RESISTANCE OF COPPER PLATINGS

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In an earlier report [1] on this subject, data supplied by Ron Scanlan [2], for (apparently) 8-mil platings were considered. Additional data for 4-mil platings [3], that I wasn't aware of when I wrote that report, are considered here.

The data are presented in Table 1. These data are plotted on a Kohler diagram, Fig. 1. (See Appendix for Kohler plot and nomenclature.) The data for the 8-mil platings correlate well with data for bulk copper [4]. The data for the 4-mil platings correlate well with one another, but are considerably below (higher resistivities for a given RRR) than those for the 8-mil platings.

For practical purposes, a straight-line fit to the Kohler-plot data is sufficient. The form is

$$y = C_1 \cdot x^{C_2}$$

which gives

$$\rho(T,B) = \rho(273,0) \left\{ C_1 [B \cdot RR(T,0)]^{C_2} + 1 \right\} / RR(T,0)$$

INCRA [4] gives $\rho(273,0) = 1.545 \times 10^{-8}$ ohm-meters.

For the range of x from 300 to 6000, corresponding to B from 1.5 to 6 T and RRR from 200 to 1000, eyeballed fits yield the following.

	Best straight-line fit			Best fit for C_2 =1	
	C_1	C_2	Max error,%	C_1	Max error,%
8-mil	.0054	0.93	~7 *	.0033	~10
4-mil	.00089	1.06	~7	.00145	~20

These resistivity for the 8-mil plating as a function of B for various RRR's is shown in Fig. 2 , and the conductivity, corresponding to RR, in Fig. 3. A comparison of the conductivity vs. field relationship for RRR=600 for the two sets of data is shown in Fig. 4.

The Kohler correlation (as nearly as I can dope it out) says that the resistivity data for a particular nearly pure metal should fall on a line (not necessarily straight or with a slope of one) independent of field, temperature, and RRR. Not all metals correlate; aluminum, for example, does not. The

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* In Ref. [1] these were presented as C_1 = 0.0067, C_2 = 0.9; the difference is negligible.

fact that the data for the 8-mil platings correlate among themselves and with well established data for bulk copper, even though their RRR's vary widely, is encouraging evidence of the applicability of the Kohler correlation. But we have no experimental evidence of its applicability at temperatures above 4K. The fact that the data for 4-mil platings fall on a different line, giving resistivities twice as large as those for the 8-mil platings at high fields, is disturbing. Clearly we need more data. A specification of thickness and RRR ranges may <u>not</u> be sufficient.

REFERENCES

1. R. Meuser, SSC-N-216.
2. R. Scanlan, private communication.
3. D. Bittinger, SSC-N-184.
4. INCRA (International Copper something or other) wall chart.

APPENDIX

Here we reserve the term '<u>residual</u> resistivity ratio' (RRR) for the resistivity ratio at zero field and temperature, and use the term 'resistivity ratio' (RR) for the value at non-zero temperature or field. Others often use the term RRR for both, but I don't think that is correct.

The subscripts are designated (temperature, K; field, T).

$$RRR = \rho(273,0)/\rho(0,0)$$

$$RR(T,B) = \rho(273,0)/\rho(T,B)$$

The Kohler diagram gives log y vs. log x where

$$x = B\cdot\rho(273,0)/\rho(T,0) = B\cdot RR(T,0)$$

$$y = [\rho(T,B) - \rho(T,0)] / \rho(T,0) = [RR(T,0)/RR(T,B)]-1$$

For T near zero these become

$$x = B\cdot RRR$$

$$y = [RRR / RR(0,B)]-1$$

For a straight line on log paper, $y = C_1 x^{C_2}$, which gives

$$\rho(T,B) = \rho(273,0) \left\{ C_1 [B\cdot RR(T,0)]^{C_2} + 1 \right\} / RR(T,0)$$

INCRA [4] gives $\rho(273,0) = 1.545 \times 10^{-8}$ ohm-meters.

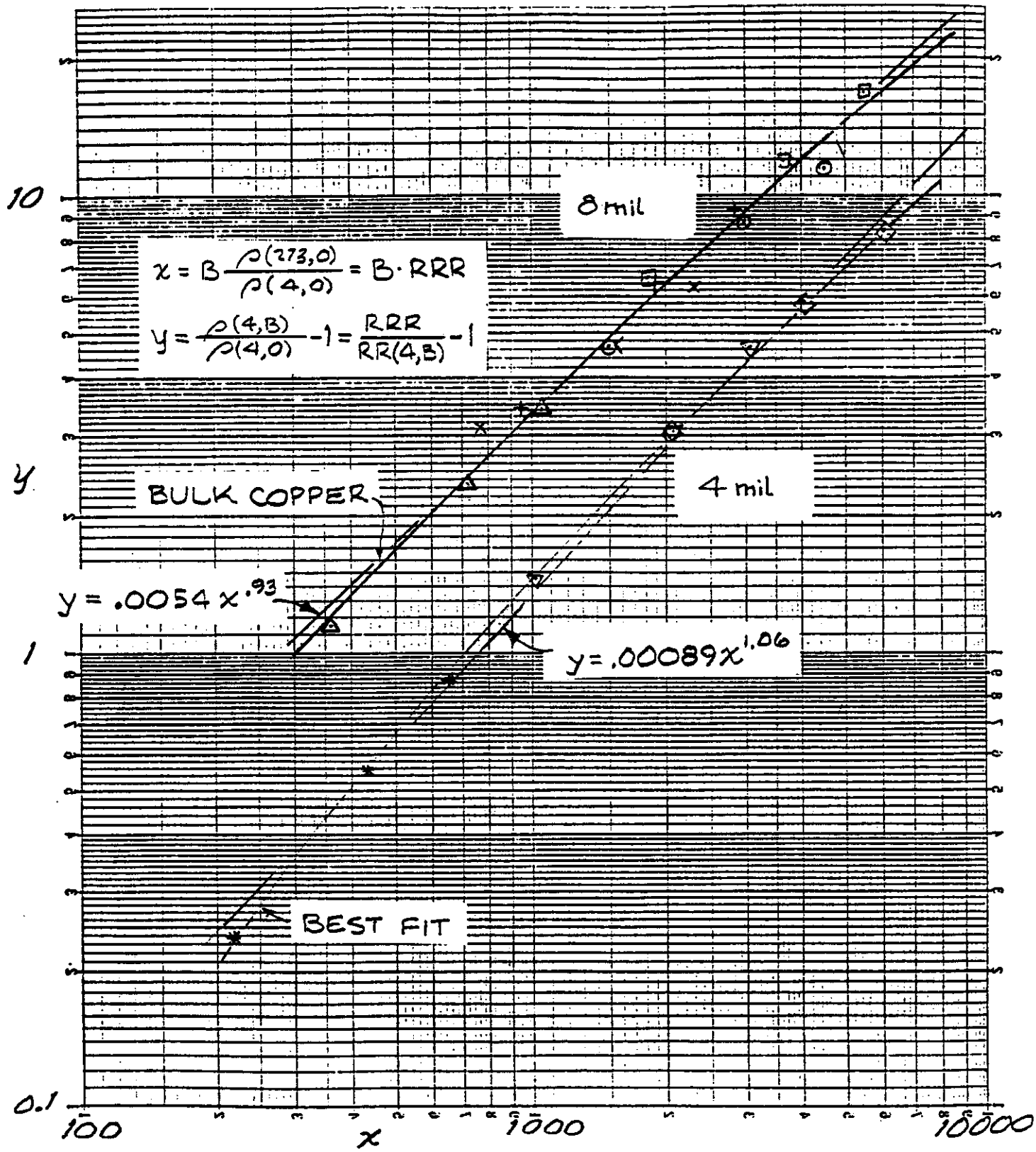

Figure 1. Kohler plot for copper platings and bulk copper.

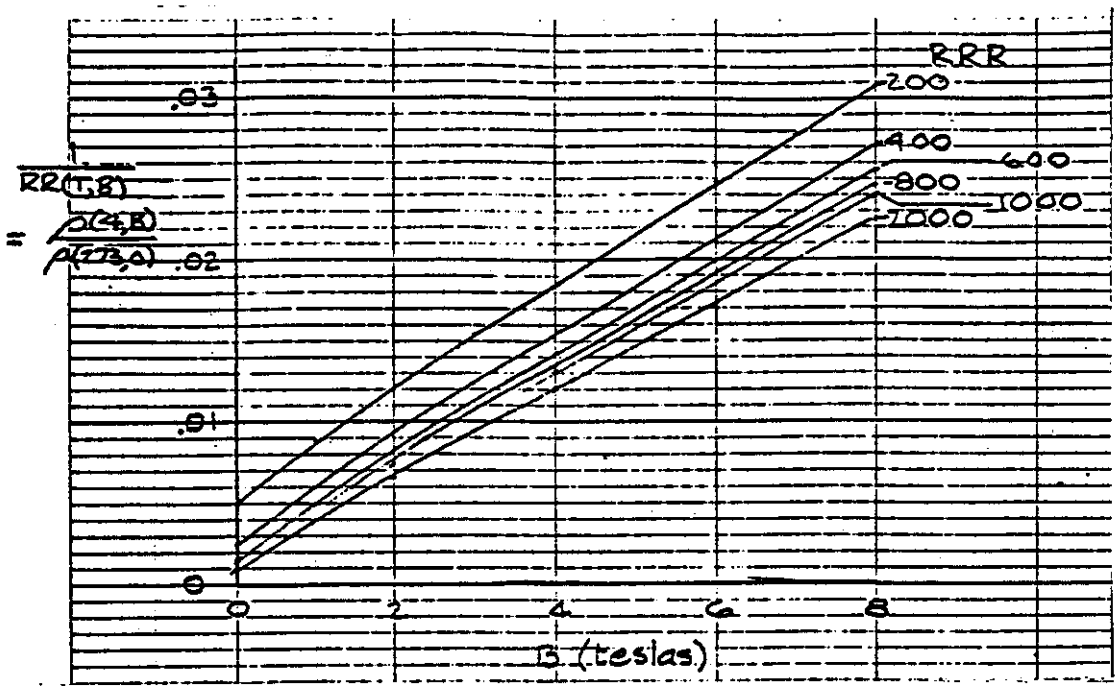

Figure 2. Relative resistivity (1/RR) as affected by RRR and field for 8-mil platings.

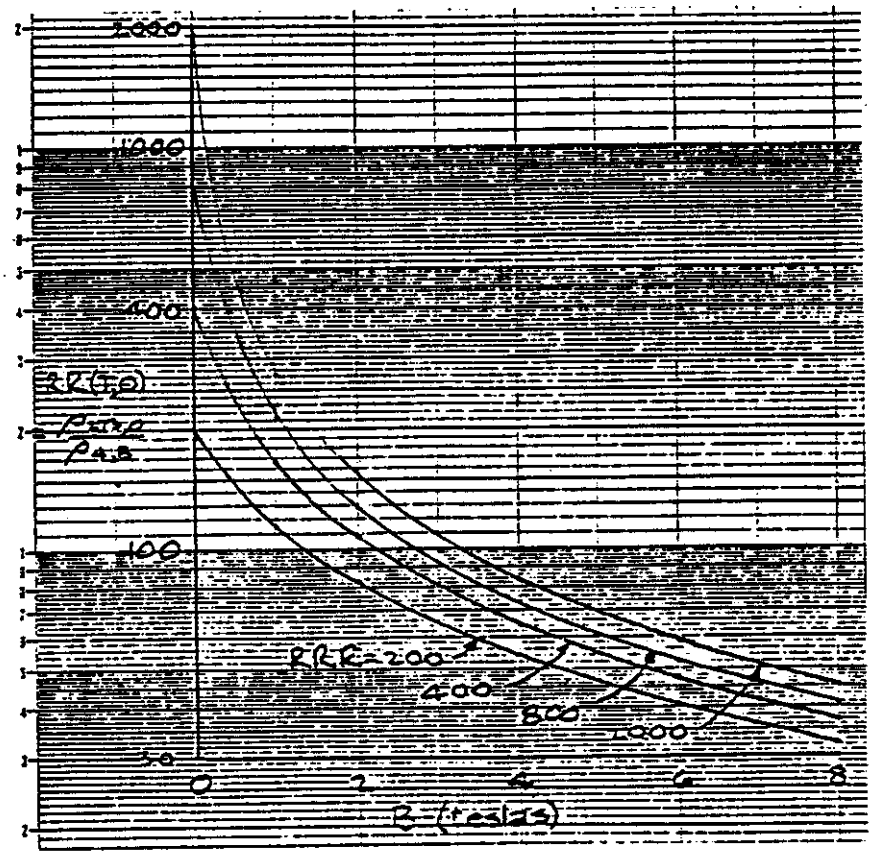

Figure 3. Relative conductivity (RR) as affected by RRR and field for 8-mil platings.

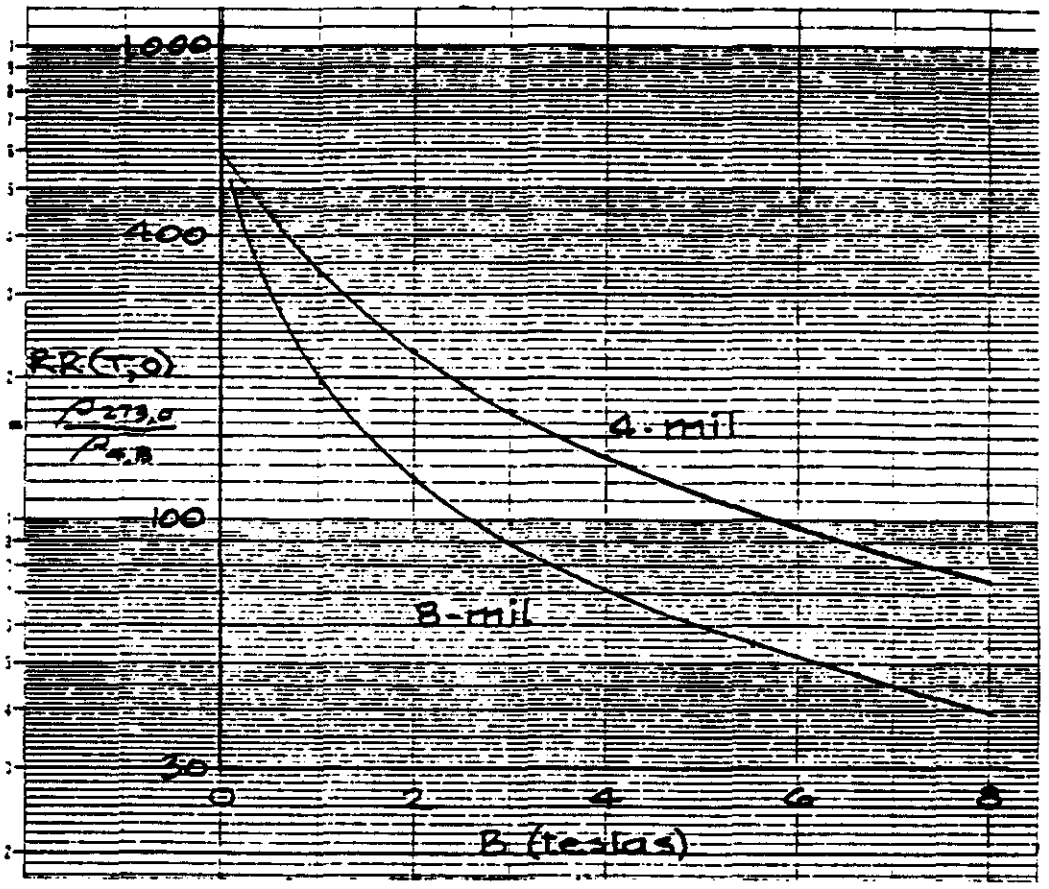

Figure 4. Relative conductivity as affected by field for 8- and 4-mil platings for an RRR of 600.

TABLE 1

	SAMPLE		THICKNESS	RR FOR B = 0 T	2 T	4 T	6 T
Ref. [1], [2]	3 - 4	---	008?	181	84	54	41
	8 - 9	---	.008?	387	94	70	53
	2	Pure copper, perhaps annealed, copper anode	.008	747	132	77	56
	9	Pure copper, Pt-Ti anode	.008	908	119	70	51
	9B	Pure copper, electropolished, Pt-Ti anode	.008	474	106	63	46
Ref. [3]	---	Pure copper, Pt-Ti anode	.004	513	208	126	91
	---	Pure copper, pulsed current, Pt-Ti anode	.004	1018	252	149	108
	---	PG-Clean, a commercial printed circuit plating solution, Pt-Ti anode	.004	109	88	70	58

Descriptions are from Ref. [3]