resistor.

4.6 Voltage Coefficient

When voltage is applied to a carbon or film-type resistor there may be a decrease in resistance apart from changes caused by loading of the resistor (Wellard, 1960). This decrease in resistance with increase in voltage results from the breakdown of contact resistances between carbon particles in carbon composition resistors or the breakdown of boundary resistances between islands of material on substrates of film-type resistors. This change in resistance per applied volt is called the voltage coefficient of resistance. In carbon composition resistors, the change in resistance value due to applied voltage is usually - 200 ppmN or less. For carbon-film resistors, the VCR can vary from -10 to - 50 ppmN. Metal-film resistors have VCRs from - 1 to - 30 ppmN depending on their wattage, whereas metal-oxide-film resistors have VCRs from - 1 to - 5 ppmN. Wire-wound resistors do not exhibit a VCR.

4.7 Humidity Effects

Unless the resistive element is hermetically sealed in a glass or metal container with glass-to-metal seals, moisture can permeate a resistor and change its resistance value. Moisture can produce two reversible effects:

4.8 Pressure Effects

Resistance materials are affected by changes in pressure (Meaden, 1965). These changes of resistance as a function of pressure are not well understood, and, depending on the material, resistors may have either a positive or negative pressure coefficient of resistance. Fortunately, for well-constructed resistors these changes of resistance with pressure are only significant for those of the highest quality. For pressure changes of 500 hPa, the change in resistance would be within 1 ppm.

4.9 Frequency Effects

A resistor may be represented to a first approximation by the circuit of Fig. 2, which shows a pure dc resistance R in series with

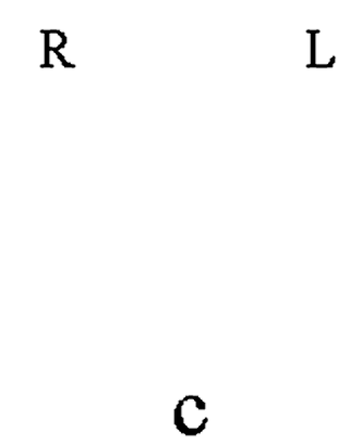

FIG. 2. Simplified model of a resistor.