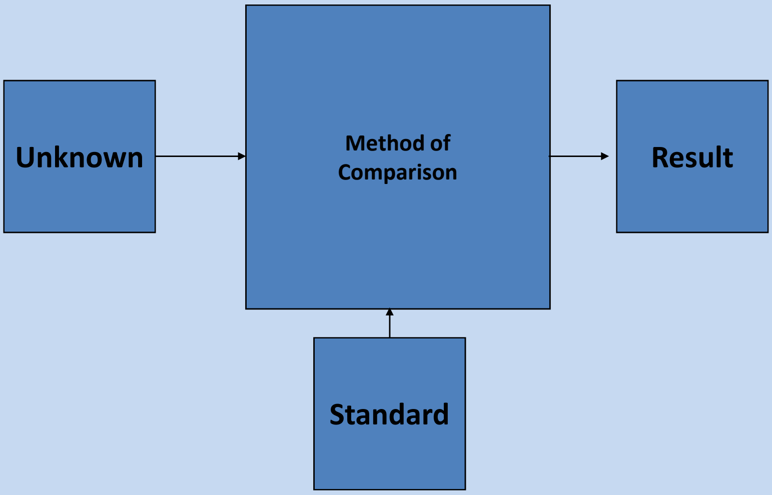
PRINCIPLES of MEASUREMENT UNCERTAINTY EVALUATION A Résumé

Alex Williams, Chairman EURACHEM Uncertainty WG

Overview

- **Principles of Measurement**
  - **Traceability**
  - **Uncertainty**
- **Why these are important**
  - **For comparison of results**
  - **For assessment of compliance**
- **How is uncertainty evaluated**
  - **Component by Component**
  - **Using existing data**
  - **Numerical Methods**
- **Assessment of compliance**

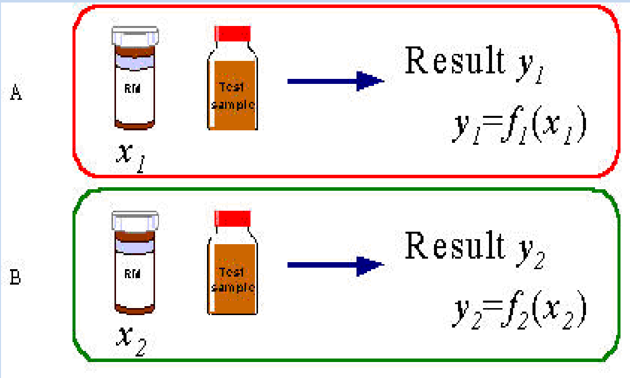
Principles Of Measurement



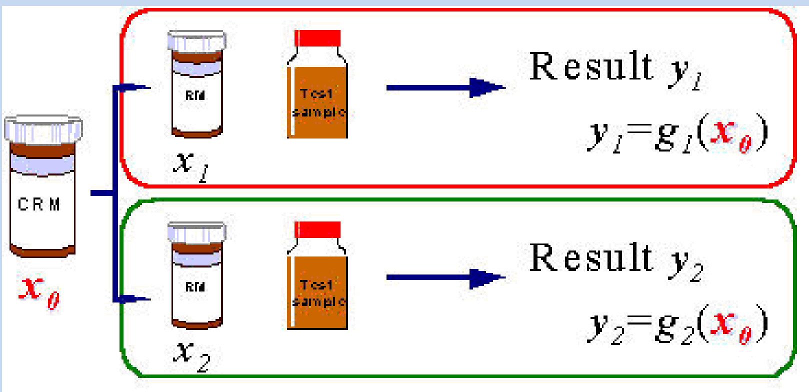
Principles Of Measurement

- **Traceability is to the value of the standard**
- **Uncertainty on result is:-**
- **Uncertainty from comparison with standard.**
- **Plus the uncertainty on the value of the standard.**
- **Many sources of uncertainty associated with the comparison**
- **Uncertainty on standard usually small**

Traceability



Traceability



Traceability

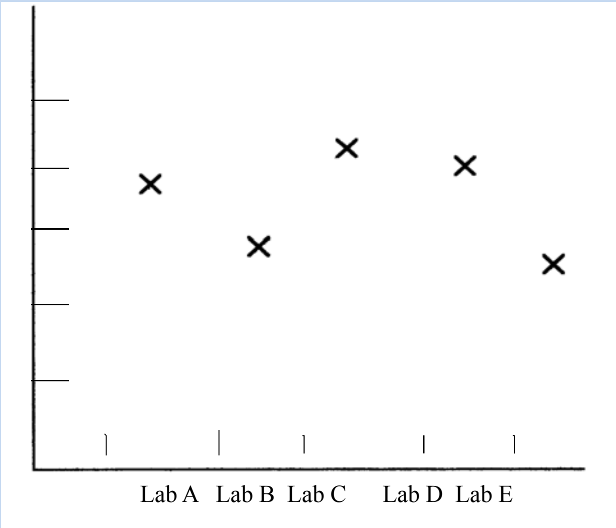
The value of the result is calculated from

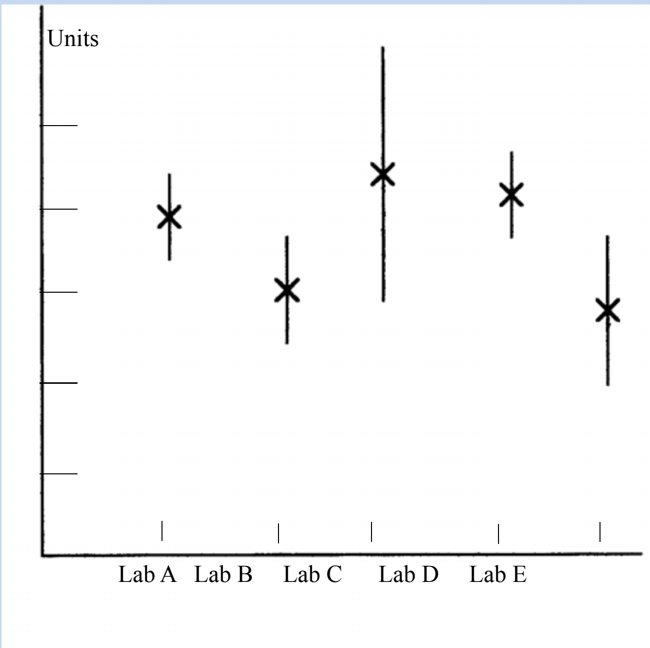
$$y = f(x_1, x_2 \ldots \quad x_m)\Big|_{x_{m+1}, x_{m+2} \ldots \quad x_n}$$

Where x_1 *etc* are measured or fixed quantities

Method validation checks the validity of this relationship

Establishing traceability to common references provides the basis for making comparisons but more is required





Uncertainty of Measurement

Uncertainty should be quantified in a way that is

Universal:

- applicable to all kinds of measurements

Internally consistent:

- independent of how components are grouped

Transferable:

- use uncertainty on a result in derivation of uncertainty on dependant results

Procedures set out in

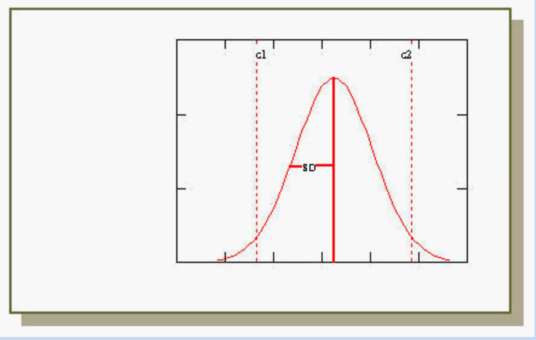
Guide to the Expression of Uncertainty in Measurement (GUM)

Uncertainty of Measurement

- **parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand**

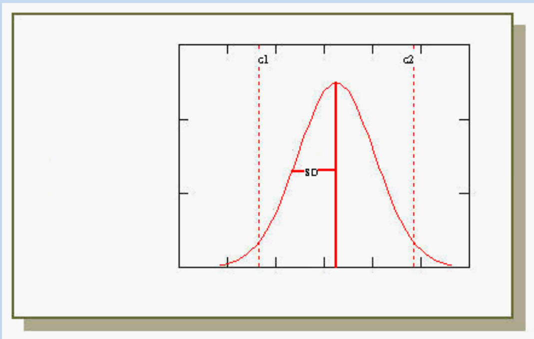
Standard Uncertainty

Uncertainty of the result expressed as a Standard Deviation.



Expanded Uncertainty

..interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand.



Evaluation of Uncertainty

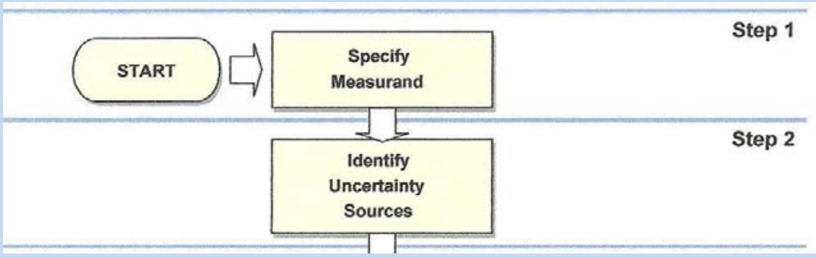
The value of the result is calculated from

$$y = f(x_1, x_2 \ldots \quad x_m)\Big|_{x_{m+1}, x_{m+2} \ldots \quad x_n}$$

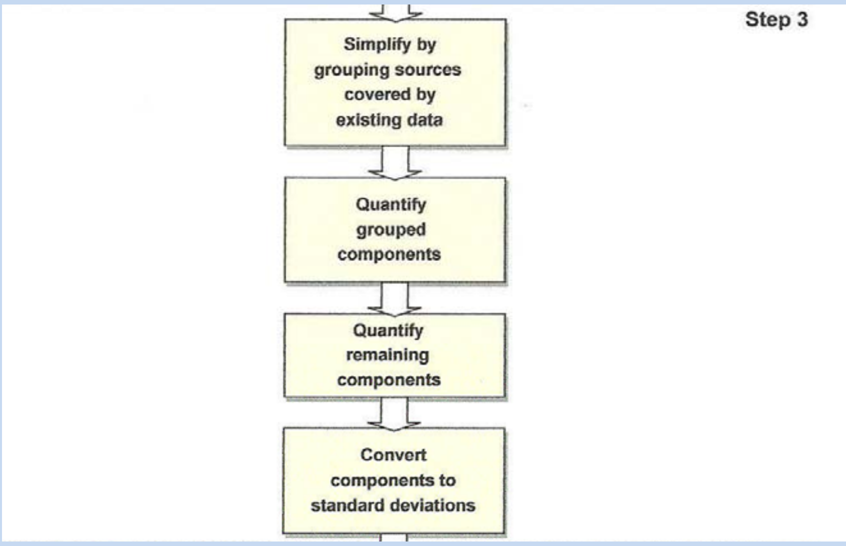
Where x_1 *etc* are measured or fixed quantities

The uncertainty can be derived from the uncertainty on each of these quantities

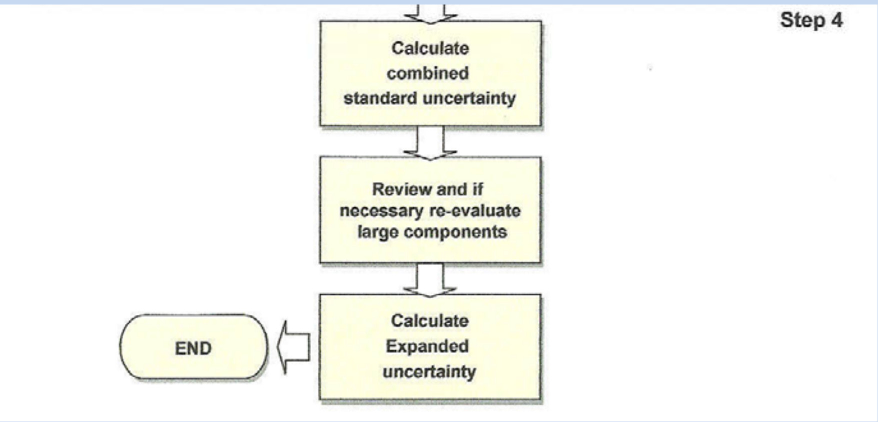
Evaluation of Uncertainty



Evaluation of Uncertainty



Evaluation of Uncertainty



Evaluation of Uncertainty

$$y = f(x_1, x_2 \ldots \quad x_m)\Big|_{x_{m+1}, x_{m+2} \ldots \quad x_n}$$

The uncertainty on each of these quantities is combined

- **As described in GUM**
- **Using the Kragten spreadsheet**
- **By Monte Carlo simulation**

Combination as in GUM/Kragten

- Formally using first order Taylor Series
- Usually by simple rules e.g.
- Sum of quantities $\sqrt{\text{sum of variances}}$
- Product/Quotient $\sqrt{\text{sum of relative variances}}$
- More complicated use Kragten –numerical approximation to first order Taylor Series

Monte Carlo Simulation

- Requires probability distribution of each quantity x_i
- Select a value for each x_i at random using its probability distribution
- Calculate

$$y_j = f(x_1, x_2 \ldots \quad x_m \rvert\, x_{m+1}, x_{m+2} \ldots \quad x_n$$

- Repeat many times ≈ 10^5 times

Evaluation of Uncertainty

Using Existing Data

From collaborative method development and validation study

This establishes the validity of

$$y = f(x_1, x_2 \ldots \quad x_m)\Big|_{x_{m+1}, x_{m+2} \ldots \quad x_n}$$

The reproducibility SD s_R can be used as the standard uncertainty

Providing!

Evaluation of Uncertainty

Using Existing Data

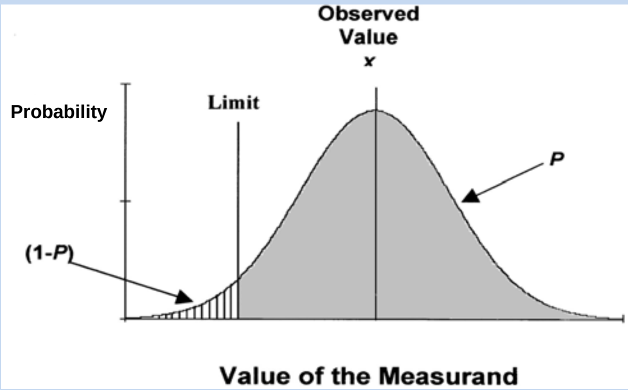
- ❑The method is operating within its defined scope
- ❑Laboratory bias & precision in line with study data
- ❑All identified sources of uncertainty have been included in the study

More details in the Guide and on use of in house validation and PT data

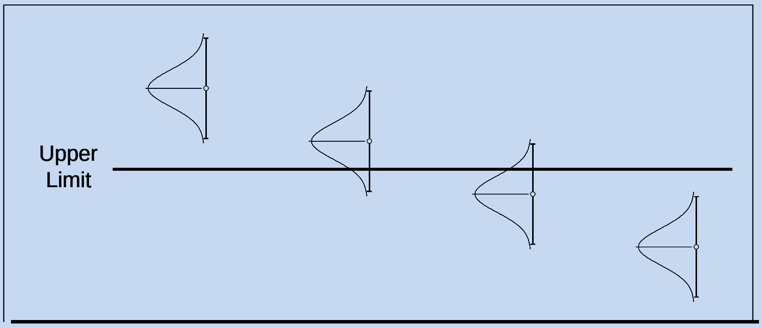
Compliance

- Many analyses carried out to check compliance with a specification or regulation
- Necessary to take into account the measurement uncertainty when assessing compliance
- How can this be done?

Probability Distribution of Value of Measurand



Only possible to give probability that result is above limit



(i) Result minus expanded uncertainty U above the limit

(ii) Result above the limit: limit within the expanded uncertainty interval

(iii) Result above the limit: limit within the expanded uncertainty interval

(iv) Result plus expanded uncertainty U below the limit

Need additional information to deal with cases (ii) & (iii)

- This information is provided by the use of “Decision rules

- Decision rules, enable an “Acceptance Zone” and a “Rejection Zone” to be clearly defined

For Example

Non compliant with an upper limit if the measured value exceeds the limit by more than 2u

Decision Rule

The batch will be considered to be non-compliant if the probability of the value of the measurand being greater than the limit exceeds 95%.

Assessment of compliance requires

a) a measurement result and a stated uncertainty
b) a specification giving the upper and/or lower permitted limits of the characteristics (measurands) being controlled
c) a decision rule that describes how the measurement uncertainty will be taken into account with regard to accepting or rejecting a product according to its specification and the result of a measurement.
d) a reference to the decision rules used when reporting on compliance

A Reminder

- This a **workshop** on the revised EURACHEM/CITAC Uncertainty guide
- We need your input
- WG members can be identified by their badges
- Give us your views