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PROPAGATION MODELING AND ANALYSIS FOR HIGH ENERGY LASERS

.

Science Applications, Incorporated

Prepared for:

Naval Surface Weapons Center

April 1975

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PROPAGATION MODELING AND ANALYSIS

FOR HIGH ENERGY LASERS

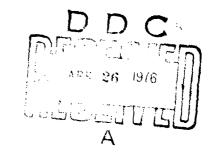
FINAL REPORT

SA1-74-629-WA

Mr. L.N. Peckham Mr. P.R. Carlson Dr. R.T. Liner Dr. C.W. Wilson

This work was performed under Contract No. N60921-75-C-0007, July 1974 through March 1975.

April 1975



SCIENCE APPLICATIONS, INCORPORATED

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DISTRIBUTION STATIMENT A Approved for public release; Distribution Unlimited This is the final report covering work performed for the Naval Surface Weapons Center under contract N60921-75-C-0007. The purpose of the contract was to analyze simplified propagation codes and recommend improved models for characterizing the propagation of high energy CW laser beams. The work was performed under the direction of Mr. Larry Jobson of NSWC.

FOREWORD

This report documents the work performed during the period January-March 1975. It also provides a review of the earlier work (July 1974-January 1975). The earlier work was described in detail in interim reports SAI-74-587-WA (October 1974) and SAI-74-622-WA (January 1975).

The authors wish to express their appreciation to Dr. Tom Tuer of the SAI Ann Arbor office for his development of the multi-line absorption coefficients. We also thank Mrs. T. Peckham for implementing the numerous code modifications.

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Section 1 INTRODUCTION

In support of the Systems Analysis Team of the Naval Surface Weapons Center, Science Applications, Inc. (SAI), performed a series of tasks designed to develop a better understanding of the modeling alternatives available to laser systems analysts and to assist in the continual improvement of the NGL Engagement Cude (NOLEC). Emphasis was placed on the resolution of propagation issues of interest to systems analysts. The tasks involved quantitative comparison of simplified HEL propagation codes used by DOD analysts, clarification of the beam quality problem, development of beam distortion and displacement models, development of a simplified optical train model, and expansion and improvement of the AFWL COMBO code.

The work was divided into six tasks. The first four tasks are reviewed in this report (Section 4), but are covered more extensively in interim reports (References 1 and 2):

> First Interim Report - July-September 1974, SAI-74-587-WA, October 1974 (Reference 1) Task 1. Quantitative Comparison of Simplified Propagation Codes

> > Task 3. Beam Quality Mudeling.

Second Interim Report - September 1975-January 1975, SAI-74-622-WA, January 1975 (Reference 2) Task 2. Beam Shape and Displacement Due to Thermal Lensing.

Task 4. Effect of Truncation and Obscuration on the Far-Field Beam Profile.

Task 5 required the development of a simplified optical train model. This work is described in Section 2 of this report. Task 6 involved modification and extension of the AFWL CONBO code and included the incorporation of models developed in the earlier tasks. The new version of the code was named SAICON. Section 3 describes the modifications and provides a user's guide to SAICON.

Section 2 A SIMPLIFIED OPTICAL TRAIN MODEL

When performing lacer application studies, the system analyst all too frequently assumes that the characteristics of the beam leaving the transmitting optic are the same as the characteristics of the beam leaving the laser device without regard for any changes induced by the optical elements and/or components required to get the beam from the laser device to the transmitting optic, i.e., the optical train. It is known, however, that significant changes to the characteristics of the beam do occur as it propagates through the optical train (see for example References 3 and 4). The finite absorptivity of the high power mirrors, clipping and blockage of a portion of the high power beam, and diffraction effects all reduce the available power in the beam at the transmitting optic. In addition the optical quality of the beam is affected by nearly every component or element through changes in the phase and amplitude distribution of the beam. Therefore, if realistic estimates of the performance of candidate laser systems are to be obtained during these application studies, it is important to include the effect of the opt cal train on the characteristics of the laser beam.

An accurate assessment of the impact of the ptical train is a tedious and difficult calculation requiring a wave optics approach and sophisticated analytical tools for modeling each of the elements in the optical train. Obviously these are not very practical for use in systems analysis

application studies in which a large parameter space must be investigated. Therefore, if the effect of the optical train is to be included in such analyses, the development of simple but reasonably accurate models is required.

One such model has been developed by the AFWL (Reference 5) which is used in their simplified propagation code (COMBO). However, its use is somewhat restrictive in that most of the component effects are left for the user to specify. Prescriptions for scaling these effects in terms of system parameters are not given. In addition, the impact of the optical train on the beam quality is assessed in terms of peak intensity reduction. Based on work under this contract, it is felt that an assessment in terms of the far-field power distribution provides a better characterization of the beam quality (see Reference 1 and Section 4.3 of this report).

We have developed a more comprehensive "simplified" optical train model which can be used to estimate the degradation in system performance caused by the optical components required to direct the beam from the laser device to the transmitting optic (i.e., aerodynamic window, mirrors, beam expander, etc.). The intent of the model is not to provide detailed engineering design data but rather to provide the systems analyst with a rapid assessment capability which will allow him to perform more realistic systems analyses of candidate HEL systems. Hence, emphasis is placed on formulating simple but reasonably accurate models for the various factors influencing the performance of the laser system. The approach is similar to that taken by the AFWL in their simplified model but with new additions and modifications to make the model more flexible. The model has been implemented in a subroutine called OPTRAIN and is included in the SAICOM code as described in Section 3 below.

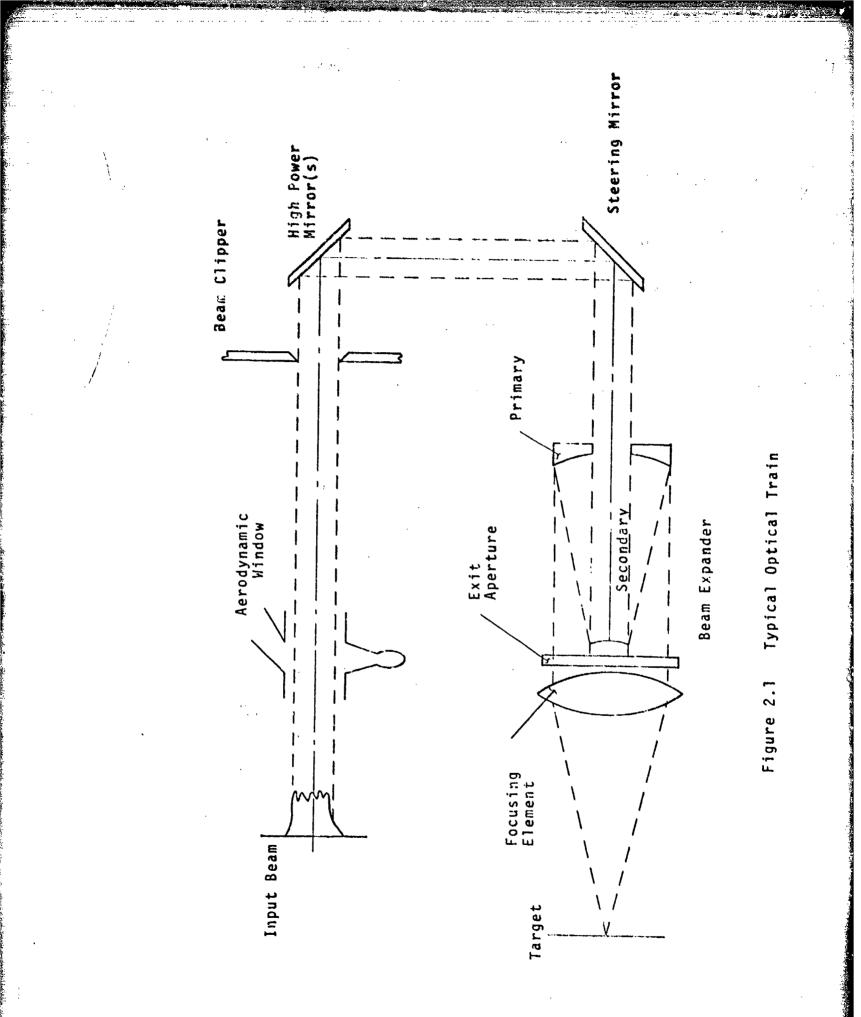
2.1 MODEL FORMULATION

Conceptually, the optical train may be viewed as a "black box" located between the laser device and the transmitting optic. The input to the box is the output beam from the laser. The model operates on this beam according to the number and type of elements in the train, and its output, in the form of certain performance parameters, provides the input to an atmospheric propagation model. The performance parameters are: (1) the power available at the transmitting optic, (2) beam quality, (3) beam divergence, and (4) beam jitter. In addition, the actual diameter of the beam at the exit aperture is computed for use in the propagation model.

The essential features of the model are illustrated in Figure 2.1. The optical elements and components include (1) an aerodynamic window, (2) a beam clipper, (3) several high power mirrors, (4) a beam expander, (5) an exit aperture, and (6) a focusing element for transmitting the beam to the target plane. In most practical cases the beam expander and focusing element are combined into a single telescope. However, it is convenient for the present analysis to separate them into an ideal beam expander which simply expands the beam and a separate element which applies the curvature to the beam phase front for focusing purposes.

2.1.1 Input Beam

Although it is not an optical element or component, the input beam is necessarily an integral part of the model since it has strong influence on the behavior of the mest of the optical train. In order to simplify the analysis of the components in the optical train, it is assumed that the beam from the laser is circular. However, because of



the widespread use of unstable resonator configurations to extract power from high power devices, the possibility of * central obscuration in the input beam is incorporated into the model. The inner and outer diameters of the input beam are εD_B and D_B respectively. An unobscured input beam profile can be realized by defining $\varepsilon = 0$. Other parameters required to specify the input beam are (1) the power in the beam, P_L , (2) the pulse length; Δt , (3) the curvature of the phase front, R_i , and the beam jitter, Θ_i .

In order to evaluate the effect the beam has on the high power mirrors in the optical train, it is also necessary to characterize the intensity profile entering the optical train. This is achieved by specifying both the magnitude and scale size of the intensity fluctuations, the magnitude being specified as a fraction of the average intensity $(\Delta I/I_{ave})$ and the scale size as a fraction of the beam diameter (ℓ_I/D_B) . Thus the input beam profile may be visualized as having a uniform intensity I_{ave} with fluctuations ΔI superimposed upon this level.

The optical quality of the input beam is specified by a wavelength scaling factor, n_L . Unfortunately, this definition of beam quality does not allow one to easily incorporate the other beam quality degrading factors induced by the various elements of the optical train. Therefore this parameter is converted by the model into an equivalent root-mean-square phase distortion, σ_1 .

Two alternative approaches for this conversion were investigated for use in the model. The first approach is to define the equivalent phase distortion so as to match the reduction in the peak intensity, I_p . According to the analysis presented in Reference 6, the peak intensity reduction is (for a gaussian beam containing small scale random phase variations)

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$$I_p/I_g = \exp(-\sigma_L^2)$$

where I_g is the ideal on-axis intensity. According to the wavelength scaling definition of beam quality

$$\frac{I_p}{I_g} = \frac{1}{n_L^2}$$

so that

$$\sigma_{L} = \sqrt{2 \ln(n_{L})} \quad (1)$$

It should be noted that this approach is equivalent to the power scaling definition of beam quality and is also the approach taken by the AFWL in their optical system model (Reference 5).

The second approach investigated was to define the equivalent phase distortion to match the power in the "bucket" ($R\lambda/D = 1$) predicted by wavelength scaling. This is given by (Reference 1):

$$P(R\lambda/D) = P_0 \{1 - \exp(-\pi^2/2n_L^2)\}.$$

Again, following the analysis of Reference 4, the power in the bucket for a non-diffraction-limited gaussion beam is given by

$$P(R\lambda/D) = P_{o} \exp(-\sigma_{L}^{2}) \{1 - \exp(-\pi^{2}/2)\}$$

assuming all of the quality degradation can be characterized as a scattering loss. Equating these expressions and solving for σ_1 yields,

$$\sigma_{L} = \left\{ -\ln \left[\frac{1 - \exp(-\pi^{2}/2n_{L})}{1 - \exp(-\pi^{2}/2)} \right] \right\}^{1/2}$$
(2)

Intuitively it would seem that both of these approaches should yield approximately equivalent results. Quantitatively however, substantial differences were found. These are illustrated in Figure 2.2 which compares the phase distortion computed from Equations (1) and (2). The phase distortion based on matching the peak intensity reduction is always considerably higher than that based on matching the power-in-the-bucket, e.g., over a factor of 2.5 for a 1.5 times diffraction-limited input beam. The reasons for these differences are not clear. One possible explanation is the equivalence of wavelength and power scaling methods of defining peak intensity reduction. It was found during previous work under this contract (Reference 1) that power scaling was always more pessimistic in its predictions of the beam quality than wavelength scaling. Therefore, matching the peak intensity based on a method that is equivalent to power scaling might be expected to produce more pessimistic results (i.e., higher σ_1) than matching the power-in-the-bucket based on wavelength scaling.

Whatever the reasons for the differences, we recommend the use of Equation (2) because the power-in-thebucket is a more meaningful measure of laser performance than peak intensity reduction. The latter suffers from its sensitivity to defocusing errors and difficulty in experimental measurement.

2.1.2 Aerodynamic Window

The first component in the optical train is the aerodynamic window isolating the optical cavity of the laser

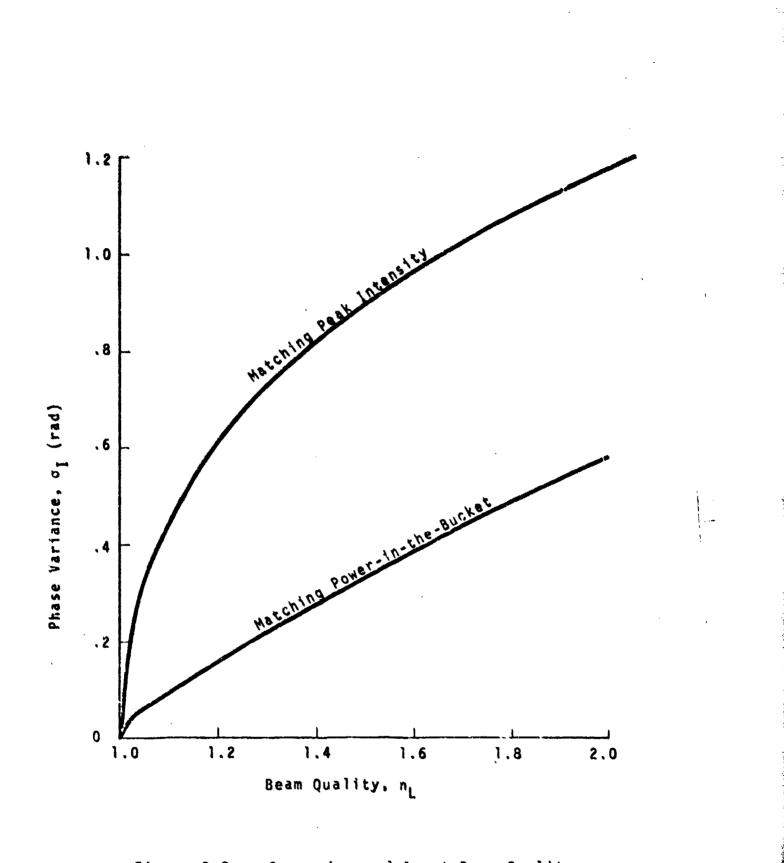


Figure 2.2. Comparison of Input Beam Quality Specifications

from the atmosphere. Basically there are two types of aerodynamic windows currently being considered for HEL applications: (1) focused and (2) unfocused. In both cases, if the window is properly designed, there should be little or no power loss when the beam passes through it. In addition, it is also assumed that no spherical distortion to the phase front will be induced by the aerodynamic window. The shock waves supporting the pressure rise and the turbulence generated by the aerodynamic window will, however, induce a loss in the beam quality. An expression for this loss is given by (Reference 4)

$$\Delta I/I = 2.84 \times 10^{-10} \left(\frac{\Delta p}{P_{g}} \frac{D_{B}}{\lambda}\right)^{2}$$

where $\Delta \rho$ is density change across the shear layer and ρ_s is a reference density at STP. Again this formulism of beam quality degradation is not convenient for use in the model and is converted into an equivalent phase distortion, σ_{aw}^2 by use of the Strehl formula (Reference 4):

$$\Delta I/I = \sigma_{AW}^2.$$

Solving for the phase distortion yields

$$\sigma_{aw} = 1.69 \times 10^{-5} \left(\frac{D_B}{\lambda} - \frac{\Delta \rho}{P_S} \right).$$

A typical value of σ_{aw} for a 10 cm beam from a chemical laser ($\lambda = 3.8 \text{ µm}$), assuming $\Delta \rho / \rho_s = 0.25$ for the density variations, is $\sigma_{aw} = 0.11$ radians. This corresponds to an intensity reduction of $\Delta I/I \approx 1.2\%$.

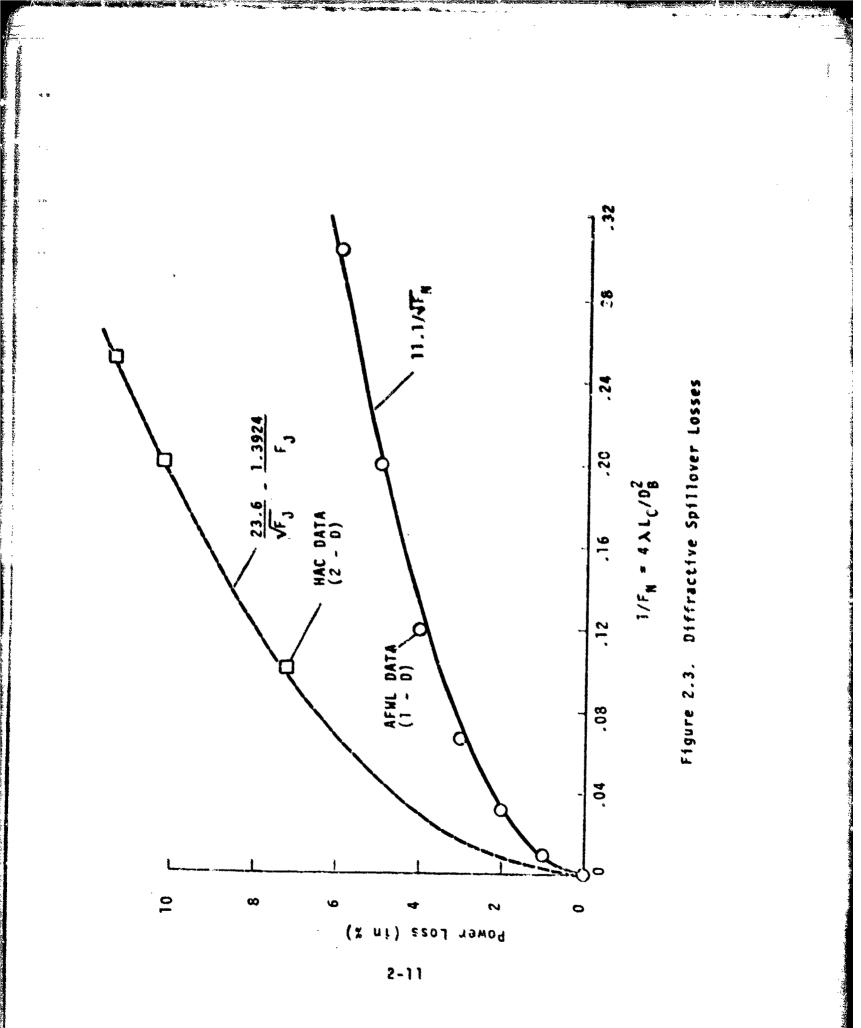
For the focused aerodynamic window, the beam diameter will typically be very small (<0.1 cm) so that the phase distortion can be reglected, i.e., $\sigma_{aw} \approx 0$.

2.1.3 Beam Clipper

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For NEL systems in which the laser device and the pointer/tracker are not closely coupled, a beam clipper or scraper will probably be employed near the pointer/tracker to control the size of the high power beam entering the transmitter. The beam clipper will influence both the power available at the transmitting optic and the beam quality, the latter by limiting the maximum diameter at the transmitting optic.

The loss in power at the beam clipper is due primarily to diffractive spreading of the beam as it propagates between the aerodynamic window and the beam clipper. In general, the diffractive spreading will depend upon the phase and amplitude aberrations in the input beam profile. An accurate assessment of the actual losses requires a detailed calculation involving numerical solutions of the Fresnel diffraction integral or spatial frequency approaches to optical propagation (i.e., Fourier Optics). These techniques are very time consuming and were not considered as viable candidates for the "simplified" model. Instead, an empirical approach based on curve fits of available data in the literature was taken. Unfortunately very little data were available for examination. Only two sources were found (References 4 and 7). The data obtained from these sources are illustrated in Figure 2.3 which shows the variation in power diffracted into the geometric shadow of a uniformly illuminated aperture as a function of the propagation distance from the aperture. The AFWL data were calculated for a one-dimensional beam profile while the HAC (Hughes



Aircraft Company) calculations were performed for a round beam. Therefore, the data must be adjusted for these differences before a direct comparison can be made.

Intuitively one would expect a factor of two difference between the data based on simple geometrical arguments. For example, a square beam profile would have twice the loss of a one-dimensional profile because of the two additional edges. For a round beam, however, the ratio is not quite as straightforward. Assuming circular symmetry, the fractional power loss is

$$\Delta_{2-0} = \frac{2\pi \int_{a}^{\pi} I(\sigma) \sigma d\sigma}{\pi a^2 I_0}$$

where a is the radius of the aperture and I_0 is the initial intensity. The major contribution to the integral occurs near the edge of the aperture. Thus over this region the radius can be taken as being approximately constant (= a) and removed from the integral without affecting its value, i.e.,

$$\Delta_{2-D} = \frac{2}{aI_0} \int_{a}^{b} I(\sigma) d\sigma.$$

For the one-dimensional beam profile the fractional power loss is given by

$$\Delta_{1-D} = \frac{\int_{a}^{b} I(x) dx (1)}{\frac{1}{a} I_{0} (1)}$$

so that if one further assumes that the intensity profiles at the aperture plane are the same in either case, i.e., I(r) = I(x), then one again gets a factor of two difference between the power losses.

The actual ratio indicated by the data was somewhat higher than a factor of 2 as shown by the corresponding curve fits of the data. Both sets of data correlated very well as a function of the reciprocal of the square root of the Fresnel number. However, the proportionality constant for the HAC data was found to be 23.6 versus 11.1 for the AFWL data.

In order to use these results in the optical train model, the power loss was assumed to be related to an effective increase in the beam diameter at the aperture plane, i.e.,

$$\frac{D_{B}}{D_{B_{0}}} = (1 - \log s)^{1/2} 1 - \frac{0.112}{\sqrt{F_{N}}}$$

where D_{B_0} is the new diameter of the beam at the beam clipper station and $F_N = D_B^2/4\lambda L_C$ is the propagation Fresnel number. It was also assumed, for the case of an obscured beam, that the hole in the beam filled in as much as the diameter of the hole would grow were it a uniformly illuminated aperture (i.e., Babinet's Principle). Thus the inner diameter of the obscured beam, D_{Ri} , is computed by

 $D_{Bi} = \epsilon D_B (1 - 0.112/\epsilon \sqrt{F_N}).$

If D_c is the diameter of the beam clipper, then the power transmission through the aperture is

$$T_{c} = \begin{cases} 1.0 & \text{if } D_{B_{0}} \leq D_{c} \\ (D_{c}/D_{B_{0}}) & \text{if } D_{B_{0}} > D_{c} \end{cases}$$

In the latter case, the beam diameter is set equal to the clipper diameter for the remaining calculations in the model.

2.1.4 High Power Nirrors

The mirrors in the optical train will affect all the performance parameters. Although it is not necessary we assume that all of the mirrors are identical in order to reduce the number of inputs.

A mirror alters the amplitude of the beam by absorbing a fraction of the incident radiation. For a series of N mirrors each having a surface reflectivity R, the transmission factor is

$$T_{\rm H} = R^{\rm H}$$
.

It should be noted that in the present analysis N includes all of the mirrors in the optical train, i.e., relay, steering, secondary and primary.

The beam quality degradation is due to (1) surface roughness and manufacturing errors in the mirror figure, and (2) surface distortions due to absorption of power from the incident beam. The former are independent of the power in the beam while the latter is a function of both the power and the irradiance distribution. In addition, if cooled mirrors are used, there will also be distortions induced by the pressure variations inside the coolant passages. However, these distortions will depend upon the details of the mirror construction and their characterization is felt to be beyond the scope of this model. Therefore, for this analysis, distortions of this type will be included in (1) above.

The beam quality degradation induced by the mirrors is incorporated into the optical train model through an equivalent phase variance, σ_M where

 $\sigma_{M}^{2} = N\sigma_{f}^{2} + [(N - 1)\sigma_{I} + \sigma_{I}/M^{2}]^{2}.$

The first term on the right hand side of the above expression represents the <u>uncorrelated</u> sum of the phase distortion due to fabrication errors such as surface roughness, figure error, coolant passage distortion, etc. The remaining terms represent the <u>correlated</u> sum of the irradiance mapping phase distortion. The distortion of the primary mirror is reduced by the square of the magnification of the beam expander to account for its reduced thermal loading.

In practice, σ_f is not known but is instead specified as a tolerance on the manufacturing process. Therefore, for modeling purposes this parameter was left to the user to specify.

The approach taken to model σ_{I} was to assume that the distortions scale directly with the irradiance fluctuations. That is,

σ_I = KI rms

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where K is a constant which depends upon the physical parameters of the mirror, the cooling scheme, etc. If we assume that the peak to peak intensity fluctuations specified in the input beam description are uniformly distributed and random in character, then

$$I_{rms} = \frac{I_{ave}}{\sqrt{12}} \left(\frac{\Delta I}{I_{ave}} \right)$$

where, for a circular beam,

$$I_{ave} = \frac{4 P_L}{\pi D_B^2}$$

Expressions for the evaluation of K depend upon whether the mirror is water cooled or not, i.e., for cooled optics

 $K(m^2/watt) = 5 \times 10^{-14} (1 - R) (2\pi/\lambda)$

whereas, for uncooled optics

 $K = 4\pi (1 - R) \alpha \Delta t / \lambda C \rho$

where

- α = the thermal expansion coefficient of the mirror material
- C = the specific heat of the mirror material
- ρ = density of the mirror material.

The expression for cooled optics is based on the NPT/Chemical Laser Compatibility Study conducted by Hughes Aircraft Company for NSWC (Reference 8) in which similar expressions were employed to compute the phase distortion caused by the NACL irradiance profile. The expression for uncooled optics is based on a simplified one-dimensional heat transfer analysis (Reference 9).

Local surface distortion is not the only performance degrading factor caused by the finite absorptivity of the mirrors. A bending distortion is also induced by the differential growth of the front and rear mirror surfaces. For properly designed, cooled mirror configurations, this distortion can be kept small. However, for uncooled mirrors, it may be important.

To first order, the bending distortion is primarily a function of the total beam power and not the irradiance distribution. In addition it produces mostly a spherical phase front distortion. Thus in the optical train model, we compute this distortion mode as a beam divergence instead of a quality loss since, in theory, it could be corrected by the focusing optic (if detected).

For an uncooled mirror that was initially flat, the change in the focal length with time can be approximated as (see Reference 9)

$$f = \frac{D_B^2 \ell \cos \Theta}{2.44 P_L (1 - R) \alpha} \left(\frac{D\rho K}{\Delta t}\right)^{1/2}$$

where

£ is the mirror thickness O is the beam angle of incidence on mirror

- K is the thermal conductivity of the mirror material
- f is the focal length of the distorted mirror.

The mechanism by which the defocusing errors induced by the individual mirrors are accumulated throughout the optical train is explained later.

2.1.5 Beam Expander

In the formulation of the beam expander model, we allow for two types: (1) an on-axis or (2) an off-axis system. Either type system affects the available power at the transmitter, the beam quality, beam jitter and beam divergence. A discussion of the methodology for computing the transmission factor and beam quality is given below. The beam jitter and divergence are discussed in a later section.

The power transmission through the beam expander is computed by projecting the exit aperture (defined by the user) onto the plane of the beam clipper station. Simple geometry then allows one to compute the power lost due to a mismatch between the beam diameters and exit aperture diameters. The formulas are illustrated in . Table 2.1 for both the on-axis and off-axis cases.

The beam quality is not affected by the off-axis system except to the extent that the limiting diameter is $MD_{B_0} \leq D_t$ for spot size calculations at the target plane. This is also true of the on-axis case. However, the onaxis system also introduces a central obscuration ε , which reduces the beam quality. The expressions used in the model to compute the final obscuration of the beam leaving the optical train are also given in Table 2.1.

TYPE	GEOMETRY	TRANSMISSION	OBSCURATION
1 6 0 0 1		$\frac{D_{0}^{2} - D_{i}^{2}}{D_{B_{0}}^{2} - D_{B_{i}}^{2}}$	D _i /D _o
ON		$D_0^2 - D_{B_1}^2$ $\frac{D_0^2 - D_{B_1}^2}{D_{B_0}^2 - D_{B_1}^2}$	D _{Bi} /D _o
AXIS		$\frac{D_{B_0}^2 - D_{i}^2}{D_{B_0}^2 - D_{B_i}^2}$	D _i /D _{Bo}
		1.0	D _{Bi} /D _{Bo}
OFF		^{(D} o ^{/D} Bo ²	D _{Bi} /D _o
AXIS		1.0	D _{Bi} /D _{Bo}

Table 2.1. Summary of Beam Expander Transmissions and Obscuration Calculations

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The effect of the obscuration on the beam quality is again computed by relating it to an equivalent phase distortion. This relationship was derived empirically based on the results of the previous work under this contract (Reference 2), and is illustrated graphically in Figure 2.4. Within the computer code, this relationship is represented by a third order polynomial developed from a "least-squares" regression analysis of the data presented in Figure 2.4. Also shown on the figure is the effective scale size of the phase distortion. Its use in the model will be explained below.

2.1.6 Exit Aperture

Provisions were also made in the optical train model for an exit aperture downbeam of the pointer/tracker. It can be either a material window or open port, with an aerodynamic curtain protecting the optics from the environment, based on user specified option parameters.

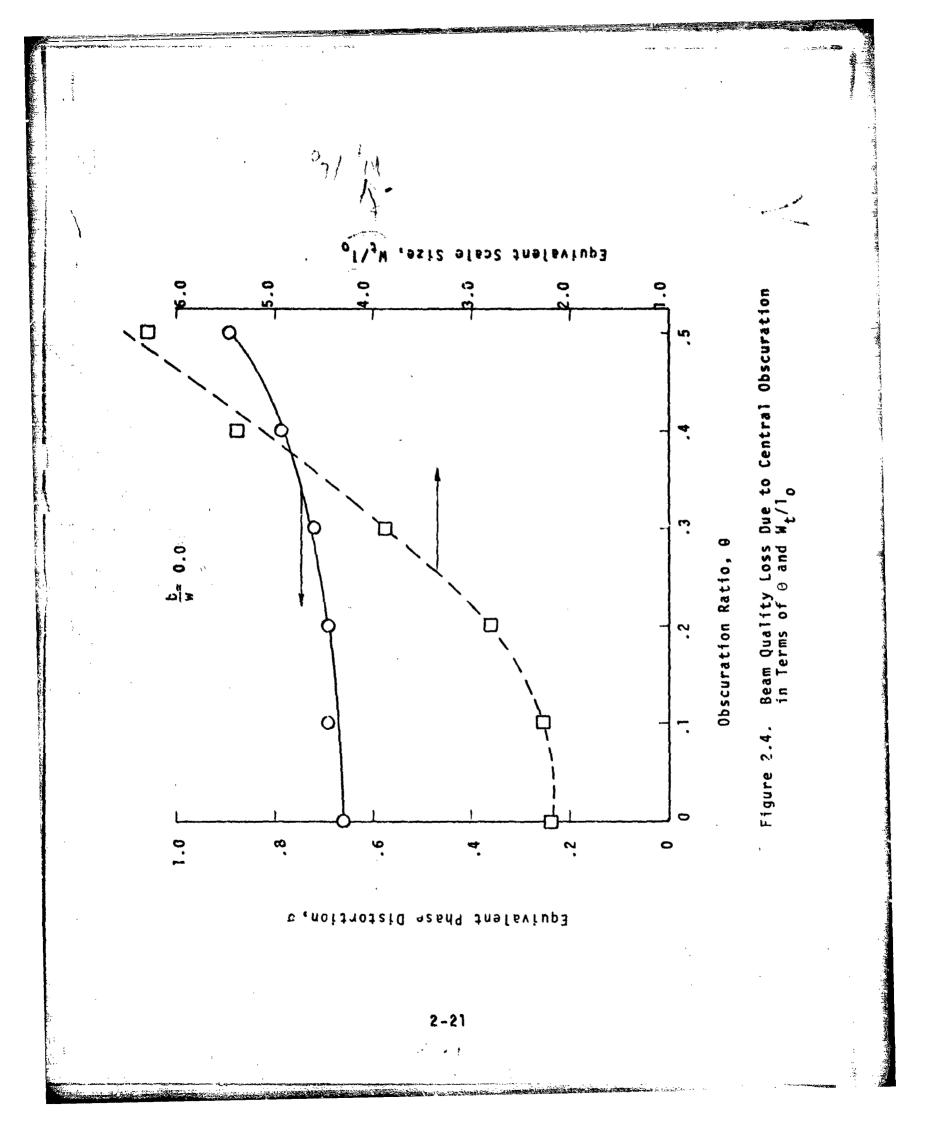
In either case the loss in power through this exit aperture will be

$$T_{E} = e^{-\beta L_{W}} (1 - A_{s}/A_{B})$$

where

- β = absorption coefficient of material window
- L_w = thickness of material window
- A_s = area of struts supporting window or secondary mirror in the case of an on-axis beam expander

 $A_{B} = beam area (\pi M^{2}D_{B_{D}}^{2}/4).$



Note that an open port can be simulated by setting $\beta = 0$.

For simplicity, the phase distortion induced by the material window is assumed to be proportional to the local intensity fluctuations in the beam profile. That is

$$\sigma_{W} = \left(\frac{2\pi}{\lambda}\right) \frac{\beta \Delta t L_{W}}{\rho c} \left[(n - 1) \alpha + \frac{\partial n}{\partial T} \right] \frac{I_{rms}}{M^{2}}$$

where (in addition to those parameters previously defined) n is the refractive index and T is the temperature. The mignification appears because of the assumed location of the window downstream of the beam expander. In order to minimize the number of inputs to the model, the raterial constants were lumped into a single parameter defined as

$$\gamma = \frac{1}{\rho C} \left[(n - 1) \alpha + \frac{\partial n}{\partial T} \right]$$

which varies between 4 x 10^{-12} m³/j for the fluoride windows aF₂, MgF₂, SrF₂) to 15 x 10^{-12} m³/j for the salt windows (NaCl, KCl). A value of 5 x 10^{-12} m³/j was hardwired in the model as being representative of current window technology.

The presence of struts in the beampath will also cause a reduction in the beam quality. To first order, this loss will be directly proportional to the area of the beam blocked by the struts. Consider, for example, the on-axis intensity which, in the context of scalar diffraction theory, is given by the integral of the complex field leaving the transmitting aperture, i.e.,

$$I(o) \sim \left[\iint u(x,y) d x dy\right]^2.$$

Thus, for a constant field aperture strength, the integral is simply the area of the clear aperture. That is

$$1(o) - (A_B - A_S)^2$$

so that the intensity reduction relative to no struts is simply

$$\frac{1(0)}{10} = \left(1 - \frac{A_{s}}{A_{B}}\right)^{2} = T_{s} (1 - A_{s}/A_{B}).$$

For modeling purposes, this intensity reduction was considered to be separable into (1) a power loss due to the transmission of the aperture, T_s , and (2) a beam quality loss characterized by wide angle scattering, $(1 - A_s/A_B)$. The latter can be related to an equivalent phase distortion via the Strehl equation

$$\sigma_{\rm s} = \left({\rm A}_{\rm s}/{\rm A}_{\rm B}\right)^{\rm L} \, .$$

The phase distortion induced by an open port is not intensity dependent but instead a function of the turbulence level inside the beam expander and aerodynamic curtain. Because of the presence of turbulence, this effect is treated as an additional source of beam jitter in the model. The magnitude of the jitter is estimated from (Reference 8)

$$\sigma_{\rm J} = 2.14 \times 10^{-7} \left[\frac{L_{\rm e}^3 \, \Delta T^6}{\lambda \, D_{\rm t}^2} \right]^{1/5}$$

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where L_e is the path length through the beam expander and ΔT is the magnitude of the temperature fluctuations within the beam expander. Some representative values of the jitter are illustrated in figure 2.5 for a 0.7 meter transmitter diameter. For example, a 1°C temperature fluctuation produces approximately 4.5 µrad of beam jitter for a 3.8 µm wavelength beam.

2.2 ASSESSMENT OF OVERALL PERFORMANCE

The previous discussion was primarily concerned with the influence each of the elements has on the characteristics of the laser beam as it traverses the optical train. In the following section we show how these individual effects are accumulated to arrive at an overall assessment of system performance.

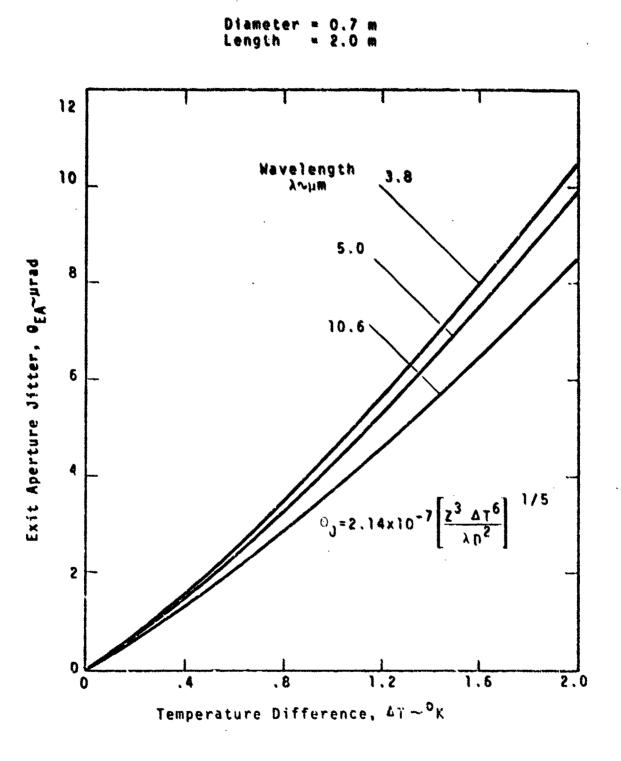
2.2.1 Transmitted Power

The power available at the transmitting optic is simply the input power from the laser device modified to account for all of the power losses that have occurred along the optical train. That is

 $P_t = T P_L$

where T is an overall transmission factor. Since the power losses are multiplicative, the overall transmission factor is

 $T = (T_c) (T_M) (T_{BE}) (T_E)$



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Figure 2.5. Effects of Exit Aperture Temperature Fluctuations on Beam Jitter

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where T_c is the transmission factor of the beam clipper, T_N is the transmission factor of all the high power mirrors, T_{BE} is the transmission factor of the beam expander, and T_E is the transmission factor of the exit aperture. Formulas for all of these factors were given previously.

2.2.2 Beam Quality

The quality of the beam at the transmitting optic is characterized by the two beam quality parameters, m_1 and m_2 (see Reference 1 and Section 4.3 of this report). Unfortunately, the calculation of m_1 and m_2 is not simple. The basic problem is to combine the effect of all the quality degrading factors occurring within the optical train. This is somewhat complicated because the phase distortions induced by the individual components do not add up in a straightforward manner but instead depend, in a complicated manner, upon the distribution as well as the magnitude of the phase distortion. For example, a "smooth" distortion behaves differently than a very "rough" distortion even though their magnitudes are the same.

To circumvent this problem, a statistical approach is used within the model to accumulate the phase distortions. This approach is somewhat loosely based on the theoretical investigations of nondiffraction-limited gaussian beams by B. Hogge at the AFWL. Briefly, the approach is to consider the overall beam profile at the focal plane as being composed of two gaussian beam profiles of different relative amplitudes and widths. That is, a certain fraction of the energy in the beam is propagated completely unaffected by the phase distortion, i.e.,

$$I_u(r) = e^{-\sigma^2} \exp\left(-\frac{2r^2}{w_f^2}\right) I_0$$

where w_f is the diffraction limited waist parameter, I_0 is the on-axis intensity and σ^2 is the variance of the phase distortion (assumed to a gaussian random variable). The remaining energy is smeared or spread by the phase distortion into a somewhat larger beam profile, i.e.,

$$I_{s}(r) = (1 - e^{-\sigma^{2}}) \left(\frac{w_{f}^{2}}{w_{f}^{2} + 20^{2}f^{2}}\right) \exp\left(\frac{-2r^{2}}{w_{f}^{2} + 20^{2}f^{2}}\right) I_{0}$$

where O is the angular spread of the scattered beam.

The problem thus reduces to characterizing the overall phase variance, σ , and beam spread parameters, Θ , that "best" model the summation of all of the phase distortions in the optical train.

A true characterization of σ and Θ is, in reality, not possible. Some theoretical arguments can be made for isolated phase ditributions such as the random gaussian noise model investigated by Hogge. In the real world, however, optical systems do not produce such amiable distortions. Nevertheless, using these results as being at least qualitatively correct, we compute the total phase distortion as simply the uncorrected sum of each of the individual distortions, i.e.,

 $\sigma^2 = \sigma_L^2 + \sigma_{AW}^2 + \sigma_N^2 + \sigma_{BE}^2 + \sigma_S^2 + \sigma_W^2.$

Instead of computing the beam spread, 0, it is more convenient to compute an effective scale size or correlation length of the overall phase distortion, L. This scale size is related to the beam spread via $\Theta^2 = (\lambda/\pi L)^2$. In the

aforementioned work of Hogge, it was noted that the effective correlation length for a number of sources of phase distortion was found to be an average of the correlation lengths of the individual sources, each weighted by its respective variance. Again, taking the inductive leap, we compute L from

 $L = \frac{1}{\sigma^{2}} \left[k_{L} \sigma_{L}^{2} + k_{AW} \sigma_{AW}^{2} + k_{N} \sigma_{M}^{2} + k_{BE} \sigma_{BE}^{2} + k_{S} \sigma_{S}^{2} + k_{W} \sigma_{W}^{2} \right].$

In practice very little is known about the magnitude of the scale sizes characterizing the individual components. Therefore, for the present model, we have made some additional assumptions regarding their respective sizes. For example, the irradiance mapping phase distortions such as σ_{T} and σ_{U} are assumed to have the same scale size as the intensity fluctuations in the input beam profile. For other components, such as the laser device, the aerodyanmic window and the struts, we assume that the scale size is zero. In effect this is assuming that each of these components scatters the energy in the beam beyond a usable radius in the focal plane and therefore is somewhat conservative. The scale size of the beam expander was determined empirically since the effect of obscuration on the nearfield beam profile was readily calculated (see Figure 2.4). Within the model this relationship is represented by a third order polynomial.

The computed values of the phase variance and scale size are used to evaluate the power distribution at two radial positions in the far-field, namely $r = w_f$ and $r_2 = 2w_f$. These power points are then used to generate the beam 4 lity parameters m_1 and m_2 . The procedure for doing this is outlined in Reference 1.

2.2.3 Beam Jitter

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The beam jitter is accumulated throughout the optical train by assuming that the sources of beam jitter are independent of each other. Thus they may be root-sumsquared to get the total jitter. The primary consideration for the beam jitter calculation is whether or not the source of the jitter is upbeam or downbeam of the beam expander. The beam expander reduces the jitter by a factor of $1/M^2$ where M is the magnification.

The sources of beam jitter considered by the model

- Tracking jitter, 0, p
- Boresight jitter, O_{BS}
- Autoalignment system jitter, Θ_{ΔΑ}
- Servo jitter, Θ_{c}
- Device jitter, O₁

Exit aperture induced jitter, Θ_F.

The jitter of the input beam and the jitter induced by the beam steering mirror in the autoalignment system are assumed to occur before the beam expander. The remaining jitter sources are assumed to occur after the beam expander. Thus the total jitter leaving the optical train is given by:

 $\sigma_{\rm J} = \{ \Theta_{\rm TR}^2 + \Theta_{\rm BS}^2 + \Theta_{\rm S}^2 + \Theta_{\rm E}^2 + (\Theta_{\rm L}^2 + \Theta_{\rm AA}^2)/M^2 \}^{\frac{1}{2}}.$

2.2.4 Beam Divergence

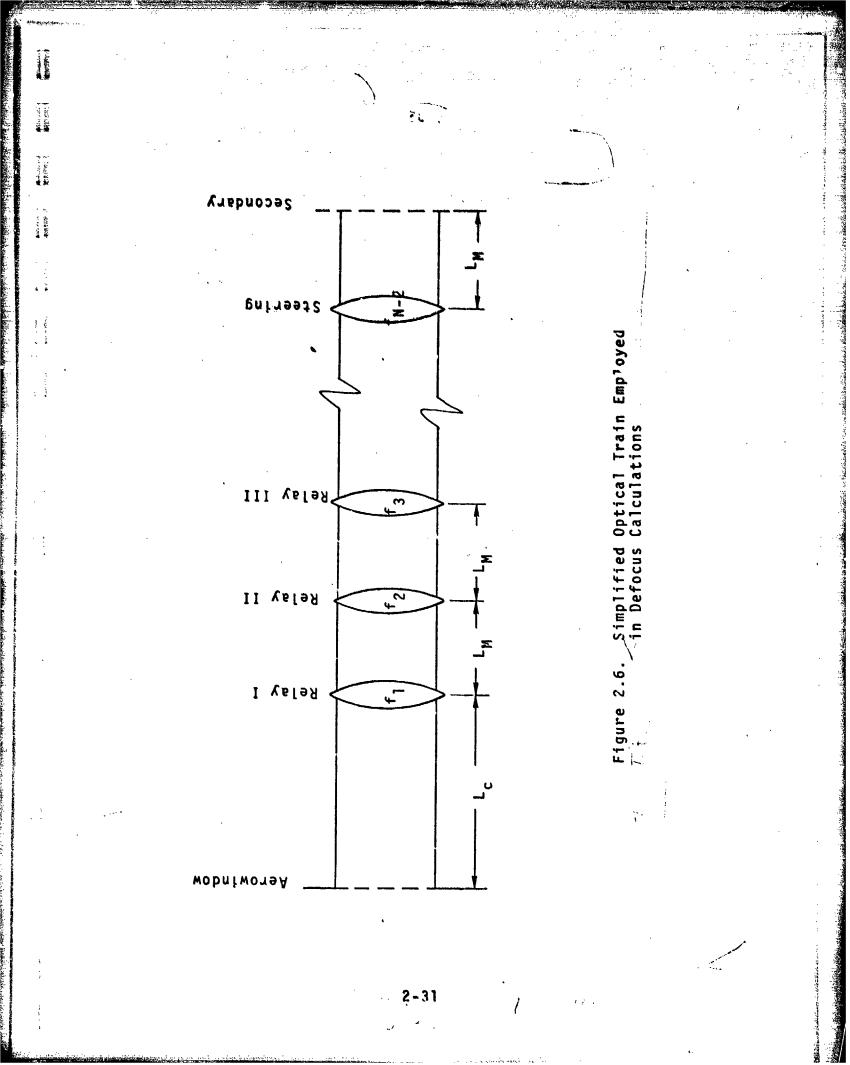
The beam divergence represents the spherical phase curvature in the beam as it enters the transmitting optic and results in a larger spot size at the target than one would expect had the beam been collimated when it entered the transmitting optic. As an example, consider a collimated ideal gaussian beam which has been focused to produce a spot size of w_f (actually a radius to the e^{-2} intensity point) at a target. If the beam is instead diverging (or converging) with a radius of curvature $-R_B$ $(+R_B)$ as it is reflected from the same transmitting optic, the new spot size w_f^{+} is larger than the original by

$$\left(\frac{w_{f}}{w_{f}}\right)^{2} = 1 + \left(\frac{\pi D_{B}^{2}}{4\lambda R_{B}}\right)^{2}$$

where D_B is the (e^{-2}) diameter of the ideal gaussian beam and λ is the wavelength. For example, 0.1λ spherical phase error will increase the spot size approximately 20% for a 100 cm diameter optic transmitting at $\lambda = 3.8 \mu$. For the present study we assume that any phase curvature in the output beam from the optical train behaves in a similar manner.

The change in the curvature of the phase front of the beam as it propagates through the optical train is computed by employing a simplified geometric optics calculation through the optical elements preceding the beam expander. The usual simplifying assumptions, i.e., paraxial rays, thick lenses, etc., are made in order to make the calculation tractable.

Following the ray matrix approach of Reference 10 we first obtain the equivalent ray matrix of the optical train illustrated in Figure 2.6 by multiplying together the individual ray matrices of the individual elements, i.e.,



$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 1 & L_M \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -1/f_{N-2} & 1 \end{bmatrix} \cdots \begin{bmatrix} 1 & 0 \\ -1/f_2 & 1 \end{bmatrix} \begin{bmatrix} 1 & LM \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -1/f_1 & 1 \end{bmatrix} \begin{bmatrix} 1 & L_C \\ 0 & 1 \end{bmatrix}$$

where (going from right to left) the first matrix represents the propagation distance between the aerodynamic window and the beam clipper, the second matrix represents the reflection of the beam from the first relay mirror in the optical train, the third matrix represents the propagation distance between the first relay mirror and the second relay mirror, the fourth matrix represents the reflection of the beam from the second relay mirror, and so on until the beam is incident upon the secondary mirror. At this point we assume that the beam expander simply expands the beam by the specified magnification. The cur sture of the phase front at this point, R_B , is related to the phase front curvature of the input beam, R_i , by

$$R_{B} = M\left(\frac{AR_{L} + B}{CR_{L} + D}\right).$$

The computed value of R_B is then used to compute the new spot size of the focused beam. In order to transfer this information to the propagation model, the beam quality parameter, m_2 , which characterizes the spread of the beam profile in the absance of other effects, such as thermal blooming, turbulence and beam jitter, is internally adjusted by the model to reflect the increased beam spread, i.e.,

$$(m_2)_{\text{final}} = \sqrt{1 + \left(\frac{\pi D_B^2}{4\lambda R_B}\right)^2} \quad (m_2).$$

2.3 SAMPLE CALCULATIONS

As an illustration of how the optical train influences the performance of a laser system, we present below a sample calculation for the optical train schematically illustrated in Figure 2.7.

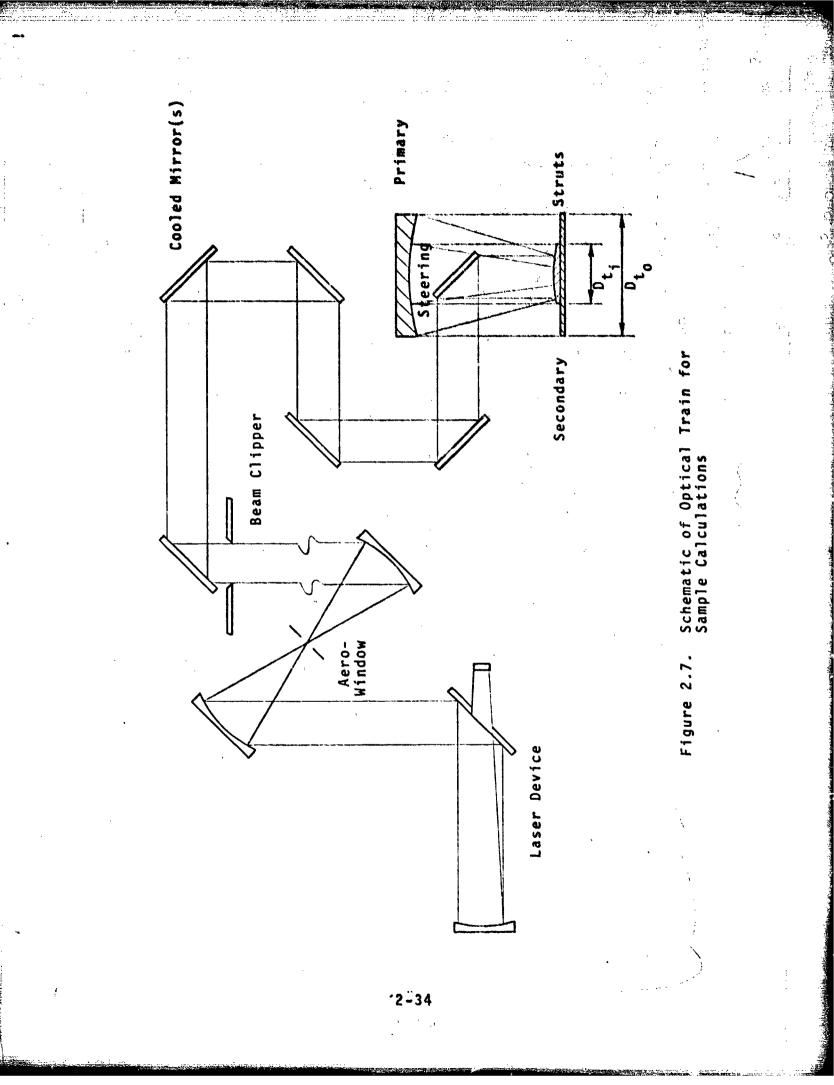
The laser device is assumed to be operating in an unstable confocal resonator mode with the power coupled out of the device via a scraper mirror located in front of the convex optic of the resonator. Accordingly, the output beam contains a central obscuration. The parameters assumed for this beam are:

> Beam Diamter = 0.1 meters Power = 400 kw Wavelength = 3.8 microns Obscuration = 0.5

In addition, it is assumed that the beam is essentially collimated ($R_{\perp} = \infty$) and contains peak-to-peak intensity fluctuations that are 50 percent of the average intensity ($\Delta I/I_{ave} = 0.5$). The scale size of these fluctuations is taken to be 1 cm or $\ell_I/D_B = 0.1$. We also assume that the quality of the beam leaving the device is characterized as being 1.2 times diffraction-limited ($n_{\perp} = 1.2$). This corresponds to an equivalent rms phase distortion in the beam of $\sigma_1 = 0.16$ radians or about $\lambda/40$ (see Figure 2.2).

The output beam from the laser device is focused through an aerodynamic window to a collimating mirror. Since the beam size is very small (typically < 0.1 cm) at the aerodynamic window, we neglect any phase distortion induced by the aerodynamic window (i.e., $\sigma_{aw} = 0$).

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For the example, we assume that the beam expender is located 50 meters from the aerodynamic window. Over this distance, diffraction effects cause the beam to expand somewhat. The Fresnel number for this propagation distance is

$$F_{\rm N} = \frac{4D_{\rm B}^2}{\lambda L_{\rm C}} = 13.16$$

so that the beam diameters at the entrance to the beam expander are

$$D_{B_0} = \frac{D_B}{1 - 0.112 \text{ // }F_N} = 0.103 \text{ m}$$

and

١,

$$D_{B_i} = \left(\varepsilon - \frac{0.112}{\sqrt{F_N}}\right) D_B = 0.047 \text{ m}.$$

In this example, we have assumed that the diameter of the beam clipper is 16 cm so that no power loss due to clipping occurs, i.e., $T_c = 1.0$.

The nine (9) mirrors employed in the optical train are assumed to be water cooled with a reflectivity of $R_i = 0.986$. We also take the fabrication error as being $\lambda_v/8$ where λ_v is 0.564 microns. Accordingly, the power lost to the beam due to the finite absorptivity of the mirrors is

$$T_{\rm M} = (0.986)^9 = 0.88.$$

The phase distortion induced by each mirror depends upon the rms intensity fluctuations, which for the case being considered are

$$I_{rms} = \frac{4P_L}{\pi D_H^2} \frac{\Delta I/I_{ave}}{12} = 7.35 \times 10^6 \text{ w/m}^2$$

so that

 $\sigma_{\rm I} = 5 \times 10^{-14} (1 - R)(2\pi/\lambda) I_{\rm rms} = 0.0085$ radians.

Combining this with the fabrication error yields (for all of the mirrors in the optical train)

$$\sigma_{\rm M} = 9\sigma_{\rm f}^2 + [8\sigma_{\rm I} + \sigma_{\rm I}/{\rm M}^2]^2 = 0.3454$$
 radians.

The beam expander is an on-axis system of magnification. M = 4.376. The inner and outer diameters of the clear output aperture are $D_{t_0} = 0.7$ and $D_{t_1} = 0.252$ meters respectively. Since the beam entering the expander is not perfectly matched to the reduced clear aperture dimensions (i.e., $D_{t_0} = 0.16$ and $D_{t_1} = 0.576$), there is a power loss

induced by the beam empander. From the geometry of the case being considered, this loss is computed to be approximately 13 percent or $T_{BE} \approx 0.87$. In addition, the beam expander has altered the obscuration of the input beam because of clipping. final obscuration of the beam leaving the beam expander is $\varepsilon = 0.0576/10.3 = 0.558$. Note that the final obscuration is not the observation of the

telescope $(D_{t_i}/D_{t_0} = 0.36)$ because the input beam was not large enough to fill the transmitting optic. The effective phase distortion of the actual beam is therefore much larger than one would compute based on the obscuration of the telescope. For the example being considered, this equivalent phase distortion is $\sigma_{\rm RF} = 0.72$ radians.

The exit aperture was assumed to be an open port so that the only power loss is that due to blockage by the struts required to support the secondary mirror of the beam expander. Thus, $T_E = 0.95$. The quality loss due to the struts is

 $\sigma_{\rm s} = (A_{\rm s}/A_{\rm B})^{\frac{1}{2}} = 0.2236$ radians.

Within the model, the open port would also induce jitter into the beam. However, for the purposes of this example, we have ignored any performance loss caused by beam jitter.

Combining the above losses, we get for the overall transmission factor

 $T = T_{C} \cdot I_{BE} \cdot T_{E} = 0.727.$

Thus, the power from the device that is available for propagation to the target is

 $P_t = 0.727 P_L = 290 kw.$

The total distortion is

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$$\sigma = \left(\sigma_{\rm m}^2 + \sigma_{\rm BE}^2 + \sigma_{\rm S}^2 + 0.433\right)^{\frac{1}{2}} = 1.06$$
 rads.

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This phase distortion is characterized by a scale size

$$\frac{1}{DB} = \frac{1}{\sigma^2} \left\{ \frac{x_{BE}}{D_B} \sigma_{BE}^2 + \frac{x_1}{D_B} \left[(N - 1)\sigma_1 + \frac{\sigma}{N^2} \right]^2 + 0.196 \right\} = 0.114$$

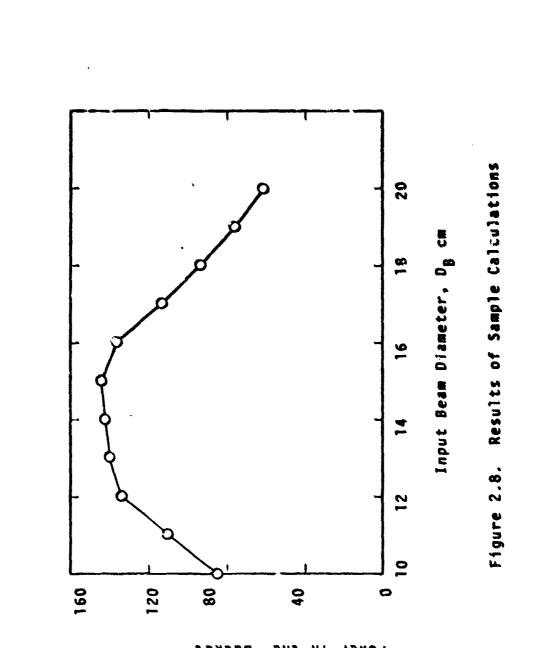
in terms of the two parameter descriptions of the beam quality employed by the model $m_1 = 0.3536$ and $m_2 = 1.1076$. For this example, there were no defocusing errors induced by any of the components in the optical train so that no adjustment was made to the beam spread parameter m_2 . Note that the constraints in the last two equations (0.433 and 0.196) are needed to ensure the proper conversion of σ and $\frac{1}{D_B}$ to m_1 and m_2 .

In order to quantify the impact of the optical train, we evaluate the power delivered to a particular spot in the focal plane, namely $r^* = f\lambda/D_t$. In the absence of atmospheric effects and beam jitter, this power is simply

$$P(r^{\star}) = P_t m_1 \left\{ 1 - exp \left[-\frac{\pi^2}{m_2^2} \left(\frac{D_B}{D_{t_0}} \right)^2 \right] \right\}$$

where D_B is the actual diameter of the beam on the transmitting optic, i.e., $D_B = M D_{B_n} \leq D_{t_n}$.

The results of this calculation for the example being considered is shown in Figure 2.8 along with some additional calculations made for various input beam diameters. For the conditions described above, only 83 kw of the initial 400 kw are delivered to the target. Note, however, that by expanding the input beam a significant increase in power can be achieved. The initial beam size of 10 cm was too small to effectively use the entire diameter of the transmitting optic. Hence, the beam profile at the target was



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Power in the "Bucket"

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larger than it should have been. In addition, because of the mismatch of device output beam and beam expander clear aperiure, a significant power loss occurred. As the beam diameter is allowed to increase, both of these effects are reduced. Of course, at the point where the beam begins to spill-over onto the beam clipper, the near-field power is again reduced resulting in the performance fall-off shown in the figure.

It is recognized that a true performance evaluation cannot be made without including the propagation effects between the transmitter and target plane. However, the example does point out the necessity of including the effects of the optical train in any application study, since it indeed has a substantial impact on the near-field characteristics of the beam. In addition, the model also should provide some insight into the problems of integrating lasers and pointer/tracker systems. It is interesting to note that a detailed study of a similar system using a wave optics code resulted in an additional beam expander (M = 1.3) being placed in the optical train.

The simplified optical train model has been developed using state-of-the-art knowledge of the contribution of each element (windows, mirrors, etc.). It should be noted, however, that the model has not been verified using the more detailed wave optics codes. Such comparisons would be useful to not only verify, but also to improve, these simplified models.

Section 3

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CREATION OF SAICON

One of the High Energy Laser (HEL) propagation codes commonly used by the laser systems analysts is the COMBO (or ATM) code developed by the Air Force Weapons Laboratory (Reference 11). ATM is the propagation model documented in Reference 11. COMBO is a code which combines ATM with the Air Force HEL weight and volume projections (Reference 12). COMBO also includes some additional features such as the ability to perform reverse calculations in which the user specifies a desired intensity and the code determines the range at which the intensity can be delivered (given the power) or the power required (given the range). The primary asset of CONBO (or ATM) is its ability to make variable altitude calculations, including propagation paths extending to or from space.

One of the tasks performed under the present contract was devoted to modifying COMBD. The objectives were to reduce execution time, improve computational accuracy and to incorporate several of the newer developments resulting from the other tasks of this contract. A number of other minor additions, corrections and deletions were also made.

All of the primary modifications are discussed in Section 3.1. Collectively, they are sufficient to warrant a new code name -- SAICOM. A brief user's guide to SAICOM is provided by Section 3.2.

3.1 MODIFICATIONS OF COMBO

The primary modifications are dealt with in individual subsections below. The basic structure and organization

of the code remain essentially the same as in the original version (Reference 11). A summary of the more important equations is given in Section 3.1.9.

3.1.1 Improvements to Computational Speed and Accuracy

A substantial part of the CONBO modification effort was devoted to improving the speed of the calculations. Several modifications simply involved improvements in coding techniques. These included: (1) reducing the number of calls to MEGAIR (the subroutine which provides altitude dependent parameters such as temperature, pressure, etc.); (2) lumping several blooming parameters (viz., n, $\partial n/\partial T$, and C_p) into a single curvefit (GALTIN); (3) using a better search algorithm in the reverse calculations; and (4) reducing the subroutine calls.

Most of the improvement in both speed and accuracy was obtained by developing a completely new algorithm for performing the double integration required to compute the blooming parameter, NI. The expression for NI is of the form

NI =
$$C \int_{0}^{L} \frac{1}{r(z')} \int_{0}^{z'} G(z') dz'' dz'$$

where C is fixed for a given set of conditions (Reference 13). The integration paths are along the beam. In the original code, the double integral was evaluated by assuming the integrals to be constant between uniformly spaced points along the beam. The evaluation was successively repeated with reduced spacing until the results for consecutive evaluations agreed with 10 percent. This procedure

was found to be inefficient and often inaccurate. This should be readily apparent from Figure 3.1, which shows the important elements of the integral for a particular case of a highly focused beam. Note that the value of NI is dominated by the conditions within the last few percent of the range.

The new algorithm examines the local behavior of the integrand and chooses an efficient scheme and mesh spacing dynamically. It selects either a locally quadratic or locally exponential representation of the integrand. If neither is satisfactory, it reduces the mesh spacing and tries again. On the other hand, if the local convergence exceeds the accuracy requirements, it increases the mesh size to increase speed. Both integrations as well as a third implicit in G are performed in a single loop.

When the new algorithm was used for the severe example illustrated in Figure 3.1, the calculation required 1.49 seconds; the original COMBO exceeded a time limit of 200 seconds without completing the calculation!

As mentioned earlier, an additional improvement in computation time was obtained by modifying the convergence algorithm used in the reverse propagation calculation where the range is successively adjusted to obtain a desired target plane intensity. The range R' for one iteration is determined by modifying the previous range, R, viz.,

 $R' = KR \sqrt{I/0I}$

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4.4

where OI and I are the desired and computed intensities, respectively. In the original COMBO, the constant K was always 1.0, whereas in SAICOM, it varies between 0.7 and 1.0 to accelerate convergence. In addition, the convergence criterion was relaxed from 1% to 5%.

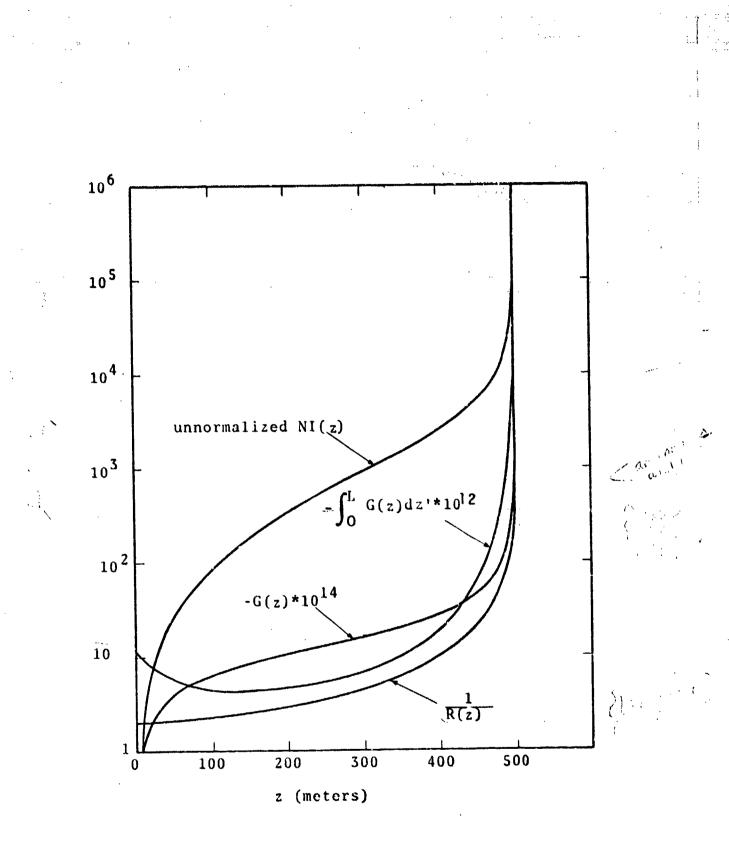


Figure 3.1 Variations in Elements of the Blooming Calculation

3.1.2 Beam Quality

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The SAICOM code includes a significant innovation in the treatment of beam quality. It essentially replaces the usual one parameter concept of an "m x diffraction limited" beam by a two parameter representation. The two parameters, designated m_1 and m_2 , are used to specify a gaussian representation of the focal plane intensity profile so as to approximate the actual integrated power distribution. The two parameter model is inherently capable of including effects leading both to beam spreading (m_2) and to power loss due to wide angle scattering (m_1) .

The origin and interpretation of m_1 and m_2 are discussed in some detail in Reference 1 and in Section 4.3 of this report. Their use in characterizing the effects of beam truncation and obscuration is discussed in Reference 2. In general, they are calculated in the new optical train model which is an integral part of SA1COM (see Section 2).

SAICOM incorporates the two parameter approach even though the user is only required to stipulate a single parameter, m. If the device power (P_D) and beam quality (m) are stipulated, the optical train portion of the code converts them to the appropriate aperture or transmitted power (P_T) and beam quality (m_1 , and m_2). If the optical train calculations are bypassed because the user specifies P_T , the specified beam quality is assumed to be pure beamspread.

The SAICOM intensity expression for a focused beam is of the form

$$I = \frac{[1 - (1 - 0.865 m_1 z/L)] P_T e^{-\alpha z}}{\pi r^2(z)}$$

where

$$r^{2}(z) = \frac{D}{4L^{2}} |L - z|^{2} + 4z^{2} \left[\left(\frac{0.3183 m_{2}\lambda}{D} \right)^{2} + \sigma_{T}^{2} + \sigma_{J}^{2} \right]$$

The term in the numerator that decreases as z increases represents the power losses that may be thought of as wide angle scattering. The 0.865 factor is present because the basic propagation equation used in the code is based on the $1/e^2$ radiance of an infinite Gaussian beam. Since m_1 and m_2 are used to account for the effect of different beam profiles as well as phase perturbation, these terms may be not the unity even for perfect beams. This situation is clarified in Table 3.1. In this table the M1 and M2 terms are the parameters computed in the optical train subroutine while m is the user specified beam quality for the total system. Note that if the optical train is bypassed (the user specifies P_T) and m=1, m_1 and m_2 are 0.89 and 1.29 respectively for a uniform beam and not unity because the basic propagation equation is based on an infinite gaussian model. But if the optical train is not bypassed, $m_1 =$ M1=0.89 and $m_p=M2=1.29$ because the basic profile used in the optical train subroutine is uniform.

3.1.3 The Optical Train Model

The development of an improved optical train model was the prime objective of Task 5 and is discussed in detail in Section 2 of this report. The model has been incorporated into SAICOM as subroutine OPTRAIN. It computes power losses, jitter, and beam quality degradation associated with transmission of the beam from the laser through

Beam Quality Parameters Table 3.1

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Aperture .	Intensity Profile	Infinite Gaussian	1/e ² Gaussian	Uniform
OPTRAIN	L	-	-	0.89
BYPASSED	C E	p	1.41 m	1.29 m
OPTRAIN	E	0.89 %]	0.89 %1	EW
USED	ک E	0.775%2	1.092M2	M2

the final the described above. It accepts a quite general specification of the optical train through a list of input parameters. OPTRAIN accounts for beam truncation and obscuration and for various contributions to phase perturbations. The output includes the two beam quality parameters m_1 and m_2 described above.

transmitted power, P_T , rather than the device power in the input. In this case, beam quality is based on wave-length scaling as usual.

3.1.4 Multi-Line Propagation

Since many of the lasers of interest for high energy applications emit several lines simultaneously, it is desirable to include these multi-line characteristics in the simplified propagation codes.

The approach used in SAICOM is to compute the amount of energy absorbed by the air on a line-by-line basis. This means that $\exp\{-\int_{0}^{R} d(z^{"})dz^{"}\}$

$$\sum_{i} \frac{P_{i}}{P_{T}} \exp \left\{-\int_{0}^{R} \alpha_{i}(z^{**}) dz^{**}\right\}$$

and

 $\alpha(Z^{*})\exp\left\{-\int_{0}^{Z^{*}}\alpha(Z^{*})dZ^{*}\right\}$ in the integrand of the

expression for the blooming parameter becomes

$$\sum_{i} \frac{P_{i}}{P_{T}} \alpha_{ai}(Z^{"}) \exp\left\{-\int_{0}^{Z^{"}} \alpha_{ei}(Z^{"'}) dZ^{"'}\right\}$$

where

 α_{ai} = absorption coefficient of the ith line α_{ai} = extinction coefficient of the ith line.

In SAICOM, the 3.8 µm DF propagation has been extended to include three distinct families of lines. These encompass ten lines of the DF laser, and represent 80% of the output of the BDL device. With the basic modification having now been made, it is straightforward to include multi-line HF or CO propagation.

The derivation of the DF absorption coefficients is given in Appendix A and is based on the BDL spectral data. The resulting SAICOM equations are

$$\alpha_i = A_0 e^{-A_1 + h(-A_2 + A_3 h)}$$

 $\Lambda_0 = 1 + (0.9446 \text{ RH-1})e$

where

for groups 1 and 2

= 1, for group 3

A₁ = 10.047, 10.082, and 9.948 for group 1, 2 and 3, respectively

 $-h(6.738 \times 10^{-5} + 9.61 \times 10^{-9} h)$

 $A_2 = 6.388 \times 10^{-4}$, 6.952×10^{-4} , and 2.199×10^{-4} $A_3 = 2.25 \times 10^{-8}$, 1.55×10^{-8} , and -1.96×10^{-8} h = altitude in meters.

These equations imply that at sea level α varies between 0 and 0.0409 km⁻¹ as relative humidity varies between 0 and 100%, α_2 between 0 and 0.0395 km⁻¹, and α_3 is a constant 0.0478 km⁻¹.

The above equations are only valid to around h=13 km; for the higher altitude the original COMBO coefficients are used. Unfortunately, a discontinuity existed at the 13 km altitude; so transition equations were created to connect the multi-line data below 13 km with the single-line data above that point. Figures 3.2, 3.3, 3.4, and 3.5 plot the α_1 , α_2 , α_3 , and $\alpha_{resultant} = \frac{equations}{2}$ where

 $\alpha_{resultant} = \frac{\alpha_1 + \alpha_2 + \alpha_3}{3}$

The scattering equations are the same as those used in the original COMEO (Reference 11).

3.1.5 Modification of Turbulence and Jitter to Include Short and Long Term Effects

During the code comparison work in Task 1 of this contract, it was noted that one of the useful features of ESP was the flexibility of including beam jitter in the blooming calculation if the frequency were high enough and excluding it otherwise (References 1 and 14). This feature has been included in SAICON. The output jitter factors in SAICOM are high-frequency jitter (σ_{JHF}) and low-frequency jitter (σ_{JLF}) . The former is used in the calculation of the blooming parameter and both are combined to give the total beamspread due to jitter. Similarly, the turbulence calculations are expanded to include the total, long-term turbulence (σ_{TLT}) and the high-frequency, short-term turbulence (σ_{TST}) . The turbulence equations in SAICON are based on work of Yura (References 15 and 16) whereas the COMBO code was based on Fried's work (Reference 17), but the results differ only slightly in the regions of interest. The equations used are

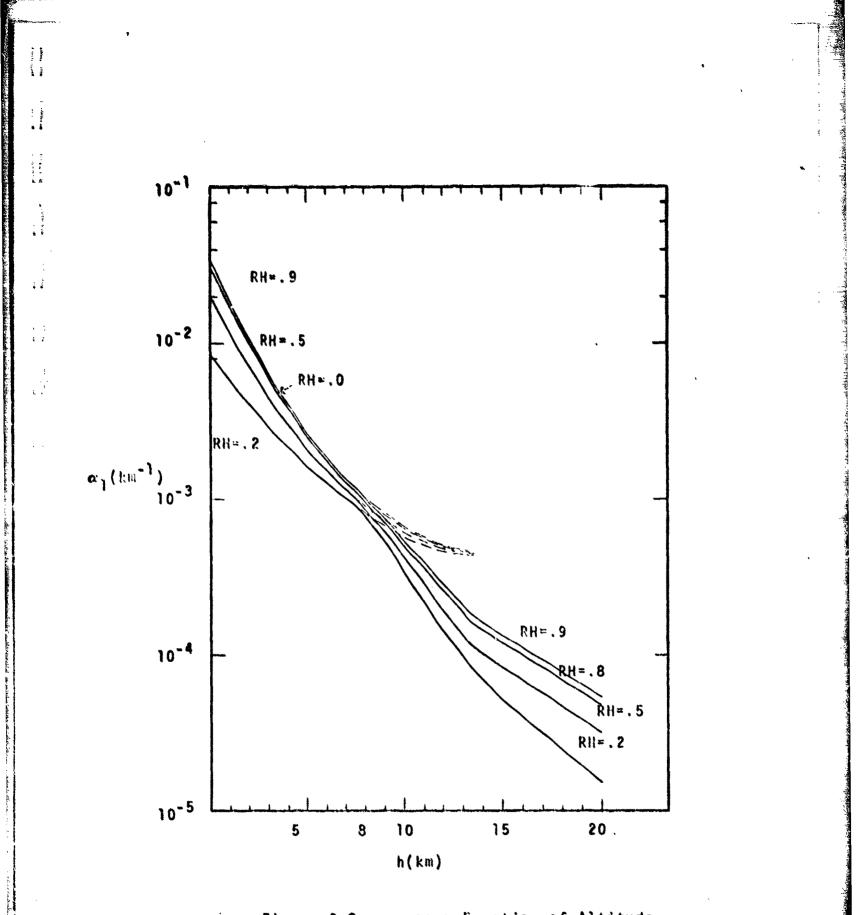
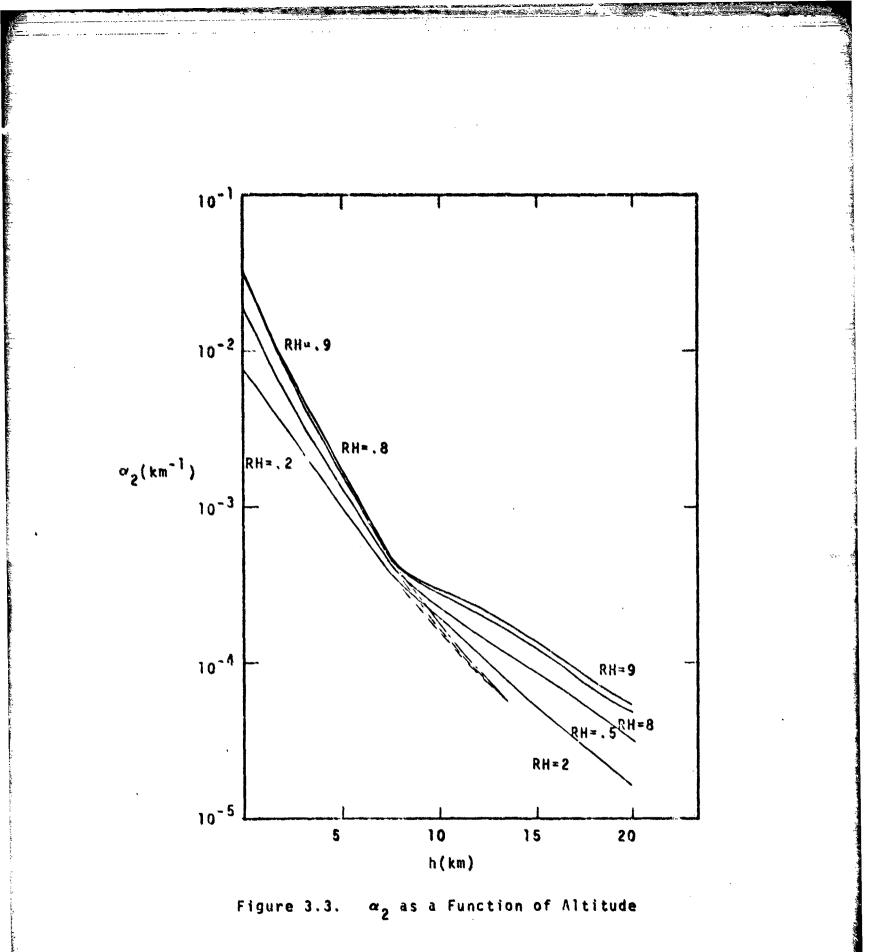
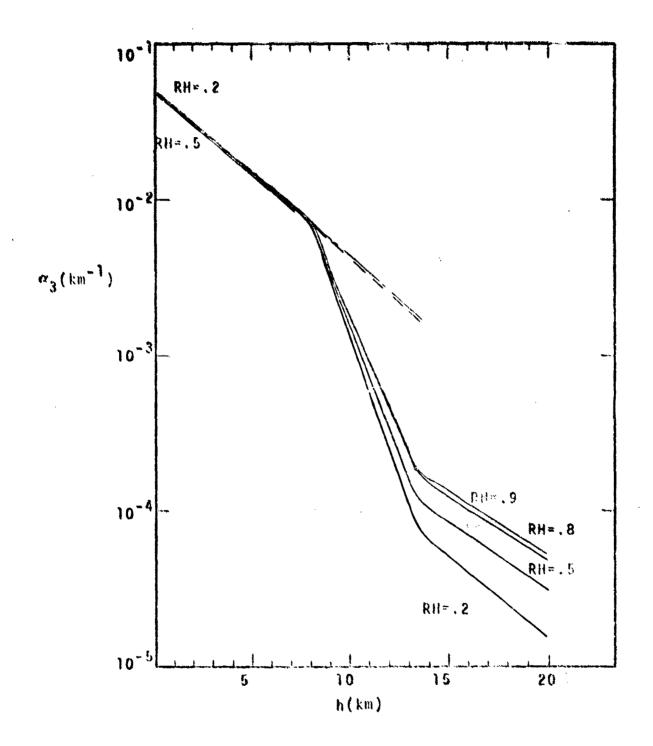


Figure 3.2. α_1 as a Function of Altitude





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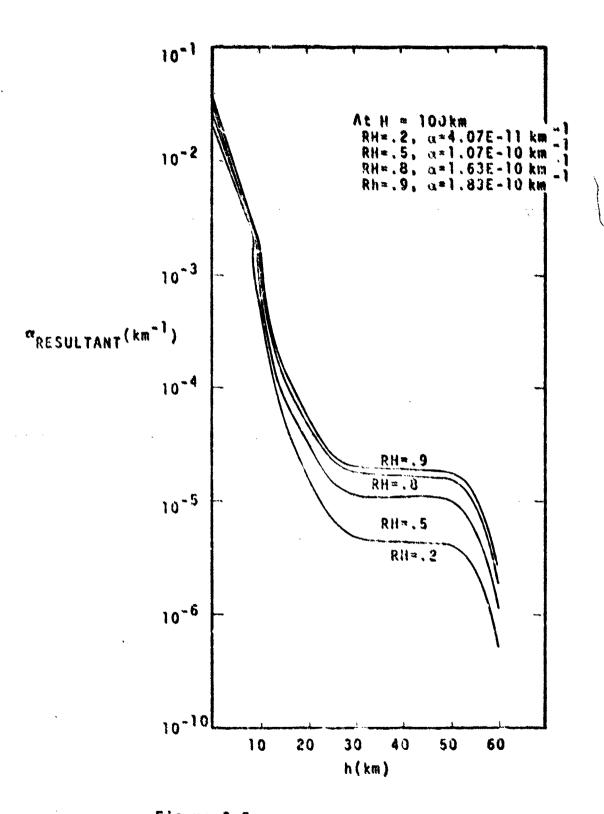


Figure 3.5.

"RESULTANT as a Function of Altitude

$$\sigma_{TLT} = \frac{2.549}{\lambda^{-1/5}} \left[\int_{0}^{L} c_{N}^{2} (z) \left(\frac{L-Z}{L}\right)^{5/3} dz \right]^{3/5}$$

and

where

$$\rho_0 = \frac{1.439}{k^{1.2}} \left[\int_{0}^{1} c_N^2 (z) dz \right] 3/5$$

 $\sigma_{TST} = \left[1-0.37 \left(\frac{\rho_0}{D}\right)^{1/3}\right] \sigma_{TLT}$

 $k = 2\pi/\lambda$ D = diameter of the exit operture.

These equations are generalizations of the co-altitude expression developed in Reference 16. In the blooming calculation σ_{TST} is used instead of the long-term expression, but it should be noted that some research indicates that no turbulence should be included in the heamspread before the blooming calculation (Reference 18).

3.1.6 Far-Field Intensity Distribution

In COMBO the standard calculation of the average intensity is based on the $1/c^2$ intensity radius in the farfield with a few other radii available for user specification (e.g., 1/e and 1/2 intensity points). Since SALCOM is based on a gaussian approximation to the actual far-field distribution, it is a simple matter to use the $1/e^2$ results to describe the complete far-field profile. In addition to $I(1/e^2)$, the peak intensity $I_p=2.312\times I(1/e^2)$, is printed along with contour data. These contour data assume a

bivariant normal profile of the beam due to blooming distortion as developed in Reference 2. For each 10% contour $(I=\gamma I_p, \gamma=0.9, 0.8, ..., 0.1)$ the area within that contour,

$$\Lambda(1>\gamma I_p) = \frac{dr^2 \ln(1/\gamma)}{2 \text{ KIP}}$$

the total power within that area.

 $P(1>1_{0}) = P(1-\gamma)$

and the corresponding average intensity are printed. In addition, the beam displacement due to non-linear bending into the wind and the eccentricity of the resulting eliptical profile are computed and printed.

3.1.7 Calculation of Optimum Power

One of the more useful bits of information that comes from laser effectiveness studies is specification of optimum power based on maximizing energy on the target (Reference 19). Using the Gebhardt and Smith curve-fit for the intensity reduction due to blooming (Reference 20), the far-field intensity is related to transmitted power, T_{T} , by

 $I = aP_T I_{REL}(N)$

where $N=bP_T$ and a and b are constants (independent of power). Setting $\partial I/\partial P_T=0$ leads to

$$\partial \ln(I_{REL}) = -\partial \ln N$$

as the optimum condition. For the Gebhardt and Smith curve,

this condition is satisfied when N=5.54. Therefore, the component optimum power is given by

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 $P_{\text{optimum}} = \frac{5.5^{4}P_{T}}{N}$

where N is the value of the blooming parameter corresponding to the power P_{T} . The corresponding maximum intensity is

$$I_{optimum} = \frac{1.205 \, I}{N \, \text{KIP}}$$

(KIP is the computer variable representing I_{REL}). It should be noted that the optimization does not include the possible effects associated with the optical train, i.e., it does not involve an iterative recall of OPTRAIN.

SAICOM prints the optimum power as derived above unless the corresponding intensity exceeds the air breakdown threshold. In that case, it prints the power at which breakdown would occur as the optimum power. The breakdown power level is estimated on the basis of peak intensity without blooming.

3.1.8 Miscellaneous Modifications

Several relatively minor additions, deletions and corrections are described below.

3.1.8.1 Variable Turbulence in Blooming Computations

In COMBO the turbulence is not varied as the blooming along the beampath is computed; instead only the final value is used. In SAICOM the distributive nature of turbulence is included in the integral calculation of the blooming parameter.

3.1.8.2 Extinction Calculations in Blooming Integral

In COMBO the linear power losses due to absorption and scattering are computed using $\exp[-\alpha_e(h)z]$ in the integrand whereas the expression should have been

 $exp[-\int_{0}^{t} \alpha_{e}(h) dz].$

This error causes an over-estimate of the extinction losses when firing downward and an under-estimate when firing upward. The appropriate correction has been made in SAICOM.

3.1.1.3 Power Variation

The reverse calculation option in CONBO involving calculation of the required power to deliver a desired intensity at a given range has been replaced in SAICOM. Now. whenever the intensity is calculated in a normal propagation run, the power is automatically varied between one-tenth the specified value and twice the original power. The output then lists the average intensity within the 1/e² intensity area, the area over which the intensity is above a spacified minimum value, and the total power available within that area. The equations used in these computations were discussed in Section 3.1.6. The user is allowed to stipulate the minimum intensity of interest through the input parameter OI. If the user doe: not specify the desired minimum intensity contour, the program automatically selects 10 kw/cm^2 .

3.1.8.4 Deletion of Weight and Volume Calculations

The technology projection portion of COMBO is an interesting but seldom used facet of the code. Therefore, it has been eliminated.

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3.1.9 Summary of Equations

The basic equations used in SAICOM are as follows: Average intensity in the $1/e^2$ intensity radius

$$I(Z) = \frac{\left[1 - (1 - 0.865 \text{ m}_{1L}^{2})\right] P_{T} k_{B} e^{-\sum_{i} \int_{0}^{z} \alpha_{ci}(Z') dZ'}{\pi r^{2}(Z)}$$

where

k_B = intensity reduction due to blooming (sometimes written as KIP) = f(N)

$$r^{2}(z) = k_{2}r_{0}^{2} + k_{3}\frac{r_{0}^{2}}{L^{2}}|L-2|^{2}+4z^{2}\left[\left(\frac{0.3183m_{2}\lambda}{D}\right)^{2} + \sigma_{TLT}^{2} + \sigma_{J}^{2}\right]$$
$$\sigma_{J}^{2} = \sigma_{JHF}^{2} + \sigma_{JLF}^{2}$$

$$\sigma_{TLT} = \frac{2.549}{\lambda^{1/5}} \left[\int_{0}^{L} c_{N}^{2} (z) \left(\frac{L-Z}{L} \right)^{5/3} dz \right]^{3/5}$$

The blooming parameter, N, is computed by

$$N = \frac{6.54}{\pi} \int_{0}^{L} \frac{1}{r(2')} \int_{0}^{Z'} \frac{\left[1 - (1.865m_{1L}^{Z}) + F(2'')G(2'')dZ''dZ\right]}{v(2'')r^{2}(2'')}$$

where

$$F(Z^{*}) = P_T \sum_{i}^{n} \frac{P_i}{P_T} \alpha_{Ai}(Z^{*}) e^{-\int_{0}^{n} \alpha_{ei}(Z^{*}) dZ^{*}}$$

$$r^{2}(Z'') = k_{2}r_{0}^{2} + k_{3}\frac{r_{0}^{2}}{L^{2}}|L-Z|^{2} + 4Z^{2}\left[\left(\frac{0.318m_{2}\lambda}{D}\right) + \sigma_{TST}^{2} + \sigma_{JHF}^{2}\right]$$

$$= r_{TST}^{2} + \sigma_{JHF}^{2}$$

$$\sigma_{TST} = \left[1 - 0.37\left(\frac{k_{0}}{D}\right)^{1/3}\right]\sigma_{TLT}$$

$$e_{0} = \frac{1.439}{k^{1.2}} \left[\int_{0}^{L} c_{N}^{2} (Z) dZ \right]^{3/5}$$

 $k = 2\pi/\lambda$

$$G(Z'') = \frac{\frac{\partial n}{\partial T}(Z'')}{n(Z'')\rho(Z'')C_p(Z'')}$$

3.2 A USER'S GUIDE TO SAICOM

A brief description of the key features of the SAICOM code is given along with a discussion of how to operate the code. Users familiar with COMBO (Reference 11) should have little trouble with SAICOM since many of the subroutines are unchanged and the same modular format has

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been retained. The basic structure of the executive routine (SAICOM) is shown in Figure 3.6. A substantial portion of this routine is devoted to initializing the input variables. As with COMBO, most of the input parameters are defined through a default namelist which requires the user to specify only those parameters which will differ from the default values. However, it should be noted that even if the propagation and optical train namelists are not used, namelist cards are required which read \$INPUT \$ and \$CASES \$, respectively. The optical train is called if the user specified PD; if PT is given, this subroutine is bypassed. A subtle point worthy of note is that when PD is given, SIGMF is assumed to refer to the device jitter only, and this term is combined with the four lo jitters (THIR, THES, THAA, and THSV) given in namelist CASE to determine the high-frequency jitter of the total system.

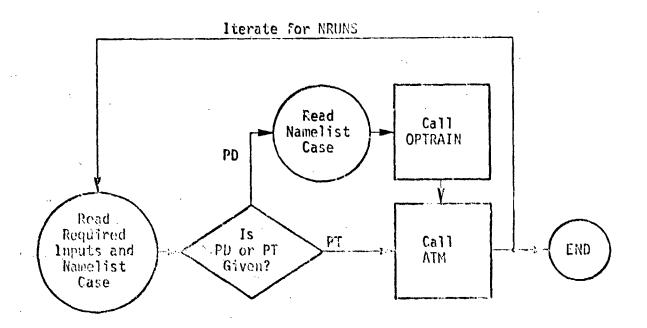


Figure 3.6 SAICOM Flow Diagram

Following these initialization activities, control is transferred to ATM, which handles the propagation calculations; control returns to SAICOM only after the calculations are completed and the results printed. Then SAICOM cycles through the same process until all of the specified cases have been completed.

In Table 3.2 a complete list of the SAICOM subroutines is given along with brief descriptions of their functions. Three of the subroutines, OPTRAIN, ATM, and BB, are discussed in further detail since they are the more important and complex portions of the program.

3.2.1 OPTRAIN

The calculation procedure within the Optical Train Model (OPTRAIN) is schematically shown in Figure 3.7. All inputs to the subroutine are passed through a labeled COMMON/ OPTIN/statement and must be defined by the user prior to calling the subroutine. Following some initial calculations characterizing the input beam, the effect that each component within the optical train has on the transmitted power and beam quality is evaluated in a step by step manner. Although the specific elements within the optical train are fixed, i.e., aerodynamic window, beam clipper, mirrors, beam expander, and exit aperture, the user is allowed to specify, through the input parameters, different types of individual components such as cooled or uncooled mirrors, on-axis or off-axis beam expanders, and open port or material window exit apertures.

The output from the model is returned to the calling program via the labeled COMMON/OPTOUT/ and consists of (1) the diameter of the laser beam at the exit aperture, (2) the power in the beam, (3) the total beam jitter and (4)

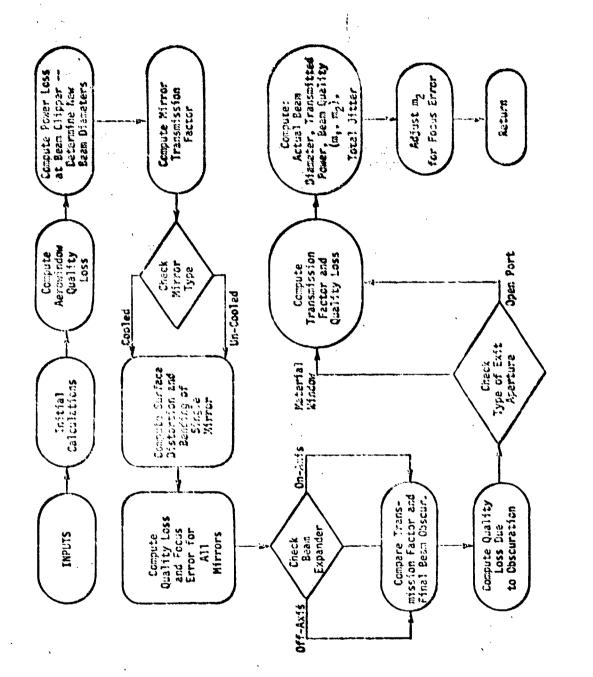
Table 3.2 SAICOM Subroutines

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NAILE	DESCRIPTION
OPTRAIN	Calculation of Power Loss and Beam Degradations in the Optical Train.
ATM	Initialization of Propagation Para- meters and Iteration of Reverse Calculations.
۸۸	Calculations for Lasor and Target Above 100 km.
AA	Calculation for Loser Above 100 km and Target Below 100 km.
BA	Calculation for Laser Below 100 km (and Target Above 100 km.
BB	Calculations for Laser and Target Below 100 km.
ALFSET	Sets Power Ratios for Multi-Line. Propagation.
ALFFAC	Calculations of $\alpha_A e^{-\alpha_e Z}$ and $e^{-\alpha_e Z}$.
ALFAAD	Single Line Absorption Coefficients.
ALFAEX	Single Line Scattering Calculation.
CNSQ	Atmospheric Structure Constant.
κı	Computer Reduction in Intensity Due to Blooming.
GALTIN	Altitude Dependent Parameters Used in Blooming Integral.
MEGAIR	Pressure, Density and Temperature as a Function of Altitude.
VX	Calculation of Total Crosswind.



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Figure 3.7 CPIRAIN Flow Diagram

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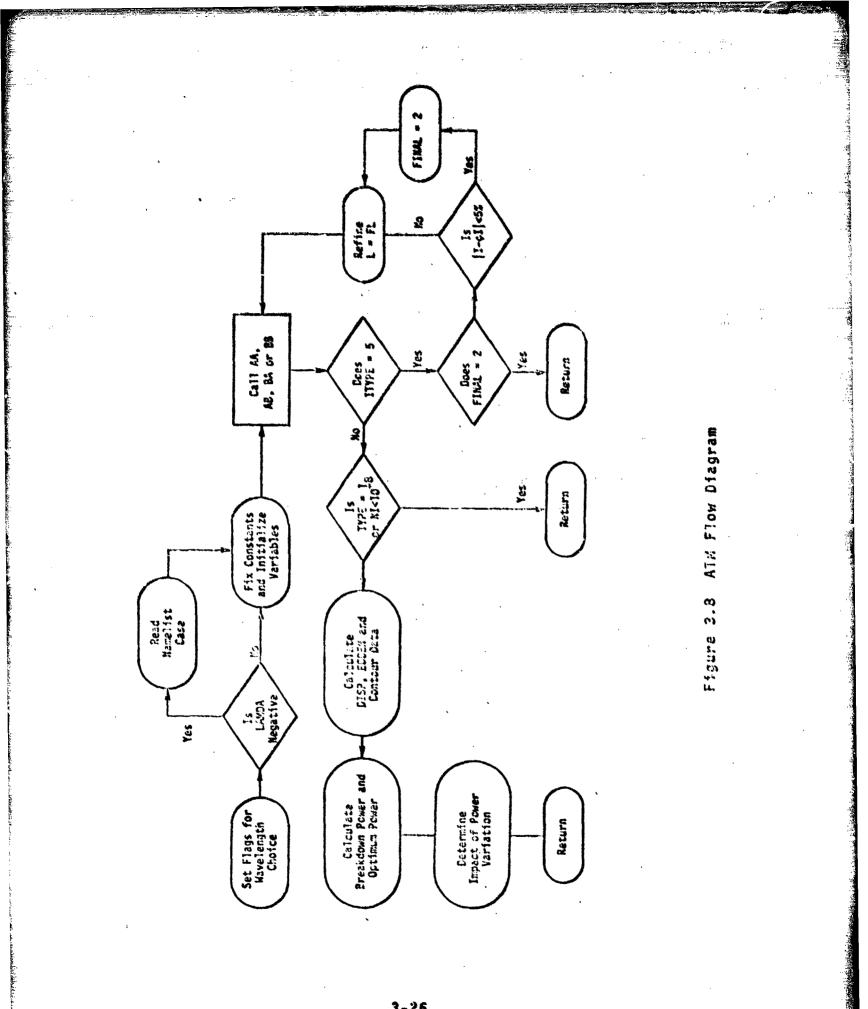
two parameters $(m_1 \text{ and } m_2)$ characterizing the optical quality of the beam. The beam quality parameter m_2 is internally adjusted to account for any defocusing error induced by the high power mirrors in the optical train.

3.2.2 ATH

Part of the initialization process in ATM is to determine if the user has specified a negative wavelength (e.g., -1.06E-5 or -3.8E-6) which means the user is specifying his own single line absorption and scattering coefficients

> $\alpha_A = ABL * EXP (-ABE * B)$ $\alpha_S = SCL * EXP (-SCE * B)$

or his own power ratios for the multi-line 3.8 µm propagation (see Figure 3.8). Note that single-line 3.8 µm propagation is available only if the user specifies his own coefficients. Also note that if one wishes to alter the power ratio, PLINE(I), I = 1, 2, 3 without altering the built-in multi-line coefficients, simply set LAMDA equal to -3.8E-6 and leave the absorption and scattering coefficients off namelist USPEC. The three power ratios need not total unity since the program is self-normalizing. The heart of ATM is the call to AA, AB, BA, or BB where the intensities for the pathlengths of interest are calculated. If AB or BA are called, they in turn call BB for those portions of the propagation path that lie below 100 km. Following the return to ATM, the beam displacement, eccentricity, contour data, breakdown power, optimum power, and effects of power variations are determined for straight propagation unless the propagation path is totally exoatmospheric (AA), or the blooming parameter NI is less



than 10⁻⁰. It should be noted that when the power is varied to compute the impact of propagating a beam that is more or less powerful than the specified level, the beam quality is not altered; this gives some error to the results since beam quality is affected by the total power transmitted through the optical train.

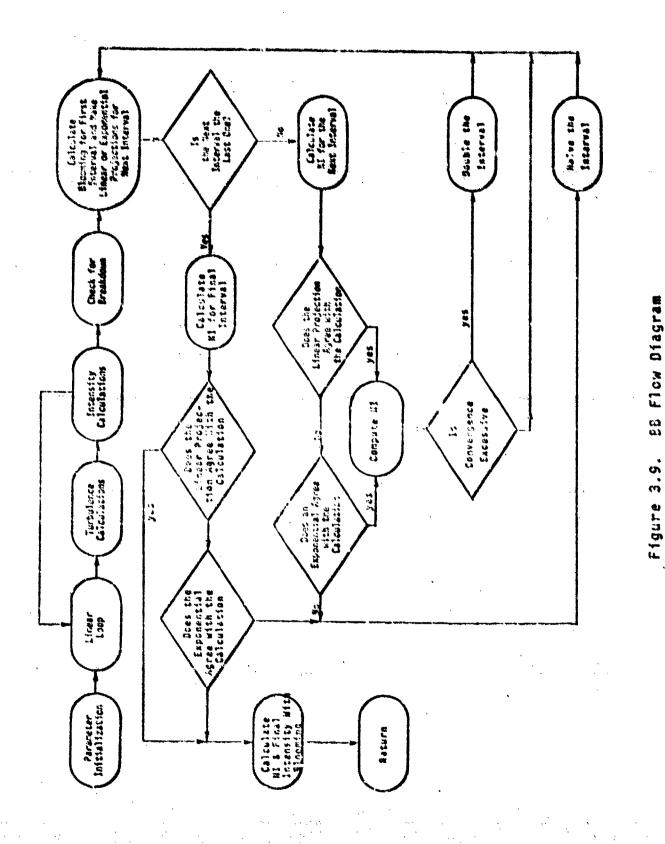
If the reverse propagation option (ITYPE = 5) has been chosen, the calculations are repeated using different target ranges (= focal ranges for ITYPE = 5) until the calculated intensity is within 5% of the desired value. If convergence is not achieved within 20 iterations, the program returns control to SAICOM and goes to the next case.

3.2.3 BB

In Figure 3.9, the logic flow for the BB subroutine is shown, all cases except AA use this subroutine to compute the elmospheric effects on the high-power heam propagation. The subroutine performs culculations at discrete points along the beampath. For calculations of the linear propagation effects, the pathlergth intervals are fixed (NSTEP = 30 is the default value) while in the blooming loop the intervals are increased or decreased as required to migimize time and increase accuracy of the calculation. A series of linear or exponential extrapolations for the ith interval based on the ith - 1 interval are made and compared with the actual calculation for the ith interval. If the comparison is unfavorable, the interval is decreased. If the comparison is favorable, the contribution from the interval is incorporated into the integral, if the comparison is unnecessarily good, the interval is increased. This procedure replaces the time-consuming multiple interations used in CONBO.

3.2.4 Input Data

In Table 3.3 a list of the input parameters and their functions is given. This reference list does not



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Table 3.3 Input Parameters

REQUIRED

ITYPEIf ITYPE = 5 reverse calculation is
called with OI and PD or PT specific.
All other entries will result in
straight propagation.PD or PTUser may slipulate either device
power or telescope power: if iT is
specified CPTHAIR is hyparsed.GIDesired intensity of ITYPE = 5; other-
wise it is the minimum intensity con-
tour in the variable power calculation.LRange from laser to the target if ITYPE
f 5; if ITYPE = 5, L is a first guess
for the range.

OPTION/ - NAMELIST/INSUT/

Beam	$0 \Rightarrow Collimated, 1 \Rightarrow Focused.$			
CHI	Horizontal projection of beampath with respect to the direction of platform movement.			
DEPUG] ⇒ no extra diagnostic statement, 2 ⇒ extra diagnostic statement.			
ΓL	Focal length.			
GL	Ground level.			
HTM	Target altitude.			
ном	Laser altitude.			

Table 3.3 (Continued)

OPTIONAL - NAMELIST/ INPUT/ (Continued)

LANDA	Wavelength
	3.8x10 ⁻⁶ , 5.0x10 ⁻⁶ , and 1.06x10 ⁻⁵ are the acceptable values. A negative sign in front is a flag that the user will specify the multi-line power ratios or the single line absorption and scatter- ing coefficients.
Ν	Seam quality.
NSTEP	Beampath intervals in the linear calcu- lation.
OMEGA	Slewing rate.
OUT	1 ⇒ standard output, 2 ⇒ extra output.
PHI	Firing angle with respect to zenith. If PHI is specified HIM should not be given and vice versa.
PR 0P	1 ⇒ 1/e ² 2 ≥ plane wave, truncated Gaussian 3 → infinite Gaussian.
RII	Relative humidity.
RI	Radius of obscuration.
RO	Outer radius of exit aperture.
SIGHF	High-frequency turbulence.
VP	Platform velocity.
V X B	Total crosswind across beam. If it is specified VP, ONEGA and natural wind are inoperative.
NTHR	>1 ⇒ high turbulence, low natural wind 0 ⇒ nominal turbulence and natural wind 1 ⇒ low turbulence, high natural wind.

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Table 3.3 (Continued)

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OPTIO	RAL -	NAMEL	ST/	CASE	1
VI I I V		1117,11 1 1 4 14 4	Q 17		

DB	Beam diameter coming from the laser.
EPS	Obscuration ratio.
DL	Pulse length.
XRI	Phase front curvature.
DIOVI	Peak-to-peak intensity fluctuation.
DLI	Scale size of fluctuation wrt beam size.
DELTAR	Acrowindow.
RREF	Acrowindow density divided by ambient density.
XLC	Distance from laser exit to beam clipper.
DC	Clipper diameter.
N	Number of mirrors in optical train.
REFL	Reflectivity of each mirror.
SFAB	Mirror fabrication error.
ITYPE	Mirror type: 1 \Rightarrow cooled, 2 \Rightarrow uncooled.
XLMIR	Distance between mirrors.
XIIAG	Telescope magnification.
ITYPEB	felescope type:] ⇒ on-axis, 2 ⇒ off-axis.
XLEA	Exit aperture width.
BETA	Exit aperture absorption coefficient.
ASAB	Strut area/beam area.
ΙΤΥΡΕΛ	Type of exit aperture:] ⇒ material window, 2 ⇒ open port.

Table 3.3 (Continue	ed)	
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OPTIONAL - N	AMELIST/CASE/(Continued)
THTR	Tracker jitter (1o).
THBS	Boresight jitter (lo).
τηνα	Autoalignment jitter (lø).
τιιςν	Servo jitter (lo).

OPTIONAL - NAMELIST/ USPEC/

PLINE (1)	Percent (or actual) power in line 1.
PLINE (2)	Percent (or actual) power in line 2.
PLINE (3)	Percent (or actual) power in line 3.
ABL	User specified linear absorption and the second sec
ЛВЕ	User specified exponential absorption coefficient.
SCL	User specified linear scattering coefficient.
SCE	User specified exponential scattering coefficient.

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include the first two cards which must precede each set of runs. The first uses I2 format in columns 1 and 2 to state the number of cases (NRUN) which will be run, the second uses free-field format to allow the user to title each of the runs. The first card appears only once while the title card must precede each new case. Hence, the data stream is as follows:

> NRUN CARD Title Required Inputs Namelist INPUT Namelist CASE Namelist USPEC (if required)

Case 1

litle Required Inputs Case 2 Namelist INPUT Namelist CASE Namelist USPEC (if required)

Table 3.4 provides a convenient work sheet format that may be used to specify each case. It includes a list of the default values and units. Those familiar with COMBO will recognize a change in some of the default values; the default statements now reflect sea level applications. Note that either PHI or HTM may be specified, but that PHI should always be given as a positive angle (measured from the zenith). A negative PHI is a flag that HTM was specified.

For additional convenience, Table 3.5 lists several of the important program flags which may be of interest to the user. A complete program listing and sample run is supplied along with a sample problem output in Appendix B.

Table 3.4 Sample Input Form with Default Values

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Required	Туре	Position	Units	Case 1	Case 2	Case 3
ттуре /	(3,5)	15				
PD ² or	(3,5)	11-20	W			
PT	(3,5)	21-30	W			
01 ⁵	(3,5)	31-40	w/m ²			
L	(3)	41-50	m			
Namelist "INPUT" Optional	De	fault	Units	Case 1	Case 2	Case 3
ВЕАМ 🖌	l (focu	ised)				
СИІ	0.52		rad			
FL	L		nt			
GL	υ.		m			
ном	50.		m			
HTN	10.		m			
LAMDA	3.88-6		m			
И истрь /	1.5					
HOILF	30					
OMEGA	0.		rad/sec			
VU1	1 (shor	·t)				
PU13 .	-1.8-6		rad			·
PROP	1 (Gaus	isian)				
RH	0.5					
RI	.08		m			
RÖ	. 35		a a			
SIGHF	5.E-6					
SIGLF	5.E-6					
VP	15.		m/sec			
VXB	0.		m/sec			
NTHR Y	0 (nora	al)				

Table 3.4 (Continued)

13

Hamelist "CASE" Optiona's	Default	Units	Case)	Case 2	Case 3
ASAB	0.05		****		
BETA	0.01	m-1			
D0	. 16	n			
VC	0.165	kı			
DELT	1.0	°K		•	
DELTAR	0.1				
DIGVI	0.5				
DLI	0.1	L/NT			
D1 .	.2.0	seconds			
EPS	, 35		متالينين والبراني ويهيه		
зтурам 🦌	1 (focused)				
ITYPEA	2 (open)				
ITYPEB '	l (on-axis)				
ITYPEN	1 (cooled)			ł	
н 🖌	5				
REFL	0.985				
K1	1.870	- n			
RRLF	2.5				
SFAB	1./8.	vis Iemda)		}	
THAA	5.E-6	rad			
TAÌB S	5.E-6	rad			
THEY	5.E-6	red			
THER	5.2-6	rad			
XLC	50.	m			
XLEA	0.05	a a			
XLMIR	. 15	R)			
XNAC	4.375				·
Namelist "USPEC" Optional	Default	Units	Case 1	Case 2	Case 3
Pline (1)	. 338				
Pline (2)	. 32			ļ	
Pline (3)	. 342				
ABE	0.	n. I			
ABL	0.	m_)		1	
SCE	0.	m ⁻¹			
SCL	o.) _m -1		1	1

NOTES:

1. Check mark $(\sqrt{})$ indicates "I" format is required.

2. User may specify either power exiting the device or telescope.

3. PHI need not be specified if HIM is given.

4. Although data on \$INPUT\$ card are optional, the card must be present even when all default values are to be used. The same applies to data card \$CASE\$. The namelist card \$USPEC\$ is only read when a negative lamba has been inserted on data card \$INPUT\$ as a flag.

5. If ITYPE = 5, OI is the desired intensity for the reverse calculation; otherwise it is the minimum useful intensity for the variable power tabulation (default value of 10^7 w/m^2).

Table 3.5 Flags

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FORM	NEANING
Inputs	
Negative LAMDA	The users will specify the multi-line power ratios or the single-line absorp- tion and scattering coefficients.
Negative PHI	HTM is specified (Default).
Internal	
CNVRGD	TRUE => the last blooming interval passed over the end point.
ENDED	TRUE => this is the last blooming interval.
ERR	TRUE => the reverse calculations have not converged in 20 iterations.
FINAL	= 1, the reverse calculations have not converged yet;
	<pre>= 2, last pass through the propagation calculation.</pre>
FRA CT	Tells the fraction of the last blooming interval that is within L.
LAM	 1, 10.6 μm 2, 3.8 μm (multi-line) 3, 5 μm (single-line at present) 4, user will specify single-line absorption and scattering coefficients.
OK	TRUE => save previous values for multi- line absorption and scattering calcula- tions.

Table 3.5 (Continued)

FORM

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MEANING

Internal (Continued)

TYPE

3	8B
	AB -
•	BA.
	•

UNIFRM

TRUE => last two blooming intervals were the same.

Section 4

SUMMARY OF TASKS I-IV

The purpose of this section is to briefly review the objectives and results of the original four tasks. Specific details may be found in the first and second interim reports (References 1 and 2). The primary objective here is to highlight some of the issues which arose during the course of the work and to indicate some of their implications as they relate to propagation modeling in general.

4.1 REVIEW OF TASK I. CODE COMPARISONS

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The objective of Task I was to quantitatively compare the results obtained from three propagation codes over a parameter space representative of realistic engagement conditions. The codes were: NOLEC (Naval Surface Weapons Center); COMBO (Air Force Weapons Laboratory); ESP-I (United Aircraft Research Laboratories). The comparisons were presented at the First DOD Conference on High Energy Laser Technology on 3 October 1974 in San Diego (Reference 14). An unclassified version of this paper is included as an appendix in the first interim report (Reference 1). The major conclusions from these comparisons were that all three codes give comparable results for situations in which thermal blooming is not severe, but that ESP-I gives intensities up to an order of magnitude or more higher than the other two codes when blooming is significant. NOLEC and COMBO agree reasonably well under most conditions.

A secondary objective of Task I was to ascertain the reasons for major discrepancies between the codes. The effort was concentrated on COMBO and ESP-I since there is considerable disparity in their results even though they both use essentially the same approach for calculating thermal blooming. NOLEC uses an entirely different approach. In reviewing the theoretical basis of the codes, several issues were raised whose significance goes beyond the immediate objectives of the present work.

The blooming subroutines in both COMBO and ESP-I are based on the theoretical and experimental work of Gebhardt and Smith (Reference 20). The essence of the basic approach is the representation of the ratio of the bloomed and unbloomed focal plane peak intensities, I_{RFI} , as a function of a single "blooming parameter," N. N is a theoretically derived, dimensionless, similarity parameter. However, the relationship between I_{REL} and N was obtained experimentally. Both COMBO and ESP-I use the same empirical relationship for I_{RFL} (N). They yield different results in blooming calculations because they compute N differently. The differences in the complex for calculating N were identified explicity in the First Interim Report (Reference 1). The question as to which method is more "correct" could not be resolved on theoretical grounds for several reasons.

1. An approximation to the theoretically derived expression for N was used in correlating the experimental data. The approximation was not generally valid even for the conditions of the experiments. It is even more questionable for realistic engagement-scale conditions such as those for which the simplified propogation codes are used.

2. COMBO uses the theoretical expression for N except for a relatively minor <u>ad hoc</u> correction. In principle, this has some important advantages, such as an inherent capability to treat non-coaltitude engagements. Unfortunately, it is not consistent with the empirical relationship used to correlate the experimental data.

3. ESP-I uses the same expression for N as was used for the empirical correlation. In that sense, it is at least consistent. However, it does not engender much confidence in the extrapolation from small scale laboratory experiments to realistic engagement conditions.

To summarize the situation, both COMBO and ESP-I use a semi-empirical blooming model which is flawed by a basic inconsistency between its theoretical and empirical components. The First Interim Report implies a preference for COMBO simply because it was in closer agreement with NOLEC. It should be emphasized, however, that this may be, at least to some extent, fortuitous. Furthermore, there does not exist sufficient data to provide convincing validation of any of the codes.

Evaluation of the codes on theoretical grounds in any kind of absolute sense was beyond the scope of the study, but two observations are in order. First, the consistency problem with the Gebhardt and Smith blooming model does not necessarily reflect adversely on its basic approach; the deficiencies are primarily associated with its implementation. Secondly, there are no clear and obvious theoretical reasons why either of the basic approaches should be superior in accuracy to the other. All of the codes incorporate numerous simplifying assumptions and approximations, both explicit and implied, and rely to some extent on heuristic arguments.

4.2 REVIEW OF TASK II. BEAN SHAPE AND DISPLACEMENT

The objective of this task was to develop empirical models for predicting beam shape distortion and displacement in the focal plane due to thermal lensing. Results from the NRL non-linear propagation code were used as he data base for the analysis.

Since beam distortion and displacement both are closely related to thermal blooming, I_{REL} (the reduction in peak intensity due to blooming) was used as the primary correlation parameter. This automatically accounts for much of the dependence on the independent parameters and has the further advantage of being readily computed from the NRL scaling law.

The beam displacement model is represented by

$$\left(\frac{d}{a_f}\right)\eta^{29} = \frac{-0.519 + \sqrt{(0.519)^2 + 1.500 \ln (1/I_{REL})}}{0.750}$$

where d is the displacement of the peak intensity into the wind, a_f is the e^{-1} beam radius (without blooming) in the focal plane, a_i is the e^{-1} beam radius in the source plane, and $n = a_f/a_i$.

The beam shape model represents the constant intensity contours as ellipses and the intensity distribution as

$$I(x,y) = I_{PEAK} \exp \left\{ -SD \left[\left(\frac{x}{a_f} \right)^2 + \left(\frac{y-d}{Da_f} \right)^2 \right] \right\}$$

 $D = 0.3 + 0.7 I_{REL}$ $S = I_{REL}$ $I_{PEAK} = \frac{P e^{-\alpha R} I_{REL}}{\pi \epsilon_{F}^{2}}$

ci.

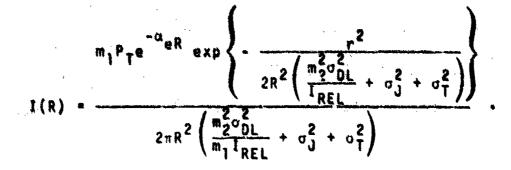
This model automatically gives the correct peak intensity and conserves total power. It also provides an excellent representation of the data in terms of the area within a given constant intensity contour and the eccentricity of the constant intensity contours.

These models, of course, are subject to the same limitations as the data from which they were derived. For example, they do not apply (unless suitably modified) in the presence of jitter or turbulence or when slewing is not in the same plane as the wind. Actually, the most significant result of this task is that both distortion and deflection are probably too minor to have a significant impact on system effectiveness.

4.3 REVIEW OF TASK III. BEAM QUALITY

The objective of this task was to develop an approach to modeling the effect of phase and amplitude aberrations in the aperture plane on the far-field beam profile. In more general terms, it was desired to obtain a rational approach to representing beam quality.

The recommended approach involves approximating the far-field intensity profile (neglecting blooming) as a Gaussian distribution of the form



The parameters m_1 and m_2 are the proposed beam quality parameters and are determined so that the integrated power distribution corresponding to the above expression matches the actual distribution at two specified points, e.g., $r = w_c$ and $r = 2w_c$, where w_c is the beam waist.

This two parameter representation of beam quality is a significant advance over the usual "m x diffraction limited" concept. It can account both for power loss due to wide angle scattering and for beam spreading. It should be fully adequate to represent all situations in which the far-field beam profile is dominated by a central lobe. Furthermore, the general approach is sufficiently flexible that it can include effects associated with beam truncation and obscuration (see following section) as well as with other amplitude perturbations and with phase aberrations. For example, the simplified optical train model (OPTRAIN) described in Section 2 provides a method of estimating m₁ and m₂ for a wide range of system parameters.

4.4 REVIEW OF TASK IV. BEAM TRUNCATION AND OBSCURATION

The effect of truncation and obscuration were investigated both analytically and within the empirical framework of the beam quality model developed in Task III, i.e., the results were presented in terms of the parameters m_1 and m_2 . Detailed results of the analysis are presented in Reference 2. Since the degree of truncation and obscuration is determined by the optical train, the model itself has been incorporated into the optical train model (Section 2).

Section 5 CONCLUSIONS

In any high technology program, like the DOD laser program, it is important that technologists and analysts work together to resolve the issues and support the efforts of the other group. During the early phases of a new program the technologists severly bound the problem under study to facilitate modeling of complicated processes. On the other hand, the analysts use extremely simplistic models for the elements of the system under study because they must address every aspect of the problem albeit in a naive manner. As time passes these two groups move closer together with the theoreticians studying ever increasing segments of the problem and the systems analysts improving their models and studying the issues in greater depth.

The atmospheric propagation coding studied under this contract is really second generation modeling. Improving the speed and accuracy of a program, adding multi-line propagation, and studying beam shape are exemplary of the movement of HEL system analysts toward increasingly complex modeling. One of the other areas investigated -the optical train analysis -- is less well developed. The detailed tools for modeling the beam propagation through the optical train have been operational only recently. Hence, the simplified codings developed under this contract are first generation models. The authors hope that both of these modeling tasks will contribute to the continuing covergence of laser technology and systems analysis.

APPENDIX A

Molecular Absorption of DF Laser Radiation

A.1 INTRODUCTION

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This appendix was written by Dr. T. Tuer of the Ann Arbor SAI office. This work was undertaken to provide better values for the molecular absorption coefficients used in the thermal blooming code. These coefficients are required as a function of both altitude and of atmospheric water vapor content for several "typical" DF laser line groups. Here, "typical" means a characteristic laser propagation-altitude function (this will be clarified in SectionA.3). For convenience in the thermal blooming code, the coefficients are given as a simple analytical function of altitude and water content, with different sets of coefficients (i.e., one for each typical group).

A.2 APPROACH

Due to time constraints, it was decided to use McClatchey's DF absorption coefficients (ReferenceA.1) rather than re-calculating them with our own line-by-line codes. The ten BDL laser lines that McClatchey considered were selected for this study (see Table A-1). However, since McClatchey did not include the water continuum absorption in his calculations, it was necessary to add this component. A simple computer program DAFT (\underline{DF} <u>Altitude Fitting Code</u>), was written to: (1) evaluate this continuum component for the frequencies, altitudes and model atmospheres desired, (2) add this to McClatchey's

A-1

results, and (3) plot the total absorption coefficient as a function of altitude.

DF Laser Line	Frequency (cm ⁻¹)	Relative Power	Considered by McClatchey and Here
P ₃ (8)	2546.37	10.7	yes
$P_{3}(7)$	2570.51	10.2	yes
P_(10)	2580.16	6.2	yes
P ₃ (6)	2594.23	7.7	yes
P_(9)	2605.87	9.7	yes
$P_{3}(5)$	2617.41	1.8	yes
P_(8)	2631.09	12.9	yes
$P_{2}(7)$	2655.97	10.0	yes
$P_{1}(10)$	2665.20	3.9	yes
$F_{2}(6)$	2680 .28	6.2	yes
P](9)	2691.41	9.1	no
P (8)	2717.54	6.6	no
, (7)	2743.03	3.5	no
P ₁ (6)	2767 91	2.0.	no

Table A-1. List of DF-BDL Lines

The water continum absorption coefficient is given by (Reference A.2).

$$n = c_{s}^{0}, w_{w}^{*} + c_{N}^{0}, w_{w}^{*}$$

where p_w is the partial pressure of water vapor, P is the total pressure and the * indicates the density-equivalent-

A-2

pressures¹. This reference also gives measured values of c_{s,w_0}^{o} as a function of frequency at 294° K², and recommends value of $c_{N,w}^{o} = 0.12 c_{s,w}^{o}$. The absorption coefficient n differs from the usual coefficient k by:

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k = nU/L

where U is the absorber thickness and L is the path length. Values for p*, P* and U were calculated as a function of altitude using data given by the Handbook of Geophysics and Space Environment (Reference A.3).

The attenuation of most of the DF laser lines is dominated by atmospheric water absorption (i.e., H_20 or HDO line absorption, or H_20 continuum absorption). In order to account for different atmospheric water content, the calculated absorption coefficient was normalized by:

 $k^* = k/\rho^*$

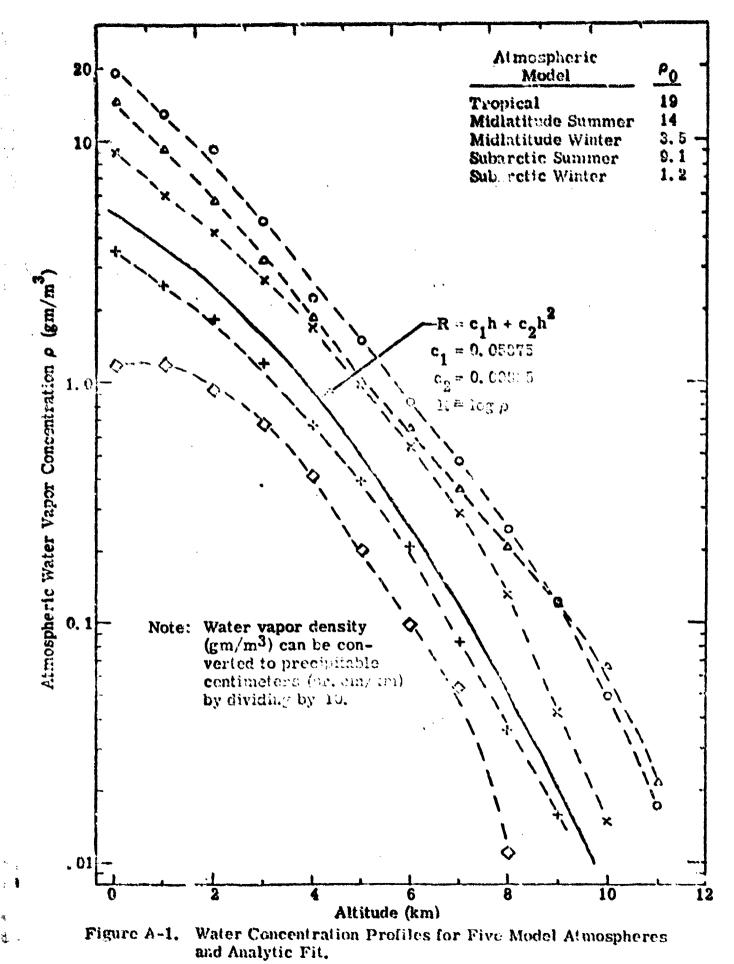
Here ρ^* is a normalized water density-altitude profile which varies between a value of ρ_0^* at sea level, to unity as $h + \infty$. The quantity ρ_0^* is the sea level density of the model atmosphere under consideration, normalized to that of the midlatitude summer model atmosphere. The form of ρ^* was arbitrarily taken to be:

 $\rho^{\star} = 1 + (\rho_{0}^{\star} - 1)10^{R/2}$

- Since the pressures are generally less than one atmosphere, we used the usual pressure in place of the density-equivalent-pressure.
- 2 Since the temperature dependency of this quantity is uncertain, its value at 294°K was used throughout.

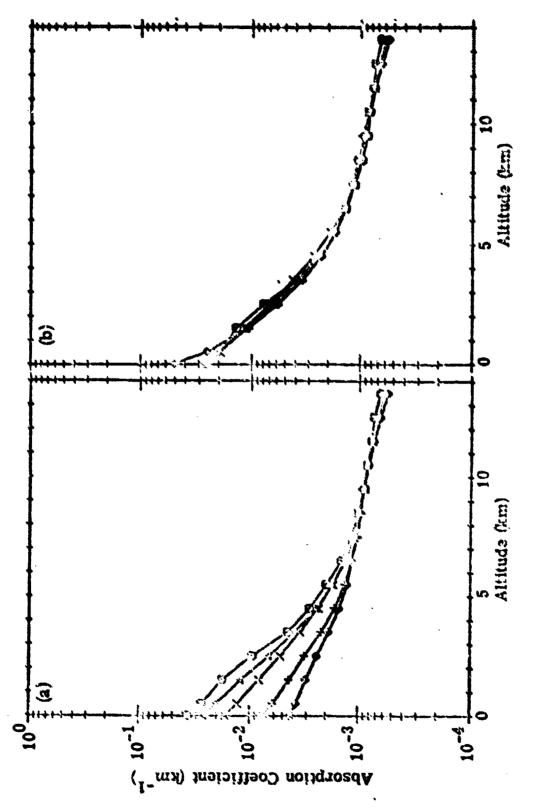
where R is the normalized water density profile based on the data in Reference A.3 (see Figure A-1). An example of the effect of this scaling is shown in Figure A-2, where the absorption coefficient profiles for the five different model atmospheres are seen to collapse nicely into a narrow band.

A-4 1



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A.3 DETERMINING TYPICAL GROUPS

Normalized profiles for all the water dominated laser lines were plotted on a common scale. Af course the lines which are dominated by other species (e.g., N_2O line absorption), were not normalized in this fashion but simply plotted. These plots tend to collect in three general groups. Those laser lines which are dominated by water at low altitudes, but happen to fall on underlying absorption lines (Type A), have a knee in their profile (see Figure A-3). Those that do not have underlying lines (Type B), de not have a prenowneed knee but continue to decrease with altitude, alleast for the altitude range considered here (see Figure A-4). Lines which are not dominated by water (Type C), have no knee but fall off less rapidly with altitude (see Figure A-5).

The mechanism for each type can be clucidated by examining the details of the absorbing lines and continuum. Figure A-6 shows components of the absorption coefficient of a Type A laser line at sea level. Notice the underlying CH₄ absorption line (M2), which will become important at higher altitude as the absorption by water diminishes. Figure A-7 shows a Type B laser line where there is no important underlying absorption lines. Finally, a Type C laser line is shown in Figure A-8, which is dominated by N₂O absorption even at sea level, and is affected little by water.

A.4 RESULTS

A least squares fit was applied to each group of laser lines (i.e., Types A, B and C). The analytic form used was:

 $\ln k^* = A_0 + A_1 h + A_2 h^2$

A-7

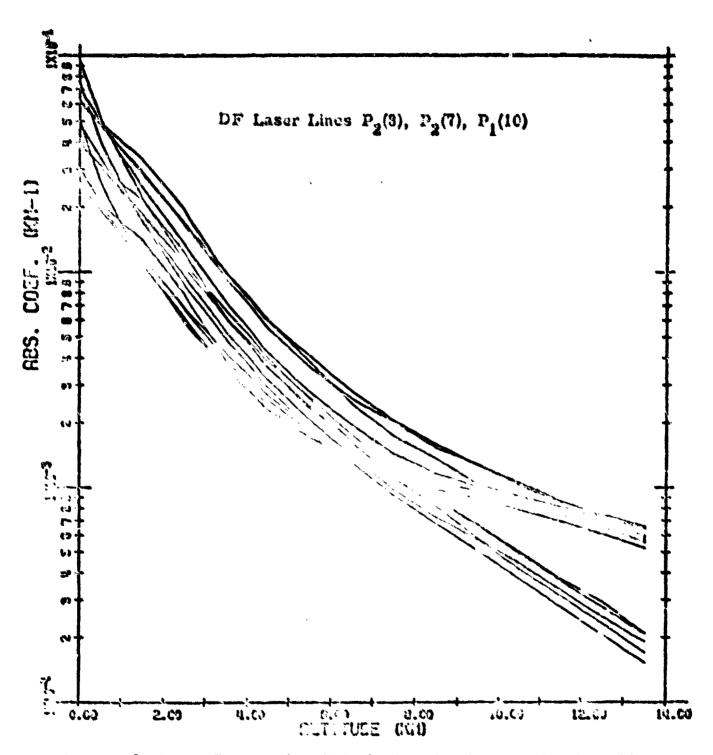


Figure A-3. Laser Propagation-Attitude Function Type A: Dominated by Water at Low Altitudes but with Underlying Absorption Lines which become Important at High Altitudes.

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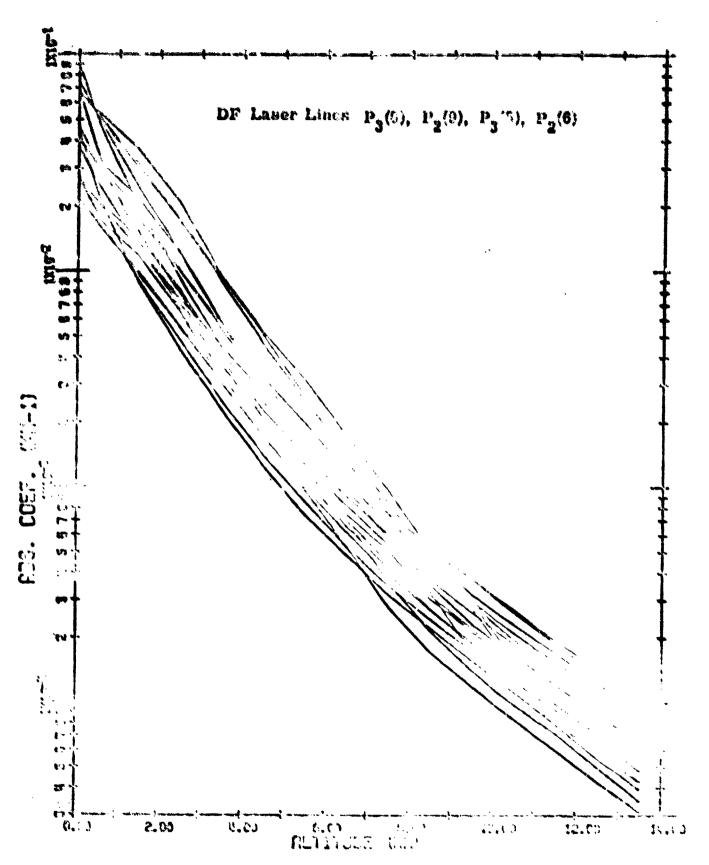


Figure A-4, Laser Propagation-Altitude Function Type B: Dominated by Water at Low Altitudes but with Underlying Absorption Lines which become Important at High Altitudes.

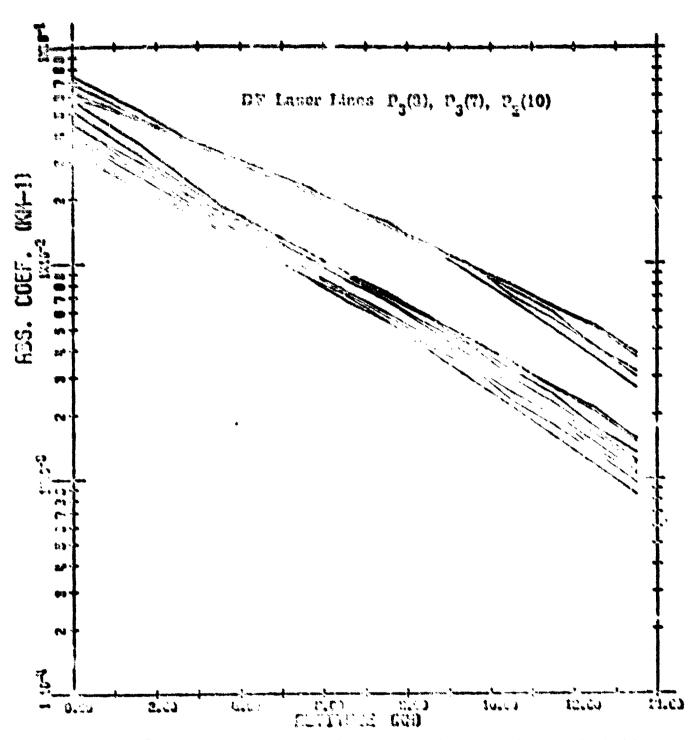
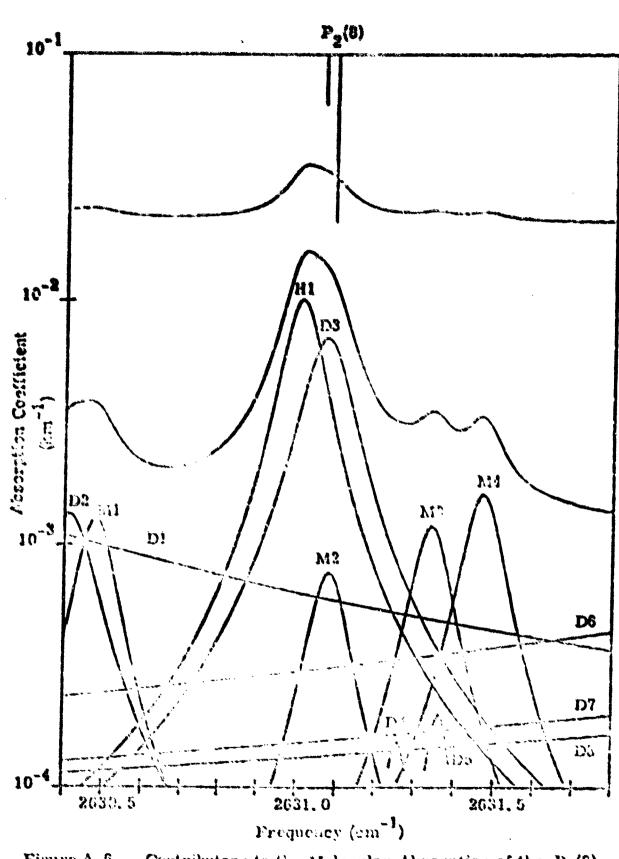
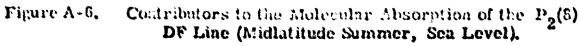


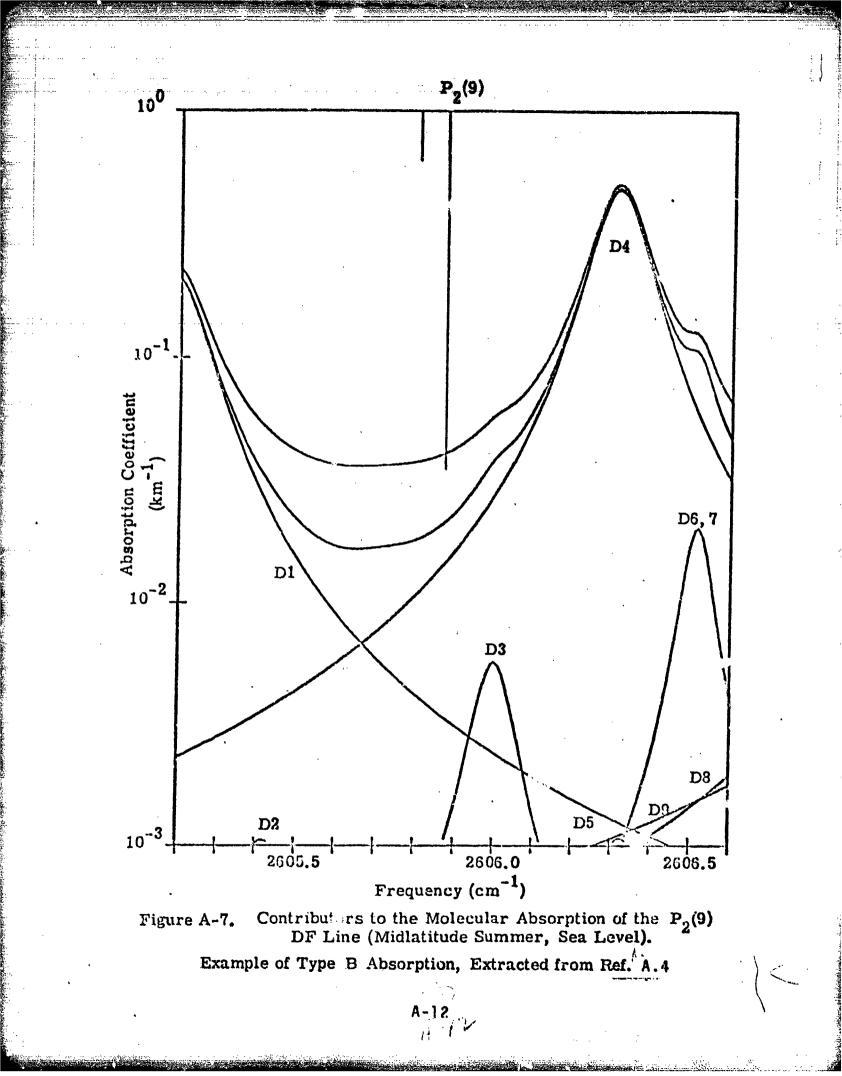
Figure A-5. Laser Provide Condition Altitude Substitute Type C: Dominated by Water at Low Altitudes but with Underlying Absorption Lanos which become Important at High Altitudes.

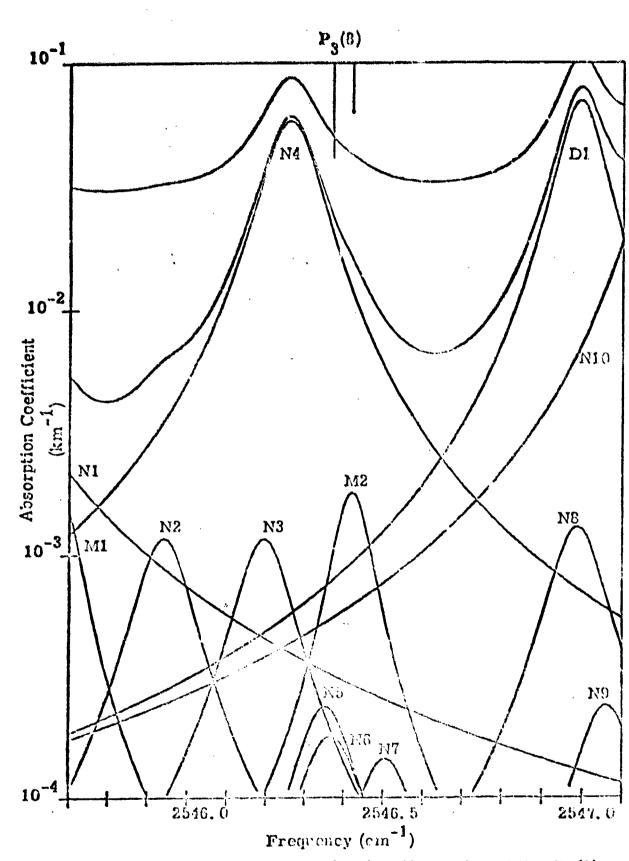


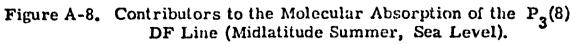


Example of Type A Absorption, Extracted from Ref. A.4.

A-11







Example of Type C Absorption, Extracted from Ref. A.4

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where k* is the normalized absorption coefficient (km⁻¹) and h is the altitude (km). The results of this fit for each group are shown in Figures A-9 through A-11, and the determined coefficients (i.e., Λ_0 , Λ_1 , Λ_2) given in Table A-2.

Туре	DF Laser Lines	•••	A ₁	A ₂
A	$P_2(8), P_2(7), P_1(10)$	-3.138	-0.6388	0. 0225
В	$P_{3}(6), P_{2}(9), P_{3}(5), P_{2}(6)$	-3.173	-0, 6952	0. 0155
С	$P_3(8), P_3(7), P_2(10)$	-3, 039	-0, 2199	-0. 00196

Table A-2. Coefficients of Least Squares Fit

For Type C laser lines this normalized coefficient k* is identical to the un-normalized coefficient k (since water absorption is insignificant):

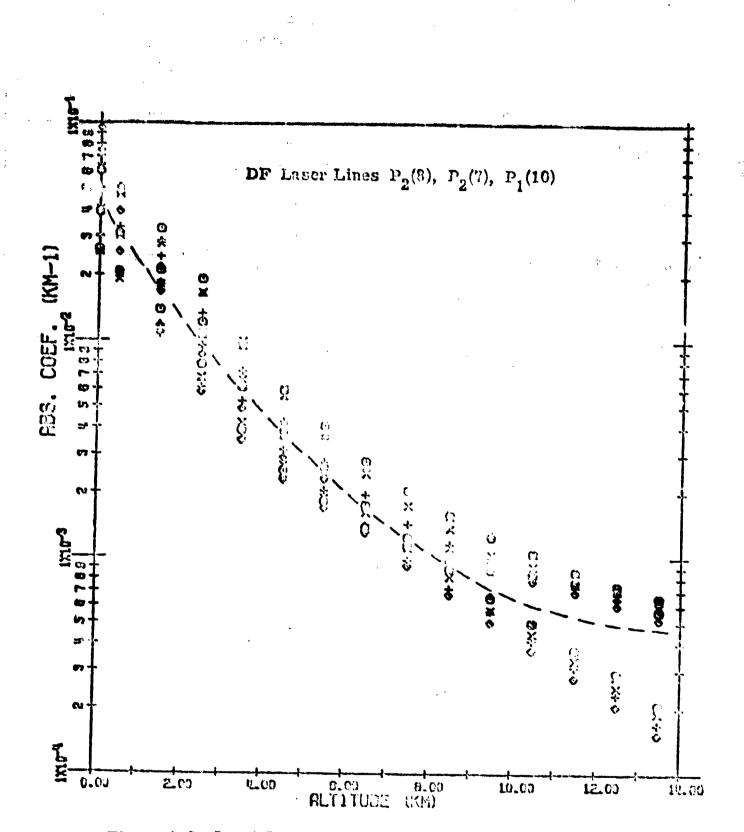
 $k = k^*$ (for Type C)

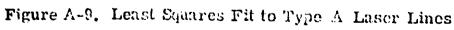
Type A and B lines must be un-normalized by:

 $k = \rho^* k^*$ (for Types A & B) where $\rho^* \equiv 1 + (\rho_0^* - 1) 10^{R/2}$ and: $\equiv f - (f_0^* - 1) 10^{R/2}$ and: $= f - (f_0^* - 1) 10^{R/2}$ and $= C_1 h + C_2 h^2$

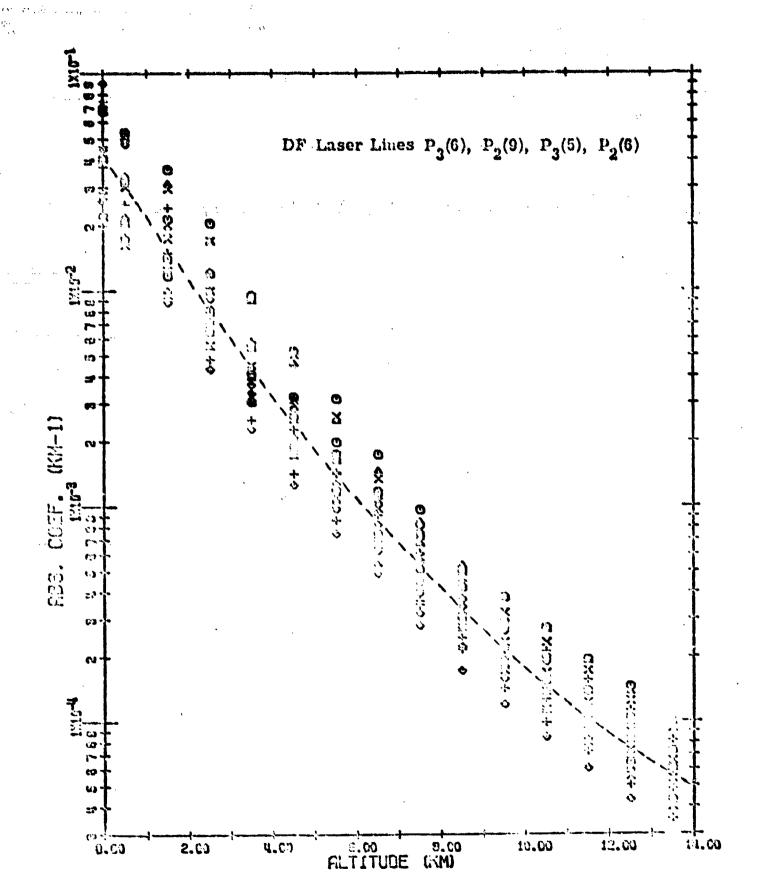
with $C_1 = 0.05375$ and $C_2 = 0.00835$.

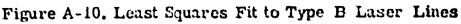




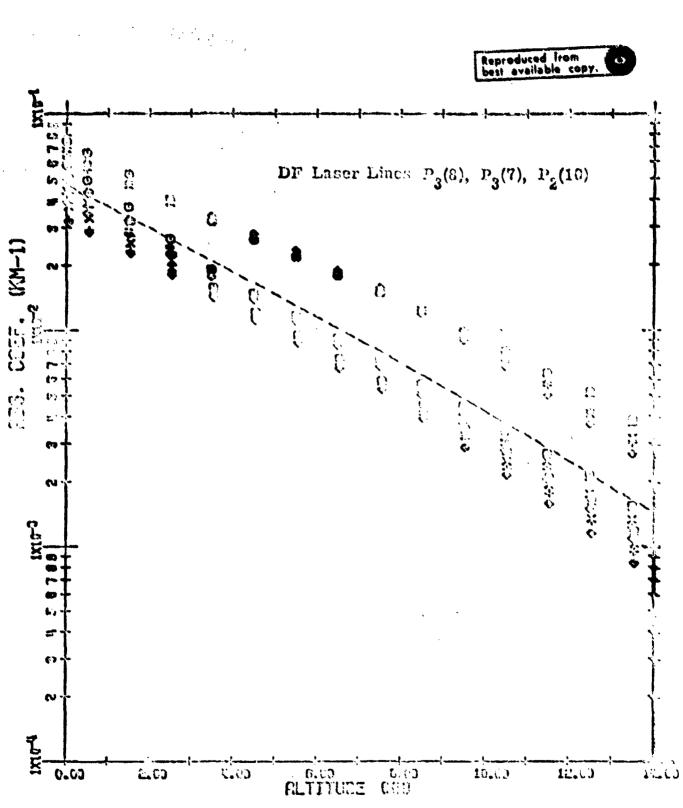


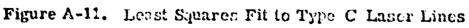
A-1.5





A-16 1 (2





A-17

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\$\$\$\$\$ \$\$ \$\$ \$\$ \$\$ \$\$ \$\$ \$\$ \$\$ \$\$ \$\$ \$\$

APPENDIX B

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<ul> <li>If 1041.4.2.001 60 10 6</li> <li>IF 10414.4.2.001 60 10 7</li> <li>IRE 400002-691W0021/C</li> <li>E=TA14/FIO</li> <li>CARA464FOO</li> <li>C 10 12</li> </ul>	IF 10+1.42.001 60 T0 6 IF 10+1.42.011 60 T0 7 THE=1070-2-641N0021/C E=Tall//00 CA=446000 CA=46000 CA=46000 CA=46000 CA=100-2-01021/C E=01/00 CHE2010 CA=1.00 CO T0 12 IF (54104-201) 60 T0 9	U	04-4415	140			
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7 14E = (D)==2-D]==21/C 63 14E = (D)==2-D]==21/C 64 = 446*D0 64 10 12	CARRAGEOO 63 TO 12 THE = (0)-02-01-021/C E = 01/03 CH = 466-00 60 TO 12 If (Calive LE.DI) 60 TO 9 Take 1.0			90	501	•	
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10     17     17     17       14     17     17     17     17       11     17     17     17     17       11     17     17     17     17       11     17     17     17     17       11     17     17     17     17       11     17     17     17     17       12     17     17     17     17       13     17     17     17     17       14     17     17     17     17       15     17     17     17     17       16     17     17     17     17       17     17     17     17     17       18     17     17     17     17       17     17     17     17     17       18     17     17     17     17       19     17     17     17     17       17     17     17     17     17       18     17     17     17     17       19     17     17     17     17       10     17     17     17     17       10     17     17     17			
10     If (031.LE.00) c0 10       11     THE (02.70061)*2       12     Erol1.V00       03     10       13     FE01.V00       04     10       14     FE01.V00       15     FE01.V00       16     FE01.V00       17     FE01.V00       18     FE01.V00       19     FE01.V00       11     FE01.V00       12     FE1.00       13     S5155.01165       14     FE1.00       15     FE1.00       16     FE1.00       17     FE1.00       13     S5155.01165       14     FE1.00       15     FE1.00       16     C01.015       17     FE1.00       18     FE1.00       19     FE1.00       10     FE1.00       11     FE1.00       12     FE1.00       13     FE1.00       14     FE1.00       15     FE1.00       16     FE1.00       17     FE1.00       18     FE1.00       19     FE1.00       10     FE1.00       10     FE1.00       11     FE1.00			
10     17     0.011.0.00     0.010     18       11     7.6011.0.00     0.010     12       12     7.6011.0.00     0.010     10       13     7.6011.000     0.010     10       14     7.6011.000     0.010     10       15     7.6011.000     0.010     10       16     7.6011.000     0.010     10       17     7.6011.000     0.010     10       18     7.6011.000     0.010     10       17     7.6011.000     0.010     10       10     7.6010.00     0.010     10       11     7.6010.00     0.010     10       12     7.6010.00     0.010     0.000       10     7.6151.00     0.000     0.000       11     7.6151.00     0.000       12     7.611.00     0.000       13     5.5100     0.000       14     0.000     0.000       15     7.6110     0.000       16     7.6110     0.000       17     7.6110     0.000       10     10     0.000       11     7.6110     0.000       12     7.6110     0.000       10     10.000     0.000			
11     17     (0.91).45.000     0.013       12     12     12       13     12     12       14     12     12       15     15.45.001     00       16     10.12       17     15.45.001       18     14.401       19     15.45.001       10     12       11     14.401       12     545.00       13     545.00       14     14.401       15     555.277342457-31115571       16     15.45.00       17     14.401       18     555.277342457-31115571       19     551.5277342457-31115571       10     11.400       11     12.551.5277342457-31115571       12     551.5277342457-31115571       13     551.5277342457-31115571       14     14.551.6277342457       15     17.451.400       16     14.451.400       17     14.551.400       18     554.551.400       19     14.551.400       10     14.51.400       11     15.51.400       12     14.51.400       13     14.51.400       14.51.400     14.51.400       15.51.400     10.11.400			•
11     E = 0 - 1 (10)       12     E = 0 (1 (10)       13     E = 0 (1 (10)       14     E = 0 (10)       15     E = 0 (10)       16     E = 0 (10)       17     E = 0 (10)       18     E = 0 (10)       19     E = 0 (10)       18     E = 0 (10)       19     E = 0 (10)       19     E = 0 (10)       19     E = 0 (10)       10     E = 0 (10)       11     E = 0 (10)       12     E = 0 (10)       13     E = 0 (10)       14     E = 0 (10)       14     E = 0 (10)       15     E = 0 (10)       16     E = 0 (10)       17     E = 0 (10)       18     E = 0 (10)       19     E = 0 (10)       10     E = 0 (10)       11     E = 0 (10)       12     E = 0 (10)       14     E = 0 (10)       19     E = 0 (10)       10     E = 0 (10)       11     E = 0 (10)       12     E = 0 (10)       13     E = 0 (10)       14     E = 0 (10)       10     E = 0 (10)       10     E = 0 (10)       10     E = 0 (10)	•		
11     Exc-1://D0       0     10       12     TEE1.0       0     10       13     ECMIL/081       0     10       14     TEE1.0       15     ECMELOSI       0     16       16     ECMELOSI       17     ECMELOSI       18     ECMELOSI       19     ECMELOSI       11     ECMELOSI       12     ECMELOSI       13     ECMELOSI       14     ECMELOSI       15     ECMELOSI       16     COMPACTIONSI (COMULTINICONSTINCE)       17     ECMELOSI       18     ECMELOSI       19     ECMELOSI       10     COMULTINICONSTINCE       11     ECMELOSI       12     ECMELOSI       13     ECMELOSI       14     ECMELOSI       15     ECMELOSI       16     COMULTINICONSTINCE       17     ECMELOSI       18     ECMELOSI       19     ECMELOSI       11     ECMELOSI       12     ECMELOSI       13     ECMELOSI       14     ECMELOSI       15     ECMELOSI       16     ECMELOSI <td< td=""><td>. 021 122</td><td></td><td></td></td<>	. 021 122		
0       0       10       12         11       TEE:1.0       0       12         12       TEE:1.0       0       12         13       TEE:1.0       0       0       10         14       TEE:1.0       0       0       10       13         15       TEE:1.0       0       0       10       13         16       TA: AND ILLINGS       0       0       10       13         17       TEE:1.0       0       0       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       13       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14       14 <td< td=""><td></td><td></td><td></td></td<>			
11       70       12         12       75       70       12         13       55       50       10       10         14       55       50       10       10         15       55       50       10       10         16       17       10       10       10         17       55       50       50       10       10         18       16       55       50       50       10       10         17       18       55       50       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10       10			
11       TEC 1.0         C COMPUTE OUMLITY LOSS DUE TO         545:0.5         12       545:0.5         14       60         15       15.15.0         16       1113501105011000         17       10.1135011000         18       15.15.11135011000         19       11135011000         10       14.4151.6         11       55155.277342557-3311155011000         12       55155.2773425577-3311155011000         13       55155.2773425577-3311155011000         14       42.6444-4151.6         15       15.6444-4151.6         16       14.4151.6         15       15.44151.6         16       14.4151.6         17       15.5521244553.8         18       55444-4-4514.6         19       11.466-7         14       14.4151.6         15       15441.6         16       14.4151.6         18       55444.6         19       11.466-7         19       11.466-7         10       14.4151.6         10       14.4151.6         19       14.667-1.444.6         10       14.			
I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I     I <td></td> <td></td> <td></td>			
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C COMPUTE OUNLITY LOSS DUE TO 545:00.9 12 545:00.9 15 (E.U.E.0.) 60 TO 13 42:6911114407114000 15 (E.U.E.0.) 60 TO 13 42:.071342557-311155591692 5425.277342557-311155591692 5425.471(4044-19621190453)/1598 5525.471(4044-19621190453)/1598 5525.471(4044) 5525.471(4041) 5525.4312-514524 16 C SCL 10 MTVDOA 16 C SCL 10 MTVDOA 16 EREEN(-SETA-LEADIANSA 5525.4312-514524 16 C SCL 10 MTVDOA 16 C SCL 10 MTVDOA 16 C SCL 10 MTVDOA 16 EREEN(-SETA-LEADIANSA 5525.4312-514524 16 C SCL 10 MTVDOA 16 C SCL 10 MTVDOA 17 FEALL C-ASAB 5525.4312-514524 17 FEALL C-ASAB 5525.4312-5514-55344952-55449594 17 FEALL V-AS1400L10(1(14-1))*59459 5525.4312-5514-55449 5525.4312-5514-55449 5525.4312-5514-55449 5525.4312-5514-55449 5525.4312-55449594415-6400L10(1(14-1))*5849 5525.4312-55449594415-6400L10(1(14-1))*5849 5525.4312-5514-55449 5525.4312-5514-55449 5525.4312-5514-550 551.552-55449594415-6400L10(1(14-1))*5849 5525.4312-5514-55449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 551.552-55449594405-56449 552.54312-56445594405-56449 552.54312-56445594405-56445594405-56449 552.5440594405500 551.552-55449594405-56445594405-56445594405-56445594405-56445594405500 551.552-55449594405-56445594405500 551.552-55449594405500 551.552-55449594405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.552-554405500 551.55200			
C C C VEUTE OUALITY LOSS OUE TO SEE 20.9 LIFE (E.J.E. 0.) 60 TO 13 A:	_		
C COMPUTE OUMLITY LOSS DUE TO S45=0.9 IF (E.LE.0.) CO TO 13 A=6551114691184607140407 B=2.2277342557-3.11555011607 B=2.2277342557-3.11555011607 B=2.2277342557-3.11555011607 B=2.2277342557-3.11555011607 B=2.2277342557-3.11555011607 B=2.2277342557-3.11555011607 C E K1 L LETERVICE D C (14+15). [TYPEA C SCL TO MITODA D C (14+15). [TYPEA D C COVENTE TOTAL D15109453)/(1581 D C COVENTE TOTAL D15109453) D C COVENTE TOTAL D151094530 D C COVENTE TOTAL D151094530 D C COVENTE TOTAL D151094100 D C C COVENTE TOTAL D151094100 D C C C C C C C C C C C C C C C C C C C			
12       545.00       1         14       15.500       0       0       1         15       15.500       0       0       1         15       15.500       0       0       1         15       15.500       0       0       1         15       15.500       11.11557       1         15       15.5111       15.500       1         15       15.515       17796       1         10       10.104       1       1       1         10       10.111257       1       1       1         10       10.111257       1       1       1         10       10.111257       1       1       1         10       10.1112       1       1       1       1         10       10.1112       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1       1			
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L=5xx(-50) 5x1,-2,-(LTeLT) 5x1,-2,-(LTeLT) 7x2, 7x2,-2,-2,-4)0(1,-2,-2,-2,-2,-2,-2,-2,-2,-2,-2,-2,-2,-2,			
5=1,-2,-/(LT0LT) F1=,054450504(1,-4)0(1,-EAP(-2 P2=,44,:55544(1,-4)0(1,-EAP(-2 R=2,-2 T=2,-71 T2=EAP(-2,-/K) T2=EAP(-2,/K) T2=EAP(-6,/K)			
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7 1=			
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2 -PAGE 472 13.10.03, 202 205206 200 203 203203 210 216 213 219 172 16 6 886.84 88 36 96 212 214 215 5 168 69 70 52 177 52 80 83 89 000 16 26 66 56 97 98 66 21 201 211 213 04/08/75 1d0 140 OPT 1CP 5 0 P T 0PT 0PT 1 do 1dC ldo OPT DP1 0P1 Ido 3 100 0PT 1 dC 100 140 Lido 1 dO L dO 1dC 20 **PPT** 1dC P T F d 100 P P 1dQ OPT DP1 0PT DP T DP1 1 dO DP1 0PT 0P1 1 1 0 1 DPT 0 0P1 <u>F</u>GO 140 0 P T 1 40 001 0 P F 5 1 do 2 (6.25) BLK+ONE+SI+ZR+BLK+ONE+SAW+ZR+BLK+TC+ZR+ZR+HM(ITYPEM)+ (TM+SM+LM+MH(ITYPE9)+TBE+SBE+LBE+HEA(ITYPEA)+IEA+SEA+DLI+BLK+T+S+LT •• • • • * • H=SORT(THTR++2+THSV++2+THBS++2+THE++2+(TH1++2+THAA++2)/(MA6++2)) 4 • 2 2 \$ -B,GI2.4+* PEAK-TO-PEAK*) 2 20 4 +312.4+* VIS. LAMBDAS*/ 612.4.* HETERS*/ G12.4+* METERS*/ GL2.4.* METERS*/ E12.4.* METERS*/ 612.4.* METERS*/ METERS#/ .JPG12.4.* METERS-1 ++0P612.4+* RADIANS FTN 4.0+P357 *+612.4+* RADIANS .512.4. METERS*/ *,0PG12.4.* KATTS ,612.4.* SECONDS + 512.4+* RADIANS *. 312.4.* RADIANS . 512.4 . RADIANS • 312.4.* METERS • 312.4+* DEG K *+312.4+* L/WT 612.44* FORMAT(10X+30(1H*).*INPUT TO OPTICAL TRAIN*.30(1H*)) .0PG12.4.* +0P612.4+* +3P612.4+* +512.4.2 +512.4+* +.12.4.* +312+4+ 12. • 48 • • 4 6 • • 483 164. * 20X+*INTENSITY FLUCTUATIONS (22X+*SCALE SIZE OF FLUCTUATIONS 20X+*TYPE OF AEROWINDJW ORMAT (20X+*DISTANCE HETWEEN MIRRORS 20X+*TELESCOPE MAGNIFICATION 20X+*TELESCOFE DIAMETER WR=1 .. (3.14159*D8*D8/(4.*WL*R2)) **2 20X+*AEROWINDOW DELTA RHO/RHO 20X.*TENPERATURE FLUCTUATION 20X ** AHSOMPTION COEFFICIENT 20X+*PULSE LENGTH 20X+*PHASE FRONT CURVATURE 20X++TYPE OF EXIT APERT"SE 20X+*STPUT AREA/ BEAN AREA ORMAT (201. + LASER BEAM DIAMETER 20%,*EXIT APERTURE LENGTH 204+*SERVO JITER Pex+*AUTOAL CARVENT JITTER LF (ABS(16).61.1.E-5) 60 TO 17 WRITE (6.26) 08;0.41,XM2,WR.M2 WRITE (6.27) TH.R2 204,*DISTANCE TO CLIPPER 20X+*CLIPPER UIAMETER 20X+*NUMMER OF MIMRORS SOX+#HOHE-SIGHT JITLER 20X+*FAHRICATION EHROR TRACE 20X+#IYPE OF MIRRORS ORMAT (20X - FIRECHER JITTEN 20X+*IELESCOPE TYPE 20X+"REFLECTIVITY 20X++HEAM OUALITY 20X+*2H0/RH0 REF 20X+*LASER POWER 20X+#0BSCURATION 20X + WAVELENGTH 0=T=0 20X+*JITTER 16=(T2/T4-Y)/T5 =TC+TM+TBE+TEA **RANSHISSION** ARTE (6.23) (6,24) 73/74 WRESORT (WW) NP=SORT (X) H2=4R+K2 M1=P1/12 x=x-16 Idel=d JITTER RETUAN RMAT 5112=112 HRITE WRITE SUBROUTINE OFTRAIN 585 20 23 21 175 195 200 205 210 215 220 225 1.45 190 80

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TRACE
0-1-0
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04/08/75 13.10.03.

FTN 4.0+P357

PUT BEAM **AB*Z**F8*4*Z**F5*4/	FORMAT(201.+*INPUT BEAM +*A9,2X,FB,4,2X,2FB,4/ 1 201.+4/Froyynamic WINDOW *+A9,21,5FB,4,7X,2FB,4/
	JIJYNAMIC WINDOW **A9*2X*F8.4+2X+2F8.4/

		v	KUNATION NARAANA	
	•	2	20X+*M]XXURS	**AK*2X*F8_4*2X*2F8=4/
215			204. SEAN EXPANDER	* • A5 • 2X • F5 • 4 • 2X • 2F8 • 4/
		• ••	204. *EXIT APENTURE	**A8*2X*F8*4*2X*278*4/
			204+*T0TALS	**A3*2X*F8*4*2X*2F8*4)
	26	FORMAT (	20X .* TRANSHITTED BEAM	FORMATIZOX.*TRANSMITTED BEAM DIAMETER**FR.4.* METERS*/
	•	1	20X.+TRANSMITTED POWER+612.4.* WATTS"/	*+612.4+* WATIS#/
240		2	DX,48EAM QUALITY BEFO	20X, 48EAM QUALITY BEFORE ACCOUNTING FUR DIVERGENCE*/
2		1	31K+**] =**F8*4*4K****2 =**F8*4/	2 =#•FR.4/
		4	DX . FFFECT OF HEAM DI	20X, PEFFECT OF HEAM DIVERGFUCE ON WAIST*, G12,4/
		×	CX, FINAL REAM SPREAD	20X, FINAL REAM SPREAD PAWAMETER. M2*.612.4)
	27	FORMAT (	FORMAT (20%, *TOTAL REAM JITTER*, 512,4,* RADIANS*/	R*+512.4+* RADIANS*/
245	1	×	OX . * PHASE FRONT CURVA	20X.*PHASE FRONT CURVATURE*. GI2.4.* METERS*.//)

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SUBROUTINE ATH	АТН	73/74 OPT#0 TRACE FIN 4.0+P357	04/08/15	13-10-09	•	79K	-	
•		SURPOUTINE ATH	ATH 474	N 7				
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		INTEGER TYPED(4),TYPEE(4) THITCEED HEAM.DEMIG.FING.COUT.PO.PHOP.TYPE.WIHR	ATH ATH	10				
2		REAL 1.1190+1010+KAS+K0L+K1P+L+LAMDA+LT2+LT250+M+MS0+NBAR+NU	ATM ATM	12				
U				11			•	
15		COM4ON /EHROP/ ERR Com4ON /AIMIN/ M+OI+PROP+SIGLF+SIGHF+WIHR+MI+M2		<u>.</u>				
		/WESH/ XPKAS•ZPHEV•XN•AREA /a fnta/ Dummy(4)•P tne(3)•ABL•ABE•S	ATX ATX	17 18		٠		
		ATMS/	WIY	19				
20								
		HI-FOUL FINAL-FIVE	ATM 62. 41M	22				
		55+HTF+T+TFLAG+KAS+KIP+L2+L2+L250+MS0+VSML+PT+P0+						
25	-	210+516454+5164454+5164441+51454+440LU C0440N /ALFA/ LA4+RH	E LA	9 9 7 7				
			A14 A14					
U			ATA	56	• •			
30		EXTERNAL ALFAEX+CNSU Namelist /uspec/ pline+ <b>abl+Abe+Scl+Sce</b>	ATM ATH	90 91 91				
U			ATM	32				
		DATA PI/3.14159/ data typed/shahove,5mbelo4.5mabove.5mbelow/ data typee/shahove,5mpelo4.5mbelow.5mabove/	N N N N N N N N N N N N N N N N N N N	n 4 9				
35		SELECT LAWS	ATM	36 37	. •	•		
		LAM=1 Di Enf (1)=.33H	A14 A14	8 6 6				
			ATH	40				
04		PLINE (3)=.342 Abl=a45=SCL=S <b>CE=0</b> .	HIA	14				
		IF (LAMDA.GT.0.) 60 TO 2 dean (4.154fc)	ATM - Atm -	M 4 4 4	•			• .
		IF (ABL. WE.O.) LAM=4	ATM	5 Y	•			
40 1		LEMAZ=A45(LEMDA) TEMP=1,/(PLINE(1)+PLINE(2)+PLINE(3))	A I A A I A	40				
•		DD      = +3 BuitweittitaureittitateuD	ATM Atm	, 84 7				
4	_	11E (4+44) P	ATM.	5				
20 7		ןר לאנייא 15 (באיר 10 10 3) דר נו מאחמירין 1.אר-גון מאו=?	2 H H	0 0 1 0				
. (		(LAMDA.E0.5E-6) LI		53				
50		COLLIMATED OR FOCUSED BEAM	- +					
22		(FOCUSED)	ATM	56 7 6				
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			References and a state of the	والمقاطعة والمتناخرة والمراجع لأحدث فلمع والتلالي والمناهلا	รับมีราคมสมบัตร มีสายเหตุการในสมบัตรกรรมสมบัตรกระ	e la sua a constante a la managéria dan a la sa sa sang mangang	and the restrict structure sector structure and the structure of the sector of the sec	
				* * + *				
	SUBJOUTINE ATM	73/74 OPT=0 TRACE	FTN 4.0+P357	04/08/75	13.10.09.	PAGE		
	u	IF (REAM.E0.1) GO TO 4 (Coilimated)		ATH ATH	65 60			
		GS≢0. G4≡1.		ATH	61			
	<b>.</b>	SET CONSTANTS AND VARIABLES		414 474	6 6 4 6		•	
	4			ATH ATH	65 44			
	60	COFF 2=21/71 COFF 3=2455=M]=PF			67 67	•		
		EAPASEL. FINAL=2	,	AIA	8 6 9 8 9			
	30	FIVE3=5./3. FIVE9=5./9.		ATM Atm	70			
		N0M=H1W+6L		ATH ATH	72 73			
	;	IfLAG=1 I#=×THR+2		ATM	74 75			
	5	K 45≡0. K0U:4T≡0		ATH Ath	91 11			
		L_COUNT=0 M=1/2		ATM	78 79		•	
	V	250=2+2 014=1-0501	-	ATM	00			
	•			MTA	18			
/ <b>B</b> -		PG=1 R0SG=RQ+RQ		ATM	83 48			· · · · ·
12.	85	R16=R0+10. S1660=S161F=+2-S16HF++2		ATH	85 85	×		•
, <u>***</u> *				ATM	87			
•		SIG4A#=0。3183=M2#L&MDA/(R0#2。) Sigaso=51gmars1gmar		ATM	80 3			
	06	SIG42=S7RT(SIGRS0+SIGS0) SIG42=SIGM&*SIGM&		ATM .	66 66 6			
<u></u>	•	SIGMATEO.		ATH	6			
Part and the		Z=0. If (ITYPE.NE.5) GO TO 5		ATH	66 67	•		
	62 62	CALCULATE L FOR REVERSE PROPAGATIONOI AND PT	T XNOWN	818 818	6 96		•	
		FL=L If (L.6Y.0.) 60 TO 5		ATM Ath '	97 98	•	•	
<u></u>		NU=。865*PT*Ml-PI=64*R0S0*UI L=SURT(NU/(4。*PI*01*SI6AS0))		ATH .	99 100			
	100	IF (DEMUG.EU.2) WRITE (6,33) NU.L If (l.L.LT.R10) L=100.		ATH	101			
	<b>.</b>			ATM	104	•		
		CALCULATE PHI OR HIM		ATM	105			<b>1</b>
		IF (PHI.LT.0.) GO TO 6		ATA	107			
		COSPH1=COS(PH1)		ATA ATA	108	1		
	110 6	63 10 / CPMI=,IMUE,		8   8 8   8	111			
		10=113=164 10p=445 (10)		ATM	112			
		NKD=1 TF (400,5)F,40) NHD=-1		A14 A14	114			
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	IF (L.LT.+HDP) HO≖L*NHD	АТН	116	<i>x</i> .	
	COSPH1=H0/L	ATM 414	117		
	THE FECON COULTEN Contructer (	ATM	119		
-		ATM	120		
120	H1F=3_231~H1×	ATM	121		
	LT2=L*2.	ATH	122	•	•
•		ATH	123	-	
	IF (HOM.GI.IES.AND.HTM.GI.IES) NSTEP=1	ATM	124		
	MSW1=NSTEP-1	ATM	125		
125 C	•	A   A	071		
	CALLECTIN DO DI ANC MANE		124		
		I.I.	129		
	IF (PROP.E0.2) 62=3.5A	ATM	130		
130	IF (PRUP.EU.3) 62=0.9	ATM	131		
	IF (GUT .EQ. 2) WRITE (6.49)	TCP	23		
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	ACCOUNTING ON BRUTLER BOODLEATTON		146		
د	TRUFTOR / OR APPORT INVESTIGATION	ATM	147		
U	KUVY KUM TKUTAGAL DANNU ZAU TI KAUSA				
	1-1421-1				
<b>U</b> (	PEGULAR PROPAGATION				
<b>U</b>			241		
U	COMPUTE STARTING VALUES OF AREA AND INTENSITY	ATM			
	APEA=P1*R050	ATM	104	•	
155	I=p1/APEA	ATH	155		
	IP=2.312*I	ATM -	156		
	F X PK 45=1 -	ATM	157		
	A A A H G I	ATH	158		
		AT 9	159		
		ATK	160		
101					
	IT (001.500.504NU.511.104).500.500.500.500.500.500.500.500.500.50				
	10441+210101+CAPAAUA+AREA+1		201	-	
U					
	GO TO (13-14-15-16)+ TYPE				
165 13	CALL AA (HOM)		<b>CO1</b>		
	G0 T0 4A		100		
14	CALL 44 (HGM)	ATM	167		
	G0 T0 4e	ATM	168		
15	CALL AH (HOM)	ATM	169		
	GO TO 48	AIM	170	•	
110	60 T0 48	A14	170		

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U 4	IF (FOU) DETUDN	ATH ATH	172	
	i	ATH	174	
175	F. 1	ATH	175	
	IF (ITYPE.EQ.5) GO TO 22 IF (ITYPE.EQ.5) GO TO 22		177	• z
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	COMPUTE AND PRINE DISPLACEMENTS ECCENTRICITE AND ISU-INTENSITY Pontair Data.			
		2 - X	191	
	AF = ,70710578*40L0	A14	182	
	PT0TAL=PT*XPKAS*(1,-G3)	A1M		
165	ETA=ROLD/RG Andu=3 14150244AE4AE/KTB			
C01			1.46	
	CISP=(-0.692)+S02T(0.47AA64-2.6666667*AL06(K1P))	ATM	167	
	015p=af + (E1ase (-, 29)) +01SP	ATM	186	
	IF (PD .E0. 0.) WRITE (6+49)	1CP	24	
190	#P[TE (6+42) DISP+ECC	¥	269	
	G4M14#1.0	ATA	196	
	DURATO I		201	
		ATM	E 4 1	
195	AREAT (-ANGM) FALOG (GAMMA)	N14	751	
	-6AP	41M	195	
	avg1=P0+E2/APEA	ACM	196	
		ATM	197	
17	CONTINUE	A 14	961	
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ο U		ATH	201	
		100	25	
	PRD = [40 + PI + KJP / (2.312 + 1)	ATA	202	
205	PR[w] 45. [80.P90	ATM	203	
	P24X#P1+5。54/XN	A1%	204	
		ATM	205	
	IF (P44X.LE.PHD) GO TO 18	ATM	206	
	CHGZ ZDHJ	ATM	207	
210	0HI=1X	ATM	208	
91	PRINT 32, AI, PMAX		209	
U I			212	
	EFFECT OF POWER VARIATIONS		112	
215 C				
		ATM	214	
	PP=0.	ATA	215	
	YN=0.	ATH	215 .	
	£101=1/(K[bept]	ATM	217	
220	DO 20 III=1.20	NTA .	518	
		ATH	219	
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		16	PUSE=PT01*PP*(1FACT0R) Ausf=-0.5*AfE4*AL06(FACT0R)/ZZ			231				
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2.12000			IF (KAT.LT.0.45.0P.KAT.GT.2.22) 60 TO 26		MIN	245				
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			IF (CPHI) 60 TO 28 #10-46mil #FOSEMI		A7%	260 267	•			1912
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	275		IF (HUP,NE,HD) NHD=1		ATH	. 573				
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		3			307	
310	37	FCP:4AT (//10%+13HAEFINED FL = +E12.5+8H+ HTM =	•E12.5.8H. PHI =	•E ATH	203	
				47M	309	
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<ul> <li>ZIGULGLAFE RADIUS. STEMATISTISOP.NELD</li> <li>C. CLULAFE RADIUS. AREA. AND INTEMSITY RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESCRIPSOS</li> <li>RESULTS</li> <li>RETURN</li> <li>RETURN<td></td><td>COMMON / DATA/ COULTING/ARCHIG/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATI</td><td></td><td>15</td></li></ul>		COMMON / DATA/ COULTING/ARCHIG/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATION/ACCURATI		15
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C CALCULATE RADIUS. AREA. AND INTENSITY RESERTINGSON RESERTINGSON RESERTINGSON AREARTINGSON RESERTINGSON RESERTINGSON RESERTINGSON RESERTINGSON RESERTINGSON RESERTING RETURN C WRITE (6.2) L.HOM.II.AREA.IN RETURN RETURN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN RETURN RETURN RETURN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN RETURN RETURN RETURN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN RETURN RETURN RETURN RETURN C MATTE (6.3) HTM.HTF.L.R.ANEA.IN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RET				11
RSD=LTSC0*SIG4S0 RSD=LTSC0*SIG4S0 AREART+450 I=CCEF3/AKEA F (FINAL-662.2.AND.0ERUG.ED.1) RETURN VRITE RESULTS C WRITE RESULTS ROLDER F (001.60.1) G0 T0 1 WRITE (6.3) HTW-HTF-L.R.A.REA.R ROLDER F (001.60.1) G0 T0 1 WRITE (6.3) HTW-HTF-L.R.A.REA.R RETURN C WRITE (6.3) HTW-HTF-L.R.A.RE	U	CALCULATE RADIUS.		
RESCRITESC) RESCRITESC) RECEFJAREA IF (FILAL-ME.2.AND.DERUG.ED.I) RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN R				61
AREARTON I=COEF3/AKEA I=COEF3/AKEA F (FINAL-NE.2.AND.DERUG.ED.1) RETURN C WRITE RESULTS ROLD=R I (0011.60.1) GO TO 1 F (fOUT.ED.1) GO TO 1 F (0011.60.1) F (0011.60.1)				
I=CCEF3/AKEA IF (FINAL-ME.2.AND.DERUG.ED.I) RETURN RRITE RESULTS ROLDER IF (OUT.ED.I) GO TO I RRITE (5.2) L.HOH.I.AREA.R RETURN RETURN RETURN C NRITE (5.3) HTW.HTF.L.A.AREA.F RETURN RETURN C NRITE (5.3) HTW.HTF.L.A.AREA.F RETURN C NRITE (5.3) HTW.HTF.C NRITE (5.3) HTW.HTF.C NRITE (5.3) HTW.HTF.C NRITE (5.3) HTW.HTM.F RETURN C NRITE (5.3) HTW.HTF.C NRITE (5.3) HTW.HTF.C NRITE (5.3) HTW	50	AREAFP1+450		21
IF (FILAL-GE-2.AND.DERUG.ED.1) RETURN C WRITE RESULTS ROLDER IF (OUT.EO.1) GO TO 1 WRITE (6.2) L.HOH-1:AREA.R RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN RETURN RETURN C WRITE (6.3) HTM.HTF.L.A.AREA.R RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN RETURN R		3/AKEA	44	22
C WRITE RESULTS ROLDER IF (OUT.ED.1) 60 TO 1 WRITE (5.2) L.HOW.1.AREA.R RETURN C WRITE (5.3) HTW.HTF.L.R.AREA.T RETURN C FORMAT (104.12MAROVE 100 KW/IX.1P2E15.4.5X.2M0.6X.3E15.4.5X.10M1. C FORMAT (1110X.23HTARGET ALTITUDE (HTM) =.1P210.3.9H METERS (.E10.3 10002E-0C/) T C PART (//IDX.23HTARGET ALTITUDE (HTM) =.1P210.3.9H METERS (.E10.3 10002E-0C/) C PARTEA MITHOUT FLOOMING (R) =.CPFT_2.7H METERS (.E10.3 1.42FAREA MITHOUT RUOMING (AREA) 2.42FAREA MITHOUT RUOMING (AREA) 3.42FAREA MITHOUT RUOMING (AREA) 3.42FAREA MITHOUT RUOMING (AREA) 4.42.08X.23HTARGET PLANE RUTENSITY (1) =.1PE10.3.10H METERS		IF (FINAL.NE.2.AND.DERUG.ED.1)		24
<pre>C ROLDER IF (OUT.EO.1) E0 T0 1 WaITE (6.2) L.HOW.I.AREA.R RETURN C WRITE (5.3) HTW.HTF.L.A.AREA.I RETURN C FOPMAT (10K.12HAROVE 100 KW/IK.1P2E15.4.5X.2M0.6X.3E15.4.5X.10M1. C FOPMAT (10K.12HAROVE 100 KW/IK.1P2E15.4.5X.2M0.6X.3E15.4.5X.10K. C FOPMAT (10K.110K.2HAROVE 100 KW/IK.1P2E15.4.5X.2M0.6X.3E15.4.5X.10K. C FOPMAT (10K.2HAROFET PLANE FNTEMETTY (1) *E11.4.11H WATTS/W**27) END</pre>		01107		1
F. COUT.ECO.1) GO TO 1         WRITE (5.2) L.HOH.1.AREA.R         RETURN         C         WRITE (5.3) HTW.HTF.L.R.AREA.F         RETURN         C         WRITE (5.3) HTW.HTF.L.R.AREA.F         RETURN         C         RETURN         C         FOPMAT (104.12HAROVE 100 KM/1K.1P2E15.4.5X.2M0.6X.3E15.4.5X.10M).         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C         C			44	56
Kaite (6.2) L.HOH.I.AREA.R         Return         Retext         Retext      <	G	rf (our fo.1) 60 TO 1		27
RETURN         1       WRITE (5:3) HTW.HTF.L.R.AREA.I         RETUKN         C       WRITE (5:3) HTW.HTF.L.R.AREA.I         RETUKN         C       FOPMAT (10K.12HAROVE 100 KM/1K.1P2E15.4.5X.2M0.6X.3E15.4.5X.10M1.         C       FOPMAT (10K.12HAROVE 100 KM/1K.1P2E15.4.5X.2M0.6X.3E15.4.5X.10M1.         10003E-0C/1       FOPMAT (//10X.23HTARGET ALTITURE (HTM) =.1P210.3.9M METERS (.E10.3.10M1.         3       FOPMAT (//10X.23HTARGET ALTITURE (HTM) =.1P210.3.9M METERS (.E10.3.10M1.         3       +22HAREA WITHOUT BLOOMING (R) =.0071.2.7H METERS/10X         4=2.8X.23HTARGET PLANE [NTENSITY (1) =.1P11.0.3.10M METERS         5       -2.11.0.11 MUTHOUT BLOOMING (R) =.0077.2.7H METERS/10X         5       -2.8X.23HTARGET PLANE [NTENSITY (1) =.1P11.0.3.10M METERS		(6.2)	84	2á
C WRITE (5.3) HTW.HTF.L.R.AREA.T RETUKN C FOPMAT (10K.12HAROVE 100 KM/1K.1P2E15.4.5X.2M0.6X.3E15.4.5X.10M1. 10002E-0C/) 10002E-0C/) 2 fopmat (//10X.23HTARGET ALTITUDE (HTM) =.1P210.3.9H METERS (.E10.3 1.5H FEET)/10X.42HTARGET ALTITUDE () 2.42HAREA WITHOUT RUDOHING (AREA) 2.5HTARGET PLANE [NTENSITY (1) =.E11.4.11H WATTS/W002/) END			44	6 N
<pre>1 WRITE (5.3) HTW.HTF.L.R.AREA.T Retukn C Format (104.12HAROVE 100 Km/1K.1P2E15.4.5X.2M06X.3E15.4.5X.10M1. 10002E-0C/) 3 Format (//10X.23HTARGET ALTITURE (HTM) =.1P210.3.9H METERS (.E10.3 1.5H FEET)/13X.42HTARGET ALTITURE (HTM) =.1P210.3.9H METERS (.E10.3 2.42HAREA WITHOUT BLOOMING (R) =.6P77.2.7H HETERS/10X 3.42HAREA WITHOUT RLOOMING (AREA) 4.62.8X.23HTARGET PLANE [NTENSITY (1) =.E11.4.11H WATTS/W002/) END</pre>	U		22	
RETUKN C FOPMAT (10K+12MAROVE 100 KM/1K+1P2E15.4+5X+2M0.+6X+3E15.4+5X+10M1- 10002E+0C/) FOPMAT (//10X+23HTARGET ALTITUDE (HTM) =+1P510.3+9H METERS (+E10-3 1+5H FEET)/13X+42HTARGET ALTITUDE (HTM) =+1P510.3+9H METERS (+E10-3 2+42HAREA WITHOUT BLOOMING (R) =+0077.2+TH METERS/10X 3+42HAREA WITHOUT BLOOMING (R) =+0077.2+TH METERS/10X 4+2-8X+23HTARGET PLANE [NTENSITY (1) =+011.4+11H WATTS/M**2/) END		JT15H		1
C FOPMAT (10X+12HAROVE 100 KM/1X+1P2E15.4+5X+2M0.+8X+3E15.4+5X+10M1- 10003E+0C/) FOPMAT (//10X+23HTARGET ALTITUDE (HTM) =+1PE10.3+9H METERS (+E10-3 FOPMAT (//10X+23HTARGET ALTITUDE (HTM) =+1PE10.3+9H METERS (+E10-3 1+5H FEET)/10X+42HTARGET ALTITUDE (HTM) =+1PE10.3+9H METERS (+E10-3 2+2FAREA WITHOUT RLOOMING (R) =+0PF1.2+7H METERS/10X 3+42HAREA WITHOUT RLOOMING (AREA) 4+2-8X+23HTARGET PLANE [NTEMSITY (1) =+[1].4+11H WATTS/M**2/) END		RETUKN		
C FOPMAT (10X+12MAROVE 100 KM/1X+1P2E15.4+5X+2M0.+8X+3E15.4+5X+10M1- 10003E+0C/) FOPMAT (//10X+23HTARGET ALTITUDE (MTM) =+1P510.3+9M METERS (+E10-3 1+5H FEET)/10X+22HTARGET RANGE (L) 2+42HAREA WITHOUT RLOOMING (R) =+CP77.2+TH METERS/10X 3+42HAREA WITHOUT RLOOMING (AREA) 4+2+8X+23HTARGET PLANE ENTENSITY (1) =+E11.4+11H WATTS/M**2/) END	U			14
<pre>C FOPMAT (10K+12MAROVE 100 KM/1K+1P2E15.4+5X+2M0.+8X+3E15.4+5X+10M1- 10003E+0C/) 3 FOPMAT (//10X+23HTARGET ALTITUDE (HTM) =+1PE10.3+9H METERS (+E10.3 1+5H FEET/10X+42HTAFGET RANGE (L) 2H METERS+12X+29HAADIUS WITHOUT BLOOMING (R) =+0P77.2+TH METERS/10X 2+42HAREA without RLOOMING (AREA) =+0PF10.3+10H METERS+10X 4+2+8X+29HTARGET PLANE ENTENSITY (1) =+E11.4+11H WATTS/H0+2/) END</pre>	U (	-	1	6
<pre>c 1000056-06/) 3 F0PHAT (//10X.23HTARGET ALTITUDE (HTM) =.1PE10.3.9M METERS (.E10.3 1.6H FEET)/10X.42HTARGET RANGE (L) 2.H HETERS-12X.42HTARGET RANGE (L) 2.H HETERS-12X.42HTARGET RANGE (L) 3.42HAREA WITHOUT RLOOMING (AREA) =.1PE10.3.10H HETERS-10X 4.2.8X.23HTARGET PLANE ENTENSITY (1) =.E11.4.11H WATTS/M002/) END</pre>		Tenner		0
<pre>3 FOPMAT (//IDX+23HTARGET ALTITUDE (HTM) =+1PE10.3.9H METERS (+E19.3 1.6H FEET)/IDX+42HTARGET RANGE (L) 2H HETERS+12X+29HAADIUS WITHOUT BLOOMING (R) =+CPFT_2+TH HETERS/IDX 2H4REA WITHOUT RLOOMING (AREA) 4-2.8X+29HTARGET PLANE [NTENSITY (1) =+CI1.4+11H WATTS/M=+2/) END</pre>				. 37
1.64 FEET)/10X.424TARGET RANGE (L) 24 METERS-12X.4294RADIUS WITHOUT BLOOMING (R) 3.424AREA WITHOUT ALOOMING (AREA) 4.2.8X.294TARGET PLANE KWTENSITY (1) =.Ell. END	"	177007	(.E10.3	29
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<pre>1 kaitE (5*5) MfH+Mif+SlGMAT+L*SIGTST+EXPKAS.4*KJP+J-MEA+JP+DLMEA E kaitE (5*5) MfH+Mif+SlGMAT+L*SIGTST+EXPKAS.4*KJP+J-MEA+JP+DLMEA E kaitE (//+10x+esEL.4 100 KM+O) E format (//+10x+esEL.4 100 KM+O) E form</pre>				t <b>«</b> t	1	
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<ul> <li>FERINMU</li> <li>FORMAT (/*1X*1P95.5.4)</li> <li>FORMAT (/*1X*1P95.5.4)</li> <li>FORMAT (//*10X**AEL.M 100 KM*)</li> <li>FORMAT (//*10X**AEGUE 109 KM*)</li> <li>FORMAT (//*10X**AEGUE 109 KM*)</li> <li>FORMAT (//*10X**AEGUE 100 KM*)</li> </ul>		T	KAITE (S.S.) MIN.HIF'SIGHAT.L.SIGIST.CAPKAS.Z.KIP.J.ANEA.IP.BL		<b>1 7 7</b>	
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<pre>X FORME! (//10%*emBL.# 100 KMe) 3 FCP4AF (//*10%*emBL.# 100 KMe) 4 FOPXAF (//*10%*emBL.# 100 KMe) 5 FUV4FF (//*10%*effauGET aLTFFUGE (MTM) sex1PE10.3*e METERS (ee BA 1E10.5*e FACTION STATE ALTELE (L) 2</pre>				1월 14월 14 18월 14	5	
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C. M. L. Harrison M.	115	<b>د</b> ۹	IF (PRINT) WRITE (6+24) Z+H0+SIGMAT+SIGTST+EXPKAS+AREA+I+IP Continue	8 8 8 8 8 8 8 8	116 117 118	، ر.			. : 
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1-1-1-4 (1972); ·		υυι	START COMPUTATION OF BLOOMING LOSSES	889	123			•	• • • •
•	125		ENDED=.FALSE. CNVRGD=.FALSE. Hom=Hom Sigkat=Sort(Sigtso) Call AlfSet (NLAM,LAM)	888 898 898 898	125 125 127 127 127 127 127 127 127 127 127 127			·	· · · · · · · · · · · · · · · · · · ·
	130		TEWD3=(SIGHF+SIGHF)**2+4,*SIGBSO TEWD4=A4*2050 Umirtym=.FALSE RSO=TEMP4+TEMP3*ZPREV**2	83 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	132 132 132 132 132 132 132 132 132 132	·			en an
	135	000	CALCULATIONS FOR Z = R + 10	88 83 83	135				
			DZ=+10 HDZ=22*0.5 TFDZ=DZ*0.341656666667	83 88 88 88	133 133 140	• [*] •			
B-23	140		UET L=2271 с ТЕКРЈ=824COSPHI 0154=62*01 Текрб=63402/L Бререу=64LTIN(н0м)*ALFFAC(0,•М0м+ОК)/(VX(6L•Н0%+МОМ•РНІ•0•)*RSQ)	8 3 3 3 3 3 6 3 6 3 6 3 6 4 6 6 6 6	141 142 1443 1443 1443 1443 1443 1443 14	,	• 200 • 200 •		
•	145			0 m m	146 147 148	-	۰.		· · - · · · · · · · · · · · · · · · · ·
	150		RC=1.+UZFL RSO=IEMP4+TEMP5+PC++2+(TEMP3+SVSTSO(KJ))+(Z+ZPREV)++2 GCUPR=GALTIX(H)+;LFFAC(DZ+H+OK)+G3TRM/(VX(GL+H+H0M+PHI+Z)+RSQ) XCUPR=DZSO+(-0.5+GPREV-(GPREV-6CURR)+0.04166655666667)/SQRT(RSQ) NT=XCUPR G=(GCURR+GPREV)+HDZ G=(GCURR+GPREV)+HDZ GUESS=GCURR+GCURR-GPREV	88888888 8888888 8888888 888888 88888 8888	90940940 90940940 9197777	•			
	155	000	CALCULATIONS FOR NEXT INTERVAL	200 m 200 m	150	•	•		
	160	06 H	Z=Z+DZ IF (Z-GE-L) GO TO 16 H=H-TFYP1 GJT4M=GJT4M-TEMP6 RC=FC-D2FL TGTND=Z0FINDT0+1. IV0T0=T01A0		12000000000000000000000000000000000000				
	165		<pre>IF (1x070.GE.NSTEP) INDIO#NSTEP-1 SIGTSU=SVSfSQ(IN0TQ) SIGTSU=SVSfSQ(IN0TQ) SIGTSU=SIGTSO+(TOIND-FLOAT(INDTQ))+(SVSTSQ(INDTO+1)-SIGTSO) MSD=TEMP4+TEMP5*2C**2+(TEMP3+SIGTSO)#(2+ZPREV)**2 GNEJ=CALTIN(H)*ALFFAC(UZ+H+OK)*63TRM/(VX(GL+H+HOM+PH1+Z)*RSO) CONTACTIN(H)*ALFFAC(UZ+O+OK)*63TRM/(VX(GL+H+HOM+PH1+Z)*RSO) CONTACTIN(H)*ALFFAC(UZ+H+OK)*63TRM/(VX(GL+H+HOM+PH1+Z)*RSO) CONTACTIN(H)*ALFFAC(UZ+H+OK)*63TRM/(VX(GL+H+HOM+PH1+Z)*RSO)</pre>	8 8 3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	165 166 168 170			· .	
	170	U	IF (ABSUDERVALIATION OF IN AN IN AN OKAGEACTOR	) ဘ ယ ၁ သ လ	171 172	•	•		
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U	CHECK ACCURACY OF LINEAR EXTRAPOLATION		173			
•	DEVIAT=4AS((GNE#-GUESS)/GUE <b>SS)</b>		175			
175	IF (DEVIAT.GT.0.05) 60 TO 15 OK=.TRUE.	89 19 19 19	176			
	HSOHLD=250		173		•	
	19月1日までまたした。 しょうしょう しょうしょう しょうしょう しょうしょう インドレイド アンプレイド しょうしょう ひょうしょう ひょう ひょうしょう ひょう ひょう ひょう ひょう ひょう ひょう ひょう ひょう ひょう ひ	888	179		•	
180	XCUAR=D3*([H02*6NEW-6]-(GCURR-6NEW)*1F02)/50RT(RSQ) N1=N1*XCU4K		181	·	•	
	IF (EUDED) GO TO 17 IF (DEVIAT.LT.0.01) GO TO 12		181			•
11 185	СФРЕКТАСОЧА ССОБИТЕСТЕХ ССПОИТЕСТЕХ	20 80 0 60 80 0	100			
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190	2 Ü		105 105 1			
	INCREASE SIZE OF INTERVAL		192	-		•
13	CONTINUE		761 761			·
195		9 C.	961	•		
	UKIFAME_FALSE. IF ((Z+DZ).GE.L) GO TO 14	89.99	191			
	TEDZ=TENZ+TEDZ 6256 =0756 =0751	83	661			
200		69	201	•		
	TEXP6#TEXP6+TEXP6 GC10%#6%8f%	69	202			
	6UE45=6CUAR+6CUAP-6PREV 60 IO 9		204			• • •
20 <b>2</b> C		0 80	206			
υι	FINAL INTERVAL	63 63	207			
<b>4</b>	CNV96D=,TAUE, F0ACT=14-73,407		209			·
210	IF (FRACT-LT-5.6-4) 60 10 17 16 (FRACT-LT-5.6-4) 60 10 17 07-44 - 24-80.6		211			
			213		•	
9	1FUZ=UZ*U+941656565667 QZFL=UZFL+AATT		215			•
215	1 8 2 0 1 = 1 8 2 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	89	216 217			
	GUESS=(GREx+GCURD) <b>+FRACT+GNEM</b> GPREV=GREx+GREX+GUESS	80 g 9 g 9 g	218			
130	6CULX4=GNE4		220			
2		89	222			
υu	TRY EXPONENTIAL EXTRAPOLATION	ଅଧି ଅ	22 <b>3</b> 224			
225 225	DEVIAT=ABS(GCURR**2/(GPREV*GNEW)-1.) If (Béviat.L1.0.05) GO TO 19	89	225 276			
	IF (02.LF.0.01) 60 TO 19 Cavrs0≃.FalsE.	69 69	223			

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\$C2	00	INTERVAL MUST BE REDUCED	80 80 8 80 80 8 80 80 8	230 231 212		
	د:	M#H=TEMP1 Gjt4k#eGjt4k <b>+TEMP6</b>	88	233		•
235		RC=4C+DZFL Z=Z-DZ	88 88 88 88	235 236 775		•
		D2=HDZ HDZ=U2 <b>+0,65</b> TEN2=1:740, 041/4444447	2 82 8 2 9 9	238 238 239	•	
4 F		r D/r = 0, = 0, = 0, = 0, = 0, = 0, = 0, = 0		241		
A 4 7		1 EXPERITY \$ 70 0 5 FX 20 FT 7 X 20 0 5 FX 20 FY 4 FX 4 0 5 5	68	242		
			8.8	245		
245	U:		88 8	246		
	01	FACT=:[-2+92]/DZ  F (#ACT.[:]:[-3] 60 T0 <b>17</b> TF /ABCT.[:]:1 F 1 F 3 <b>CO TO 10</b>		248		•
		IF (PASTRADUTION-LEGICERS) 60 TU IU Unifermentise Ost - //or	0 60 8 0 60 0 0	250 251		
AC2		10		252		
		TFDZ=DZ*0.04165666667 DZF1=UZFL#FH4CT	69 69	253 254		
			66	255		
255		152255=152254544401 Guesss=(6Curr-Grrev)+Fract+6Curr		251		
		Gapry=GGUHR+GGUHR-GUESS Filde _ TkuE -	8 8 9 9	259	•	
		CWVP60= 1 AUE	63 83	260		
707	!	TO 10		262		
	17			264		
265		NI=NI#(77.6+5.A4E-13/LAMD <b>A**2)/(77.6+5.84E-13/1.1236E-10</b> SIGT5U=5IGMAI**2	88	265 265		
	0 U	CALCULATION OF INTENSITY WITH BLOOMING	88 83 83	261 268		
	•	REAM+ABS(NI))	68	269 270		
270		1=14V14 19=2,42 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=140 14=1400 1400		272	·	
		APE4=P1*KOLOSO/KIP	200	272		
		IF (FINAL.ME.2.4ND.DERUG.EO.1) RETURN 15 Anut.ed.1) an to 18	68 63	214		
275		WAITE (4.25) NI+KIP+RLAHEA+I+IP	ទាំ	276	•	
	U	RETURN.	83 83	278		
	18	WRITE (6.26) HIM+HIF+SIGMAT+L+SIGTST+EXPKAS+R+KIP+I+ARE) Dettedn	• AREA • IP • 3LAREA 69 AR	279 280	•	•
280	19	IN FRAME SEALSE	88	281		
		0X=_TKUE_ GULA=G/SORT (?SQHLD)	59 69	28 <b>3</b>		
		RSOHLCERSO Geballcerso	60 đế 30 đế	284	•	•
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والفوج فقفوا فالمنفخ منفقات مستار ومحاليات لأوتز والجزارات لتراثو مقدمهما معامر فللمركز أراريا ومريد الأركار مار

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298 305 305 308 Ele 30.0 302 EO е З С 311 312 202 30 3 E 04/08/75 PHON-LINEAR EFFECTS CORMAT(/ICX*INTENSITY HAS REACHED RREAKDOWN, Z(J) = *, IPE10.3.* IB FCPMAT (59H THE LEWGTH OF THE BEAM PATH IS LESS THAN 10 TIMES R0. Z = 1PE10.3.7H R10 = E10.3) FORMAT (///+* NI = *+IPE12,5+8X,*KIP = *-E12,5+8X,*SLAYEA = *-[E12,5+8X,*IAV] = *-E12,5+3X,*EIPEAK = *+E12.5+/) FO2MAT (//+ICX,*TARGET ALTITUDE (HTM) =*+E10.3+* METERS (*+ [E10,3+* FEET)*+9X,*LONG-TERM TUMPULENCE (SIGMAT) =*+E10.3+ ON TRANSMISSION (KIP) =++F6.3+19X+#AVERAGE INTENSITY (I) =+.1PE11.4++ WATTS/P*-3H++Z/10X+*APEA WITHOUT BLOOMING (AREA) =+.E10.3++ WETERS++3H++2+5X+PEAK INTENSITY (IP) HAUJAHS*+/+JUA+*LINEAR EFFECTS ON THAMSMISSION (EAPKAS) . =**EIL.4.* MATTS/H*+3H**2/10X*ANEA WITH BLOGHING (BLAREA) FTN 4.0+P357 =# .f7.3. 50PF6.3.19X+*HADIUS WITHOUT BLOOMING (R) PAULANS*./+LUK+#TARGET HANGE (L) XCURRED7 * (GOLD-YEMP) / ALOG (TEMP/GOLD) =++E10+3++ METERS++3H++2+/) (ENDED) GO TO 17 (DEVIAT.LT.0.01) GO TO 21 TRACE METERS*+/+10A+ GUE SS=GCUR4+GCURP-GPREV (CNVP.GU) 60 TO 20 FORMAT (1X+1PREIS.4) 0=140 4=+.11341+4+4 0 = * (10.3)73/74 NI=NI+XCUHR 6P4FV=00044 SPREV=XCUAR #320=8+000 60 TO 13 10 4 540 u. с С L ۵ ê J SUBROUTINE 88 UUUN N 53 54 52 28 20 21 300 305 290 310 295 315 **B-26** 

i i

OPT=0 TRACE
SUBROUTINE ALFSET (NL+IL)
POWER RATIOS FOR MULTILINE PROPAGATION
COMMON /ALFDIA/ P(3).RHOFAC.PLINE(3)
LAM.RH
I (LAM.E9.2) GO TO 1
P(I)=PLINE(I)
PH=1.E-6
RHOFAC#6.944642H+1.

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MULTI-LINE POWER LOSSES         LOGICAL OK         COMMON /ALFDIA/ P(3), HHOFAC         COMMON /ALFA/ LAM.RM         COMMON /ALFA/ LAM.RM         DIMEUSION POLD(3)         IF (LAM.EU.2) GO TO 3         IF (LAM.EU.2)         P(1)=POLD(1)         P(1)=POLD(1)         P(1)=FEMD         P(1)=FEMD         P(1)=FEMD         RETURN         IF (UN) GO TO 5         IF (UN) GO TO 5	90000000000000000000000000000000000000	N 7 4 9 9 1 9 9 9 1 1 1 1 1 1 1 1 1 1 1 1 1	· · ·
DD 4 1=1.3 P(1)=PCLO(1) GO TO 7 CO 6 1=1.3 POLD((1)=P(1) ASSTGN 17 TO J1 ASSTGN 20 TO J2 ASSTGN 22 TO J2 ASSTG	) () () () () () () () () () () () () ()	NN X X X X X X X A A A A A A A A A A A A	
		4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	
P(1)=IEMP SUV=SUM+IEMP+AS ALFFAC=SUM RETURN RETURN P(1)=IEMP P(1)=IEMP SUV=SUM+TEMP	00000000000000000000000000000000000000	8 <b>6 8 8 8 8 8 8 8 8 8 8 8 8 8</b> 8 8 8 8 8 8	-

**B-28** 

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	ALFFAC=SUM RETUAN	FAC	<b>6</b> 9 9
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•	20 H GAT-1	100	3 <b>(*</b> 1
		100	34
	AS3 = ALFAS	102	35
	TEMP=P(1)*EXP(-(AS+ALFAS)*DZ)	FAC	64
	p(1)=1Exp	FAC	65
U			0 1
;			- 62
14		FAC	6.9
a -		FAC	10
	-) 0 082+H0(-6,0525-4+H0),555-	Fac	11
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		102	64
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ſ		FLC	23
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<b>5</b> 4	ALFFAC=SUX+1EKP	) 4 L	
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	P(1)=15%P		
	ALFFACETEXP	FAC	ナ   テ
	RETURN		95
U		F AC	96
25	5	FAC	16
1	2	FAC	69
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**B-**29

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	FUNCTION ALFAAB	FAA8	73/74	0PT=0	TRACE	FTN 4.0-2357	03/05/75	18,22,06	6. PAGE	-		
		FURC	FURCTION ALFAAR	AB (H)				<b>N</b> 7			·	
	U	SINGLE	LINE	35022T10	ARSORPTION COEFFICIENTS IN 1/M			h 🗣 .J	•			•
	د n	NCAMOD Commod	ON /ALFE/ LA	LAM.24	LAM•24 ./ Cum47(7)• <b>Ar</b> l• <b>Ar</b> f		ी ते त त्राच्या राज्या					
	U 01	NF C P B P B C C	.221 • H Kegair (1 359*F4876.	4F • T R • PMF • 4 76 80 25 4	6.5°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7°, 6.7		જા છે. હું જ સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્રેન્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ્ર સ્ટ સ્ટ સ્ટ સ્ટ સ્ટ સ્ટ સ્ટ સ્ટ સ્ટ સ્ટ	3001	,		! ·	
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<b>B-30</b>	55 25	15 ALFCO 18-155 2005-9 60 70		0-01 GO 1 26585-1-1 27161346-	IF '.GT.55060.01 GO TO <b>3</b> ALFCO2#7.67462658E-+-1.8 <b>9713935E-7</b> *M+1.9 <b>8650379E-11*</b> 1E-15*H**3*4.04716134E-20##**4-7.90401506E-25*M**5*1. 2**6-9.03345645E-35*H**7*2 <b>.92529072E-40*H**U</b> GO TO 4	E-11енен-1。14976017 •65•1。19826061E~29ен	વ લ લ ન લ લ	N N N N N N N N N N N N N	معد			
	ບ m (	<u> </u>		•Exp(-1.1	.0E-7=EXP(-1,74 <b>E-4=</b> M+12,18)			201 201				
i	04` R	ALFH: ALFA! RETUK	ALFH20=4。32E-9+PW+ (? ALFAAA#ALFC02+ALFH20 RET1)R1;	3+PW+ (P+1 +ALFH20	-9+Ри+ (2+193 <b>,0+Ри</b> ) 2+ALFH20		र्ड प्रत त्र प्रव द प्रव	-964				
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•	U Çş	15 (: ALFC( 60 T(	IF (H.GT.7500.01) GO TO Alfcc2=1.642E-64Exp(-2, GO TO 7	.0) 60 TC -64EXP(-2	0 6 2.272E-4*H)		ा र द स द द य द द द ब ब द द	0 - N M - 4 4 4 4 -				<u></u>
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	FUNCTION ALFAEX	FAEX 73/74 OPT=0 TRACE FTM 4.0+P357	64/68/75 13.	13-10-27.	PAGE
	•	FUNCTION ALFAEX (M)	ACX	<b>N</b> 7	
	<b>U U</b>	THIS ROUTIVE CALCULATES THE EXTINCTION COEPFICIENT IN 1/M	€ 3€ 3 3 13 13 1 ≪ 5	<b></b>	
	U 4	POWER /A.C./ (AV.DH	€ ×: 3 1.3 4 ≪	n -n	
		COMMON /ALFUTA/ DUMMY(7)+ABL+ABE+SCL+SCE	20 H	~ 4	
-	U	GO TG (1-2+3+12)+ LAM	( <del></del>		
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			14 1 1 1 1 1	12	
	-	4LFFSD#1。DE-5+EXP(4=75+RM) GJ 10 4	まん	11	
	15	LANDA IS 3.6	A MA	15 16	
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20		INSERT EQUATIONS FOR OTHER WAVELENGTHS HERE		21	
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	000	L4×D4 15 5.0	بر بر ال ال	24	
	50 m	ALF459#3.E-60EXP(4.20PM)	C 7C		
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2	υι	THE REST OF THE FUNCTION IS INDEPENDENT OF LANDA		29	
		IF (H.GT.13509.0) GO TO T		66	
m	30	IF (H.GI.9505.0) 50 TO 6 IF (H.GI.570.0) 50 TO 6	× 11	31	
to a be		11 11 61 62 62 60 62 62 62 52 52 52 52 52 52 52 52 52 52 52 52 52	LEX.	::	
	•	60 10 9			
"	у и У	4; F25=4; FA5C+2.586+ExP(-M+1.031E-3)	4 M 10 M 10 M	<u> </u>	
			માટે કે ફોડરે દે અનુ વ	37	
	04	1-17. (27.17.2.17.2.17.2.17.2.17.2.17.2.17.2.1	4 1 4 4	190	
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	•	63 10 9	417 1 1 1		
1		2; F25±2; FA5C+1.85-3+5XP( <b>-1.5355-6+(M-23000.))</b>		0-1 1-1	
		ALFAS = ALFAS/9.7725	100		
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		E.w.) .	¥3¥	52	

FUNCT ]	FUNCTION CNSO	73/7+ OPT=0 TAACE	FTN 4.8+P357	51/20/60	18.22.15.	Pade	-
		FUNCTION CHSO (H)		CNO	•••		
		ATMOSPHERIC STRUCTURE CONSTANT IN MODIZ/3)		53	<b>-</b> •		
¥				20	<b>.</b>		
•	ະ ເ			N N 7 7 1 1	• •		
		IF (M.GE.1.0) GO TO 4		Care			
	3 2 2 2	SET CASO FOR ALTITUDES LESS THAN 1 METER		2 U 2 U	, <b>o</b> i		
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<pre>DA:20:0000755710:1:1:1:221/0:00:00175475:000007554740.0000 HER DA:20:00004757143:00000542412/ DA:20:0000024312/ DA:20:0000024312.00000043412/ DA:20:0000000044112.00000043412/ DA:20:00000004412.00000043412/ HACE AN FUDEX APPADSIMATION 10 KER HACE APPALATION 10 KER HACE A CALCULATIONS FOR H LESS THAN 300000 FEET AND GADEENT. HERE APPALATION HACE ACCULATIONS FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR H LESS THAN 300000 FEET AND FOR AFTIC HERE PARATION FOR A AFTIC AND FOR AFTIC AND FOR AFTIC AND FOR AFTIC HERE PARATION FOR A AFTIC AND FOR AFTIC AND FOR</pre>	<pre>26.20.000754711:1=1.221/0.00019475.0000075475.0000075475.000001546 #FG 26.20000075711:1=1.221/0.000075475.0000075475.0000075475.000001466 #FG 26.200000757141:.0000025412.00.0001774475.00000754475.00000716444 #FG 26.20000757141:.0000025412.00.0000.000446 12.00.000015715471.0551254.00000075445.00000754454 12.00005571411.0551254.00000015 G1 12.000055714041.001 USING A STRAIGHT LIKE APPAOAIMATION 10 WEG 12.0000557154.00000016 G1 17.112.0000557154.000001 G0 10 17.112.0000557154.000001 G0 10 17.112.0000557154.0000 17.112.000055714.000 17.112.000055714.000 17.112.000055714.000 17.112.000 17.112.000 17.112.000 17.112.000 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00 17.112.00</pre>	Dista (DEF73(1):1=1.22)/0.0000(9476475.00000754475.00000154475.00000154475.00000154475.00000154475.00000154475.00000154475.00000154415.00000154415.000001574475.00000754415.0000001574475.00000754415.00000554124.000001574475.00000754415.00000554124.00000554124.00000554124.00000554124.00000557134.00000056124.000005600.00001501000001000000000000000	141.9	98+56+54+30*4	4.31.55	.31.37.31.3	5+33.36+36	3+34 8002-20	2470	c	70					
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1.00.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.	LUCIA LUCCIAL STRATCH LINE APPROXIMATION 10 %65 HAKE AN INDEX APPROXIMATION USING A STRAIGHT LINE APPROXIMATION 10 %65 FF (H-LTDECLEVIC) 60 T0 9 FF (H-LTDECLEVIC) 60 T0 9 FF (H-LTDECLEVIC) 60 T0 1 FF (H-LTDECLEVIC) 1 F=1-1 FF (H-H-HDECLEVIC) 1 F=1-1 FF (H-H-H-HDECLEVIC) 1 F=1-1 FF (H-H-HDECLEVIC) 1 F=1-1 FF (	1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010       1.0010					•		•		•					
1000.0.0.0.1.9501255-12**.05-12*0.5106       0.0.0         10000557325-12**.05-12*0.5106       0.00         10.00055732****1.00       0010         10.00055732****1.00       0010         10.00055732****1.00       0010         10.00055732****1.00       0010         10.00055732****1.00       0010         1000055732****1.00       0010         11.1.10500.00       0010         11.1.10500.00       0010         11.1.10500.00       0010         11.1.10500.00       0010         11.11100       0.010         11.11100       0.010         11.11100       0.010         11.11100       0.010         11.11100       0.010         11.11100       0.010         11.11100       0.010         11.11100       0.010         11.11100       0.0000         11.11100       0.0000         11.11100       0.010         11.11100       0.010         11.11100       0.0000         01.111100       0.010         01.111100       0.010         01.111100       0.010         01.111100       0.000	100001.057125E-12.4.02-12.0.5156E-12.0.0./       MEG         MATE       AN INDEX APPROXIMATION USING A STRAIGHT LINE APPROXIMATION 10 MEG         MATE       AN INDEX APPROXIMATION USING A STRAIGHT LINE APPROXIMATION 10 MEG         MATE       MEGUAL         MATE       AN INDEX APPROXIMATION USING A STRAIGHT LINE APPROXIMATION 10 MEG         MATE       MEGUAL         MATE       MEGUAL         MATE       MATE         MATE	100001.053125E-12.4.02-12.0.5156E-12.0.0.0./       MEG         MARC       AN INDEX APPROXIMATION USING A STRAIGHT LINE APPROXIMATION 10 MEG         MARC       MINDEX APPROXIMATION USING A STRAIGHT LINE APPROXIMATION 10 MEG         MEG       MEG00001 60 TO 5         F (H-11-1050001 60 TO 5       MEG         MEG       MEG00001 60 TO 5         F (H-11-1050001 60 TO 5       MEG         MEG       MEG00001 60 TO 5         F (H-11-1050001 60 TO 1       MEG         F (H-11-1050001 60 TO 1       MEG         F (H-11-10000 50F PRESSURE. TEMPERATURE. AND GRADIENT.       MEG         MEGELIARI(1)       MEGELIARI(1)         MEGELIARI(1)       MEG         MEGELIARI(1)       MEG <td>DATA</td> <td>4 (CUEFF3(1)+</td> <td>(22+11)</td> <td></td> <td></td> <td>0 - • 0 - • 0 - • 0 - • 4 - ME</td> <td>11.0</td> <td></td> <td>76</td> <td></td> <td></td> <td></td> <td></td> <td></td>	DATA	4 (CUEFF3(1)+	(22+11)			0 - • 0 - • 0 - • 0 - • 4 - ME	11.0		76					
MAKE AN INDEX APPADXIMITION USING A STRAIGHT LINE APPNOXIMATION 10 MEG	MAKE AN INDER APPOXIMATION USING A STRAIGHT LINE APPNOXIMATION 10 MEG GRAPH OF H VERSUS 1. F (H.G.H.2505000.1 GO TO 9 F (H.G.H.250500.1 GO TO 9 F (H.G.H.250500.1 GO TO 9 F (H.G.H.250500.1 GO TO 9 F (H.G.H.250500.1 GO TO 15 F (H.G.H.250500.1 GO TO 16 F (H.G.H.250500.1 GO TO 17 F (H.G.H.250000.1 GO TO 17 F (H.G.H.25000.1 GO TO 17 F (H.G.H.25000.1 GO TO 17 F (H.G.H.11/10) F (H.G.H.11/10	MAKE AN INDER APPADATIVATION USING A STRAIGHT LINE APPROXIMATION 10 MEG GRAPH OF H VERSUS 1. F (H-GTL-200500-1 60 TO 9 F (H-GTL-10) J (H-G	l0.		953125E-	-12.4.02-12	.3.5156E-1	• 0 • •	AF.	e	£ L		:			
МАКЕ АN: INDEX APPADXIMATION USING A STRAIGHT LINE APPROXIMATION 10 MEG         IF (H-LL-1-05030.1 G0 T0 9         IF (H-LL-1-05030.1 G0 T0 9         IF (H-LL-1-05030.1 G0 T0 9         IF (H-LL-1-05030.1 G0 T0 1         IF (H-LL-1-050351-4-4-1.08)         IF (H-LL-1-050351-4-4-1.08)         IF (H-LL-1-050351-4-4-1.08)         IF (H-LL-1-05041 (H-1-4)1)         IF (H-LL-1-1041 (H-1-4)1)         IF (H-LL-1-1041 (H-1-4)1)         IF (H-LL-1-1041 (H-1-4)1)         IF (H-LL-1-1041 (H-1-4)1)         IF (H-LL-1041 (H-1-4)1)         IF (H-11)         IF (H)         IF (H)         IF (H)         IF (H)         IF (H-11)         IF (H)         IF (H)<	HAKE AN INDER APPADRIMATION USING A STRAIGHT LINE APPROXIMATION 10 WEG F (H.H.L LUEGOD., 60 T0 5 T (H.H.L LUEGOD., 60 T0 1 F (H.H.L LUEGOD., 60 T0 2 H = FL HA(1) H = FL HA(1) F = FL H	HAKE AN INDER APPADATIMATION USING A STRAIGHT LINE APPROXIMATION 10 WEG F (H.H.L DEG03-) 60 T0 5 F (H.H.L DEG03-) 7 F							14L		78	•				
GRAPH OF H VECSUS       F (H-L-10500)       65 10 9         F (H-L-105000)       66 10 9         F (H-L-1050000)       66 10 9         F (H-L-10500000)       66 10 9         F (H-L-1050000000000000000000000000000000000	GRAPH OF H VERSUS       GF H VERSUS         F (H.1.T1050000): GC T0 9       F (H.1.T1050000): GC T0 9         F (H.1.T1050000): GC T0 9       F (H.1.T1050000): GC T0 9         F (H.1.T1050000): GC T0 9       F (H.1.T1050000): GC T0 9         F (H.1.T1050000): GC T0 9       F (H.1.T1050000): GC T0 9         F (H.1.T1050000): GC T0 9       F (H.1.T1050000): GC T0 9         F (H.1.T1050000): GC T0 1       F (H.1.T1050000): F (H.1.10)         E51ALTBH (1)       F (H.1.T101000)         F (H.1.T10100)       F (H.1.T101000)         F (H.1.T10100)       F (H.1.1000)         H = 76L114(1)       F (H.1.1000)         H = 76L114(1)       F (H.1.1000)         F (H.1.1000)       F (H.1.1000)         F (H.1.1000)       F (H.1.1000)         F (H.1.1000)       F (H.1.1000)         F (H.1.4000)       F (H.1.4000)         F (H.1.4	GRAPH OF H VERSUS       GF H VERSUS         F (H-LT-20000) 1 G5 T0 9       F (H-LT-20000) 1 G5 T0 9         F (H-LT-20000) 1 G5 T0 9       F (H-LT-20000) 1 G5 T0 9         F (H-LT-20000) 1 G5 T0 9       F (H-LT-20000) 1 G5 T0 9         F (H-LT-20000) 1 G5 T0 9       F (H-LT-20000) 1 G5 T0 9         F (H-LT-20000) 1 G5 T0 9       F (H-LT-10000) 1 G5 T0 9         F (H-LT-20000) 1 G5 T0 9       F (H-LT-10000) 1 G5 T0 9         F (H-LT-1000) 1 G5 T0 9       F (H-LT-10000) 1 G5 T0 9         F (H-LT-1000) 1 G5 T0 9       F (H-LT-10000) 1 G5 T0 9         F (H-LT-1000) 1 H F10000 1 H F10000 1 H F10000 1 H F100000 1 H F10000000000		T AN THOFY 60	LANTXOUD	LTON HETME	A CTUATCHT	19.42	22	ť	04			•		
F       (**.(T10500.0) 5: 10 9)         F       (**.(T10500.0) 5: 10 1)         F       (**.(T10500.0) 5: 10 1)         F       (**.(T10500.0) 5: 10 1)         F       (**.00000.0) 5: 10 1)         F       (**.0000.0) 5: 10 1)         F       (**.00000.0)	If       (1+1(1-1+0500-3)       (5)       (1+1)         IF       (1+2(1-1+0500-3)       (5)       (1+1)         IF       (1+2(1-1+01))       I=1)       (1+1)         IF       (1+2(1-1))       (1+1)       (1+1)         IF       (1+1)       (1+1)       (1+1)         IF       (1+1)       (1+1)       (1+1)         IF       (1+1)       (1+1)       (1+1)         IF       (1+1)       (1+1)       (1+1)         IF	рикани и и и и и и и и и и и и и и и и и и						1	2	5 1	•					
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Fr (H.GT.300000) 100 5       MEG         Fr (H.GT.300000) 100 5       MEG         Fr (H.GT.300000) 100 5       MEG         Fr (HSR) - GE.SELTHH(1) 100 10       MEG         Fr (HSR) - GE.SELTH(1) 100 50       MEG         Fr (HSR) - GE.SELTH(1) 100 50       MEG         Fr (HSR) - GE.SELTH(1) 100 50       MEG         Fr (HSR) - GE.SELTH(1)       MEG         Fr (HSR) - GECULATIONS FOR H LESS THAN 300000 FEET       MEG         Fr (HSR) - GECONTILL HEIGHT       MEG         Fr (HSR) - GECULAR SCALE FEMPERATURE EDUALS KINETIC         Fr (HSR) - GECULAR SCALE FEMPERATURE         Fr (HSR) - GECULAR SCALE FEMPERATURE         <	F (445(1):905000) 60 TO 5       #EG         F (445(1):62.05LT#4(1-11)) 60 TO 1       F         F (445(1):62.05LT#4(1-11)) 60 TO 1       F         F (445(1):62.05LT#4(1-11)) 60 TO 1       F         F (445(1):62.05LT#4(1)-11) 15-1       F         F (445(1):62.05LT#4(1-11)) 60 TO 1       F         F (445(1):62.05LT#4(1)-11) 15-1       F         F (445(1):61.06)       F         F (445(1):61.06)       F         F (410)       F         F (410)       F         F (411)       F         F = 55LTAI(1)       F         F = 55CUTE       F         F = 55CUTE       F         F = 55CUTE <td>FF (4:61:3905000) 60 TO 5       #EG         FF (4:85(F): 6E:0E:[T=H(1])) 60 TO 1       FF (4:85(F): 6E:0E:[T=H(1])) 60 TO 1         FF (4:85(F): 6E:0E:[T=H(1])) 60 TO 1       FF (4:85(F): 6E:0E:1E=1)         FF (4:85(F): 6E:0E:1E=1)) 1E=1       #EG         FF (4:8) (F): 6E:0E:1E=1)       #EG         FF (4:1) (F)       #EG         FF (1:1) (F)       #EG         FF (1:2) (F)       #EG<!--</td--><td>] I</td><td>(H.LT16500.</td><td>0 60 10</td><td>¢</td><td></td><td></td><td>2</td><td>ق</td><td>19</td><td></td><td>-</td><td></td><td></td><td></td></td>	FF (4:61:3905000) 60 TO 5       #EG         FF (4:85(F): 6E:0E:[T=H(1])) 60 TO 1       FF (4:85(F): 6E:0E:[T=H(1])) 60 TO 1         FF (4:85(F): 6E:0E:[T=H(1])) 60 TO 1       FF (4:85(F): 6E:0E:1E=1)         FF (4:85(F): 6E:0E:1E=1)) 1E=1       #EG         FF (4:8) (F): 6E:0E:1E=1)       #EG         FF (4:1) (F)       #EG         FF (1:1) (F)       #EG         FF (1:2) (F)       #EG </td <td>] I</td> <td>(H.LT16500.</td> <td>0 60 10</td> <td>¢</td> <td></td> <td></td> <td>2</td> <td>ق</td> <td>19</td> <td></td> <td>-</td> <td></td> <td></td> <td></td>	] I	(H.LT16500.	0 60 10	¢			2	ق	19		-			
I000025734+++1.06       I000025734+++1.06         IF (345610.05.05ELTAH(1)) J=1-1       5.000025734+++1.06         E5 FALTSH HASE VALUES OF PRESSUPE. TEMPERATURE. AND GRADIENT.       WEG         H1=05L1AT(1)       MEG         H2=05L1AT(1)       MEG         H2=05L1AL(1)       MEG         H2=05L1AL(1)       MEG         H2=05L1AL(1)       MEG         H2=H/(1,+H7R0)       MEG <td><pre>I000257JATATIAN I000257JATATIAN IF (495(TH).05.05LTAT(I-1)) I=I-1 ESTAL(5H HASE VALUES OF PRESSUPE. TEMPERATURE. AND GRADIENT. 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GEOPOTENTIAL HEIGHT         HP=H/(1H/RO)         FEWSCRATURE         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP 10 300000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         PRESSURE (P). IX. LB/FT=2.	GEOPOTENTIAL HEIGHT       MFG         HP=H/(1,+H/RO)       MFG         TEW=FA/(1,+H/RO)       TEW=FA/(1,+H/RO)         TEW=FA/(1,-H/RO)       TEW=FA/(1,-H/RO)         U2 T0 305000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC       WFG         U2 T0 305000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC       WFG         U2 T0 305000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC       WFG         U2 T0 305000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC       WFG         U2 T0 305000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC       WFG         U2 T0 305000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC       WFG         TFWJEPJENE.       TH=U=(HP-HPA)       WFG         TF (12 22       P=EK2P(EPE-(GO*MMO/(L=R)))=ALGG(TM/TB))       WFG         C0 T0 .       P=EK2P(EPE-(GO*MMO/(L=R)))=ALGG(TM/TB))       WFG         P=EK2P(EPE-(GO*MWO/R)=((HP-HPB)/TB))       WFG       WFG         P=EK2P(EPE-(GO*MWO/R)=((HP-HPB)/TB))       WFG       WFG         P=EK2P(EPE-(GO*MWO/R)=((HP-HPB)/TB))       WFG       WFG         P=EK2P(EPE-(GO*MWO/R)=((HP-HPB)/TB))       WFG       WFG         P=EK2P(EPE-(GO*MWO/R)=(GO*MUO/R)       WFG       WFG         P=ENSIT       D=(WFG)       WFG       WFG         P=ENSIT       MFG       W	GEOPOTENTIAL HEIGHT HP=H/(1,+H/RO) TEWSPATURE UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EDUALS KINETIC TEW-EPATUPE. THEW-EPATUPE. THEW-EPATUPE. TEV-EPATUPE. TEV-EPATUPE. TEV-EPATUPE. TEV-EPATUPE. TE (L) Z2 P=EX2(EQ-(G) * HP-HPH)/TA)) CO TO ' P=EX2(EQ-(G) * HP-HPH)/TA)) CO TO ' P=EX2(EQ-(G) * HP-HPH)/TA)) P=EX2(EQ-(G) * HP-HPH)/TA)) P=EX2(EQ-(G							2	ڻ ڻ	<del>2</del> 4					
HP=H/(1.+H/R0)         TEMPEH/(1.+H/R0)         TEMPEH/(1.+H/R0)         TEMPERATURE         UP T0 305000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         VEG         TEMPERATURE         TH-TH+L*(HP-HPA)         TEMPERATURE         PRESSURE (P). TH LB/FT002.         TF (L) 22         PRESSURE (P). TH LB/FT002.         TF (L) 22         PRESSURE (P). TH LB/FT002.         TF (L) 22         PRESSURE (P). TH L06(TM/TB))         REG         PRESSURE         PRESS	HP=H/(1,+H/R0) TEMPERATURE TEMPERATURE TEMPERATURE TEMPERATURE EQUALS KINETIC TH=TH+L*(HP-HPA) TH=TH+L*(HP-HPA) PRESSURE (P). IN LB/FT++2. TH=TH+L*(HP-HPA) PRESSURE (P). IN LB/FT++2. PRESSURE (P). PRESSURE (P).	HF=H/(1,+H/RO) TEWPERATURE UP TO 305000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC VEG TEMPERATURE TH-TH+L*(HP-HPA) PRESSURE (P). IK LB/FT+2. TH=TH+L*(HP-HPA) PRESSURE (P). IK LB/FT+2. TH=TH+L*(HP-HPA) PRESSURE (P). IK LB/FT+2. TH=TH+L*(HP-HPA) PRESSURE (P). IK LB/FT+2. PRESSURE (P). IK LB/FT+2. P		POTENTIAL HEL	GHT				ίι. 3	9	96					
TEWDERATURE         UP TO 305000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         UP TO 305000 FEET. HOLECULAR SCALE TEMPERATURE EDUALS KINETIC         TEWDEPATUDE.         TH4TH+L*(HP+HPA)         PRESSURE (P). IK LB/FT**2.         TF (L) Z***2         PRESSURE (P). IK LB/FT**2.         PRESSURE (P). IK P.HPH)/TB).         PRESSURE (P).         PRESSURE (P). <td>TEWPERATURE UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EQUALS KINETIC TEWPERATURE UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EQUALS KINETIC THETPLP(HP-HPA) PRESSURE (P). IN LB/FT==2. PRESSURE (P). IN LB/FT==2. P</td> <td>TEMPERATURE TEMPERATURE UP TO 305060 FEET. HOLECULAR SCALE TEMPERATURE EQUALS KINETIC TEMPERATURE TEMPERATURE THATBHLE (HP-HPA) PRESSURE (P). IN LB/FT++2. TF (L) 22 PRESSURE (P). IN LB/FT++2. TF (L) 22 PRESSURE (P). IN LB/FT++2. PRESSURE (P). IN LB/FT++2. PRESSURE</td> <td></td> <td>100/H+ 11/1</td> <td></td> <td></td> <td></td> <td></td> <td>. 14</td> <td></td> <td>6.3</td> <td></td> <td></td> <td></td> <td></td> <td></td>	TEWPERATURE UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EQUALS KINETIC TEWPERATURE UP TO 300000 FEET. MCLECULAR SCALE TEMPERATURE EQUALS KINETIC THETPLP(HP-HPA) PRESSURE (P). IN LB/FT==2. PRESSURE (P). IN LB/FT==2. P	TEMPERATURE TEMPERATURE UP TO 305060 FEET. HOLECULAR SCALE TEMPERATURE EQUALS KINETIC TEMPERATURE TEMPERATURE THATBHLE (HP-HPA) PRESSURE (P). IN LB/FT++2. TF (L) 22 PRESSURE (P). IN LB/FT++2. TF (L) 22 PRESSURE (P). IN LB/FT++2. PRESSURE		100/H+ 11/1					. 14		6.3					
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UP       T0       305000       FET: HOLECULAR SCALE TEMPERATURE EDUALS KINETIC       JEG         TEMPEPATURE:       HUPTEPE-(HP-HPA)       MEG       MEG         TH=TP+L*(HP-HPA)       MEG       MEG       MEG         PRESSURE (P):       TK       LB/FT=2.       MEG         PRESSURE (P):       TK       MEG       MEG         PRESSURE (F):       TRIL       MEG       MEG         PRESSURE (F): <td< td=""><td>U2       T0       305000       FET: HOLECULAR SCALE TEMPERATURE EDUALS KINETIC       VEG         TEMPEPATURE:       TH-LP(HP-HPA)       WEG       WEG         TH-TH+LP(HP-HPA)       PRESSURE (P): IN LB/FT++2.       WEG         PRESSURE (P): IN LB/FT++2.       WEG       WEG         PRESSURE (P): PALOG(TM/TB))       ALOG(TM/TB))       WEG         PRESSURE (P): PALOG(TM/TB))       MEG       WEG         PRESSURE:       PRESSURE:       WEG         PRESSURE:       PRESSURE:&lt;</td><td>UP       T0       305000       FET: HOLECULAR SCALE TEMPERATURE EDUALS KINETIC       VEG         TEMPEPATURE:       THIEL (HP-HPA)       WEG       WEG         THIETL' (HP-HPA)       WEG       WEG       WEG         PRESSURE (P):       THIETC       VEG       WEG         PRESSURE (P):       THIETC       WEG       WEG         PRESSURE (P):</td><td></td><td>DEATURE</td><td></td><td></td><td></td><td></td><td>2</td><td>ď</td><td>5 C</td><td></td><td>•</td><td></td><td></td><td></td></td<>	U2       T0       305000       FET: HOLECULAR SCALE TEMPERATURE EDUALS KINETIC       VEG         TEMPEPATURE:       TH-LP(HP-HPA)       WEG       WEG         TH-TH+LP(HP-HPA)       PRESSURE (P): IN LB/FT++2.       WEG         PRESSURE (P): IN LB/FT++2.       WEG       WEG         PRESSURE (P): PALOG(TM/TB))       ALOG(TM/TB))       WEG         PRESSURE (P): PALOG(TM/TB))       MEG       WEG         PRESSURE:       PRESSURE:       WEG         PRESSURE:       PRESSURE:<	UP       T0       305000       FET: HOLECULAR SCALE TEMPERATURE EDUALS KINETIC       VEG         TEMPEPATURE:       THIEL (HP-HPA)       WEG       WEG         THIETL' (HP-HPA)       WEG       WEG       WEG         PRESSURE (P):       THIETC       VEG       WEG         PRESSURE (P):       THIETC       WEG       WEG         PRESSURE (P):		DEATURE					2	ď	5 C		•			
ТЕМ-ЕРАТИРЕ. ТЧ=ТЮ-L°(КР-НРА) РаЕ55URE (P) - IX LB/FT••2. IF (L) 22 PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) GO TO . PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) GO TO . PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG PEEXP(PQ=(5C°MWO/(L*R))•4L0G(TM/TB)) REG REG REG REG REG REG REG REG	ТЕМ-ЕРАТИРЕ. 14=78-L*(#2-4PA) PRESSURE (P) - IK LB/FT*2. F (L) 22 PRESSURE (P) - IK LB/FT*2. F (L) 22 PRESSURE (P) - IK LB/FT*2. PRESSURE (P) - IK LB/FT*3. PRESSURE (P) - IK LB/FT*3.	ТЕМ-ЕРАТИРЕ. ТЧ=ТЮ-L+(КР-НРА) РаЕ55U2E (P) - IX LB/FT+2. IF (L) 2++2 PEEXP(P9-(5C*M40/(L+R))+ALGG(TM/TB)) GO TO * PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) CO TO * PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/TR)) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((НР-НРВ)/R) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)+((HP-HPB)/R)) PEENEXP(P9-(5C*M40/R)) PEENEXP(P9-(F9-(F9-F9-R))) PEENEXP(P9-(F9-F9-R)) PEENEXP(P9-(F9		ro 3000000 FEE	T . MCLEC			EOUAL	1	c	100					
ТЧ=Т₩-Г+Г+Г+РА) РАЕ55U2E (P) • IX LB/FT+•2. IF (L) 2+-/2 P=EXP(PQ+(5C*M40/(L*R))•ALGG(TM/TB)) GO TG * P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/TR)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/R)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/R)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/R)) P=EXP(PQ+(5C*M40/R)•((HP-HPH)/R)) P=EXP(PQ+(5C*M40/R)*((HP-HPH)/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5C*M40/R)) P=EXP(PQ+(5	ТЧ=ТН+L*(н2-нРа)         Paessure (P). IX LB/FT+2.         F (L) 22         F (L) 22         P=EXP(P3+(52*M40/(L*R))*ALGG(TM/TB))         Go TO .         P=EXP(P3+(52*M40/(L*R))*ALGG(TM/TB))         Go TO .         P=EXP(P3+(52*M40/(L*R))*ALGG(TM/TB))         REG         P=EXP(P3+(50*M40/(L*R))*ALGG(TM/TB))         P=EXP(P3+(50*M40/(L*R))*ALAGG(TM/TB))         P=EXP(P3+(50*LACGELERATION	ТЧ=ТН+L*(н2-нРа)         Paessure (P). IN LB/FT+2.         Ff (L) 22         Ff (L) 22         P=EXP(Pq+(5C*M40/(L*R))•ALGG(TM/TB))         G0 T0 *         P=EXP(Pq+(50*M40/R)*((HP-HPB)/TR))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R)*((HP-HPB)/R))         P=EXP(Pq+(50*M40/R))         P=EXP(Pq+(50*M40/R))         P=EXP(		CEDETIDE.					1		101					
PRESSURE (P) - IX LB/FT0-2.         F (L) 22         PEEXP(PG-(GC0MWO/(L*R))+AL0G(TM/TB))         WEG         PEXP(PG-(GC0MWO/R)*((HP-HPB)/TR))         WEG         PREXP(PG-(GC0MWO/R)*((HP-HPB)/TR))         WEG         PREXP(PG-(G00MWO/R)*((HP-HPB)/TR))         PREXP(PG-(G00MWO/R)*((HP-HPB)/R))         PREXP(PG-(G00MWO/R)*((HP-HPB)/R))         PREXP(PG-(G00MWO/R)*((HP-HPB)/R))         PREXP(PG-(G00MWO/R)*((HP-HPB)/R))         PREXP(PG-(G0MWO/R)*((HP-HPB)/R))         PREXP(PG-(G0MWO/R))         PREXP(PG-(G0MWO/R))         PREXP(PG-(G0MWO/R)) <td>Paessure (P) - IX LB/FT0-2.         F (L) 2-0.2         F (L) 2-0.2         Paessure (GC0MMO/(L00))04L06(TM/TB))         G0 T0 3         G0 T0 3         Paest (GC0MMO/(L00))04L06(TM/TB))         Paest (GC0MMO/(L00))04L00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MO/(L00)         Paest (GC0MO/(L00)      <t< td=""><td>PRESSURE (P). IX LB/FT0.2.         PRESSURE (P). IX LB/FT0.2.         Ff (L) 22         PRESSURE (P). IX LB/FT0.2.         PRESSURE (P). I</td><td></td><td></td><td></td><td></td><td></td><td></td><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<></td>	Paessure (P) - IX LB/FT0-2.         F (L) 2-0.2         F (L) 2-0.2         Paessure (GC0MMO/(L00))04L06(TM/TB))         G0 T0 3         G0 T0 3         Paest (GC0MMO/(L00))04L06(TM/TB))         Paest (GC0MMO/(L00))04L00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00))04C00         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MMO/(L00)         Paest (GC0MO/(L00)         Paest (GC0MO/(L00) <t< td=""><td>PRESSURE (P). IX LB/FT0.2.         PRESSURE (P). IX LB/FT0.2.         Ff (L) 22         PRESSURE (P). IX LB/FT0.2.         PRESSURE (P). I</td><td></td><td></td><td></td><td></td><td></td><td></td><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	PRESSURE (P). IX LB/FT0.2.         PRESSURE (P). IX LB/FT0.2.         Ff (L) 22         PRESSURE (P). IX LB/FT0.2.         PRESSURE (P). I							31							
PRESSURE (P). IN LB/FT002. IF (L) 22 PEEXP(PR=(G20M40/(L01))04L0G(TM/TB)) G0 T0 . Prexp(PR=(G20M40/R)0((HP-HPB)/TR)) Prexp0x4 Prexp0x4 Prexp0x4 Prexp0x4 Prexp0x4 Prexp0x4 Prexp0x4 Prexp0x4 Prexp0x4 Prexp114T1042L ACCELERATION Prexp0x4 Prexp124T1042L ACCELERATION Prexp124T1042L ACCELERATION	PRESSURE (P). IN LB/FT002.         IF (L) 2002         PRESSURE (P). IN LB/FT002.         PRESSURE (C) 2003	PRESSURE (P). IN LB/FT002.         IF (L) 22         PreExP(PP-(5C0MMO/(L+P)))04L0G(TM/TB))         GO TO '         GO TO '         PreExp(PP-(G00MWO/(L+P)))04L0G(TM/TB))         GO TO '         PreExp(PP-(G00MWO/(L+P)))04L0G(TM/TB))         FEG         PreExp(PP-(G00MWO/R)0100000000000000000000000000000000000							4J 5	•	205					
PRESSURE (P) • IX LB/FT • 2.         IF (L) 22         PEEXP(P2-(6C*MWO/(L*R))•AL0G(TM/TB))         G0 T0 .         PEEXP(P3-(GC*MWO/(L*R))•AL0G(TM/TB))         PEEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-HPH)/TB))         PEENEXP(P3-(GC*MWO/R)•((HP-H	PRESSURE (P) • IX LB/FT•2.         IF (L) 22         FE(L) 22         PEEXP(PR=(GC*M40/(L*R))•4L0G(TM/TB))         G0 T0 4         PEEXP(PR=(GC*M40/(L*R))•4L0G(TM/TB))         PEEXP(PR=(GC*M40/R)•((HP-HPH)/TR))         PEEXP(PR=(GC*M40/R)•(	PRESSURE (P) • IX LB/FT • 2.         IF (L) 22         PEEXP(PR=(6C*MWO/(L*R))•AL0G(TM/TB))         GO TO .         GO TO .         PEEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PECXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(GC*MWO/(L*R))•AL0G(TM/TB))         PEXP(PR=(FEXP(PR=(FEXP))•AL0G(TM/TB))         PEXP(PR=(FEXP(PR=(FEXP))•AL0G(TM/TB))         PENEXP(FEXP(FEXP))         PENEXP(FEXP(FEXP))         PENEXP(FEXP(FEXP))         PENEXP(FEXP(FEXP))         PENEXP(FEXP(FEXP))         PENEXP(FEXP(FEXP))         PENEXP(FEXP(FEXP))         PENEXP(FEXP)         PENEXP(FEXP)         PENEXP(FEXP)         PENEXP(FEXP)         PENEXP(FEXP)         PENEXP(FEXP)         PENEXP(FEXP)							7 1		P O T					
IF (L) 2++2 P=EXP(P9+(5C*M40/(L*R))*ALGG(TM/TB)) GO TC 4 P=EXP(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/TR)) P=Exp(P9+(50*M40/R)*((HP-HPH)/R)) P=Exp(P9+(50*M40/R)*((HP-HPH)/R)) P=Exp(P9+(50*M40/R)*((HP-HPH)/R)) P=Exp(P9+(50*M40/R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(50*R)*((HP-HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R)) P=Exp(P9+(FP+HPH)/R))	IF (L) 2-0-2 P=EXP(PQ=(6C*M40/(L*R))•AL0G(TM/TB)) GO TG * P=EXP(PQ=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PQ=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) P=EXP(PG=(50*M40/R)•((HP-HPH)/TR)) 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P=EXP(PQ=(5C*MWO/(L*R))•AL0G(TM/TB)) G0 IG 4 P=EXP(P9=(30*MWO/R)*((HP-HPB)/TR)) P=EXP(P9=(30*MWO/R)*((HP-HPB)/TR)) REG P=EXP(P9=(30*MWO/R)*((HP-HPB)/TR)) REG REG REG REG REG REG REG REG REG REG	P=EXP(PQ=(6C*MWO/(L*R))*AL0G(TM/TB)) GO TO 4 PEEXP(PQ=(GO*MWO/(L*R))*AL0G(TM/TB)) PEEXP(PQ=(GO*MWO/R)*((HP-HPB)/TR)) PEEXP(PQ=(GO*MWO/R)*((HP-HPB)/TR)) PEEG PENSITY DENSITY DENSITY DENSITY DENSITY DENSITY CANITATIONAL ACCELERATION MEG	P=EXP(PQ+(5C*MWO/(L*R))*AL0G(TM/TB)) GO TO 4 P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) MEG P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) MEG P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) MEG P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) MEG P=EXP(PQ+(40*MWO/R)*((HP-HPB)/TR)) MEG P=(HWU*P*GO)/(R*TM) MEG MEG P=(HWU*P*GO)/(R*TM) MEG MEG MEG P=(HWU*P*GO)/(R*TM)	IF	(1.) 22					14	e	105					
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2	CALCULATIONS FOR M GREATER THAN 300000 FEET.	CONSTANT, MÖLECULAP SCALE Inftic Temperature, scale In the region apove 300000 UES of H Greater than 30000	60 10 7 88 60 10 6	I)) I=I-I ues of temperature. Pressure. And Gradient.	I) ) McLecular Weights From Empirical. Graphically derived. I)-coeff2(I)+H+Coeff3(I)+H+H	AR SCALE TEMPERATURE AND CONVERT TO KINETIC *M4)/M40 L8/FT0+2.	/ (Х# (R0+HB))+(]./(Х#Х))#ALOG(({H-HB+TB/L)#(R0+HB L#R)	LERATION	APPROXIMATION FOR VALUES OF H GREATER THAN 492126 THAN 584252 FEET. 2.) GC TO R 50006. 04348*Z*Z H(1-1) 15-1
G¤50° (RO/ (PO+H) ) ●*2 RETURN	PERFORM	C SINCE WOLECULAR WEIGHT IS NO LONGER C TEMPERATURE IS NO LONGER EQUAL TO K C THREE INDEX EQUALIONS ARE REDURFD C MAKE AN INDEX APPROXIMATION FOR VAL		IF (H-GE-DELTAH(I-1)) ] C ESTAHLISH HASE VALUES ( HA=DELTAH(I) TH=PELTAT(I)	PE=DELTAP(I) L=DELTAL(I) C CALCULATE MOLECULAR WEIGHTS FRO C EQUATIONS. Wa=CUEFFJ(1)-COEFFZ(I)+H+COEFF3 HP=H/(1,+H/RO)	- IN	X=F0+H2-F2-F2-F2 Y=1,/(x0+H))-1,/(X=(R0+HR)) B=(G0+K¥0+R0+R0+R)) F=(G0+K¥0+R0+R0+R)/(L=R) P=EXP(PH-B+Y) P#R=P=X89	C DENSITY D=(M*0P0GU)/(R*TM) C GRAVITATIONAL ACCELERATION G=60*(AU/(KO+H))**2 Return	C MAKE AN INDEX APPROXIMATION C FEET OUT LESS THAN 984252 F C IF (H.GT.984252.) GC TO A Z=(H-740000.)/50000. I=17.456.06LIAH(I)) GO TO 6 I=(H.66.05LIAH(I-1)) GO TO 6 I=17.66.05LIAH(I-1)) I=I-1

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FTN 4.0+P357	METERS/SECOND		-				
	CLOCITY IN MET					•	
TRACE	•PH[+ZJ] LUS SLEW VEL REV VP•VPSC•VXB	م بە د	100	VX=VX+0.2 SC			
0P1=0	(5L+H+H0M felocity P 4/ XTRA+2P 4/ IM chi+0mega+	VXB (VXA_KE.0.) RETURN 04EG4@(2J+2PHEV) 13.6 (H.65.5.24) 60 T0 (H.65.22.24664) 60 T0	25+6 5+6 5+6 5+6 5+6	.61.10.) .vx) vx≖vp		1	
73/74	FUNCTION VK (GL+H+HQH+PHI+ZJ) CROSS WIND VELOCITY PLUS SLEW VI COMMON /HESH/ KTRA.ZPREV COMMON /CGVW/ IW COMMON /K/ CHI.OMEGA+VP+VPSC+VKI	VX=VXB VX=VXB VS=09E64#12. VX=13.6 IF (H.65.252 TF (H.65.252)	IF (H.6E-1.22E4) 60 TO I VX=3.421-384+8.75 60 TO 3 VX=A2.4-2.53E-3*H 60 TO 3 VX=27.2-2.72E-4*H IF (1.4-2) 4+5+6 VX=VX*0.27	60 TU 6 VX=VX=0.5 IF (F0~-6L) IF (VPSC-6E) VX=VX=VS SETURN END			
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FUNCTION VX							
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CASE 1 BELOW-BELOW+PD

SHORT OUTPUT FORMAT+ WITHOUT CEBUG

TARGET RANGE (L)	1.000E+03 KETERS 1.000E+03 KETERS	DEVICE PONER (70)
GROUND LEVEL (GL)	0. NETERS 1.000002 XETERS 1.286.402 FEET	KAVELENGTH (LAM.A)
TARGET ALTITUDE (HTH)		TRACKING RATE CONFIG TO THE COORDINANS SEC
VERTICAL ANGLE (PHI)	R	OBSCURATION HADIUS
<b>Z</b> IMUTM ANGLE (CHI)	.520 RADIANS 0.meters/sec 0rmal 50	EEAM TYPE (PROP) GAUSSIAN TYPE OF PHOPAGATION (BEAM) FOCUSED BEAM QUALITY (M) 1.50 NUMAER OF BEAMPATH INCREMENTS 30

3:34	WΑΤ	50-3	•3600	1.500	2.000 SECONCS	.1000E+71 METERS		0	0	FOCUSED	.1000		S0.00 METERS		-	.9550	.1250 VIS. LAMBDAS		.1500 METERS	6.375	.7000 METERS	ON-AXIS		-	METER			.5000E-US RADIANS	-5000E-05 RADIANS	Stalday 20006-05	SCOOE-US RADIANS
LASER REAM DIAMETER	LASEP POWER	HAVELENGTH	CASCURATION	REA% UUALITY	PULSE LENGTH	PHASE FRONT CURVATURE	JITTER	117	SCALF SIZE OF FLUCTUATIONS	TYPE UP AEROWINDW	AEPOKINDOK DELTA KHCZEHO	RHO/MHO FEF	DISTANCE TO CLIPPER	CLIPPER DIAMETER	RUMARN OF MIRRORS	REFLECTIVITY	FERRICATION EPHON	TYPE OF MIJROPS	DISTANCE HETHERN MIRRORS	TELESCOPE WAGNIFICATION	TELESCOPE DIAMETER	TELESCOPE TYPE	TYPE OF EXIT APERTURE	EXIT APEPTUNE LENGTH	AASSAMTICA COEFFICIENT	TEMPERATURE FLUCTUATION	STHJT ANEAN REAM ADEA	A.S.	BORE-SIG4T JITTER	SERID JITTER	AUTOALIGHTEVI JIILER

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いい .1000 .1010 0000-0 SIGNA .3333 6263. TALASMITTED REAM DIAMETER ...7000 WEIERS Talusmitted Poker ...8233E+05 Matts Peam quality refore accounting for divergence TRANSMISSION 1.0000 1.020 M1 = .4437 M2 = 1.1130 EFFECT OF REAM DIVERGENCE ON WAIST 1.00 FINAL BEAM SPREAD PARAMETEM. M2 1.013 TOTAL REAM JITTER .4884E-05 RADIAMS PMASE FRONT CUMVATURE .4375E+71 METERS 1.0000 1.6000 9526 622H. .9650 5576. CODLED CN-AXIS WINDOW AERODYNAMIC WINDOW BEAN CLIPPER PEAN EXPANDER SOURCE INPUT REAM SHUNDIN 101415

M2 = 1.215.560 H ï RESULTANT BEAM QUALITY CALCULATIONS FOR GRIGIN BELOW ICO KM AND TARGET RELOW 100 KM.

) = 1.159E-06 T)= 8.633E-07	1	= 1.77125+05	# 4.0958E+ <b>08</b>
LONG-TERM TURBULENCE (SIGMAT) = 1.159E-06 SudMT-TERM TURBULENCE (SIGMAT) = 8.633E-07	RADIUS AITHOUT BLOCMING (R)	AVERAGE INTENSITY (T)	PEAK INTENSITY (12)
[ 0. FEET] = 1.005+03 METERS	• 945	. 560	= 1.0655-03 METENS++2 = 2.1312-03 METENS++2
METERS ( 0.	(EXPKAS) =	ION IVIN H	H H
TARGET ALTITUDE (HTH) = 0. Target Ramge (L)	LIMEAR EFFECTS ON TPARSMISSION (EXPRAS) = .946		AREA WIIMOUT BLOOMING (APEA) Area WIIM Blooming (Blarea)

METERS NATTS/2=+2 200H/STIA

RADTANS RADIANS

AVERAGE Intensity	3.25555458 3.17555458 2.9756458 2.97564568 2.97567458 2.95557458 2.955554508 2.925557408
CUM: LATIVE PC #ER	2-71-01-01-01-01-01-01-01-01-01-01-01-01-01
AREA (METE2++2)	1.122E 2.3777-00 3.9906-00 5.4426-00 7.34426-00 7.3440-00 9.7056-00
I/TPEAK Contour	0 m h o i s * * * * * *

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ECCENTRICITY =

.025 PETERS

DISPLACEMENT =

2.050E.08 1.761E+0 1.301E+0

2.64 26.05 3.0155.05 3.3505.05

1.2635-03 1.7155-03 2.4530-03

**•••**••

In the second second

RAEAKDOWN INTENSITY = 1.00E+12 MAXIMUM INTENSITY ON TARGET = 2.56E/08

ACHIEVE. AT TELESCOPE POWER = 1.01E-00 ACHIEVED AT TELESCOPE POWER = 2.74E-06

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## POVER RANGE AVAILASLE

TELESCOPE PONER	INTENSITY	USEFUL POWER	OVER AREA
(WATTS)	(22115/H4+2)	(24775)	(Xee2)
6.2335+04	3.4265+07	3.5426+07	1.1395-02
1.6476+05	6.333E+07	7.0855.67	1.3076-02
2.470E • 05	8.632E+07	1.063£+08	3.469E-02
3.2436+05	1.063E+04	1.417E+08	1.552E-02
4.116E+05	80 · Uce I · I	1.7776+08	1.8535-02
4.640E+03	1.3115.09	2.1745408	2-0315-02
5.753E+05	1 • 4 5 4 E • 0 8	2	2.1755-02
6.525E+03	2 • 5 + 3E • 64	2 • 7 3 4 5 • 0 8	2.3075-02
7.4096+05	1.6x7E.0A	3.1300-03	2.4505-62
6.233E+05	1.7716.04	G • 5 + 3 + 0 B	2.6055-02
9 • C 5 6 E + C 5	3 • 834E + 04	3.8977.08	2.7776-02
5.P19E+US	1.37/E+08	4.751 - 408	2.5075-02
1.0705+05	1.9355.04	4 • 50 JB • 33	3.1205-02
1.153E+66	1.9905.04	4 * 51 9E + 0 A	3.27Cc-02
1.2355+06	2.062E+03		, <b>3.</b> 405E-02
1.3176+65	2 • 3 255 • 0 <del>8</del>	5 = 5622 = 58	3.5345-02
1.4065+05	2.15.45.49	6 * C 2 2 E + C B	3.6525-02
1.4325+05	2 • 2 3 9 E • 0 B	6.2775+03	3.7916-02
1.5542+05	2 • 290E • 0B	6.731E+C8	3.9225-02
1.647E+05	2.3355.05	7-0026-03	4 COSE+02

USEFUL INTENSITY = 1.0005+04WATTS/MM+2

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