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RF POWER AND NUCLEAR MAGNETIC RELAXATION IN $GdAl_2$

by

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Abstract

We have measured the ^{27}Al and ^{157}Gd nuclear magnetic relaxation times and their rf power dependence in $GdAl_2$ at 4.2 K. The relaxation times at the two peaks in the ^{27}Al spectrum are different, confirming that the main contribution to the NMR signals comes from domain walls in the first peak (49 MHz) and from domains in the second peak (61 MHz).

Key-words: Domains; Domain walls; Amplification factor.

1. Introduction

$GdAl_2$ is an intermetallic compound that crystallizes as a cubic Laves phase (C15). It is a simple ferromagnet with T_c= 176 K [1].

NMR studies at the Al site [2,3] indicate that the signals arise from ^{27}Al nuclei in domains and domain walls. The ^{27}Al spectrum consists of two peaks; the first one (49 MHz) is formed mainly by signals from nuclei in domain walls [2,3].

In the present study we have extended the investigation on the origin of the NMR signals, using the power dependence of the nuclear magnetic relaxation times.

2. Experimental

The $GdAl_2$ samples were prepared by arc melting the pure elements; the buttoms were then crushed under acetone and the powder mixed with silicone oil. Several samples were prepared, exhibiting varying degrees of resolution in the ^{157}Gd spectrum; the values of the relaxation times were of the same order of magnitude; . These values also depended of the time interval of the measurement. The X-ray diffractograms and the narrow Gd lines are indicative of the quality of the sample used in the

present study.

The NMR spectra were obtained with a Bruker SXP spectrometer: the pulse widths were 0.5 and 1.3 μs for ^{27}Al and ^{157}Gd. The echo decay was measured by automatically varying τ; the relaxation times were obtained by computer fitting exponentials to these decays, in the interval 0 - 0.3 ms. T_1 was obtained from the echo decay after a three-pulse sequence, and T_2 after a two-pulse sequence. All the experimental measurements were made at 4.2 K.

3. NMR Spectra

The ^{157}Gd NMR spectra show three resolved lines (Fig. 1), the central line of width 0.24 MHz at 27.0 MHz, in general agreement with the results of Dormann et al. [4]. The spectra are practically independent of rf power, in the range 2-60 W. On further increasing the power, the amplitude of the signals falls rapidly.

The ^{27}Al NMR spectrum shows two lines, around 49 MHz and 61 MHz, as reported by other authors [2,3]. We have observed that the appearance of the spectrum is dependent on the level of rf power.

4. Nuclear Relaxation Times

The transverse relaxation times T_2 were

measured on the ^{157}Gd center line and on both peaks of the ^{27}Al spectrum, as a function of rf power. The results (Fig. 2) show that T_2 increases with power. Computer fits of this power dependence to an exponential function show saturation values for T_2 of 1.5 ± 0.1 ms (^{157}Gd), 0.19 ± 0.01 ms (^{27}Al, 1st line) and 0.52 ± 0.03 ms (^{27}Al, 2nd line). The first aluminium line (49 MHz) saturates at lower power. The longitudinal relaxation times T_1 show essentially the same behavior (Fig. 3). The saturation values are 7.5 ± 0.4 ms for ^{157}Gd, 1.1 ± 0.1 ms (^{27}Al, 1st line) and 3.9 ± 0.3 ms (^{27}Al, 2nd line).

5. Conclusions

The power dependence of the relaxation times T_1 and T_2 for the ^{27}Al nuclei show that: a) the saturation values for T_1 and T_2 are smaller in the case of the first ^{27}Al line (49 MHz); b) T_1 and T_2 tend to saturate with power, this saturation occurring at lower powers for the first line. This is an indication that the amplification factor η is larger in the first line, since these NMR signals require less power to reach saturation.

The above facts point to the conclusion that the signals that constitute the first line arise mostly from nuclei located in Bloch walls, the second (60 MHz) line being formed in a higher proportion from

nuclei in domains. Larger amplification factors are found in domain walls, and shorter relaxation times too, due to the presence of other relaxation mechanisms, like the thermal fluctuation of the walls themselves [5]. The increase of the relaxation times (T_1 and T_2) with rf power originates from the distribuition of relaxation times in the sample and from the selective excitation of different regions with increasing power.

Taking the ratio of rf fields H_1 that give maximum echos for a sequence of equal rf pulses we derive the ratio of amplification factors $\eta(49)/\eta(61) \simeq 2.0 \pm 0.5$. The values of η are not expected to differ much between domains and walls in $GdAl_2$ [2]. Assuming that the turning angle for the spins corresponding to these maxima is $2\pi/3$ [6], we obtain $\eta(49) \simeq 850$, in good agreement with the estimate of Bowden et al. [2], derived from the value of this parameter measured with Dy NMR in $GdAl_2$ [7].

The relaxation time measurements in the Gd site do not allow us to draw conclusions about the location (domain or wall) of the resonant nuclei.

6. Acknowledgements

The authors would like to acknowledge several discussions with Dr. S.R. Rabbani.

Figure Captions

Fig.1 ^{157}Gd NMR spectrum of $GdAl_2$ at 4.2 K showing a resolved quadrupole interaction. The continuous line is a computer fit to three gaussian lines.

Fig 2 Rf power dependence of the transversal relaxation time T_2 for $GdAl_2$ at 4.2 K for a) ^{27}Al line at 61 MHz, b) ^{27}Al line at 49 MHz and c) ^{157}Gd, central line. The continuous line is a computer fit to an exponential function.

Fig 3 Rf power dependence of the longitudinal relaxation time T_1 for $GdAl_2$ at 4.2 K for a) ^{27}Al line at 61 MHz, b) ^{27}Al, line at 49 MHz and c) ^{157}Gd, central line. The continuous line is a computer fit.

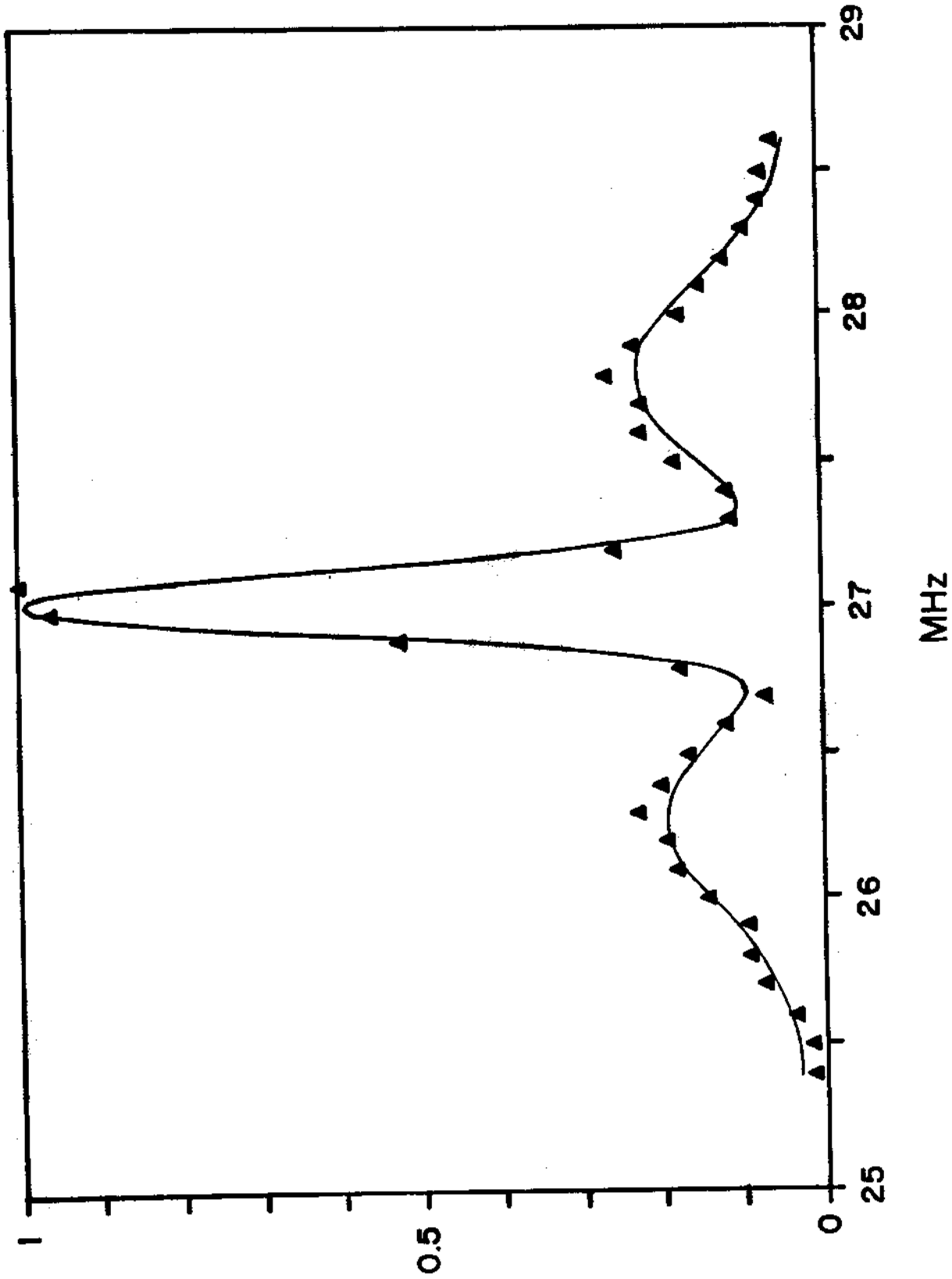

Fig. 1

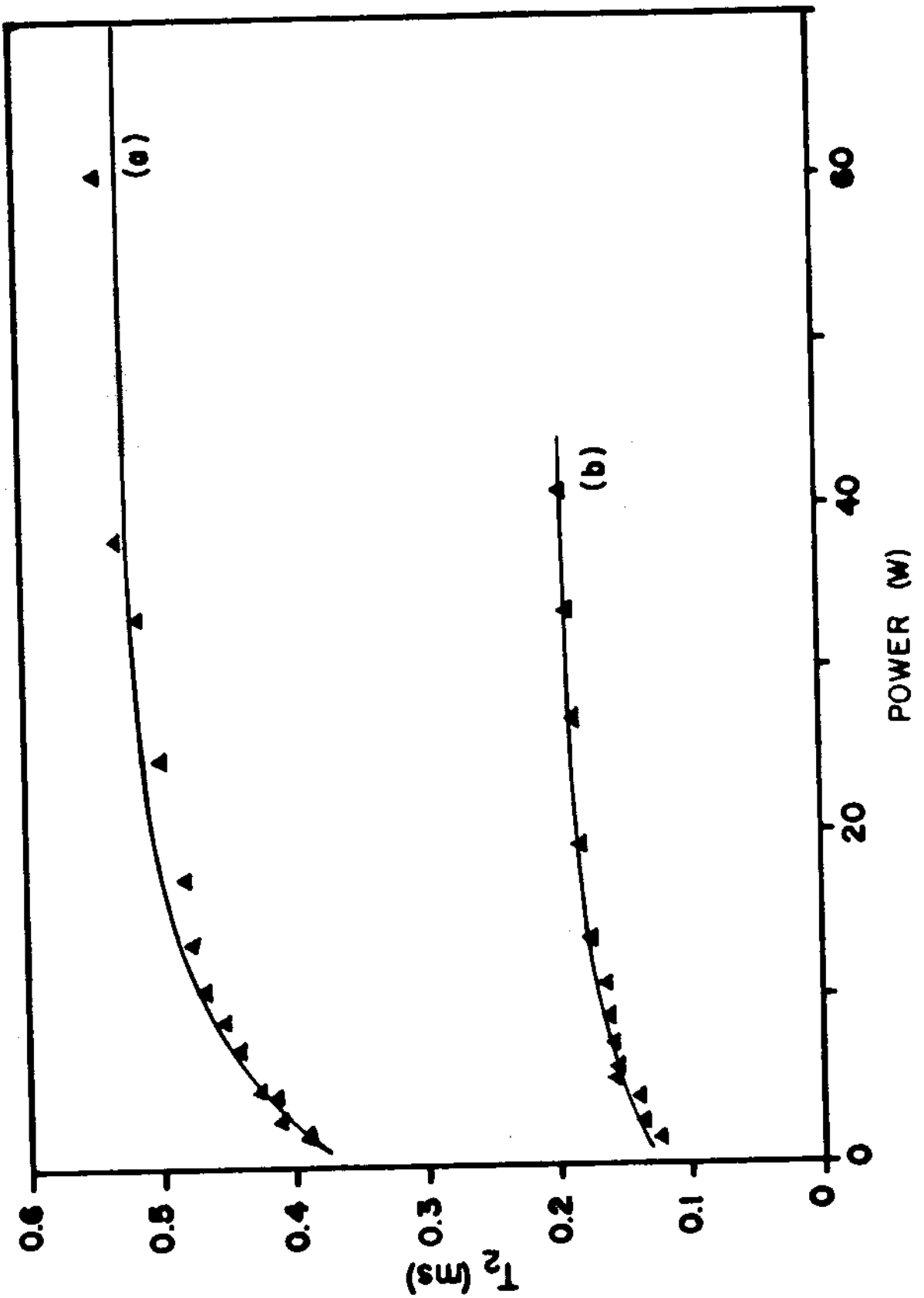

Fig. 2

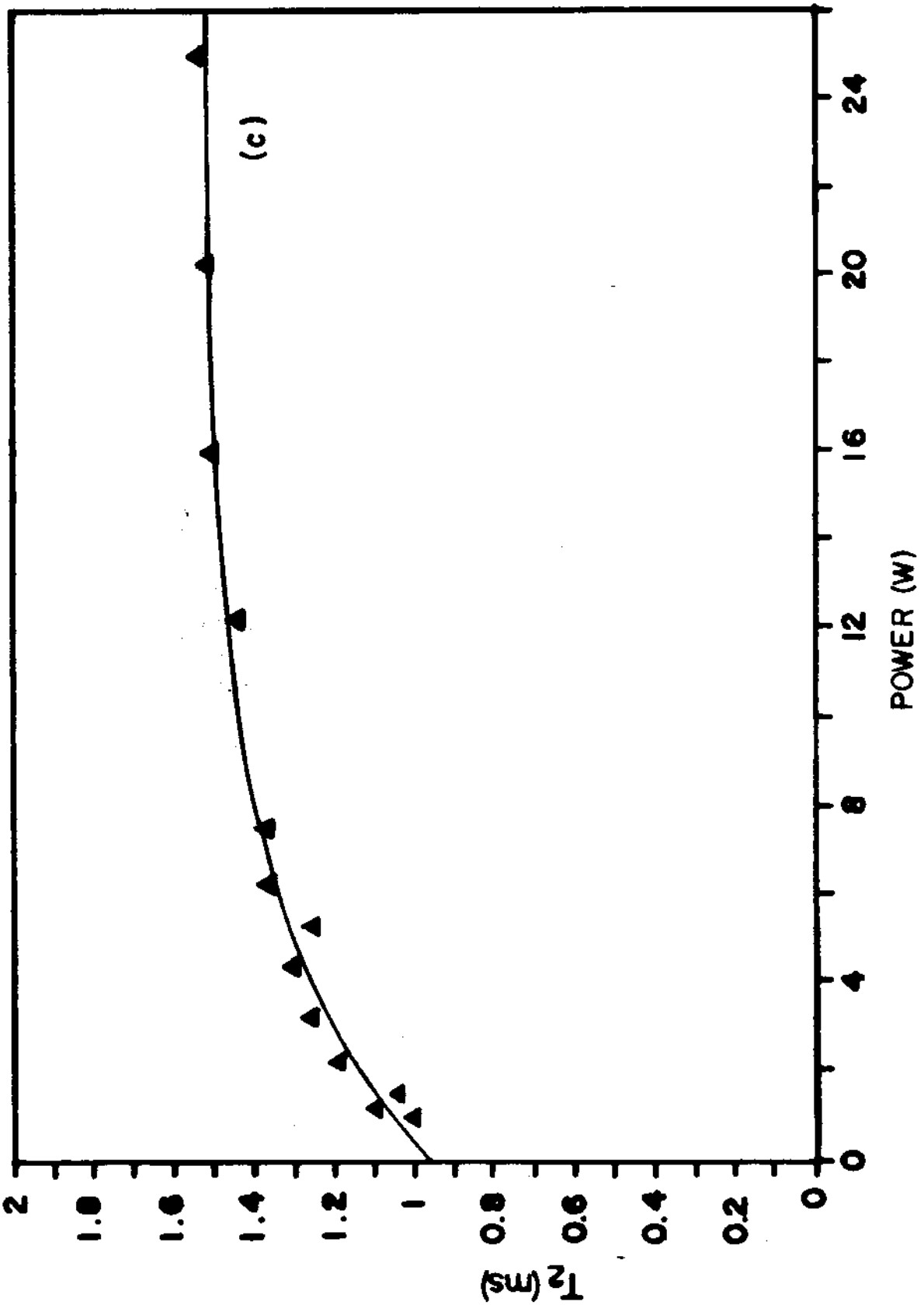

Fig. 2

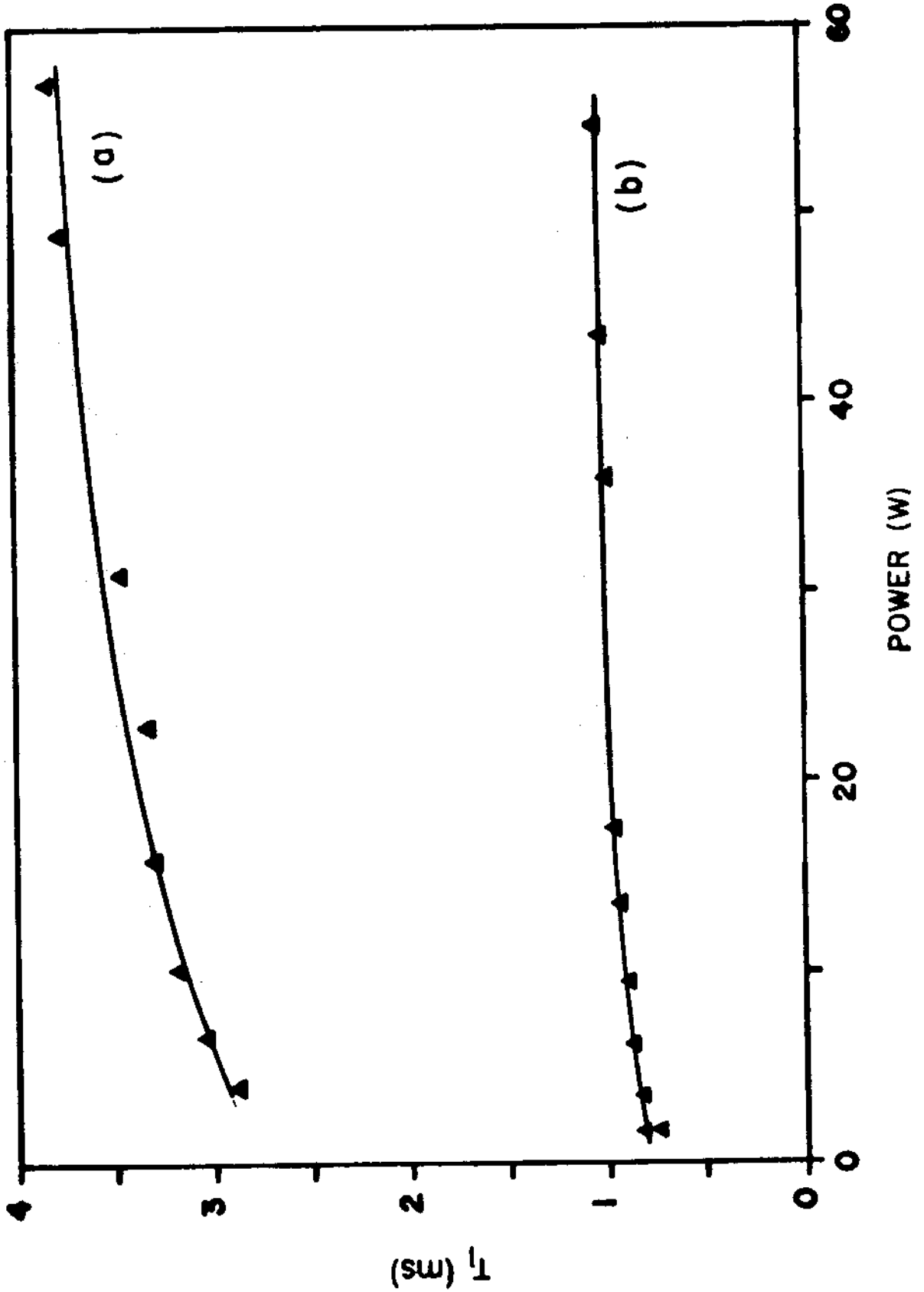

Fig. 3

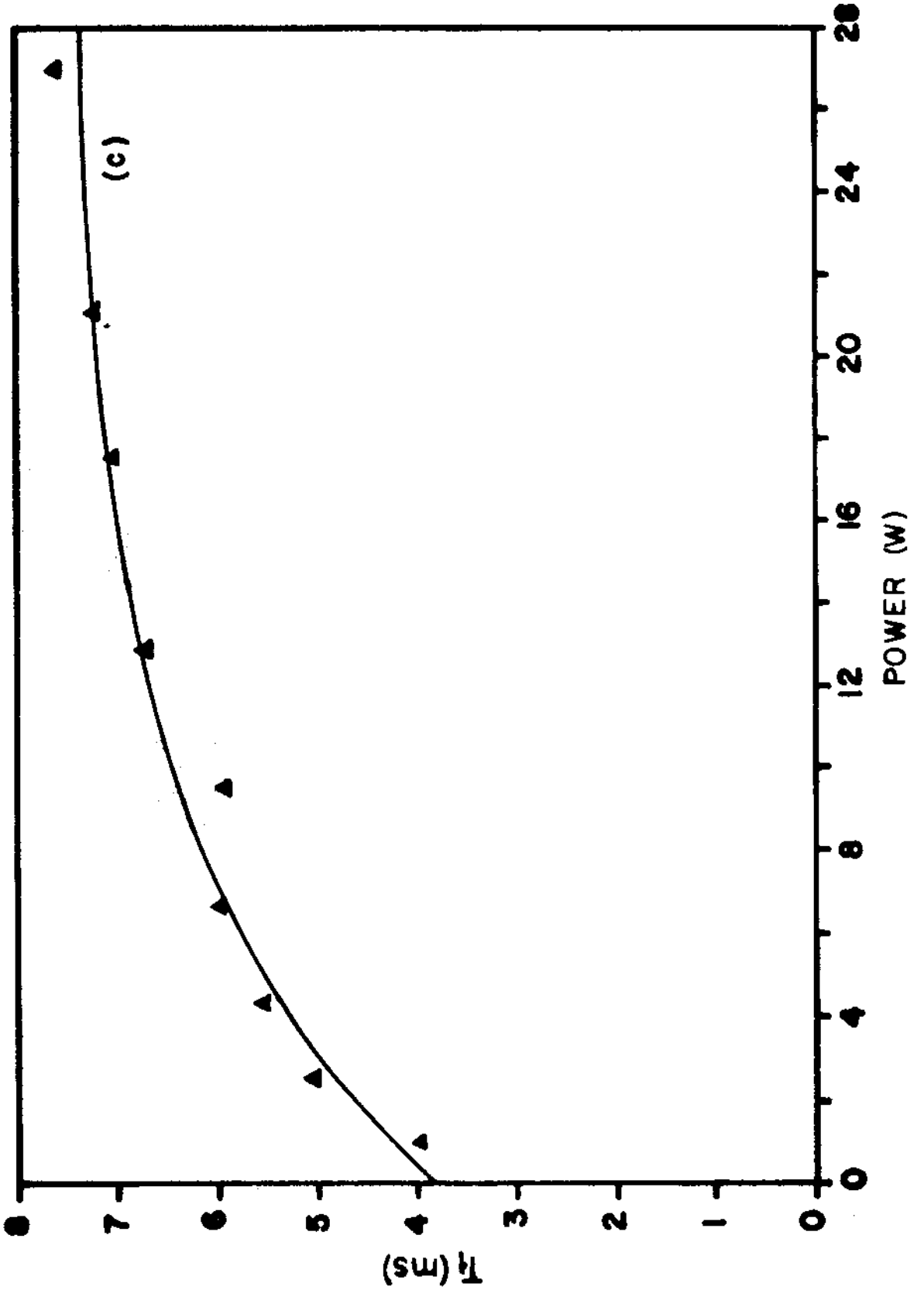

Fig. 3

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