Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

The planned Multi MicroFlow Facility at PTB

- MMFF-

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MMFF

- Metrological background
- Characteristics and realization
- Potential sources for measurement uncertainties

Metrological background

Metrology:

- Science and application of correct measurement
- Traceability of results to the SI through national standards
- Determination of results with verification of uncertainty

PTB:

- National Metrology Institute (NMI)
- Federal Ministry of Economics and Technology (BMWi)
- 212 Mio. € budget + third party funding
- ~1300 permanent staff and 570 non-permanent staff including 170 PhD students
- 600 scientific papers per year

Metrological background

Metrology for different purposes:

Equivalence of units (1 kg = 1 kg)

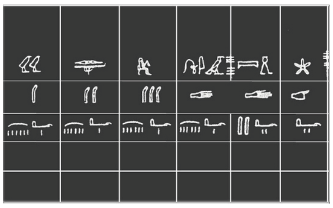
Equivalence of measurements (consumer protection)

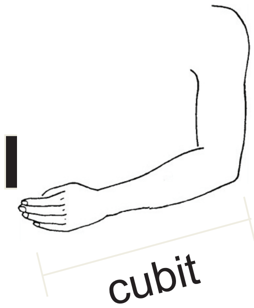
Equivalence of measurements (international trade)

⇨ Aim: high degree of equivalence in each sector

Realization of Units

Need for cross-national harmonisation – The past





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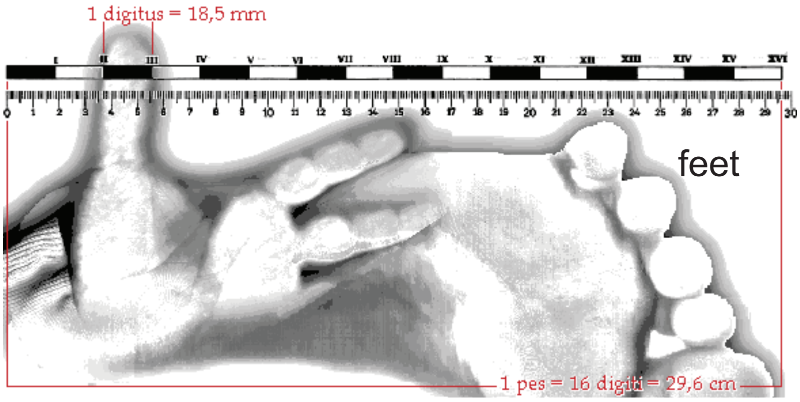


⇨ **distribution in length of different cubits, feets etc.**

The meter convention

BIPM

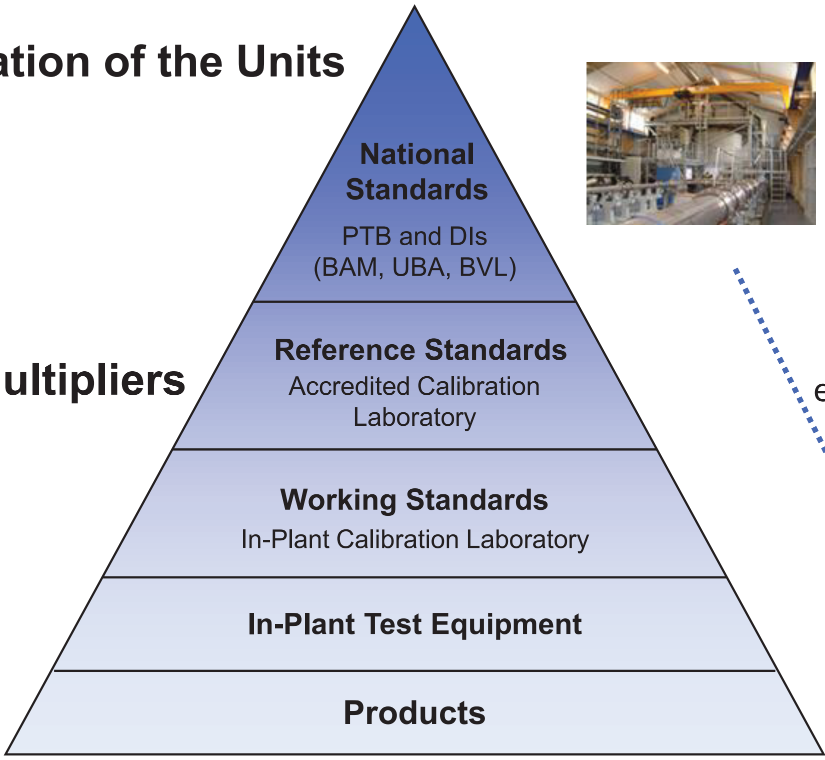
established by the meter convention, signed in Paris 1875

Photograph of the members of the Comité International des Poids et Mesures on the steps outside the 'Grande Salle' of the Pavillon de Breteuil in September 1894 (cliché Bureau International des Poids et Mesures)

"... to establish an internationally applied system of measurement units based on the meter."

Traceability chain

Dissemination of the Units



…using multipliers

e. g. DKD

Calibration versus verification

Calibration

- Comparison with a (higher-level) standard
- By calibrating a device it is **traced** back to a standard.
- A calibration yields the quantitative information how much the measurement with a device deviates from the value of the standard.

Verification

- Qualitative assessment of a device regarding conformity with regulations (incl. measurement accuracy) by Federal Verification Authorities (can be supplemented with a calibration)

Calibrations

How good is a calibration?

A calibration result is only meaningful when a **measurement uncertainty** is given for the measurement value.

Standard clause by PTB:

The combined uncertainty of the measurement … represents the expanded measurement uncertainty which is based on a standard uncertainty multiplied by a coverage factor k=2. This provides a level of confidence of 95 %. The estimate of the standard uncertainty has been carried out with the methods reocmmended in the „Guide to the Expression of Uncertainty in Measurement“ (ISO, 1995).

Measurement quality

Every measurement comes with a measurement uncertainty.

Sources e. g. derive from

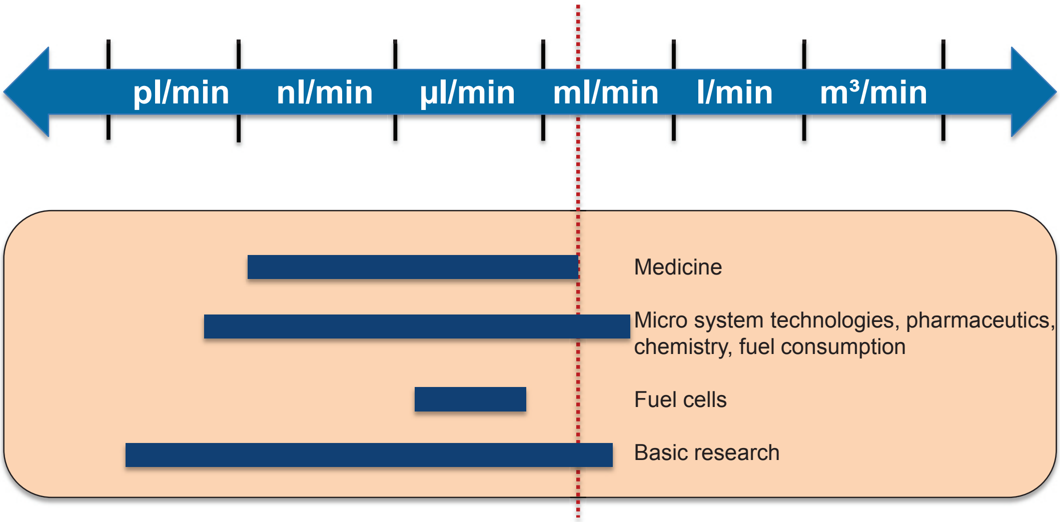
- Noise
- Fluctuations in measurement conditions
- Disturbances
- Influencing factors which are still unknown

Aim of metrology: to quantitatively describe and minimize measurement uncertainties

The compilation of all uncertainty components to a total measurement uncertainty is addressed in the GUM („Guide to the Expression of Uncertainty in Measurement“, ISO, 1995).

Need for MMFF activities

Growing importance of micro- and nano flow rates

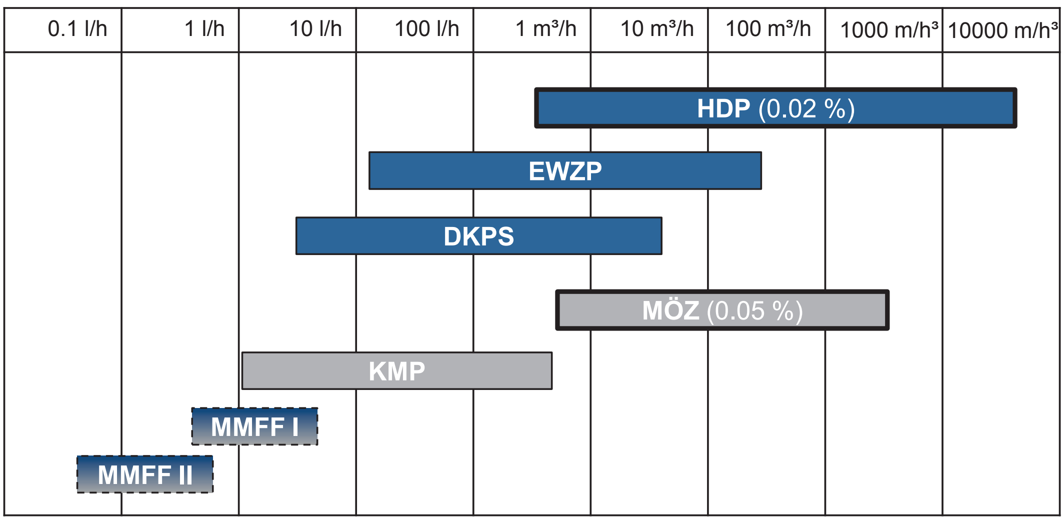


Requests by customers to provide means of comparability and traceability

Flow test facilities at Dept. 1.5

Currently 5 test rigs for liquid flow measurements

- Water and white spirit

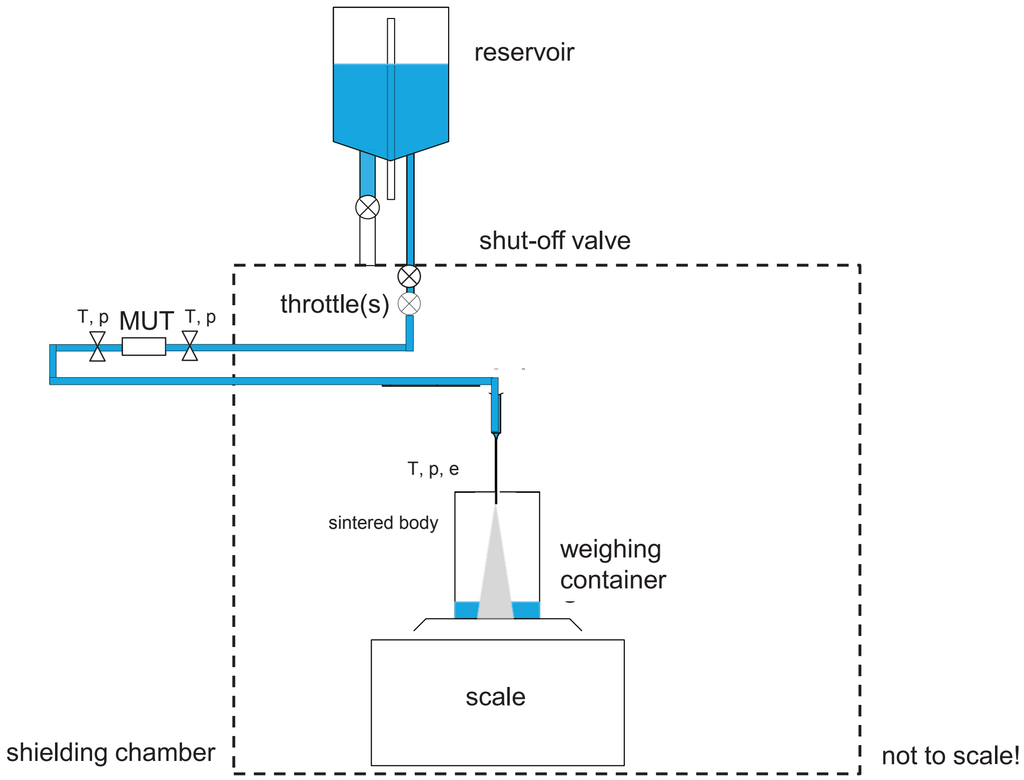


Requirements for MMFF

- Flow range from 5 l/h down to 60 ml/h
    - realized with two devices
- Stable measurement conditions
- Suitable for water, white spirit and similar liquids

- Modular design
- Primary standard

Schematic measurement setup



Dynamic measurements

Influencing factors

- changing drop height
- impact of liquid on scale
- evaporation
- changes in environmental conditions

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Dynamic measurements

Influencing factors

- changing drop height

$$\dot{q}(t) = q_0 \left(1 - \frac{\Delta h_r(t) + \Delta h_w(t)}{h_0}\right) = q_0(1 - \mathrm{c}\,\Delta m_c\,(t))$$

$\dot{q}(t)$ change in mass flow rate

Δh_r height change in reservoir

Δh_w height change in weighing container

h_0 initial height difference between liquid levels in reservoir and weighing container

$c =$ *f*(reservoir/container cross section, initial height difference, liquid density, liquid friction,…)

Dynamic measurements

Influencing factors

- changing drop height

simplified approach: change in weighing signal

$$\Delta m_c\,(t) = \dot{q}\ \mathrm{t}$$

integration yields

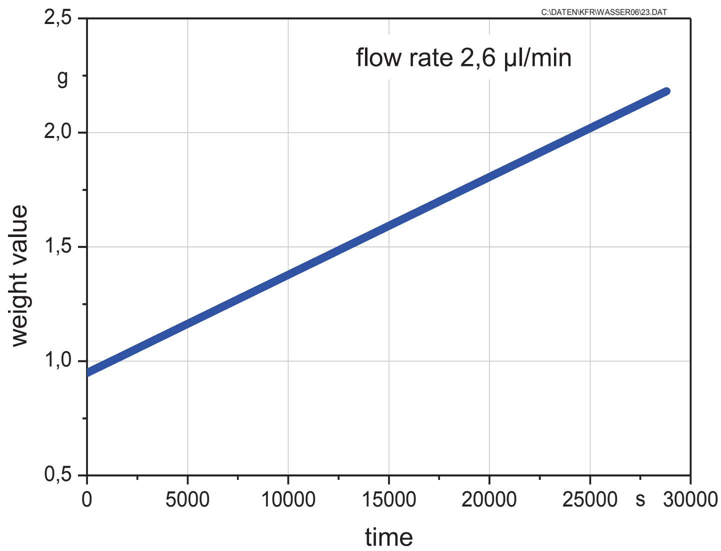
$$\Delta m_c\,(t_1) = \int_0^{t_1} \dot{q}(t)dt = \int_0^{t_1} q_0\ \ (1 - \mathrm{c}\, q_0\ \mathrm{t})\mathrm{dt} = q_0 t_1 - \frac{1}{2} q_0^2 \mathrm{c}\, t_1^2$$

$$\boldsymbol{\Delta m_c = a\,t + b\,t^2}$$

Dynamic measurements

Influencing factors

- changing drop height



$$\Delta m_c = a\,t + b\,t^2$$

Dynamic measurements

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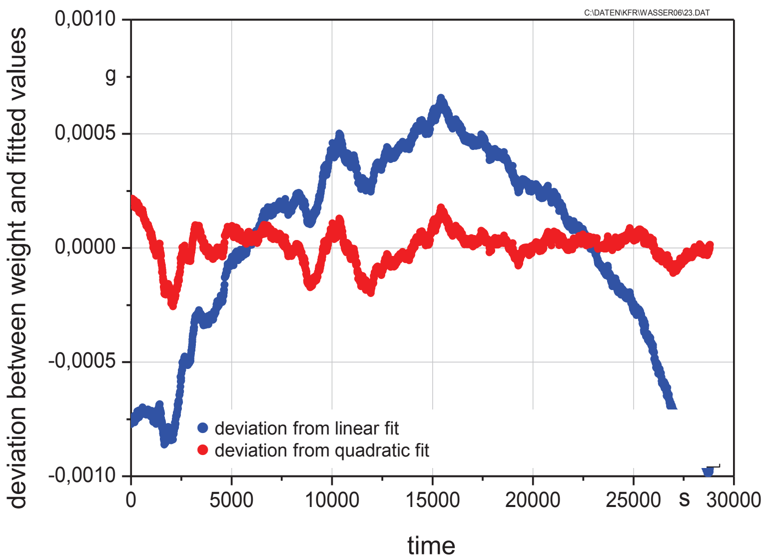


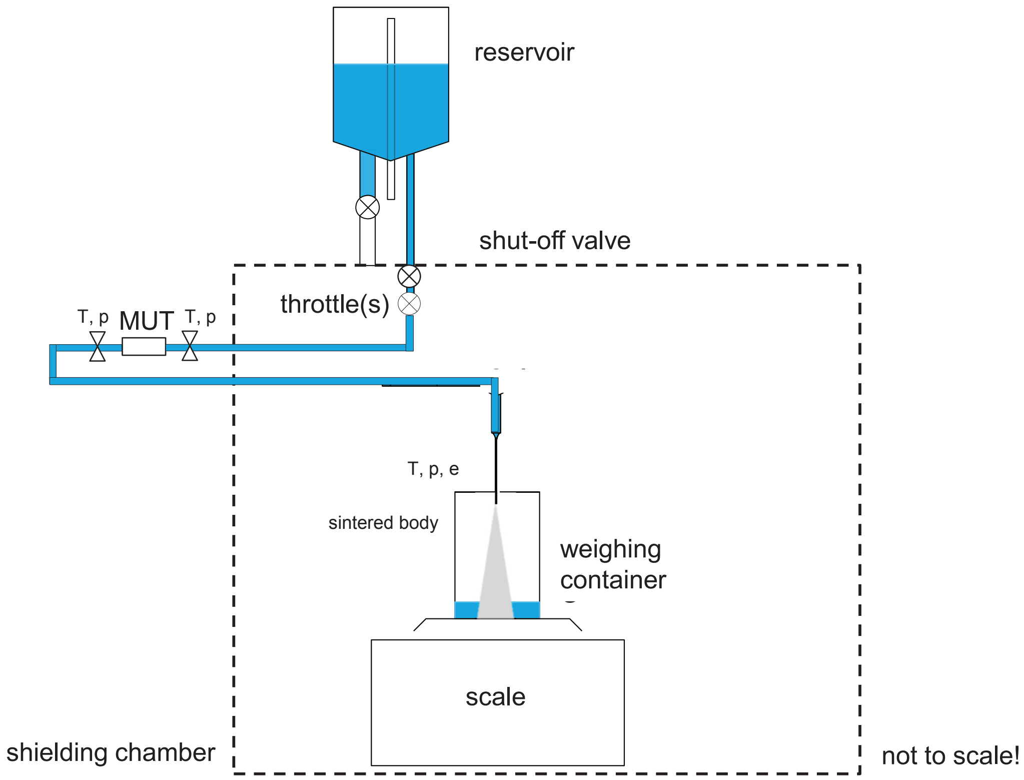
$$\Delta m_c = a\,t + b\,t^2$$

Dynamic measurements

Influencing factors

- changing drop height
  - can be computed
- impact of liquid on scale
- evaporation
- changes in environmental conditions

Schematic measurement setup



Dynamic measurements

Influencing factors

- changing drop height
  - can be computed
- impact of liquid on scale
  - approx. constant during measurement
- evaporation
- changes in environmental conditions

Dynamic measurements

Influencing factors

- changing drop height
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Dynamic measurements

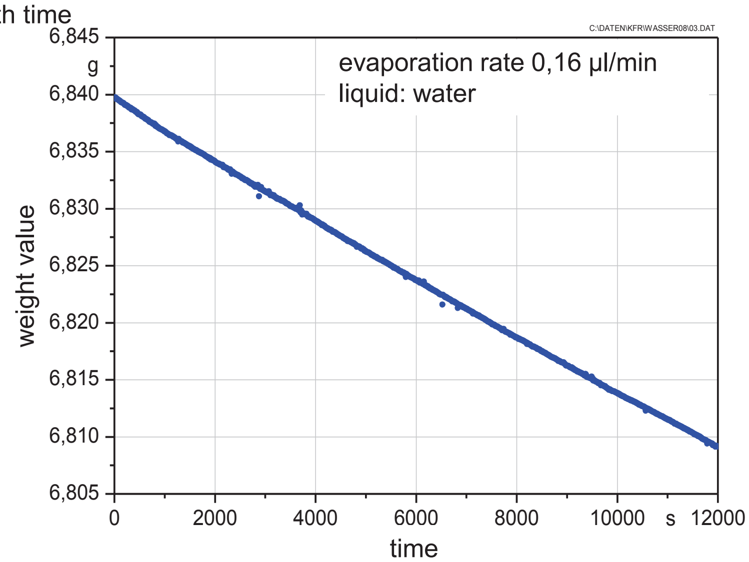
Influencing factors

- evaporation
  - size of the free surface of the liquid
  - convection
  - temperature
  - heat transfer into the liquid
  - degree of saturation of the shielding chamber‘s atmosphere

Dynamic measurements

Influencing factors

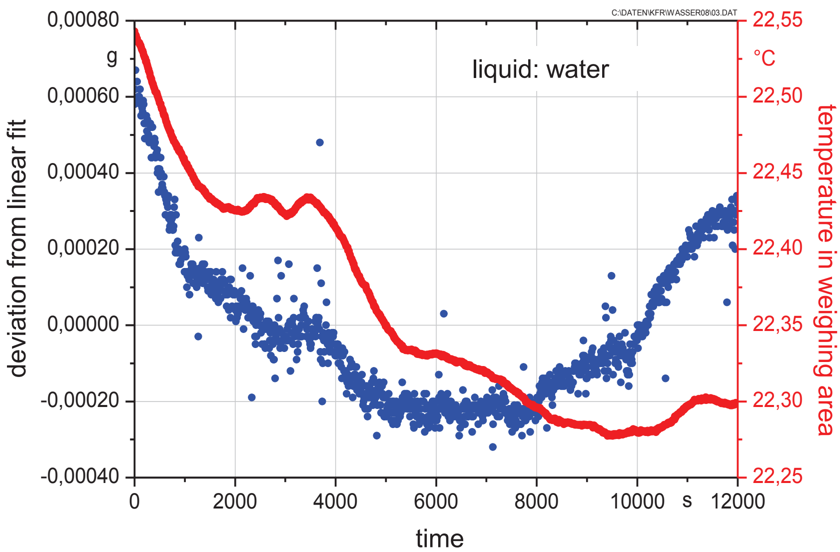
- evaporation
  - at first approximation linear with time



Dynamic measurements

Influencing factors

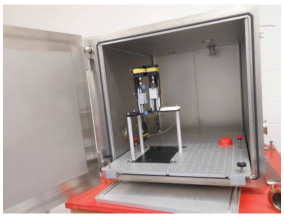
- evaporation



Dynamic measurements

Influencing factors

- changing drop height
- impact of liquid on scale
- evaporation
  - reduction of evaporation rate
    - stabilization of measurement conditions
    - saturation of atmosphere, but condensation needs to be avoided
    - experimental determination of evaporation rates

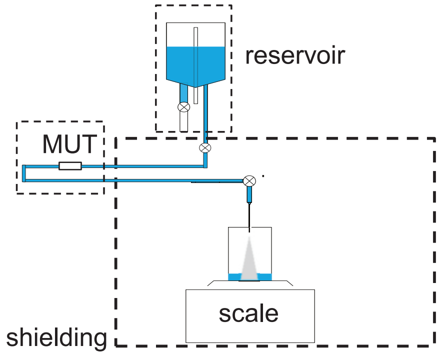


shielding chamber
example MMFF II

Dynamic measurements

Influencing factors

- environmental conditions
  - additional stabilization by separate measurement chamber
  - no air conditioning system
  - modular design of facility with separate shielding compartments
  - temperature stabilization of the chamber can be added



Summary

- MMFF designed in such a way that
  - sources for measurement uncertainties are reduced
  - suitability for water and hydrocarbons is ensured

- MMFF is currently being set up
- experience gained
- in a second step realization of a fully automated system

…to be continued

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