Visualization and the Production of Thermophysical Facts

Technologies of Remembering, Techniques of Forgetting

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Scientific visualization is commonly associated with the presentation of empirical results, yet it plays an important and under-studied role in the production of scientific facts in collections of reference data. In this paper I'll analyze how graphs of thermal conductivity of the elements (Ho, Powell, and Liley 1974; see Figure 1) are used to produce the numerical thermophysical facts subsequently encoded into reference data tables in scientific handbooks. This analysis shows that the rigor, precision, and comprehensiveness of these visualizations are the source of the scientific license to 'forget'. In other words, the graphs' structure, arraying empirical results alongside a mathematically generated Recommended curve of values, is an inscriptive maneuver that licenses the exclusion of empirical results from reference data works. Thus, these visualizations are simultaneously a memory practice (Bowker 2005), a technology of remembering, and a technique of forgetting.

Thermophysical reference data presents an interesting and important question for philosophy of science and philosophy of information at once. First, the sense of 'data' in this case is not empirical measurement. No set of empirical measurements in Figure 1 correspond with the numerical thermal conductivity values given in Figure 2, intended for incorporation into scientific handbooks. Rather, 'data' here is used in the sense of *given*. This givenness can be identified as the site of Bowker's forgetting: because Ho et al. have analyzed the data exhaustively, and provided such a thorough visualization, we are scientifically licensed to *take* the given as fact and use it, leaving measurement behind. This is precisely what scientific handbooks have done with this data. While it might initially seem that the givenness is an assertion of some form, its codification into tables and subsequent publication in handbooks simultaneously constitutes a declarative speech act (Searle 1976), and exemplifies what Derrida called the jussive archive. Ho et al.'s mathematical curve is re-christened (declared to be) Recommended Values for Thermal Conductivity, jussively shedding its empirical basis in the process. As a scientist attempting to locate the 'truth' of the thermal conductivity of an element, I am able to consult the handbook, not as a messy store of empirical measurements but rather as a store of *given* declaratives. The 'success' of these declaratives is the production of a thermophysical fact.

Wittgenstein wrote, "To be sure there is justification; but justification comes to an end" (Wittgenstein 1969, sec. 192); in this light, my project is to locate and describe how visualizations can form a terminus for scientific justification. The vast majority of scientific claims are experienced by scientists as second hand knowledge. Thus, a crucial task of the scientist using reference data is determining the level of cognitive authority to grant to this knowledge (Wilson 1983). Conversely, the reference data research community must produce facts and attempt to claim the cognitive authority to do so. Visualization is a key technique that Ho et al. use to justify their claim to this authority. The techniques of forgetting embodied in Ho et al.'s graphs are simultaneously jussive in Derrida's sense and declarative in Searle's. This suggests important new ways for philosophers of science and information to approach the production of facts.

Figures

Figure 1: Thermal conductivity of copper (adapted from Ho, Powell, and Lilley 1974, p. I–244). Each empirical result series is indexed to a bibliographic table containing the details of the study it represents. The Recommended line is a curve calculated from the formula $k = \frac{1}{a'T^n + \beta/T'}$ where $a' = a''\left(\frac{\beta}{na''}\right)^{(m-n)(m+1)}$ for $\beta = 0.0237$, $a'' \times 10^4 = 0.0423$, $m = 2.63$, $n = 2.12$ (Ho, Powell, and Liley 1974, I–12, I–15, I–242).

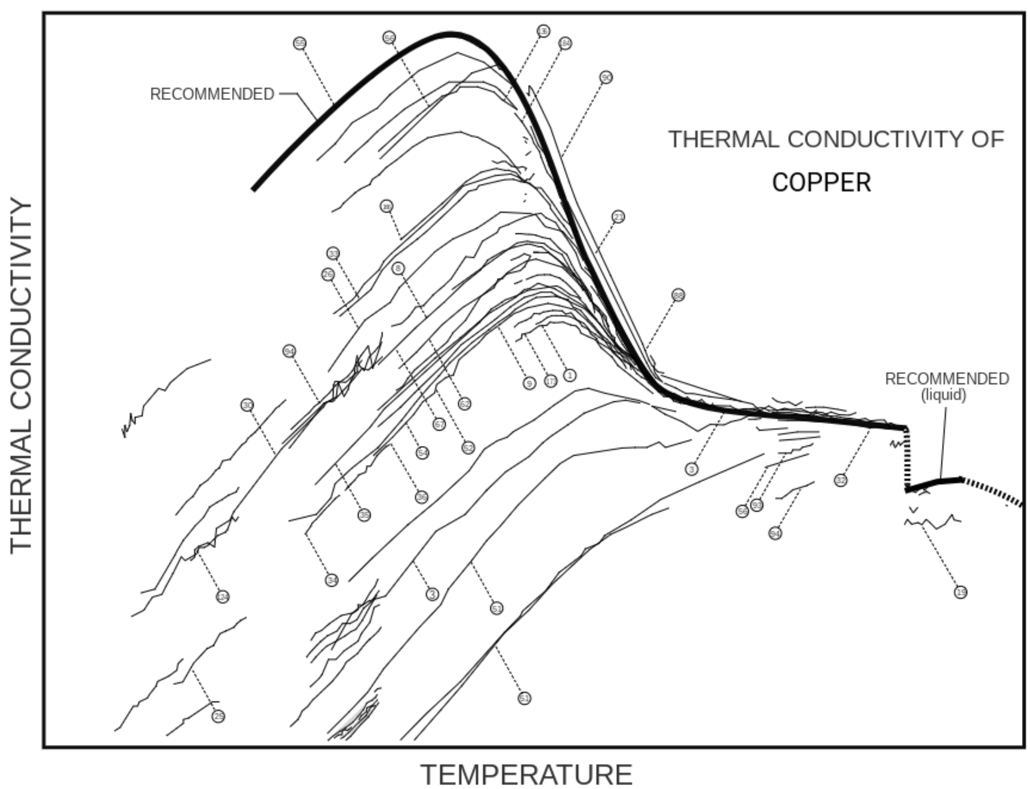
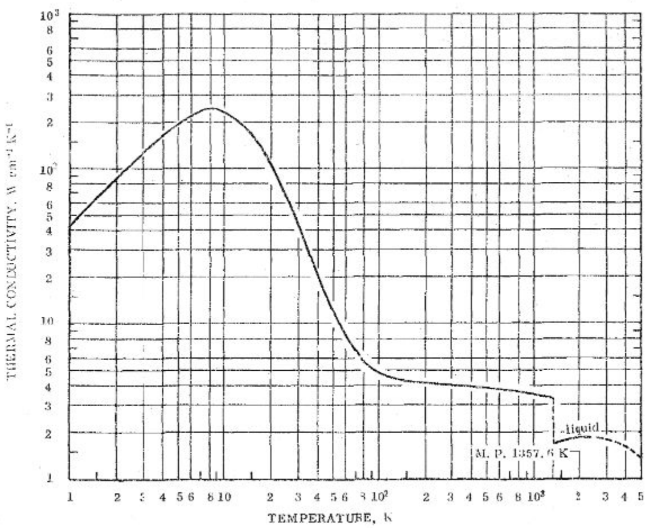


Figure 2: The thermal conductivity of copper: recommended values only, from the abridged version of the Comprehensive Review (Ho, Powell, and Liley 1972, 332). The data in the table on the right remains virtually unchanged within recent editions of scientific handbooks such as the CRC Handbook of Chemistry and Physics.

THERMAL CONDUCTIVITY OF COPPER



RECOMMENDED VALUES †

[Temperature, T, K; Thermal Conductivity, k, W cm⁻¹ K⁻¹]

SOLID				LIQUID			
T	k	T	k	T	k	T	k
0	0	123.2	4.47	1357.6	1.66	3473	1.73*
1	42.2	150	4.29	1373.2	1.66	3600	1.70*
2	84.0	173.2	4.20	1400	1.67	3673	1.69*
3	125	200	4.13	1473.2	1.70	3800	1.66*
4	162	223.2	4.09	1500	1.71	3873	1.65*
5	195	250	4.06	1573.2	1.73	4000	1.61*
6	222	273.2	4.03	1600	1.74	4073	1.60*
7	239	298.2	4.01	1673.2	1.76	4273	1.54*
8	248	300	4.01	1700	1.77	4500	1.48*
9	249	323.2	3.99	1773.2	1.79	4773	1.40*
10	243	350	3.96	1800	1.79	5000	1.33*
11	232	373.2	3.95	1873.2	1.80	5273	1.24*
12	218	400	3.93	1900	1.81	5500	1.17*
13	202	473.2	3.88	1973.2	1.82	5773	1.07*
14	186	500	3.86	2000	1.82	6000	0.989*
15	171	573.2	3.81	2073.2	1.83	6273	0.889*
16	157	600	3.79	2173.2	1.84	6500	0.804*
18	131	673.2	3.74	2200	1.84	6773	0.698*
20	108	700	3.73	2273.2	1.84	7000	0.611*
25	68.3	773.2	3.68	2400	1.84	7273	0.503*
30	44.5	800	3.66	2473.2	1.84	7500	0.414*
35	30.4	873.2	3.61	2600	1.84*	7773	0.305*
40	21.7	900	3.59	2673.2	1.84*	8000	0.212*
45	16.2	973.2	3.54	2800	1.83*	8273	0.097*
50	12.5	1000	3.52	2873.2	1.82*	C.T.≈8500	0.036*
60	8.29	1073.2	3.47	3000	1.80*		
70	6.47	1100	3.46	3073	1.79*		
80	5.57	1173.2	3.41	3200	1.78*		
90	5.08	1200	3.39	3273	1.76*		
100	4.82	1273.2	3.34	3400	1.74*		
		1300	3.32				
		1357.6	3.28				

REMARKS

The recommended values are for well-annealed high-purity copper and are considered accurate to within ±2% of the true values near room temperature and ±4% at low and high temperatures. The values for molten copper up to about 2000 K should be good to ±15%. The thermal conductivity at temperatures near and below the corresponding temperature, T_m, of the conductivity maximum is highly sensitive to small physical and chemical variations among different specimens, and the recommended values below 100 K are applicable only to a specimen having residual electrical resistivity ρ_0 = 0.000579 μΩ cm. Values at temperatures below about 1.5 T_m are calculated to fit experimental data by using equation (7) and using constants m, n, and α'' as listed in Table 1 and β = 0.0237.

Works Cited

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