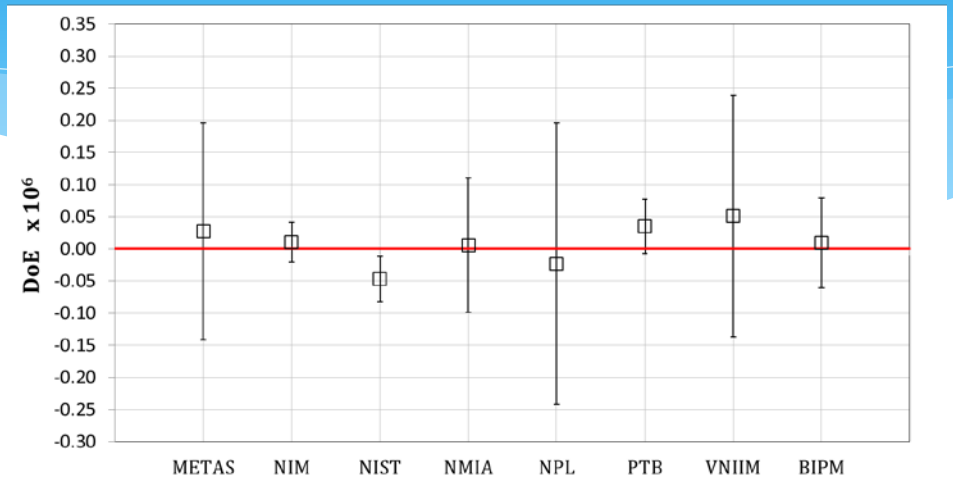
WGLF summary to CCEM 28 March 2019

Jonathan Williams

WGLF Chairman

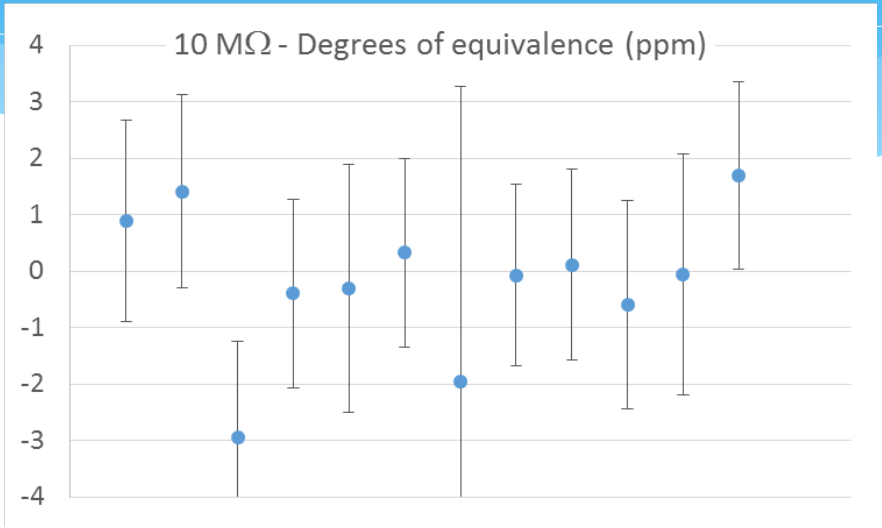
Completed Key Comparisons

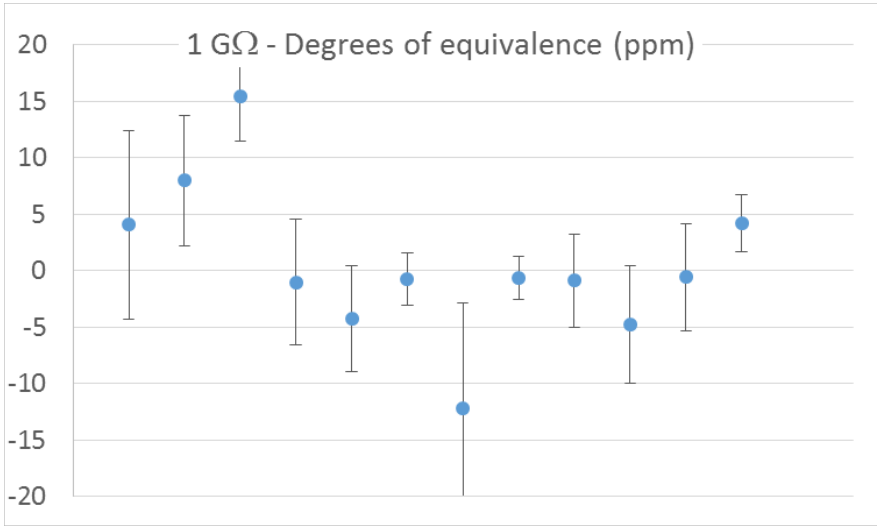


* **K4** – capacitance, 10 pF and 100 pF, 1 kHz and 1.592 kHz
* Adopted a **star** approach
  * BIPM, METAS, NIM, NIST, NMIA, NPL, PTB and VNIIM
  * Measurements March 2017 to November 2018 are completed and the Draft B report is approved for publication in the KCDB. Total duration **20 months**.
  * Measurement of R_K compared with CODATA: $(39 \pm 23) \times 10^{-9}$

Ongoing Key Comparisons

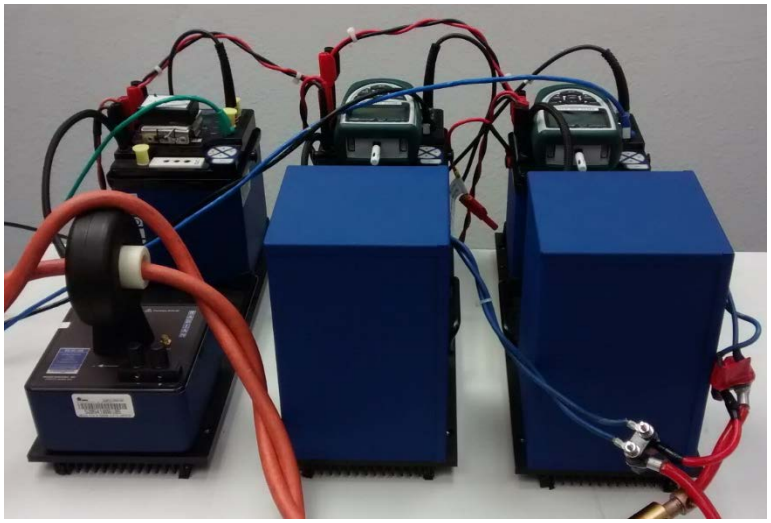
- **K2** – resistance at 10 MΩ and 1 GΩ
  - Pilot laboratory: NRC
  - Started September 2012
  - Measurements completed, Draft A report prepared
  - Draft B report will be available in 2-3 months from now





Ongoing Key Comparisons

- **K5** – primary power at 120 & 240 V, 5 A, 53 Hz; phase 0°, ± 60°, ± 90°, two Radian travelling standards
  - Aimed uncertainty level < 20 µW/VA
  - Planned loop:
    - Pilot measurements: **PTB**
    - SIM: **NIST, CENAM** and **INMETRO**
    - EURAMET: **VSL, LNE** and **SP**
    - APMP: **NIM, NMIA** and **VNIIM**
    - From Afrimets: **NMISA**
  - Measurements: January 2018 to September 2019
  - Draft A report: January 2020



Ongoing Key Comparisons

* **K13** – power harmonics
  * Participants: NIST, NRC, RISE, PTB, NPL, VNIIM, NIM, NMIA
  * Travelling standard Fluke 6105
  * Technical protocol has 3 waveforms:
    * Sine wave at 120 V, 5 A, unity power factor
    * IEC62053-21 signals: voltage 10%, current 40%, 5th harmonic
    * Field-recorded waveform
  * Support group NIST, NRC, RISE, NPL, NIM (pilot)
  * Comparison started autumn 2018 and the standard is now with the third participant, expected completion Dec 2019

Ongoing Key Comparisons

* **K6a/K9**, ac/dc voltage transfer:
  * 3 V, 10 Hz - 1 MHz & 500 - 1000 V, 10 Hz – 100 kHz
* Two travelling standards are being circulated, allowing K6c to be run in parallel to save on transport and reporting costs
* RISE, INTI, PTB, NMIA, NIST, NRC, JV, NMIJ, NIM, LNE, NMISA, INMETRO, VNIIM
* Support group: RISE (protocol), INTI (reporting), NIST (pilot measurements), PTB and NMIA
* Comparison started at the end of 2018 and the third participant is currently making measurements, end Oct 2020

Ongoing Key Comparisons

* **K6c**, ac/dc voltage transfer:
  * 3 V, 500 kHz - 100 MHz
  * Running in parallel with K6a/K9
* RISE, PTB, NIST, NRC, NIM, LNE, VNIIM, A*STAR
* Support group: RISE (protocol), NIST (pilot measurements), PTB
* Comparison started at the end of 2018 and the second participant is currently making measurements, end Oct 2020

Ongoing Key Comparisons

* **K3** – inductance 10 mH and 1 kHz
* Two temperature-controlled standards made available by PTB

NMI	Country	Region
KRISS	Korea	APMP
NMIA*	Australia	APMP
NIM*	China	APMP/COOMET
VNIIM	Russia	APMP/COOMET
LNE	France	EURAMET
VTT	Finland	EURAMET
PTB*	Germany	EURAMET/COOMET
Inmetro	Brazil	SIM
NIST	USA	SIM
NRC	Canada	SIM
NMISA	South Africa	AFRIMETS

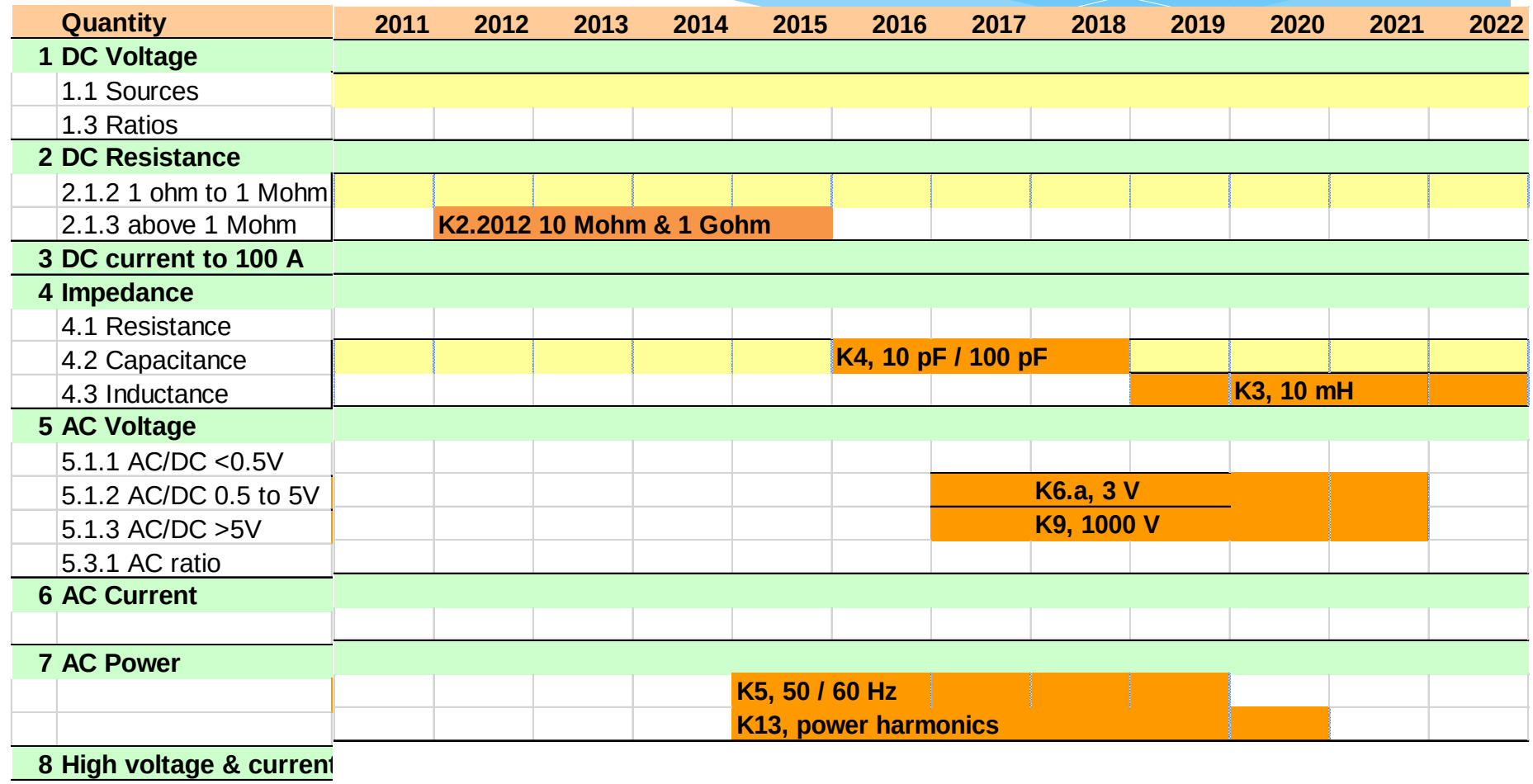
WGLF strategy for comparisons

* 10 Key quantities, 1 -4 values in each quantity
* Discipline of NOT increasing the number of quantities without a strong case
* Review the values within a quantity
* Interval between comparisons typically 10 years, based on evolution in laboratories, some quantities longer or even no future comparison scheduled
* Choices also strongly influenced by the activities in the RMOs

Comparison overview

	Quantity	<1998	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	**DC Voltage**														
	1.1 Sources	**BIPM.K10, K11**													
	1.3 Ratios					**K8, 8.1**									
2	**DC Resistance**														
	2.1.2 1 ohm to 1 Mohm	**K1, 1 & 10 k**		**BIPM.K12 QHR,**		**K10, 100**			**K13a/b, 1 / 10 k**						
	2.1.3 above 1 Mohm			**K2, 10 M & 1 G**											
3	**DC current to 100 A**														
4	**Impedance**														
	4.1 Resistance														
	4.2 Capacitance	**K4, 10 pF**						**BIPM.K14a/b, 10 pF / 100 pF**							
	4.3 Inductance	**K3, 10 mH**											**K3.1, 10 mH**		
5	**AC Voltage**														
	5.1.1 AC/DC <0.5V					**K11, 10 mV, 100 mV**			**K11.1 10 / 100 mV**						
	5.1.2 AC/DC 0.5 to 5V		**K6.a, 3 V**												
	5.1.3 AC/DC >5V		**K6.b, 500 / 1000 V**			**K9, 1000 V**									
	5.3.1 AC ratio			**K7, 1 kHz**											
6	**AC Current**														
										K12, 10 mA / 5A					
7	**AC Power**														
			K5, 50 / 60 Hz												
8	**High voltage & current**														

Comparison overview



Further comparisons

* Reviewed the case for DC voltage
  * 1 V and 10 V are sufficiently covered by Josephson effect standards and comparisons – quantum standard maintains equivalence, supplemented by BIPM Zener comparisons
  * **1000 V** – review requirements and methods with NMIs to establish a comparison approach: voltage ratio or voltage
* Reviewed the case for DC resistance
  * 100 ohm resistance is sufficiently covered by the quantum Hall effect standards, 10 kΩ is covered by BIPM comparisons.
    1 TΩ – review requirements with NMIs to establish a comparison approach

Further comparisons

* Reviewed the case for AC voltage ratio, K7
  * Inductive voltage dividers are very stable. Previous comparison meets the present needs
* Reviewed the case for **AC/DC current, K12**
  * Now 15 years since the previous comparison so – review requirements and methods with NMIs to establish a comparison approach
* Reviewed the case for **High Voltage and Current**
  * **100 kV** - review requirements and methods with NMIs to establish a comparison approach

BIPM Comparisons

* Three to four 1 V and 10 V Zener bilateral comparisons per year
* One or two bilateral resistance comparisons per year at 1 Ω and 10 kΩ
* One or two bilateral capacitance comparisons per year
* Calibrations: 3-5 Zener, 30 resistance, 20 capacitance per year carried out to 170025:2017.
* On-site Josephson comparisons continue
* Following the first on-site QHR comparison in the new series, there are now two per three per year.
* Plan to use a PJVS for comparison of ac voltages, table-top QHR using graphene samples and the acQHR as an impedance standard

Other matters

* Any other business
  * Presentation on the work done by NIM to support the emerging need for traceability for DC power relating to charging of electric vehicles
  * Presentation from NIM on the use of big data from smart meter installations to establish metrology of meters in service
* New WGLF chairman
  * Murray Early (MSL) will be taking over as the next WGLF chairman