SHIFT MEASUREMENTS OF THE STARK-BROADENED
IONIZED HELIUM LINES AT 1640 AND 1215 Å

by

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ABSTRACT

Title of Dissertation: SHIFT MEASUREMENTS OF THE STARK-BROADENED IONIZED HELIUM LINES AT 1640 AND 1215 Å

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Time-resolved measurements were made of the shifts of the ionized helium lines at 1640 Å (n = 3 → 2) and 1215 Å (n = 4 → 2), and of the Stark profile of the λ 1215 Å line. An electromagnetic shock tube was used as a light source. The plasma conditions corresponded to electron temperatures of ~3.5 eV and electron densities of 0.8 to 1.8 × 10^{17} cm^{-3}. The measured shifts fell between two previous estimates of plasma polarization shifts. The measured Stark width of the λ 1215 Å line was up to 30% greater than the theoretical width.
DEDICATION

To my wife, Nita, who kept my nose to the grindstone.
ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

Spectroscopy has long been recognized as an important diagnostic tool for both astrophysical plasmas, where it is often the only method available, and in the laboratory where, unlike many methods, it does not disturb the plasma under study.

The considerable theoretical and experimental efforts in this field have resulted in good understanding of the pressure broadening and shifts of spectral lines due to the Stark effect of nearby charged perturbers. Particular attention has been paid to the lines of hydrogen and the hydrogenic ions, for which the quasistatic and impact theories predict considerable broadening but no shifts. However, in 1962, Berg et al. reported\(^1\) a blue shift for the He II 4686 line, which they attributed to the reduction of the Coulomb potential of the nucleus by the polarization of the plasma near the radiating ion. Later measurements\(^2\) demonstrated this "shift" had been simulated by some unresolved Si III lines on the blue wing of the helium line. Greig et al. then reported blue shifts of the He II 304 line\(^3\). Subsequent photographic measurements\(^4,5\) did not verify the shift of the 304 line, but higher series members (256, 243, etc.) had blue shifts which could have been due to plasma polarization. The most recent measurement\(^6\) showed blue shifts for the 256 and 243 lines, with a greater shift for the 304 line, in agreement with Greig's result.

The polarization shift is expected to be important for high-Z ion lines and may limit wavelength accuracies in, for example, laser-produced plasmas. The theoretical treatments of this effect have
been unsatisfactory,\textsuperscript{7,8} and no attempts have been made to measure shifts of the "Balmer" (or "second Lyman") series lines of ionized helium, at 1640, 1215, 1084 ... Å. The primary aim of this experiment was to look for such shifts, and investigate their possible dependence on plasma conditions. A secondary purpose was to measure the Stark broadening of the higher series members, to check the theoretical calculations.\textsuperscript{9,10}

A T-tube was chosen as a source because it produces a fairly homogeneous plasma\textsuperscript{6} near local thermal equilibrium (LTE),\textsuperscript{11,12} at a density and temperature suitable for the emission of ionized helium lines. The line positions were measured relative to nearby impurity lines. Plasma conditions were determined from photoelectric measurements of the He II 4686 line, and plasma reproducibility was checked by monitoring the total intensities of the 4686 line and the continuum near 4976 Å.

The first chapter of this dissertation has served as an introduction. In Chapter 2 some of the relevant results of plasma spectroscopy are presented. A description of the experimental apparatus and method appears in Chapter 3. The experimental results, with a discussion of them and possible errors, are in Chapter 4.
CHAPTER II

THEORETICAL BACKGROUND

A. Line Intensities

The relative intensities of emission lines depend on the population densities of atoms in the upper state and the probability of radiative transition to the corresponding lower state.

In equilibrium, the density \( N_z \) of ions of charge \( Z \) is related to the electron density \( N_e \) and the density of atoms in the next lower ionization stage according to the Saha equation

\[
\frac{N_e N_z}{N_{z-1}} = 2 \frac{Z_z(T)}{Z_{z-1}(T)} \left( \frac{m_e kT}{4\pi e^2} \right)^{3/2} \exp \left( -\frac{E_{z-1}^\infty - \Delta E_{z-1}^\infty}{kT} \right).
\]  

(2-1)

Since nearly all the atoms are in the ground state, the partition function \( Z_z(T) \) can usually be replaced by the statistical weight \( g_z \) of the ground state. In this case, \( z=0 \), and we have \( g_z = 2S+1 \) (1 for \( \text{He}^+ \), \( \text{He}^0 \), and \( \text{He}^{++} \); 2 for \( \text{He}^0 \) and \( \text{He}^+ \)). The correction \( \Delta E_{z-1}^\infty \) to the ionization energy \( E_{z-1}^\infty \) due to Coulomb interactions in the plasma is

\[
\Delta E_{z-1}^\infty = \frac{Z e^2}{4\pi \epsilon_0 \lambda_D^2},
\]

(2-2)

where \( \lambda_D \) is the plasma Debye length

\[
\lambda_D = \left( 4\pi \sum_i \frac{N_i q_i^2}{k T_i} \right)^{1/2},
\]

(2-3)

where \( N_i \) is the density of particles with charge \( q_i \). Plots of helium ionization stage concentrations as functions of temperature appear in Fig. 2-1. Plots of \( \lambda_D \) and other plasma properties appear in Fig. 2-2,
Fig. 2-1 Calculated helium ionization stage concentrations
Fig. 2-2 Calculated conditions for a pure helium plasma
where the shaded region is typical of T-tubes. Note that the plasma approximation $N_e \lambda_D^3 \gg 1$ (indicating many particles in a Debye sphere) is only marginally satisfied.

The population densities $N_{nLS}$ of the state $(n, L, S)$ of a given ionization stage is given by the corresponding Boltzmann factor

$$N_{nLS} = g_{nLS} \exp \left(- \frac{E_{nLS}}{kT} \right), \quad (2-4)$$

together with the normalization condition. The exponential term is nearly always much less than one for excited states, justifying the earlier statement that most atoms are in the ground state. Note that an isolated atom has an infinite number of bound states, whose energies tend to the ionization energy $E_i$. When the atom is embedded in a plasma, however, the ionization energy is reduced as described above, and only a finite number of bound states remain.

Treating an atom as an electric dipole radiator, the transition probability per unit time for spontaneous emission is

$$A_{lu} = \frac{4e^2 \omega^3}{3\hbar c^3 [4\pi \varepsilon_0^2]} g_l \sum_i |<l| x_i |u>|^2 a_{uv}, \quad (2-5)$$

which is tabulated for many spectral lines. The sum is over the components of the coordinate vector of the radiating electron, and the average is over possible final states. Multiplying by the energy $\hbar \omega$ of the photon, and using (2-4) to relate the upper state population density to the ground state population density $N_g$ (with statistical weight $g_g$) we find the total power per unit volume spontaneously radiated in the given line to be

$$P_{lu} = 2\pi \hbar c \frac{N_g A_{lu} g_u}{\lambda} g_u \exp \left(- \frac{E_u}{kT} \right). \quad (2-6)$$
Since the line intensities are proportional to the concentration of atoms in the appropriate ionization stage, the intensity ratio of lines of different ionization states is an extremely sensitive function of temperature (see Fig. 2-3), and can be used to measure the temperature. Note, however, that this measurement depends strongly on the assumption of local thermal equilibrium, which can require a long time and considerable distance to establish between states with very different energies.

B. Continuum Intensities

Plasmas emit continuum radiation due to radiative recombination (inverse photoionization), bremsstrahlung, and the formation of negative ions. A pseudo-continuum results when the Stark profiles of nearby lines overlap.

The extremely weak bremsstrahlung radiation due to ion-ion and nonrelativistic electron-electron collisions can be neglected. That due to electron collisions with ions of charge $z$ is given by $^{16}$

$$\epsilon_{ei} = \frac{16\pi e^6}{3c^2} \frac{N_e N_z}{G_z(\omega, T_e)} z^2 G_z(\omega, T_e), \quad (2-7)$$

where $G_z$ is the free-free Gaunt factor, which is usually of order one. $^{17}$

The radiation from electron-neutral collisions (approximated by elastic, billiard-ball type interactions) is given by $^{16}$

$$\epsilon_{e0} = \frac{32e^2}{3c} \frac{N_e N_0(\kappa T_e)^{3/2}}{(2\pi m)^{3/2}} C_0(\omega, T) \quad (2-8)$$

When an ion captures a free electron, the binding energy and the electron's kinetic energy are given to a photon. For recombination into a given orbital $(n,L,S)$, the photon then has the minimum energy
Fig. 2-3 Calculated helium line intensities.
\[ \hbar \omega = E_{z-1,n} - E_{z-1,n} \]  

(2-9)

Viewed another way, this restricts the possible final states for the electron for a contribution to the continuum at a given frequency.

The recombination continuum is then, by detailed balancing,\(^{16}\)

\[ \frac{\varepsilon_R}{\omega} = \frac{2\pi n^4}{c^2} \frac{N_e N_z \omega^3}{(2\pi m_e kT_e)^{3/2}} \exp \left( \frac{-\hbar \omega}{kT_e} \right) \sum_n \frac{g_{z-1,n}}{g_{z,1}} \sigma_{z-1,n}, \]  

(2-10)

where \(\sigma_{z-1,n}\) is the photoionization cross section\(^{18,19}\), \(g_{z-1,n}\) and \(g_{z,1}\) are statistical weights, and the sum runs from the lowest allowed state to the highest bound state (i.e., with energy less than the reduced ionization energy calculated from (2-2)).

Some electronegative atoms (H, N, O, C, etc.) can capture a free electron and form a negative ion, while emitting a continuum as in recombination. The spectral emission coefficient is, similarly\(^{16}\)

\[ \frac{\varepsilon_s}{\omega} = \frac{2\pi n^4}{c^2} \frac{3N_e N_z g^- \omega}{(2\pi m_e kT_e)^{3/2}} \exp \left( \frac{-E_a - \hbar \omega}{kT_e} \right) \sigma^-(\omega) \]  

(2-11)

where \(g^-\) is the statistical weight of the negative ion (which usually has only one bound state), \(Z_0\) is the partition function of the neutral atom, \(E_a\) is the binding energy of the new electron (generally less than 2 eV), and \(\sigma^-\) is the cross section for the inverse process of photodetachment.\(^{20}\)

This process is unimportant in hot plasmas, where the density \(N_a\) of neutral atoms is low.

The pseudo-continuum of lines is generally important only for hydrogenic atoms, which are subject to the linear Stark effect, and then only near a series limit. The last clearly distinguishable line of a series is then given by the Inglis-Teller limit.\(^{21}\)

Since both line and continuum intensities increase with electron
density, but scale differently with temperature, the ratio of the line intensity to that of the nearby continuum can be used to measure the temperature.

C. Radiation Transfer

In previous sections we have discussed the spectral emission coefficient \( \varepsilon_\omega \) of the plasma, expressed as power radiated per unit solid angle, frequency interval, and volume. The experimentally measurable quantity is \( I_\omega \), the power radiated per unit solid angle, frequency interval, and surface area of plasma observed. In the simplest situation, i.e., neglecting scattering, it obeys the differential equation \(^13\)

\[
\frac{d}{dx} I_\omega = \varepsilon_\omega - k' I_\omega , \tag{2-12}
\]

where \( k'_\omega \) is the effective absorption constant, equal to the actual absorption constant minus the induced emission. \( \varepsilon_\omega \) includes only the spontaneous emission. If the plasma is in LTE, the emission follows Kirchoff's law \(^13\)

\[
\varepsilon_\omega = k'_\omega B_\omega (T) , \tag{2-13}
\]

where \( B_\omega \) is the Planck function. If we further assume the plasma to be homogeneous, the solution of (2-12) is

\[
I_\omega (z) = B_\omega (T)[1 - \exp(-k'_\omega z)] . \tag{2-14}
\]

The quantity \( k'_\omega z \) is the "optical depth", and if \( k'_\omega << 1 \), the equation reduces to

\[
I_\omega (z) = B_\omega (T)k'_\omega = \varepsilon_\omega z , \tag{2-15}
\]
as expected. In the opposite limit, \( k^i_\omega >> 1 \), the plasma radiates as a blackbody. Stellar atmospheres have great optical depth at almost all wavelengths, while laboratory plasmas are normally optically thin except possibly near the centers of some resonance lines.

D. Line Broadening

Spectral line broadening in a plasma is a complex phenomenon, and no attempt is made here to discuss all the results of investigations in atomic spectroscopy, astrophysics, and plasma spectroscopy. Only a physical picture of the various effects is presented.

Let the (frequency-space) spectral line profile \( I(\omega) \) be proportional to the light intensity between \( \omega \) and \( \omega + d\omega \), subject to the normalization condition

\[
\int_{-\infty}^{\infty} I(\omega) d\omega = 1 .
\]  

(2-16)

These spectral intensities are the squares of the corresponding Fourier components \( C(\omega) \):

\[
I(\omega) = |C(\omega)|^2 ,
\]  

(2-17)

where \( C(\omega) \) is the Fourier transform of the amplitude \( f(t) \)

\[
C(\omega) = \sqrt{\frac{1}{2\pi}} \int_{-\infty}^{\infty} e^{i\omega t} f(t) dt .
\]  

(2-18)

Since each atom emits light for only a short time, the light from an ensemble is not monochromatic. It is physically reasonable to assume that \( f(t) \) for one atom has the exponentially decaying form:

\[
f(t) = \begin{cases} 0 & t<0 \\ \sqrt{2\gamma} e^{i\omega t} e^{-\gamma t} & t>0 \end{cases},
\]  

(2-19)
which satisfies the normalization condition

$$\int_{-\infty}^{\infty} |f(t)|^2 dt = 1,$$

(2-20)

and has the Fourier components

$$C(\omega) = \sqrt{\frac{\gamma}{\pi}} \frac{-i}{\omega_0 - \omega + i \gamma},$$

(2-21)

leading to the Lorentz or dispersion profile

$$I(\omega) = |C(\omega)|^2 = \frac{\gamma}{\pi} \frac{1}{(\omega_0 - \omega)^2 + \gamma^2}.$$  

(2-22)

The half-half width $\gamma$, the frequency separation at which the intensity is half the maximum, is given by the sum of the transition rates for transitions originating from either the upper or lower state of the line

$$\gamma_{\xi u} = \sum_{u} A_{u', u} + \sum_{\xi'} A_{\xi', \xi}.$$  

(2-23)

Since atomic excited states have relatively long lifetimes ($A_{\xi u} < 10^9 \text{ sec}^{-1}$), this natural broadening is almost always smaller ($\Delta \lambda < 10^{-4} \lambda$) than the other effects we will discuss. It can of course be derived rigorously from the quantum theory of radiation.

When the energy levels of the radiating atoms are well separated, compared to mean thermal energies, electron collisions rarely exchange energy with the radiator, but change the polarization or phase of the emitted light. Although this approximation does not hold, for example, for neutral helium (where there are nearby perturbing levels with the same $n$ but different $l$), it is well satisfied for hydrogenic atoms. Assuming the light to be monochromatic between collisions, we have a sinusoidal wave train of duration $\tau$, with the Fourier components
producing the intensity

$$I_\tau(\omega) = \frac{\sin^2 \left( \frac{1}{2} \frac{(\omega_0 - \omega) \tau}{c} \right)}{2\pi \left( \frac{1}{2} \frac{(\omega_0 - \omega)}{c} \right)^2}.$$  \hfill (2-25)

If the probability per unit time $\gamma_c$ of a collision is constant, the intervals between collisions have the Poisson distribution

$$P(\tau) = \gamma_c e^{-\gamma_c \tau} \, d\tau.$$  \hfill (2-26)

Weighting the intensities (2-25) by the corresponding probabilities, we again arrive at the dispersion profile (2-22), now with width $\gamma_c$.

The frequency of light emitted by a moving atom is Doppler-shifted according to

$$\omega = \omega_0 \sqrt{1 - \frac{v^2}{c^2}} = \omega_0 \left( 1 - \frac{v}{c} \right).$$  \hfill (2-27)

Assuming the atoms have a Maxwellian distribution of velocities,

$$f_M(v) = \left( \frac{m_1}{2\pi kT_1} \right)^{3/2} \exp \left( -\frac{m_1 v^2}{2kT_1} \right) d^3v,$$  \hfill (2-28)

the collection will emit light with the Doppler or Gaussian line profile

$$I_D(\omega) = \frac{1}{\Delta\omega_D} \sqrt{\frac{1}{2\pi}} \exp \left( -\frac{(\omega_0 - \omega)^2}{2\Delta\omega_D^2} \right),$$  \hfill (2-29)

where the characteristic width is

$$\Delta\omega_D = \sqrt{\frac{k_1}{m_1 c^2}},$$  \hfill (2-30)

and the Doppler half-half width is $\sqrt{k_1 4\Delta\omega_D}$. 

$$C_T(\omega) = \frac{\sqrt{\frac{1}{2\pi}}}{\sqrt{2\pi}} \int_0^\tau e^{i\omega_0 t} e^{-i\omega t} dt = e^{\frac{i(\omega_0 - \omega)\tau}{i(\omega_0 - \omega)/2\pi}}.$$  \hfill (2-24)
In contrast to the fast electron impacts, nearby ions can usually be considered stationary, and supply only perturbing electric fields. These fields perturb the energy levels (each labeled by \( n, L, S, \) and \( J \)) of the radiating atom and usually split them into several sublevels, each a linear combination of states of different magnetic quantum number \( m_j \). Transitions between such sublevels of different principal quantum number give rise to the Stark components of a line. Since the operator \( -q_{\text{e}} \mathbf{F} \cdot \mathbf{F} \), expressing the interaction of the electric field and a given electron, has odd parity (therefore no diagonal elements), there is usually no first-order interaction, and second-order perturbation theory is used. In the hydrogenic case, however, the terms (labeled only by \( n \)) are degenerate, and a linear effect is found. This problem is most conveniently solved in the parabolic coordinates \((\xi, \eta, \phi)\):

\[
\begin{align*}
\xi &= r+z \\
\eta &= r-z \\
\tan \phi &= \frac{y}{x} \\
(r^2 &= x^2 + y^2 + z^2) ,
\end{align*}
\]

(2-31)

where the unperturbed wavefunction is\(^{27}\)

\[
\psi(n_1, n_2, m|\xi\eta\phi) = e^{-\frac{\xi+n}{2n}} \frac{m/2}{n_1} \frac{m/2}{n_2} \psi_n_1 (\xi) \psi_n_2 (\eta) e^{im\phi} \sqrt{2n}
\]

\[
n = n_1 + n_2 + |m| + 1 = 1, 2, \ldots
\]

\[
m = 0, \pm 1, \ldots, \pm(n-1) ,
\]

(2-32)

and the energy, correct to second order in field strength, is\(^{27}\)

\[
\text{(in units of } m_e^4/\hbar^2 \text{)}
\]
\[ c(n_1n_2m,F) = -\frac{1}{2} \frac{Z^2}{n^2} + \frac{3}{2} \frac{n(n_1-n_2)}{Z} |F| + \frac{1}{16} \frac{n^4}{Z^4} [17n^2 - 3(n_1-n_2)^2 - 9m^2 + 19]|F|^2 \]  

(2-33)

For a first approximation, we may assume the ions in the plasma are uncorrelated. In this case, they produce an electric field \( F \) with the Holtsmark distribution

\[ H \left( \frac{F}{F_0} \right) = \frac{2}{\pi} \frac{F}{F_0} \int_0^\infty \exp(-x^2/2) \sin \left( \frac{x}{F_0} \right) x dx, \]  

(2-34)

plotted in Fig. 2-4, where the Holtsmark normal field strength produced by perturbers with density \( N_p \) and charge \( q_p \) is

\[ F_0 = 2\pi \left( \frac{4}{15} N_p \right)^{2/3} q_p \]  

(2-35)

Integrating the energies (2-33) over the distributions (2-34) for each level (though the effects on the upper level usually predominate) we arrive at the Holtsmark profile, shown for the hydrogen line \( H_B \) in Fig. 2-5. Profiles of lines subject to the linear Stark effect are usually expressed in terms of the reduced wavelength separation, defined by

\[ \alpha = \frac{\Delta \lambda}{F_0}. \]  

(2-36)

Note that where there is no unshifted Stark component (as in hydrogen transitions \( n=4 \to 2 \) or \( 3 \to 1 \)), the low probability of very small fields (since \( H(0) = H'(0) = 0 \)) gives a line profile with a central dip, usually partly filled by other effects.

Finally, observed profiles are broadened by the instrument response function of the observing monochromator. According to physical optics,
Fig. 2-4 Holtsmark field strength distribution
Fig. 2-5 Holtsmark profile for the $H_S$ line
(broadened only by statistically uncorrelated ions)
it is a profile like (2-29) folded with the two rectangular slit functions, plus a constant background. With wide slits, Gaussian or triangular profiles are good approximations.

The profile of a line broadened by two independent effects is the convolution of the two profiles,

\[ I(x) = I_1(x) \otimes I_2(x) = \int_{-\infty}^{\infty} I_1(x')I_2(x'-x)dx' , \]  

(2-37)

and if we assume all of these effects are independent, we may find our theoretical profile by convolving all the profiles:

\[ I_{\text{theory}} = I_{\text{natural}} \otimes I_{\text{electron}} \otimes I_{\text{Doppler}} \otimes I_{\text{ion}} \otimes I_{\text{instrument}} . \]  

(2-38)

This assumption of statistical independence is reasonable for plasmas, because, e.g., collisions leading to significant changes of radiator velocities (Doppler effect) usually involve ions whose direct contribution (Stark effect) is insensitive to ion and radiator velocities.

E. Validity of LTE

A plasma is in local thermal equilibrium (LTE) if, locally and instantaneously, all quantum state population densities (except for photon states) correspond to a system in complete thermal equilibrium (CTE) which has the same mass density, energy density, and chemical composition. Departures from LTE occur when some transitions have unbalanced rates, so that some (generally low-energy) states are over- or under-populated when compared to the corresponding CTE system. In optically thin plasmas, where the rates of radiative excitation (photoexcitation and photolization) are negligible compared to
those of radiative de-excitation (spontaneous emission and radiative recombination), the lower-energy states will be overpopulated unless collisional processes dominate radiative ones. That is, populations will be within ~10% of LTE if collisional processes are about an order of magnitude more important than radiative ones. Since collision cross sections are generally larger, and energy gaps smaller, for excited states, LTE is most easily satisfied for them. An estimate of the electron density required for the hydrogenic level \( n \) to be within ~10% of LTE with respect to the ion density is\(^{13}\)

\[
N_e > (7 \cdot 10^{18} \text{ cm}^{-3}) \frac{7}{n^{17/2}} \left( \frac{\kappa T}{\nu^2 E_h} \right)^{1/2}
\]  

(2-39)

The largest gap between atomic energy levels is generally between the ground and the first excited states, so the requirements for LTE for the ground state are usually the most restrictive. Near LTE, the largest transition rates are those to and from the first excited state, and collisional rates can be expected to dominate if\(^{13}\)

\[
N_e > (9 \times 10^{17} \text{ cm}^{-3}) \left( \frac{E_2}{E_h} \right)^3 \left( \frac{\kappa T}{E_h} \right)^{1/2}
\]  

(2-40)

It often happens that the resonance line is optically thick, so that radiative de-excitation of the first excited state is balanced by photoexcitation. The resonance line profile is generally dominated by Doppler broadening (for \( N_e \) sufficiently low that electron collisions cannot maintain LTE), so its optical depth can be estimated by\(^{13}\)

\[
k_{\text{reson}}' \propto (2 \cdot 10^{-10} \text{ cm}) f_{12} \lambda_{12}^2 \left( \frac{\Delta E_H}{\kappa T} \right)^{1/2} N_z^{-1/2} a_{11}^d
\]  

(2-41)

where the resonance line has wavelength \( \lambda_{12} \) and absorption strength \( f_{12} \), and the atoms of interest have atomic weight \( A \) and ground state density.
If the optical depth of the resonance radiation is greater than 
\( \approx 20 \), the requirement (2-40) can be relaxed by about an order of magnitude.

The validity of LTE for ionization stage populations in stationary plasmas usually need not be checked separately, since the excited states of a given stage are well connected with the ground state of the next ionization stage.

In transient plasmas, populations may depart from LTE if equilibrium times are long compared to the times over which plasma parameters change. The lowest transition rates for given stage usually involve the collisional excitation of atoms in the ground state. Assuming hydrogenic behavior, the equilibrium time is then estimated by

\[
T_{z-1} = \frac{(1.1 \times 10^7 \text{sec cm}^{-3}) \lambda_3^3}{2 f_{21} N_e} \left( \frac{N_z^a}{N_z^a + N_z^{a-1}} \right)^{\frac{E_z^{z-1,a}}{z^2 E_H}} \left( \frac{\kappa T}{z^2 E_H} \right)^{1/2} \exp \left( \frac{E_z^{z-1,a}}{\nu T} \right)
\]

(2-42)

where \( E_z^{z-1,a} \) is the energy of the first excited state and the term in brackets is the fraction of atoms or ions that must be excited into the next ionization stage. If only partial LTE is required (i.e., the state with principal quantum number \( n \) is in equilibrium with higher states) the equilibrium time is much shorter, and is estimated by

\[
T_{z-1} = \frac{(4.5 \times 10^7 \text{sec cm}^{-3}) \lambda_3^3}{n^4 N_e} \left( \frac{\kappa T}{z^2 E_H} \right)^{1/2} \exp \left( \frac{2z^2 E_H}{n^3 \kappa T} \right).
\]
CHAPTER III

EXPERIMENTAL METHOD

A. Apparatus

A.1 T-tube and circuit. The plasma studied in this work was produced in a T-tube similar to those developed by Kolb\textsuperscript{29,30} and used in several previous experiments at the University of Maryland\textsuperscript{31-36} and elsewhere\textsuperscript{37,38}. In this device, illustrated in Fig. 3-1, an aluminum (alloy 2024-T4) electrode was sealed into either end of the top of a T-shaped tube of high-temperature glass with inside diameter of 16 mm. This tube was filled with the test gas at a pressure near .5 Torr (70 Pascals). A current flowed across the 16 mm gap between the electrodes, ionized the gas and ohmically heated it, then returned via a backstrap above the T. The backstrap current created a transverse magnetic field in the current-carrying plasma, and pressure and Lorentz force accelerated it down the leg of the T. This luminous front traveled 12 cm down the tube at several cm/μsec and struck an adjustable reflecting plate, where some of its directed motion was converted to random thermal motion. Longer expansion tubes and higher fill pressures are required for the formation of a separated shock, but this device produced the high temperatures (3.5 eV) and electron densities ($2 \cdot 10^{17}$ cm\textsuperscript{-3}) needed to excite ionized helium lines. The decaying plasma lasted approximately one μsec.

The circuit used appears in Fig. 3-2. The relatively modest energy needed by the tube was supplied by a .5 μF capacitor charged to 40 kV (thus storing 400 J). When charged, this capacitor was disconnected.
Fig. 3-1 T-tube schematic

Fig. 3-2 Experiment circuit diagram
from both the high voltage supply and ground, preventing discharges from either electrode to the monochromator. The high-voltage circuit was enclosed by a copper shield to reduce electromagnetic interference.

To start the discharge, the nitrogen in a two-electrode pressure switch (initially at 30 PSI above atmospheric) was released until its dielectric strength was low enough for electron cascade. Since nitrogen was used, no ozone or nitrogen oxides were formed, as in a discharge in air. The poor control over discharge timing was no problem, since the discharge itself triggered the recording system.

The measured quarter-cycle time was .675 μsec, indicating a total circuit inductance of 370 nH. A carbon resistor of about .01 Ω damped out the oscillations after two cycles.

The vacuum system is shown in Fig. 3-3. During the experiment, valve V3 was closed, while shut-off valve V1 and leak valve V2 were opened, so the test gas flowed from the inlet, through liquid nitrogen cold trap CT3, into the T-tube. It then leaked into the monochromator through entrance slit S1, and was removed by pumps DP1 and MP1. V2 was adjusted so the leak rates into and out of the T-tube balanced, and the pressure, measured by thermistor gauge G2, stayed at the desired value.

Between experimental runs, the T-tube was isolated by closing slit valve V9 and shut-off valve V1, and kept clean by the small diffusion pump DP2. Cold trap CT2 was cooled by a conventional refrigeration system and valves V3 and V4 were solenoid-controlled, so this secondary pumping system could operate unattended. Since the small pump was not forced to pump through a slit, it proved more effective than the large pump at outgassing the T-tube and associated plumbing.
G1 ionization gauge Veeco RG-83
G2,G3 thermistor gauge CVC CT-340A
G4,G5 Gauge thermocouple
G6 Gauge cold cathode discharge
V1 Metering valve, 1/4 in.
V2 Screw valve Veeco, 3/8 in.
V3 Solenoid valve Veeco, 3/4 in.
V4 Solenoid valve Veeco, 3/4 in.
V5 Gate valve
V6 Solenoid valve
V7 Solenoid valve
V8 Entrance slit valve
V9 Exit slit valve
V10 Air inlet valve
DP1 Diffusion pump, NRC, 6 in.
DP2 Diffusion pump, 2 in.
CT1 Liquid nitrogen cold trap
CT2 Freon cold trap
CT3 Liquid nitrogen cold trap
MP1 Fore pump DuoSeal 1397
MP2 Fore pump DuoSeal serial 16025-2
S1 Entrance slit
S2 exit slit
PM photomultiplier tube

Fig. 3-3 Schematic of vacuum system
A.2 VUV monochromator and detector. The optical arrangement is shown in Fig. 3-4. A McPherson 225 one-meter monochromator scanned the ultraviolet lines shot-to-shot. Its 50 μ entrance slit was flush with the wall of the T-tube, about .5 mm from the reflector. Since the plasma conditions changed sharply as the reflector was moved, the position was chosen which gave the most reproducible plasma. A 1200 lines/mm Pt-coated grating, with speed about f/13.6, focused the light onto a 30 μ exit slit, for a measured reciprocal dispersion of 8.3 Å/μm (4.2 Å/μm in second order) and an approximately Gaussian instrument response function of width ν.41 Å (ν.19 Å in second order). The light then fell on a p-terphenyl coated disc, causing it to fluoresce. These visible photons left the vacuum chamber through a quartz window and were detected by an EMI 6522 photomultiplier. For some work, a 2 mm thick MgF₂ filter was placed between the exit slit and the fluorescent screen to remove light from second order, since it transmitted 40% of the light at 1215 Å but essentially none below 1100 Å. The exit slit, screen, and PM tube were replaced by a film holder for photographic work. The instrument function and wavelength calibration were checked using a low-pressure Tanaka lamp.

A.3 Visible monochromators and detectors. For diagnosis of the plasma conditions, three Jarrell-Ash visible-light monochromators were used. One 1/2-meter focal length monochromator, with instrument width .4 Å, scanned the He II 4686 line shot-to-shot to determine the electron density (from line width) and temperature (from line: continuum ratio). The reproducibility of the plasma was monitored on each shot by two 1/2-meter instruments, one for the continuum at 4976 Å.
Fig. 3-4 Schematic of optical arrangement
(sensitive to electron density), and one for the He II 4686 line
(sensitive to temperature, and used for later data processing).

PM tube response was checked using neutral density filters and
pulses from a light emitting diode, and was found linear for signals
of up to .2 V (1.1 mA) with a PM supply voltage of 900 V.

Each PM tube housing was insulated from its monochromator, and
signals were taken from both the anode (negative pulse) and last
dynode (positive pulse), carried by shielded, coaxial cables terminated
by 90 Ω resistors, subtracted to suppress noise, amplified, digitized,
and stored electronically For details on the waveform recorder, see
Appendix A.

B. Data Reduction

The best-fit values of the four parameters (line intensity I,
line position λ₀, background intensity B, and electron density Nₑ) are
found using the following procedure. Assume we have the n measurements
yᵢ(λᵢ) and the corresponding theoretical intensities Tᵢ = \frac{1}{F₀} T\left(\frac{λᵢ - λ₀}{F₀}\right),
where T(α) is the theoretical profile after convolution with the instrument
profile G(α)

$$T(α) = \int_{-∞}^{∞} S(α - α')G(α')dα', \quad (3-1)$$

and the instrument function has been transformed into α-space. The best-fit
values minimize the sum

$$σ^2 = \frac{1}{n-4} \sum_{i=1}^{n} \left[ yᵢ - (IT_i + B) \right]^2, \quad (3-2)$$
giving the conditions
\[ \frac{\partial}{\partial I} \sigma^2 = \frac{\partial}{\partial B} \sigma^2 = 0 , \]

so I and B are found by solving the linear system

\[ \begin{pmatrix} \sum T^2_1 & \sum T_1 \\ \sum T_1 & n \end{pmatrix} \begin{pmatrix} I \\ B \end{pmatrix} = \begin{pmatrix} \sum y_1 T_1 \\ \sum y_i \end{pmatrix} . \tag{3-3} \]

The computer program "guesses" an electron density to use for the transforming of the instrument function, convolves the theoretical and instrument profiles, then finds \( \sigma^2 \) from (3-2) (subject to (3-3)) for many values of \( N_e \) and \( \lambda_0 \). When the best values are found, the new \( N_e \) is used to again transform the instrument function. The entire convolution and fit are repeated until successive values of \( N_e \) are sufficiently close, e.g., within 2% of each other. A general discussion of least-square fitting when the functional parameters do not occur linearly (e.g., \( \lambda_0 \) and \( N_e \)) appears as Appendix B. Details on the computer programs appear in Appendix C.
CHAPTER IV

RESULTS AND DISCUSSION

A. Results

Examples of photoelectric measurements of the emission profiles of the ionized helium lines at 4686, 1640 and 1215 Å are shown in Figs. 4-1 through 4-3. In each case, the solid line is the best-fit theoretical curve of Kepple,9,10 convolved with the instrument profile (taken to be Gaussian), Dashed lines are the best-fit continuum levels, determined primarily by points far from line center, which are not shown. Crosses represent points not used in the best-fit procedure.

The 4686 line was found to be unshifted, as in previous experiments.2 Its profile was in good agreement with theory, and the plasma electron density and temperature were deduced from its width and line continuum ratio, respectively.

The position of the 1640 line was measured relative to the Al II 1670 line, and a fairly constant red shift of .11 Å was found. These shift measurements can be found in Table 4-1 and Fig. 4-4. No conclusions could be drawn about the Stark width of this helium line, because the observed profile was dominated by instrument broadening.

The relative positions of the He II 1215 and Si III 1210 lines were measured photoelectrically. The helium line was found to have a red shift of approximately .19 Å, increasing as the density and temperature fell at the end of the discharge. The halfwidth of the 1215 line was also determined as a part of the best-fit procedure.
Fig. 4-1 Measured and best-fit profile for He II λ 4686 Å line
Fig. 4-2 Measured and best-fit profile for He II λ 4686 line
Fig. 4-3 Measured and best-fit profile for He II λ1215 line
Fig. 4-4 Estimated and measured shifts of He II $\lambda$ 1640 Å line
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<tr>
<th>t</th>
<th>$V_{\text{monitor}}$</th>
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<td>[\text{eV}]</td>
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<td>[Å]</td>
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<td>1670.32±.07</td>
<td>1639.99±.02</td>
<td>.14±.07</td>
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</table>

Table 4-1 Plasma Conditions, Shifts of HeII $\lambda$ 1640 Å
These data are shown in Fig. 4-5 and Table 4-2.

B. Discussion of Possible Errors

B.1 Impurity Lines. Photographs of spectra near each of the helium lines showed many Si, O, and Al lines. The Jarrell-Ash 1/2-m monochromator could easily resolve the Si III and O II lines near He II 4686, and photoelectric scans were made using points between these impurity lines (see Fig. 4-6).

A survey spectrum was taken near the 1640 line using Kodak SWR film in the camera attachment for the McPherson 225 vacuum monochromator (see Fig. 4-7). Many Si, O, and Al lines were identified, in both first and second orders. Fortunately, none of these obscured the 1640 line. The nearby Al II 1670 line, chosen as the wavelength standard for position measurements of the 1640 line, was partially obscured by second order lines of O II and O III. Photographs using an MgF$_2$ filter were then taken, which showed no further problems with impurity lines. To eliminate second order lines during photoelectric scans, the filter was placed between the exit slit and the scintillating disc.

A photographic spectrum near 1215 Å showed many O II, O III, O IV Si III, and Si IV lines, including the second order O IV 608 line on the red wing of the helium line (see Fig. 4-8). To eliminate these, the MgF$_2$ filter was again used for both photographic and photoelectric runs.

The resonance lines of N II at 1084 Å prevented any observation of the next member of the He series, while the He II 1025 line proved too weak for reliable observation.
Fig. 4-5 Estimated and measured shifts of He II λ 1215 Å line.
<table>
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<tr>
<th>$t$ [μsec]</th>
<th>$\kappa T$ [eV]</th>
<th>$\lambda_{\text{HHW, 4686}}^\text{exp}$ [Å]</th>
<th>$N_e$ [10$^{17}$ cm$^{-3}$]</th>
<th>$\lambda_{\text{HHW, 1215}}^\text{theory}$ [Å]</th>
<th>$\lambda_{\text{HHW, 1215}}^\text{exp}$ [Å]</th>
<th>$\lambda_{\text{HHW, 1215}}^\text{exp} / \lambda_{\text{HHW, 1215}}^\text{theory}$</th>
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Table 4-2 Plasma Conditions, Shifts and Widths of HeII $\lambda$ 1215 Å
Fig. 4-6 Densitometer scan of spectrum near He II \( \lambda 4686 \) Å line
Fig. 4-7 Densitometer scan of spectrum near He II λ 1640 Å line
Fig. 4-8 Densitometer scan of spectrum near He II λ 1215 Å line
B.2 Wavelength Standards. All line position measurements were made relative to nearby impurity lines, and the accuracy of this procedure had to be verified. The Stark shifts of these ion lines are expected to be small\textsuperscript{42} (just as their widths are small), but a plasma polarization shift certainly cannot be ruled out a priori. To check for such shifts, several line position measurements were made on a Grant comparator-microphotometer. The second-order lines were found to be shifted with respect to the first-order lines by \(0.10\ \text{	extmu} \text{m}\), but otherwise, shifts were less than the measurement accuracy of \(0.05\ \text{	extmu} \text{m}\). This is consistent with previous measurements\textsuperscript{3} in which no shifts were found for the \text{O III} and \text{N III} lines near 300 \(\text{	extmu} \text{m}\). In photoelectric (time-resolved) studies, no absolute shifts of the reference lines were measured as the plasma cooled, also arguing against substantial absolute shifts. Only the statistical errors in the measured shifts are indicated in the tables and figures.

The monochromator wavelength scale was checked by measuring photographically the wavelength displacement between settings corresponding to the centers of the helium and reference lines. The errors in both cases were less than the setting error of 0.02 \(\text{	extmu} \text{m}\).

B.3 \text{He II 1215 Asymmetry}. The helium 1215 line was expected to have a symmetric, double-peak profile (like that of \text{H}\textsubscript{\textbeta}), but photoelectric scans showed only the peak on the blue side (see Fig 4-3). This was interpreted as showing reabsorption by hydrogen in a cooler boundary layer, since the hydrogen Lyman-\(\alpha\) line lies \(0.50\ \text{	extmu} \text{m}\) to the red of the (unshifted) helium line center. To check this explanation, two scans were made, using mixtures of helium plus 0.5\% hydrogen, and helium plus 1.0\% deuterium, respectively. The amount of absorption increased with the increasing admixture of hydrogen, and, in the case of the deuterium, the dip shifted to the blue, as expected.
The residual concentration of hydrogen was estimated from these runs to be approximately 0.2%. Since natural, Doppler, and Stark broadening are all very small for the hydrogen line (<1 Å), points near the dip were merely excluded from the fitting procedure.

B.4 Departure from LTE. Temperature determination from a helium ion line:continuum ratio requires that LTE holds also for the ion ground state populations, so that the line intensity (proportional to the population in the excited state) and the continuum intensity (due mainly to recombination radiation) both have their equilibrium values. The equilibration time for atomic states can be estimated from (2-42) to be only a few nanoseconds, for both neutral and ionized helium. On the other hand, the recombination times (into the ground states) are estimated to be 2 μsec for formation of singly ionized helium and 20 μsec for neutral helium. Singly and doubly ionized states are, then, expected to be overpopulated, simulating a temperature higher than the true electron temperature.

For the validity of complete LTE in a stationary plasma with temperatures near those in the experiment, Eq. (2-11) gives an optical depth of α150, for the resonance line (He II λ304 Å). We are thus justified in relaxing (2-40) by an order of magnitude, and the electron density required for complete LTE is $N_e \approx 1.4 \times 10^{18} \text{ cm}^{-3}$, which is not reached in the experiment. On the other hand, the requirement (2-39) for partial LTE for the level n=4 (upper state of the 4686 Å line) is easily satisfied.

Since the actual electron density is about an order of magnitude lower than that required for complete LTE, and the continuum intensity is proportional to the electron density while the line intensity is not, we estimate that the line:continuum ratio may be too high by an order of magnitude, compared with the LTE value at the true
temperature. This yields a temperature (\(\approx 3.5 \text{ eV}\)) that is too high by about .5 eV. Similarly, if the neutral excited state population density were too low by an order of magnitude, the intensity ratio of an ionized and a neutral line would overestimate the temperature by about .5 eV. A measurement of the intensity ratio of the He II 4686 and the He I 3889 lines was performed, yielding temperatures near 4.1 eV. Since the two effects (overpopulation of singly ionized states due to recombination relaxation during the rapid cooling, and overpopulation of excited states of He II due to low collision rates) are additive, the true electron temperature is estimated to be less than the lower figure by \(\approx 20\%\), i.e., near 3.0 eV.

A previous measurement\(^{38}\) of the absolute intensity of the He II 4686 line in a shock-tube plasma at \(N_e \approx 10^{17} \text{ cm}^{-3}\) indicated the populations of the lower excited states of the ion deviate by perhaps a factor of 4 from LTE. However, measurements of temperature in the same experiment by Thompson scattering of laser light (which does not depend on LTE for atomic states) and the intensity ratios of the He II 4686 and He I 5876 lines showed good agreement.

**B.5 Summary of Errors.** Possible errors in the determination of electron density were judged to be 5% due to statistical fluctuations and 10-15% due to theoretical uncertainties. Errors in temperature measurements were estimated to be .1 eV statistical and .2 eV theoretical (after applying the 20% correction). These possible diagnostic errors were not judged to endanger the principal conclusions of the work. The tables and figures indicate only statistical errors.

Errors in the measurements of the shifts were .05 Å or less due to statistical fluctuations. Systematic errors due to the shift of the
reference lines could not be ruled out, but were shown to be less than .05 Å and are expected to be smaller.

C. Discussion of Results

As mentioned in the Introduction (Chapter I), previous shift measurements of He ion lines have concentrated on the Lyman-series lines (n_{\text{lower}} = 1). In principle, these measurements can be used to calculate the energy level perturbations, and the shifts of the "Balmer"-series lines can be found in turn. Since the agreement between the various measurements is so poor, little is learned in this way.

The polarization shift is difficult to treat theoretically, and only estimates have been made thus far. Conceptually, the radiating ion is expected to attract plasma electrons, which partially screen the nuclear charge seen by the optical electron. A simple classical argument\(^3\) gives the wavelength (or wavenumber) shifts of the Lyman-series lines to be

\[
\frac{\Delta \lambda}{\lambda_0} = -\frac{\Delta \nu}{\nu} = -\frac{8}{3} \frac{N e^2 \pi a_0^2 (n^2+1)}{n^4} \exp\left(\frac{V}{kT}\right),
\]

where \(a_0\) is the radius of the first Bohr orbit: \(a_0 = \hbar^2/m_e^2\), and \(V\) is the interaction energy between the perturbing plasma electron and the radiating ion. Since the wave packet of the perturbing electron will be comparable in size to the atom, Griem proposes\(^1\) to use the averaged interaction \(V = e^2/r\), where \(r\) is the characteristic distance between the nucleus and the optical electron. \(r = n^2 a_0/z\). Neiger proposes\(^6\) the modified formula \(V = (1/2)e^2/r\), which is the electrostatic energy of a uniform sphere of charge \(e\) and radius \(r\).
in the field of an equal but opposite charge at its center. Burgess and Peacock argue that the density of electrons near an ion is low enough that their velocities are not in equilibrium with the surrounding plasma, being directly related to their electrostatic energies. They suggest using the interaction energy at the average perturber-perturber distance, \( V = \frac{e^2}{N_e} \). Note that all these estimates predict blue shifts (for the Lyman-series lines) proportional to \( N_e \), but decreasing with temperature (since, at high temperature, the electron's thermal energy is large compared with the electron-ion interaction energy, and it doesn't see the potential well). Denoting by \( V_n \) the chosen interaction energy when the optical electron has principal quantum number \( n \), and expressing the unperturbed energy levels in terms of the Rydberg constant \( R \), we find, for the wavenumber shifts of the "Balmer"-series lines,

\[
\Delta \nu = \frac{8}{3} \pi \frac{N_e a_0^3}{e^2} R \left\{ (n^4-1) \exp \left( \frac{V_n}{\kappa T} \right) - (2^4-1) \exp \left( \frac{V_2}{\kappa T} \right) \right\}.
\]

This can be converted to a wavelength shift by multiplying with \( \lambda_0^2 \), or an energy shift by multiplying by \( h \omega \). Shifts predicted by each of these choices for \( V \) (\( \frac{e^2}{n^2 a_0^2} \), \( \frac{3}{2} \frac{e^2}{n^2 a_0^2} \), and \( e^2 N_e^{1/3} \)) are plotted in Figs 4-4 and 4-5. For both lines, Burgess and Peacock predict very small blue shifts, nearly independent of temperature. Griem's estimate gives somewhat larger shifts, while the stronger interaction proposed by Neiger gives large shifts with strong temperature dependence. Using the measured values of the temperature, the data are consistent with an interaction energy between those of Griem and Neiger, while Burgess and Peacock underestimate the shifts. To illustrate the effect of the systematic error discussed above in the temperature
measurement, the shift predicted by Griem's formula was recalculated using a 20% lower temperature, the results being shown as the dashed curve in Figs. 4-4 and 4-5. After this correction, his interaction energy gives the best fit to the data.

The halfwidth of the 1215 Å line was up to 30% greater than that calculated by Kepple. This is to be compared to a previous theta-pinch experiment, in which the ratio of the widths of the 4686 and 1215 Å lines agreed with the calculated value. However, this experiment was done at a substantially higher temperature, $T_e > 10$ eV, so that the difference may not be significant.

D. Conclusions and Suggestions

Shifts have been measured of the first two lines of the "Balmer" series of ionized helium. They are consistent with a plasma polarization shift, where the interaction energy between the radiating ion and the plasma electrons is between those proposed by Griem and Neiger and probably closer to the former.

The Stark width of the 1215 Å line of ionized helium has been measured, and found to be up to 30% greater than calculated by Kepple, and increasing as the temperature and density of the plasma decreased at the end of the discharge. This is perhaps due to an increased interference by the 1215 Å line of hydrogen.

Further studies of the plasma polarization shift might include more careful measurements of shifts of the hydrogenic spectra of heavier atoms, e.g., C VI 33.8 Å. Previous measurements showed no shifts, but with a possible error of .05 Å. (In this connection, it is interesting to note that measured center wavelengths, e.g.,
of helium-like copper (Cu XXVIII) are slightly below theoretically predicted values.) An attempt might also be made to observe shifts of the higher "Balmer"-series members of ionized helium, perhaps in a Z-pinch or θ-pinch, with their greater optical depth.
APPENDIX A

WAVEFORM RECORDER

To reduce the error and delay of manual data taking with the usual Polaroid oscillographs, a waveform recorder was designed and built for this experiment (Fig.A-1). The signal from one of the PM tubes is amplified and applied simultaneously to 31 comparators. A voltage divider provides reference voltages for the comparators, so for a given signal voltage some of the comparators will be "on" and the rest "off". Integrated circuits accept the output of all the comparators, count the number "on", calculate the corresponding 5-bit binary number, and store it in a 5-bit by 64 word random access memory. When triggered, control circuits advance the memory address counter and give write commands once every 100 nanoseconds (or selectable, slower rates) for a total of 64 cycles. It then switches to "playback" mode, supplying the stored numbers, each in turn, to a digital-to-analog converter. This analog signal is a reconstructed version of the original signal, and can be displayed on an oscilloscope.

The recorder consists of five such analog-to-digital converters and memories, plus two digital-to-analog converters, so 5 signals can be recorded, then any two displayed simultaneously.

If the waveform is acceptable, the investigator may set the twelve "fixed data" thumbwheel switches and initiate recording. The shot number (incremented each time the device is triggered), the fixed data, and the contents of all 5 digital memories are written to a 9-track magnetic tape for later computer processing. The waveform recorder then
Fig. A-1 Block diagram of waveform recorder
reverts to "ready" mode, waiting for the next trigger pulse. If the shot was unacceptable (due to switch misfire or abnormal time history of a monitor signal, for example), recording can be bypassed.

Details on operation procedures and performance specifications of the waveform recorder appear in the following instruction sheet.
Digital Data Acquisition System
Instruction Manual

1. General Information

The Digital Data Acquisition System (DDAS) is a high-speed analog to digital converter and memory. It can record 64 data samples on each of 5 channels, with a sample interval as short as 100 nsec. These stored samples can be displayed on an oscilloscope and recorded onto a 9-track magnetic tape.

2. Technical Specifications

- **Sample rate**, once every: .1, .2, .5, 1., 2., 5., 10, or 20 μsec.
- **Internal amplifier risetime**: 80 nsec
- **Useful signal range**: 0 to +32 V
- **Maximum signal range**: -1 to +1 V.
- **Resolution**: 3.1% of full scale
- **Channels**: 5
- **Signal input impedance**: 50 Ω
- **Trigger level**: +1.1 V
- **Max trigger signal range**: -.6 to +5 V.
- **Trigger input impedance**: 1MΩ
- **Playback sweep output**: 22.7 Hz sawtooth, 0-2.6 V
- **Analog output**: 0-5 V
- **Enabling circuit**: enabled if external circuit resistance is less than 100 Ω
- **Mating input amplifier**: Tektronix type 127 preamp power supply, with matching Tektronix oscilloscope preamp.
- **Mating digital tape deck**: Cipher model 70M-360, producing 800 BPI, 9-track, IBM-compatible magnetic tapes.
- **Magnetic tape record**: 329 bytes of 8 bits each...
  - 6 bytes (BCD, 2 digits/byte) fixed data from thumbwheel switches
  - 3 bytes (BCD, 4 low order bits) experiment count
  - 320 bytes (binary, 5 low order bits) data, grouped by time
3. Installation

For optimum protection against radio frequency interference, the unit should be mounted in a shielded 19 in. relay rack. Several inches clearance below the unit are necessary for ventilation.

4. Operation

The Cipher tape deck should never be switched on unless the DDAS is on, so the proper logic inputs are provided.

1. Turn on the DDAS and associated preamplifiers. Allow preamps to warm up.

2. If a tape is desired, turn the tape deck on and load a tape. The "RECODER READY" lamp should light.

3. Switch the operating mode to "AUTO SEQUENCE", switch to "TRIGGER ENABLE INT", and press "RECORD BYPASS". The "ENABLED" lamp should light.

4. Switch "DISPLAY CHANNEL SELECT" to "1". The "A-D DISPLAY" lamps are now displaying, in binary digital form, the signal on channel 1.

5. Ground the channel 1 preamp input. Advance the preamp "vertical position" control until all display lamps are lit. If this cannot be done, adjust the 127 preamp power supply "DC level" (on top of case).

6. Back off the "vertical position" control until all lamps just go out. The zero level is now adjusted. Repeat steps 4-6 for the remaining channels now, and frequently during the experiment.

7. Connect the trigger and signal cables. If an "enable" circuit cable is to be used, connect it and switch to "TRIGGER ENABLE EXT". Set the desired sampling interval. When triggered (by a signal or by using the "MAN TRIGGER" button) the unit will record its 64 samples of each channel and increment the "EXPERIMENT COUNT".

8. If a visual monitor is desired, connect the "PLAYBACK SWEEP" to the "EXT HORIZ IN" jack of an oscilloscope, and one or both of the "ANALOG OUTPUT"s to the vertical amplifier inputs. Set "ANALOG CHAN SELECT" to the desired channels.

9. When a signal is recorded, the unit will automatically switch to playback mode, the corresponding mode lamp will light, and the stored waveforms will be displayed on the oscilloscope.
10. If a recording is desired, set the desired "FIXED DATA", and press "RECORD DATA". Otherwise, press "RECORD BYPASS". The unit is again ready to record a set of signals. The unit may be switched to "MAN PLAYBACK" to again display the recorded signals.

11. After experiment has been completed, press "EOF" several times, and rewind and unload the tape.

12. Turn the tape deck off, then the DDAS and other equipment.

Alternate operating modes are provided for diagnostic purposes. In "SINGLE STEP PLAYBACK" mode, the contents of one word in memory, corresponding to the "DISPLAY CHANNEL SELECT" setting and the octal address shown under "MEMORY ADDRESS", are displayed under "MEMORY DISPLAY" and appear at the "ANALOG OUTPUT" jacks. The associated pushbutton steps to the next sample.

In "MAN SAMPLE" mode, the unit stores samples one at a time, when the "SAMPLE STROBE" pushbutton is pressed. The unit must be enabled and triggered before sampling can begin.

In "CAL" mode, the analog to digital converters operate continuously and any of them can be displayed on the "A-D DISPLAY" lamps.
APPENDIX B

STATISTICS

In most experiments the investigator assumes a functional form governing his data which has several parameters, and the object of his experiment is to determine the values of the parameters. If there is only one parameter, the quoted result might be

\[ a = a^* \pm \sigma, \]

where \( a \) is the true value (usually unknown), \( a^* \) is the "best" value which can be determined using the data, and \( \sigma \) indicates the error in \( a^* \). We usually mean by \( \sigma \) the mean square deviation of the data from the best value

\[ \sigma^2 = \left( \sum (x_i - a)^2 \right) / n, \]  \hspace{1cm} (B-1)

where the \( x_i \) are the results from several similar experiments. It is necessary to extend this to the case of several parameters and specify a way of calculating the quoted values.

Assume the functional form is

\[ y = f(a, x), \]  \hspace{1cm} (B-2)

where \( x \) is the independent variable, \( y \) the dependent variable, and the \( a \) are parameters. We define the error function

\[ M(a) = \sum_{k=1}^{n} \frac{(y_k - f(a, x_k))^2}{\sigma(x_k)^2}, \]  \hspace{1cm} (B-3)

and let the "best" \( a \) be that value \( a^* \) which minimizes \( M \). We find it by solving the set of \( m \) equations...
The errors in these parameters are given by the elements of the variance-covariance matrix

\[ \sigma_{ij} = (a_i - a_i^*) (a_j - a_j^*) \]  \hspace{1cm} (B-5)

which can be calculated from

\[ \sigma_{ij} = (H^{-1})_{ij} \quad \text{and} \quad H_{ij} = \frac{1}{2} \frac{\partial^2 M(\theta)}{\partial a_i \partial a_j} \] \hspace{1cm} (B-6)

The variance of one of the parameters is then \( \sigma^2 = \sigma_{ii} \), and the correlation matrix is

\[ C_{ij} = \frac{\sigma_{ij}}{\sigma_{ii} \sigma_{jj}} \] \hspace{1cm} (B-7)

If all the \( \sigma(x_k) \) have a common value \( \sigma \), the solution of (B.4) is independent of that value. After this least square solution is found, \( \sigma \) can be calculated using

\[ \sigma^2 = \frac{1}{n-m} \sum_{k=1}^{n} \left[ y_k - f(\theta_0, x_k)^* \right]^2 \] \hspace{1cm} (B-8)

where we divide by \( n-m \) because after the parameters \( a_1 \ldots a_m \) have been calculated from the data, only \( n-m \) degrees of freedom remain.

If \( f(\theta; x) \) is linear in its parameters, the calculations are, of course, much simpler, since (B-4) is then a linear system which can be solved exactly. Failing this, a search must be performed in \( \theta \) space for the best value.
APPENDIX C

PROGRAMS

The data read from the waveform recorder tapes are processed by several programs, each accepting an input file plus control or data cards, and producing one or more output files. The last programs, PROFILE, VPLOT, and THEORY, also print their results. Other programs are available to read and list each file for debugging. All mainline programs were written in FORTRAN for use on a Univac 1108 computer with the EXEC-8 operating system. Intermediate files are "direct-access" files on disc or drum storage, like those developed by IBM for their computers, but not defined within ANS FORTRAN. Other nonstandard features used include PARAMETER statements and FORTRAN procedures.

The first program, REVERT, uses the assembly-language subroutine TREAD to read the 9-track tape produced by the waveform recorder. The tape record format is shown in Fig. C-1. REVERT assumes the scale settings of the input amplifiers and the sample rate of the recorder were set on the "fixed data" thumbwheel switches. The alphanumeric file header (a prose description of the run), number of channels used, and wavelength for each channel and shot number are read from cards. The file header is written into the output file, copied by later programs, and identifies all printed output. Specified shots may be dropped at this point.

Since the waveform recorder stores 6.4 μsec of the signal, while the plasma lasts only about one μsec, REVERT tries to select only the useful part of each signal. The first twelve records are read, the average time $T_{max}$ of the maximum of the monitor signal is found, and the tape is
rewound. Each record is then read, and the data for eight samples, starting at time $T_{\text{max}}$, are scaled and written to the output file, with format shown in Fig. C-2. An end-of-file marker is written after the last record.

During the experiment, the light is sometimes attenuated to prevent PM tube saturation, and PARAM corrects the measured intensities to account for this. Since PROFILE requires that the monitor signal be strictly decreasing, PARAM also chooses a decreasing portion of each signal and discards the rest. The output record format is shown in Fig. C-3.

BSORT sorts the records, first on wavelength, then on shot number. Experimental points can be taken in any order, but in this step all data for a given wavelength are collected. The format of the records is unchanged by BSORT.

PROFILE unfolds the data, recorded as intensity as a function of time at different wavelengths, into intensity as a function of wavelength (a line profile) at different times. Since the ionized helium line intensities are sensitive to temperature, all data for one profile must be taken under the same plasma conditions. PROFILE does this by taking all the data for equal monitor signal (from the total intensity of the He II 4686 line). The time at which the monitor signal decays to this level is found, and the shot is discarded if this time is further than 1.73 standard deviations from the mean. Similarly, any intensities at a given wavelength which differ from the mean by more than 1.8 standard deviations are discarded. Profiles are then found for successively lower monitor intensities (therefore later times). The means and standard deviations of intensities at each wavelength go to one file (shown in Fig. C-4), which VPLOT uses to make a printer-plot of the line
profile. All undeleted data points are written to a second file (shown in Fig. C-5), used for fitting.

The actual least-squares fit is done by THEORY. As described in the section on data reduction, the convolution of the theoretical line profile with the instrument response function is done first, in alpha space, using an assumed electron density. The instrument function is assumed Gaussian, so the convolution integrals are done using the Gaussian-Hermite 3-point quadrature formula. This profile is fit to the experimental data and a new electron density is found. The convolution and fit are repeated until the electron density converges, usually within four iterations. Each of these fits requires a search for the values of the four parameters (line intensity I, background intensity B, line center \( \lambda_0 \), and electron density \( N_e \) (line width)) that minimize the mean square deviation \( \sigma^2 \) of the fitting function from the experimental points. The subroutine ZXPOWL, from the International Mathematical and Statistical Library (IMSL) uses the function-minimization algorithm described by Zangwill to find the best-fit values of \( \lambda_0 \) and \( N_e \). For each trial values of \( \lambda_0 \) and \( N_e \), it calls the subroutine FUNCT3, which in turn calls other subroutines to calculate the best values of the two linear parameters, and the corresponding \( \sigma^2 \), using standard methods.

When the best values of all four parameters are found, subroutine FUNCT2 finds the second derivative matrix of \( \sigma^2 \) numerically, inverts it, and normalizes it to get the standard deviations and correlation matrix of the best-fit parameters. If the line is He II 4686, it uses the line:continuum ratio to calculate the plasma temperature Sub-
routine TPLOT plots the average of the experimental points at each wavelength, the best-fit theoretical profile, and the background level. The entire procedure is repeated for each profile, but since the line center and electron density are carried over each time, subsequent fits converge rapidly.

<table>
<thead>
<tr>
<th>6 bytes</th>
<th>3 bytes</th>
<th>320 bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIXED</td>
<td>COUNT</td>
<td>DATA</td>
</tr>
<tr>
<td>FIXED</td>
<td>6 bytes BCD, 2 characters/byte</td>
<td>data from thumbwheel switches</td>
</tr>
<tr>
<td>COUNT</td>
<td>3 bytes BCD, 1 character/byte</td>
<td>shot number</td>
</tr>
<tr>
<td>DATA</td>
<td>320 bytes binary number, 1/byte</td>
<td>data, grouped by time total. 329 8-bit bytes/record (excluding parity and check bits)</td>
</tr>
</tbody>
</table>

Fig. C-1 Record format of waveform recorder tape

<table>
<thead>
<tr>
<th>2 words</th>
<th>1 word</th>
<th>1 word</th>
<th>16 words</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABEL</td>
<td>SCALE</td>
<td>COUNT</td>
<td>$T_1$, $Y_1$, $T_2$, $Y_2$, ... $T_8$, $Y_8$</td>
</tr>
<tr>
<td>LABEL</td>
<td>2 words, FIELDATA</td>
<td>First 5 characters are the wavelength in Å (decimal point assumed before last character). Next 3 characters are the shot number</td>
<td></td>
</tr>
<tr>
<td>SCALE</td>
<td>1 word, real (R)</td>
<td>Amplification on preamplifier (V/div)</td>
<td></td>
</tr>
<tr>
<td>COUNT</td>
<td>1 word, integer</td>
<td>Shot number (same as above).</td>
<td></td>
</tr>
<tr>
<td>$T_i$</td>
<td>1 word, R</td>
<td>Time of sample ($\mu$s after trigger pulse)</td>
<td></td>
</tr>
<tr>
<td>$Y_i$</td>
<td>1 word, R</td>
<td>Signal amplitude (V)</td>
<td></td>
</tr>
<tr>
<td>total:</td>
<td>20 words/record</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. C-2 Format of data record written by REVERT
<table>
<thead>
<tr>
<th>MONITOR</th>
<th>WAVELENGTH</th>
<th>AVERAGE</th>
<th>SIGMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONITOR</td>
<td>1 word, R</td>
<td>Intensity of monitor for this profile</td>
<td></td>
</tr>
<tr>
<td>WAVELENGTH</td>
<td>36 words, R</td>
<td>Wavelengths (Å)</td>
<td></td>
</tr>
<tr>
<td>AVERAGE</td>
<td>36 words, R</td>
<td>Average of signal intensities at corresponding wavelength</td>
<td></td>
</tr>
<tr>
<td>SIGMA</td>
<td>36 words, R</td>
<td>Standard deviation of signal intensities</td>
<td></td>
</tr>
</tbody>
</table>

Total: 109 words/record

Fig. C-4 Format of plot-file data record written by PROFILE.

<table>
<thead>
<tr>
<th>MONITOR</th>
<th>BLOCK</th>
<th>NUMBER</th>
<th>WAVELENGTH</th>
<th>INTENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MONITOR</td>
<td>1 word, R</td>
<td>Intensity of monitor signal for this profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLOCK</td>
<td>54 words, integer</td>
<td>(currently not used)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NUMBER</td>
<td>36 words, R</td>
<td>number of shots at this wavelength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAVELENGTH</td>
<td>36 words, R</td>
<td>Wavelengths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTENSITY</td>
<td>1008 words, R</td>
<td>INTENSITY (I,J) is the signal for the Jth shot at wavelength WAVELENGTH(I)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 1135 words/record

Fig. C-5 Format of fit-file data record written by PROFILE.
A code is used to describe the parameters of some subroutines. For example, in TIM,

\[
\text{INT R,I Given intensity},
\]

the R indicates INT is real (single precision floating point) and the I means it's used only for input (i.e., the subroutine doesn't change its value). Possible parameter modes are:

- \(F\) single precision floating point
- \(DP\) double precision floating point
- \(I\) integer
- \(S\) statement number, for alternate return
- \(L\) logical
- \(C\) complex,

and possible uses are:

- \(I\) input only (unchanged)
- \(O\) output only (changed, contains useful information)
- \(IO\) input and output
- \(W\) work area (changed, not meaningful on return).
Programs Listed

REVERT

TREAD*, OPT*

PARAM

BSORT

STORES, START, SADD, SDROP, HADD, HDROP, ADDTO,
FINDTO, E_PUSH, E_POP

PROFILE

TIM, INTENS, LOOKUP, YESNO*

VPLOT

THEORY

DBANK, GROUP, FETCHS, FUNCT3, FUNCT2, TPLOT,
AXISN**, NEWS, NEWT, NEWU, SIGMA, SYMSLV**, VALUE**

*Programs in UNIVAC Assembly Language.

**These programs may be of general interest
***** REVERT *****

2U537J1M#OKSPACE$1).REVERT
1
C
NAME *
2
C
REVERT
3
C

PURPOSE
4
C
TO ACCEPT A TAPE PRODUCED BY THE DIGITAL DATA ACQUISITION
5
C
SYSTEM AND PRODUCE A FILE ACCEPTABLE TO PROGRAM *PARAM*.

USAGE
6
C
*NOT REVERT (NOT Q,REVERT)
7
C
(DATA CARDS)
8
C

OPTIONS:
9
C
"L" PRINTS INFORMATION FROM DATA CARDS AND FIXED DATA
10
C
FROM TAPE RECORDS (THUMMWHEEL SWITCHES)
11
C
"N" IGNORES IMPROPER SCALE OR INTERVAL FROM TAPE
12
C
RECORD HEADER...NO MESSAGES
13
C
"R" OMIT INITIAL REWIND (DEFAULT: REWIND TAPE BEFORE READING)

INPUT
14
C
DATA TAPE WITH NAME "INTAPE", PRODUCED BY THE DIGITAL DATA
15
C
ACQUISITION SYSTEM
16
C
DATA FROM THUMM WHEEL SWITCHES IS INTERPRETED AS FOLLOW S:
17
C
DIGITS 1-5..SCALE (V/DIV) FOR CHANNELS 1-5
18
C
DIGIT 6...SAMPLE INTERVAL (MICROSEC)
19
C
SETTING 0 1 2 3 4 5 6 7 8 9
20
C
MEANING  .005 .01 .02 .05 1 2 .005 .LE. SCALE .LE. 2 .
21
C
.05 .LE. INTERVAL .LE. 2 .
22
C
INTERVAL SPECIFIED ON CARD 3 SUPERCEDES DIGIT 6.
23
C
A WARNING IS PRINTED IF INTERVAL ISN'T .5 MICROSEC.

THE FOLLOWING DATA CARDS:
24
C
CARDS 1 AND 2...
25
C
(72A1/72A1) ALPHANUMERIC HEADER IMAGES
26
C

CARD 3...*
27
C
(I5) NUMBER OF CHANNELS BEING USED
28
C
(F5.0) SAMPLE INTERVAL IN MICROSECONDS
29
C
(I5) MONITOR SIGNAL CHANNEL (IF BLANK, THE PROGRAM
30
C
USES THE FIRST CHANNEL WITH BLANKS IN THE
31
C
WAVELENGTH SPECIFICATION COLUMNS OF CARD 4.)
32
C
(I5) STARTING SAMPLE NUMBER (IF BLANK, THE PROGRAM
33
C
READS THE FIRST 12 RECORDS AND USES THE
34
C
AVERAGE OF THE MAXIMA OF THE MONITOR.)
35
C
CARDS 4-M
36
C
(SORTED BY SHOT #) INCREASING)
37
C
(I5) FIRST SHOT NUMBER OF A GROUP OF SHOTS WITH
38
C
THIS SET OF WAVELENGTH SETTINGS.
39
C
(5F5.1) WAVELENGTHS IN ANGSTROMS FOR EACH CHANNEL
40
C
BLANK FIELD INDICATES A MONITOR CHANNEL
41
C
CARD N+1...
42
C
"EOF" IN FIRST FIVE COLUMNS
43
C
CARDS N+2-M
44
C
(I5) SHOT NUMBER WITH INCORRECT SCALE #
45
C
(5F5.4) NEW SCALE #S (BLANKS FOR CORRECT ONES)
46
C
CARD M+1...

ORIGINAL PAGE IS OF POOR QUALITY.
FIRST FIGURE COLLECTIVE

DATA RECORD FORMAT: LABEL(2), SCALE(9), NSHOT(6), T1, T2, Y1, Y2 ... T6, Y6

TOTAL: 69 HMT'S

SUBPROGRAMS REQUIRED...

BEGIN

OPT

READ

PARAMETER POINTS=11

PARAMETER MBAD=15

PARAMETER MCHAN=4

PARAMETER MPEG=S

PARAMETER MSAD=S

PARAMETER CHAN=4

PARAMETER NSAV=N

INTEGER HEADERS, CARD, APTE

LOGICAL I, APTE, IE, TVN

INTEGER SCALE(9), IREC(10), POISSON(PTS)

REAL ( )

DATA SCALE/0.5, 2.0, 5.0, 1.0, 0.5, 2.0, 5.0, 1.0, 2.0, 5.0/

DATA IPE(4), JPE(4), KPE(4)

DATA JPTS, NFIL, ENDM, IRD, CAR, WAP, MAPI, SGIVE

DATA J, I0, EO, P, 5, 5, 5, FALSE, FALSE/

DATA (CHAN), MPTS, SRCU, +BAD

DATA ICHAN, NSAV(12), NSAV(15)

CALL REVERT(1.23)

QUIET=OPT('1')

LONG=OPT('L')

IF(.NOT.OPT('P')) CALL EMIF

WRITE(FILE,'(A10)') HEADER

TRANSFER HEADER INFORMATION

DO 10 I=1, 2

READ(CARD, 810, END=100) HEAD

WRITE(810, 100) HEADER

READ(CARD, 812, END=100) HEADER

WRITE(812, 100) HEADER

100 FORMAT(12A6)

101 IF(LAT=0) THEN 103

WRITE(NFILE,'(A10)') HEADER

103 FORMAT(12A6)

READ(CARD, 820, END=100) MCHAN, SAMPLE, MONT, TIVE

WRITE(820, 100) HEADER

104 FORMAT(15.S5, 0, 2.15)

ORIGINAL PAGE IS OF POOR QUALITY
114 IF(ZLAT*UVRT .OR. UCHAN.EL.0) GO TO 108
115 IF(ZLAT*PLE.EL.0) GO TO 12
116 IF((ZLAT*.PLE.LT.05 .OR. SAMPLE(CT,	2,1)) GO TO 110
117 "GIVEBACK TRUE.
118 12 IF(KTIME.LT.0 .OR. MOJIT.GT.NCHAN) GO TO 112
119 15 IF(KTIME.LT.0 .OR. KTIME.GT.5) GO TO 114
120 18 IF((LONGI+PRINT .AND. NCHAN) .AND. .NOT.((F6,? .AND. USEC) .OR. SAMPLE INTERVAL?/)
121 - ' CHANNEL.12.+ IS MONITOR. STARTING CHANNEL NOT SET.)
122
123 C
124 C READ WAVELENGTHS FOR EACH SHOT NUMBER
125 C IF((LONG+AND. .NOT.OPT(1Y)) PRINT 925
126 C 825 FORMAT(15X// 'SHOT N WAVELENGTHS')
127 DO 23 NPTS=1+PTS
128 READ(1CARO,830,END=25)KSHOT(NPTS),(WAVEL(NPTS,M).NCHAN)
129 C 830 FORMAT(15,5A5)
130 DO 20 =1+NCHAN
131 20 DECODE(322#AVEL(NPTS,M))W(M)
132 C 832 FORMAT(F5.1)
133 IF((LONG+AND. .NOT.OPT(1Y)) PRINT 835,KSHOT(NPTS,1,4),H=1+NCHAN)
134 C 835 FORMAT(15,15+2X,5F9.2)
135 GO TO 116
136 25 KSHOT(NPTS)=1000
137 NPTS=NPTS+1
138 READ(1CARO,860,END=30)KSHOT(NBAD),(WAVEL(NBAD,1,4),H=1+NCHAN)
139 C 860 FORMAT(15,5F5.4)
140 CONTINUE
141 GO TO 117
142 .30 LSHOT(NBAD)=1000
143 NBAD=NBAD-1
144 IF(NMONIT+H=0) GO TO 40
145 C
146 C WE WERE/T TOLD THE MONITOR CHANNEL #...
147 C 147 IF((LONG+AND. .NOT.OPT(1Y)) PRINT 901
148 C 901 FORMAT(15X// 'NO MONITOR SPECIFIED...USING CHAN. 1')
149 C 901 FORMAT(15X// 'NO MONITOR SPECIFIED...USING CHAN. 1')
150 C
151 CONTINUE
152 C C THERE'S STILL NO MONITOR CHANNEL SPECIFIED...
153 C USE CHANNEL 1
154 C
155 C
156 C
157 C 157 CONTINUE
158 C PRINT 901
159 C 901 FORMAT(15X// 'NO MONITOR SPECIFIED...USING CHAN. 1')
159 C 901 FORMAT(15X// 'NO MONITOR SPECIFIED...USING CHAN. 1')
160 C MONIT=1
161 40 IF(KTIME+H=0) GO TO 50
162 C
163 C WE WERE/T TOLD WHICH TIME TO START WITH...
164 C FIND AVERAGE TIME FOR PFAK OF MONITOR SIGNAL
165 C AMONG FIRST 12 RECORDS
166 DO 124 L=1,12
167 CALL TCRD(INSHOT+KEOF)
168 IF(KEOF+H=0) GO TO 118
169 MAX=N1SIG(MOJIT)
170 I=1
171 124 CONTINUE
172 IF(NSIG(MOJIT)+K).LE.MAX) GO TO 45}
I=K
MAX=SIG(AWHIT+X)
45 CONTINUE
47 KTI=L-KTI+1
KTI=KTI+MOD(S+KTI/12)
CALL READ
10 IF(WT('L'))STOP
58 INREC=0
178 MSHOT=0
179 IF(MSUGI)PRINT 838
838 FORMAT(IX/*RECORD SHOT.# FIXED DATA*/)
DO 82 L=1,4RCO
182
183 CALL READ(MSHOT,KEOF)
184 IF(KEOF.NE.0)GO TO 85
186 MSHOT=MSHOT+1
187 IF(MSUGI)PRINT 840,MSHOT,MSHOT+NUM
188 840 FORMAT(IX*,I19,**X*,SI2,12,2,612)
189 INREC=INREC+1
190
191 IF(KEOF.NE.0)GO TO 82
192 JPTS=MSHOT(JPTS+1)
193 DO 62 L=1,ISTOP
194 JPTS=JPTS+1
195 62 CONTINUE
196 63 CONTINUE
197 DO 82 L=1,1CHAN
200
201 IF(AVAIL(JPTS,M).NE.999999)GO TO 82
202 IF(AVAIL(JPTS,M).NE.999999)GO TO 82
203 IF(IS=NU(M))GO TO 65
204 IF(.NOT.QUIET)PRINT 100,INREC,MSHOT,KEOF
205 65 CONTINUE
206 IF(UPT('L'))IS=NUM(M-1)
207 IF(IS.GT.0)AND. IS.LT.90)GO TO 65
208 IF(.NOT.QUIET)PRINT 100,INREC,MSHOT,KEOF
209 902 FORMAT('TAPE RECORD#,*L*, SHOT#15,*CHANNEL*,12,
210 = ***SCALE # OUT OF **.8,T,,15/
211 = * USING .005 V/DIV*)
212 213 IS=1
214 65 K=KTI+1
216 217 SUBSTITUTE CORRECT AMPLIFICATION IF NEEDED
218 AMPLF=SCALE(IS)
219 IF(ISHOT(JBAD).EQ.10000)GO TO 68
220 IF(ISHOT(JBAD)+LSHOT(JBAD),BAD=1
221 IF(ISHOT(JBAD).EQ.10000)GO TO 67
222 JBAD=JBAD+1
223 GO TO 66
224 67 IF(ISHOT(JBAD)+LSHOT(JBAD),BAD=1
225 AMPLF=GOOD(JBAD,M)
226 68 IF(SGIVJ1)GO TO 71
227
***** REVPT *****

220  C  PICK UP SAMPLE INTERVAL FROM RECORD HEADER
221  IT=IT+1 (i)
222  IF(IT.GT.3 AND IT.LE.9) GO TO 70
223  NERR=ERR+1
224  IF(FOOT=PCJT) PRINT '03:1REC|SHOT|IT
225  903 FOR PAT: TAPE RECORD IS*, SHOT IS,
226  - '***SAMPLE INTERVAL # OUT OF RANGE!*IS/
227  - ' USING .1 MICROSEC*/
228  IT=2
229  70 SAMPLE=SCALE(IT)
230  C  GIVE ONE WARNING IF INTERVAL ISN'T =1 US
231  IF(ISAMPLE.EQ.1 OR WARNED) GO TO 72
232  NERR=ERR+1
233  WARNING=TRUE
234  PRINT '904, INREC|SHOT|SAMPLE
235  904 FORMAT: TAPE RECORD IS*, SHOT IS*, ***SAMPLE INTERVAL 1.0US,
236  - ' Fb.2, ' MICROSEC*/
237  C
238  C  TRANSFER DATA POINTS
239  72 TIMESK*SAMPLE
240  UD 75 HH=7*INRDG+2
241  RECOND(KK)=TIME
242  C WE MAKE A CORRECTION OF A FACTOR OF 10 BECAUSE
243  THERE ARE TWO EXTRA AMPLIFIERS IN THE DATA SYSTEM
244  RECOND(KK)=1*ISIG(MA)*AMPLIFY
245  X=K+1
246  75 TIME=TIME+SAMPLE
247  C  SET UP OUTPUT RECORD HEADER
248  76 KCON=1
249  760 INREC|SHOT|SAMPLE
250  350 FORMAT(A*13)
251  350 RECOND(3)=AMPLIFY
252  350 INREC(4)=SHOT
253  WRITE(4,FILE*INREC|RECORD
254  82 CONTINUE
255  GO TO 124
256  C  END OF FILE...QUITTING TIME
257  85 PRINT '060|SHOT|INREC
258  860 FORMAT(1X,16.5*, SHOTS PROCESSED/1X,16.5** RECORDS WRITTEN
259  860 E16.5*CHAI
260  860 FORMAT(1X,16.5*, ENHORS OR *AMPS*)
261  860 E10 GO TO 199
262  C  COMPLAIN
263  106 PRINT 986
264  906 FORMAT(' HEADER CARDS ARE *MISSING*
265  906 GO TO 199
266  108 PRINT 986|CHAIN|MCHEI
267  986 FORMAT(' NUMBER OF CHANNELS,N, IS OUT OF RANGE 1 TO *12]
268  986 GO TO 199
269  110 PRINT 910|SAMPLE
270  910 FORMAT(' SAMPLE INTERVAL OF,615.5, IS BAD*/
271  - ' USING TAPE RECORD HEADER*)
272  910 GO TO 12
****** REVERT (Sample data) ******

@COT.L REVERT

AL DATA ON MFD 19 NOV 75, PRESSURE = 18.5 psig, TO = 70°F, REFLECTOR = .8
SCANS OF HC II 1640 AND 4688, AL II 1670,...
FILTER RUN 101

3 channels were used.

First shot number at these wavelengths

Channel 1 set at 3280.0 Å

Channel 2 set at 4688.0 Å

Discard data for channel 2, shots 84-92.

Channel 3 is for monitor signal.

Shot 76 had wrong amplifier setting recorded

Channel 1 amplification was .005 V/div

Channel 2 amplification was correctly recorded

Some signals were attenuated

Attenuation factor was .151.

Signals for 4670 Å through 4696 Å were attenuated
**REVTR (Tape)**

SUBSTR().MAIN().CALL

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

DATAFILE

PACP.

PURPOSE...

TO READ THE HIGH SPEED DATA ACQUISITION SYSTEM TAPE.

CALLING SEQUENCE...

CALL READ (BUFFER+EOF)

BUFFER[33] WORD DATA INPUT BUFFER, INTERRUPT
BUFFER[1] IS THE EXPERIMENT COUNT
BUFFER[2-13] ARE MISC FIXED DATA
BUFFER[14-33] THE DATA POINTS, DIMENSIONED (5,64)
EOF END OF FILE, ANY OF SET NON-ZERO IF EOF

ONE TAPE RECORD IS READ AND UNPACKED INTO THE USER'S BUFFER

CALL RET

THE DATA TAPE IS FILED.

INPUT...

TAPE RECORD FORMAT IS:
6 BYTES (3CD, 2BYTE) FIXED DATA
3 BYTES (BCD) EXPERIMENT COUNT
320 BYTES (BINARY) DATA GROUPED BY TIME

XI AARE.

XI ENTRY POINT

TREAD.

ARE WE AT THE END OF THE FILE?

FETCH A BUFFER FULL

FETCH STATUS AND CHECK.

SHOULD HAVE AN ASCII OF 5

OKAY

XI WILL POINT TO THE NEXT WORD IN THE

USER'S BUFFER ALL THROUGH THE PROGRAM

PICK UP EXPT COUNT

LA A0+INBUF+1.

WIPE OUT EXTRANEOUS STUFF

LA A2+AL.

SSL A0+8.

MSI.UP A1+10.

AA A2+AL.

SSL A0+8.

ORIGINAL PAGE IS

OF POOR QUALITY
***** REVET (THE) *****

57  ANDU A2,017.
58  MC1+U A1+100.
59  AA A2:AI.
60  SA A2:0:*X1.
61  * PICK UP MISc DATA
62  * DL A2+MUF.
63  * SIX BYTES OF TWO CHARACTERS/BYTE
64  LRVU M2:5.
65  DSC A9:A.
66  LOOP1 LUSC A9:12.
67  ANDU A1:017.
68  MOVF LAST DIGIT TO A2(3-0)
69  SA A2:0:*X1.
70  DSC A9:A.
71  ANDU A1:017.
72  PUT ONE DIGIT INTO A2(3-0)
73  JGC R2:LOOP1.
74  STORE BCD DIGIT
75  * GET REAL DATA
76  * SX X2:SAVEX+1.
77  * X2 POINTS TO NEXT PAIR
78  LX X2+(P+MUF+2).
79  * OF WORDS IN INPUT BUFFER
80  LOOP3 LRVU R2:34.
81  * MOVE 35 PAIRS OF WORDS (315 BYTES)
82  LOOP2 LUSC A9:A.
83  ANDU A1:0377.
84  TRANSFER ONE BYTE TO A2(7-0)
85  SA A2:0:*X1.
86  JGU R1+LOOP2.
87  * SHIFT UNTIL 'DOUBLE WORD IS FINISHED'
88  JGD N1+LOOP3.
89  * FINISH 35 WORD PAIRS
90  LOOP4 LUSC A9:A.
91  ANDU A1:0377.
92  TRANSFER ONE BYTE TO A2(7-0)
93  SA A2:0:*X1.
94  JGD R1:LOOP4.
95  * FINISH THE LAST 5 BYTES
96  SX X1:SAVEX.
97  RETU LX X1:SAVEX.
98  LA X2:SAVEX+1.
99  J 3*X11.
100  * END OF FILE OR TAPE ERROR
101  E0F LAVS1 A3:PKT+3.
102  TEST FIRST FOR EOF
103  TCVU A9:01.
104  01 MEANS END OF FILE.
105  J B3.
106  NOT THAT EOF REACHED
107  SA A9:*00.
108  SA A9:*1X11.
109  TELL CALLING PROGRAM ABOUT EOF.
110  J RETURN.
111  B0 LAVHS A3:PKT+3.
112  TEST FOR WRONG RECORD LENGTH
113  THEU A3:79.
114  J B1.
115  SLJ PRINT.
116  LENGTH WRONG...PRINT STATUS
117  ER ABORT.
118  AND QUIT.
119  B1 LAVS1 A3:PKT+3.
120  GET I/O COMPLETION STATUS CODE AGAIN.
121  00 MEANS NORMAL COMPLETION, (MUST BE
122  THEU A9:00.
123  J OKAY.
124  COPIED TAPE, SINCE FRAME CT IS NORMAL)
**REVLT (THENJ)**

114 TL+U AO+RD. 04 MEANS ABNORMAL FRAG. COUNT.
115 J BZ. 04.
116 SLJ PRINT. ARC NOT 5, SO WE PRINT STATUS AND
117 J ANOTHER. GET NEXT RECORD.
118 SLJ PRINT. SAME OTHER 1/0 ERROR...PRINT STATUS
119 ER ABDRTS. AND QUIT.
120 *
121 * SUBROUTINE FOR PRINTING OUT THE STATUS WORD
122 *
123 PRINT * S5. GET THE STATUS WORD
124 LA AO+PKT+3. 02
125 LH+U R2+1. 02
126 E2 SA R2+IMUf+1. (USEFUL ON 2ND ITERATION OF LOOP)
127 LH+U R1+5. 02
128 EL AN+U AO+07. MOVE ONE OCTAL DIGIT TO AO(2-0)
129 LA+U AO+05. 02
130 DSC A1+6. MOVE INTO A2(35-30)
131 SSL AO+3. MOVE NEXT OCTAL DIGIT TO AO(2-0)
132 JG0 R1+51. 02
133 JGD R2+1. 02
134 SA AO+IMUf. 02
135 LA AO+(0104+IMUf-2). 02
136 EN PRINTS. 02
137 J *PKT.+1. 02
138 *
139 * REWIND ENTRY POINT
140 *
141 REWIND L+U AO+RD. REWIND THE TAPE
142 ER IOMS. 02
143 LA+SI AO-RD+3. CHECK FOR BAD STATUS
144 TZ AO. 02
145 J HEZ. 02
146 SLJ PRINT. STATUS BAD...PRINT THE STATUS
147 ER ABDRTS. AND QUIT
148 RE2 SZ END. NOTE WE AREN'T AT AN END OF FILE NOW
149 J 1+XII. 02
150 *
151 * STORAGE AREA
152 *
153 3(IO) SAVEX RES 2. 02
154 PKT+ ISO+ INTAPE+P+ 7+IMUf. 02
155 * 'I/O STATUS', 02
156 INUF RES 7+4. 02
157 STATUS +ISO+INTAPE+REWS. 02
158 END + 0. 02 02 SET NONZERO WHEN EOF FOUND
159 RWD ISO+INTAPE+REWS. 02
160 END 02 02

**ORIGINAL PAGE IS OF POOR QUALITY**
*** REVERT (OPT) ***

*WORKSPACE(*).OPT
 1  *  NAME...
 2  *  OPT
 3  *  PURPOSE...
 4  *  TO OBTAIN FOR THE USER PROGRAM THE OPTIONS SPECIFIED ON
 5  *  THE EXECUTING STATEMENT.
 6  *
 7  *  CALLING SEQUENCE...
 8  *
 9  *  LOGICAL SWITCH=TEST=OPT
 10  *
 11  *  SWITCH=OPT("U")
 12  *
 13  *
 14  *
 15  *  TEST=OPT("T")
 16  *
 17  *
 18  *
 19  *  SWITCH WILL HAVE THE VALUE "TRUE", IF THE "U" OPTION WAS
 20  *  SPECIFIED ON THE "XGET OR "FILE PROGRAM CARD, AND "FALSE"
 21  *  OTHERWISE. TEST WILL SIMILARLY Indicate THE PRESENCE OF
 22  *  THE "T" OPTION.
 23  *
 24  *  LITERAL...
 25  *
 26  *  OPT=TZ HAVE
 27  *
 28  *
 29  *
 30  *
 31  *
 32  *
 33  *
 34  *
 35  *
 36  *
 37  *
 38  *
 39  *
 40  *
 41  *
 42  *
 43  *

W=EXEC
**** PARAM ****

200373J104K5PACES(1) PARAM

1 C NAME:
2 C PARAM
3 C PURPOSE:
4 C TO CREATE RECORDS WITH STRICTLY DECREASING MONITOR SIGNALS
5 C USAGE:
6 C PARAM OR OXOT PARAM
7 C OPTIONS:
8 C (OXOT ONLY) AMPLIFY SOME SIGNALS WHICH WERE
9 C ATTENUATED WITH A NEUTRAL DENSITY FILTER
10 C <LOW-HIGH> (FREE) SIGNALS WITH WAVELENGTHS IN THE
11 C RANGE (<LOW-HIGH>) WILL BE AMPLIFIED BY 1/294
12 C INPUT...
13 C ACCEPTS FILES CREATED BY PROGRAM 'RECOVER' OR 'REVERT'.
14 C RECORDS 1 & 2:
15 C (72A1/72A1) FILE HEADER
16 C RECORDS 3-N:
17 C WORDS 1,2: (F5.1,1J) WAVELENGTH, SHOT #
18 C WORD 3: (R) SCALE: VOLTS/DIV
19 C WORD 4: (I) SHOT #
20 C WORD 5: (I) # POINTS IN THIS RECORD
21 C WORDS 6-13: (R) TIMES (USEC)
22 C WORDS 14-21: (R) SIGNALS (V)
23 C RECORD N=1:
24 C 'QEOF' IN FIRST WORD
25 C OUTPUT...
26 C FILE ACCEPTABLE TO PROGRAM 'SORT'
27 C RECORDS 1,2:
28 C (72A1/72A1) FILE HEADER
29 C RECORDS 3-N:
30 C WORDS 1,2: (F5.1,1J) WAVELENGTH, SHOT #
31 C WORD 3: (R) SCALE: VOLTS/DIV
32 C WORD 4: (I) SHOT #
33 C WORDS 5-20: (R) PAIRS OF TIME (USEC), SIGNAL (V)
34 C RECORD N=1:
35 C 'QEOF' IN FIRST WORD
36 C SUBPROGRAMS REQUIRED...
37 C BEGIN OPT
38 C LOGICAL OPT
39 C DIMENSION A(8),B(8), FACTOR(B), LOW(B), HIGH(B)
40 C EQUIVALENCE (A(1), HEAD(1)), (B(1), HEAD(13))
****** PARAM ******

```
57 DATA ENDF, INFILE, OUTFILE, INREC, OUTREC
58 15, 10, 15, 0, 0/
59 DIMENSION X(9), Y(9), A(8)
60 EQUI=1.2*CL (X(11), (11))
61 LOGIC L=.TRUE.
62 CALL BEGIN(1, 11)$!
63 KATT=1
64 IF(.NOT.OPT('A')) GO TO 5
65 PRINT 000
66 000 FORMAT(' ENTER ATTEN AND WAVELENGTH RANGE')
67 DO 3 KATT=1, 8
68 READ 805, END=5, FACTOR(KATT), LOW(KATT), HIGH(KATT)
69 805 FORMAT(I, N)
70 LOW(KATT)=LOW(KATT)*.05
71 HIGH(KATT)=HIGH(KATT)*.05
72 IF(FACTOR(KATT).GT.1.) PRINT 901
73 901 FORMAT(I, 12)
74 3 CONTINUE
75 KATT=20
76 5 LOW(KATT)=LOW(KATT)*.555,
77 DEFINE FILE INFILE(NKCD+1,U, INREC)
78 DEFINE FILE OUTFILE(NKCD+2,U, OUTREC)
80 C TRANSFER FILE HEADER
81 DO 5 J=1,2
82 READ(INFILE, J)(HEAD(I), I=1,12)
83 WRITE(OUTFILE, J)(HEAD(I), I=1,12)
85 C READ A RECORD
86 10 READ(INFILE, INREC)(HEAD(I), I=1,4), X(I), Y(I), I=1,N)
88 C QUIT AT END OF FILE
90 IF(HEAD(1).EQ. END) GO TO 50
91 AMPLFY=1
92 C REMOVE BAD RECORDS OR CORRECT AMPLIFICATION
93 DECOIL (830, HEAD(I))AVE
94 830 FORMAT(I, 1)
95 DO 12 KK=1,KATT
96 IF(WAVE.LT.LOW(KK)) GO TO 12
97 IF(WAVE.LE.HIGH(KK)) GO TO 14
98 12 CONTINUE
99 GO TO 15
100 14 AMPLFY=AMPLFY*FACTOR(KK)
101 C TRANSFER RECORD TO OUTPUT AREA
102 15 NMIN=0(N+8)
103 DO 20 I=1+N
104 A(N+I-1)=X(I)
105 20 B(N+I-1)=Y(I)/AMPLFY
107 C SORT POINTS ON TIME
108 IF(N+1) GO TO 40
110 DO 24 J=N+2,1
111 SAME=.TRUE.
112 DO 25 J=2, J
113 IF(A(I).GE.A(I-1)) GO TO 25
```
***** PARAM *****

114  S=AI
115  A(I)=A(I-1)
116  A(I-1)=S
117  S=AI
118  HI-1(H-1)
119  B(I-1)=S
120  SAE=.FALSE.
121  25 CONTINUE
122  28 IF(SAME) GO TO 30
123  28 CONTINUE
124
125  IF THIS IS A MONITOR SIGNAL, ENSURE IT'S
126  MONOTONICALLY INCREASING
127  30 DECODE(N40.HEAD) TEST
128  AND FORMAT(A5)
129  IF(ITEMS+EQ.1) 160 TO 31
130  10 EQ.0.1,=0 TO 34
131  31 DROP=0.
132  31 HIGH=1
133  31 VALLEY=I
134  31 PEAK=I
135  31 IB=I
136
137  FIND A LOCAL MAXIMUM
138  32 IB=IB+1
139  IF(ITEMS+EQ.1) GO TO 35
140  IF(IB+LE.BCH1-APRC11-I))=32
141  31 HIGH=ID
142  31 NOTE LOCATION OF LOCAL MAXIMUM
143
144  FIND A LOCAL MINIMUM
145  34 IB=IB+1
146  IF(ITEMS+EQ.1) GO TO 36
147  IF(IB+LE.BCH1-APRC11-I)=34
148  31 IS THIS DROP BIGGER THAN PREVIOUS BIGGEST?
149  31 IF(S(HIGH)+B(IB)+DROPL=32
150  31 NOTE THIS IS BIGGEST DROP
151  31 DROP=Q(HIGH)-H(I)
152  31 PEAK=HIGH
153  31 VALLEY=IB
154  36 GO TO 32
155  31 IF(IB=HIGH) B(IB-1)+LE.DROP=30
156  31 PEAK=HIGH
157  31 VALLEY=IB-1
158
159  HAVE FOUND BIGGEST DROP...GET RID
160  OF POINTS BEFORE PEAK
161  38 IB=3
162  40 IB=IB+1
163  40 IF(IB+EQ.PEAK) GO TO 42
164  A(13)=A(13)
165  B(IB)=B(IB)
166  GO TO 40
***** PARA 1 *****

1/1
1/2
GET RID OF POINTS AFTER VALLEY
173
174
175
176
177
178
179
GO TO 44
C
C
IF(I0.GT.0) GO TO 45
A(I0)=A(VALLY)
B(I0)=B(VALLY)

C
C
WRITE A RECORD
181
182
WRITE(OUTFIL='OUTREC')HEA0
183
184
GO TO 10
C
CLOSE THE FILE AND EXIT
185
186
WRITE(OUTFIL='OUTREC')I01
187
PRINT 899,1
188
899 FORMAT(IS3,1 CURVES PROCESSED*)
189
STOP
190
END
**** SORT ****

2UB37JL*OKSJ ALES(1).HXT

<table>
<thead>
<tr>
<th>C</th>
<th>NAME...</th>
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<tbody>
<tr>
<td>C</td>
<td>OSORT</td>
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<table>
<thead>
<tr>
<th>C</th>
<th>PURPOSE...</th>
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<tbody>
<tr>
<td>C</td>
<td>TO SORT THE RECORDS FIRST BY WAVELENGTH THEN BY SHOT #.</td>
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<tr>
<th>C</th>
<th>USAGE...</th>
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<tbody>
<tr>
<td>C</td>
<td>W*OSORT OR QXQRT *OSORT (NO OPTIONS)</td>
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<tr>
<th>C</th>
<th>SUBPROGRAMS CALLED...</th>
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<tbody>
<tr>
<td>C</td>
<td>BEGINSTART;SADD;DROP;HADD;HDRP;ADDTO;FINDTO;EFLUSH;EPOP</td>
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<tr>
<th>C</th>
<th>METHOD...</th>
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<tr>
<td>C</td>
<td>ON A FORWARD PASS, EACH RECORD IS READ. IF IT RANKS HIGH ENOUGH (HIGHER THAN LEAST ONE CURRENTLY SAVED) IF THE BUFFERS ARE FULL, IT IS SAVED AND, IF THE BUFFERS ARE FULL, THE LEAST ONE CURRENTLY SAVED IS WRITTEN IN ITS PLACE. WHEN THE END OF THE UNSORTED PORTION OF THE FILE IS REACHED, ALL RECORDS BEING HELD ARE EXCHANGED WITH STORED RECORDS. THE PROCESS IS REPEATED IN ALTERNATING DIRECTIONS UNTIL THE ENTIRE FILE IS SORTED.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>INCLUDE STORES LIST</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>LOGICAL FOUND</td>
</tr>
<tr>
<td>C</td>
<td>DATA EJ/*EOF */</td>
</tr>
<tr>
<td>C</td>
<td>DATA HFILE/15/</td>
</tr>
<tr>
<td>C</td>
<td>CALL BEGIN('OSORT 2.01 Q')</td>
</tr>
<tr>
<td>C</td>
<td>DEFINE FILE HFILE(100+2*UMREC)</td>
</tr>
<tr>
<td>C</td>
<td>CALL START</td>
</tr>
<tr>
<td>C</td>
<td>NEXT=2</td>
</tr>
<tr>
<td>C</td>
<td>FOUNQ=.FALSE.</td>
</tr>
<tr>
<td>C</td>
<td>LAST=0</td>
</tr>
<tr>
<td>C</td>
<td>IREC=2</td>
</tr>
<tr>
<td>C</td>
<td>INCR=1</td>
</tr>
<tr>
<td>C</td>
<td>NPASS=0</td>
</tr>
<tr>
<td>C</td>
<td>NWRITE=0</td>
</tr>
<tr>
<td>C</td>
<td>NREAD=0</td>
</tr>
<tr>
<td>C</td>
<td>KNOW=0</td>
</tr>
<tr>
<td>C</td>
<td>SURE=.TRUE.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C</th>
<th>BEGIN NEW SWEEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>10 CHANGE=.FALSE.</td>
</tr>
<tr>
<td>C</td>
<td>NPASS=NPASS+1</td>
</tr>
<tr>
<td>C</td>
<td>12 IREC=IREC+INC</td>
</tr>
<tr>
<td>C</td>
<td>IF(NCAN.EQ.LAST)GO TO 40</td>
</tr>
<tr>
<td>C</td>
<td>IF(KNOW.LE.0).AND.(.NOT.SURE))GO TO 30</td>
</tr>
<tr>
<td>C</td>
<td>IF(NHASE).EQ.15)GO TO 14</td>
</tr>
<tr>
<td>C</td>
<td>14 IF(NCAN*.EQ.*FROM(NHASE))GO TO 24</td>
</tr>
<tr>
<td>C</td>
<td>READ NEW RECORD</td>
</tr>
<tr>
<td>C</td>
<td>15 CONTINUE</td>
</tr>
<tr>
<td>C</td>
<td>READ(HFILE,IRCC,INCC,IREC,BUFFER,I=1,LOW)</td>
</tr>
<tr>
<td>C</td>
<td>NREAD=NREAD+1</td>
</tr>
<tr>
<td>C</td>
<td>IF(FOUND)GO TO 20</td>
</tr>
</tbody>
</table>
****怡* 500Ti *******

57-C STOP STEP IF THIS IS END OF FILE
58 IF(I, BUFFER)++ ELSE 10 TO 20
59 PUNT××, TRUE.
60 LAST=IREC
61 RECORD=IREC-3
62 GO TO 40
63 C 20 CONTINUE
64 FROM BUFFER=IREC
65 CALL ADDO BUFFER)
66 BUFFER=Demand($)91)
67 GO TO 12
68 C WE ARE HOLDING A RECORD WE WANT TO WRITE HERE...
69 DO 50 THEN ADD IT TO THE SORT STACK
70 C 20 CONTINUE
71 WRITE(INFILE,IREC)R(I+BASE),I=1,1GH)
72 NWRITE=1
73 CALL ADDO DROP($)91)
74 IF(SJ, E)GO TO 12
75 CALL [PUSH DROP($)91)
76 GO TO 12
77 C THERE’S NOT ENOUGH ROOM TO DO ANY SORTING DURING
78 C 20 CONTINUE
79 GO TO 12
80 C THIS SCAN...BYPASS ALL READING
81 30 IF(I+BASE,LE.0)GO TO 32
82 IREC=POZ[HASE]E)
83 WRITE=NWRITE-1
84 CALL EPUSH DROP($)91)
85 GO TO 30
86 32 IREC=LAST
87 C CALCULATE NEXT SLEEP LIMITS
88 40 CONTINUE
89 LAST=EXT
90 NEXT=IREC=INCP+KNOW
91 IF(I, IOT, CHANGE).AND.(KNOW.E.GT.0)GO TO 88
92 KNOW=O
93 C RECORD DESTINATIONS OF RECORDS TO BE HELD
94 ISBASE=O
95 NTO=O
96 51 IF(I, IOT, 55, 52
97 52 CONTINUE
98 CALL ADDO(I)
99 I=IUP(I)
100 GO TO 51
101 C SET POINTERS
102 55 CONTINUE
103 J=LAST-INCRO/TO
104 JTOSHTO
105 CALL FINDO(W)
106 INCH=I+INC
107 SURE=TRUE.
108 STOP=STOP
109 STOP=O
110 SOBASE=O
111 C WRITE SORTED RECORDS IN PROPER ORDER
112 50 IF(TOP74,74,60
113 60 IREC=IREC+1NCR
***** disat *****

114 IF(INC= FILE*PUSH(1TOP)) GO TO 64
115 IF(INC= FILE*PUSH(1TOP)) GO TO 64
116 JTOP=JT0+1
117 C FILE RECORD THAT WAS HERE IS IN THE SORT STACK AND CAN BE OVERWRITTEN
118 C STACK AND CAN BE OVERWRITTEN
119 C FILE RECORD THAT WAS HERE IS IN THE SORT STACK AND CAN BE OVERWRITTEN
120 C FILE RECORD THAT WAS HERE IS IN THE SORT STACK AND CAN BE OVERWRITTEN
121 WRITE(INC*PUSH (1TOP), I=1+1GH)
122 WRITE(INC=PUSH(I1TOP), I=1+1GH)
123 WRITE(INC=PUSH(I1TOP), I=1+1GH)
124 CALL EPUSH(TTOP)
125 TTOP=I
126 GO TO 58
127 C FILE RECORD THAT WAS HERE MUST BE HELD AND WRITTEN BACK LATER THIS SWEEP
128 C FILE RECORD THAT WAS HERE MUST BE HELD AND WRITTEN BACK LATER THIS SWEEP
129 C FILE RECORD THAT WAS HERE MUST BE HELD AND WRITTEN BACK LATER THIS SWEEP
130 READ(INC*PUSH)(1(i= i nj u -, I=1+1GH)
131 READ(INC*PUSH)(1(i= i nj u -, I=1+1GH)
132 READ(INC*PUSH)(1(i= i nj u -, I=1+1GH)
133 WRITE(INC=PUSH(I1TOP), I=1+1GH)
134 WRITE(INC=PUSH(I1TOP), I=1+1GH)
135 WRITE(INC=PUSH(I1TOP), I=1+1GH)
136 BUFFER*PUSH
137 TTOP=I
138 GO TO 58
139 C ASSIGN DESTINATIONS TO THE RECORDS HELD
140 C ASSIGN DESTINATIONS TO THE RECORDS HELD
141 C ASSIGN DESTINATIONS TO THE RECORDS HELD
142 I=SHTOP
143 I=SHTOP
144 I=SHTOP
145 I=SHTOP
146 I=SHTOP
147 C GO FOR REST OF THIS SWEEP
148 C GO FOR REST OF THIS SWEEP
149 C GO FOR REST OF THIS SWEEP
150 C GO FOR REST OF THIS SWEEP
151 C GO FOR REST OF THIS SWEEP
152 PRINT [[000, PREAD, IN, PREAD, IN, PREAD, IN]
153 PRINT [[000, PREAD, IN, PREAD, IN, PREAD, IN]
154 PRINT [[000, PREAD, IN, PREAD, IN, PREAD, IN]
155 PRINT [[000, PREAD, IN, PREAD, IN, PREAD, IN]
156 PRINT [[000, PREAD, IN, PREAD, IN, PREAD, IN]
157 STOP
158 STOP
159 STOP
160 STOP
161 STOP
162 STOP
163 STOP

END
**NSOR (SAUD)**

**SUBROUTINE SAUD (WHERE)**

**PURPOSE***

TO ADD A RECORD TO THE 'SORTED' STACK

**USAGE...**

CALLED BY PROGRAM 'ISORT'

**INCLUDE STORES.LIST**

**IF($SURE)known=known+1**

**STOP=STOP+10**

**STOP=WHERE**

**DOWN(WHERE)=0**

**RETURN**

10 IF(COMPARE(WHERE,STOP))20,15,15

15 ENTER RECORD AT TOP OF STACK

16 UP(1) = WHERE

17 IF(CHANGE=TRUE)20,22,22

20 CHANGE=TRUE

22 IF(COMPARE(WHERE,SHAPE))20,22,22

23 RETURN

24 ENTER RECORD AT BASE OF STACK

25 SHAPE=WHERE

26 DOWN(WHERE)=SHAPE

27 SHAPE=WHERE

28 RETURN

29 IF(CHANGE)30,30,30

30 ENTER RECORD ABOVE RECORD 1

31 UP(1)=WHERE

32 UP(WHERE)=UP(1)

33 DOWN(WHERE)=1

34 UP(1)=WHERE

35 RETURN

36 END
****  BSORT (STORES) ****

20537$JIM=ORKSPACES(1), STORES
1   STORES  PROC
2   C
3   C    PROCEDURE NAME...
4   C
5   C
6   C    PURPOSE...
7   C      TO COMMUNICATE THE RECORD STACK INFORMATION FOR SORTING
8   C      PROGRAM 'BSORT'.
9   C
10  C
11  C    STORES
12  C    PROCEDURE NAME...
13  C
14  C
15  C
16  C    PURPOSE...
17  C      TO COMMUNICATE THE RECORD STACK INFORMATION FOR SORTING
18  C      PROGRAM 'BSORT'.
19  C
20  C
21  C
22  C
23  C
24  C
25  C

END

****  BSORT (START) ****

20537$JIM=ORKSPACES(1), START
1   SUBROUTINE START
2   C
3   C    PURPOSE...
4   C
5   C    TO INITIAlIZE STORAGE FOR PROGRAM 'BSORT'.
6   C
7   C
8   C
9   C
10  C
11  C
12  C
13  C
14  C
15  C
16  C
17  C
18  C
19  C
20  C
21  C
22  C
23  C
24  C
25  C

END

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****** JSORT (SOMOP) *******

05/17/73 Jim

** PURPOSE... TO DROP A RECORD FROM THE *SORTED* STACK **

** USAGE... CALLED BY PROGRAM *CSORT' **

** INCLUDE STORES.LIST **

10 IF(SUASE)=90,98,5 **

11 SOMOP=SBASE **

12 SBASE=UP(SUASF) **

13 IF(SBASE)=10,16,10 **

14 10 STOP **

15 RETURN **

16 15 DOWN(SUASE)=0 **

17 RETURN **

18 90 PRINT 901 **

19 901 FORMAT(' SORT STACK OVERWROPPED') **

20 RETURN 1 **

21 END **
SUB37JH=WSKSPACE$(1),IAND

C SUBROUTINE IAND(WHERE)

C PURPOSE...
C TO ADD A RECORD TO THE 'HOLD' STACK

C USAGE...
C CALLED BY PROGRAM 'DSORT'

C
C INCLUDE STORES$LIST

C IF(HTOP)=5,10
C IF(HTOP)=WHERE
C WHERE=HERE
C UP(WHERE)=0
C DOWN(WHERE)=0
C RETURN

C 10 IF(CMPARE(WHERE+WHERE)15,20,20)
C C ENTER TO BOTTOM OF STACK
C 15 DOWN(WHERE)=HERE
C 19 UP(HERE)=WHERE
C 20 DOWN(WHERE)=0
C 21 WHERE=HERE
C 22 RETURN
C 23 20 IF(CMPARE(WHERE+HTOP)15,22,22)
C C ENTER TO TOP
C 22 UP(HTOP)=WHERE
C 26 DOWN(WHERE)=HTOP
C 27 UP(WHERE)=WHERE
C 28 HTOP=HERE
C 29 RETURN
C 30 25 I=HTOP
C 30 30 I=DOWN(I)
C 32 C ENTER ABOVE ELEMENT I
C 35 J=UP(I)
C 35 I=DOWN(J)
C 36 I=UP(I)
C 37 DOWN(WHERE)=I
C 38 UP(WHERE)=HERE
C 39 RETURN
C 40 END

Q.E.D.
****** BSORT (HMOP) ******

2U53JIM# 00KSPACE's1(I)  HMOP

1  I:Retun FUNCTION HMOP(I)
 2  C
 3  C  PURPOSE***
 4  C  TO DROP A RECORD FROM THE "HOL" STACK
 5  C
 6  C  USAGE...
 7  C  CALLED BY PROGRAM 'BSORT'
 8  C
 9  C  INCLUDE STORES LIST
10  C  IF(HBASE)90.90.95
11  S  HMOP=HBASE
12  C  HMASE=UP(HMASE)
13  C  IF(HMASE)10.10.15
14  C  HTOP=0
15  C  RETURN
16  C  DO IT(I)HMASE)20
17  C  RETURN
18  C  90 PRINT 902
19  C  902 FORMAT(' HOLD STACK OVERFLOW')
20  C  RETURN
21  C  END

****** BSORT (ADTO) ******

2U53JIM# 00KSPACE's1(I) ADTO

1  SUBROUTINE ADTO(I)
 2  C
 3  C  PURPOSE***
 4  C  TO ADD A RECORD TO THE 'TO' STACK
 5  C
 6  C  USAGE...
 7  C  CALLED BY PROGRAM 'BSORT'
 8  C
 9  C  INCLUDE STORES LIST
10  C  STOP IF STACK IS FULL
11  C  NTOS=TO+1
12  C  IF(NTOS,ST.LE.LL)G0 TO 90
13  C  FIND PROPER PLACE TO INSERT RECORD
14  C  CALL FINDTO(I)
15  C  MOVE REST OF RECORDS & INSERT NEW ONE
16  C  J=TO
17  C
18  J=J+1
19  C  IF(J.LE.ITO)GO TO 10
20  C  TO(J)=IT(J)
21  C  GO TO 16
22  C  STOP
23  C  ERROR***STACK OVERFLOW
24  C  99 FORMAT(' TO OVERFLOW ')
25  C  STOP
26  C  END

9*EJCT
*** ISORT (FI'I'TO) ***

**55373J1M**ORKSPACE(1) .FI'I'TO
1 SUBROUTINE FI'I'TO(I)
2 C PURPOSE...
3 C SET POINTER *ITO* TO POINT IN *TO* STACK WHERE
4 C A GIVEN NEW RECORD SHOULD *F* INSERTED
5 C
6 C USAGE...
7 C CALLED BY PROGRAM 'BSORT'
8 C
9 INCLUDE STOLES.LIST
10 ITO=IT0
11 5 ITO=ITO-1
12 IF(I(ITO))=10
13 10 IF((FROM(I)-TO(ITO))=INCH)5,15,15
14 15 RETURN
15 END

*** BSORT (EPUSH) ***

**55373J1M**ORKSPACE(1) .EPUSH
1 SUBROUTINE EPUSH(LOC)
2 C PURPOSE...
3 C TO STORE A LOCATION IN THE 'EMPTY' STACK
4 C
5 C USAGE...
6 C CALLED BY PROGRAM 'BSORT'
7 C
8 C INCLUDE STOLES.LIST
9 DOWN(LOC)=ETOP
10 ETOP=LOC
11 RETURN
12 END

*** BSORT (EPOP) ***

**55373J1M**ORKSPACE(1) .EPOP
1 INTEGER FUNCTION EPOP(*)
2 C PURPOSE...
3 C TO GET A LOCATION FROM THE 'EMPTY' STACK
4 C
5 C USAGE...
6 C CALLED BY PROGRAM 'BSORT'
7 C
8 C INCLUDE STOLES.LIST
9 IF(ETOP)>90:90,5
10 5 EPOP=ETOP
11 ETOP=DOWN(ETOP)
12 RETURN
13 90 RETURN 1
14 END

[ORIGINAL PAGE IS OF POOR QUALITY]
 PROFILE

NAME... PROFILE

PURPOSE... TO UNFOLD THE DATA INTO INTENSITY VS WAVELENGTH CURVES

USAGE...

Q . PROFILE OR EXIT . PROFILE

OPTIONS:

A PRINT AND WRITE TO OUTPUT FILE POINTS FOR ALL

B MONITOR INTENSITIES (OTHERWISE, IF < 50% OF THE

C POINTS ARE ACCEPTED, THE WHOLE PROFILE IS DISCARDED)

D DISCARD POINTS WITH TIMES FOR THIS MONITOR INTENSITY

E FURTHER THAN 1.6 SIGMA (DEFAULT 1.73) FROM THE MEAN,

F DELETING ABOUT 111 (DEFAULT 86)

G DELETE 10 DATA POINTS OVERPOINTS (C OPTION),

H PROVIDE FULL LISTING (OTHERWISE, ONLY A SUMMARY)

I REPORT RESULTS FOR ALL WAVELENGTHS (EVEN IF MOST

J POINTS ARE DISCARDED)

K SKIP SOME PROFILES

L GENERATE FILES FOR PROGRAM "THFOPY*

M PROVIDE FILE FOR PROGRAM "PEQUIPEO...

N BEGIN/ OPT.TIM, INTLNLOOK YESNO

O MAXIMUM NUMBER OF WAVELENGTHS

P MAXIMUM NUMBER OF POINTS PER WAVELENGTH

Q OUTPUT RECORD LENGTH

R PARAMETER CSIZE=360

S PARAMETER LIMEXP=36

T PARAMETER CSIZE2=CSIZE+2

U DIMENSION NU(LIMEXP)+1, L(1), LENGTH(LIMEXP)

V DIMENSION MAXLOC(NL), EVLOC(S)

W EQUIVALENCE (INTREF, ULOCK(1)), (TAV, ULOCK(2)), (J, BLOCK(3))

X INTEGER TEMP(20), AREF

Y DIMENSION HEADER(24), SIG(LIMEXP), ERROR(LIMEXP), LABEL(20)

Z EQUIVALENCE (TEMP (4), RESHOT(1)), (TEMP (5), AREF(1)), (TEMP (13), BREF(1))

A EQUIVALENCE (LABEL(4), RESHOT), (LABEL(5), AREF(1)), (LABEL(13), AREF(1))

B DIMENSION AREF(1), BREF(1), ALIN(1), LNLIN(8), LOCATE(CSIZE)

C = LIST(CSIZE)

D LOGICAL SLOPE(10), REORDER, OPTCLOSE ALL THEORY, RT, SKIP EVERY

E LOGICAL YESNO, REPORT

F REAL INTENS(14), ITAV(LIMEXP), LAMBDA, LENGTH, INTREF

G REAL BEGIN, INTAN

H EXTERNAL INTENS

I INTEGER POOL, ERTyro, FCOUNT

J INTEGER GROUP(8), PBEGIN(8), END(8), CREGFILE, PREC/1, GPT, TRY, OUT

K INTEGER SHOT, REFD, FILE, CINFO, CFIELD, EI, POI, BAD

L INTEGER SHOT(LIMEXP), 1TAG(LIMEXP), 1NTAG(10), 1NTAG(LIMEXP)

M INTEGER TFILE, TREC, TPOI

N DATA (BLOCK(1)), I=1, 231, 1980,

DATA (BLOCK(1)), I=1, 231, 1980,
... PROFILE ... 57  DATA INFIL=DELL, I, LADA, NOFL, OF, RTFL, CFIL, 7, FILL, TMF 59  DATA LST(I(1)+ALTER+SPRD+EVICT 60  / 132, 136, 3*), 1, 1, 1, 1, 1, 1 61  CALL LENO('PROFILE 2,41,71) 62  DECLARE FILE INFIL=1090,25,U,IMEC 63  DEFINE FILE CFIL=SIZE=20,U,INREC 64  C 5 FIND OUT WHETHER TO PRINT PROFILE OUT 65  ALL =OPT(AA)* 66  CLOSE =OPT(C1)* 67  EVERY =OPT(E1)* 68  PRINT =OPT(L1)* 69  REPORT =OPT(R1)* 70  PRES =OPT(S1)* 71  THEORY =OPT(T1)* 72  IF(CLOSE) =SPREAD(2,56) 73  IF(NOT(EVERY)) =GO TO 74  75  EWNOT(1) = ' I1C' 76  EWNOT(2) = ' LUNED' 77  IF(LIM-THEORY) =IF FILE=0 78  IMER(1) = 0.0 79  K=0 80  C 81  SAVE FILE HEADER 82  HEAD(INFIL=I) (HEADER(1) = I,2) 83  HEAD(INFIL=2) (HEADER(1) = I,2) 84  C 9 FIND BEGINNING AND END OF EACH GROUP 85  10 READ(INFIL=99999, LABEL 86  IF(LABEL(1)) =EO.ELGO TO 25 87  DECOE(99999, LABEL) 88  800 FORMAT(A5) 89  DECOE(99999, LABEL) 90  863 FORMAT(A5) 91  GPST = GP(1) 92  IF(GPST.9E.9) = ' 100 TO 12 93  BEGIN(1) (BEGIN=BLIN(1)) 94  END(1) 95  LOCATE(K) = NS NOT 96  12 =0 97  15 =0 98  IF(I=0) = GO TO 20 99  IF(IGRP=GROUP(1)) = GPST + GPST +103 + GROUP(1)) = GO TO 15 100  C 101  20 IF (I=0) = GO TO 197 102  LG11 + 1 103  GGP=GROUP(L) + GPST 104  PSIN(L) = INREC-1 105  PRINT GPST- GROUP(L) = PSIN(L) 106  800 FORMAT (GROUP(1) = PSIN(L) AT RECORD 191 107  IF(LINE=END(L) = INREC-2 108  GO TO 10 109  25 IF (I=0) = END(L) = INREC-2 110  C 111  NOTE BEGINNING & END OF REFERENCE SIGNAL GROUP 112  INREC =1 113  K=0 114  GO 30 KX=1,L
**FILE**

```
114  30 IF(GND(JP(KK))NE+0)GO TO 32
115  GO TO 191
116  32 IF(NOT(LG(IN(KK)))
117  REF=LG(IN(KK))
118  KK=0
119  KLIM=-1
120  IN=J=J+1
121  IF(I==J)PRINT PRINT 906
122  906 FORMAT('FILES INTENSITY POINTS/';
123     - ' (VOLTS) FOUND BAD')
124  C     PRODUCE NEW-FILE FOR EACH LINE PRESENT
125  C     INITIALIZE THE FILE
126  C     35 KK=KK+1
127  C     36 IF(KK.GT.KLIM)GO TO 190
128  C     IF(GROUP(KK).EQ.'*)GO TO 35
129  C     38 IF(FAIL(KK).NE.0)GO TO 35
130  C     PFILE=CFILE+K
131  C     CREC=1
132  C     JS=END(GIN(KK))
133  C     JS=END(KK)
134  C     IF(JA-JA+1.GT.CSIZE)GO TO 190
135  DO 30 J=J+1,J=J+1
136  30 READ(I*FILE,J)LAHEL
137  C     WRITE(CFILE)CPECLAEL
138  C     DC=THE FILE PFILE(I1+3*111 EXP+1,UPREC)
139  C     WRITE(PFILE1)HEADER
140  C     NT=K
141  C     NT=K
142  C     NT=J
143  C     NT=I
144  C     NT=J
145  C     NT=J
146  C     NT=J
147  C     NT=J
148  C     NT=J
149  C     NT=J
150  C     NT=J
151  C     NT=J
152  C     NT=J
153  C     NT=J
154  C     NT=J
155  C     NT=J
156  C     NT=J
157  C     NT=J
158  C     NT=J
159  C     NT=J
160  C     NT=J
161  C     NT=J
162  C     NT=J
163  C     NT=J
164  C     NT=J
165  C     NT=J
166  C     NT=J
167  C     NT=J
168  C     NT=J
169  C     NT=J
170  C     NT=J
```

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* * * * * PROFILE * * * * *

171 C FIX R-LEAD & STANDARD DEVIATION OF TIMES FOR THIS 
172 C MONITOR INTENSITY.
173 C IF(IN.GT.1)GO TO 44
174 C WE MUST SO READ THE FILE THE FIRST TIME THROUGH
175 T=0.
176 TS=0.
177 DO 44 L=1,RF1,RF2+1
178 READ(INFILE,L)TF IP
179 T(AJ)=LJREF,AREF,BRF,RF2,RF2)
180 NTJ=NTJ+1
181 TS=TA
182 TS=TS+TA
183 42 CONTINUE
184 GO TO 50
185 C RECORD TIMES FOR ALL MONITOR SIGNALS NOT USED
186 FOR THIS PROFILE
187 DO 44 L=1,RF1,RF1-1
188 CALL LOCATE(L+1,RF1,LIST+49)
189 READ(INFILE,L)TE
190 TA=T+(INREF,AREF,BRF,TS5,TS4)
191 TS=TS+TA
192 NTJ=NTJ+1
193 TS=TS+TA
194 45 CONTINUE
195 50 IF(IN.LT.1)GO TO 192
196 CALL EMPTY(LIST)
197 TAVE=T/FLOAT(IT)
198 TSIGNA=(TS-TAVE*T)/FLOAT(IT-1)
199 TSIG=(TS-TAVE*T)/FLOAT(IT-1)*SPREAD
200 T=0.
201 TS=0.
202 NTJ=0
203 INREC=REF1
204 NSHOT=2
205 C GET ANOTHER CURVE UNLESS WE'RE AT THE END OF THE FILE
206 52 IF(INC.NE.0)GO TO 70
207 C IF WE HAVE DATA FOR THIS WAVELENGTH FIND AVERAGES
208 IF(IN.GT.0)GO TO 70
209 C IF WE HAVE DATA FOR THIS TIME GO RECORD IT
210 IF(J.GT.1)GO TO 81
211 C GO TO NEXT TIME
212 GO TO 90
213 C GET NEW CURVE
214 54 READ(CFILE,L>CREC,LABEL
215 DECODE(IS12,LAMDA,LANGA
216 812 FORMAT(IS12)
217 IF(AJS(LAMDA,LENGTH(JJ)) .LT. 0.021GO TO 58
218 IF(IJ.GT.0)GO TO 70
219 56 LENGTH(J)=LAMDA
220 N=0
221 N=0
222 C GET REFERENCE CURVE FOR THIS SHOT
223 58 NF=MINA(NF+1,10)
224 SHOT(J)=NF=SHOT
225 TAG(J,NF)=V
226 IF(INREC.LE.REFEND)GO TO 59
227 IF=REF1

ORIGINAL PAGE IS OF POOR QUALITY
GO TO 60
59 IF LOCATE(INREC+1,RECP+1,EOL,NSHOT) GO TO 61
       I=1
60 DO 61 I=RECP+1,RECF+1,0,NSHOT GO TO 63
61 IF LOCATE(INREC+1,RECP+1,EOL,NSHOT) GO TO 63
62 C NO MONITOR SIGNAL FOUND FOR THIS SHOT IN FILE!

63 IF (LOCATE(INREC+1,RECF,40+1,NOUT)) GO TO 63

64 READ(INFILE,INREC+1)

65 C RECORD TIME AT EXT INTENSITY

66 C IF TIME FOR THIS MONITOR INTENSITY IS MORE THAN

67 1.73 (OR 1.6: UNDER *C* OPTION) SIGMA FROM THE MEAN:

68 C THE MONITOR SIGNAL IS BAD AND WE DISCARD THIS POINT.

69 C THIS SHOULD BE ASSUMING A GAUSSIAN DISTRIBUTION:

70 C DELETE ABOUT 84 (OR 11%) OF THE POINTS.

71 C THIS SHOULOS ASSUME A GAUSSIAN DISTRIBUTIO:

72 C DELETE ABOUT 86 (OR 11%) OF THE POINTS.

73 C IF((TA-TAVER,T)/TSIG) GO TO 65

74 C POOR=POOR+1

75 C IF (.NOT.EVERY) GO TO 62

76 C FOUND ONE MORE CURVE FOR THIS LEVEL...RECORD

77 65 N=N+1

78 C IF(N-5=(N-5)) GO TO 16

79 C INT(N)=INT(N)+1

80 C IF (.NOT.EVERY) GO TO 52

81 C IF((TA-TAVER,T)/TSIG) GO TO 65

82 C POOR=POOR+1

83 C IF (.NOT.EVERY) GO TO 52

84 C IF((TA-TAVER,T)/TSIG) GO TO 65

85 C FOUNO ONE MORE CURVE FOR THIS LEVEL...RECORD

86 C INT(N)=INT(N)+1

87 C IF(.NOT.EVERY) GO TO 52

88 C IF((TA-TAVER,T)/TSIG) GO TO 65

89 C POOR=POOR+1

90 C IF (.NOT.EVERY) GO TO 52

91 C IF((TA-TAVER,T)/TSIG) GO TO 65

92 C POOR=POOR+1

93 C IF (.NOT.EVERY) GO TO 52

94 C IF((TA-TAVER,T)/TSIG) GO TO 65

95 C POOR=POOR+1

96 C IF (.NOT.EVERY) GO TO 52

97 C IF((TA-TAVER,T)/TSIG) GO TO 65

98 C POOR=POOR+1

99 C IF (.NOT.EVERY) GO TO 52

100 C IF((TA-TAVER,T)/TSIG) GO TO 65

101 C POOR=POOR+1

102 C IF (.NOT.EVERY) GO TO 52

103 C IF((TA-TAVER,T)/TSIG) GO TO 65

104 C POOR=POOR+1

105 C IF (.NOT.EVERY) GO TO 52

106 C IF((TA-TAVER,T)/TSIG) GO TO 65

107 C POOR=POOR+1

108 C IF (.NOT.EVERY) GO TO 52

109 C IF((TA-TAVER,T)/TSIG) GO TO 65

110 C POOR=POOR+1

111 C IF (.NOT.EVERY) GO TO 52

112 C IF((TA-TAVER,T)/TSIG) GO TO 65

113 C POOR=POOR+1

114 C IF (.NOT.EVERY) GO TO 52

115 C IF((TA-TAVER,T)/TSIG) GO TO 65

116 C POOR=POOR+1

117 C IF (.NOT.EVERY) GO TO 52

118 C IF((TA-TAVER,T)/TSIG) GO TO 65

119 C POOR=POOR+1

120 C IF (.NOT.EVERY) GO TO 52

121 C IF((TA-TAVER,T)/TSIG) GO TO 65

122 C POOR=POOR+1

123 C IF (.NOT.EVERY) GO TO 52

124 C IF((TA-TAVER,T)/TSIG) GO TO 65

125 C POOR=POOR+1

126 C IF (.NOT.EVERY) GO TO 52

127 C IF((TA-TAVER,T)/TSIG) GO TO 65

128 C POOR=POOR+1

129 C IF (.NOT.EVERY) GO TO 52

130 C IF((TA-TAVER,T)/TSIG) GO TO 65

131 C POOR=POOR+1

132 C IF (.NOT.EVERY) GO TO 52

133 C IF((TA-TAVER,T)/TSIG) GO TO 65

134 C POOR=POOR+1

135 C IF (.NOT.EVERY) GO TO 52

136 C IF((TA-TAVER,T)/TSIG) GO TO 65

137 C POOR=POOR+1

138 C IF (.NOT.EVERY) GO TO 52

139 C IF((TA-TAVER,T)/TSIG) GO TO 65

140 C POOR=POOR+1

141 C IF (.NOT.EVERY) GO TO 52

142 C IF((TA-TAVER,T)/TSIG) GO TO 65

143 C POOR=POOR+1

144 C IF (.NOT.EVERY) GO TO 52

145 C IF((TA-TAVER,T)/TSIG) GO TO 65

146 C POOR=POOR+1

147 C IF (.NOT.EVERY) GO TO 52

148 C IF((TA-TAVER,T)/TSIG) GO TO 65

149 C POOR=POOR+1

150 C IF (.NOT.EVERY) GO TO 52

151 C IF((TA-TAVER,T)/TSIG) GO TO 65

152 C POOR=POOR+1

153 C IF (.NOT.EVERY) GO TO 52

154 C IF((TA-TAVER,T)/TSIG) GO TO 65

155 C POOR=POOR+1

156 C IF (.NOT.EVERY) GO TO 52

157 C IF((TA-TAVER,T)/TSIG) GO TO 65

158 C POOR=POOR+1

159 C IF (.NOT.EVERY) GO TO 52

160 C IF((TA-TAVER,T)/TSIG) GO TO 65

161 C POOR=POOR+1

162 C IF (.NOT.EVERY) GO TO 52

163 C IF((TA-TAVER,T)/TSIG) GO TO 65

164 C POOR=POOR+1

165 C IF (.NOT.EVERY) GO TO 52

166 C IF((TA-TAVER,T)/TSIG) GO TO 65

167 C POOR=POOR+1

168 C IF (.NOT.EVERY) GO TO 52

169 C IF((TA-TAVER,T)/TSIG) GO TO 65

170 C POOR=POOR+1

171 C IF (.NOT.EVERY) GO TO 52

172 C IF((TA-TAVER,T)/TSIG) GO TO 65

173 C POOR=POOR+1

174 C IF (.NOT.EVERY) GO TO 52

175 C IF((TA-TAVER,T)/TSIG) GO TO 65

176 C POOR=POOR+1

177 C IF (.NOT.EVERY) GO TO 52

178 C IF((TA-TAVER,T)/TSIG) GO TO 65

179 C POOR=POOR+1

180 C IF (.NOT.EVERY) GO TO 52

181 C IF((TA-TAVER,T)/TSIG) GO TO 65

182 C POOR=POOR+1

183 C IF (.NOT.EVERY) GO TO 52

184 C IF((TA-TAVER,T)/TSIG) GO TO 65

185 C POOR=POOR+1

186 C IF (.NOT.EVERY) GO TO 52

187 C IF((TA-TAVER,T)/TSIG) GO TO 65

188 C POOR=POOR+1

189 C IF (.NOT.EVERY) GO TO 52

190 C IF((TA-TAVER,T)/TSIG) GO TO 65

191 C POOR=POOR+1

192 C IF (.NOT.EVERY) GO TO 52

193 C IF((TA-TAVER,T)/TSIG) GO TO 65

194 C POOR=POOR+1

195 C IF (.NOT.EVERY) GO TO 52

196 C IF((TA-TAVER,T)/TSIG) GO TO 65

197 C POOR=POOR+1

198 C IF (.NOT.EVERY) GO TO 52

199 C IF((TA-TAVER,T)/TSIG) GO TO 65

200 C POOR=POOR+1

201 C IF (.NOT.EVERY) GO TO 52

202 C IF((TA-TAVER,T)/TSIG) GO TO 65

203 C POOR=POOR+1

204 C IF (.NOT.EVERY) GO TO 52
***** PROGRAM *****

205 SUM=SUM+SPJ(I)  
206 I=I+1  
207 CONTINUE  
208 NUM=0  
209 IF(N+1)179,75,73  
210 73 INTAV(J)=SUM/N  
211 SIG(J)=SUM-SUM+INTAV(J)*(N-1)  
212 C DISCARD POINTS ONLY ONCE  
213 C IF DELETE)GO TO 76  
214 C THROWS OUT ALL POINTS FURTHER AWAY THAN 1.8 SIGMA  
215 C THIS SHOULD DELETE ABOUT 6% OF THE POINTS.  
216 74 CONTINUE  
217 C RECALCULATE MEAN & STANDARD DEVIATION IF  
218 C WEREThrown OUT ANY MORE POINTS  
219 C IF(REPORT)GO TO 71  
220 GO TO 70  
221 70 INTAV(J)=SUM  
222 SIG(J)=0  
223 76 SIG(J)=SIGT(SIG(J))  
224 IF(1.0+INTAV(J))<LT_5.0*.32)GO TO 144  
225 ERROR(J)=ERROR(J)/(INTAV(J)/SIG(J))  
226 AVERAGE=ERROR(J)  
227 LIMITs=LIMIT(J)+1  
228 J=J+1  
229 GO TO 88  
230 88 IF(REPORT)J=J+1  
231 FOUND=FOUND+1  
232 IF(CCrear.GT.CECD)GO TO 81  
233 IF(J+1.LE.LINEP)GO TO 95  
234 J=J-1  
235 PRINT 950 J  
236 900 FORMAT(*MORE THAN*** WAVELENGTHS; REST DISCARDED ****)  
237 C DO NOT OTHER RECORDING OR PRINTING IF MORE  
238 C THAN 40% OF THE POINTS WERE THROWN OUT  
239 81 FOUND=FOUND+1  
240 IF(FOUN0D>50+POOR+OUT+FAPLY+LATE)  
241 IF(FOUND.LT.50)GO TO 195  
242 PCE=100*1/2.0+POOR+OUT+EAPLY+FAPLY+LATE+HAD)  
243 J=J-1  
244 IF(JALL)GO TO 82  
245 IF(PCE+GT.40)GO TO 92  
246 92 IF WAVELENGTH IS IN UV DIVIDE BY TWO  
247 C TO COMPENSATE FOR INCORRECT MCHEOARSON SCALE  
248 82 IF(LENGTH(I).GT.30000)GO TO 96  
249 DO 84 J=1  
250 84 LENGTH(I)=.5*LENGTH(I)  
251 86 IF(PRINT60 GO TO 87
***** PROFILE *****

PRINT B13,PFILPFILE+INTERF+FOUNDF+PCENT
B13 FORMAT(+I12,I13,F8.3,I19+I19,F1.19)
GO TO 91
C
PRINT PROFlILE IF REQUESTED TO
C
97 LINES=LINES+J+17
IF (LINES.LT.5) GO TO 88
IF (LINES+5) GO TO 99
88 PRINT B14,HEA4ER
B14 FORMAT(+I12A6+I12A6)
C
LINES=LINES+19
C
99 PRINT B15,TAVER,TSEQA+INTERF+FILE+FOUNDF+NONOM+
   - POOR+EVENT+OUT+EARLY+LATE+BAD+EVENT+POINTS
B15 FORMAT(I12,TIME=F8,5.+F8.5+MSEC+MONITOR=+
   - F6.4+V+FILES*I13+*FI30+/
   - T10+I3+1+POINTS FOUND+/
   - T10+I3+1+POOR MONITOR SIGNALS (N)+/
   - T10+I3+1+HAU POOR MONITOR SIGNALS (P)+,2A6/
   - T10+I3+1+OUT OF MONITOR RANGE (O)+/
   - T10+I3+1+TIES TOO EARLY (E)+/
   - T10+I3+1+TIES TOO LATE (L)+/
   - T10+I3+1+SIGNS TOO FAR FROM MEAN (B)+,2A6/
   - T10+I3+1+ACTUALLY USED+/
C
PRINT B16
B16 FORMAT('AVELENTH+INTER=ITY+ERROR'+T30+POINTS FOUND+/
   - +ANGSTROMS+VOLTS+))
IHEAD=1
DO 90 I=1,J
III=I+AA(I)
90 PRINT B!B+LLENGTH[I,1]+TAV[I,1]+SIG[I,1]+ERROR[I,1],
   - (SHOT[I,1],TAU[I,1],IL=IH+IIT
A18 FORMAT(F10,2,F9.5,+F7.5+F6.0,T35+I19
   - 2X,1014,F14+I1)
AVERAGE=AVEvar(J)
PRINT B21,
B21 FORMAT(T17,*,AVERAGE SIGMA '+F6.0+T35+I19)
C
WRITE IFORMATION TO FILFS
C
IF (J+J+LENGTH(J+1)=J+DO
WRITE(PFILE+PREC)+TREF+LENGTH+TAV+SIG
IF (THEORAT) WRITE(TFILE,']FC)LOCK, +59+LENGTH+INEXP
GO TO 96
C
REPORT ONE PROFILE DISCARDED
C
92 NOPROF=NOPROF+1
IF (I=0,PRINT) GO TO 96
C
GO TO NEXT PAGE IF THIS PAGE HAS A PROFILE ALREADY
C
IF (IHEAD+0) PRINT 814
PRINT B23,INTERF+PCENT+NONOM+POOR+OUT+EARLY+LATE+BAD
B23 FORMAT(' MONITOR =+F5J,15+X DISCARDED+/
   - -I4+1+II+I4+1+P+I4+1+O+I4+1+E+I4+1+L+I4+1+8+/
   - +IHEAD=1
GO TO 96
C
REPORT ERRORS OCCURRING WITHIN MAJOR LOOP
C
100 PRINT 901,GROUP(KK),J,A,B,CFILE,FSIZE
901 FORMAT(' GROUP =15+USES RECORDS I4+ THROUGH I4+')
******* PROFILE *******

399 1...too many POINT, FILE, I4/
400 \ WHICH HOLDS I1*** RECORDS *)
401 \ TO 97
402 192 PRINT 902, INTREF
403 902 FORMAT(' MONITOR ztel.3,1: TOO FEW VALID MONITOR SIGNALS')
404 \ TO 97
405 193 INTREF=1
406 \ PRINT 903, 1(TTEND(I),=I),,87(I),,1(l,2),,(TEMP(I),=I,2.02)
407 903 FORMAT(' IN Valid DATA IN RECORDS, GROUP '; RANgE, SCALE, F6.3,
408 \ -` SHOT', l4/
409 \ 1X,6F8.5/1X,8F8.5)
410 194 FOUND=FOUND+1,MONON=PONR+OUT,EARLY,LATE
411 195 PRINT 904,J,SHOTS(J),,TAS(J),,80(J),,1(=,1)
412 904 FORMAT(' ERROR ON POINT',',13,'(**F6.2,' A)AV INTENS=',,F6.5/
413 \ -' FOUND',13,' POINTS USING THE FOLLOWING',13,11')
414 \ PRINT 810,LETH(J),,INTAV(J),,SIG(J),,EPOJO(J),
415 \ (SHOT(J),,TAS(J),,I=1),
416 \ ' PRINT' 905
417 905 FORMAT('X/I PREVIOUS POINTS...')
418 \ PRINT 915,TAVERTSIGIA,FILE,FILE,FOIN,MONON,
419 \ -' PRINT,AVENO=OUT,EARLY,LATE,GAB,AVNEPT,POINTS
420 \ TO 97
421 196 KKK=LISH
422 \ PRINT 906,KKK,J,INTAV(J),,SHOTS(J),,1(=,1)
423 906 FORMAT(' CURVES FOUND FOR POINT',',13,
424 \ -' OF PROFILE',**F6.5/
425 \ \-INCLUDING THESE=',10(15,1X,11')
426 \ TO 97
427 \ TRY TO FIND 10 PROFILES IN ALL
428 96 IF(PREC.LT.14) AND, (PCENT.LT.40 .OR. PREC.LT.4) GO TO 90
429 \ TO 97
430 \ FINISH FILL
431 \ REPORT ERRORS OCCURRING BEFORE MAJOR LOOP
432 \ IF==PREC=1,4)WRITE(PFILL,PREC=1)
433 \ =PREC=3
434 \ PRINT 830,1,X
435 \ 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 

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* * * * * PROFILE (TIM) * * * * *

2UB53JIM:OHKA3PE&31,T1:

FUNCTION TIM(INT,A,B,S)

C

PURPOSE...

TO FIND THE TIME CORRESPONDING TO A GIVEN INTENSITY

C

USAGE...

T=TIM(INT,A,B,S)

C

TIM R=O CALCULATED TIME

C

INT R=I GIVEN INTENSITY

C

A R=I ARRAY OF TIMES

C

B R=I ARRAY OF CORRESPONDING INTENSITIES

C

$90 S=I EXIT USED IF DESIRED INTENSITY IS OUTSIDE THE

C

RANGE OF THE INTENSITIES IN ARRAY B

C

$90 S=I EXIT USED IF GIVEN DATA IS INVALID

C

( I.e., TIMES NOT INCREASING OR INTENSITIES NOT

C

DECREASING)

C

METHOD...

LINEAR INTERPOLATION.

C

REAL INT

DIMENSION A(B),N(B)

IF(A(B).LT.A(I)) OR (B(B).GT.B(I)) RETURN 5

C

IF((INT.LT.B(I)) OR (INT.GT.B(I))) RETURN 4

C

10 CONTINUE

IF(B(B).EQ.B(I-1)) GO TO 15

11 TIM=A(I)

12 RETUW

13 TIM=A(I-1)-A(I-1)*(B(I)-INT)/(B(I)-B(I-1))

14 RETURN

15 END

W-EXEC
REAL FUNCTION INTENS(TIME, A, B, $90, $90)

PURPOSE...
TO FIND THE INTENSITY FOR A GIVEN TIME

USAGE...

Y = INTENS(TIME, A, B, $90, $90)

TIME R I GIVEN TIME
A R I SAMPLE TIMES
B R I SAMPLES (INTENSITIES)
$90 S O ERROR EXIT TAKEN IF GIVEN TIME TOO EARLY
$90 S O ERROR EXIT TAKEN IF GIVEN TIME TOO LATE

METHOD...
LINEAR INTERPOLATION

DIMENSION A(B), H(B)

IF (TIME .LT. A(1)) RETURN 4
IF (TIME .GT. A(N)) RETURN 5
DO 10 I = 2, N
10 CONTINUE
IF (A(I) .NE. A(I-1)) GO TO 12
RETURN

IF (A(I) .LE. TIME .LT. A(I-1)) GO TO 15
INTENS = (H(I) - H(I-1)) * (A(I) - TIME) / (A(I) - A(I-1))
RETURN

END
SUBROUTINE LOOKUP(NUMBER, LIST, S)

NAME...  TABLE LOOKUP

PURPOSE...  TO CREATE AND LATER FIND ENTRIES IN A SORTED TABLE OF INTEGERS.

USAGE...

CALL EMPTY (LIST)  MARK LIST AS EMPTY

LIST  I:10  WORK ARRAY (SAVED BETWEEN CALLS)

CALL ENTER (NUMBER, LIST, S)  ADD NUMBER TO LIST

CALL LOOKUP (NUMBER, LIST, S)  SEARCH FOR NUMBER IN LIST

DIMENSION LIST(50)

IF(List(2).LT.3) RETURN

DO 20  I=3, LIST(2)

20  IF(List(I).EQ. NUMBER) RETURN 3

IF(Number. EQ. NUMBER) RETURN 3

END

ENTRY ENTER(NUMBER, LIST, S)

LIST(I)= NUMBER

RETURN

ENTRY EMPTY(LIST)

LIST(2)=2

RETURN

END
**PROFILE (YES, NO)**

```
* PURPOSE...
  TO GET A YES OR NO ANSWER TO A QUESTION FOR
  AN INTERACTIVE PROGRAM.

* CALLING SEQUENCE...

  IF(YESNO('SHALL I SKIP OPTIONAL PART?', $90)) GO TO 40
  CONTINUE

  IF(YESNO('SHALL I REPEAT OPTIONAL PART?')) GO TO 20

  <REST OF PROGRAM>

  <SPECIAL SECTION FOR END-OF-FILE RETURN>

  THE QUESTION MUST END WITH THE STOP CHARACTER Q (WHICH
  ISN'T PRINTED); IF THE QUESTION IS FOLLOWED BY A
  WHOLE STRING OF TRASH AND THE PROGRAM MAY BLOW UP, THE
  QUESTION WILL BE PRINTED; AND THE TELETYPOE WILL WAIT ON
  THE SAME LINE FOR THE USER TO TYPE HIS ANSWER; THAT
  ANSWER MAY START IN ANY COLUMN AND CONSIST OF ANY NON-
  AFFIRMATIVE OR NEGATIVE WORD (I.E., ANY ONE I COULD THINK
  OF WHEN I WROTE IT). THE USER MAY SUPPLY AN EOF RETURN
  ADDRESS AS THE SECOND ARGUMENT, BUT THIS IS OPTIONAL
  (THE PROGRAM WILL FIND IT'S WAY BACK EITHER WAY).

  CONTENTS OF ALL REGISTERS EXCEPT AO ARE SAVED.

* ERROR CONDITIONS...

  IF THE USER'S ANSWER IS A BLANK LINE OR A CHARACTER
  STRING THE PROGRAM DOESN'T RECOGNIZE (IT CAN BE FOILED)
  IT TRIES AGAIN, PRINTING ONLY 'WHAT?'. IT WILL REPEAT THE
  ORIGINAL QUESTION ONE TIME IN FOUR.

  IF THE RESPONSE IS EOF, THE PROGRAM USES THE ALTERNATE
  RETURN ADDRESS, IF SUPPLIED, THIS CAN BE USED FOR
  INSTANCE TO TERMINATE THE PROGRAM OR RE-ASK A
  PREVIOUS QUESTION (THIS WAY YOU DON'T HAVE TO RE-RUN THE
  WHOLE PROGRAM); IF THE ANSWER IS ANY OTHER CHARACTER
  STRING BEGINNING WITH A, THE SYSTEM THINKS THE PROGRAM
  IS TRYING TO READ A CONTROL CARD. AND ALLOWS NO FURTHER
  READS. IN THIS CASE, OR IF EOF IS ENCOUNTERED AND NO
  EOF RETURN ADDRESS HAS BEEN SUPPLIED, THE PROGRAM PRINTS
  A SHORT MESSAGE AND EXITS.
```
********** PROFILE (YES 10) **********

57 $0) LIT.
59 $1) AAS.
60 $2) SA X11 RETR.
61 $3) DS A1 SAVE.
62 $3) DX A3 SAVE.
63 $4) SX R1 SAVE.
64 $4) SY R1 SAVE.
65 $5) E EDIT.
66 $6) LX X11 RETURN.
67 $7) LH1 A0+x11 SET FIRST WORD FOLLOWING QUESTION POINTER.
68 $8) A=U A0.0722008 COMPARE TO JUMP INSTRUCTION.
69 $9) S A0.09 PRESENT THIS INDICATES PRESENCE OF QEOF ADDRESSES.
70 $A) L A0.0+x11 GET ADDRESS OF USER'S QUESTION.
71 $B) LA X11 ENQ. 
72 $C) LJ X11 EDIT. END EDIT MODE & RESTORE REGISTERS.
73 $D) LU A4.3 INITIALIZE QUERY COUNTER.
74 $E) ASK LU A0. READ.
75 $F) READ LU A1 BLANKS.
76 $G) LXX A0.1 PREVIOUS INPUT DOES NOT CONFUSE THE ISSUE.
77 $H) LXX+U A2 INPUT.
79 $J) BT A2.0+x1.
80 $K) ER TENDS.
81 $L) LSS L A0.4 IS REPLY ACTUALLY IN 'INFORM' FORMAT?
82 $M) JP A0 EXAMINE.
83 $N) LA A0 RFAN PKT+1 INPUT IS IN 'INFORM' FORMAT... REREAD.
84 $O) EX EXAMINE.
85 $P) EXAMINE LX1U A2.0 INITIALIZE INDEX REGISTERS.
86 $Q) LS1 A3 INPUT.
87 $R) L A0 INPUT.
88 $S) TE U A3.5 05 IS A BLANK.
89 $T) J MATCH.
91 $V) LA A3 BLANKS.
92 $W) SHE A1 INPUT+1 A2 FIND FIRST WORD NOT ENTIRELY BLANKS.
93 $X) J AGAIN.
94 $Y) L A0 INPUT+1 A2 GET THAT FIRST NON-BLANK CHARACTER.
95 $Z) LX A3.5 FIGURE OUT WHICH CHARACTER IT IS.
96 $AA) LOOP A0.0+x (07220000000000). MACK OUT LAST 5 CHARACTERS.
97 $AB) TE A1. (00500000000000). IS IT A BLANK?
98 $AC) J LOAD "40...00 LOOK FOR A MATCHING ONL.
99 $AD) LSS L A0.6 YES... TRY NEXT CHARACTER.
100 $AE) JED A3. LOOP.
101 $AF) LOAD DL A0 INPUT+1 A2 GET THE MESSAGE.
102 $AG) EX MOVE A3.
103 $AH) LH+U A3.5.
104 $AI) MATCH LX U R1. WROUN.
105 $AJ) SE A0 TABLE+ A2 LIST WORDS.
106 $AK) J AGAIN.
107 $AL) L A0. A2 FOUND A MATCH... ASK AGAIN.
108 $AM) LS L A0.35 LAST IT IS 1 IF 'YES' 0 IF 'NO'平常
109 $AN) SSL A0.35 (SINCE A2 HAS BEEN INCREMENTED)
110 $AO) SJ RESTORE.
111 $AP) TZ PRESENT.
112 $AQ) J 2X11.
113 $AR) J 3X11.
*** PROFILE (YES NO) ***

AGAIN L=U  
A0,AAGAIN,
   "IT'S THE ONLY OPTION ONLY ONE TIME"
115  JD  A0,REMEM
116  "OUT OF FOUR"
117  L=U  A0+3
118  JD  ASK:
119  E0F  R=STORE  
   "RID OF FILE RETURN", RELOAD REGISTERS
120  THE  PRESENT  
   "RETURN ONLY IF EOF RECOMMENDED"
121  JR  A0+11  RETURN TO EOF ADDRESS
122  L  A0+PF 1\PRG\17\PRGN\C'  
123  EM  PRINTS  
   "NON-EOF CONTROL CARD ENCOUNTERED"
124  JR  "EXIT"  
   "WE'RE FORCED TO EXIT"
125  RESTORE RES 1  
   "ROUTINE FOR RESTORING REGISTERS"
126  DL A1,SAVE  
127  DL A3,SAVE3  
128  LR R1,SAVER1  
129  LR R14,SAVER14  
130  LX XI,RETURN  
131  J  *RESTORE*
132  S(0)  
133  WBCA  *YESNO*
134  RETURN 0  
135  SAVE RES 2  
136  SAVEL RES 2  
137  SAVEL RES 1  
138  SAVEL RES 1  
139  PRESENT 1  
140  PACKET ESPX  
   "A LINE 'YES', 'NO' IF USER FORGETS THE STOP"
141  "A CHARACTER, A 0 IS THE CHARACTER MOST LIKELY TO BE FOUND BY ACCIDENT"
142  PRCTLN  "CONTROL CARD FORCES PROGRAM EXIT"
143  PRENT EQU 5\PRCTLN  "NUMBER OF WORDS IN MESSAGE"
144  PF  FORM 12,6,18  
145  READPAC PF 1\2\LNE  
146  +  EOF\INPUT  
147  LINE RES 24  
148  AGAIN PF 1\1\QUESTION  
149  +  EOF\INPUT  
150  QUESTION  "WHAT?"
151  INPUT RES 14  
152  BLANKS  
153  "THIS ENSURES THE SECOND CARD LOADED HAS"  
154  "BLANKS IF THE LAST WORD IN INPUT HAS INSTR."  
155  MOVE LSDL A0+30  
156  LSDL A0+21  
157  LSDL A0+11  
158  LSDL A0+12  
159  LSDL A0+5  
160  NP+  
161  "YES"  
162  "NO"  
163  "Y"  
164  "N"  
165  "OUI"  
166  "NON"  
167  "ALRIGH"  
168  "NDRE"  
169  "YES"  
170  "NAW"  

ORIGINAL PAGE IS OF POOR QUALITY
***** PROFILF (YESNO) *****

171  'YEA'  *
172  'JA'   *  
173  'NEIN' *
174  'JA'   *  
175  'NEIN' *
176  'YET'  *  
177  'DA'   *  
178  'NOT'  *  
179  'DA'   *  
180  'NOT'  *  
181  *OK*   *
182  *OK*   *  
183  *OKAT* *
184  *NI*   *
185  *SI*   *
186  #ACCOUNT EQU 5-TABLE  THE NUMBER OF WORDS IN THE TABLE
187  END  *    

N=EJECT
***** VPLOT *****

C NAME... VPLOT
C PURPOSE... TO PRODUCE A PRINTER-PRINT OF THE EXPERIMENTAL LINE PROFILE
C PRODUCED BY PROGRAM 'PROFILE'.
C
C USAGE...
C OR VPLOT OR J,VPLOT
C <FILE #1> (FREE) NUMBER OF 1ST FILE TO PLOT
C <FILE #2> (FREE) NUMBER OF 2ND FILE TO PLOT
C EOF
C
C OPTIONS:
C T PLOT IS TO BE ON A TERMINAL, SO IT USES ONLY
C COLUMNS 1-72.
C
C INPUT...
C DATA FILE AS PRODUCED BY PROGRAM 'PROFILE'
C SUBPROGRAMS REQUIRED...
C BEGIN+OPT+NUMBER
C
C PARAMETER LIMEXP=36
C LOGICAL OPT+RATCH
C REAL INT+LENGTH,INTAV,INCR+NL
C DIMENSION LINE(105),HEADER(24),LENGTH(LIMEXP),INTAV(LIMEXP),
C SIG(LIMEXP)
C DATA X(1)/EOF/XMARK/*+/IZERO/*+/IONE/*+/JCOL=X(1)*INCX
C CALL BEGIN(1,VPLOT,1.12(1)
C IDIF=IONE-IZERO
C
C FIND FILE AND READ FILE HEADER
C S NFILE=NUMBER(FILF NUCN?7.29,599)
C DEFINE FILE N FILE(14,1+3*LIMEXP+1+1+1)
C READNFILE(14)(HEADER,4)
C DECIDE WHETHER SMALL ('T' OPTION) OR LARGE GRAPH
C ICOL=11
C BATCH=N9T+OPT('T')
C IF(BATCH)ICOL=101
C COL=FLOAT(ICOL-1)
C LAST="*
C IF(BATCH)LAST=MARK
C
C READ A PROFILE
C B IF(NREC.LE.14)GO TO 11
C I=MAX(0,NREC-2)
C 10 PRINT 805?1
C 805 FORMAT(I1X/13," PROFILES")
C PRINT 808
C 808 FORMAT(1H1)
C GO TO 5
C 11 READNFILE(NREC)INTMON+LENGTH,INTAV,SIG
C IF(INTMON.EQ.1)GO TO 10
C
C SET UP SCALING PARAMETERS
***** vPlT *****
***** THEOR Y *****

NAME...  
THEORY  

PURPOSE...  
TO FIND THE VALUES OF THE PARAMETERS (LINE POSITION,  
LINE INTENSITY, LINE WIDTH OR ELECTRON DENSITY, AND  
BACKGROUND INTENSITY) WHICH BEST FIT THE THEORETICAL  
PROFILE TO THE EXPERIMENTAL DATA.  

USAGE...  
Q.THEORY OR QXOT.THEORY  
<Data>  
OPTIONS:  
'D' DELETE SOME POINTS  
'N' PRINT DIAGNOSTIC INFO FOR EVERY POINT REQUESTED  
'S' SKIP SOME POINTS  
'RE' REQUEST RE-AIMING PROFILES AS NEEDED  
  
DATA IMAGES;  
CARD 1:(FREE) INPUT FILE 'NUMBER'  
CARD 2:(FREE) OUTPUT FILE 'NUMBER' (ONLY WITH 'T' OPTION)  
CARD 3:(FREE) WAVELNGTHS TO DELETE (ONLY WITH 'D' OPTION)  
CARD 4:(FREE) LII LNUMBER  
  
CARD 5:(FREE) CARD 6:(FREE) CARD 7:(FREE) CARD 8:(FREE) CARD 9:(FREE) CARD 10:(FREE)  
  
SUBPROGRAMS REQUIRED...  
 fetchs obtains the normalized line profile and theoretical  
profile for the line.  
ZXPOW (FROM IHSL) GENERAL FUNCTION MINIMIZER, USED TO  
FIND THE NONLINEAR PARAMETERS WHICH MINIMIZE THE SUM  
of the squares of the deviations of the experimental  
points from the theoretical profile.  
Funct3 has the theoretical profile calculated for the  
current parameters, and obtains the mean square  
devoiation of the data from the new profile.  
Funct2 finds the correlation matrix of the best-fit  
parameters, using the second partial derivatives  
of the error function.  
Iplot plots the experimental data and theoretical profile.
****** THEORY ******

57 C
58 C USE I. THE OFF-LINE PLOTTER.
59 C
60 C METHOD...
61 C
62 C "SL ROUTINE 'EXPRJL' FINDS THE MINIMUM OF THE ERROR
63 C FUNCTION (THE SUM OF THE SQUARES OF THE DEVIATIONS OF THE
64 C FITTED FUNCTION FROM THE DATA POINTS) AS A FUNCTION OF
65 C ITS TWO 42-LINEAR PARAMETERS. THE COVARIANCE MATRIX IS
66 C COMPUTED AS THE INVERSE OF THE MATRIX OF SECOND
67 C DERIVATIVES OF THE ERROR FUNCTION NEAR ITS MINIMUM.
68 C
69 C INCLUDE D90H.LIST
70 C INCLUDE GROUP.LIST
71 C COMMON /FOCOM/ ARG2(2)
72 C EXTERI AL FUNCTION
73 C REAL I4X
74 C LOGICAL YESNO,KEEP,OUT=OPT,LATER=ALL
75 C DEFSION HEADER(24),M14044,NA(25)
76 C DEFAULT I4X
77 C INTEGER OUTFIL,OUTFMT,OUTREC,*FILE,ONPER,TFMT
78 C DATA (E,RN,CL0P,CL04R:,E ID, FPSRC, EPS1,OUTFMT,TFMT
79 C - 1 E-4, 1 E-4, 3 E-6, 1 E-6 */2, .02, 700, 503/
80 C DATA LINEP
81 C - 0/
82 C DATA (LABELCI),I=1,10) /*HE II '*,46A6 ',*HE II *,1640 ',
83 C /*HE II *,1215 /*HE II *,1025 ',*HE II *,45P6 */
84 C PRINT(OUT)IF(300,AS(25),5)
85 C CALL BEGIN('THEORY 1.74 *)
86 C GET OPTIONS FROM CONTROL CARD
87 C OUT=OPT('IT)
88 C LATE=NOT.OPT('IT)
89 C ALL=NOT.OPT('IT)
90 C
91 C SET UP PARAMETERS
92 C IF(LINEP.NE.0 PRINT 820
93 C OFILE=NUMBER(*INPUT FILE)*/7,29.96)
94 C DEFIF FILE OFILE(13,ISIZE,JMREC)
95 C IF(OUTFIL.EQ.9L(R('OUTPUT DESIGN FILE')*/7,29.96)
96 C IF(OUT)DEFINE FILE OUTFIL(13,ISIZE,JOUTREC)
97 C KEEP=I4X,OPT('IT)
98 C IFKIEP=20 TO 15
99 C PRINT 900
100 C FORMAT(' ENTER WAVELENGTHS TO DELETE')
101 C READ(401,EN=13)(BAG(IdBAD)+BAG=1,2)
102 C FORMAT(30)
103 C NBAD=26
104 C NBAD=0, NAD=-1
105 C IF(NBAD.0) KEIPE TRUE.
106 C CALL FETCHS(ARGONE+(LINE)
107 C READ(DFILE11)EXT=HEADER
108 C IF(INPFILE.NE.TPMT160 TO 97
109 C IF(OUTFIL.EQ.1OUTFMT=HEADER
110 C PRINT 820-HEADER
111 C FORMAT(11,12,AT,1,12,AT)
112 C LINEP=2
113 C READ DATA FOR HFX MONITOR INTENSITY
114 C 20 READ(DFILE*8REC)BLOCK,NSHOT,LENGTH,INEXP
***** THEORY *****

114  
115  DO 22 I=1,NARG
116  22 ARI(I)=AUSHQWI)
117  LINES(I)=LENF
118  IF((A(F(I))+BASEE,LT.,2*LENGTH(I)-LENGTH(NU)) .OR.
119  IF(ABS(LENGTH(NU)-BAD(I)>.LT. .001)GO TO 92
120  NU1=1
121  NU2=NU
122  IF(KEEP)GO TO 50
123  NU1=0
124  NU2=NU+1
125  IF(NU1.GE.NU2)GO TO 49
126  DO 44 I=1,NARG
127  44 CONTINUE
128  NU2=NU2-1
129  IF(NOU.E.4U2)GO TO 40
130  DO 48 I=1,NARG
131  48 CONTINUE
132  NU2=NU
133  PRINT LABEL'IG
134  TOTAL=0
135  BOT=LENGTH(NU1)
136  TOP=LENGTH(NU2)
137  AVG=0.
138  DO 51 K=1,NU
139  51 AVG=AVG+LENGTH(KU)
140  AVG=AVG/N
141  IF(NU1.GE.NU2)GO TO 53
142  PRINT 830,TOTAL,REPOIT
143  KSHOT=N
144  N=NSHOT(KU)
145  TOTAL=TOTAL+N
146  DO 51 KSHOT=1,N
147  PRINT 830,TIME,MONIOT,..F6.35,MONITOR:..F6.4/
***** Theory *****

171 IF (ALL) GO TO 65
172 IF (1.0*FIT**2+SIG**2) GO TO 55
173 LINESLINE = 11.
174 GO TO 20
175 C CHECK THAT THE SYSTEM ISN'T DEGENERATE
176 IF (NU2-NU1) GO TO 93
177 C SET UP FOR SOLUTION
178 NEVAL = 0
179 60
180 DO 65 ITER = 1, 6
181 A1 = ARG(1)
182 ARG(1) = 9.9
183 ARG(2) = 9.9
184 CALL HETP(ARG, NARG)
185 LI4 = 10
186 C HAVE MINIMUM FOUND (USING ROUTINE FROM IMSL)
187 CALL ZXPOL(FUNCT, CLOSE, NARG, ARG, VALUE, LIMIT, IER)
188 IF (OPT(*)) PRINT 638, RESULTS
189 760, ARG(1), ARG(2), VALUE, IER
191 C IF ELECTRON DENSITY CHANGED MUCH, REPEAT SOLUTION
192 65 CONTINUE
193 60 CONTINUE
194 IF (ABS(ARG(1)-A1) < 1.0*EST) GO TO 65
195 60 CONTINUE
196 A1 = ARG(1)+1.0*EST
197 PRINT 636, *TAR = A1
198 C REPEAT WITH CLOSER TOLERANCES
199 65 ITER = ITER+1
200 C REPEAT WITH CLOSER TOLERANCES
201 CALL HETP(ARG, NARG)
202 ARG(1) = 9.9
203 CALL ZXPOL(FUNCT, CLOSE, NARG, ARG, VALUE, LIMIT, IER)
204 IF (VALUE < 1.0*EST) GO TO 94
205 C UPDATE ESTIMATE OF MINIMUM VALUE
206 EST = VALUE
207 FNIM ERRORS IN CALCULATED PARAMETERS
208 C CALL FUNCT2
209 C PRINT RESULTS
218 840 FORMAT(* A = ARG(2)+BASE
219 840 FORMAT(* A = ARG(2)+BASE
220 840 FORMAT(* A = ARG(2)+BASE
221 840 FORMAT(* A = ARG(2)+BASE
222 840 FORMAT(* A = ARG(2)+BASE
223 840 FORMAT(* A = ARG(2)+BASE
224 840 FORMAT(* A = ARG(2)+BASE
225 840 FORMAT(* A = ARG(2)+BASE
226 840 FORMAT(* A = ARG(2)+BASE
227 840 FORMAT(* A = ARG(2)+BASE

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**** THEORY ****

228 PRINT 447,11,T(1)=E(1)*I(1)*I(2)/((C0VARI)1,3,I(1,3))
229 IF RATI0(LT.1.E-5) I070 TO 70
230 IF NOT YES(.PLOT,3) GO TO 20
231 LINEP=LINEP+1
232 IF LINES(LT.10) 1070 TO 20
233 CALL TPLOT(IAAX,BOTTOM.TOP)
234 LINEP=LINEP+1
235 GO TO 20
236 C
237 933 FORMAT(' INPUT DATA FILE FORMAT IS**.17,' RATHER THAN**.14)
238 STOP
239
****** THEORY (MAIN) ******

20537J1.60K'S VZ'I111.GJAMK
1          MAIN PROC
2          PROCEDURE MAIN...
3          MAIN
4          PURPOSE...
5          TO TRANSMIT THEORETICAL, EXPERIMENTAL, AND CALCULATED
6          INFORMATION PAST THE LIBRARY ROUTINE 'FMCG'...
7          PROGRAMS USING THIS PROCEDURE...
8          FETCHS=FUNCTION1,FUNCTION2,NEWS,NEWNEW,SIGMA,SUM,THEORY,TPLT
9          PARAMETER LINC=20
10          PARAMETER LEXP=36
11          PARAMETER LIONH=28
12          INTEGER TOTAL
13          LOGICAL OPT
14          REAL LEXP,LCNOTH
15          COMMON KS,LUU,UU2,SHOT,TOTAL,NEVAL,ITER,ICR,ELPS,ELPSUE,HHW,
16          SIGNS,PRI0U5BASE,
17          - ALPH1(LL,LS),ALPH2(LL,LS),ALPH1(L1,LS),ALPH2(L1,LS),
18          - GEL(L1,LS),TOC(1,LS),
19          - SHOT(L1,EXP),LE(1,1,1,1,1),ITVXP(L1,EXP,LSH1),
20          - SUM(4,5),ERROR(4).P(10),
21          END

****** THEORY (GROUP) ******

20537J1.60K'SGROUPS(1).GROUP
1          GROUP PROC
2          PROCEDURE GROUP...
3          GROUP
4          PURPOSE...
5          TO COMMUNICATE PARAMETER ERROR ESTIMATES...
6          PROGRAMS USING THIS PROCEDURE...
7          THEORY,FUNCTION1,NEW
8          PARAMETER LS1=55+(2+LIMH)+LIMEXP
9          COMMON/GROUP/ INTMON+TAVER+NU1+M2+IARG+TEMP+ETEMP,
10          - LINES(10),
11          - VALUE+WIDTH,
12          - ARS(4)+SIG(4)+INT(4)+RATIO(3)+ERATIO(3)+COVAR(4,4),
13          DIMENSION ULOCK(55)
14          EQUIVALENCE (RLOCK(1).INTO1)
15          REAL INTMON,INT
16          END

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*** THEORY (FETCHS) ***

SUBROUTINE FETCHS(ARG,NARG,LINES)

NAME...

PURPOSE...

to determine which line has been scanned, read in the corresponding theoretical profile, and initialize the nonlinear parameters.

CALLING SEQUENCE...

CALL FETCHS(ARG,NARG,LINES)

ARG R0

ARG(1) IS THE ELECTRON DENSITY TIMES 1.0E-16.

ARG(2) IS THE DISTANCE FROM THEORETICAL TO ACTUAL LINE CENTER.

NARG I0

NUMBER OF NONLINEAR PARAMETERS

LINES I0

LINE CODE NUMBER.

1 HE II 4686 (DENSITY 1.0E17)

2 HE II 1025

3 HE II 1215

4 HE II 4686 (DENSITY 1.0E18)

VARIABLES IN BLANK COMMON:

NARG I0

NARG

NS1+NS2 I0

# ENTRIES IN ARRAYS ALPH1, SALPH1 AND ALPH2, SALPH2, RESPECTIVELY

(HOLE SET POSITIONS)

HHW R0

HALF HALF WIDTH OF ILLUMINATE FUNCTION

BASE R0

THEORETICAL LINE CENTER MINUS 10 ANGSTROMS

ALPH1+ALPH2 R0

ARRAYS OF VALUES OF ALPHA & SALPHA

INCLUDE DBANK,LIST

DIMENSION ARG(4)

INTEGER STHEO

LOGICAL OPT

DATA STHEO/29*,IFMT/000/

DEFINE FILE STHEO(10*2+LINES+2)*IFMT

READ(STHEO(1+)*IFMT)

IF(NFT.GT.NFT)160 TO 90

NARG=2

START WITH AN ELECTRON DENSITY OF 1.0E17

ARG(1)=1.0E-16+1.0E17

LINES=NUMBER(*LINE NUMBER)+1.9+30

READ(STHEO(1)*BASE+1,ALPH1,ALPH2)

NS1=0

NS2=NS1+1

ARG(2)=10.

BASE=BASE-10.

IF(BASE.LT.3000)60 TO 25

HHW=3
***** THEFT (FUNCT3) *****

SUBROUTINE THEFT

1 FUNCTION FUNCT3(ARG)
2 C PURPOSE
3 C TO FIND THE MEAN SQUARE DEVIATION OF THE DATA FROM THE
4 C THEORY USING CURRENT PARAMETERS.
5 C
6 INCLUDE UBANK,LIST
7 INTEGER IJCT3/0/
8 DIMENSION ARG(1)
9 LOGICAL OPT
10 COMMON/FACOM/A(2)+OLDVAL,OLDANG
11 C NEEDN'T CALL HELP UNLESS DENSITY CHANGED
12 IF(ARG(1)+=ARG(11)+ARG(2)) NE.ARG(1)+=ARG(2)
13 ANGLE=SQR(AM-2(ARG(2)-ARG(21)+AMG(1)-(11))
14 IF(ARG(2)+=ARG(2)+GT.20) IJCT3=FUNCTION=1
15 IF(ARG(2)+=ARG(21)+LT.1.E-7*ARG(1)) GO TO 10
16 IF(ARG(2)+=ARG(2)+*AMG(1)+AMG(1)+50 TO 10
17 IF(ARG(2)+=ARG(2)+AMG(1)+AMG(1)+10*ARG(2)) IJCT3=FUNCTION=1
18 C IF(IJCT3+AMG.8) GO TO 90
19 IF(BRIGHT+LT.-1.5*ARG(2) TO 90
20 CALL BEGIN(ARG,2)
21 A(1)=ARG(1)
22 CALL BEGIN(ARG.2)
23 FUNCTION=SIGN(ARG)
24 IF(ANGLE-LE.0.1) ANGLE=0.1GLE+100.
25 IF(OPT('Z') .AND. ABS(ANGLE-OLDANG.GT.4)
26 C PRINT 701, A+OLDVAL, OLDANG
27 IF(OPT('Y'))
28 C PRINT 701, ARG(1)+ARG(1)+FUNCTION, ANGLE+BRIGHT, BACKGO
29 701 FORMAT(3G15.8,F5.0,I3G9.3)
30 A(2)=ARG(2)
31 OLDVAL=FUNCTION
32 OLDANG=ANGLE
33 NEVAL=NEVAL+1
34 RETURN
35 90 PRINT 703
36 703 FORMAT('**FUNCTION** FINDS WAIFASMABLE ARGUMENTS (BUT TIME,*)')
37 PRINT 703,A+OLDVAL,OLDANG
38 P=11. AR=ARG(3)+BASE,ARG(2)+FIND=IGHT+BACKGO
39 707 FORMAT('** FUNCTION** (I,I) = HSavel+BASE+ARG(2)')
40 - G9JY 'RIGHT+IFC(XU+209.3)
41 DO 92 KUMUL=+UP
42 AX=ML+6.5J(KU)
43 YY=VALUE(URL+TOE+V522+XX+BASE+ARG(2),/)
44 YZ=0.
45 W=SHOT(KU)
46 DO 91 KSHOT=+1
47 91 Y2=YY=INT(LP(KU+KSHOT)
48 Y2=Y2/1
49 92 PRINT 724,XX,Y2,YY
50 724 FORMAT(1PG14.6,2Il.2)
51 STOP
52 END
*** THFYR (FUNCT2) ***

SUBROUTINE FUNCT2

NAME...

FUNCTION...

TO FIND THE EXPECTED ERRORS IN THE BEST-FIT PARAMETERS.

CALLING SEQUENCE...

CALL FUNCT2

VARIABLES IN BLANK COMMON:

TOTAL I+ data points
EPSI R+1 step in wavelength
EPSNE R+1 step in electron density = arg(1)
FO R+0 Holmesmark field strength
JASE R+1 theoretical line center minus 10 angstroms

VARIABLES IN COMMON /GROUP:*

NARG I+1 number of elements in arg
ARG R+1 array of nonlinear parameters
VALUE R+10 input: sum of squares of deviations
SIG R+0 array of expected errors in the nonlinear parameters
LIT R+0 array of linear parameters
E R+0 array of expected errors of linear parameters
COVAR R+0 upper triangle is set to a normalized variance-covariance matrix
RATIO R+0 line to (100 angstrom) continuum ratio
ERATIO R+0 expected error in ratio
TEMP R+0 temperature from the lin/continuum ratio
ETEMP R+0 expected experimental error in temp
HWIDTH R+0 half half width of experimental line (angstroem)

METHOD...

THE VARIANCE-COVARIANCE MATRIX IS NORMALIZED BY DIVIDING EACH ROW AND EACH COLUMN BY THE SQUARE ROOT OF THE ORIGINAL DIAGONAL ELEMENT, THE CALCULATIONS OF FRATIO AND ETMP MAKE USE OF THE APPROXIMATELY KNOWN COVARIANCE MATRIX ELEMENTS.

THE TEMPERATURE IS FOUNO USING THE THEORETICAL RESULTS OF DELCR0X AND VOL0RSE.

SUBPROGRAMS REQUIRED...

NEWTNEW=SUMF=SIGM=STMINV

DIMENSION ARGUM(4)
LOGICAL OPT
DIMENSION TATTLE(6)

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***** THEORY (FUNCT2) *****

57    DATA +IGI/10.,SIGNE/10./
58    REAL INT
59    INCLUDE JoAM=LIST
60    INCLUDE GROUP=LIST
61   &C GET THE FINAL VALUES OF THE SUM OF SQUARES & ERROR
62   &C MATRIX ELEMENTS
63    CALL NEWT(ARG,NAH)
64    CALL NEWT(ARG,NAH)
65      VI=SIGMA(ARG)
66    IF(OPT('O')PRINT 701,ARG(1),ARG(2),V1
67    701 FORMAT(' **',2G13.6,13X,F40.*62.6)
68      VI=FULLTS(ARG)
69    IF(OPT('O')PRINT 701,ARG(1),ARG(2),V1
70    MARKER=1
71    EPSI=DIAG*EPSI
72    EPSNE=DIAG*EPSI
73    DO 10 I=1,NARG
74  10 ARGUM(I)=ARG(I)
75    CALL NEWT(ARGM+ARG)
76    CALL NEWT(ARGM+ARG)
77    CALL SUMF(ARGM+ARG,5F5,F5D,VALUE)
78      TATTLE(4)=VALUE
79      INT(1)=SUM(1,1)
80      INT(2)=SUM(1,2)
81      V=VALUE
82    ARGUM(2)=ARG(2)+EPSI
83      SIGMA=ARGM
84    IF(S2*VALUE-1)MARKER=1
85    TATTLE(N)=S1   
86    ARGUM(2)=ARG(2)+EPSI
87    CALL SUMF(ARGM+ARG,5F5,F5D,VALUE)
88    IF(S2*VALUE-1)MARKER=1
89    TATTLE(5)=S2
90    COVAR(2,2)=0.5*(TOTAL-1)*(S1-2*VALUE+S2)/EPSI**2
91    ARGUM(1)=ARG(1)+EPSI
92    CALL NEWT(ARGM+ARG)
93      SIGMA=ARGM
94    IF(S1*VALUE-1)MARKER=1
95    TATTLE(6)=S3
96    ARGUM(1)=ARG(2)
97    CALL SUMF(ARGM+ARG,5F5,F5D,VALUE)
98    IF(S3*VALUE-1)MARKER=1
99    TATTLE(7)=S3
100   COVAR(1,2)=0.5*(TOTAL-1)*(S1-2*VALUE+S2)/EPSI**2
101   ARGUM(1)=ARG(1)-EPSI
102   CALL NEWT(ARGM+ARG)
103   SIGMA=ARGM
104   IF(S1*VALUE-1)MARKER=1  &CALL NEWT(ARG,NAH)
105   TATTLE(8)=S1
106   IF(MARKER.CO.1)PRINT 702
107   702 FORMAT(**** LEAST SQUARE SOLUTION NOT FOUND...NEARBY VALUES****,
108       * FOLLOW *****)
109   IF(MARKER.CO.1)OR.OPT('O')PRINT 707+TATTLE
110   707 FORMAT(13X=2G13.6,13X=2G13.6)
111   COVAR(1,1)=0.5*(TOTAL-1)*(S1-2*VALUE+S3)/EPSI**2
112   COVAR(1,3)=(SFD-SF)/DIAG*EPSI
113   COVAR(1,4)=(SFD-SF)/EPSI
```
C PROGRAM

DO 15 J=1,4

C INPUT TO FIND THE VARIANCE-COVARIANCE MATRIX

DO 70 I=1,5

C FORMAT(1X,4G13.6)

CALL XMHVJ(COVAR=4*4+60)

DO 10 J=1,4

C FORMAT(1X,4G13.6)

CALL XMHVJ(COVAR=4*4+60)

DO 20 J=1,4

C RESCALE ELECTRON DENSITY

C WE MUST RECALCULATE THE HOLTSMARK FIELD STRENGTH

R=.20B.ALOG(ARG(2))+.209.ALOG(PATIO(1))-5.10

TC=-.09/ITJT2

TEMP=SQRT(ABS(TF*TFO*COVAR(1,1)

-+TL*TL*COVAR(3,3)

+2.*TL*TC*COVAR(1,3)

+.2*TL*TC*COVAR(1,4)

-+.2*TL*TC*COVAR(3,4))))

C NORMALIZE THE VARIANCE-COVARIANCE MATRIX

COVAR(I,J)=COVAR(I,J)/R**2

C EXTRACT THE VARIANCES OF THE INDIVIDUAL PARAMETERS

SIG(I)=SIG(I)/ABS(COVAR(I,I)

SIG(2)=SIG(2)/ABS(COVAR(2,2)

SIG(3)=SIG(3)/ABS(COVAR(3,3)

SIG(4)=SIG(4)/ABS(COVAR(4,4)

C PRINT THE LINE: CONTINUUM RATIO & ERROR

IF LINE IS HF II 46/86 FIND TEMPERATURE & ERROR

TEMP=2.069/ARG(1)

+2.069/INT(1)

TC=-.09/INT(2)

C TEMP=SORT1ABS( T/INT=1*COVAR(1,1)
***** THEORY (FUNCT2) *****

171  COVAR(2,4) = COVAR(2,4) / (SIG(2) * E(2))
172  COVAR(3,4) = COVAR(3,4) / (SIG(3) * E(2))
173  DO 40 J=1,4
174  40  COVAR(J,J) = 1.
175  C  FIND HALF INTENSITY POINT OF EXPERIMENTAL PROFILE
176  HALF = TDEL(2) / 2.
177  DO 45 K=1,4
178  IF(TDEL(K) .LT. HALF) GO TO 49
179  45  CONTINUE
180  KS = N5 + 2
181  48  X1 = TDEL(KS)
182  X2 = TDEL(KS + 1)
183  Y2 = TDEL(KS + 1)
184  DO 54 J=1,4
185  X = (Y2 - HALF) * X1 - (Y1 - HALF) * X2 / (Y2 - Y1)
186  50  Y1 = VALUE(TDEL, N5, X)
187  X2 = X1
188  X1 = X
189  50  Y1 = VALUE(TDEL, N5, X, Y)
190  Y2 = TDEL(KS + 1)
191  54  DO 54 J=1,4
192  50  Y1 = VALUE(TDEL, N5, X, Y)
193  RETURN
194  60  PRINT 908
195  908  FORMAT(' INVERSION FAILURE FINDING COVARIANCE MATRIX')
196  RETURN
197  END

W.EJLT
******** THEORY (TPILOT) ********

SUBROUTINE TPILOT(YMAX,BOTTOM, TOP)

NAME*** TPILOT

PURPOSE*** TO PLOT THE EXPERIMENTAL DATA AND THEORETICAL BEST-FIT PROFILE.

USAGE***

CALL TPILOT(YMAX,BOTTOM, TOP)

VARETERS R0 L0BB0 FOR END OF Y AXIS

VARETERS R0 L0BB0 FOR ORIGIN OF X AXIS

VARETERS R0 L0BB0 FOR END OF X AXIS

VARIABLES IN COMMON: ALVOST, EVFYPYTHINO

SUBROUTINES USED...

PLOTC: STANDARD PLOT SUBROUTINE USED TO POSITION THE PEN

NSC0LE: F19M'S PLOT SCALING PARAMETERS FOR EASILY INTERPRETED

AXIS: LABELS

AXIS: DRAWS AN AXIS

'SYMBOL' DRAWS A SYMBOL AT THE DESIRED POSITION

PAGEUP: COMPLETES THE PLOT AND P08ITIONS THE PEN ONTO THE NEXT PAGE

METHOD***

NOTE THAT THE AXES USED IN THIS ROUTINE ARE ROTATED 90 DEGREES CCW FROM THOSE USED BY THE SYSTEM ROUTINES. Thus, MY 'Y' DIRECTION IS THEIR 'X', AND MY '+X' IS THEIR '+Y'.

DIMENSION ARG(4), INT(4)

INCLUDE OBANK LIST

INCLUDE GROUP LIST

REAL INT, FIT(2), NUM

DATA WIDTH, HEIGHT, NY, NX

BEST FIT CURVE

FIT(Z)=INT(1)*VALUE(DEL,TOEL+NS2+Z,0)+INT(NAPG)

FIND LARGEST & SMALLEST VALUES ALONG EACH AXIS

BOTTOM=LENGTH(1)

TOP=LENGTH(NU)

YMAX=FIT(0)

CENTER=ARG(2)*BASE

LBOUND=BASE+10.*HEIGHT

BOUND=BASE+10.*HEIGHT

DO 15 KU=1,NU

15 IF(LENGTH(KU),GE,LBOUND)BOTTOM=AMAX1(BOTTOM,LENGTH(KU))

IF(LENGTH(KU),LE,LBOUND)TOP=AMAX1(TOP,LENGTH(KU))

N=SHOT(KU)
***** THEORY (PLOT) *****

DO 10 K=1,N
10 YMAX=MAX(MAX(YMAX,INTERP(KU,SHOT)))
PLOT AT LEAST 6 PTW TO EACH SIDE
BOTTOM = A IN1(BOTTOM+LENGTH-4.**M1,14)
TOP = A MAX1(TOP+CENTER+4.**M1,13)
C
FIND SCALING PARAMETERS
NTICX=NX
CALL NSCALE(BOTTOM, TOP, NTICX, WIDTH, DX, DTICX, NTICY, ZERO)
CALL NSCALE(ZERO, YMAX, NTICY, HEIGT, DTICY)
DX = 1./DX
CALL PLOTC(.5,1.0,3)
C
DRAW AXES
CALL AXISN(.0,.0,NTICY-HEIGT,.1,180.)
CALL AXISN(.0,.0,NTICX,WIDTH,.1,90.)
C
DRAW A DOTTED LINE FOR THE CONTINUUM LEVEL
IF(114T(ARG)LT.0.)GO TO 20

IF(114T(RJARG)LT.0.)GO TO 20
U=0. INT{ARG)
L=DX.(TO-BOTTOA)
DLZ-L/69.
18 K=1,35
CALL PLOTC(U,L,3)
C
DRAW THE EXPERIMENTAL POINTS
NSYM=4
DO 30 K=1,N
IF(KU.EQ.KU1)NSYM=0
IF(LENGTH(KU).LT.BOTTOM .OR. LENGTH(KU).GT.TOP) GO TO 30
U=0.

DO 25 KSHOT=1,N
25 KSHOT=1,N
CALL SYMUCL(DY+1.1DX*LENGTH(KU)-BOTTOM)**1+NSYM+96**1)
30 IF(KU.EQ.KU2)NSYM=4
C
DRAW THE THEORETICAL CURVE
L=TOP
DL=TOP-BOTTOM)/250.
NPEN=3
DO 40 K=1,25
U=FIT(CEINTC-L)
CALL PLOTC(DY+U*DX*(L-BOTTOM),NPEN)
NPEN=2
40 L=L+DL
CALL PAGEUP
RETURN
END
***** THEOY (AXIS) *****

SUBROUTINE AXIS (XX+YY+TIC+ALNTH+TIC+ANGLE)

NAME***

PURPOSE***
TO DRAW ONE AXIS FOR A 2-DIMENSIONAL GRAPH

USAG***

CALL AXIS (X+Y+TIC+ALNTH+TIC+ANGLE)

X+Y R=1 POSITION OF START OF AXIS (INCHES FROM PAPER ORIGIN)

TIC R=1 NUMBER OF LINE SEGMENTS_TAKEN TIC MARKS

ALNTH R=1 LENGTH OF AXIS (INCHES)

TIC R=1 LENGTH OF TIC MARKS (INCHES)

TIC+LT.0 FOR TICS ON COUNTERCLOCKWISE SIDE

TIC+LT.0 FOR TICS ON CLOCKWISE SIDE

ANGLE R=1 ANGLE OF AXIS FROM X-AXIS (DEGREES)

A=ALNTH/TIC
X=XX
Y=YY
C=COS(A0174531*ANGLE)
S=SIN(A0174531*ANGLE)
AXC=A
AY=S*A
TX=S*TIC
TY=C*TIC
CALL PLOT(X+TX+TY,3)
DO 10 I=TIC
CALL PLOT(X+Y+2)
X=X+AX
Y=Y+AY
CALL PLOT(X+Y+2)
10 CALL PLOT(X+TX+TY+2)
CALL PLOT(X+TX+TY+3)
RETURN
END

**** END ****

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***** THEORY (PLAC) *****

2US3JUNAORKSPALE1(1).HE IS
SUNNI ONIC KEY(2ARG+HAG)
NAME...

PURPOSE...
TO CONVOLVE THE THEOREICAL AND THE INSTRUMENT PROFILES.

CALLING SEQUENCE...

CALL NEWS(ARG,2ARG)

ARG R1 ARRAY OF NONLINEAR PARAMETERS
ARG(1) IS THE ELECTRON DENSITY TIMES 1.E-16.
NARG 1, NUMBER OF NONLINEAR PARAMETERS PRESENT

METHOD...
THE HOLTZMARK FIELD STRENGTH IS CALCULATED AND USED TO
FIND THE AMOUNT OF BROADENING NEEDED IN (S(\alpha),\alpha)
SPACE. THIS IS ACCURATE IF THE FINAL ELECTRON DENSITY IS
CLOSE TO THE ORIGINAL ESTIMATE USED HERE. THE GAUSSIAN
HERMITIAN QUADRATURE FORMULA USED HERE IS EXACT FOR THE
INTEGRAL OF A GAUSSIAN INSTRUMENTAL PROFILE AND A FIFTH ORDER
CURVE FOR THE THEORETICAL PROFILE.

INCLUDE BLANKLIST
DIMENSION ARG(4)

WE USE THE HOLTZMARK "VIRTUAL" FIELD STRENGTH
F0=2.6035*1+4.8035E=16**2(3)
F0=1.2503E-9*(\L 655666666667
WE USE THE QUADRATURE FOR THE 3 POINT GAUSSIAN
HERMITIAN QUADRATURE FORMULA

DELTA=1.47106R5*HRO/F0
DELTA=1.47106R5*HRO/F0

DELTA=(\HO/F0)=\OSRT13/(2*ALOG(2))

N=NS1
DO 10 KS=2+N
ALPH2(KS+1)=ALPH2(KS)
10 SALPH2(KS+1)=SALPH2(KS)

ALPH2(1)=ALPH2(1)
SALPH2(1)=SALPH2(1)

RETURN
END
**THEORY (NEWT)**

SUBROUTINE NEWT(ARG,NARG)

! PURPOSE...
TO CALCULATE THE PROFILE IN WAVELENGTH SPACE,
FOLLOWING
THE ELECTRON DENSITY AND THE PROFILE IN (S,ALPHA), ALPHA)
SPACE

CALLING SEQUENCE...

CALL NEWT (ARG,NARG)

ARG(1) ARRAY OF NONLINEAR ARGUMENTS.
ARG(1) IS ELECTRON DENSITY TIMES 1.E-16,
NARG = NUMBER OF NONLINEAR ARGUMENTS

INCLUDE DOAHK.LIST

DIMENSION ARG(5)
WE USE THE HOLTZMAP NORMAL FIELD STRENGTH
FO=2.603*10.3E-10*NE**(2/3)
IF(ARG(1)<=0)GO TO 90
FO=1.2503E-9*(1.16*ARG(1)**0.666667
F0INV=1./FO
N=NSZ2
DO 20 KS=2,N
TDDEL(KS)=1/F0+ALPH2(KS)
20 DEL(KS)=FOINV*ALPH2(KS)
TDDEL(1)=TDDEL(3)
DEL(1)=DEL(3)
RETURN
90 PRINT 901,ARG(1)
901 FORMAT(' NEWT: DENSITY OF ',15X,6.9,2X,*1.16 **1)
STOP
END

*EXCT

[ORIGINAL PAGE IS OF POOR QUALITY]
THEORY (HEAVY)

** SUBROUTINE NEWU(ARGU,NARGU)**

** INCLUDE DOAW,LIST**

** INCLUDE GROUP,LIST**

** DIMENSION ARRUM(4)**

** ASARGUM(2)+BASE**

** DO 15 J=1+NARGU**

** DO 1 1=1+J**

** SUM(1,1)=0.**

** DO 25 K=1+NU2**

** T=VALUE(DEL+TDEL1,52,A=LENGTH(KU)+1)**

** SUM(1,1)=SUM(1,1)+T*T**

** SUM(1,2)=SUM(1,2)+T*N**

** SUM(1,3)=SUM(1,3)+INJEXP(KU,KSHO)T**

** SUM(1,4)=SUM(1,4)+INJEXP(KU,KSHO)**

** 25 CONTINUE**

** SUM(1,2)=TOTAL**

** SAVE ELEMENTS FOR CALCULATION OF VARIANCE-**

** COVARIANCE MATR IX**

** COVARI(3,3)=SUM(1,1)**

** COVARI(3,4)=SUM(1,2)**

** COVARI(4,4)=SUM(1,2)**

** HAVE THIS SYMMETRIC SYSTEM SOLVED**

** CALL SYMSLV(SUM, SUM(1+NARGU+1), NARGU+4, 0, 40)**

** RETURN**

** 40 PRINT 908**

** 908 FORAT(' SINGULAR MATRIX!!')**

** STOP**

** END**
PURPOSE: To find the new start deviation of the data from the current parameters.

PARAMETERS: 
- THE NEW START DEVIATION OF THE DATA FROM THE CURRENT PARAMETERS.

PROGRAM: 

```
INCLUDE DUALIST
LOGICAL OPT, HUE
DO 20 K=1, N
   T=VALUE(DELTwL.S,E:32+A32+L:2+M+1)+T+SU4(3)-(S+3)
   U=SU4(3).T+SU4(3)
   M=NZJ4SHOT(XU)
   10 C=RETURN
   DO 20 K=1, N
   S=SGAAS(3)+TENT(3)
   19 RETUR
   END
```

END
THEORY (SYMSLV)

SYMMETRIC LINEAR EQUATION SOLVER

NAME...

SYMSLV

PURPOSE...

TO SOLVE A LINEAR SYSTEM AX=B WHEN THE MATRIX A IS
SYMMETRIC AND POSITIVE DEFINITE. THE ROUTINE CAN BE
CALLED SUBSEQUENTLY TO PERFORM THE SOLUTION FOR
A NEW RIGHT HAND SIDE WITHOUT RECOMPOSING AGAIN.

CALLING SEQUENCE...

CALL SYMSLV(A,N,N,IT,S60)

ARGUMENTS ON ENTRY:
A  MATRIX OF COEFFICIENTS. SINCE IT IS SYMMETRIC,
ONLY ELEMENTS NEEDED ARE A(I,J), 1.LE.I.LE.J.LE.N .
B  ARRAY OF ELEMENTS FROM RIGHT HAND SIDE
N  DIMENSION OF MATRIX A.
M  MAXIMUM NUMBER OF ROWS IN A (FIRST DIMENSION)
IT  SWITCH...IT=1 IF MATRIX A WAS DECOMPOSED ON A
PREVIOUS CALL TO SYMSLV, AND ONLY THE ARRAY B
IS DIFFERENT THIS TIME. IT=2 IF A IS NEW.
S60  CONTROL WILL BE PASSED TO THIS STATEMENT IF
A PIVOT ELEMENT IS FOUND OF ABSOLUTE VALUE
LESS THAN 1.E-11.

ARGUMENTS ON RETURN:
A  ORIGINAL MATRIX IS DESTROYED. LOWER TRIANGLE HOLDS
LOWER TRIANGLE OF MATRIX L. (DIAGONAL ELEMENTS OF L
ARE 1's.) DIAGONAL ELEMENTS HOLD MATRIX D.
B  SOLUTION ARRAY X.

METHOD...

SYMMETRIC FACTORIZATION IS USED TO FIND A LOWER
TRIANGULAR MATRIX L AND A DIAGONAL MATRIX D SUCH
THAT A=L*D=L TRANSPOSE. THE UNKNOWN
VECTOR IS CALCULATED BY BACK SOLVING THESE TRIANGULAR
SYSTEMS: UZ=B , DY=Z , LX=Y .

DIMENSION R(5),A(25)

IF(N.GT.1)GO TO 10
N=1
RETURN
10 IF(IT.EQ.1)GO TO 28
DO 25 K=1,M-1
IF(ABS(A(KM)+A(K,N))) .LT. 1.E-10)RETURN 6
DO 25 J=M+1,N
25 CONTINUE
28 RETURN
STOREY (SINSLV) STOREY

57 S=(K+J+1)/A(K)+K+J+1)
58 DO 20 J=1,N
59 A(J+I+1)=S(J+I+1)
60 DO 25 K=1,J+1
61 A(J+K+J+I+1)=S+(K+J+I+1)
62 DO 30 J=2,N
63 T(J)=J+1,J+1
64 DO 50 J=1,N
65 S(J)=(J+1)/(J+1+J+1)
66 DO 50 J=2,N
67 DO 50 J=1,N
68 S(J)=S(J)+A(J+1)+J+1)*B(J)
69 RETURN
70 END

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****** THEORY (VALUF) ******

FUNCTION VALUE(X,Y,N,W,P)

NAME VALUE

PURPOSE TO INTERPOLATE IN A TABLE TO FIND INTENSITIES FROM
THE THEORETICAL LINE PROFILE.

CALLING SEQUENCE CALL VALUE(WAVE,R,N,WANT,P)

WAVE R ++ ARRAY OF WAVELENGTHS (DISPLACEMENTS FROM
LINE CENTER)

INT R ++ ARRAY OF CORRESPONDING LINE INTENSITIES

N I ++ NUMBER OF ENTRIES IN WAVE OR INT

WANT R ++ WAVELENGTH AT WHICH INTENSITY IS DESIRED

P R ++ WORK ARRAY OF LENGTH 4. P(1) IS USED TO STORE
A POINTER BETWEEN CALLS. SO EACH SEARCH OF
WAVE REGIONS WHERE THE PRECEDING SEARCH ENDED.

METHOD BEYOND THE END OF THE TABLE, A 9/2 POWER LAW IS USED TO
EXTRAPOLATE. WITHIN THE TABLE, ALIKE'S PROCEDURE IS
APPLIED USING 4 POINTS. SINCE AN EVEN NUMBER OF POINTS
IS USED, THE INTERPOLATING FUNCTION IS CONTINUOUS.

DIMENSION X(N),Y(N),P(4)

IF(XBAR+GE.X(N))GO TO 90

SAVEJ=P(1)

IF(XBAR=X(J))GO TO 50

IF(XBAR=X(J)+1)GO TO 30

SEARCH UP

IF(J.LE.1)GO TO 50

JSTART=J

DO 12 J=JSTART+2,1

IF(XBAR=X(J))GO TO 12

CONTINUE

J=J

GO TO 50

SEARCH DOWN

10 IF(J.LE.1)GO TO 50

JSTART=J

DO 12 J=JSTART,2,-1

IF(XBAR=X(J))GO TO 12

CONTINUE

J=J

GO TO 50

12 CONTINUE

GO TO 50
125

***** THEORY (VALUE) *****

S A V E T H I S P O I N T E R

S E T J T O P O I N T T O F I R S T O F T H E 4 P O I N T S

I N Y N E A R E S T X A R


T H E G R O U P O F S T A T E M E N T S T O F O L L O W I S E Q U I V A L E N T T O:

D O 6 0 1 = 2 + 1

D O 6 0 L = 2 + 1

P ( I ) = Y ( J )

P ( I ) = ( P ( L - 1 ) * ( X ( J + H - 1 ) - X A R ) - P ( I ) * ( X ( J + L - 2 ) - X A R ) ) / (

P ( 4 ) = P ( 4 - 1 ) * ( X ( J + 4 - 1 ) - X A R ) - P ( 4 ) * ( X ( J + 4 - 2 ) - X A R ) ) / 

V A L U E = Y ( J )

V A L U E = Y ( J ) * ( X ( N ) / X A R ) ** 2.5

R E T U R N
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