Type A evaluation

- Result of a measurement is determined on the basis of series of observations obtained under **repeatability conditions**

Repeatability conditions

- The same measurement procedure
- the same observer
- the same measurement procedure, used under the same conditions
- the same location
- repetition over a short period of time

– GUM B.2.15

Why variations?

- **Influence quantities** that can affect the measurement result are not held completely constant

Influence quantities

- Quantity that is not the measurand but that affects the result of the measurement
  - measurement standards, reference materials, reference data
  - ambient temperature, barometric pressure, humidity

– GUM B.2.10

ASSUMPTION

- All systematic errors
  - have been identified
  - have been corrected for

Cases of Type A

- Large sample
- Small sample
- Regression over Range

Type A, large sample

- If the instrument resolution is sufficient,
- If the measurements are normally distributed,
- a large number of readings >30, say x_1, x_2, … , x_n
- Calculate Mean $\bar{x} = \frac{\sum x_i}{n}$
- Calculate standard deviation $s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$

Type A, large sample

- Measurement result = $\bar{x}$
- Calculated sample standard deviation s equal to the population standard deviation σ
- Standard uncertainty is the Standard deviation of the values

Type A, large sample

- For the normal distribution, 95% of the distribution of means is covered by the interval

$$\bar{x} +/- 1.96 \frac{s}{\sqrt{n}}$$

Example: Type A, large sample

- Repeated hardness measurement (BHN) of a sample of material gave the following results:

  316, 307, 308, 274, 291, 312, 300, 317, 303, 291, 318, 297, 299, 286, 287, 295, 295, 297, 309, 292, 291, 283, 320, 300, 304, 303, 294, 299, 307, 292
- Determine the 95% expanded uncertainty

Solution: Type A, large sample

- Mean = 299.5667 BHN
- s = 10.97233 BHN
- Expanded Uncertainty=

$$\bar{x} +/- 1.96 \frac{s}{\sqrt{n}}$$

= 295.6403 ~ 303.4931 BHN

Type A, normal, small sample

- If the measurements are normally distributed,
- the number of readings is small, and we have to estimate the population standard deviation by the sample standard deviation,
- use the t distribution with appropriate degrees of freedom

Type A, normal, small sample

- 95% is covered by $\bar{x} \pm t_{95,\nu} \frac{s}{\sqrt{n}}$
- where t has to be chosen from the following table with suitable degrees of freedom
- $\nu = (n - 1)$

ν	1	2	3	4	5	6	7	8	9	10
t_{95}	12.71	4.30	3.18	2.78	2.57	2.45	2.36	2.31	2.26	2.23
ν	11	12	13	14	15	16	17	18	19	20
t_{95}	2.20	2.18	2.16	2.14	2.13	2.12	2.11	2.10	2.09	2.09
ν	25	30	35	40	45	100	∞			
t_{95}	2.06	2.04	2.03	2.02	2.01	1.98	1.96			

Type A, normal, small sample

- Repeated hardness measurement (BHN) of a sample of material gave the following results: 316, 307, 308, 274, 291
- Determine the 95% expanded uncertainty

Solution: Type A, small sample

- Mean = 299.2 BHN
- Standard deviation = 16.7541 BHN
- Expanded Uncertainty

t table

$$= \bar{x} \pm 2.78 * \frac{s}{\sqrt{n}}$$

= 278.3704 ~ 320.0296 BHN