The importance of (Bleeker) electrical measuring equipment

A.C. Labrujere, PhD in physics

Preface

The Historical Microscopy Foundation has a considerable collection of very accurate Bleeker measuring and control equipment. The collection includes many decade resistance boxes, potentiometers, resistance bridges (Wheatstone and Thomson), microvolt meters and compensators. This equipment was developed and produced in the Bleeker factories from the beginning of the last century until the seventies. The prices were very high for that time and we often get the question why such expensive and precise equipment was necessary. In this document we will briefly discuss the importance of this equipment in the development of research and production of electrical devices.

Development of electrical devices

The role of electricity is obvious nowadays. Every day everyone uses electric lighting, TV, radio, computers, mobile phones and tablets, cooking equipment, electric bicycles; you name it. Every day everyone actively turns on and off devices, or sets them up (harder or softer, different channel or program, ...). This happens even more often unconsciously in all kinds of automated electrical networks that are located in cars, trains and airplanes, and of course also in factories, hospitals and telecom- and electricity- networks.

This development has started about 250 years ago. The table below lists a number of relevant inventions, but it is clear that there are many thousands of other examples to mention. To develop these devices, one had to have very good measuring equipment to test the components used. One wrong component in a radio and you will never receive your favourite radio program; a wrong part in a GPS system and you will never reach your place of destination; a wrong component in the cockpit of an aircraft and .... In short, high-quality measuring equipment is at the basis of all devices that we now use so thoughtlessly and confidently.

Year	Inventor	Device
1752	*Benjamin Franklin*	*Lightning rod*
1800	*Alessandro Volta*	*Battery*
1820-1832	*Faraday, Sturgeon, Davenport*	*Electric motor*
1876	*Alexander Bell*	*Telephone*
1877	*Thomas Edison*	*Phonograph*
1879	*Thomas Edison (on basis of design of Joseph Swan)*	*Light bulb*
1895	*Guglielmo Marconi*	*Radio*
1928	*Vladimir Zworykin*	*TV (cathode tube)*
1935	*Robert Watson Watt (Christian Hülsmeyer)*	*Radar*
1944	*USA*	*ENIAC-computer*
1947	*William Schokley et al.*	*Amplifier*
1960	*Theodore Maiman*	*Laser*
around 1970	*Many companies (TI, Intel, …)*	*Microprocessor*

Table. *Overview of relevant breakthroughs of electrical equipment in the last 250 years.*

Need for measuring and control devices

Without knowledge of electrical properties and without the development of accurate measuring and control equipment, we would never have been able to develop all these electrical devices. C.E. Bleeker contributed to the development of electrical equipment and focused in particular on measuring and controlling the three basic elements of electricity: Voltage, Current and Resistance. She developed high quality equipment, which today is still amazingly accurate to use. Her equipment was widely used in scientific environments and in test and measurement laboratories for the production of new products. She developed three types of products:

1. ***Measuring devices*** that could determine voltages, currents and resistances very accurately.
2. ***Control devices*** capable of controlling voltages, currents and resistances.
3. ***Calibration elements*** with a very accurately determined resistance or voltage, which were used as reference for measuring devices.

The basis: Ohm's law

Bleeker mainly focused on the three basic elements of electricity: Voltage (V), Current (I) and Resistance (R). Ohm's law gives a relationship between these three quantities:

$$V = I \times R$$

This law says that when a voltage (V, unit Volt (V)) is applied over a device, a current (I, unit Ampère (A)) starts to run. The magnitude of the current depends on the resistance (R, unit Ohm (Ω)) that it encounters.

One can compare Ohm's law with a mountain slope over which water flows down. How fast the water flows depends on two factors. In the first place, the water will start to flow faster on a steeper slope than on a relative flat slope. A larger steepness (a larger voltage) therefore provides a larger flow (current). Second, the speed will be determined by the amount of stones and branches and other objects that it encounters. More stones and branches (more resistance) ensure a lower speed, and thus a smaller flow.

The same principle takes place in electrical circuits: a current of small particles (electrons) is flowing when voltage is applied over a conducting material. This will however encounter resistance due to the properties of the metal and impurities, following the lam of Ohm. An example is a light bulb. If a voltage (e.g. 220 Volt) is applied to the lamp, an electric current will be generated. Because the current in the lamp is intentionally pressed through a very small wire, the conductive particles (electrons) experience a large resistance. As a result, heat is generated, causing the lamp to emit light.

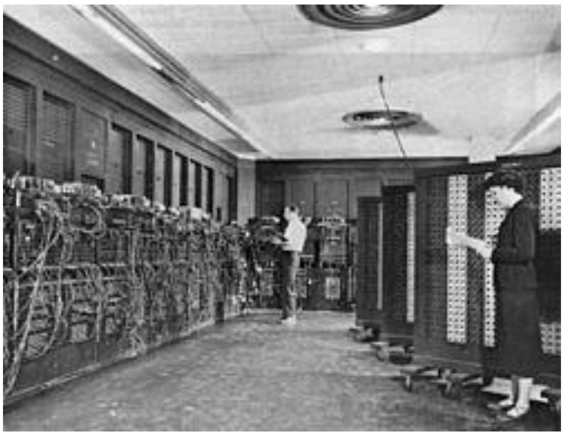

Figure 1. *The ENIAC Computer (source Wikipedia) contains 70.000 resistors.*

Electrical resistors are required in all electrical devices. A very simple, old 1940 radio soon contains at least 10 resistors and a TV a multiple thereof. The first large electrical (super!)computer in the USA (ENIAC around 1944) contained more than 70,000 resistors, 10,000 capacitors and 6,000 switches! Without accurate resistors and voltages, these devices would work insufficiently or even not work at all. Accurate measuring equipment is therefore indispensable.

Bleeker equipment in the collection of the Historical Microscopy Foundation

C.E. Bleeker has used her physics knowledge for the development of many advanced measuring and control equipment, which was very suitable for precision measurements in research laboratories (e.g. universities), production companies for high-tech equipment (e.g. Philips) and test companies (e.g. TNO). The products can be divided into:

1. **Measuring equipment.** To measure accurately voltage, current and resistance of components. The collection consists of:

   a. *Wheatstone bridges.* Used to measure very accurately the magnitude of an unknown resistance, by using a circuit (bridge) of highly accurate and adjustable resistors.

Figure 2. *A Bleeker Wheatstone bridge.*

   b. *Thomson bridges.* Modified Wheatstone bridges, suitable for measuring very low resistances.

   c. *Resistance bridges.* These are probably also based on the Wheatstone principle. Further research will have to determine exactly how these devices work.

   d. *Compensators.* These are circuits for measuring an unknown voltage by compensating it with an adjustable voltage.

Figure 3. *A Bleeker compensator.*

   e. *Diesselhorst compensators.* Specific and very accurate compensators.

   f. *Microvoltmeters.* Probably marketed by Bleeker but produced elsewhere.

   g. *Galvanometers*. Highly accurate voltage meters to measure zero voltage. Galvanometers are integrated in Wheatstone and Thomson bridges and compensators, but also separately available.

Figure 4. *Bleeker galvanometers.*

   h. *Specific measuring equipment* (customised to different applications), such as a resistance bridge for measuring effects stretch tests.

2. **Control equipment.** To accurate control resistance, voltage and current in circuits. The collection consists of:

   a. Decade resistance boxes are used to adjust an electrical resistance step-by-step with great precision. The collection contains dozens of resistance boxes, varying from 1 to 6 resistance components.

Figure 5. *Bleeker decade resistance boxes.*

b. *Pot(entio)meters* are adjustable resistors, but the resistance is now set via a rotating mechanism (a contact that can be set over a resistor). There are also two original long sliding resistances in the collection.
c. *Switched resistor boxes* in specific configurations.
d. *Adjustable power supplies and voltage dividers*, mainly to support other electrical and optical devices.

3. **Calibration elements.** For accurate absolute measurement, it is necessary to have calibrated references. Bleeker developed elements for calibrating resistances and voltage (and hence by combining these for current).

   a. *Normal resistors*. These are high-quality and very accurately determined standard resistors. The collection consists of resistors from 0.001 Ω to 100.000 Ω.
   b. *Weston normal elements*, providing a standard voltage of 1.01865 V (based on saturated $CdSO_4$). Measurements still have to show which type of Weston normal element is included in the collection and how accurate they are after all the years.