

Chapter IV

EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Experimental Results

4.1.1 The Spin-Lattice Relaxation Time of PAA

The experimental data of T_1 in pure PAA (zone refined) and impure PAA (without zone refining) are listed in Appendix II.4. The selected ones are illustrated in Table 4.1, 4.2 and plotted graphically in Fig. 4.3.

We have observed that the induction nuclear signal does not decay smoothly after a 90° pulse is applied in the isotropic phase. This phenomenon is displayed in Fig. 3.5. It may be interpreted that there are two different species of proton spin in the sample and each has a slightly different resonance frequency, to form such induction tail. Similarly, the same phenomenon occurred in 180° pulse. We can not observe a sharp null signal, a straight line, as same as that of the liquid water. Therefore, it is difficult to distinguish an exact null on the oscilloscope. We have to estimate the experimental error for T_1 of $\pm 5\%$ in isotropic phase and $\pm 10\%$ in nematic phase. The measured T_1 in the whole temperature range are of the order magnitude of one second. The detail results and discussion will be given in section 4.3.

Table 4.1 The spin-lattice relaxation time of ~~zone refined~~ PAA

T(°C)	null(msec)	T ₁ (sec)	Estimated Error(%)
169.0	1100	1.69	± 5
161.0	1060	1.63	± 5
153.0	930	1.43	± 5
151.0	850	1.30	± 5
145.5	740	1.14	± 5
141.0	640	.98	± 5
139.0	610	.34	± 5
138.5	600	.92	± 5
136.0	590	.90	± 5
135.0	575	.88	±10
134.0	625	.96	±10
133.5	645	.99	±10
132.0	665	1.02	±10
129.5	695	1.07	±10
128.0	710	1.09	±10
127.0	725	1.11	±10
124.5	730	1.12	±10
121.5	710	1.07	±10
120.0	695	1.07	±10
118.0	655	1.00	±10
117.0	665	1.02	±10
112.5	650	1.00	±10
110.0	610	.94	±10
107.0	580	.90	±10
105.0	530	.81	±10

Table 4.2 The spin lattice relaxation time of ~~commercial~~ PAA

T(°C)	null(msec)	T ₁ (sec)	Estimated Error(%)
153.0	870	1.33	± 5
146.0	710	1.09	± 5
143.0	650	1.00	± 5
138.0	600	.92	± 5
137.0	610	.94	± 5
136.0	590	.90	± 5
135.0	530	.81	±10
133.0	550	.84	±10
131.5	580	.89	±10
130.0	640	.98	±10
127.0	635	.97	±10
123.0	620	.95	±10
119.0	590	.90	±10
118.0	570	.88	±10
116.5	560	.86	±10
116.0	545	.84	±10
114.0	480	.74	±10

In addition, the data of spin-lattice relaxation time in the nematic range both of zone refined and commercial PAA are plotted vs. the inversed absolute temperature ($^{\circ}\text{K}$)⁻¹ as shown in Fig.4.2 with a comparison of the results from theoretical approach by Doane et al. The data of both are presented in Table 4.3 and Table 4.4.

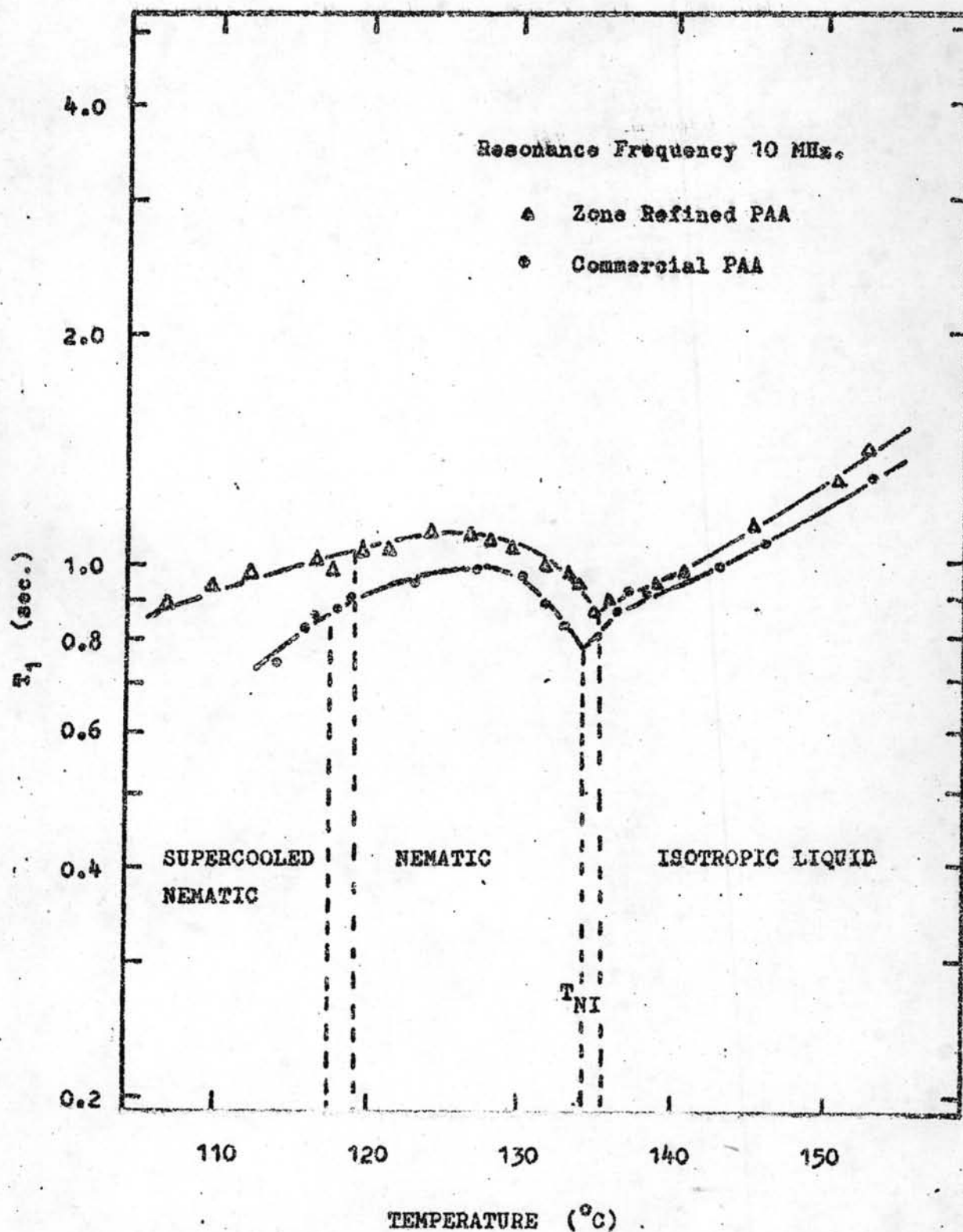


Fig.4.1 T_1 of zone refined and commercial PAA plotted versus temperature

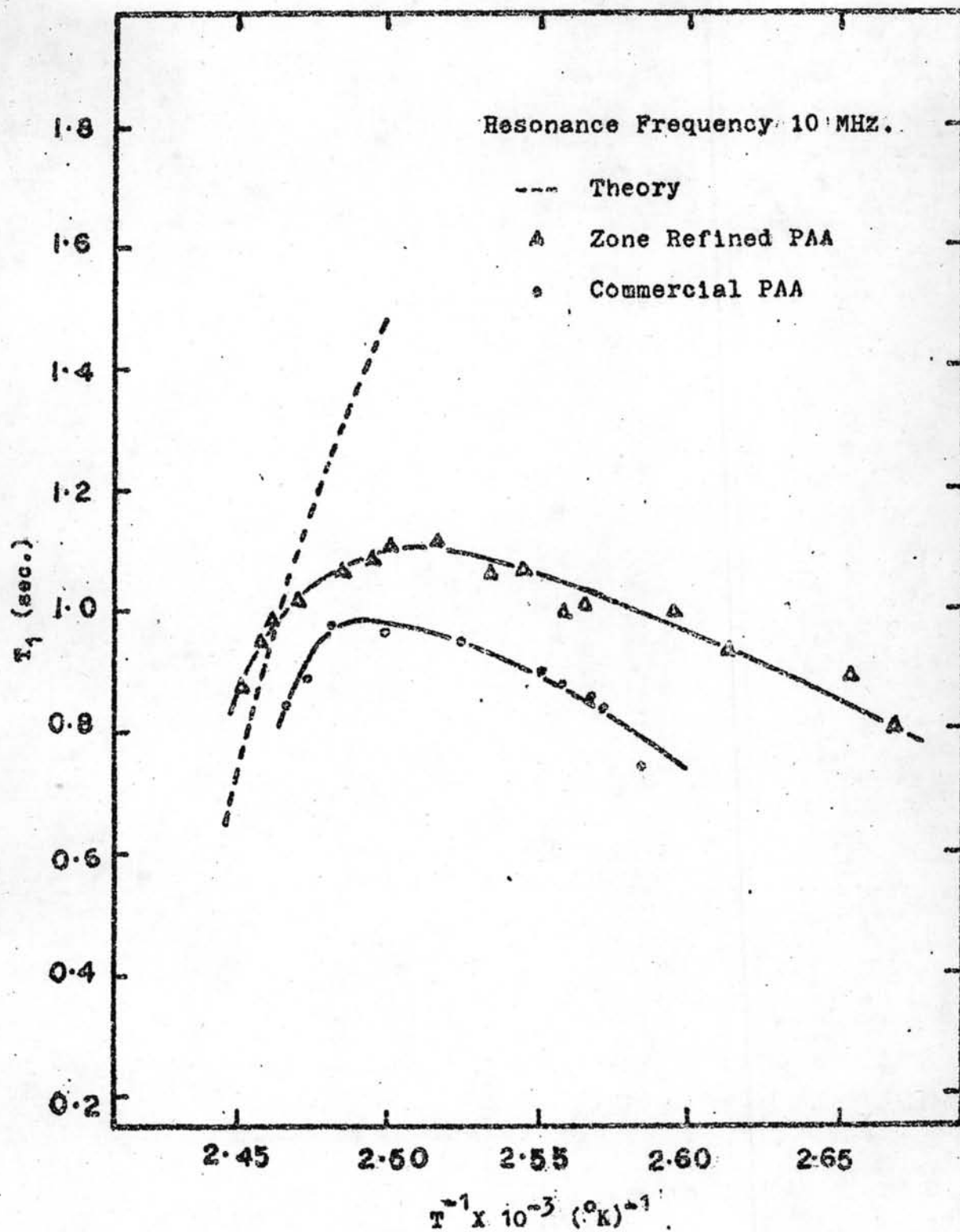


Fig. 4.2 T_1 of zone refined and commercial PAA plotted versus inverse temperature.

Table 4.3 The spin-lattice relaxation time of zone refined PAA

$T^{-1} \times 10^{-3} (^{\circ}\text{K})^{-1}$	T_1 (sec)	Estimated Error (%)
2.451	.88	± 10
2.457	.96	± 10
2.460	.99	± 10
2.469	1.02	± 10
2.484	1.07	± 10
2.494	1.09	± 10
2.500	1.11	± 10
2.516	1.12	± 10
2.535	1.07	± 10
2.544	1.07	± 10
2.558	1.00	± 10
2.564	1.02	± 10
2.594	1.00	± 10
2.611	.94	± 10
2.632	.90	± 10
2.646	.81	± 10

Table 4.4 The spin-lattice relaxation time of commercial PAA

$T^{-1} \times 10^{-3} (^{\circ}\text{K})^{-1}$	T_1 (sec)	Estimated Error (%)
2.463	.84	± 10
2.472	.89	± 10
2.481	.98	± 10
2.500	.97	± 10
2.525	.95	± 10
2.551	.90	± 10
2.558	.88	± 10
2.567	.86	± 10
2.571	.84	± 10
2.584	.74	± 10

4.1.2 The Spin-Spin Relaxation Time of PAA

The experimental data of T_2 in zone refined PAA is listed in Appendix II.B. The selected one is illustrated in Table 4.5 and plotted graphically in Fig.4.3. We have found that, the static magnetic field is not quite stable as the measurement is going on. This affects the echoes amplitude not to be formed exactly in a straight line (as shown in Fig.3.8) and then T_2 can not be calculated accurately. The experimental error is estimated to be $\pm 20\%$ in isotropic phase and ± 25 in nematic phase. In nematic phase, the order of magnitude of T_2 is 10 microsecond and in isotropic phase, T_2 is the order of 10^2 millisecond.

Table 4.5 The spin-spin relaxation of zone refined PAA

$T(^{\circ}\text{C})$	$T_2(\text{msec})$	Estimated Error(%)
155.0	492	± 20
148.0	460	± 20
140.0	410	± 20
137.5	328	± 20
134.5	.052	± 25
132.5	.045	± 25
129.5	.036	± 25
127.5	.035	± 25
123.5	.032	± 25
117.0	.030	± 25
113.0	.030	± 25
109.5	.026	± 25
107.0	.024	± 25
105.0	.024	± 25
104.0	.022	± 25

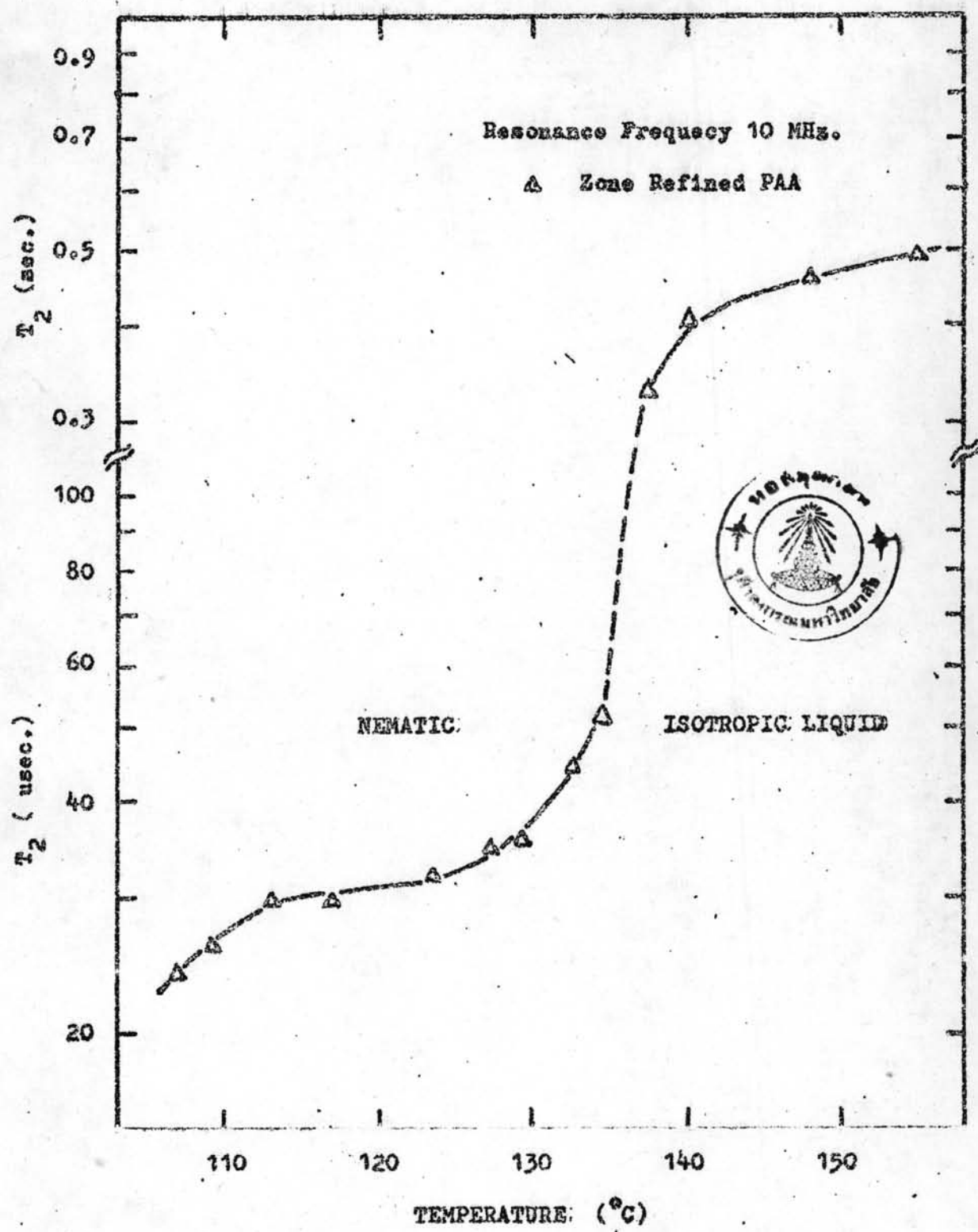


Fig. 4.3 T₂ of zone refined PAA plotted versus temperature

4.2 The Reviewed Theory of Spin Relaxation in Liquid Crystal

Consider a special case, the liquid. The conventional theory of spin relaxation for a spin $\frac{1}{2}$ pair, brought about by a fluctuation of the magnetic dipolar interaction, gives the following relaxation rate²² in the laboratory frame :

$$\begin{aligned} \frac{1}{T_1} &= (3/2)\gamma^4 \hbar^2 I(I+1) \left[J^{(1)}(\omega_L) + J^{(2)}(2\omega_L) \right] \\ &= (9\gamma^4 \hbar^2 / 8a^6) \left[J^{(1)}(\omega_L) + J^{(2)}(2\omega_L) \right] \quad (4.1) \end{aligned}$$

where $J^{(1)}(\omega_L)$ and $J^{(2)}(2\omega_L)$ are the spectral density functions. For liquid crystal approximated as perfect order limit, $J^{(1)}(\omega_L)$ can be written in form^{7,13}: (a = intermolecular distance, $\omega_L = \gamma H_0$)

$$J^{(1)}(\omega) = \int_0^\infty dt \exp(-i\omega t) \left[\frac{3\hbar}{8} + \int_{q_h}^{q_{\max}} \frac{dq}{(2\pi)^3} \langle |n(q)|^2 \rangle \exp(-t/\tau_q) \exp(-Dq^2 t) S^2 \right] \quad (4.2)$$

where $\bar{n}(q)$ is the Fourier amplitude of the long-range order director $\bar{n}(r)$,

$$\bar{n}(q,t) = \frac{1}{V} \int \bar{n}(\bar{r},t) \exp(i\bar{q} \cdot \bar{r}) d\bar{r},$$

V is the volume, q is wave vector, τ_q is the time constant of the exponential decay of the autocorrelation function of q^{th} Fourier amplitude of the order director, i.e.

$$\langle n(q,t)n(q,0) \rangle = \langle |n(q)|^2 \rangle \exp(-t/\tau_q),$$

K is the Frank elastic deformation constant²³ and S is order parameter (i.e. $S = \frac{1}{2} \langle 3\cos^2\theta - 1 \rangle$). Using the hydrodynamic

²² ABRAHAM A., The Principles of Nuclear Magnetism, Chapter VII O.U.P (1961).

²³ Frank F.C., Discuss. Faraday. Soc. 25(1958)19.

range i.e. $q \leq q_h$, where $\frac{1}{q_h}$ > molecular dimension, $\langle |\bar{n}(q)|^2 \rangle_{av}$ and τ_q can be derived⁵

$$\langle |\bar{n}(q)|^2 \rangle_{av} = kT/V(Kq^2 + \Delta\chi H_0^2) \quad ,$$

and
$$\tau_q^{-1} = \eta^{-1} (Kq^2 + \Delta\chi H_0^2) \quad ,$$

where η is the viscosity, $\Delta\chi$ is the anisotropic part of the diamagnetic susceptibility and H_0 is the resonance static magnetic field. The first integral in Eq.(4.2) corresponds to the hydrodynamic approximation and does not decay exponentially and has $w_L^{-\frac{1}{2}}$ dependence. The second integral is sum over high-frequency range $q_h < q < q_{max}$ and does not have $w_L^{\frac{1}{2}}$ dependence. Then we can write Eq.(4.1) for liquid crystal PAA in the form of

$$(T_1)^{-1} = A(T)w_L^{-\frac{1}{2}} + B(T) \quad (4.3)$$

where the first term, $A(T)w_L^{-\frac{1}{2}}$ is obtained from the hydrodynamic range of Eq.(4.2) with

$$A(T) = w_D^2 \frac{s^2}{K} \frac{kT}{[(K/\eta) + D]^{\frac{1}{2}}} \quad , ,$$

where w_D is the dipolar frequency. The second term, $B(T)$, is obtained by adding $J^{(2)}(2w_L)$ with the high-frequency part of $J^{(1)}(w_L)$. Approximately, we can consider just the first term in Eq.(4.3). Hence we obtain⁹

$$\frac{1}{T_1} = w_L^2 s^2 (kT/K) [w_L(D + K/\eta)]^{-\frac{1}{2}} \quad (4.4)$$

4.3 Discussion

There is a clear break in the temperature dependence of the relaxation time at the nematic-isotropic liquid transition point (T_{NI}). For zone refined PAA, T_{NI} is 35.0°C and commercial PAA, T_{NI} is 34.0°C , and there are supercooled nematic at the temperature range below 119°C and 117.5°C respectively.

Comparing the magnitude of T_1 in the whole temperature range of zone refined and commercial PAA, obviously, T_1 of the zone refined PAA is larger than the one of the commercial PAA. It is confirmed that T_1 varies inversely as the impurity concentration, which agrees with the published results by Dong et al. Since the impurity such as some paramagnetic substance will cause the spin to relax more quickly than usual. Also we have noted that when the sample was heated and cooled by several cycles, we observed that T_1 of the last cycle is smaller than the initial cycle. That is the evidence that the oxygen gas in the sample capsule will dissolve in the liquid, i.e. the para-magnetic substance effect as we have discussed previously.

In the isotropic phase, T_1 rises smoothly, though not linearly with temperature. As in this phase the relaxation is due mainly to the translational diffusive motion, and the diffusion constant D has a linear temperature dependence⁸ in the isotropic liquid phase, the nonlinearity of $T_1(T)$ just above T_{NI} may be due to the presence of nematic cluster²⁵ in

²⁵James D. Lee and A. Cemal Eringen, "Wave Propagation in Nematic Liquid Crystals," Journal of Chemical Physics, 54(1971)5027.

the isotropic liquid.

We do not observe the sharp jump in T_1 in going from the isotropic liquid phase to the nematic phase as reported by Dong et al.⁷ Our observation of the temperature dependence of T_1 in the nematic region thus agrees more closely with that reported by Blinc et al.¹⁰

The contribution of the cooperative fluctuation of the order director to the spin-lattice relaxation has been obtained by Pincus¹³ to be⁹

$$T_1^{-1} = \omega_D^2 \left(\frac{kT}{K} \right) \frac{1}{\left(D + \frac{K}{\gamma} \right)^{\frac{1}{2}}} \omega_L^{-\frac{1}{2}} \quad (4.2.1)$$

Recalling the elastic deformation constant K varies as S^2 , published by Saupe (1960), where S is the order parameter. In the limit of weak diffusion ($D \ll \frac{K}{\gamma}$), it has been estimated that T_1 varies as $\frac{S^3}{T \eta^{\frac{1}{2}}}$. Using the published temperature dependence of S and η for PAA,¹ Doan and Visintainer⁹ has displayed the expected temperature dependence of T_1 in this limit (by using $\omega_L = 24$ MHz). This is shown as the dashed line in Fig. 4.2, which also displays our results for the nematic phase both ~~types and of PAA~~. Our data seem to indicate that as T_{NI} is approached from below, our sample actually attains the weak diffusion limit just from 128°C to 135°C but below 128°C it does not agree with the above theory.

It has also been suggested that the change in slope was due to a biaxial -to- uniaxial nematic phase transition which has been argued to be responsible for the specific⁴ heat anomaly

at 128°C. If such phase transition actually occurs, the intermolecular dipolar relaxation would have to be changed from a one order-parameter fluctuation to a two order-parameter fluctuation process. Another alternative explanation, also suggested by Dong et al., is to consider that the order fluctuations are slowed down with increasing amplitude of oscillation as temperature approaches T_{NI} .

In addition, the results of T_2 also show a clear break in the temperature dependence of spin-spin relaxation time with a nematic-isotropic liquid transition point (T_{NI}) at 135°C.

In the isotropic phase, T_2 varies almost linearly as temperature. As far as the translation diffusion (D) is concerned, the intensity of the echo at time t is determined by

$$M_y(t) = M_0 \exp \left[(-t/T_2) + (-\gamma^2 G^2 D t^3 / 12) \right],$$

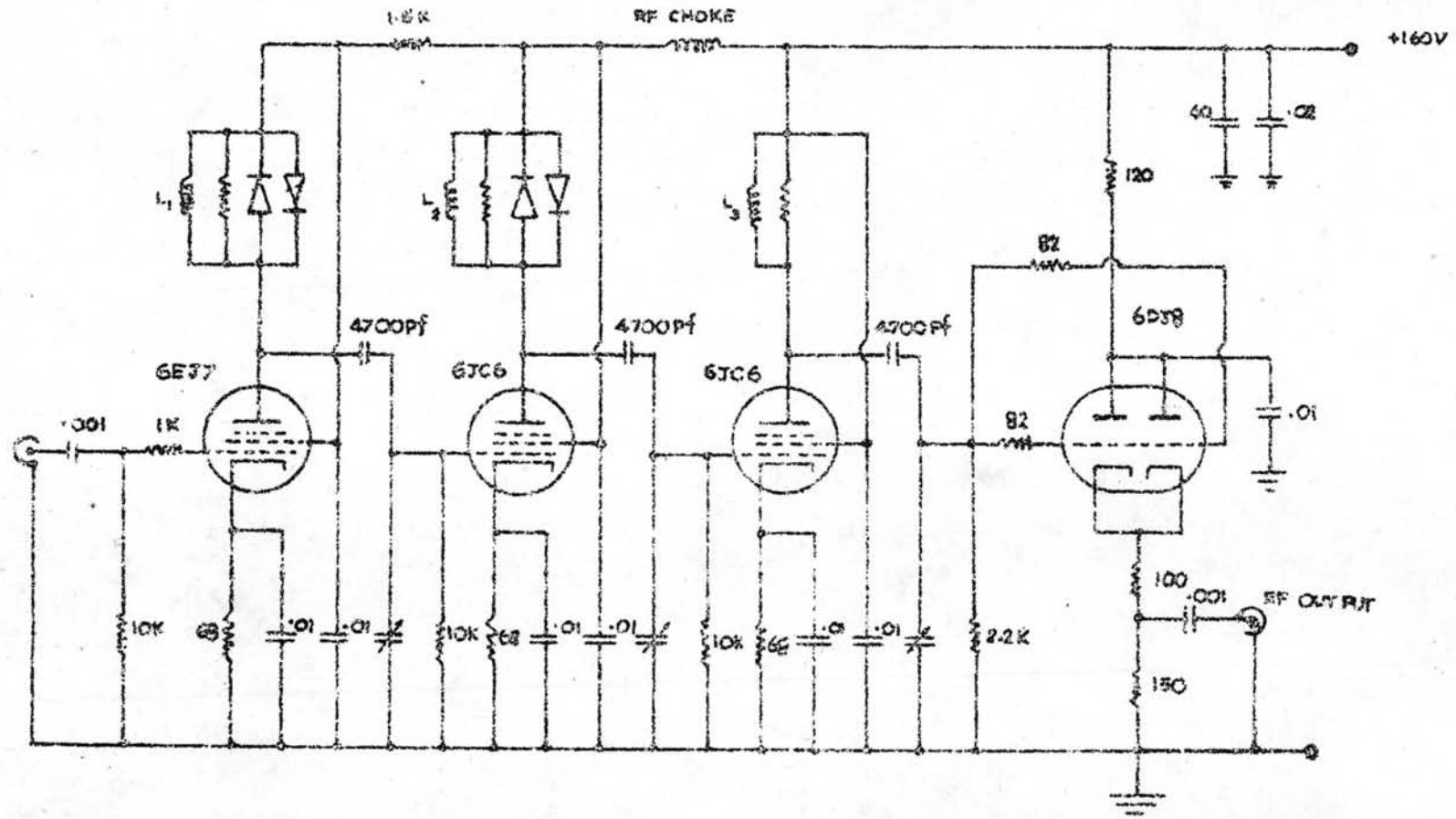
where G is average field gradient over the sample and must require that $12/\gamma^2 G^2 D \leq T_2^3$. The slope of a plot of $\ln(M_y/M_0) + t/T_2$ v.s. t^3 is used to obtain D . Therefore in the isotropic phase we can again confirm that it is due mainly to the translation diffusive motion.

But in nematic phase, T_2 are observed to be very short in magnitude of the order of microseconds, and it is almost

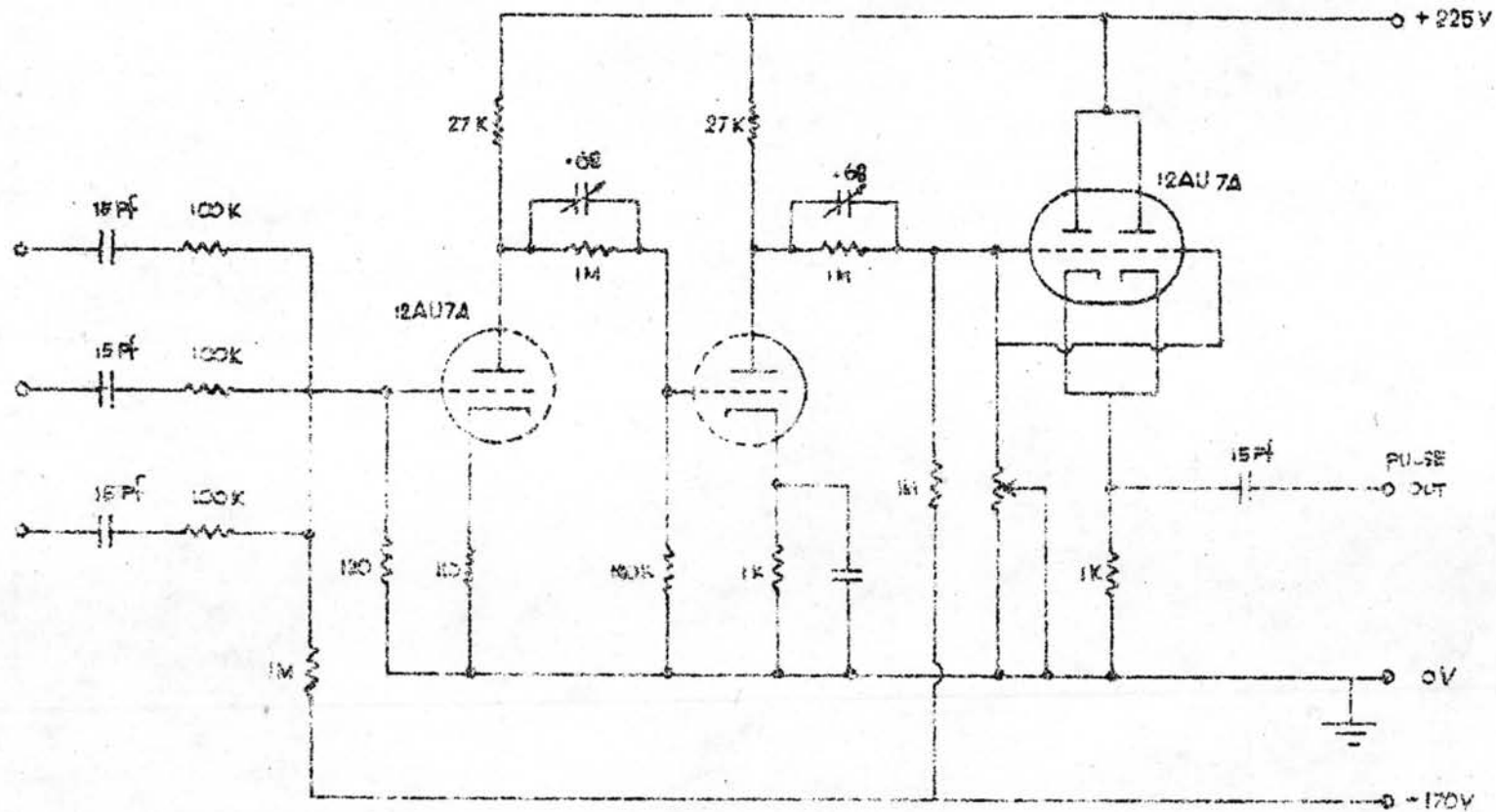
constant over the whole nematic range but above the 128°C , T_2 rises smoothly with temperature. These also support the proposal that translation diffusion, D is small and constant over the whole nematic range and actually it is also confirmed that at the temperature range above 128°C , the smooth increase of T_2 is due mainly to the slowing down of order fluctuation with increasing amplitude of oscillation. In the isotropic phase, T_2 is also satisfied with the theoretical result, since it is approximately equal to $\frac{5}{8} T_1$ (i.e. $T_2 = \frac{5}{8} T_1$).

Finally, we can conclude that the contribution of T_1 and T_2 in the nematic liquid crystal PAA is mainly due to the order fluctuation and there exists a change of relaxation mechanism which contributed to T_1 and T_2 at 128°C . In the nematic range (below 128°C) T_1 is not only due mainly to the order fluctuation, since we have noted that it is rather due to the translation diffusive motion because T_1 is increasing smoothly but not exponentially with temperature. Consequently in the temperature range $128-135^{\circ}\text{C}$, it is due to the order fluctuation by a reason that T_1 agrees well with the theoretical approach by treating D very small, and similarly T_2 rises smoothly in this range, which may be interpreted as there exists another contribution in addition to the translation diffusion and order fluctuation, i.e. it might be a collective molecular motion, a slow cooperative mode which has been proposed by Dong et al..

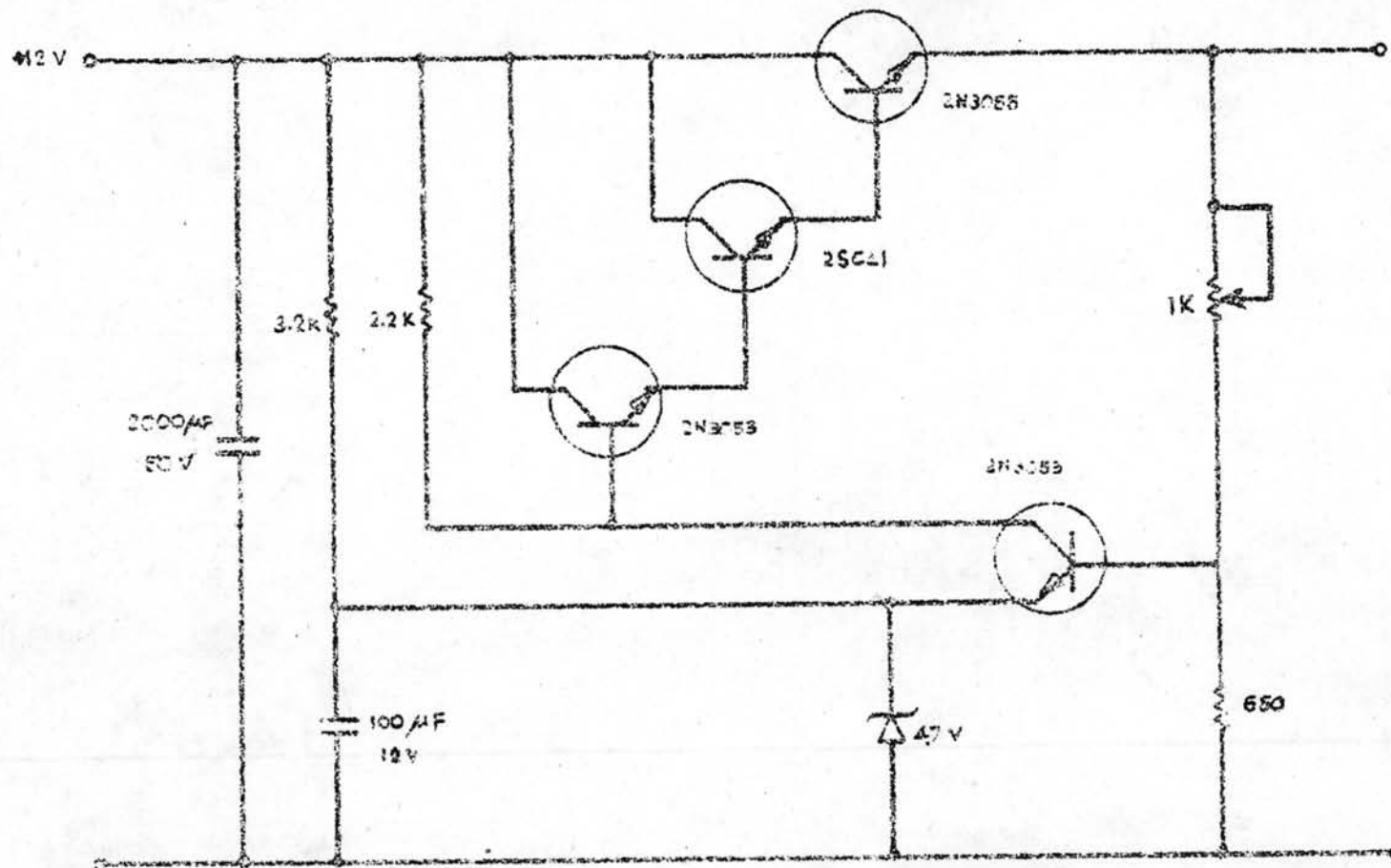
APPENDIX I



Appendix I.B RF amplifier



Appendix I.C Pulse amplifier



Appendix I E Regulated power supply

APPENDIX II



APPENDIX II.A

T₁ DATA

T₁ = Spin lattice relaxation time

$$T_1 = 1.063 T_{\text{null}} / \ln 2$$

where 1.063 is the time scale correction.

At proton resonance frequency 10 MHz.

<u>WITHOUT ZONE REFINED PAA</u>					
			137.5	560	.86
January 5, 1972			135.0	525	.80
T(°C)	null(msec)	T ₁ (sec)	133.0	600	.92
			132.5	605	.93
167.0	1000	1.54	129.5	620	.95
157.0	860	1.32	125.5	630	.97
149.0	800	1.23	124.5	610	.94
144.5	710	1.09	124.0	650	1.00
141.0	620	.95	119.0	620	.95
136.0	540	.83			
133.5	525	.81			
130.0	640	.98			
128.0	620	.95			
			<u>ZONE REFINED PAA</u>		
			January 11, 1972		
			T(°C)	null(msec)	T ₁ (sec)
January 8, 1972			173.0	1020	1.56
T(°C)	null(msec)	T ₁ (sec)	165.0	910	1.40
153.0	870	1.33	157.0	870	1.33
146.0	710	1.09	153.0	810	1.24
143.0	650	1.00	145.5	715	1.10
138.0	600	.92	140.0	610	.94
137.0	610	.94	143.0	645	.99
136.0	590	.90	137.5	580	.89
135.0	530	.81	134.5	550	.84
133.0	550	.84	134.0	560	.86
131.5	580	.89	133.5	620	.95
130.0	640	.98	133.0	690	1.06
127.0	635	.97	132.0	660	1.02
123.0	620	.95	131.5	670	1.03
119.0	590	.90	130.0	720	1.10
118.0	570	.88	129.0	685	1.05
116.5	560	.86	127.0	665	1.02
116.0	545	.84	125.0	660	1.01
114.0	480	.74	123.0	690	1.06
			122.0	680	1.04
			116.0	570	.87
January 8, 1972			115.0	550	.84
T(°C)	null(msec)	T ₁ (sec)	111.0	490	.75
143.0	640	.98	109.0	480	.74
139.0	595	.91			

January 11, 1972

T(°C)	null(msec)	T ₁ (sec)
173.0	1020	1.56
164.5	940	1.45
148.0	750	1.15
145.0	690	1.06
139.0	590	.91
135.0	500	.77
134.5	550	.84
134.0	560	.86
133.5	630	.97
131.5	700	1.07
130.5	710	1.09
129.0	690	1.06
127.5	650	1.00
126.0	620	.95
124.0	645	.99
121.0	640	.98
117.0	600	.92

January 12, 1972

T(°C)	null(msec)	T ₁ (sec)
169.0	1100	1.69
161.0	1060	1.63
153.0	930	1.43
151.0	850	1.30
145.5	740	1.14
141.0	640	.98
139.0	610	.94
138.5	600	.92
136.0	590	.90
135.0	575	.88
134.0	625	.96
133.5	645	.99
132.0	665	1.02
129.5	695	1.07
128.0	710	1.09
127.0	725	1.11
124.5	730	1.12
121.5	710	1.07
120.0	695	1.07
118.0	655	1.00
117.0	665	1.02
112.5	650	1.00
110.0	610	.94
107.0	580	.90
105.0	530	.81

January 16, 1972

T(°C)	null(msec)	T ₁ (sec)
161.0	1000	1.54
158.5	900	1.38
151.5	800	1.23
144.0	675	1.04
138.0	565	.87
137.0	550	.84
135.5	520	.80
133.0	600	.92
131.0	700	1.08
126.5	675	1.04
124.5	650	1.00
119.0	610	.44
114.0	585	.90
111.5	570	.88
107.5	500	.77

January 16, 1972

T(°C)	null(msec)	T ₁ (sec)
150.0	880	1.37
145.0	800	1.26
141.5	700	1.11
136.0	600	.92
132.5	580	.91
132.0	605	.94
131.5	690	1.08
130.5	740	1.16
128.0	730	1.14
127.0	760	1.19
125.5	765	1.20
123.5	730	1.14
123.0	715	1.12
121.5	695	1.09
119.0	660	1.02
116.5	610	.96
113.5	550	.86

January 24, 1972

T(°C)	null(msec)	T ₁ (sec)
160.5	1050	1.62
159.5	1000	1.53
153.5	820	1.26
146.5	750	1.15
138.5	620	.95

137.0	570	.88
136.0	530	.81
135.5	530	.81
135.0	550	.84
131.5	630	.97
130.5	690	1.00
127.5	735	1.13
125.0	720	1.10
121.0	650	1.00
119.5	635	.97
118.5	630	.96
115.0	620	.95
111.0	570	.87
107.5	560	.86
105.0	570	.88
103.0	550	.84
102.0	545	.84

137.5	550	.84
135.5	510	.78
134.0	655	1.000
133.0	720	1.100
132.5	675	1.04
132.5	715	1.10
130.5	750	1.15
128.5	730	1.12
126.5	715	1.10
124.5	695	1.06
121.0	675	1.04
118.5	640	.98
115.5	630	.96
114.0	595	.91
112.0	570	.87

January 24, 1972

T(°C)	null(msec)	T ₁ (sec)
158.0	950	1.46
152.0	870	1.34
151.0	790	1.21
148.5	765	1.17
144.5	670	1.03
140.0	600	.92
138.0	570	.88
135.0	520	.80
134.5	510	.78
133.0	630	.97
129.5	750	1.15
128.5	750	1.15
128.0	730	1.12
123.0	700	1.17
120.0	660	1.01
117.0	630	.97
112.5	630	.97
111.5	580	.89

January 30, 1972

T(°C)	null(msec)	T ₁ (sec)
155.0	955	1.46
149.0	810	1.24
143.0	690	1.06
141.5	650	1.06
138.5	580	.89
135.0	510	.78
133.0	560	.86
131.5	640	.98
129.5	700	1.08
127.5	680	1.04
125.5	660	1.01
122.5	645	1.00
119.0	630	.96
117.0	595	.91
113.0	580	.89
107.5	530	.81

January 29, 1972

T(°C)	null(msec)	T ₁ (sec)
154.5	890	1.36
149.0	740	1.14
141.0	600	.92

January 31, 1972

T(°C)	null(msec)	T ₁ (sec)
149.5	900	1.38
146.0	785	1.20
142.5	710	1.09
139.0	640	.98
134.5	510	.78
131.5	600	.92
127.5	785	1.20
124.5	770	1.18

120.5	710	1.09
119.0	690	1.06
115.5	660	1.01
112.5	630	.97

132.0	680	1.04
127.5	740	1.14
124.0	700	1.07
116.5	630	.97
110.0	640	.98

February 8, 1972

T(°C)	null(msec)	T ₁ (sec)
154.5	930	1.43
151.0	840	1.28
142.0	660	1.01
136.0	530	.81
135.0	500	.87
134.0	550	.84
131.5	670	1.03
128.5	750	1.15
126.0	730	1.12
123.5	695	1.06
118.0	660	1.01
111.5	630	.96
110.0	610	.94

February 9, 1972

T(°C)	null(msec)	T ₁ (sec)
153.0	975	1.40
148.0	835	1.20
140.0	690	1.00
138.0	615	.89
134.0	550	.79
129.5	700	1.01
126.5	730	1.05
121.5	710	1.02
115.0	660	.95
111.0	620	.89
107.5	580	.84

February 8, 1972

T(°C)	null(msec)	T ₁ (sec)
160.0	1100	1.68
152.0	895	1.37
144.5	705	1.08
139.0	585.0	.90
136.5	540	.83
133.5	635	.97
128.5	745	1.14
125.5	720	1.10
120.0	680	1.04
116.5	640	.98
109.5	630	.97
109.5	620	.95

February 14, 1972

T(°C)	null(msec)	T ₁ (sec)
156.0	895	1.37
153.0	840	1.29
147.5	760	1.16
142.5	620	.95
138.0	570	.87
133.0	610	.88
130.5	650	1.00
127.5	680	1.04
125.5	705	1.08
124.0	695	1.06
120.5	660	1.01
119.0	615	.94
117.5	605	.93
114.5	590	.90

February 9, 1972

T(°C)	null(msec)	T ₁ (sec)
151.0	900	1.38
147.0	825	1.26
142.5	740	1.14
139.0	645	.99
135.5	545	.84

APPENDIX II.B

T₂ DATAT₂ = Spin-spin relaxation time

At proton resonance frequency = 10 MHz.

<u>ZONE REFINED PAA</u>		146.5	230
January 24, 1972		140.5	328
T(°C)	T ₂ (msec)	138.0	246
155.0	492	135.0	328
148.0	460	134.5	61x10 ⁻³
140.0	410	133.0	34x10 ⁻³
137.5	328	130.0	33x10 ⁻³
134.5	52x10 ⁻³	128.0	31x10 ⁻³
132.5	45x10 ⁻³	123.0	30x10 ⁻³
129.5	36x10 ⁻³	122.0	
127.5	35x10 ⁻³		
123.5	32x10 ⁻³	January 29, 1972	
117.0	30x10 ⁻³	T(°C)	T ₂ (msec)
113.0	30x10 ⁻³	155.0	459
109.5	26x10 ⁻³	148.5	360
107.0	24x10 ⁻³	141.0	387
105.0	24x10 ⁻³	137.5	312
104.0	22x10 ⁻³	135.5	368
		133.0	39x10 ⁻³
		134.0	34x10 ⁻³
January 25, 1972		130.5	39x10 ⁻³
T(°C)	T ₂ (msec)	126.5	34x10 ⁻³
159.0	360	124.0	30x10 ⁻³
153.0	491	121.0	31x10 ⁻³
151.0	393	118.5	28x10 ⁻³
145.5	328	115.5	30x10 ⁻³
140.5	393	114.0	28x10 ⁻³
136.0	213	112.0	20x10 ⁻³
133.5	64x10 ⁻³		
131.0	44x10 ⁻³	January 29, 1972	
129.0	25x10 ⁻³	T(°C)	T ₂ (msec)
124.0	22x10 ⁻³	152.5	442
121.0	23x10 ⁻³	145.5	360
117.5	26x10 ⁻³	139.0	328
113.0	23x10 ⁻³	136.5	295
		134.0	344
January 25, 1972		131.0	49x10 ⁻³
T(°C)	T ₂ (msec)	129.0	39x10 ⁻³

127.0	33×10^{-3}
124.5	33×10^{-3}
122.5	29×10^{-3}
120.5	31×10^{-3}

January 30, 1972

T(°C)	T(msec)
156.0	240
149.0	190
144.5	321
139.5	295
136.0	314
134.0	52×10^{-3}
132.5	40×10^{-3}
130.5	33×10^{-3}
128.5	35×10^{-3}
126.5	30×10^{-3}
123.5	29×10^{-3}
120.0	31×10^{-3}
118.0	34×10^{-3}
114.0	25×10^{-3}
108.5	26×10^{-3}

January 31, 1972

T(°C)	T ₂ (msec)
149.0	420
145.0	256
142.5	295
136.5	256
133.5	45×10^{-3}
129.5	39×10^{-3}
126.5	36×10^{-3}
122.5	27×10^{-3}
121.0	25×10^{-3}
117.5	26×10^{-3}
114.5	22×10^{-3}
107.0	21×10^{-3}
