

The calculators may be used as “Minimum Weight” calculators but the minimum weight will be determined by the user, through successive approximation and evaluating each result.

NTEP Class III

The NTEP Class III calculators are for estimating accuracy based upon performance specs from NTEP (a third party, as it is not the manufacturer or the owner of the scale). When using the free input calculator care must be taken to use the correct approved readability, e (d), otherwise the accuracy result will be incorrect.

Precision

The precision calculator can be used for virtually any scale provided the user can supply valid and correct input data. The results can not be interpreted as legal for trade as that is an agency function.

How the accuracy is determined.

NTEP Class III accuracy estimation method.

To determine the accuracy for an applied load in the NTEP calculator, the applied load is converted to a number of approved scale divisions, e. The applied load in divisions is categorized according the HB44 Table 6 Tolerances. The Table 6 is “maintenance tolerances”, these are divided by two to determine the acceptance tolerances. The corresponding acceptance tolerance is linked with the applied load for evaluation, this value we call “Systematic Component”. In addition to the systematic component of scale error there is also a random component. The random component is extrapolated from the approved division size, e, taken from the NTEP certificate. The random component is extrapolated according to chapter 3 of the NIST document “NISTIR 6919 Recommended Guide for Determining and Reporting Uncertainties for Balances and Scales” published by NIST in January 2002. The equation used for extrapolating the repeatability error (random error, uncertainty) is:

Mettler Toledo

$$S_p = (½) \times (d/\sqrt{3})$$

S_p is standard deviation

d = the approved division size "e".

The final calculated error is the sum of the systematic component and the random component. The percentage of error is the sum of errors divided by the applied load.

% Error = (sum of errors / applied load) x 100

Note: If the individual errors including standard deviation of the repeatability can be determined by testing the scale, the user can use the "Precision" calculator to estimate the accuracy.

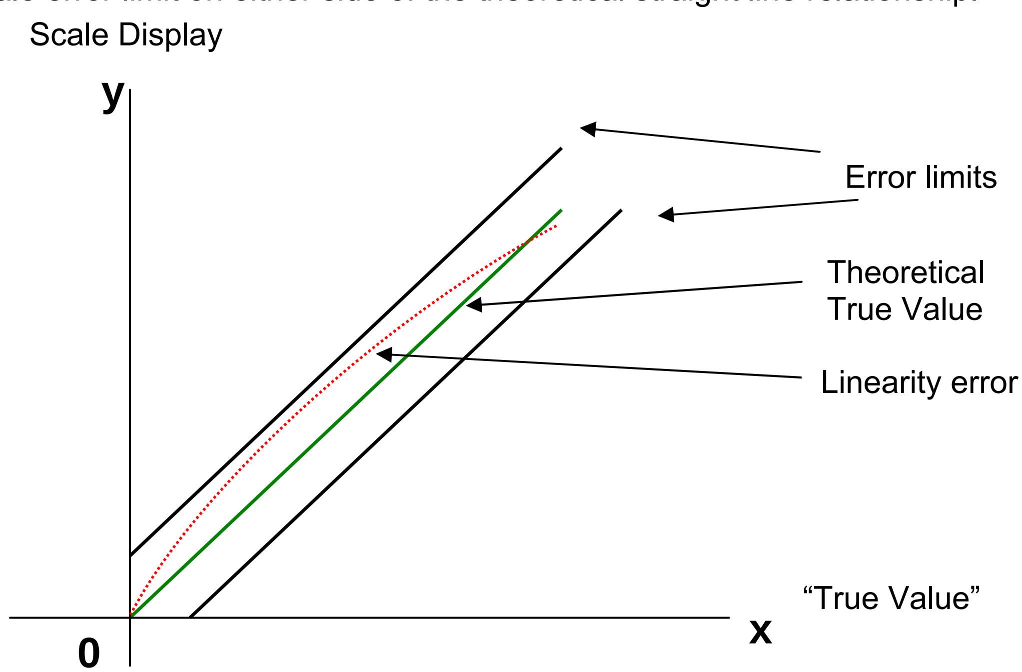
Precision scale accuracy estimation method.

The error in the precision calculator is calculated by summing the estimated "systematic component" and the "random component".

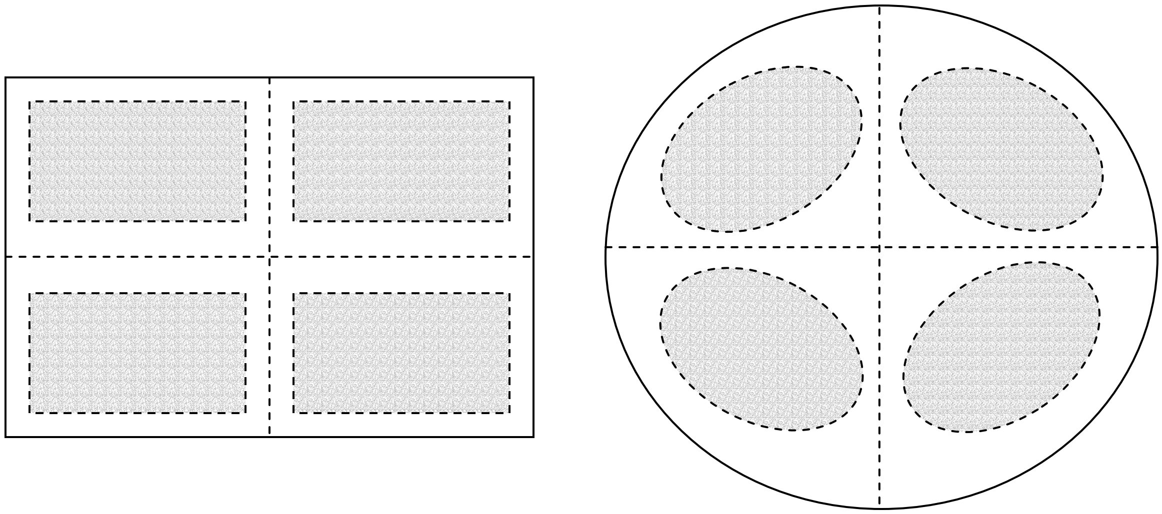
The systematic component of error consists of errors which can be identified, separated from other factors and quantified. These factors are:

Linearity
Eccentricity
Sensitivity

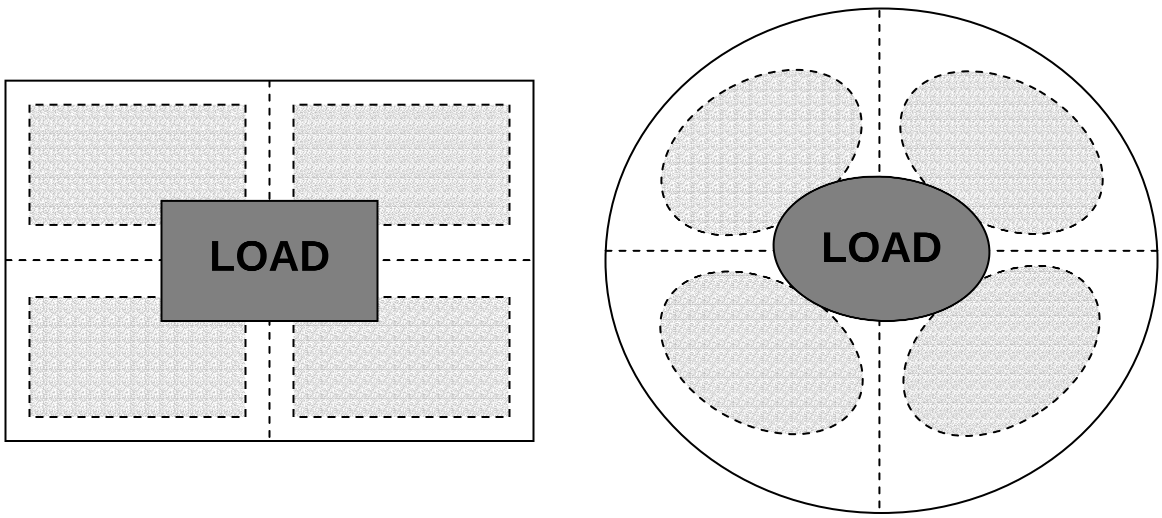
Linearity: Linearity is the deviation from a straight line which a theoretical perfect scale would produce if the "true value" were plotted on the x-axis and the scale result were plotted on the y-axis of an x-y chart. The linearity error is the band of scale error limit on either side of the theoretical straight line relationship.



Eccentricity: Eccentricity is the error caused by placing the applied load at a location on the scale load receiver other than the center. The eccentricity error is determined according to OIML R76-1 (Table 6, section 3.6.2 and appendix A.4.7). In general this amounts to loading 1/3 capacity of load at off center locations on the load receiver, see diagram below.



The user has considerable influence over the loading of the scale, thus can reduce the associated eccentricity error by loading the scale in the center, hence improving the weighing performance. This should be considered by the user.

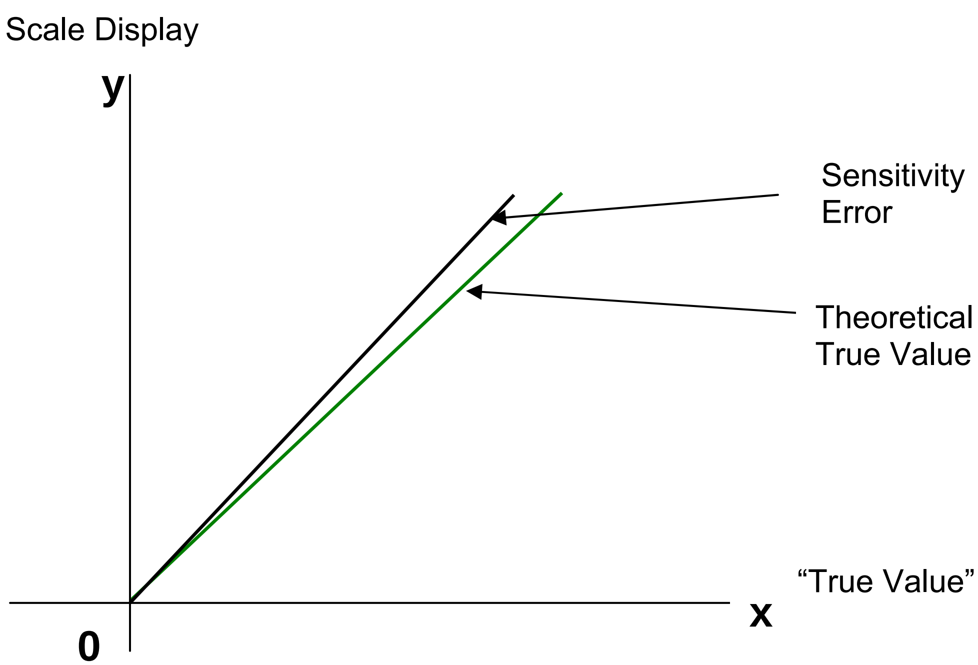


Sensitivity: The word sensitivity can have different meanings; we are using it as "sensitivity error" and is a measure of deviation between the slope of the scale display and the slope of the "true value" of the applied load. This is frequently referred to as calibration error. The sensitivity error is quantified by the following equation and is applied as a percentage of error.

Sensitivity error = $\Delta L / \Delta m$

ΔL = change in the scale display

Δm = change in the applied load



Each of these three factors is independently quantified and then summed to determine the systematic component, this is the worst case. In practice there is the opportunity that these factors could partially offset each other, thus reducing the summed systematic error.

Sum of errors: The systematic error is then summed with the random component. The random component is the repeatability error of the scale. This value must be declared by the manufacturer or determined in the field through testing of the scale.

The sum of errors is further tested to see if it exceeds a "minimum error". If it does not, then the "minimum error" is used to determine the accuracy.

Minimum error.

With the “precision scale” calculator the systematic error becomes smaller as the load is decreased, reaching a point where the systematic error becomes insignificant. At this point the error is essentially induced by the random (uncertainty) component, which we define as repeatability. With small errors due only to repeatability, the readability (the division size of the scale display) becomes more significant and should not be ignored.

How do we determine the readability error? The readability error is essentially a binomial distribution because the assumed “true value” lies between two successive display divisions. Over an infinite population the standard deviation of the readability error is:

$$\sigma_E = \sqrt{\int_{-0.5}^{0.5} e^2 p_E \langle e \rangle \, de} = \sqrt{\frac{1}{12}} \approx 0.289$$

In a binomial trial with event probability of 0.1

$$\sigma_B = \sqrt{p(1-p)} = \sqrt{0.1 \cdot 0.9} = 0.3$$

Using a readability error standard deviation of 0.3 divisions, we have two opportunities for the readability to influence the weighing result. The initial reading before applying the load and the final reading after applying the load. The standard deviation of the readability error for one “weighing” is therefore:

One weighing (final - initial): $s^*net \approx \sqrt{2} \cdot (0.3\ d) \approx 0.4\ d$

The **overriding minimum error** for the precision calculator is the normalized standard deviation of the combined repeatability and readability errors.

$$\text{Minimum Error }(s) = \sqrt{(s)^2 + (0.4d)^2}$$

End