WELMEC 2.8
Issue 1

# WELMEC

**European cooperation in legal metrology**

# Guide for Conversion of NAWI (Indicators) Test Results for AWI Purposes

May 2008

# WELMEC

**European cooperation in legal metrology**

WELMEC is a co-operation between the legal metrology services of the Member States of the European Union and EFTA. This document is the introduction to WELMEC.

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BEV – Bundesamt für Eich- und Vermessungswesen
Schiffamtsgasse 1-3
A-1025 Vienna

e-mail : welmec@bev.gv.at
website: www.welmec.org

The objective of this guide is to supply the background to simply using results of tests performed on NAWIs based on EN 45501 and OIML R76/2006.

A main prerequisite is that the AWI that is to be approved on these test results is not working dynamically (load in relative motion to the load receptor when being weighed), that is this guide does not cover e.g. checkweighers equipped with conveyors that do not stop for weighing. However, with instruments filling material e.g. in a weighing hopper this guide is applicable, although the material may not be completely at rest when being weighed.

Instead of offering detailed schemes for calculation the guide shows the principle and, if useful, supplies examples to make necessary calculation more transparent (e.g. for gravimetric filling instruments).

When cited the requirements are taken from the following OIML recommendations:

- R51/2006
- R61/2004
- R76/2006
- R107/1997

The guide is divided into three chapters:

I. Automatic catch weighers
II. Discontinuous totalizers
III. Automatic gravimetric filling instruments

General considerations

When converting test results from R76 to R51/ R61/ R107 normally

- An indicator* is tested, that does not have an e or d but only a minimum microvolt per e or d and a maximum number of scale intervals.
- The manufacturer wants to build a wide range of types of instruments with different maximum loads (Max), minimum load (Min) and (verification) scale intervals (e, d).

*including the A to D converter

I. Automatic catchweighers (OIML R51, MID MI-006 Chapter II)

I.A. The catchweigher may be considered as an automatised NAWI. A similar error regime applies for class Y instruments, yet allowing an extra error portion with regard to accuracy of zero setting.

The error of zero plays an important part especially for those instruments that do not perform a zero setting before each weighing. The error of zero directly adds to the error of the weighing. Thus the following zero errors have to be considered:

a) Zero error due to warm up effects: Error at zero must have been checked during warm up time test otherwise this test has to be repeated for zero.
b) Zero error due to temperature drift: The results of the “Temperature effect on the no-load indication” test (R76, A.5.3.2) have to be taken into account. Since OIML / IEC assumes a change of temperature of not more than 5 K/h and R76 requires zero drift to be checked per 5 K, the zero drift error due to change of temperature can be calculated for a certain period of time. Vice versa the longest time interval between zero settings may be calculated on basis of the maximum permissible error of zero and the measured drift over temperature difference of 5 K (temperature differences are not expressed in °C but in K = Kelvin, however this does not matter for the calculations).

I.B. Calculation examples for considering zero error

a) Assumptions: Drift of zero during warm up time of 0.5 h: $\Delta z$ = 1 e, linear drift over time
After 15 minutes the drift is supposed to have reached the 0.5 e limit for allowed inaccuracy of zero. So at latest after 15 minutes the instrument has be re-set to zero again.
If zero drift has not been observed since the NAWI has been set to zero each time before applying the load, then the test should be repeated observing zero, but reading weights (zero and Max) more often than prescribed by R76. The reason is that the tendency of the drift might change and with longer periods of time between reading zero the maximum absolute drift may be missed. Thus at least zero should be read e.g. every minute.

b) Assumptions: Drift of zero due to temperature drift: 0.25 e / 5 K
Provided temperature drift does not exceed 5 K per hour, the maximum drift of zero (that is zero error) of 0.5 e is reached after:

0.25 e / 5 K at 5 K / h leads to 0.5 e / 2 h that is the instrument has to reset to zero at latest after 2 h.

II. Discontinuous totalisers

II.A For totalisers employing the principle of discharge weighing the drift of zero due to warm up effects or due to temperature drift does not affect the weighing result since the instrument is tared before each discharge (weighing).

For instruments that do not perform tare after each discharge the maximum zero error is 1 $d_t$ (instrument having an *automatic* zero setting device) or 0.5 $d_t$ (instrument having a *non*automatic zero setting device).The error of zero directly adds to the error of the weighing. Thus the following zero errors have to be considered:

a) Zero error due to warm up effects: Error at zero must have been checked during warm up time test otherwise this test has to be repeated for zero.
b) Zero error due to temperature drift: The results of the "Temperature effect on the no-load indication" test (R76, A.5.3.2) have to be taken into account. Since OIML / IEC assumes a change of temperature of not more than 5 K/h and R76 require zero drift to be checked per 5 K the zero drift error due to change of temperature can be calculated for a certain period of time. Vice versa the longest time interval between zero setting may be calculated on basis of the maximum permissible error of zero and the measured drift over temperature difference of 5 K.

II.B. Calculation examples for considering zero error

a) Assumptions: Drift of zero during warm up time of 0.5 h: $\Delta z = 1$ e, linear drift over time, automatic zero setting device is working.
After 30 minutes the drift is supposed to have reached the 1 e limit for allowed inaccuracy of zero. So at latest after 30 minutes the instrument has be re-set to zero again.
If zero drift has not been observed since the NAWI has been set to zero each time before applying the load, then the test should be repeated observing zero, but reading weights (zero and Max) more often than prescribed by R76. The reason is that the tendency of the drift might change and with longer periods of time between reading zero the maximum absolute drift may be missed. Thus at least zero should be read e.g. every minute.

b) Assumptions: Drift of zero due to temperature drift: 0.25 e / 5 K, automatic zero setting device is working
Provided temperature drift does not exceed 5 K per hour, the maximum drift of zero (that is zero error) of 1 e is reached after:

0.25 e / 5 K at 5 K / h leads to 1 e / 4 h that is the instrument has to reset to zero at latest after 4 h.

## II.C Special matters to be considered

OIML R107 requires the totalisation device to be tested e.g. under temperature that is “it must be verified that the recorded total is retained during and after application of influence factors and disturbances”. However, the recorded total is digitally stored and according to agreements within WG2 digital devices are only tested for EMC, if at all. So it does neither seem to be necessary to check retained total under influence factors nor has the NAWI / indicator been tested on that.

According to OIML R107 the retained total shall also be checked under disturbances. This makes sense only if the record is stored within a memory separate from the standard RAM. The standard RAM area is deemed to be tested during the normal NAWI / indicator disturbance test since any influence on the RAM would normally have led to obvious reactions of the NAWI. Thus, if the retained total is stored in the standard RAM area, then the normal NAWI disturbance test would have revealed that it could have been affected. So no explicit check of the retained total is necessary during the disturbance test.

Transient disturbances may have an effect on the totalisation if the totaliser does not use the stability of equilibrium criteria of the totaliser. Then the indication has to be observed for transient changes under disturbances.

# III. Automatic gravimetric filling instruments

## III.A Tests of importance for conversion

- An indicator* is tested, that does not have a d but only a minimum microvolt per d and a maximum number of scale intervals.
- The manufacturer wants to build a wide range of types of instruments with different maximum loads (Max), minimum load (Min) and scale intervals (d), as well as different Minfills.
- Minfill is unknown.

Influence factors and disturbances having an effect on the result of the fill:

1. The change of span

   Tests to be considered: temperature and damp heat

2. The change of zero

   Tests to be considered: accuracy of zero / tare setting, temperature (drift of zero), warm up (drift of zero)

3. Faults due to disturbances

   Tests to be considered: short time power reductions, bursts, surge, electrostatic discharges, radiated electromagnetic fields

Note:
Transitory faults can be very critical to filling machines, but these are not considered while testing according to R76 since they are regarded as being obvious to the user. Yet, with filling machines this is different, since the instrument could consider the set value to be reached due to a temporary disturbance increasing the weight indication, and thus might open the flaps of the weighing hopper. This would lead to incorrect fillings. Therefore, the results of R76 disturbance tests cannot be generally accepted for conversion to R61, unless the transitory faults have been taken into account in the R76 report.

## III.B Conversion of relevant test results

The error limits according R76 are based on the maximum number of scale intervals only, irrespective of the mass value of the scale interval, since they are given as fractions of the scale interval. This is not the case with R61 which introduces a completely different error regime based on the concrete mass values of the fill. Therefore the minimum microvolt per e / d or a corresponding number of digits have to be assigned to a concrete value of d in gram. The d has to be listed in the type approval certificate since the attainable minimum fill (Minfill) depends on this value. The smaller d is, the smaller the permissible Minfill will be. The value of d is independent of the minimum microvolt per d (e) the indicator is specified for, since it is the load cell of which the Max is crucial, provided that its output signal is sufficiently high to fulfil the requirement not to fall below the minimum voltage per d.

Generally the fill is affected by influences on the span and on zero of the instrument. The latter is especially critical for gravimetric filling machines since zero setting is normally not part of the weighing cycle. Thus any drift of zero directly affects the fill. This effect may be more significant than any effect on the span. This can be well seen from a comparison of R76 error limits to R61 error limits. Since the latter ones are (in principle) percentage error limits the absolute maximum permissible error (mpe) for fills higher than 200 d according to R61 (setting error 0.25 $mpd_{in\ service}$) is much higher than the mpe according to R76, depending on the fill. The higher the fill related to d, the more uncritical is the R61 error limit compared to R76 (see figure 1).

<u>Remarks</u>:
For all following example calculations the percentage values instead of absolute values given in Table 1 of OIML R61 have been used. The reason can most easily be explained by giving the following example: The fill shall be e.g. 75 g. The maximum permissible deviation for this fill is 4.5 g. This is the maximum error also for the highest fill in this range (100 g) and would be the smallest relative (or percentage) permissible deviation of all fills between >50 g and ≤100 g. Thus taking this relative value of $mpd_{in\ service}$ is the worst case and will guarantee that for all fills smaller than 100 g within this range the $mpd_{in\ service}$ is not exceeded at any time.

All numbers of paragraphs appearing in the calculations are taken from the R61 valid at present unless otherwise marked.

## III.B.1. Change of span

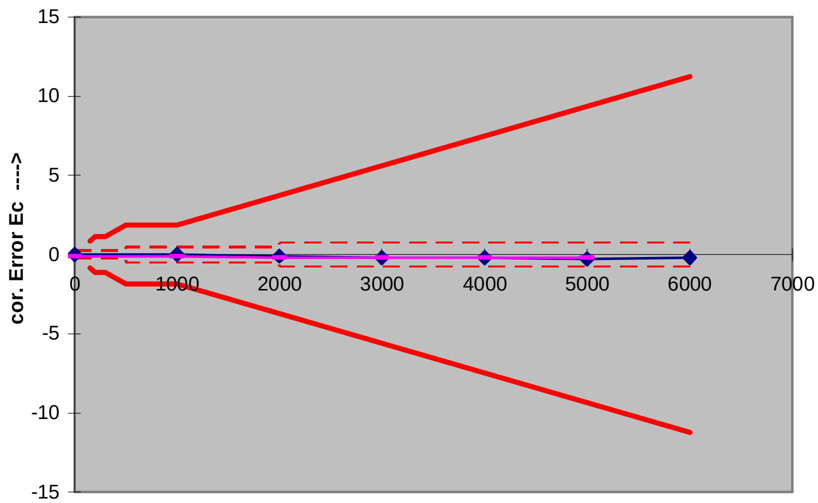
The error limits of R76 (weighing performance) compared to error limits of R61 for influence factor test:

R61, 2.5 says: mpd $_{\text{influence factors}}$ = 0.25 mpd $_{\text{in service}}$
Testing an indicator (module) $p_i$ has to be considered: e.g. $p_i = 0.5$
Furthermore the reference accuracy class Ref(x) has to be considered.

The diagram (all values in gram) below shows the following example:

Based on d = 1 g and $p_i = 0.5$ and Ref(1) error limits according to R61 (continuous line) and according to R76 (dashed line)

Figure 1: R61 error limits (continuous line) in comparison to R76 error limits (dashed line)




Example fill: 2000 g
Error limit according to R61:

mpd = Fill • mpd $_{\text{in-service}}$ • 0.25 (No. 2.5 of R61) • Ref(x) • $p_i$

mpd = 2000 g • 1.5 % • 0.25 • 1 • 0.5

mpd = 3.75 g

Error limit according to R76 at a load corresponding to 2000 e:

$mpe = 1\ e \bullet p_i = 1\ e \bullet 0.5 = 0.5\ g$

From the graph one can perceive that the higher the fill the higher is the difference between the R76 error limits and the R61 error limits. Therefore it is sufficient to consider only small loads or, to be more precise, the minimum fill (Minfill). For automatic gravimetric filling machines the error at zero is more critical with regard to Minfill and thus first Minfill should be calculated on basis of the following ideas before checking whether e.g. span drift due to temperature has an effect.

## III.B.2. The change of zero.

The change of zero is important to consider for every instrument that is not automatically set to zero before each weighing, since the zero error is directly added to the weighing result.

Effects preventing the zero from being accurate:

A) Insufficient accuracy of zero / tare setting

from 3.8: $mpd(zero) \leq 0.25 \bullet mpd(X)_{in\ service} \bullet Min(fill)$ (3.8.2)

**ó** $Min(fill) \geq mpd(zero) / 0.25 \bullet mpd(X)_{in\ service}$

The required accuracy for electronic weighing instruments according to R76 is limited to 0.25 e (or d). This fact leads to the absolutely smallest Minfills possible since the zero / tare setting error adds to the fill error under all conditions.

Example: Non-automatic weighing instrument with e = 1 g, zero setting error being 0.25 g. The reference accuracy class is Ref(x) = 1. Thus absolutely smallest Minfill is:

$Minfill \geq 0.25\ g / (0,25 \bullet mpd(X)_{in\ service})$

The problem is that $mpd(X)_{in\ service}$ is unknown since it depends on the (Min)fill. Thus as a first step the fill is estimated and a subsequent iteration is necessary. The iteration starts assuming that Minfill is smaller than 50 g, then

$mpd(X)_{in\ service} = 9\ \%$ (2.2.2, Table 1)

The first step of iteration:

$Minfill \geq 0.25\ g / (0,25 \bullet 9\ \%)$

$Minfill \geq 11,1\ g$ and rounded to d

$Minfill \geq 11\ g$

The Minfill of this instrument (having d = 1 g) can never be smaller than 11 g at a reference class Ref(X) = 1.

The same procedure must be followed for calculating all other possible Minfills depending on other values of scale interval d and other reference classes Ref(X).

## B) Temperature effect on no-load indication

from A.6.2.2: $\Delta z_{max} \leq 0.25 \bullet mpd_{in\ service} \bullet Minfill \bullet p_i \bullet Ref(X)$

ó Minfill $\geq \Delta z_{max} / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$

$mpd_{in\ service}$ $\rightarrow$ from Table 1 (2.2.2)

0.25 $\rightarrow$ from 2.5

The maximum zero drift depending on variation of temperature according to R76 is 1 e per 5 K (°C). The assumption made is that the maximum temperature drift is not more than 5 K / h. (This figure is taken from A.3.3 of R61, see also R76, A.4.1.2 ) The maximum time interval assumed to be chosen by the manufacturer between two zero settings is 2 hours. Thus the maximum zero drift to be considered is the theoretical drift within two hours, that is, twice the maximum value taken from the R76-2 protocol.

From the R76-2 protocol form the maximum zero drift has to be taken, and then Minfill can be calculated by iteration.

Example: e = d = 1 g, Ref(X) = 1, $p_i$ = 0.5, zero drift 1 e / 5 K, $mpd_{in\ service}$ = 9 % (assumption that Minfill ≤ 50 g)

from A.6.2.2: $\Delta z_{max} \leq 0.25 \bullet mpd_{in\ service} \bullet Minfill \bullet p_i \bullet Ref(X)$

ó Minfill $\geq \Delta z_{max} / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$

Assuming that the instrument is not set to zero before 2 h have elapsed:

Minfill $\geq$ (2 h • 1 e / h) / (0.25 • 9 % • 0.5 • 1)

⇔ Minfill $\geq$ (2 h • 1 g / h) / (0.25 • 9 % • 0.5 • 1)

⇔ Minfill $\geq$ 2 g / (0.25 • 9 % • 0.5 • 1)

⇔ Minfill $\geq$ 177.78 g > 50 g (assumption with regard to Minfill has been wrong)

Next iteration step: Minfill ≤ 200 g and $mpd_{in\ service}$ = 4,5 % (obviously leading to double the value calculated before)

Minfill $\geq$ 2 g / (0.25 • 4.5% • 0.5 • 1)

⇔ Minfill $\geq$ 355.56 g > 200 g (assumption with regard to Minfill has been wrong)

Next iteration step: Minfill ≤ 500 g and $mpd_{in\ service}$ = 3 %

$$\text{Minfill} \geq 2\text{ g} / (0.25 \bullet 3\% \bullet 0.5 \bullet 1)$$

⇔ Minfill ≥ 533.33 g > 500 g (assumption with regard to Minfill has been wrong)

Next iteration step: Minfill ≤ 1000 g and $mpd_{in\ service}$ = 1,5 % (obviously leading to double the value calculated before)

$$\text{Minfill} \geq 2\text{ g} / (0.25 \bullet 1.5\% \bullet 0.5 \bullet 1)$$

⇔ Minfill ≥ 1066.67 g (more than 1000 g, however for fill between 1000 g and 10,000 g a deviation of 1.5% is acceptable, thus 1067 g is the final permissible Minfill)

Shorter zero setting intervals:

In a lot of cases a zero setting interval of 2 h may not be adequate especially when caking and adhesive material is filled. Some notified bodies require even an interval of not more than 15 minutes. The following example shows what happens to Minfill when the maximum time interval between two zero settings is reduced to for example 15 minutes or 0.25 h respectively.

The maximum zero drift per 5 K and therefore per 1 h has been assumed to be 1 e. Thus in a quarter of an hour it cannot be more than 0.25 e. Minfill would then be:

$$\text{Minfill} \geq \Delta z_{max} / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$$

$$\text{Minfill} \geq 2\text{ g} \bullet 0.25 / (0.25 \bullet 9\% \bullet 0.5 \bullet 1)$$

$$\Leftrightarrow \text{Minfill} \geq 0.5\text{ g} / (0.25 \bullet 9\ \% \bullet 0.5 \bullet 1)$$

$$\Leftrightarrow \text{Minfill} \geq 44.4\text{ g}$$

C) Warm up time

from A.5.2: $E_0 - E_{0\,init} \leq 0.25 \bullet mpd_{in\ service} \bullet Minfill \bullet p_i \bullet Ref(X)$

ó $Minfill \geq (E_0 - E_{0\,init}) / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$

| | | |
|---|---|---|
| $mpd_{in\ service}$ | $\rightarrow$ | from Table 1 (2.2.2) |
| 0.25 | $\rightarrow$ | from 2.5 |
| Ref(X) | $\rightarrow$ | has to be chosen (may be given by manufacturer) |

*Remark: If ($E_0 - E_{0\,init}$) < 0 then the absolute value of ($E_0 - E_{0\,init}$) has to be used.*

From the R76-2 protocol form the maximum zero drift due to warm up has to be taken, and then Minfill can be calculated by iteration.

Example: e = d = 1 g, Ref(X) = 1, $p_i$ = 0.5, zero drift due to warm up 3 e, $mpd_{in\ service}$ = 9 % (assumption that Minfill ≤ 50 g)

$Minfill \geq (E_0 - E_{0\,init}) / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$

ó $Minfill \geq 3\ g / (0.25 \bullet 9\ \% \bullet 0.5 \bullet 1)$

ó $Minfill \geq 266.6\ g > 200\ g$,

Assumption being Minfill between >200 g and ≤ 300 g.
$mpd_{in\ service}$ = 9 g. For a new calculation that has to be put in relation to the highest fill of this range, i.e. 300 g. The maximum percentage deviation would then be: 9 g / 300 g = 0.03 = 3 %. (see initial remarks)

$Minfill \geq 3\ g / (0.25 \bullet 3\ \% \bullet 0.5 \bullet 1)$

ó $Minfill \geq 800\ g > 500\ g$, next iteration step.

Assumption being Minfill between >500 g and ≤ 1000 g.
$mpd_{in\ service}$ = 15 g. For a new calculation that has to be put in relation to the highest fill of this range, i.e. 1000 g. The maximum percentage deviation would then be: 15 g / 1000 g = 0.015 = 1.5 %. (see initial remarks)

$Minfill \geq 3\ g / (0.25 \bullet 1.5\ \% \bullet 0.5 \bullet 1)$

ó $Minfill \geq 1600\ g \leq 10000\ g$, iteration stops here.

## III.B.3. Faults due to disturbances

The significant fault for all disturbance tests is 0.25 of the maximum permissible deviation (mpd) of each fill for in-service verification, for a fill equal to the rated minimum fill (see T.4.2.6). Thus the maximum deviation must be

$$md_{disturbance} \leq 0.25 \bullet mpd_{in\ service} \bullet Ref(X) \bullet Minfill$$

($p_i$ = 1 for disturbance tests; WELMEC Guide 2.1)

⇔ Minfill $\geq$ md $_{disturbance}$ / (0.25 • mpd$_{in\ service}$ • Ref(X))

The significant fault for nonautomatic weighing instruments is 1 e. However, when testing without high resolution this could amount even to 1.5 e.

The following example is based on the assumption that the significant fault amounts to 1.5 e, while e = 1 g. The reference class of the instrument shall again be Ref(x) = 1. The error fraction $p_i$ , however, now is not 0.5 but 1 since the susceptibility to disturbances is a feature of the indicator alone as well as the influence of variation of the supply voltage (see R76-1, C.2, Table 12). The expected Minfill is between >50 g and ≤ 100 g, so mpd$_{in\ service}$ = 4.5 %

Then:

Minfill $\geq$ md $_{disturbance}$ / (0.25 • mpd$_{in\ service}$ • Ref(X))

⇔ Minfill $\geq$ 1.5 g / (0.25 • 4.5 % • 1)

⇔ Minfill $\geq$ 133.3 g

Since mpd$_{in\ service}$ for a fill of 133.3 g is 4.5% as well, no further calculations are necessary. A Minfill smaller than or equal to 50 g is not possible since maximum deviation due to disturbance would be:

md $_{disturbance}$ ≤ 0.25 • mpd$_{in\ service}$ • Ref(X) • Minfill

⇔ md $_{disturbance}$ ≤ 0.25 • 9 % • 1 • 50 g

⇔ md $_{disturbance}$ ≤ 1.125 g

Summary of example test results and conclusions

The Minfills based on the calculations above are:

| | |
|---|---|
| Based on accuracy of zero / tare setting: | 11 g (rounded down) |
| Based on temperature effect on no-load indication | 1067 g (rounded up) |
| Based on warm up time | 400 g |
| Based on faults due to disturbances | 133 g (rounded down) |

The highest Minfill (1067 g) has to be selected a being the worst case. The R61 error limit at this fill is 1067 g • 1.5 % • 0.5 = 8 g. Comparing the figure to the error limit according to R76 (considering $p_i$) being 0.5 g (1 g • 0.5) it is evident that normally the incorrect zero and the deviation due to disturbances are the crucial points. Thus the corresponding Minfills have to be calculated first and then the highest Minfill has to be compared to the R61 error limits (see figure 1) valid for temperature and damp heat tests.

## III.C Calculating of Minfills with Selective Combination Weighers

Selective combination weighers have to be handled slightly differently since the fill is composed of many partial fills. Each weighing unit producing a partial fill produces its own partial errors due to influence factors and disturbances. However, corresponding to the addition of error fractions $p_i$ within the frame of the modular approach, the single errors of the weighing units are added geometrically (see R61-1, A.6.1.3.1). The examples are based on the same data as for the single load filling instruments with the exception that the e = d of the single load instrument now is considered being the $d_{WU}$ of the single weighing unit.

$d \geq d_{WU} \bullet sqr(i)$ (A.6.1.3.2)

### III.C.1. The change of zero.

from 3.8.2 and A.6.1.3.2:

$$mpd(zero) \leq 0.25 \bullet (mpd(X)_{in\ service} \bullet Min(fill) / sqr\ (lpf))$$

[sqr(lpf) is the square root of the number of loads per fill]

A) Insufficient accuracy of zero / tare setting

The required accuracy for electronic weighing instruments according to R76 is limited to 0.25 e (or $d_{WU}$). This fact leads to the absolutely smallest Minfills possible since the zero / tare setting error adds to the fill error under all conditions.

$$0.25\ d_{WU} \leq 0.25 \bullet (mpd(X)_{in\ service} \bullet Min(fill) / sqr\ (lpf))$$

**ó** $$d_{WU} \geq mpd(X)_{in\ service} \bullet Min(fill) / sqr\ (lpf)$$

**ó** $$Min(fill) \geq d_{WU} \bullet sqr\ (lpf) / mpd(X)_{in\ service}$$

Example: Nonautomatic weighing instrument with $d_{WU}$ = 1 g, zero setting error being 0.25 g. The reference accuracy class is Ref(x) = 1. The average number of partial fills (loads per fill, “lpf”) is 4. Thus absolutely smallest Minfill is:

$$Minfill \geq d_{WU} \bullet sqr\ (lpf) / mpd(X)_{in\ service}$$

The problem is that $mpd(X)_{in\ service}$ is unknown since it depends on the Minfill. Thus as a first step the fill is estimated and a subsequent iteration is necessary. The iteration starts assuming that Minfill is smaller than 50 g, then

$mpd(X)_{in\ service}$ = 9 % (2.2.2, Table 1)

The first step of iteration:

Minfill $\geq$ 1 g $\bullet$ sqr(4) / 9 %

Minfill $\geq$ 22,2 g and rounded to d

Minfill $\geq$ 22 g

The Minfill of this instrument (having $d_{WU}$ = 1 g, average number of 4 loads per fill) can never be smaller than 22 g at a reference class Ref(X) = 1.

The same procedure must be followed for calculating all other possible Minfills depending on other values of scale interval $d_{WU}$ and other reference classes Ref(X).

The following table is shows the absolute minimum Minfills of a selective combination weigher with 4 loads per fill, related to $d_{WU}$ , depending on normal accuracy of zero setting of NAWIs:

| $d_{WU}$ (g) | Minimum permissible value of Minfill (g) / lpf = 4 | | | |
|---|---|---|---|---|
| | X(0.2) | X(0.5) | X(1) | X(2) |
| 1 | 333 | 44 | 22 | 11 |
| 2 | 1 334 | 88 | 44 | 22 |
| 5 | 3 335 | 1 335 | 110 | 110 |
| 10 | 6 660 | 2 660 | 1 330 | 330 |
| 20 | 13 340 | 5 330 | 2 660 | 1340 |
| 50 | 50 000 | 13 350 | 6 650 | 1 650 |
| 100 | 100 000 | 40 000 | 20 000 | 6 600 |
| 200 | 200 000 | 80 000 | 40 000 | 20 000 |
| $\geq$ 500 | 1000 d | 500 d | 200 d | 100 d |

As an alternative to the method above all calculations could be based on the d of whole filling instrument instead of $d_{WU}$ of the weighing unit.

| d/sqr(lpf) lpf = 4 | calculated $d_{wu}$ | permissible $d_{wu}$ | **class X(1)** Minfill | d rounded up **Minfill** |
|---|---|---|---|---|
| 2 g/2 | 1 g | 1 g | 22 g | **22 g** |
| 5 g/2 | 2,5 g | 2 g | 44 g | **45 g** |
| 10 g/2 | 5 g | 5 g | 110 g | **110 g** |
| 20 g/2 | 10 g | 10 g | 1 330 g | **1 340 g** |
| 50 g/2 | 25 g | 20 g | 2 660 g | **2 700 g** |
| 100 g/2 | 50 g | 50 g | 6 650 g | **6 700 g** |
| 200 g/2 | 100 g | 100 g | 20 000 g | **20 000 g** |
| 500 g/2 | 250 g | 200 g | 40 000 g | **40 000 g** |

B) Temperature effect on no-load indication

from A.6.2.2 and A.6.1.3.2:

$$\Delta z_{max} \leq 0.25 \bullet mpd_{in\ service} \bullet Minfill \bullet p_i \bullet Ref(X) / sqr(lpf)$$

ó $$Minfill \geq \Delta z_{max} \bullet sqr(lpf) / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$$

$mpd_{in\ service}$ $\rightarrow$ from Table 1 (2.2.2)

0.25 $\rightarrow$ from 2.5

The maximum zero drift depending on variation of temperature according to R76 is 1 e per 5 K (°C). The assumption made is that the maximum temperature drift is not more than 5 K / h. (This figure is taken from A.3.3 of R61, see also R76, A.4.1.2 ) The maximum time interval assumed to be chosen by the manufacturer between two zero settings is 2 hours. Thus the maximum zero drift to be considered is the theoretical drift within two hours, that is twice the maximum value taken from the R76-2 protocol.

From the R76-2 protocol form the maximum zero drift has to be taken, and then Minfill can be calculated by iteration.

Example: $e = d_{WU} = 1$ g, Ref(X) = 1, $p_i = 0.5$, zero drift 1 e / 5 K, $mpd_{in\ service} = 9$ % (assumption that Minfill ≤ 50 g)

from A.6.2.2 and A.6.1.3.2:

$$\Delta z_{max} \leq 0.25 \bullet mpd_{in\ service} \bullet Minfill \bullet p_i \bullet Ref(X) / sqr(lpf)$$

ó $$Minfill \geq \Delta z_{max} \bullet sqr(lpf) / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$$

Assuming that the instrument is not set to zero before 2 h have elapsed:

$$Minfill \geq (2\ h \bullet 1\ e / h) \bullet sqr(4) / (0.25 \bullet 9\ \% \bullet 0.5 \bullet 1)$$

$$\Leftrightarrow Minfill \geq (2\ h \bullet 1\ g / h) \bullet 2 / (0.25 \bullet 9\ \% \bullet 0.5 \bullet 1)$$

$$\Leftrightarrow Minfill \geq 4\ g / (0.25 \bullet 9\ \% \bullet 0.5 \bullet 1)$$

$\Leftrightarrow Minfill \geq 355.56$ g > 50 g (assumption with regard to Minfill has been wrong)

Next iteration step: Minfill ≤ 500 g and $mpd_{in\ service} = 3$ % (obviously leading to three times the value calculated before)

$$Minfill \geq 4\ g / (0.25 \bullet 3\% \bullet 0.5 \bullet 1)$$

$\Leftrightarrow Minfill \geq 1066.67$ g > 500 g (assumption with regard to Minfill has been wrong)

Next iteration step: Minfill ≤ 10000 g and $mpd_{in\ service} = 1.5$ %

$\text{Minfill} \geq 4\ g / (0.25 \bullet 1.5\% \bullet 0.5 \bullet 1)$

$\Leftrightarrow$ Minfill $\geq$ 2133.33 g < 10000 g (for fill between 1000 g and 10,000 g a deviation of 1.5% is acceptable, thus 2133 g is the final permissible Minfill)

C) Warm up time

from A.5.2: $E_0 - E_{0I} \leq 0.25 \bullet mpd_{in\ service} \bullet Minfill \bullet p_i \bullet Ref(X) / sqr(lpf)$

ó $Minfill \geq (E_0 - E_{0I}) \bullet sqr(lpf) / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$

| | | |
|---|---|---|
| $mpd_{in\ service}$ | $\rightarrow$ | from Table 1 (2.2.2) |
| 0.25 | $\rightarrow$ | from 2.5 |
| Ref(X) | $\rightarrow$ | has to be chosen (may be given by manufacturer) |

*Remark: If ($E_0 - E_{0I}$) < 0 then the absolute value of ($E_0 - E_{0I}$) has to be used.*

From the R76-2 protocol form the maximum zero drift due to warm up has to be taken, and then Minfill can be calculated by iteration.

Example: e = d = 1 g, Ref(X) = 1, $p_i$ = 0.5, zero drift due to warm up 3 e, $mpd_{in\ service}$ = 9 % (assumption that Minfill ≤ 50 g)

$Minfill \geq (E_0 - E_{0\ init}) \bullet sqr(lpf) / (0.25 \bullet mpd_{in\ service} \bullet p_i \bullet Ref(X))$

ó Minfill $\geq$ 3 g $\bullet$ sqr(4) / (0.25 $\bullet$ 9 % $\bullet$ 0.5 $\bullet$ 1)

ó Minfill $\geq$ 533.3 g > 500 g,

Assumption being Minfill between >500 g and ≤ 1000 g.
$mpd_{in\ service}$ = 15 g. For a new calculation that has to be put in relation to the highest fill of this range, i.e. 1000 g. The maximum percentage deviation would then be: 15 g / 1000 g = 0.015 = 1.5 %. (see initial remarks)

Minfill $\geq$ 3 g $\bullet$ sqr(4) / (0.25 $\bullet$ 1.5 % $\bullet$ 0.5 $\bullet$ 1)

ó Minfill $\geq$ 3200 g ≥ 1000 g, next iteration step.

Minfill between >1000 g and ≤ 10000 g, $mpd_{in\ service}$ = 1.5%,
thus Minfill is 3200 g, iteration stops here.

III.C.3. Faults due to disturbances

For selective combination weighers the significant fault for all disturbance tests is 0.25 of the maximum permissible deviation (mpd) of each fill for in-service verification, for a fill equal to the rated minimum fill (see T.4.2.5), however divided by the square root of loads per fill. Thus the maximum deviation must be

$md_{disturbance} \leq 0.25 \bullet mpd_{in\ service} \bullet Ref(X) \bullet Minfill / sqr(lpf)$

$\Leftrightarrow \quad Minfill \geq md_{disturbance} \bullet sqr(lpf) / (0.25 \bullet mpd_{in\ service} \bullet Ref(X))$

Assuming again that the real fault for nonautomatic weighing instruments could amount to 1.5 e the following example is given.

While e = 1 g, the reference class of the instrument shall again be Ref(x) = 1, and the number of loads per fill shall be lpf = 4. The error fraction $p_i$ , is again 1. (see R76-1, C.2.2, Table 12). The expected Minfill is between >100 g and ≤ 200 g, so $mpd_{in\ service}$ = 4.5 %

Then:

$Minfill \geq md_{disturbance} \bullet sqr(lpf) / (0.25 \bullet mpd_{in\ service} \bullet Ref(X))$

$\Leftrightarrow \quad Minfill \geq 1.5\ g \bullet sqr(4) / (0.25 \bullet 4.5\ \% \bullet 1)$

$\Leftrightarrow \quad Minfill \geq 266.6\ g$

Expectation has been wrong, thus next iteration:

Assumption Minfill between >300 g and ≤ 500 g, $mpd_{in\ service}$ = 3%

$\Leftrightarrow \quad Minfill \geq 1.5\ g \bullet sqr(4) / (0.25 \bullet 3\ \% \bullet 1)$

$\Leftrightarrow \quad Minfill \geq 400\ g$

A Minfill smaller than or equal to 300 g is not possible since maximum deviation due to disturbance would be:

$md_{disturbance} \leq 0.25 \bullet mpd_{in\ service} \bullet Ref(X) \bullet Minfill$

$\Leftrightarrow \quad md_{disturbance} \leq 0.25 \bullet 3\ \% \bullet 1 \bullet 300\ g$

$\Leftrightarrow \quad md_{disturbance} \leq 2.25\ g$