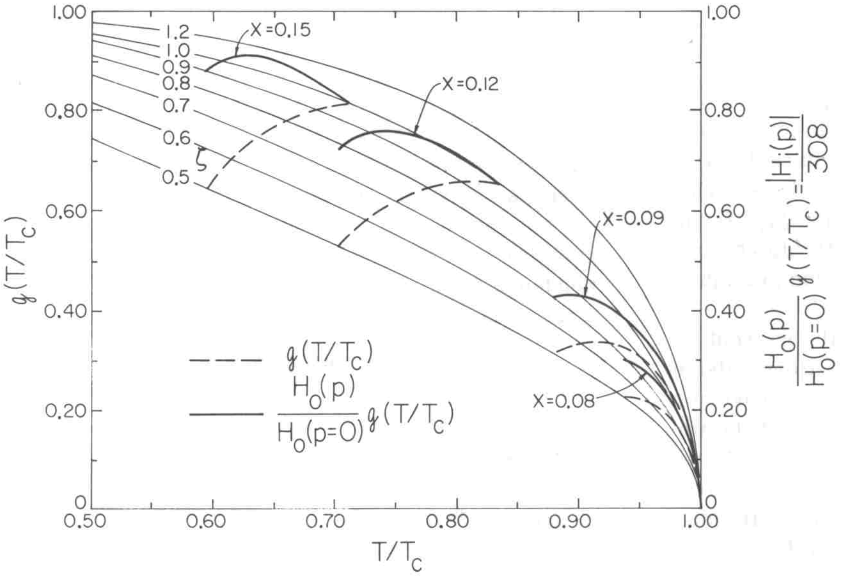

FIG. 6. Model curves of normalized hyperfine fields vs T/T_C, with different pressure dependence of the parameters ζ and H_0 from those of Fig. 5. See text.

Eq. (A3). Our use of the molecular-field spontaneous-magnetization function of spin-$\frac{1}{2}$ in conjunction with $\zeta(p=0)=1.0$ for all alloys is clearly inadequate, particularly for $x=0.09$ as seen in Fig. 4. It should be appreciated that the actual $p=0$ isobars of $H_i(T)/H_0$ for the various alloys probably do *not* lie on a single continuous curve, especially if $\zeta(p=0)$ is composition dependent. What is required here is the experimental temperature-dependent $H_i(T)$ for each alloy at $p=0$, covering at least the range of T/T_C as is spanned in each case by the pressure data of Fig. 4.

In Fig. 7 we attempt a more realistic treatment of the $x=0.08$ and $x=0.09$ data in the interesting region $T/T_C \lesssim 1$ by using the curve $H_i(T)/H_0$ vs T/T_C for Fe^{57} in nickel as a $p=0$ baseline. This curve nearly coincides with our $x=0.09$ data in the low-pressure region, and therefore is perhaps a reasonable approximation to the $p=0$ baseline for $x=0.09$. The background grid in Fig. 7 consists of the experimental curve of Dash *et al.*[63] for Fe^{57} in nickel $[=g_0(T/T_C)]$ and a family of the ζ-dependent curves $g(T/T_C)$ calculated from Eq. (A3) with $S'=\frac{3}{2}$. This value for the Fe impurity spin is sug-

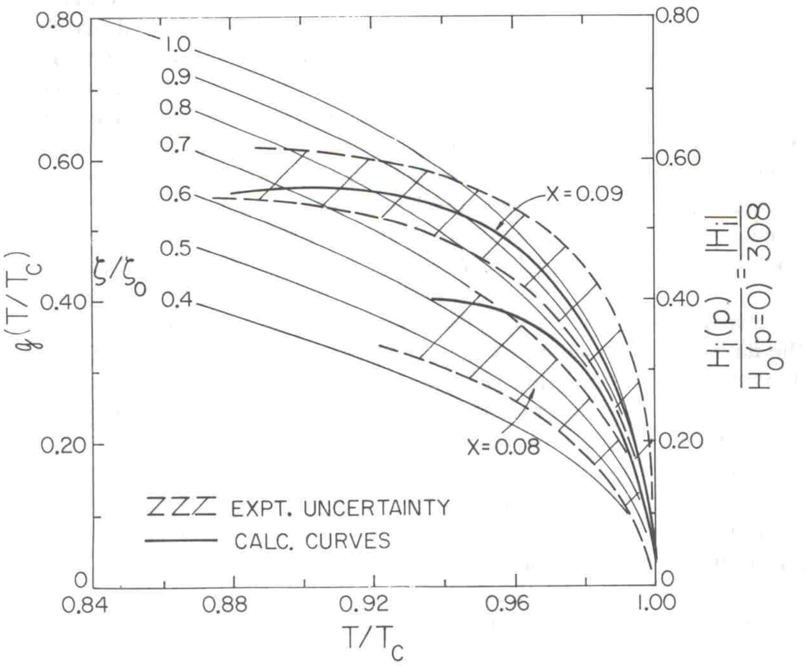

FIG. 7. Model and experimental curves of normalized hyperfine fields vs T/T_C for Pd$_{0.92}$Co$_{0.08}$ and Pd$_{0.91}$Co$_{0.09}$ at 297 °K, using the experimental baseline for Fe^{57} in nickel from Ref. 63 as described in the text.

gested by the fact that the moment localized at an Fe site in both pure Pd and pure Co (and therefore probably in *Pd*Co) is about 3 μ_B.[5,6,72] (The use, for simplicity, of $S' = \frac{1}{2}$ in Figs. 5 and 6 does not affect the semiquantitative results obtained there.) The hatched areas indicate the ranges of uncertainty of our data for the $x = 0.08$ and $x = 0.09$ alloys. The solid lines show the fits obtained using $\zeta(p)$ from Fig. 6 and $H_0(p)$ from Fig. 5 for both alloys, indicating that these parameters are also semiquantitatively valid here.

The conclusions obtainable from the current analysis are now discussed. As mentioned above, the three parameters whose pressure dependences directly affect the pressure dependence of the impurity hyperfine field are T_C, H_0, and ζ. T_C has been measured independently for each alloy here and its effects included in Fig. 4. Thus, in interpreting Fig. 4, one is left to consider $H_0(p)$ and $\zeta(p)$, separately for each alloy. With no constraints these parameters allow more than enough freedom to fit the data (given an appropriate $p = 0$ baseline in each case), and in fact satisfactory fits can be obtained solely by consideration of $H_0(p)$ alone, or $\zeta(p)$ alone, independently for each alloy. A strong constraint is imposed, however, by the fact that $H_0(p)$ is not likely to be very composition dependent. The reason is that the Fe^{57} $H_0(p=0)$ has been found to be virtually independent of composition (within several percent) over the entire composition range of $Pd_{1-x}Co_x$,[16,17,25] while the average moment per atom of the alloy and the average moment per Co atom vary considerably with composition.[3] Thus the magnitude of $H_0(p=0)$ must be determined primarily by *local* phenomena, which are insensitive to the $T = 0$ bulk magnetization of the alloy and sense mainly the local Fe moment, which is stably saturated at $\sim 3\mu_B$. The pressure derivative of a locally determined H_0 must also be locally determined, and hence cannot be composition dependent either. As for the parameter $\zeta(p)$, it is reasonable to expect some, but not a large, composition dependence in the limited range of interest here, $0.08 \leq x \leq 0.15$. We therefore assume that, to lowest order, both $d\ln H_0/dp$ and $d\ln\zeta/dp$ are roughly the same for all alloys.

Given the assumption of approximate composition independence for $H_0(p)$ and $\zeta(p)$, the data of Fig. 4 unambiguously imply (i) a positive pressure dependence for $|H_0|$ and (ii) a negative pressure dependence for $|\zeta|$. Any attempt to account for the suppression of the $x = 0.08$ curve below the $x = 0.09$ curve or the flattening of the $x = 0.09$ curve in the high-pressure region by a negatively pressure-dependent $|H_0(p)|$ results in a decreasing $|H_i(p)|$ for $x = 0.12$ and $x = 0.15$, contrary to observation. In order to achieve consistency with the $x = 0.12$ and $x = 0.15$ data, the above characteristics of the $x = 0.08$ and $x = 0.09$ curves must be determined primarily by a negatively pressure-dependent $|\zeta|$, thus requiring a positively pressure-dependent $|H_0|$, as seen in Figs. 5 and 6. The data indicate $d\ln H_0/dp \approx +(1.0 \pm 0.5) \times 10^{-3}$/kbar and $d\ln\zeta/dp \approx -(3 \pm 1) \times 10^{-3}$/kbar, with $|d\ln\zeta/dp|$ being perhaps somewhat composition dependent, increasing as x decreases. We believe these results to constitute the first observation of the pressure dependence of an impurity-host coupling constant in a ferromagnetic metal.

IV. DISCUSSION

A. $H_0(p)$

The value found here for $d\ln H_0/dp$ agrees in both sign and magnitude with that found by Raimondi and Jura[66] for Fe^{57} in cobalt at room temperature: $d\ln H_i/dp = +0.6 \times 10^{-3}$/kbar. Since T_C for cobalt is 1395 °K (fcc phase) or 1130 °K (hcp phase),[67] T/T_C for the above measurement $\simeq 0.21$ or 0.26, respectively. Contributions to $H_i(p)$ from $\zeta(p)$ at these values of T/T_C should be small, although not necessarily negligible, so the above pressure dependence of $H_i(p)$ represents mainly the effect of $H_0(p)$. [In cobalt $dT_C/dp = 0 \pm 0.05$ °K/kbar,[68] so $T_C(p)$ has no effect on $H_i(p)$ here, particularly for these low values of T/T_C.] As mentioned, the compressibilities of the *Pd*Co alloys are very close to that of pure Co, so the present value $d\ln H_0/d\ln V = -1.9 \pm 1.0$ is in rough agreement with that for Fe^{57} in Co, where $d\ln H_0/d\ln V \sim -1.1$.

If in fact the Fe moment is well localized here, it is expected that μ_0 should *not* be very pressure sensitive, and since $H_0(p) = A(p)\mu_0(p)$, the pressure dependence of H_0 is then determined mainly by the pressure dependence of the hyperfine coupling constant A. $d\ln A/dp$ has been shown to be positive for Fe^{57} in iron,[69,49,58] the main reason being[59,70] that expansion of the d-like wave functions with pressure increases the core polarization, thus increasing the hyperfine field per spin. Our positive $d\ln H_0/dp$ could well reflect a similarly positive $d\ln A/dp$ for Fe^{57} as an impurity in the *Pd*Co alloys. The pressure insensitivity of the Fe moment μ_0 follows from the work of Moriya,[71] which indicates that localized moments, when in the saturation regime, are very stable. Neutron diffraction measurements show the local Fe moment in Pd and Co to be of order 3 μ_B,[5,6,72] which is about the maximum possible considering a local Fe configuration $\sim 3d^7 4s^1$ as is indicated by the Fe^{57} isomer shifts in these metals.[59,73–75] Thus, taking $g = 2$, the Fe impurity moment is essentially saturated and therefore stable with respect to environmental perturbations. Undoubtedly, this is also the reason for the insensitivity of the Fe moment