DSE 4A CLASS

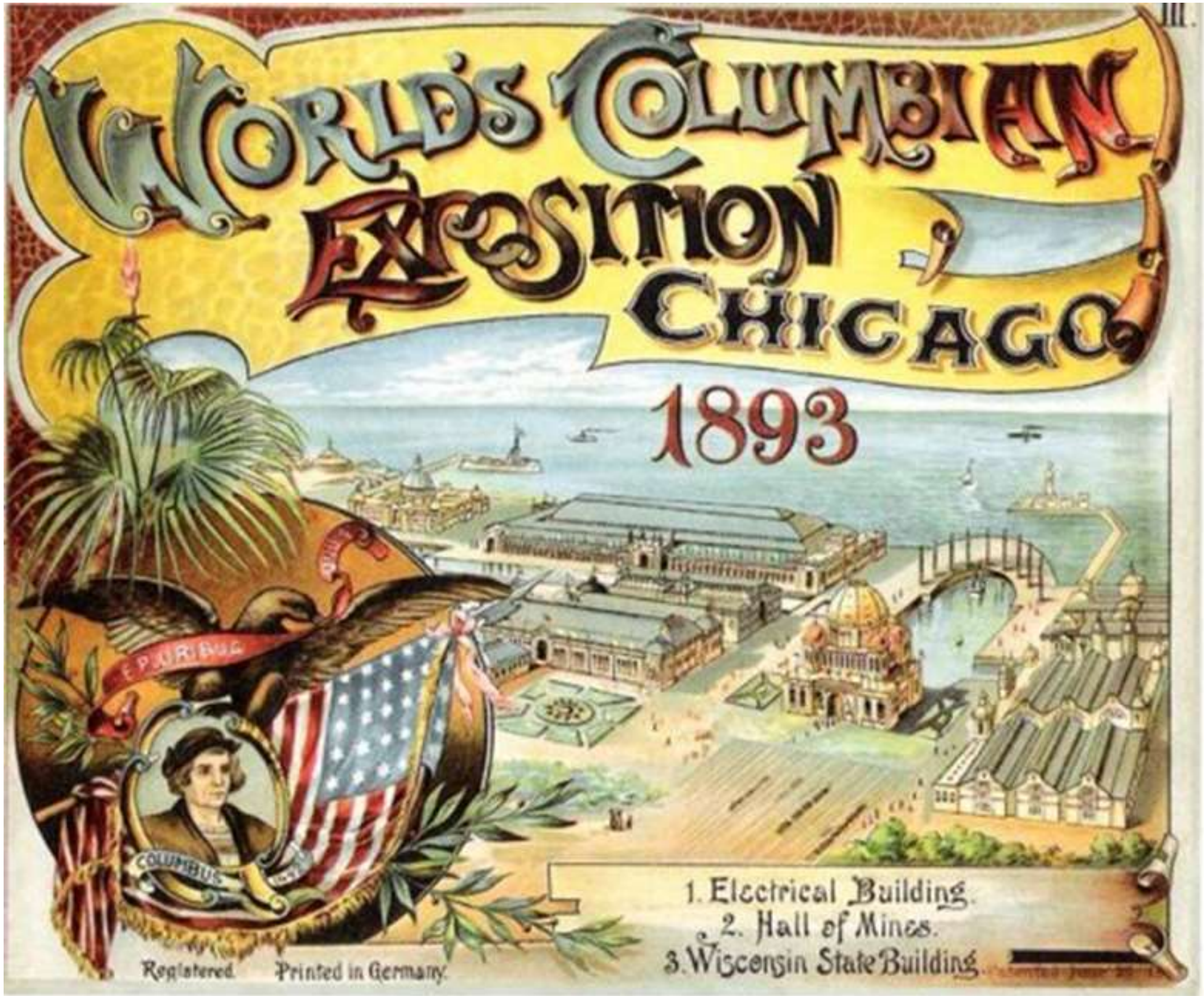
Lecture-2

29/04/2021

1881 : first international congress of electricians, first International system.

The 250 delegates came from 28 different countries. Scientists and engineers, such as the famous William Thomson (Lord Kelvin), Tyndall, Crookes, Helmholtz, Kirchhoff, Siemens, Mach, Gramme, Rowland, Becquerel, Fizeau, Planté, Lord Rayleigh, gathered together for the first time.

On 1893, a congress of electricians was held in Chicago and was considered the second official congress



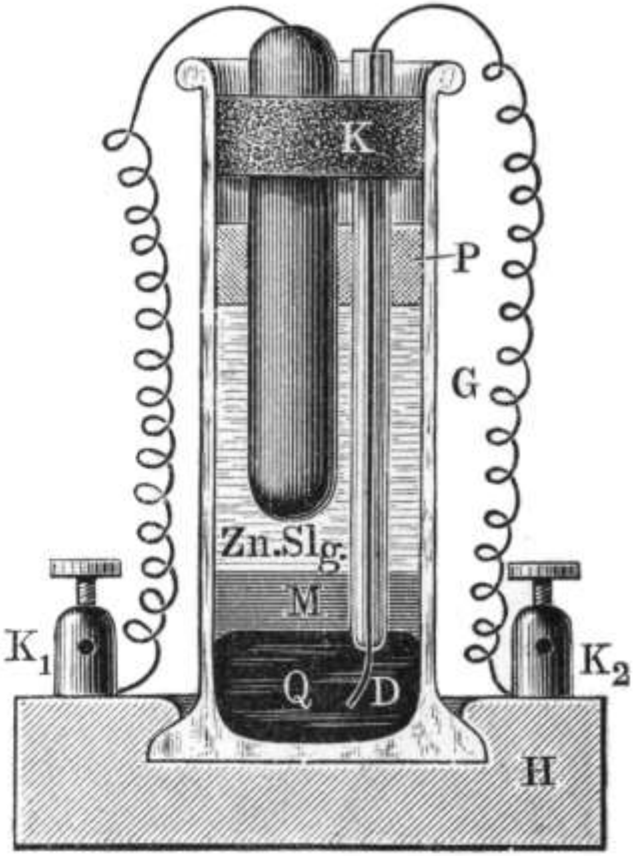
The Chicago Electrical Congress chose to recognize the resistance of a column of mercury 1.063 m long and of constant 1 mm^2 cross section, at a temperature of 0° C as the agreed-upon 1 Ω standard.

This was slightly modified for use in the United States in 1894, with the mass of the column defined as 14.4521 g, instead of defining the constant cross-sectional area

The international volt considered to be the electromotive force corresponding to 1000/1434 of a Clark battery which at that time had replaced the Daniell battery.

Josiah Latimer Clark

English electrical engineer.



The battery was formed by employing pure mercury as the negative element, the mercury being covered by a paste made by boiling mercurous sulphate in a saturated solution of zinc sulphate, the positive element consisting of pure distilled zinc resting on the paste.

The international ampere adopted at a meeting of the British Association in Edinburgh (1892) was the current that would deposit silver from a silver nitrate solution at a rate of 0.001118 g/s under specified conditions.

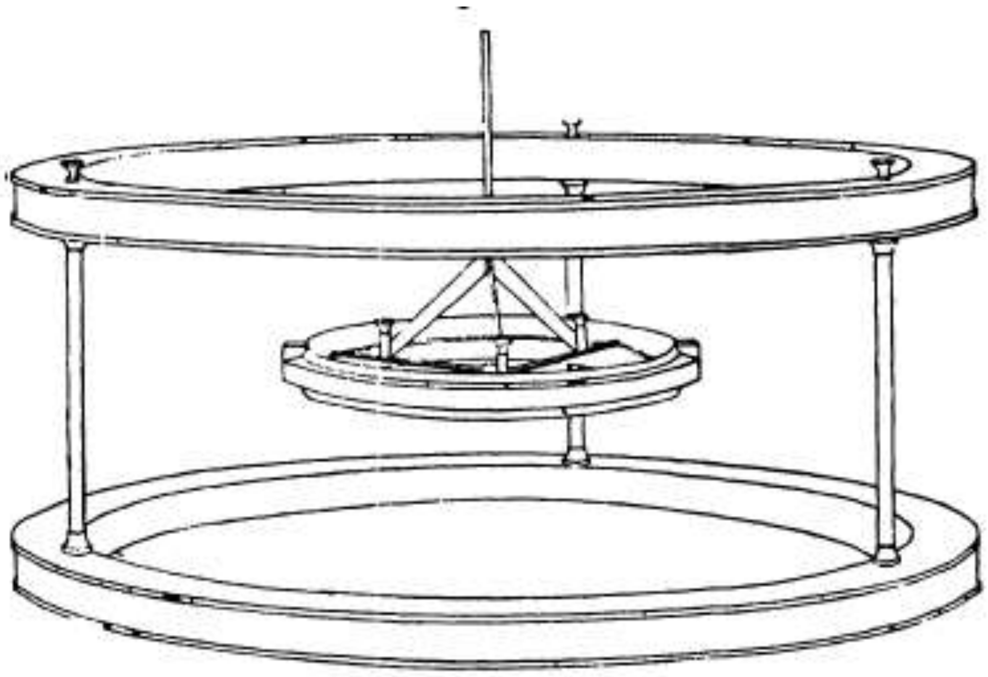
In the electromagnetic system, the ampere is defined as 10^{-1} cgs units, the ohm 10^{9} cgs units and the volt 10^{8} cgs units.

Experiments being conducted at the Bureau on the precession frequency of protons in the magnetic field of a coil carrying a current.

It showed promise of providing a precise method for determining the constancy of the current over long periods of time.

In a work on the ampere at the Bureau published in 1942 a current balance was employed.

A current can be measured in absolute amperes by determining the very small mechanical force between two parts of the circuit in which it flows.
Current is thus "weighed" at the National Bureau of Standards by means of the **Rayleigh current balance**, which measures the force between coils of wire carrying current:



In the center of two large fixed coils, a small coil is hung from the pan of a sensitive balance.

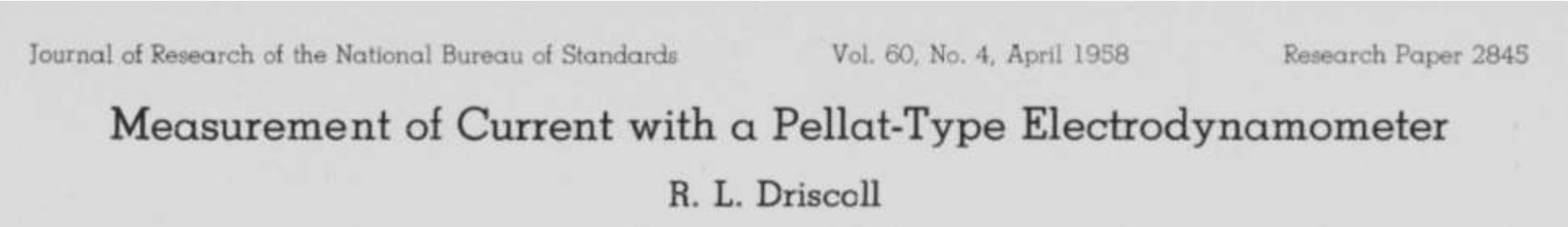
When the three coils are connected in series, the force acting on the small coil per unit of current (f) can be calculated from the dimensions of the coaxial coils and their distance apart.

The total force (F)due to the current is found by adding or removing sufficient weights from the balance pan to re store the balance to its original position.

This observed force divided by the computed force per unit current gives the current in absolute units. **F/f**

Before WW II, at about the same time that the moving-coil current balance was being used to determine the ohm, H. L. Curtis and R. W. Curtis had started to prepare a balance of a special design for the absolute ampere determination.

In 1958 R. L. Driscoll reported results from this Pellat balance



Journal of Research of the National Bureau of Standards Vol. 60, No. 4, April 1958 Research Paper 2845

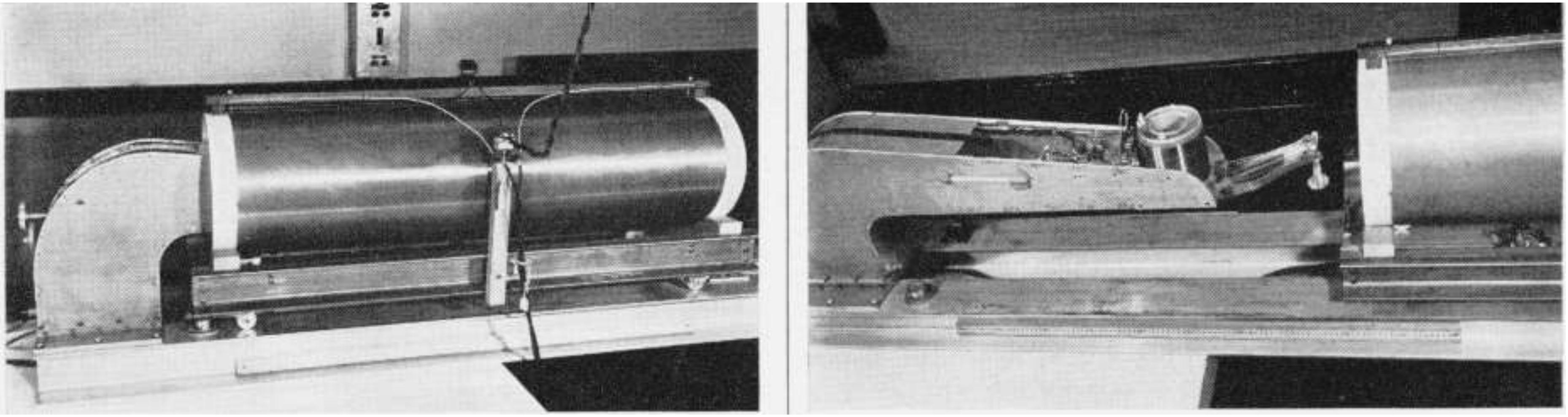
Measurement of Current with a Pellat-Type Electrodynamometer

R. L. Driscoll

The value of an electric current has been determined in absolute measured by means of an electrodynamometer, and simultaneously by standard cells and standard resistors as currently maintained.

The electrodynamometer used was of the Pellat type, and featured a fused silica balance beam and single layer helical coils.

This instrument has a long stationary solenoid with its axis horizontal ; the centered inner coil, mounted on the beam of a balance, is a short solenoid with its axis vertical.



The balance beam is equipped with conventional knife edges and supports the inner coil which thus becomes rotatable about the central knife edge.

With a steady current in both coils in series, the balance is put into equilibrium by means of a suitable counterweight ; on reversing the current in the stationary coil, the equilibrium of the balance is restored
by placing a weight of 1.48 gm on the arm of the balance.

From the known value of the balancing weight, the length of the balance arm, and th ings, the value of the current can be obtai

$$\mathscr{T} = i_1 i_2 \left[\frac{\partial M}{\partial \theta}\right]_{\theta=\frac{\pi}{2}}$$

After completing the Pellat balance measurement, Driscoll and Cutkosky repeated the 1934 Rayleigh current-balance determination of the ampere using the original apparatus.

The results of these two experiments are:

1 NBS ampere = 1.000 013 ± 0.000 008 absolute amperes by the Pellat method, and,

1 NBS ampere = 1.000 008 ± 0.000 006 absolute amperes by the current balance, were in good agreement.

This verified that the ratio of emf over resistance of the maintained standards had been constant to within about one part in 10^5 since 1942.

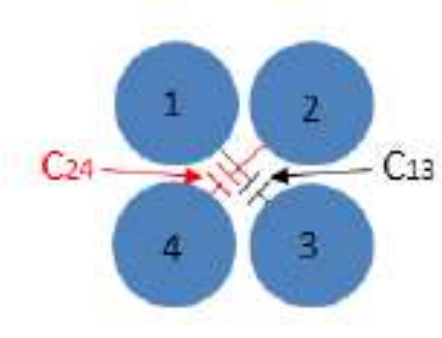
Modern Electrical Standards at NIST

National Institute of Standards and Technology

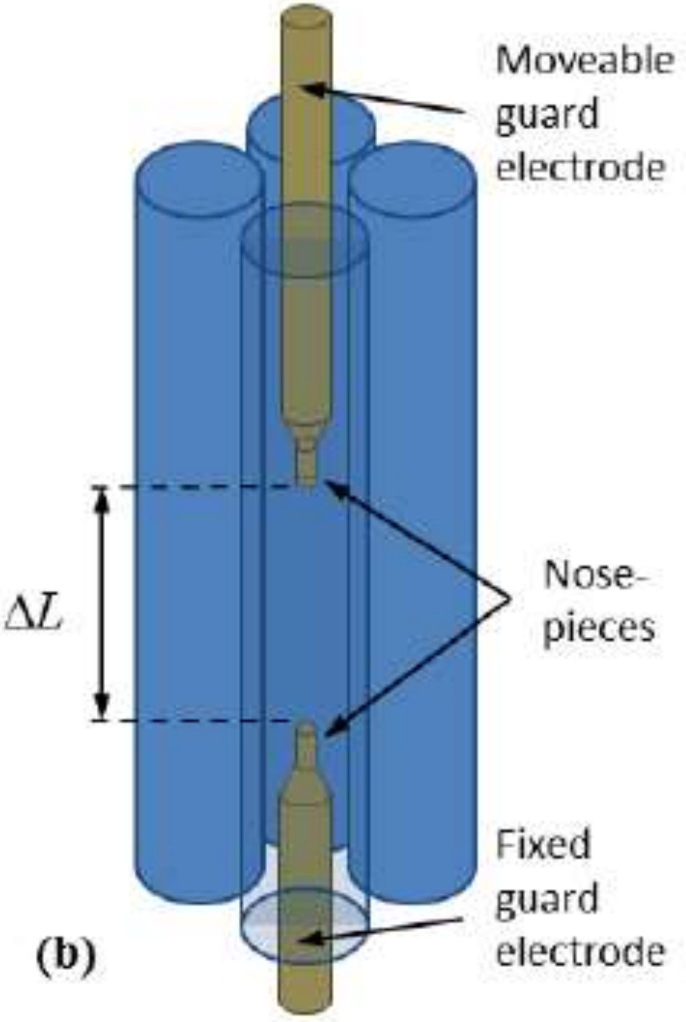
After 1960, ohm determinations were made using calculable capacitors based on the Thompson-Lampard theorem.

In 1956, Thompson and Lampard at the Australian national metrology laboratory determined that the value of a special type of cross-capacitor was dependent only on the length of the capacitor, the speed of light, and the permeability of free space. Based on this principle, the calculable cross-capacitor could provide an alternative method of evaluating the unit of resistance based on straightforward measurements of length and time.

It consists of a cylindrical capacitor composed of four vertical electrode bars separated by small isolating gaps



(a)



(b)

In the inter-electrode space two guard electrodes, one fixed and the other moveable, perfectly aligned with the cylindrical axis of the capacitor cross-section define the electrical length of the capacitor.

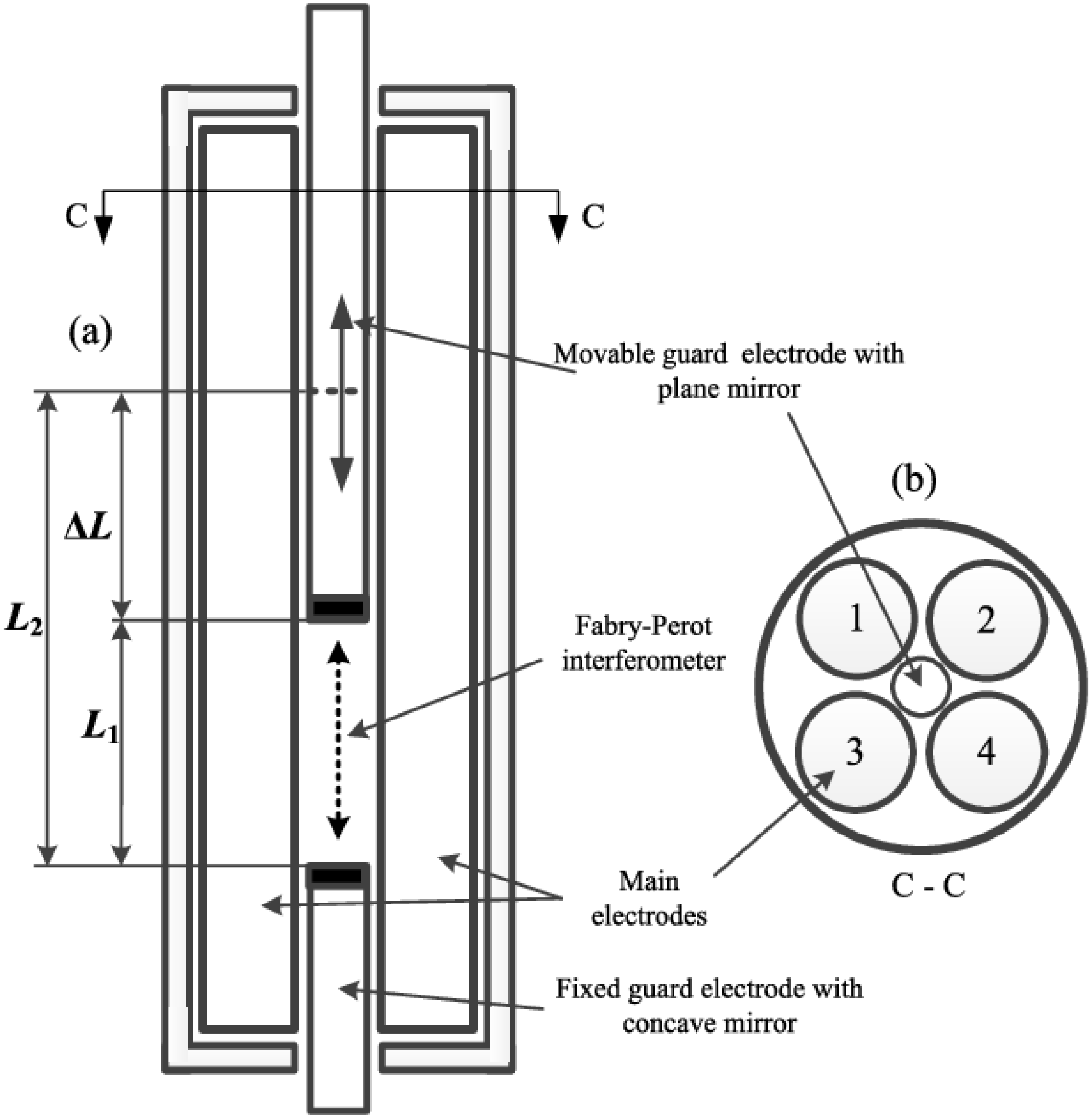
In a two-step measurement procedure, the capacitances of the opposite pairs of bars (C13 and C24) are measured before and after the position of the moveable guard electrode is changed by a distance ΔL.

Since the electrode arrangement is symmetrical, the two opposite cross capacitances are equal and the Lampard theorem allows the calculation of the capacitance variation corresponding to the mean of cross capacitances increases, ΔC, from the simple relation.

$$\Delta C = \varepsilon_0 \ (\mathrm{Ln}2/\pi)\, \Delta L$$

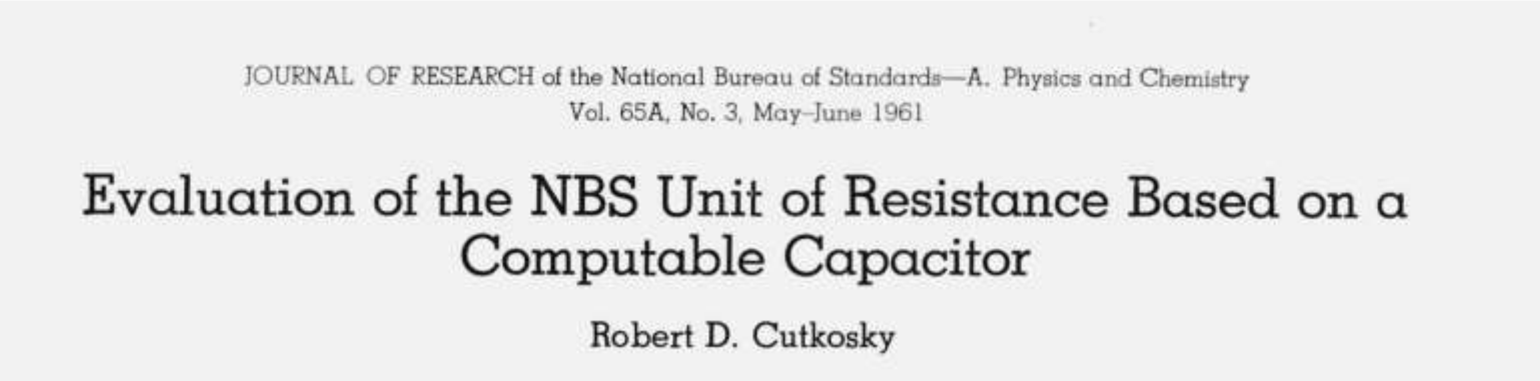
Measurements are made by comparing a fixed-value 10 pF capacitor to the calculable capacitor at two positions of the moveable electrode, where the values are 0.2 pF and 0.7 pF. Displacement of the electrode between these two positions yields a difference of 0.5 pF. By measuring the displacement of the blocking electrode rather than the absolute length of the capacitor, many problems associated with fringing effects at the ends of the capacitor are eliminated.

A Fabry-Perot interferometer measures the relative displacement of optical flats mounted in the moveable and fixed blocking electrodes.



The present relative combined standard uncertainty for this measurement is 0.019×10^{-6}

The first report of a measurement based on a calculable cross-capacitor at NIST was in 1961 by Cutkosky



JOURNAL OF RESEARCH of the National Bureau of Standards—A. Physics and Chemistry
Vol. 65A, No. 3, May–June 1961

Evaluation of the NBS Unit of Resistance Based on a Computable Capacitor

Robert D. Cutkosky

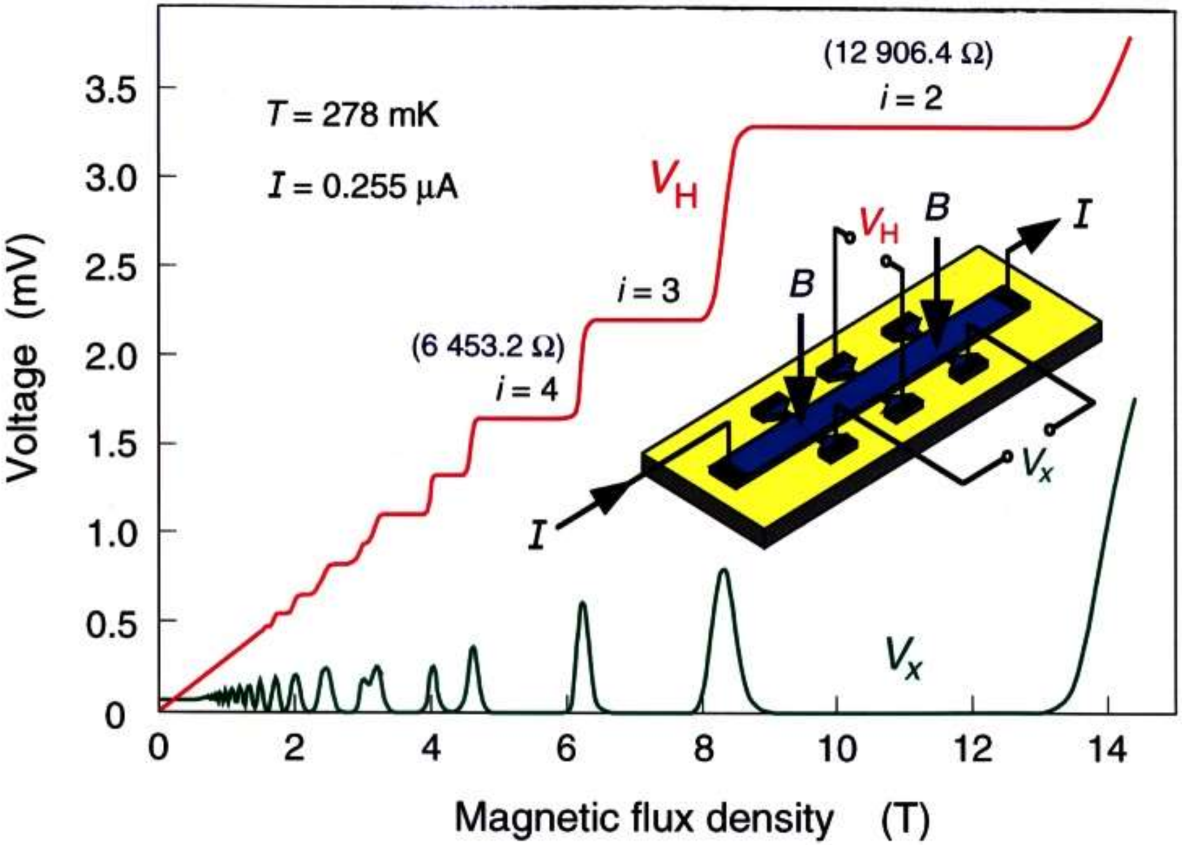
Cutkosky obtained the value of the U.S. Legal Ohm with a relative standard uncertainty of 2.1×10^{-6}

Then came the discovery of the QHE in 1980.
On January 1, 1990 the U.S. Legal Ohm was re-defined in terms of the QHE, with the internationally-accepted value of the quantum Hall resistance (or von Klitzing constant).

At that time, the value of the U.S. Legal Ohm was increased by the fractional amount 1.69×10^{-6} to be consistent with the conventional value of the von Klitzing constant

The QHE is seen only if the charged particles are confined to a two-dimensional sheet within the device by a potential that restricts their out-of-plane motion.

As the magnetic field increases, the Hall resistivity alters in steps and plateau structures form.



The plateaus have the resistance values $R_H = n\frac{h}{e^2}$ called von Klitzing constant

Workers in national metrology laboratories quickly began studying the effect. The uncertainty in measuring R_H needed to be reduced several orders of magnitude.

By August, 1980, M. E. Cage, B. F. Field, and R. F. Dziuba from NBS were doing experiments with R. Wagner at the Naval Research Laboratory in Washington, DC, initially using a Bitter magnet until a 13 T superconducting magnet was installed.

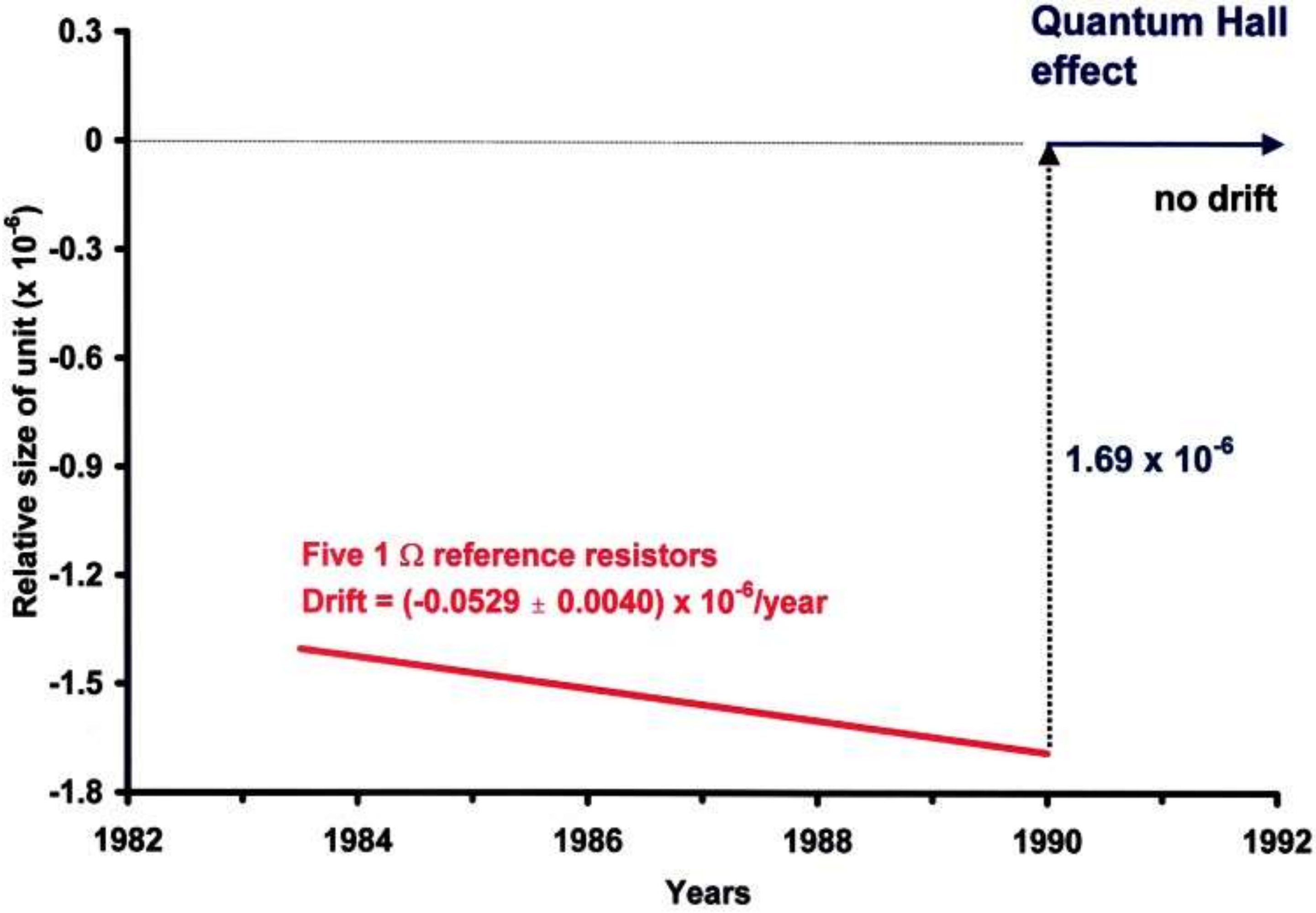
Like von Klitzing, they also used silicon metal-oxide-semiconductor field-effect transistors (Si MOSFETs) as the device.

In 1982 D. Tsui and H. Stormer invited NIST staff to Bell Labs in Murray Hill, NJ.

Their GaAs/AlGaAs heterojunction devices, made by A. Gossard, were better than Si MOSFETs because of the smaller effective masses of the electrons in the 2DEG and wider plateaus.

These devices, and improvements in the measurement system, enabled the first precision measurements of R_{H}, with an uncertainty of $2 \times 10^{-7}\ R_{\mathrm{H}}$

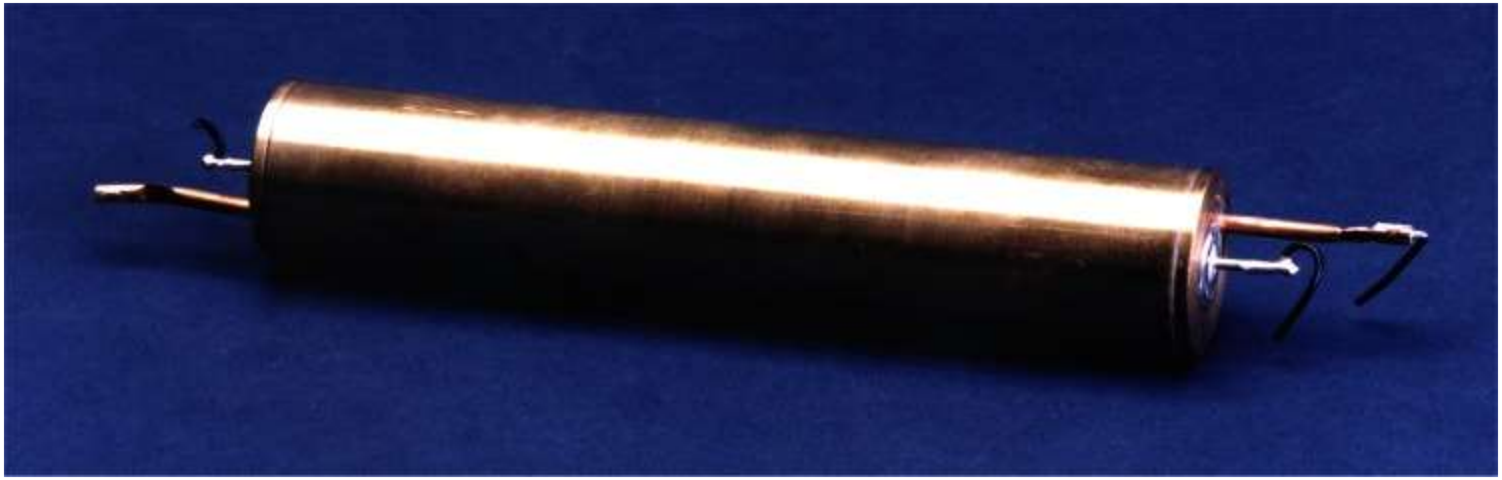
The potentiometric QHR measurement technique and resistance scaling methods were refined, allowed NBS to monitor the U.S. Legal Ohm to within the fractional amount of 1.5×10^{-8}



In 1996, R. F. Dziuba and D. J. Jarrett developed a process for fabricating stable, transportable, high-value standard resistors of nominal values from 1 GΩ to 10 TΩ.

The resistance elements of these standards consist of precious-metal-oxide (PMO) film resistors.

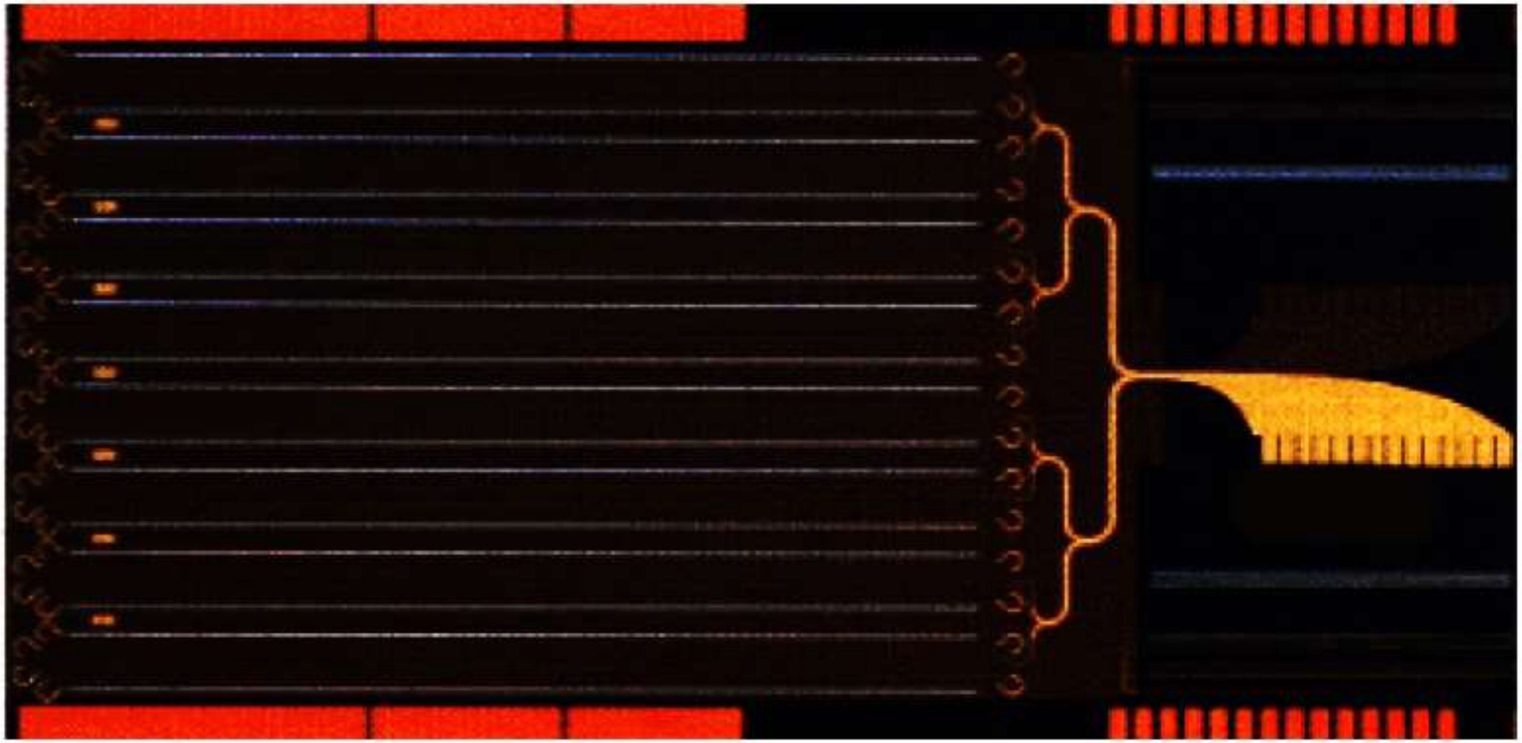
For the 1 GΩ, 10 GΩ and 100 GΩ standards, selected resistors are mounted in thick-walled brass cylinders using end plates with glass-to-metal seals



NIST maintains the representation of the volt based on the Josephson effect, as a simple relationship between the voltage across a superconductor—insulator—superconductor junction and the microwave frequency radiating onto the junction.

The relationship can be expressed by the equation $V = \mathrm{n}\nu/\mathrm{K}_J$, where V is the quantized voltage, n is an integer, ν is the microwave frequency, and $K_J = 2e/h$ is the Josephson constant.

Electricity Division's Josephson voltage and voltage-calibration laboratories responsibilities for maintaining and disseminating the volt through NIST calibration services. Two Josephson voltage standard systems, designated NIST-1 V and NIST-10 V, operate as the U.S. representation of the SI volt. The NIST-1 V system uses a 1 V Josephson array consisting of 2076 junctions in series. The NIST-10 V system uses a 10 V a



Today, a high-end digital voltmeter is able to make voltage measurements with a relative uncertainty of three or four times 10^{-6}. Calibration laboratories, and military laboratories requires NIST voltage calibration capability with a relative uncertainty of a few times 10^{-7}

C. J. Burroughs, S. P. Benz, C. A. Hamilton, and T. E. Harvey, working at the NIST Boulder laboratories, have developed a new type of array with programmable binary segments of Josephson junctions.

The noise immunity and high resolution in voltage measurements provided by the programmable array now allows its use in the NIST watt balance experiment, thereby reducing the uncertainty of the