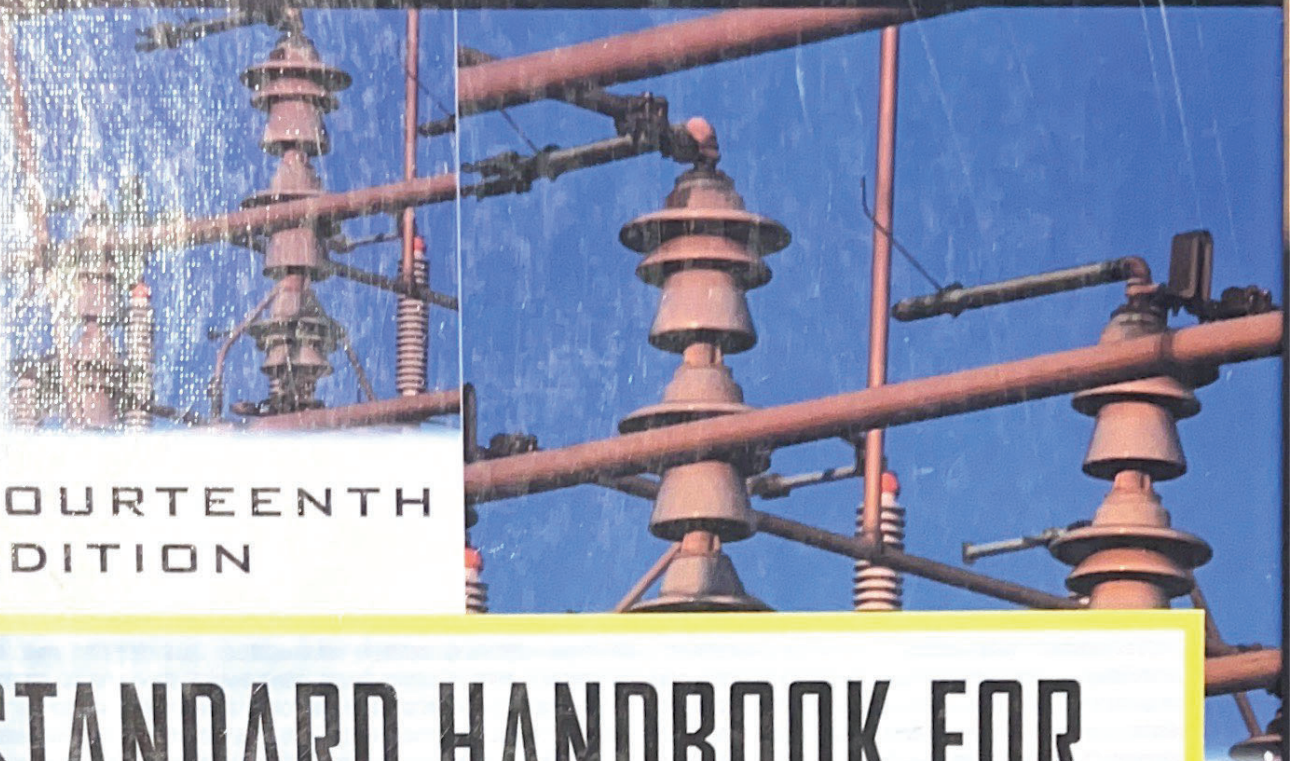


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STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

DONALD G. FINK
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STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS

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4.4.5 Thermal Conductivity of Electrical Insulating Materials

By CHARLES A. HARPER

One of the general characteristics of electrical insulating materials is that they are also good thermal insulating materials. This is true, in varying degrees, for the entire spectrum of insulating materials, including air, fluids, plastics, glasses, and ceramics. While the thermal insulating properties of electrical insulating materials are not especially important for electrical and electronic designs which are not heat-sensitive, modern designs are increasingly heat-sensitive. This is often because higher power levels are being dissipated from smaller part volumes, thus tending to raise the temperature of critical elements of the product design. This results in several adverse effects, including degradation of electrical performance and degradation of many insulating materials, especially insulating papers and plastics. The net result is reduced life and/or reduced reliability of the electrical or electronic part. To maximize life and reliability, much effort has been devoted to data and guidelines for gaining the highest possible thermal conductivity, consistent with optimization of product design limitations, such as fabrication, cost, and environmental stresses. This section will present data and guidelines

TABLE 4-64 Thermal Conductivity of Materials Commonly Used for Electrical Design

Material	Thermal conductivity	
	W/(in)(°C)	Btu/(h)(ft)(°F)
Silver	10.6	241
Copper	9.6	220
Eutectic bond	7.50	171.23
Gold	7.5	171
Aluminum	5.5	125
Beryllia 95%	3.9	90.0
Molybdenum	3.7	84
Cadmium	2.3	53
Nickel	2.29	52.02
Silicon	2.13	48.55
Palladium	1.79	40.46
Platinum	1.75	39.88
Chromium	1.75	39.88
Tin	1.63	36.99
Steel	1.22	27.85
Solder (60-40)	0.91	20.78
Lead	0.83	18.9
Alumina 95%	0.66	15.0
Kovar	0.49	11.1
Epoxy resin, BeO-filled	0.088	2.00
Silicone RTV, BeO-filled	0.066	1.5
Quartz	0.05	1.41
Silicon dioxide	0.035	0.799
Borosilicate glass	0.026	0.59
Glass frit	0.024	0.569
Conductive epoxy	0.020	0.457
Sylgard resin	0.009	0.21
Epoxy glass laminate	0.007	0.17
Doryl cement	0.007	0.17
Epoxy resin, unfilled	0.004	0.10
Silicone RTV, BeO-filled	0.004	0.10
Air		0.016

which will be useful to electrical and electronic designers in selection of electrical insulating materials for best meeting thermal design requirements. Also, methods of determining thermal conductivity K will be described.

Basic Thermal-Conductivity Data. The thermal-conductivity values for a range of materials commonly used in electrical design are shown in Table 4-64. These data show the ranking of the range of materials, both conductors and insulating materials, from high to low. The magnitude of the differences in conductor and plastic thermal-conductivity values can be seen. Note that one ceramic, 95% beryllia, has a higher thermal-conductivity value than some metals—thus making beryllia

TABLE 4-65 Thermal Conductivity of Various Types of Plastics

Material	Specific gravity	Btu/(h)(ft ²)(°F)(ft)*
Thermoplastics:		
Polyethylene	0.92–0.96	0.1–0.4
Polytetrafluoroethylene	2.15–2.25	0.1–0.2
Molded thermosets:		
Phenolic, wood-flour-filled	1.32–1.45	0.10–0.19
Phenolic, mineral-filled	1.65–1.92	0.24–0.34
Diallyl phthalate, acrylic fiber	1.31–1.45	0.18–0.19
Laminates, perpendicular-to-face:		
XXXXP, paper-phenolic	1.3–1.4	0.04–0.12
G-7, silicone-glass	1.6–1.8	0.07–0.17
G-10, epoxy-glass	1.7–1.8	0.10–0.17
PTFE glass-cloth	2.1–2.2	0.02–0.05
Casting resins and foams:		
Epoxy, unfilled	1.16	0.13–0.20
Epoxy, 73% alumina by weight		0.82
Epoxy, 50–55% silica by weight	1.6–1.7	0.29–0.53
Epoxy, hollow phenolic spheres	0.86	0.16
Epoxy, hollow glass spheres	0.95	0.38
Polyester, unfilled	1.23	0.10–0.15
Polyester, 50% silica by weight	1.6	0.19
Polyurethane foam (10 lb/ft ³)	0.16	0.02–0.03

*To obtain: Btu/(h)(ft²)(°F)(in), multiply by 12.

TABLE 4-66 Thermal-Conductivity Conversion Factors

From	To			
	$\frac{(\text{cal})(\text{cm})}{(\text{s})(\text{cm}^2)(^\circ\text{C})}$	$\frac{(\text{W})(\text{cm})}{(\text{cm}^2)(^\circ\text{C})}$	$\frac{(\text{W})(\text{in})}{(\text{in}^2)(^\circ\text{C})}$	$\frac{(\text{Btu})(\text{ft})}{(\text{h})(\text{ft}^2)(^\circ\text{F})}$
$\frac{(\text{cal})(\text{cm})}{(\text{s})(\text{cm}^2)(^\circ\text{C})}$	1	4.18	10.62	241.9
$\frac{(\text{W})(\text{cm})}{(\text{cm}^2)(^\circ\text{C})}$	2.39×10^{-1}	1	2.54	57.8
$\frac{(\text{W})(\text{in})}{(\text{in}^2)(^\circ\text{C})}$	9.43×10^{-2}	3.93×10^{-1}	1	22.83
$\frac{(\text{Btu})(\text{ft})}{(\text{h})(\text{ft}^2)(^\circ\text{F})}$	4.13×10^{-3}	1.73×10^{-2}	4.38×10^{-2}	1