during the flight. The present result is lower than the 0.4 ergs $cm^{-2}$ $sec^{-1}$ previously reported by Tousey, Watanabe, and Purcell[8] based on exposure of a thermoluminescent powder, responsive to the wavelength band 1050–1240A. Pietenpol *et al.*[9] recently reported photographic detection of $HL_\alpha$ in a flight that exceeded 80 km and estimated the intensity to be of the order of magnitude of 0.3 erg $cm^{-2}$ $sec^{-1}$.

The straight line character of the plot of logarithm of intensity *versus* residual air path shown in Fig. 1, is evidence for the monochromatic nature of the radiation that was measured. Hopfield's spectrograms[10] revealed the existence of a deep window in the $O_2$ absorption spectrum at $HL_\alpha$ and Watanabe, Marmo, and Inn[3] recently published quantitative measurements of the absorption coefficients in the neighborhood of this window. Within $\pm 1.0$A on either side of $HL_\alpha$, the absorption coefficient increased by at least 200 percent. The constancy of the measured absorption coefficient over the entire altitude range of the rocket therefore indicates that the breadth of the solar emission line must certainly be less than one angstrom unit. Pietenpol[9] judged the width of his photographed line to be about 6A. In view of the narrowness of the $O_2$ window, such an observed line width at 80 km would be difficult to explain except as instrumental broadening.

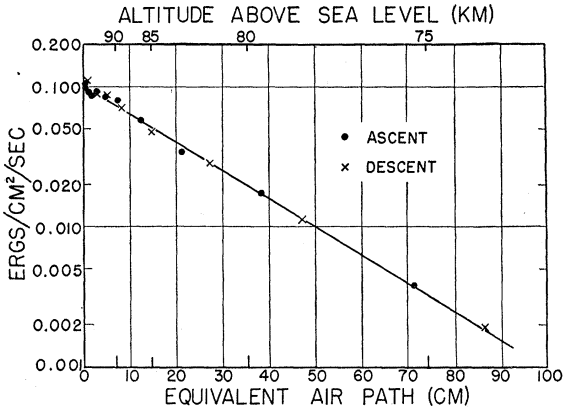


FIG. 1. Log incident energy *versus* the equivalent air path at NTP traversed by solar radiation as measured with a photon counter sensitive in the 1180–1300A region.

At the peak of the flight, 128 km, the rocket was above the molecular oxygen atmosphere. Figure 1 does not indicate all the data points obtained near the top of the flight. The rocket spent 140 seconds above 105 kilometers during which time the roll of the rocket exposed the photon counter to the sun 28 times. The rms deviation of the counting rates measured for these 28 exposures was $\pm 6$ percent, and the average value of the intensity fell within one percent of the straight line plot of Fig. 1. Any appreciable intensity outside the $HL_\alpha$ wavelength would have appeared in excess of the intercept of the $HL_\alpha$ characteristic at zero residual air path. It may be concluded from these observations and the spectral sensitivity curve of the photon counter that the continuous solar emission background in the neighborhood of 1200A must have been less than 0.01 erg $cm^{-2}$ $sec^{-1}$ per 100A. This is equivalent to a black body temperature less than 4600 degrees K.

It has been suggested that absorption of $HL_\alpha$ by NO may provide the observed *D*-layer ionization.[11,12] The present rocket data do not exclude this possibility. Although the rocket data have been explained by attributing all the absorption to $O_2$, a weak absorption due to nitric oxide or water vapor could have been present within the experimental error. If we assume that the contribution of $H_2O$ or NO to the absorption observed in the rocket experiment was less than ten percent, the maximum concentrations relative to air must have been less than $1.6\times10^{-5}$ and $9.4\times10^{-5}$, respectively, using absorption coefficients[3,4] of 390 $cm^{-1}$ and 67 $cm^{-1}$ for $H_2O$ and NO. The latter concentration is equivalent to an upper limit of 0.007 cm (NTP) of NO above 75 km, well below the value of 0.02 cm (NTP) given by Migeotte and Neven[13] as the maximum possible abundance based on their studies of the solar spectrum in the infrared. Watanabe *et al.*[3] have found that approximately 50 percent of the absorption of NO at the wavelength of $HL_\alpha$ leads to photoionization. If only one percent of the $HL_\alpha$ intensity observed in the rocket experiment were absorbed by NO, the rate of ion production in the *D* layer would average about 15 ion pairs $cm^{-3}$ $sec^{-1}$, which is of the order of magnitude required to produce the *D* layer.[11]

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## The Shape of Exchange Narrowed Paramagnetic Resonance Lines*

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THE theory of Anderson and Weiss[1] on exchange narrowing in paramagnetic resonance absorption predicts that the line shape in the case of large exchange interaction is of the resonance or Lorentz type in the observable center of the line. Organic free radicals, having very narrow absorption lines, are suitable substances for testing the validity of the line shape prediction. Measurements at 3.2-cm wavelength do indeed show that the diphenyl picryl hydrazyl absorption follows the resonance line shape.

The absorption curves were derived from recorder tracings which were made by a procedure that has been described.[2] The

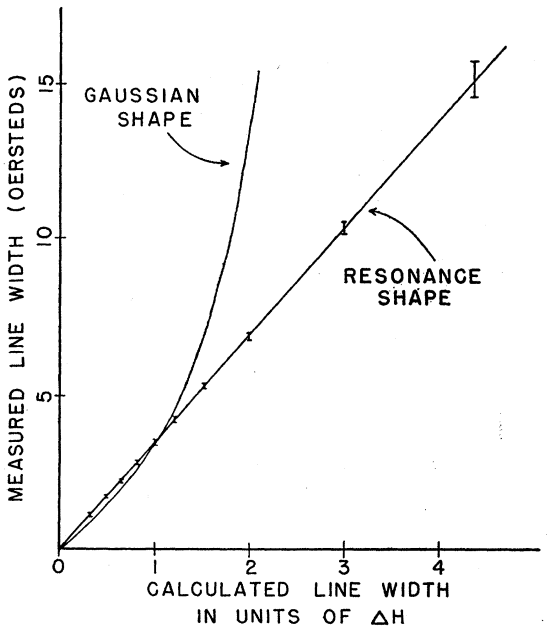


FIG. 1. Shape analysis of diphenyl picryl hydrazyl resonance at 4.2°K and 3.2-cm wavelength.

resonance shape may be written as $f=(1+x^2)^{-1}$, $x=2(H-H_0)/\Delta H$, where $f$ is the fractional absorption relative to the peak absorption at a magnetic field $H$, $H_0$ is the field at the resonance peak, and $\Delta H$ is the full line width at $f=\frac{1}{2}$. The shape analyses were made by measuring the full line widths for various values of $f$ and plotting the measured line widths against the calculated line widths for corresponding values of $f$, i.e., against $(1/f-1)^{\frac{1}{2}}$.

Figure 1 shows the results for the hydrazyl radical at 4.2°K, where the data for a number of runs, taken under various conditions of sample cavity mismatch and without saturation effects, are summarized. For comparison, the curve to be found under the assumption of a Gaussian line shape, which is predicted for the case of negligible exchange effects, is also shown, the fit with the measured widths being made at half-maximum absorption. The data are clearly incompatible with the Gaussian shape, particularly in the wings of the line. (The extreme plotted data correspond to $f=0.05$.) The value of $\Delta H$ for 4.2°K is found to be $3.46\pm0.04$ oersteds, with $g=2.0025\pm0.0003$. At room temperature the shape is also found to be of the resonance type with $\Delta H=2.70\pm0.02$ oersteds and $g=2.0036\pm0.0002$; at 77°K, $\Delta H=2.36\pm0.02$ oersteds and $g=2.0036\pm0.0003$.

These results are in qualitative agreement with those of Singer and Spencer,[3] who find at 25 Mc/sec a substantial increase in line width and a $0.10\pm0.05$ percent decrease in $g$ in going from room temperature to 4.2°K. Our data fail to show a bulge on the low-field side of the resonance line, as observed by Hutchison, Pastor, and Kowalsky;[4] this can be attributed to differences in the preparation of the samples. The effect of the anisotropy in $g$ value, found for single crystals,[4] was essentially eliminated by the use of finely powdered samples. The hyperfine structure, which is revealed when the hydrazyl radical is sufficiently diluted in benzene, makes no important contribution to the line shape in the undiluted sample, inasmuch as the nearest satellite lines rise from the wings of the central line at a field separation of about 10 oersteds as the samples are diluted.

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## A New Thermal Resistivity Maximum in Superconducting Alloys

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THE thermal conductivity of a series of homogeneous, solid solution indium-thallium alloys with thallium contents up to 50 atomic percent has been measured as a function of magnetic field and temperature in the liquid helium region, the specimens being those for which magnetic and electrical data were previously obtained by Stout and Guttman.[1] Details of the temperature variation of the thermal conductivity in the pure superconducting and pure normal states will be discussed in a later paper. The purpose of this note is to report a new thermal resistivity maximum which accompanies the isothermal destruction of superconductivity by a *longitudinal* magnetic field, at temperatures sufficiently below $T_c$, in alloys containing between 15 and 50 atomic percent Tl. This effect is illustrated in Fig. 1, where the dependence of the thermal resistivity of a long, single crystal cylinder of 20 atomic percent Tl and 80 atomic percent In upon *longitudinal* magnetic field is compared with the variation of the magnetic induction and electrical resistance found by Stout and Guttman[1] for the same specimen.

The thermal resistivity passes through a sharp maximum within the range $1<H/H_c<4$, where the gradual flux penetration and delayed return of electrical resistance imply the co-existence of

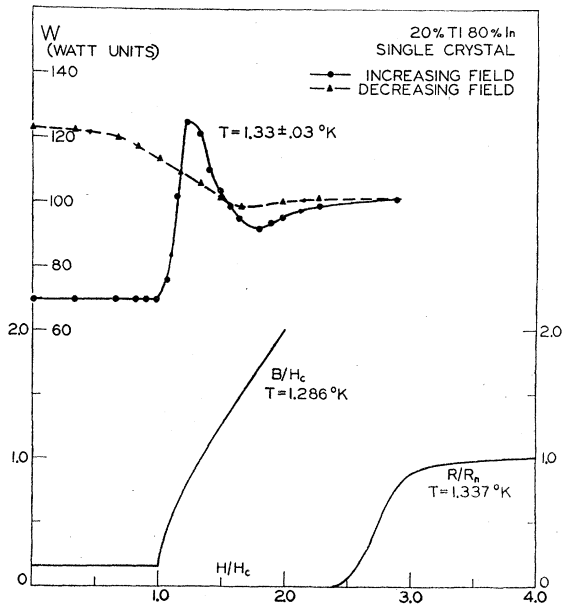


FIG. 1. Thermal resistivity, reduced magnetic induction, and reduced resistance *versus* reduced magnetic field. The induction and electrical resistance data are from Stout and Guttman (reference 1).

both superconducting and normal filaments at fields well above $H_c$. It seems possible to these additional resistivity responsible for the maximum is due to the scattering of heat carriers at the boundaries between superconducting and normal regions. The scattering of electrons at these boundaries is probably unimportant, since although the electronic thermal conductivity is still appreciable, the electronic mean free path is short ($\sim2\times10^{-6}$ cm in the 20 percent Tl specimen) even compared to the probable thickness of the boundary ($\sim10^{-5}$ cm)[2] between normal and superconducting regions. Phonons, on the other hand, have a much longer mean free path in these alloys, particularly in the superconducting state in which there are fewer normal electrons available to act as scattering centers.[3] In the 20 percent Tl specimen at 1.345°K, for example, the phonon mean free path is estimated from the experimental thermal conductivity corrected for the electronic contribution[3] to be $9.8\times10^{-5}$ cm for the pure normal state and $1.4\times10^{-3}$ cm for the pure superconducting state. Thus, if the average diameter of the normal filaments is comparable with that of the superconducting filaments, boundary scattering of phonons is probably important only in the latter.

With an appropriate separation of the lattice and electronic conductivities[4] and an allowance for the fraction of normal material as derived from the induction curve, the additional resistivity in the superconducting filaments was computed for the maximum of Fig. 1 and for similar maxima at several different temperatures. This resistivity was found to be roughly proportional to $T^{-3}$, in good agreement with the expected temperature variation for boundary scattering of phonons,[5,6] provided that the filament diameter is itself independent of temperature. If scattering at the boundaries is completely diffuse, the magnitude of the additional resistivity indicates a phonon mean free path of approximately $3\times10^{-4}$ cm, which sets an upper limit to the average filamental diameter and, moreover, satisfies the other boundary scattering condition that the wavelengths of the phonons important in heat conduction[6] ($5\times10^{-7}<\lambda<2\times10^{-6}$ cm in this case) be shorter than the distance between boundaries.

After the magnetic field is removed, the final thermal resistivity is considerably greater than the virgin superconducting or normal state values, presumably due to scattering of phonons at the boundaries of frozen-in normal regions, the presence of which is indicated by the incomplete Meissner effect. The additional lattice