Terris, Gray, and Dunlap Respond: Anderson[1] is correct in noting that dipolar energies can be ~ 1 K, and so may contribute to the magnetic transition temperatures (T_M) in these materials. However, we note the following: (1) A strong influence from dipolar effects may occur in rare-earth rhodium borides ($\mathrm{RERh_4B_4}$) for RE=Er, Tm, and Nd, but for the others, it is considerably more doubtful. For Sm, the primary interest in this paper, its maximum moment of only $0.71\mu_B$ would give dipolar energies ~ 0.01 K. Nonetheless, $T_M \sim 0.9$ K is comparable to that of $\mathrm{ErRh_4B_4}$ (0.7 K) and, thus, quite inconsistent with a strong influence from dipolar effects. For the remaining $\mathrm{RERh_4B_4}$ compounds, T_M ranges from 6 to 11 K. This seems too high to be strongly influenced by dipolar interactions. (2) The statement attributed to Varma that T_M scales throughout the RE series with $g^2J(J+1)$ better than with $(g-1)^2J(J+1)$ may be pertinent in the Chevrel-phase compounds where $T_M \lesssim 1$ K for all compounds, but is less significant in $\mathrm{RERh_4B_4}$ where many T_M are an order of magnitude larger. The deviations from de Gennes scaling have been discussed[2] in terms of Ruderman-Kittel-Katsuya-Yosida (RKKY) or dipolar crystal-field—induced anisotropy. This explains the results for T_M to within ~ 1 K, the remaining discrepancies being presumably due to dipolar interactions. (3) Evaluation of the exchange coupling from the depression of the superconducting T_c with addition of magnetic impurities to $\mathrm{LuRh_4B_4}$ gives values consistent with magnetic transition temperatures due to RKKY interactions.[3]

All of the above is consistent with RKKY's providing the primary influence in determining the magnetic transition temperatures of $\mathrm{RERh_4B_4}$. While acknowledging the difficulty of calculating T_M, we are not aware of any theoretical formalism which has attempted to incorporate both dipolar and indirect exchange on an equal basis. We would welcome such a development.

Stewart's[4] first comment concerns the appropriate incorporation of mean-free-path effects. Although de Châtel[5] carefully points out the difficulties in disordered materials, he also states that for weakly disordered materials, such as in our case, "there does not seem to be any compelling reason to abandon the simple *(sic* de Gennes) expression." Thus, agreement with our experiment may be thought of as confirmation of this statement.

Stewart's second comment is certainly correct, but the conclusions about $\mathrm{SmRh_4B_4}$ reported in our paper were pointed out to be unchanged by the assumption of two different antiferromagnetic (AF) orderings.

Finally, we would point out that it was not our intention to provide a complete description of the magnetic state of these compounds. The change from AF in $\mathrm{SmRh_4B_4}$ to ferromagnetism (FM) in $\mathrm{ErRh_4B_4}$ could very well be an instance where the influence of dipolar interactions in $\mathrm{ErRh_4B_4}$ are manifest. Rather, the desire here was to systematize a body of data and clarify the essential physics of the problems. In that context, the model calculation carried out is reasonable. We have made three basic points, and feel that they are valid given these caveats, in addition to those already stated in our paper:

(1) Incorporating systematic studies of both superconducting and magnetic transition temperatures can provide information on both the range and magnitude of the exchange interaction.

(2) The peaking of T_M with disorder in $\mathrm{SmRh_4B_4}$ is due to the more rapid quenching of the competing FM interactions as the range of the interaction is decreased.

(3) The stronger decrease of T_M with disorder in $\mathrm{ErRh_4B_4}$ vs $\mathrm{SmRh_4B_4}$ is due to the lack of competition between AF and FM order.

We would certainly welcome both more detailed theoretical calculations and other experimental work to test these ideas.

This work is supported in part by the U.S. Department of Energy.

B. D. Terris
IBM Research Lab
San Jose, California 95193

K. E. Gray
B. D. Dunlap
Argonne National Laboratory
Argonne, Illinois 60439

Received 16 August 1985
PACS numbers: 75.30.Kz, 74.70.Dg, 75.50.Ee

---

[1] P. W. Anderson, Phys. Rev. Lett. **55**, 1805 (1985) (this issue).

[2] D. R. Noakes and G. K. Shenoy, Phys. Lett. **91A**, 35 (1982); B. D. Dunlap, L. N. Hall, G. W. Crabtree, and D. G. Niarchos, Phys. Rev. B **29**, 6244 (1984).

[3] H. B. MacKay, L. D. Woolf, M. B. Maple, and D. C. Johnston, J. Low Temp. Phys. **41**, 639 (1980).

[4] A. M. Stewart, Phys. Rev. Lett. **55**, 1806 (1985) (this issue).

[5] P. F. de Châtel, J. Magn. Magn. Mater. **23**, 28 (1981).