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A discussion is given of theoretical studies on infrasound propaga- tion through the atmosphere which were carried out under the contract. Topics discussed include (1) the modification and adaptation of a computer program for the prediction of pressure signatures at large distances from nuclear explosions to include leaking guided modes, (2) the nature of guided			

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infrasonic modes at higher infrasonic frequencies and the methods of extending waveform synthesis procedures to include higher frequencies, and (3) the propagation of infrasonic pressure pulses past the antipodes (over halfway around the globe). Summaries are included of all papers, theses, and reports written under the contract and conclusions and recommendations for future studies are given. An updated version of the computer program IFRASONIC WAVEFORMS originally given by Pierce and Posey in the report AFCRL-70-0134 is included as an appendix.

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Chapter I

INTRODUCTION

1.1 SCOPE OF THE REPORT

The present report summarizes investigations carried out by the authors during the years 1973-1976 on the propagation of low frequency pressure disturbances under Air Force Contract No. F19628-74-C-0065 with the Air Force Cambridge Research Laboratories, Bedford, Massachusetts. The study performed was theoretical in nature.

The central topic of this study was the generation and propagation of infrasonic waves in the atmosphere. The principal emphasis was on waves from man made nuclear explosions although certain aspects of the study pertain to waves generated by natural phenomena including, in particular, severe weather.

Specific topics considered during the study include the following:

1.) The adaptation of the computer program INFRASONIC WAVEFORMS to include leaking modes and to improve its accuracy in synthesizing early long period arrivals. (INFRASONIC WAVEFORMS is a digital computer program for the prediction of pressure signatures as would be detected at large horizontal distances following the detonation of a nuclear device in the atmosphere. The original version of this program was developed by Pierce and Posey¹ under a previous Air Force Contract [F19628-67-C-0217].) The developed theory for this adaptation has already been explained² in Scientific Report No. 1 of the present contract; the present report describes the numerical implementation of this theory (Chapter III), and gives some specific numerical examples. The complete current version of INFRASONIC WAVEFORMS is included here as Appendix A.

2.) The development of a ray acoustic model for the synthesis of higher frequency portions of infrasonic waveforms. The theory developed during

this study is given³ in some detail in Scientific Report No. 2 and a discussion of this phase of the work is accordingly not repeated here.

3.) The modification of the multi-modal synthesis method to avoid truncation of upper limits on frequency integration. The method developed is presented here in Chapter IV and represents an extension of the W.K.B.J. technique to the case when the atmosphere has two sound channels. The resulting theory clarifies the problem of selection of modes for inclusion into the synthesis and leads to a relatively simple method for revising the synthesis program. (This revision, however, has not yet been carried out.)

4.) Study of infrasonic waveform synthesis for propagation near and past the antipodes. The method for doing this was briefly mentioned in the 1973 AFCRL report (pages 25 and 26) by Pierce, Moo, and Posey⁴. In Chapter V of the present report the theory underlying this is given and some numerical examples are given.

In Chapter II, we list all of the reports, papers, and theses which were written during the course of this study. The abstracts given there plus the abstract of the present report should be considered as a comprehensive summary of the accomplishments during the contracting period. In subsequent chapters of the present report, detailed discussions are given of some of the topics described above. In Chapter VI, some recommendations are made for future work in the field.

1.2 BACKGROUND OF THE REPORT

The general topics of infrasound propagation, generation, and detection have been of considerable interest to a large segment of the scientific community for some time. A published bibliography (the existence of which allows us to omit extensive citations here) lists [Thomas, Pierce, Flinn, and Craine, 1971]⁵ over 600 titles, most of which are directly concerned with infrasound. Literature pertaining to the infrasonic detection of nuclear explosions constitutes a considerable portion of these. Earlier work by Rayleigh [1890]⁶, Lamb [1908,1910]⁷, G. I. Taylor [1929,1936]⁸, Pekeris [1939,1938]⁹, and Scorer [1950]¹⁰,

among others, which was concerned with waves from the Krakatoa eruption [Symond, 1888]¹¹ and from the great Siberian meteorite [Whipple, 1930]¹² is also directly applicable to the understanding and interpretation of nuclear explosion waves.

The present report thus merely summarizes a continuation of a small number of facets of a lengthy pattern of research which has been carried on by a large number of investigators in the past. In a more restricted sense, the work reported here represents a continuation of work done in three previous studies performed under contract for Air Force Cambridge Research Laboratories. The first of these was Air Force Contract No. AF19(628)-3891 with Avco Corporation during 1964-1966; the second was Air Force Contract No. AF19628-67-C-0217 with the Massachusetts Institute of Technology during 1967-1969, the third was AF19628-70-C-0008 (also with M.I.T) during 1970-1972. Summaries of the earlier work may be found in the appropriate final reports by Pierce and Moo [1967]¹³, by Pierce and Posey [1970]¹, and by Pierce, Moo, and Posey [1973]⁴.

One of the principal results of the first two aforementioned previous contracts was a computer program INFRASONIC WAVEFORMS; the deck listing of the then current version of which is given in the report by Pierce and Posey [1970]¹. This program enables one to compute the pressure waveform at a distant point following the detonation of a nuclear explosion in the atmosphere. The primary limitation on the program's applicability to realistic situations is that the atmosphere is assumed to be perfectly stratified. However, the temperature and wind profiles may be arbitrarily specified. The general theory underlying this program is somewhat similar to that developed by Harkrider [1964]¹⁴ but differs from his in that it incorporates background winds and in that it has a different source model for a nuclear explosion.

Chapter II

PAPERS, THESES AND REPORTS

The following gives author, title, and abstract of papers, theses, and reports written during the course of this project.

2.1 A. D. Pierce, "Theory of Infrasound Generated by Explosions," Colloque International sur les Infra-Sons, Proceedings (Centre National de la Recherche Scientifique (CNRS) 15, quai Anatole France, 75700 Paris, September, 1973).

A review is given of recent studies by the author and his colleagues on infrasound generation by explosions and the subsequent propagation through the atmosphere. These studies include (i) development of computer programs for the prediction of pressure signatures at large distances from nuclear explosions, (ii) development of an alternative approximate model for waveform synthesis based on Lamb's edge mode, (iii) development of a geometrical acoustics' theory incorporating nonlinear effects, dispersion, and wave distortion at caustics, and (iv) theoretical models for the mechanisms of wave generation by explosions. The basic theory is briefly outlined in each case and some of the more significant results are explained in terms of simplified physical models. Such results include the predicted dependence of far field waveforms on energy yield and burst height, suggested techniques for estimating energy yield from waveforms, and an explanation of amplitude anomalies in terms of focusing and defocusing of horizontal ray paths.

2.2 W. A. Kinney, C. Y. Kapper, and A. D. Pierce, "Acoustic Gravity Wave Propagation Post the Antipode," J. Acoust. Soc. Amer. 55, S75 (A) (1974).

The previous theoretical formulations and numerical computations of pressure waveforms (such as described by Harkrider, Pierce, and Posey, and others) apply only to atmospheric traveling waves which have traveled less than $1/2$ the distance around the earth. In the

present paper, a technique resembling that previously introduced by Brune, Nafe, and Alsop [Bull. Seismol. Soc. Am. 51, 247-257 (1961)] for elastic surface waves on the earth is discussed and applied to the acoustic-gravity wave propagation past the antipode problem. The principal modification to the older theory is a shift in phase of $\pi/2$ to the Fourier transform of the wave after it has traveled over halfway round the globe from the source. The source of the wave is presumed to be a nuclear explosion of given energy E. Numerically synthesized waveforms of antipodal arrivals are exhibited and compared with those for direct arrivals. The necessary modifications to the Lambmode model theory of Pierce and Posey [Geophys. J. Roy. Astron. Soc. 26, 341-368 (1971)] are also described.

- 2.3 C. Y. Kapper, "Leaky Infrasonic Guided Waves in the Atmosphere," J. Acoust. Soc. Amer. 56, S2 (A) (1974).

Prior theoretical formulations and computational techniques for the prediction of pressure waveforms generated by large explosions in the atmosphere have considered only fully ducted modes. In the present paper, a technique for including weakly leaking guided modes in concert with fully ducted modes is developed. Modification of previous theory includes the extension of the boundary condition at the upper halfspace to include a complex horizontal wavenumber. The major alterations to the computer program Infrasonic Waveforms (as described in report by Pierce and Posey, 1970) incurred consist of the computation of the imaginary part of the newly incorporated complex wavenumber, extension of the normal-mode dispersion function to lower frequencies, and a second-order correction factor to the phase velocity.

- 2.4 W. A. Kinney, "Asymptotic High-Frequency Behavior of Guided Infrasonic Modes in the Atmosphere," J. Acoust. Soc. Amer. 56, S2 (A) (1974).

Refinement of previous theoretical formulations and numerical computations of pressure waveforms as applied to atmospheric traveling infrasonic waves could include a description of their asymptotic behavior at high frequencies. In the present paper, calculations based on the W.K.B.J. approximation and similar to those introduced by

Haskell [J. Appl. Phys. 22, 157-167 (1951)] are performed to describe the asymptotic behavior of infrasonic guided modes as generated by a nuclear explosion in the atmosphere. The results of these calculations are then matched onto numerical solutions which have been given by Harkrider, Pierce and Posey, and others. It is demonstrated that the use of these asymptotic formulas in conjunction with a computer program which synthesizes infrasonic pressure waveforms has enabled the elimination of problems associated with high-frequency truncation of numerical integration over frequency. In this way, small spurious high-frequency oscillations in the computer solutions have been avoided.

- 2.5 C. Y. Kapper, Computational Techniques in Infrasound Waveform Synthesis, M. S. Thesis, School of Mechanical Engineering, Georgia Institute of Technology (December, 1974).

This thesis is concerned with two major theoretical and programming modifications to the digital computer program INFRASONIC WAVEFORMS for the synthesization of acoustic-gravity pressure waveforms generated by large explosions in the atmosphere. The first modification involves the extension of the guided mode approximation for pressure waveforms in the atmosphere into leaking mode regions and a consequent search for the imaginary part of the complex horizontal wave number. Particular results include a plot of phase velocity versus angular frequency showing the extension of the normal mode dispersion function into a leaky mode region for a multilayer atmosphere and a report on the search for the imaginary part of the complex horizontal wave number of a leaky mode for a two layer atmosphere. The second modification involves the extension of the synthesis of acoustic-gravity pressure waveforms to distances beyond the antipode. A phase shift is noted for waves passing through the antipode and a comparison of pre and post antipodal waveforms is presented.

- 2.6 W. A. Kinney, A. D. Pierce, and C. Y. Kapper, "Atmospheric Acoustic Gravity Modes Near and Below Low Frequency Cutoff Imposed by Upper Boundary Conditions," J. Acoust. Soc. Amer. 58, S1 (A) (1975).

Perturbation techniques are described for the computation of the imaginary part of the horizontal wavenumber (k_I) for modes of

propagation. Numerical studies were carried out for a model atmosphere terminated by a constant sound-speed (478 m/sec) half space above an altitude of 125 km. The GR_0 and GR_1 modes have lower-frequency cutoffs. It was found that for frequencies less than 0.0125 rad/sec, the GR_1 mode has complex phase velocity; k_I varying from near zero up to a maximum of $3 \times 10^{-4} \text{ km}^{-1}$ with analogous results for the GR_0 mode. There is an extremely small frequency gap for each mode for which no poles in the complex k plane corresponding to that mode exist. These mark the transition from undamped propagation to damped propagation. In the complete Fourier synthesis, branch line contributions compensate for the absence of poles in these gaps. Computational procedures are described which facilitate the inclusion of the low-frequency portions of these modes in the waveform synthesis.

2.7 A. D. Pierce, and W. A. Kinney, Atmospheric Acoustic Gravity Modes at Frequencies Near and Below Low Frequency Cutoff Imposed by Upper Boundary Conditions, Report AFCRL-TR-75-0639, Air Force Cambridge Research Laboratories, Hanscom AFB, Mass. (March, 1976).

Perturbation techniques are described for the computation of the imaginary part of the horizontal wavenumber (k_I) for modes of propagation. Numerical studies were carried out for a model atmosphere terminated by a constant sound-speed (478 m/sec) half space above an altitude of 125 km. The GR_0 and GR_1 modes have lower-frequency cutoffs. It was found that for frequencies less than 0.0125 rad/sec, the GR_1 mode has complex phase velocity; k_I varying from near zero up to a maximum of $3 \times 10^{-4} \text{ km}^{-1}$ with analogous results for the GR_0 mode. There is an extremely small frequency gap for each mode for which no poles in the complex k plane corresponding to that mode exist. These mark the transition from undamped propagation to damped propagation. In the complete Fourier synthesis, branch line contributions compensate for the absence of poles in these gaps. Computational procedures are described which facilitate the inclusion of the low-frequency portions of these modes in the waveform synthesis.

2.8 A. D. Pierce, and W. A. Kinney, Geometric Acoustics Techniques in Far Field Infrasonic Waveform Synthesis, Report AFGL-TR-76-0055, Air

Force Cambridge Research Laboratories, Hanscom AFB, Mass. (1976).

A ray acoustic computational model for the prediction of long range infrasound propagation in the atmosphere is described. A cubic spline technique is used to approximate the sound speed versus height profile when values of sound speed are input for discrete height intervals. Techniques for finding ray paths, travel times, ray turning points, and rays connecting source and receiver are described. A parameter characterizing the spreading of adjacent rays (or ray tube area) is defined and methods for its computation are given. A method of determining the number of times a given ray touches a caustic is also described. Formulas are given for the computation of acoustic amplitudes and waveforms which involve a superposition of contributions from individual rays connecting source and receiver and which incorporate phase shifts at caustics. The possibility of a receiver being in the proximity of a caustic is considered in some detail and distinction is made between cases where the receiver is on the illuminated or shadow sides of a caustic. It is shown that a knowledge of parameters characterizing two rays at a point in the vicinity of a caustic provides sufficient information concerning the caustic to allow one to give a relatively accurate description of the acoustic field in its vicinity. The resulting theory involves Airy functions and uses concepts extrapolated from a theory published in 1951 by Haskell. The net result is a detailed computational scheme which should accurately cover the contingency of the receiver being near a caustic in the calculation of amplitudes and waveforms. A number of FORTRAN subroutines illustrating the method are given in an appendix. Limitations of the theory and suggestions for future developments are also given.

Chapter III

NUMERICAL SYNTHESIS OF WAVEFORMS

INCLUDING LEAKING MODES

3.1 INTRODUCTION

The computer program INFRASONIC WAVEFORMS has been modified to allow inclusion of the contribution at low frequencies from leaking modes (specifically the GR_0 and GR_1 modes) to numerically synthesized infrasonic pressure waveforms. The procedure incorporated in this modification involves a partly manual calculation of the imaginary and real parts of the horizontal wavenumber, k_I and k_R , respectively) as discussed in Scientific Report No. 1.² That calculation is outlined in more detail here. The numbers presented for illustration are appropriate to the case of observations at 15,000 km distance from a 50 megaton explosion, where the explosion is at 3 km altitude, and where the atmosphere is assumed to contain no winds. (This restriction is just for illustrative purposes, but is not a limitation on the method.)

3.2 CALCULATION OF COMPLEX WAVENUMBERS

The first step in the calculation is to obtain values for the phase velocities $v_n(\omega)$, $v_a(\omega)$, and $v_b(\omega)$ for the GR_0 and GR_1 modes, and to obtain values for the elements $R_{11}(\omega, v)$ and $R_{12}(\omega, v)$ of the transmission matrix $[R]$. These calculations should be done, in particular, for all frequencies extending below the mode's nominal lower cutoff frequency.

As mentioned in the previous report², R_{11} and R_{12} depend on the atmospheric properties only in the altitude range 0 to z_T (the bottom of the upper halfspace), and these are independent of what is assumed for the upper halfspace. Also, $v_n(\omega)$ is the phase velocity for a given (n -th) mode for values of ω greater than the lower cutoff frequency ω_L ; here $v_a(\omega)$ and $v_b(\omega)$ are values of the phase velocity ω/k at which the functions

R_{11} and R_{12} , respectively, vanish. For a given mode, the values of v_a and v_b chosen are those from the curves $v_a(\omega)$ and $v_b(\omega)$ which lie the closest of all such curves to the curve $v_n(\omega)$ for $\omega > \omega_L$.

As regards the calculation of R_{11} and R_{12} , the computer program INFRASONIC WAVEFORMS may be used, only with an alternate version of the subroutine TABLE. A copy of subroutine TABLE with the appropriate modifications incorporated and indicated is given in Appendix B. A deck listing of all of the input data that is required to obtain R_{11} and R_{12} , and that is appropriate to the running example, follows in Fig. 1. Values for R_{11} and R_{12} need only be calculated for phase velocities between, say, 143 and 0.3318 km/sec, and for frequencies between 0.001 rad/sec (as close to zero as would seem necessary and corresponding to a period of 6,283 sec or 1.75 hr) and the value of ω_B for the upper halfspace (.0128 rad/sec in our numerical example). In the calculations reported here, the upper frequency was taken as .031 rad/sec in order to confirm the continuity of the dispersion curves. A sample portion of the printout of R_{11} and R_{12} corresponding to the model atmosphere of Fig. 2 is given in Fig. 3. The same set of output from a computer run which lists the R_{11} and R_{12} also includes the $v_n(\omega)$ for the GR_0 and GR_1 modes.

Values of $v_a(\omega)$ and $v_b(\omega)$ for these modes are obtained by two successive runs of INFRASONIC WAVEFORMS using in sequence two modified versions of the subroutine NMDFN. These modifications are so minor that the deck listing is omitted and we describe here the nature of the modifications.

To obtain $v_a(\omega)$, one need only change the third from end executable FORTRAN statement of subroutine NMDFN from

$$FPP = RPP(1,1)*A(1,2) - RPP(1,2)*(GU + A(1,1)) \quad (3.1)$$

to

$$FPP = RPP(1,1). \quad (3.2)$$

```
$NAM1 NSTART=1, NPRNT=1, NPNCH=-1, NCML=-1 $END
$NAM2 IMAX=24,
ZI=1.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,25.,30.,35.,40.,45.,55.,
    65.,75.,85.,95.,105.,115.,125.,
T=292.,288.,270.,260.,249.,236.,225.,215.,205.,198.,205.,215.,227.,
    237.,249.,265.,260.,240.,205.,185.,184.,200.,250.,400.,570.,
LWANGLE=1,
WINDY=25*0.0,
WANGLE=25*0.0
$END
$NAM4
THETKD =35.,
V1 = 0.143, V2 = 0.3318,
 $\phi$ M1 = 0.001,  $\phi$ M2 = 0.031,
N $\phi$ M1 = 30, NVPI = 80,
MAXM $\phi$ D = 10
$END
$NAM1 NSTART=6, NPRNT=1, NPNCH=-1, NCML=-1 $END
```

Figure 1. Listing of input data required to generate tabulations of R_{11} and R_{12} versus phase velocity and angular frequency in the vicinity of the dispersion curves for the GR_0 and GR_1 modes.

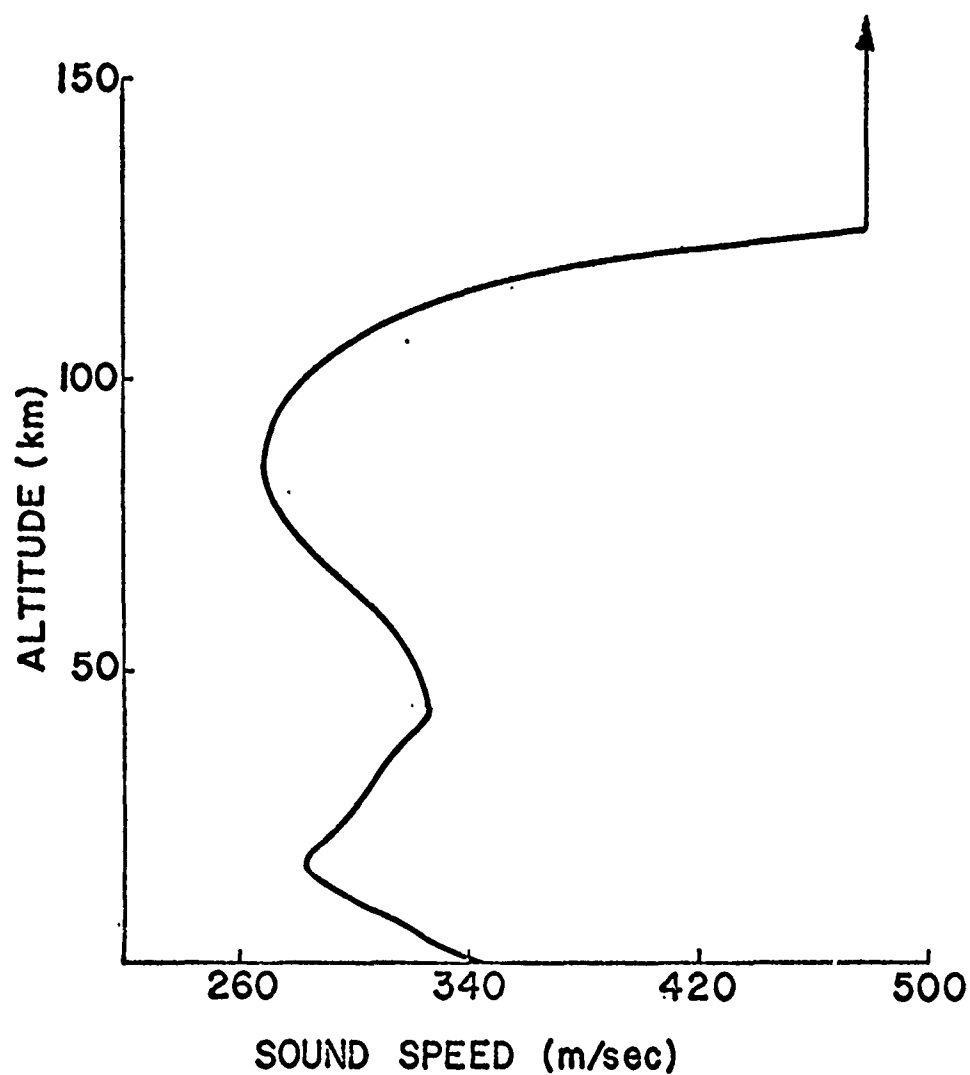


Figure 2. Model atmosphere showing sound speed versus altitude for numerical example treated in the present chapter. The atmosphere is bounded by an isothermal upper half space beginning at 125 km altitude.

v_p	R_{11}	R_{12}
OMEGA=	.30928-02	
.14300+00	.21671+01	-.65152+02
.14539+00	-.72963-01	-.22523+02
.14773+00	-.19992+01	.16898+02
.15017+00	-.34415+01	.49336+02
.15256+00	-.43200+01	.72532+02
.15495+00	-.46324+01	.85619+02
.15734+00	-.44356+01	.88833+02
.15973+00	-.38270+01	.83475+02
.16212+00	-.29260+01	.71114+02
.16451+00	-.18579+01	.53814+02
.16690+00	-.74204+00	.33657+02
.16929+00	.31761+00	.12611+02
.17168+00	.12376+01	-.75995+01
.17407+00	.19579+01	-.25568+02
.17646+00	.24418+01	-.40247+02
.17885+00	.26746+01	-.50952+02
.18124+00	.26605+01	-.57340+02
.18363+00	.24195+01	-.59371+02
.18602+00	.19834+01	-.57261+02
.18841+00	.13917+01	-.51424+02
.19080+00	.68860+00	-.42421+02
.19319+00	-.80574-01	-.30906+02
.19558+00	-.87165+00	-.17582+02
.19797+00	-.16447+01	-.31561+01
.20036+00	-.23637+01	.11690+02
.20275+00	-.29996+01	.26326+02
.20514+00	-.35295+01	.40198+02
.20753+00	-.39379+01	.52832+02
.20992+00	-.42153+01	.63849+02

Figure 3. Sample printout of R_{11} and R_{12} versus phase velocity for a fixed value of angular frequency. Output generated with the input data of Fig. 1.

To obtain $v_b(\omega)$, one need only change the same statement to

$$FPP = RPP(1,2). \quad (3.3)$$

The same limits for phase velocity and angular frequency as are used for the calculation of R_{11} and R_{12} should be used in the calculations for v_n , v_a , and v_b . In our example, when these limits are used, the GR_1 mode corresponds to mode #3, and the GR_0 mode corresponds to mode #4 for the case when $v_n(\omega)$ is calculated. For the cases when $v_a(\omega)$ and $v_b(\omega)$ are calculated, the GR_1 mode corresponds to mode #4 and the GR_0 mode corresponds to mode #6. A sample output listing of $v_n(\omega)$, $v_a(\omega)$ and $v_b(\omega)$ for the two modes is given in Fig. 4. An additional listing of $v_n(\omega)$, $v_a(\omega)$, and $v_b(\omega)$ for the two modes versus various values of ω is given in Table 1.

3.3 CALCULATION OF α AND β

The next step in the procedure is to manually calculate values for the variables α and β which enter into an approximate version [Eq. (9) in Scientific Report No. 1] of the eigenmode dispersion function. These parameters represent the partial derivatives of R_{11} and R_{12} , respectively, with respect to phase velocity v evaluated at $v=v_a$ and $v=v_b$, respectively. Since R_{11} and R_{12} also depend on ω , α and β may be considered as functions of angular frequency (but not of phase velocity).

It may be recalled that $v_a(\omega)$ and $v_b(\omega)$ are values for the phase velocity at which R_{11} and R_{12} , respectively, vanish. From the listing of, say, R_{11} versus v and ω , let the adjacent values R_{111} , R_{211} , R_{311} and R_{411} for R_{11} corresponding to the values for phase velocity v_{11} , v_{21} , v_{31} and v_{41} , respectively (for some chosen ω), such that v_{21} and v_{31} bracket a value for v_a ; R_{211} and R_{311} would then be of opposite sign. In the listing of v , R_{11} , R_{12} for various ω , the values for v should all turn out to be equally spaced. Given this fact, it is possible to reasonably approximate α from the listings of R_{11} by the formula

$$\alpha = (1/\Delta v_1)([5/6]e_{11}+[1/12]f_{11}+[1/4]g_{11}h_{11}) \quad (3.4)$$

GR₀ MODE

ω	V_n	ω	V_a	ω	V_b
.012375	.31185608	.001030	.31205939	.001030	.31209836
.013407	.31181806	.002061	.31205552	.002061	.31209447
.014438	.31177597	.003093	.31204906	.003093	.31208799
.015469	.31172882	.004124	.31204001	.004124	.31207393
.016501	.31167509	.005156	.31202834	.005156	.31206727
.017532	.31161209	.006187	.31201405	.006187	.31205303
.018563	.31153394	.007218	.31199710	.007218	.31203520
.019070	.31148610	.008250	.31197748	.008250	.31201679
.019079	.31148516	.009281	.31195515	.009281	.31199478
.019595	.31142505	.010312	.31193006	.010312	.31197016
.019853	.31138841	.011344	.31190215	.011344	.31194291
.020111	.31134515	.012375	.31187139	.012375	.31191302
.020626	.31122480	.013407	.31183768	.013407	.31188045
.021658	.31029529	.014438	.31180093	.014438	.31184518
.021659	.31029116	.015469	.31176104	.015469	.31180714
.022005	.30790129	.016501	.31171786	.016501	.31176630
.022139	.30551142	.017532	.31167120	.017532	.31172258
.022173	.30475278	.018563	.31162087	.018563	.31167591
.022240	.30312155	.019595	.31156653	.019595	.31162620
.022329	.30073168	.020626	.31150781	.020626	.31157334
.022412	.29834181	.021658	.31144415	.021658	.31151721
.022490	.29595194	.022689	.31137478	.022689	.31145763
.022566	.29356207	.023720	.31129855	.023720	.31139444
.022639	.29117220	.024752	.31121368	.024752	.31132738
.022689	.28948366	.025783	.31111721	.025783	.31125619
.022710	.28878233	.026814	.31100382	.026814	.31118049
.022779	.28639246	.027846	.31086276	.027846	.31109964
.022846	.28400259	.028877	.31066848	.028877	.31101364
.022912	.28161272	.029909	.31034189	.029909	.31092114

GR₁ MODE

ω	V_n	ω	V_a	ω	V_b
.013407	.22781499	.001030	.24434330	.001030	.25073465
.013624	.22664568	.002061	.24409612	.001738	.25054440
.014040	.22425580	.003093	.24367787	.002061	.25042454
.014424	.22186593	.003655	.24337478	.003093	.24990029
.014438	.22177526	.004124	.24307897	.004124	.24915067
.014778	.21947606	.005156	.24228453	.005156	.24815906
.015107	.21708619	.006187	.24127431	.005160	.24615453
.015413	.21469631	.006445	.24098491	.006187	.24600257
.015469	.21423833	.007218	.24001904	.006963	.24576466
.015699	.21230644	.008181	.23859504	.007218	.24535036
.015966	.20991657	.008250	.23848240	.008250	.24346182
.016217	.20752670	.009281	.23660913	.008293	.24337478
.016453	.20513682	.009479	.23620517	.009281	.24118333
.016501	.20463309	.010312	.23432740	.009362	.24098491
.016675	.20274695	.010518	.23381529	.010260	.23859504
.016886	.20035708	.011344	.23153728	.010312	.23844346
.017085	.19796721	.011381	.23142542	.011034	.23620517
.017274	.19557733	.012115	.22903555	.011344	.23514077
.017454	.19318746	.012375	.22809942	.011712	.23381529
.017532	.19211887	.012752	.22664568	.012314	.23142542
.017626	.19079759	.013311	.22425580	.012375	.23116086
.017790	.18840772	.013407	.22381942	.012855	.22903555
.017946	.18601784	.013800	.22186593	.013345	.22664568
.018096	.18362797	.014255	.21947606	.013407	.22632580
.018240	.18123810	.014438	.21842295	.013790	.22425580
.018378	.17884823	.014659	.21708619	.014199	.22186593
.018510	.17645836	.015027	.21469631	.014438	.22036670
.018563	.17547997	.015364	.21230644	.014575	.21947606
.018638	.17406848	.015469	.21151653	.014722	.21708619

Figure 4. A sample output listing of $v_n(\omega)$, $v_a(\omega)$, and $v_b(\omega)$ for the GR₀ and GR₁ modes.

where

$$\Delta v_1 = v_{41} - v_{31} = v_{31} - v_{21} = v_{21} - v_{11} \quad (3.5a)$$

$$e_{11} = R_{311} - R_{211} \quad (3.5b)$$

$$f_{11} = R_{411} - R_{311} + R_{211} - R_{111} \quad (3.5c)$$

$$g_{11} = (R_{211} - R_{311})/e_{11} \quad (3.5d)$$

$$h_{11} = R_{311} + R_{211} - R_{111} - R_{411} \quad (3.5e)$$

In like manner, from the listing of R_{12} versus v and ω , if one lets the adjacent values R_{112} , R_{212} , R_{312} , and R_{412} for R_{12} correspond to the values for phase velocity v_{12} , v_{22} , v_{32} , and v_{42} , respectively (for some chosen ω), such that v_{22} and v_{32} bracket a value for v_b , then one can approximate β by the formula

$$\beta = (1/\Delta v_2)([5/6]e_{12} + [1/12]f_{12} + [1/4]g_{12}h_{12}) \quad (3.6)$$

where Δv_2 , e_{12} , f_{12} , g_{12} , and h_{12} are defined by equations analogous to Eqs. (3.5) (last subscript changed from 1 to 2).

Because we use a numerical method (i.e., that described above) to calculate a derivative (it would be preferable to have an explicit formula), there is a small amount of numerical noise in the tabulation versus ω of α and β computed in the above manner. This noise is noticable only for the GR_1 mode and may for all practical purposes be filtered out by plotting α and β versus ω and then drawing smooth curves through the respective sets of points. (See Figs. 5 and 6.) While this procedure is somewhat laborious, it circumvents doing additional runs of the program to get values of R_{11} and R_{12} at more closely spaced values of phase velocity. It also circumvents a somewhat elaborate computer programming chore which would do

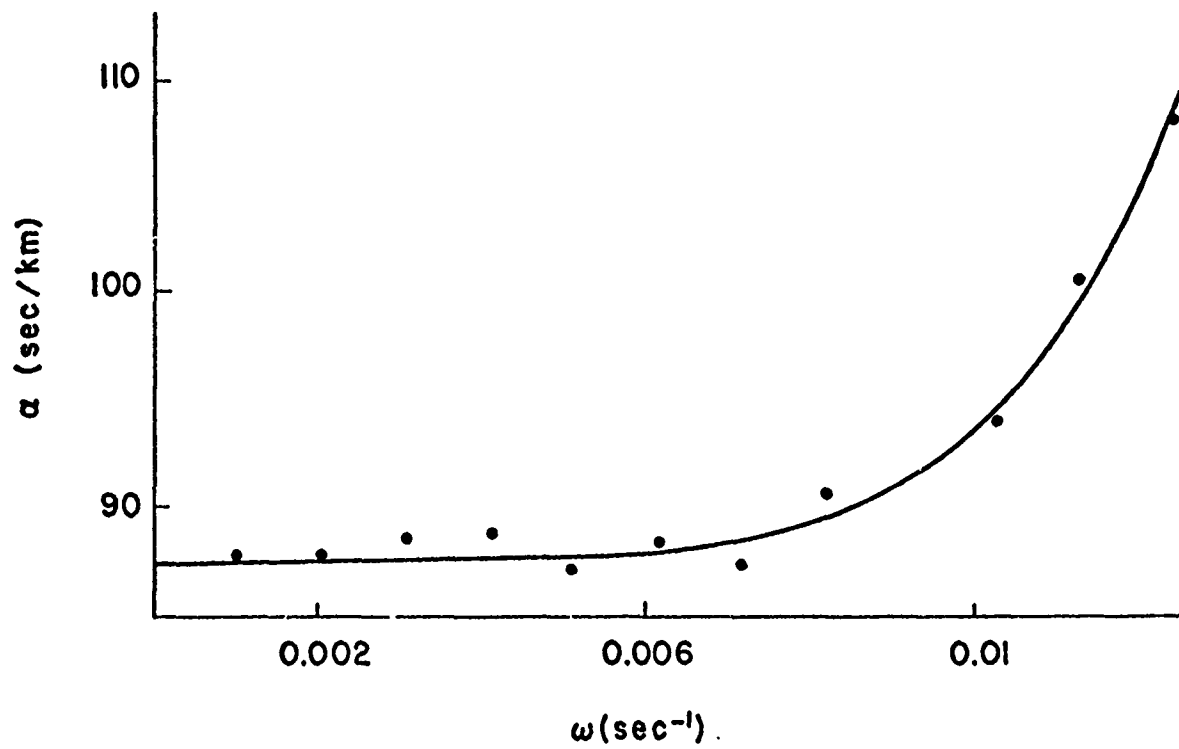


Figure 5. A plot of the parameter α versus ω for the GR_1 mode. The parameter α is $\partial R_{11} / \partial v_p$ evaluated at the phase velocity where $R_{11} = 0$.

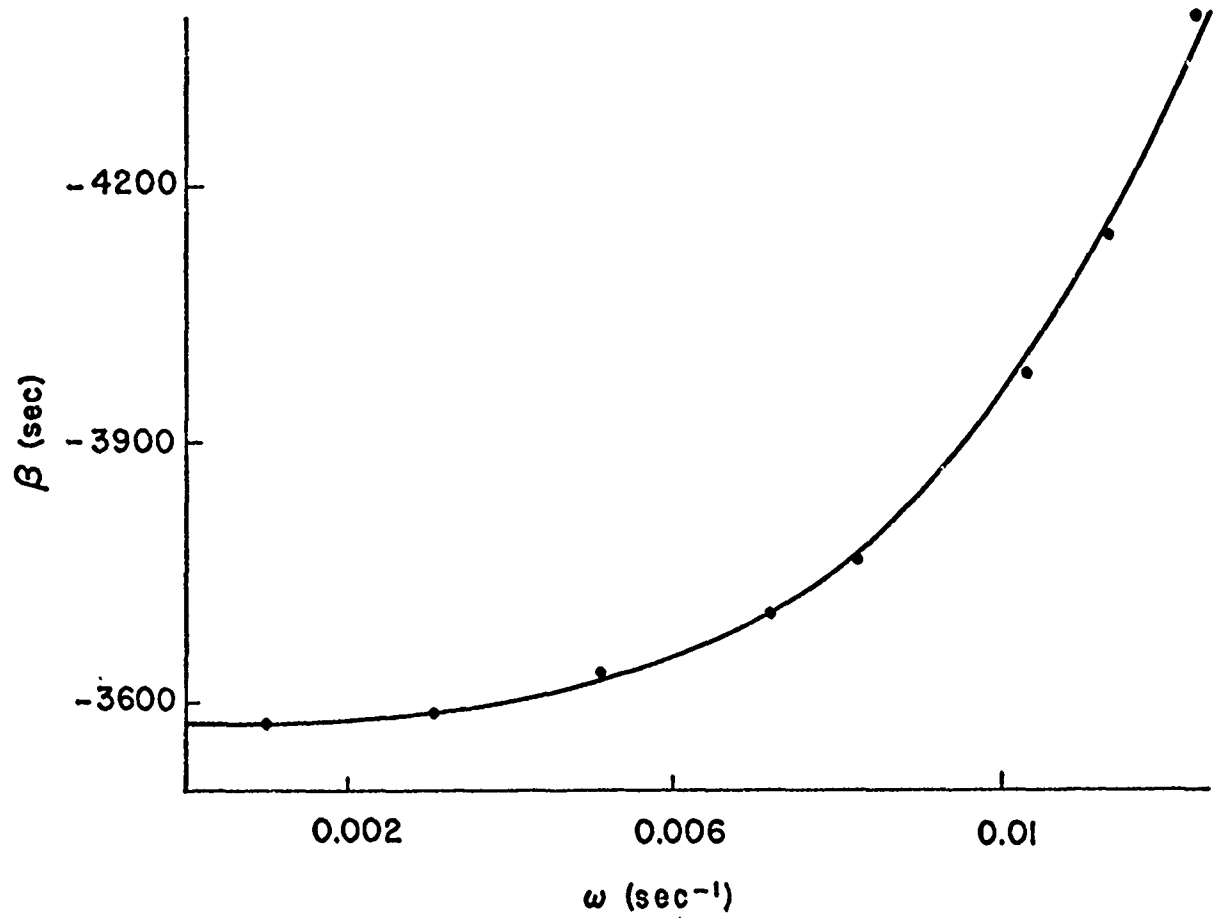


Figure 6. A plot of the parameter β versus ω for the GR_1 mode. The parameter β is $\partial R_{12} / \partial v_p$ evaluated at the phase velocity where $R_{12} = 0$.

such steps automatically. (We suspect that the programming time would surpass all time which would ever actually be spent on manual circulations such as described above.) In any event, in view of the relatively small values of k_I which are actually obtained (as described further below) and in view of the recommendations (also given further below) concerning the use of the same k_I in many different types of calculations, the accuracy of the α and β so obtained is more than sufficient.

3.4 CALCULATION OF COMPLEX PHASE VELOCITY

The applicable expression for calculation of a mode's phase velocity (real above cutoff frequency, complex below) is Eq. (10a) in Scientific Report² No. 1 (which for brevity is not repeated here). This involves parameters v_a and v_b (whose computation is described in Sec. 3.1), and X , which may be considered as a function of ω and which is defined by Eq. (10b) in the prior report. This latter quantity X depends on β/α , A_{11} , G and A_{12} . The latter three are computed by taking the phase velocity as v_a and using Eqs. (4), (7a), and (7b) of the prior report. These calculations are straight forward, and do not require detailed explanation. Listings of G , A_{11} , A_{12} , and X for various values of ω and for the GR_1 and GR_0 modes are given in Table 1.

As explained in the prior report, below cutoff (that is, below $\omega_L = 0.0125$ rad/sec for GR_1 and below $\omega_L = 0.0118$ rad/sec for GR_0 , in the running example) the real part k_R of the horizontal wave number is the real part of $\omega/v^{(1)}$, and the imaginary part k_I is the imaginary part of $\omega/v^{(1)}$. Finally, the extension by first iteration of the normal mode dispersion curves below cutoff is obtained by simply calculating ω/k_R . Listings of $v^{(1)}$, k_I , k_R , and ω/k_R for various ω for the GR_0 and GR_1 modes are given in Table 1. Plots of k_I and ω/k_R are given in Fig. 7.

3.5 INPUT DATA FOR GR_0 AND GR_1

The present version of INFRASONIC WAVEFORMS allows for the possibility of phase velocity ω/k_R , imaginary component k_I , and source free amplitude AMP to be input as functions of angular frequency ω for any given

GR₀ MODE

ω	v_a	v_b	α	β	A_{11}	A_{12}	G
0.001030	0.31205939	0.31209836	957.1	-2648.5	0.07064925	-1.3492340	0.028617461
0.005156	0.31202834	0.31206727	917.4	-2783.7	0.07066928	-1.3497015	0.025859571
0.008250	0.31197748	0.31201679	854.9	-2988.2	0.07070210	-1.3504677	0.020599491
0.011344	0.31190215	0.31194291	767.9	-3254.2	0.07075075	-1.3515959	8.16470 x 10 ⁻³

ω	X	k_I	k_R	ω/k_R
0.001030	0.14489848 + 0.05869314i	3.29323 x 10 ⁻⁸	3.3007 x 10 ⁻³	0.31205300
0.005156	0.15887128 + 0.05813477i	1.68605 x 10 ⁻⁷	0.0165355	0.31202121
0.008250	0.18298964 + 0.05331514i	2.65003 x 10 ⁻⁷	0.0264444	0.31197553
0.011344	0.22182228 + 0.02559851i	2.00717 x 10 ⁻⁷	0.0363822	0.31189059

GR₁ MODE

ω	v_a	v_b	α	β	A_{11}	A_{12}	G
0.001030	0.24434330	0.25073465	87.4	-3578	0.13415774	-2.8317742	0.043592491
0.005156	0.24284530	0.24815908	87.8	-3633	0.13695917	-2.8971705	0.040308491
0.008250	0.23848240	0.24346182	89.6	-3770	0.14232483	-3.0224265	0.033973041
0.011344	0.23153728	0.23514877	100.0	-4144	0.15281704	-3.2673565	0.019880611

ω	X	k_I	k_R	ω/k_R
0.001030	1.9394832 + 0.63020518i	4.96794 x 10 ⁻⁵	4.0319 x 10 ⁻³	0.25546528
0.005156	1.9560589 + 0.57569611i	2.19268 x 10 ⁻⁴	0.0204383	0.25269766
0.008250	1.9813366 + 0.47294644i	2.67086 x 10 ⁻⁴	0.0335205	0.24759561
0.011344	1.9381840 + 0.25214654i	2.05014 x 10 ⁻⁴	0.0474121	0.23926355

Table 1. Tabulation of frequency dependent parameters for the GR₀ and GR₁ modes. Tabulation is for frequencies below cutoff; definitions of the various quantities are given in the text and in Scientific Report No. 1.

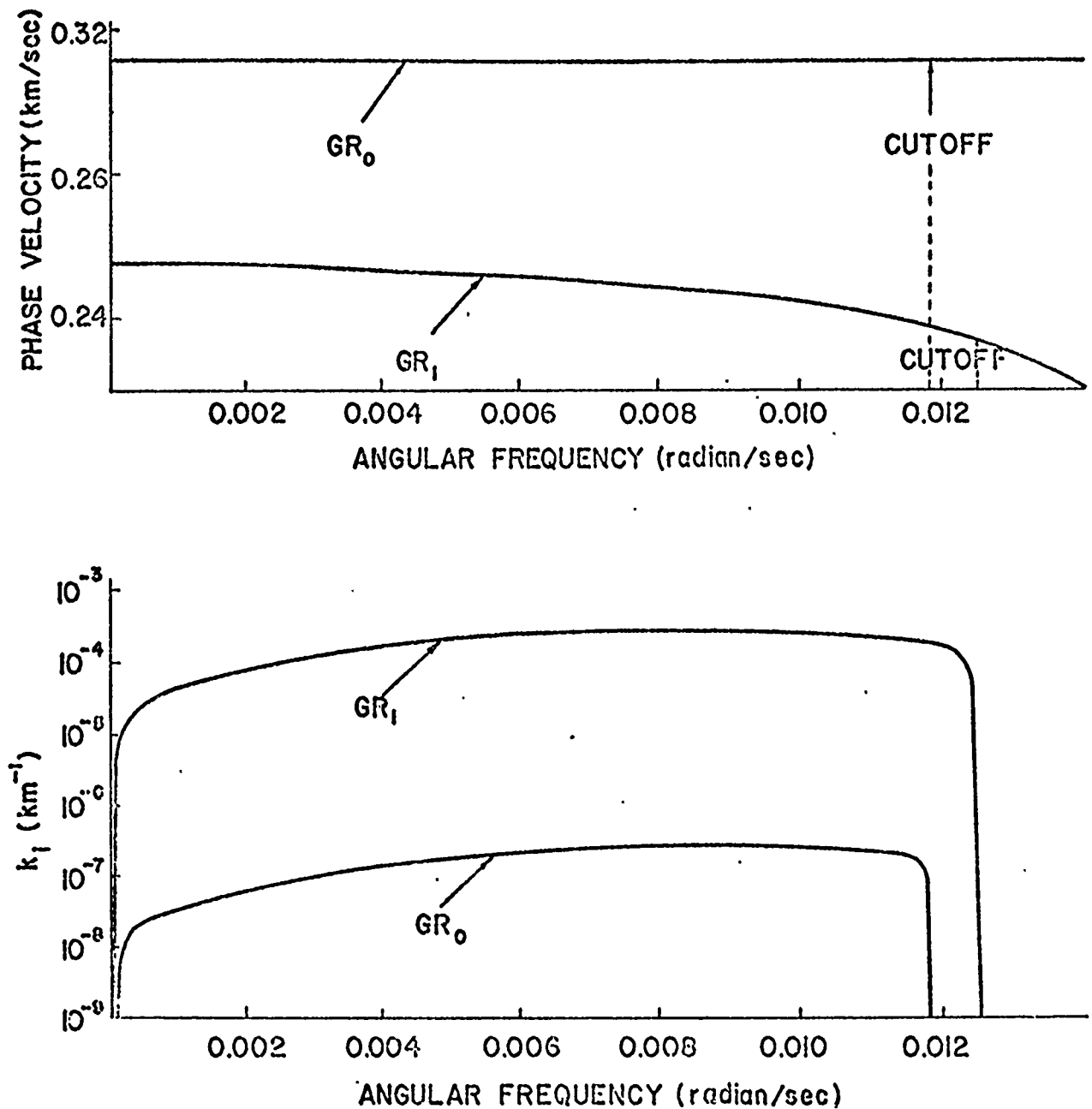


Figure 7. Numerically derived plots of phase velocity ω/k_R and of the imaginary part k_I of the complex horizontal wavenumber k versus angular frequency ω for the GR_0 and GR_1 modes. Nominal lower frequency cutoffs for these modes are as indicated. Note that k_I is identically zero above the cutoff frequency.

mode. The only modes for which this is necessary are GR_0 and GR_1 . This input data is partly obtained by the procedure described above. Here we describe how the remaining portion of the input data is obtained.

To obtain values of phase velocity and source free amplitude at frequencies above cutoff one uses the current version of INFRASONIC WAVEFORMS with the variable NCMP1 of NAMELIST NAM51 set less than zero. This gives an output essentially identical to what would be obtained with the original version of the program. The input data for this run would be the same as if one were computing waveforms without consideration of leaky modes. A sample listing of such input data is given in Fig. 8. The run will give mode numbers and tabulations of phase velocity VPHSE and amplitude AMP versus angular frequency OMEGA for the GR_0 and GR_1 modes at frequencies above cutoff. The only output which need be retained for future use are the tabulations of VPHSE versus OMEGA for these two modes, since amplitudes at frequencies above cutoff are computed automatically in the run which utilizes this information as input data. A sample tabulation of the pertinent output (for the running example considered here) is given in Fig. 9.

Input data of phase velocity VPHSE and amplitude AMP for frequencies below cutoff are obtained by a second run of the program, again with $NCMP1 < 0$, only with the original model atmosphere replaced by one which has a thick intermediate layer plus on upper half space replacing the original upper half space. Thus, in the NAM2 input list, IMAX is increased by one, the original ZI and T are unchanged, but one adds a ZI for the new value of IMAX which is, say 100 km larger than the largest ZI for the original model atmosphere; the temperature T for the new IMAX + 1 layer (i.e. for the new upper half space) is set equal to an arbitrarily very large value (say, 2×10^7 °K). Doing this will artificially shift the cutoff frequencies for GR_0 and GR_1 down to values which are, for all practical purposes, equal to zero. The input data for this run should include choices of angular frequency and phase velocity limits (V1, V2, OM1, and OM2 of NAM4) which are appropriate for an exploration of the properties of GR_0 and GR_1 at frequencies below their original cutoff frequencies. It is imperative that OM2 not be too large since INFRASONIC WAVEFORMS will

```
$NAM1 NSTART=1, NPRNT=1, NPNCH=-1, NCMPL=-1 $END
$NAM2 IMAX=24,
ZI=1.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,25.,30.,35.,40.,45.,55.,
    65.,75.,85.,95.,105.,115.,125.,
T=292.,288.,270.,260.,249.,236.,225.,215.,205.,198.,205.,215.,217.,
    237.,249.,265.,260.,240.,205.,185.,184.,200.,250.,400.,570.,
LANGE = 1,
WINDY = 25*0.0,
WANGLE = 25*0.0
$END
$NAM4
THETKD = 35.,
V1 = 0.15, V2 = 0.495,
 $\phi$ M1 = 0.005,  $\phi$ M2 = 0.1,
NCMI = 30, NVPI = 30,
MAXMOD = 8
$END
$NAM6 ZSCRC = 3.0, Z $\phi$ BS = 0.0 $END
$NAM8 YIELD = 50.E3 $END
$NAM10 R $\phi$ BS = 15000.,
TFIRST = 46.2E3, TEND = 52.2E3,
DELTT = 15.,
I $\phi$ PT = 11,
$END
$NAM1 NSTART=6 $END
```

Figure 8. Input data to obtain phase velocity versus angular frequency above cutoff frequency for the $G R_0$ and $G R_1$ modes.

GR ₀ MODE		GR ₁ MODE	
OMEGA	V _n	OMEGA	V _n
.01482759	.31175883	.01482759	.21913018
.01640552	.31167707	.01631253	.20948276
.01725743	.31162830	.01640552	.20500289
.01810349	.31157130	.01711598	.19758621
.01892241	.31151099	.01728448	.19544661
.01933193	.31145750	.01756050	.19163793
.01974138	.31140492	.01795593	.18568966
.02137931	.31179310	.01810345	.18350434
.02151539	.31166349	.01832569	.17974138
.02178679	.31198022	.01805292	.17379310
.02212362	.31170293	.01892241	.16844746
.02210359	.30614224	.01895156	.16784483
.02214436	.30535871	.01909212	.16487069
.02216121	.30502694	.01922762	.16189655
.02217751	.30465517	.01933190	.15953747
.02219828	.30416532	.01948594	.15594828
.02220976	.30391164	.01973352	.15000000
.02223357	.30316810		
.02229594	.30168113		
.02239972	.29870690		
.02259155	.29275362		
.02293273	.28086207		
.02301724	.27771666		
.02324256	.26896552		
.02353165	.25706897		
.02380369	.24517241		
.02405701	.23327586		
.02432538	.22137931		
.02458369	.20948276		
.02465517	.20622217		
.02484741	.19758621		
.02498335	.19163793		
.02512335	.18568966		
.02526862	.17974138		
.02542062	.17379310		
.02558111	.16784483		
.02566520	.16487069		
.02575227	.16189655		
.02593679	.15594828		
.02613807	.15000000		

Figure 9. Sample output of phase velocity versus angular frequency at frequencies above cutoff for the GR₀ and GR₁ modes corresponding to the input data of Fig. 8.

encounter numerical difficulties at higher frequencies when the height of the upper halfspace is as high as considered here. (If it were not for this fact, this run could be used to generate essentially the same information as in the previous run.) For comparison, Fig. 10 indicates the types of atmospheric profiles used in the two runs with $NCMPL < 0$.

The second run gives values for the source free amplitudes AMP and phase velocities VPHSE for the GR_0 and GR_1 modes for frequencies below cutoff. The latter of these are expected to be virtually identical to the ω/k_R which are obtained by the method described in Sec. 3.4. Also, the source free amplitudes are expected to match on smoothly to those obtained from the prior run for high frequencies even though the two model atmospheres are not identically the same. (This is because the energy transported by the GR_0 and GR_1 modes is predominantly in the lower atmosphere.) Furthermore, we expect these amplitudes to be virtually the same as would be obtained by the modified residue method described in Scientific Report No. 1 for the original model atmosphere. The actual amplitudes should have a small imaginary part, but in view of the relatively small values of the k_I (less than 10^{-3} nepers/km) obtained, we are confident that this imaginary part may be neglected to an excellent approximation. The only aspect of the leaking phenomena which conceivably could be of significance is the accumulative exponential decay represented by the factor $\exp(-k_I r)$, which is retained in subsequent calculations.

Sample input data for this second run with $NCMPL < 0$ are given in Fig. 11; a listing of the output values for OMEGA, VPHSE, and AMP below the original cutoff frequencies for the GR_0 and GR_1 modes of the running example is given in Fig. 12.

3.6 WAVEFORM SYNTHESIS

The final step in the waveform synthesis is to run the program INFRASONIC WAVEFORMS with input data including the information concerning the GR_0 and GR_1 modes computed as described in the preceding two sections. The essential difference between this run and the first such

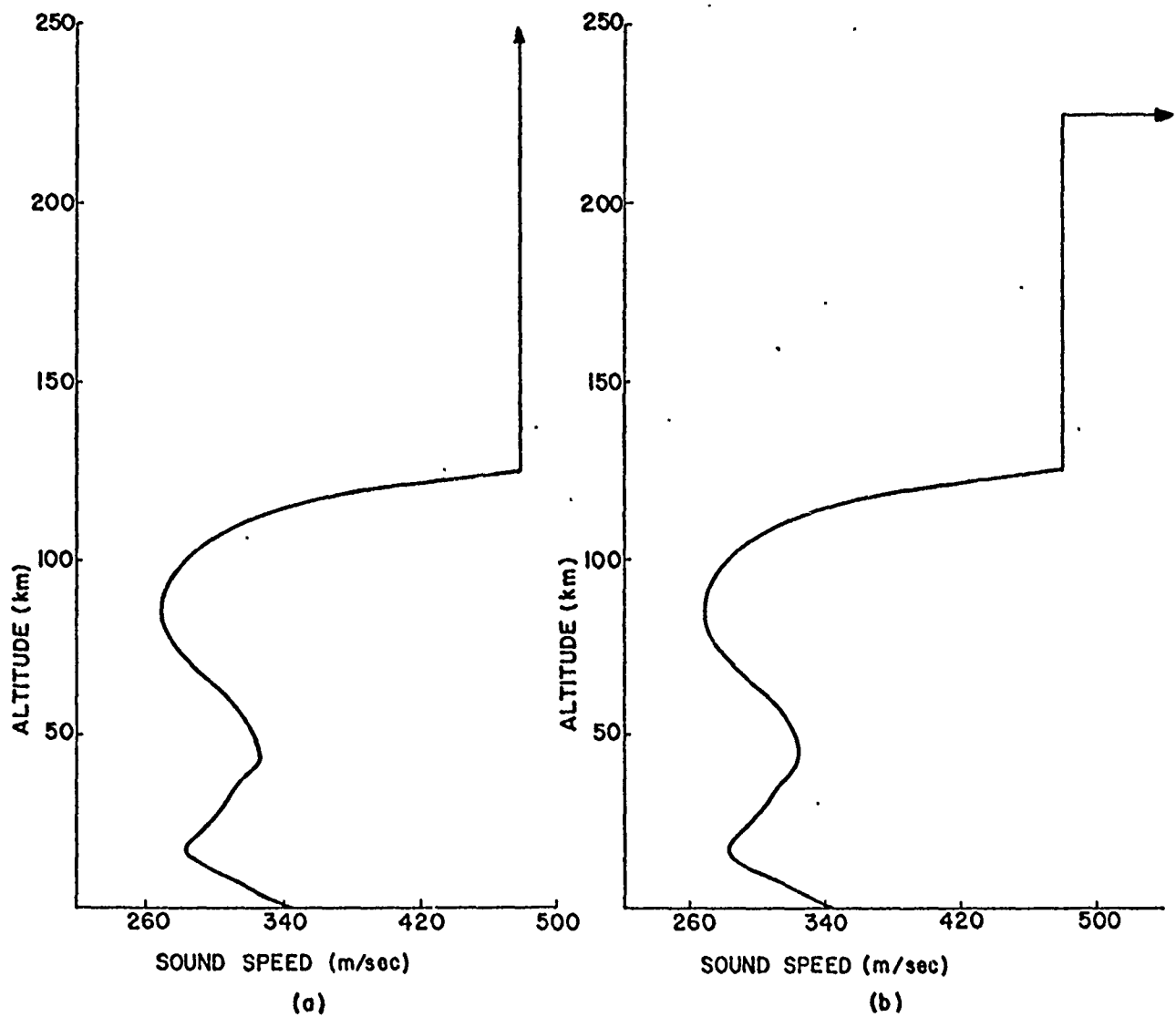


Figure 10. Two model atmosphere profiles; the first is the same as in Fig. 2; the second has the original upper halfspace replaced by a layer of finite but large thickness with a halfspace above it of extremely high temperature and sound speed. Second atmosphere is used to generate phase velocities and source free amplitudes at frequencies below nominal cutoff frequencies.

```
$NAM1 NSTART=1, NPRNT=1, NPNCH=-1, NCMP1=-1 $END
$NAM2 IMAX=25,
ZI=1.,2.,4.,6.,8.,10.,12.,14.,16.,18.,20.,25.,30.,35.,40.,45.,55.,
    65.,75.,85.,95.,105.,115.,125.,225.,
T=292.,288.,270.,260.,249.,236.,225.,215.,205.,198.,205.,215.,227.,
    237.,249.,265.,260.,240.,205.,185.,184.,200.,250.,400.,570.,2.E7,
LWANGLE=1,
WINDY=26*0.0,
WANGLE=26*0.0
$END
$NAM4
THETKD= 35.,
V1 = 0.18, V2 = 0.34,
 $\phi$ M1 = 0.001,  $\phi$ M2 = 0.02,
N $\phi$ M1 = 30, NVPI = 30,
MAXM $\phi$ D = 8
$END
$NAM1 NSTART=6 $END
```

Figure 11. Input data to obtain phase velocity and source free amplitudes below nominal cutoff frequencies for the GR_0 and GR_1 modes.

GR ₀ MODE			GR ₁ MODE		
OMEGA	VPHSE	AMP	OMEGA	VPHSE	AMP
.00100	.31206	-.03102934	.00100	.28308	-.00003660
.00166	.31205	-.03101968	.00166	.28237	-.00003722
.00231	.31205	-.03100520	.00231	.28129	-.00003831
.00297	.31205	-.03098589	.00297	.27983	-.00004009
.00362	.31204	-.03096170	.00317	.27931	-.00004082
.00428	.31203	-.03093260	.00362	.27797	-.00004295
.00493	.31203	-.03089855	.00428	.27567	-.00004754
.00559	.31202	-.03085951	.00473	.27379	-.00005235
.00624	.31201	-.03081546	.00493	.27289	-.00005510
.00690	.31200	-.03076637	.00559	.26958	-.00006819
.00755	.31198	-.03071222	.00582	.26828	-.00007507
.00821	.31197	-.03065299	.00624	.26569	-.00009291
.00853	.31196	-.03062146	.00668	.26276	-.00012320
.00886	.31196	-.03058865	.00690	.26116	-.00014672
.00952	.31194	-.03051919	.00740	.25724	-.00024331
.01017	.31192	-.03044457	.00755	.25598	-.00029422
.01083	.31190	-.03036475	.00805	.25172	-.00063749
.01148	.31188	-.03027970	.00821	.25040	-.00084929
.01214	.31186	-.03018936	.00853	.24780	-.00156605
.01279	.31184	-.03009365	.00878	.24621	-.00225436
.01345	.31182	-.02999249	.00886	.24571	-.00248871
.01410	.31179	-.02988574	.00937	.24345	-.00335025
.01476	.31176	-.02977324	.00952	.24292	-.00346229
.01541	.31173	-.02965474	.01017	.24075	-.00365399
.01607	.31170	-.02952988	.01019	.24069	-.00365562
.01672	.31166	-.02939809	.01083	.23860	-.00365194
.01738	.31162	-.02925846	.01148	.23628	-.00358599
.01803	.31158	-.02910932	.01178	.23517	-.00354504
.01869	.31152	-.02894743	.01214	.23372	-.00348656
.01934	.31146	-.02876557	.01279	.23084	-.00336176
.02000	.31136	-.02854424	.01304	.22966	-.00330833
			.01345	.22758	-.00321275
			.01406	.22414	-.00305033
			.01410	.22387	-.00303760
			.01476	.21961	-.00283239
			.01490	.21862	-.00278409
			.01541	.21469	-.00259141
			.01561	.21310	-.00251310
			.01607	.20895	-.00230706
			.01621	.20759	-.00223902
			.01672	.20220	-.00196998
			.01674	.20207	-.00196321
			.01720	.19655	-.00168722
			.01738	.19420	-.00156992
			.01761	.19103	-.00141297
			.01798	.18552	-.00114281
			.01803	.18462	-.00109941
			.01831	.18000	-.00087957

Figure 12. Sample output of phase velocity and source free amplitude at frequencies below cutoff for the GR₀ and GR₁ modes corresponding to the input data of Fig. 11.

run described in Sec. 3.5 is that one sets $NCMPL > 0$, and that one supplies values for the parameters in the input list NAM51. A listing of the input data for the run, allowing for the leaking modes, and appropriate to our running example is given in Fig. 13. The phase velocities input for the GR_0 and GR_1 modes are those derived from the two computer runs described in Sec. 3.5. The source free amplitudes for these modes are supplied only for frequencies below cutoff and these are derived from the second run of Sec. 3.5. The imaginary parts of the wave number are the numbers whose computation is described in Sec. 3.5. The reason we use the phase velocities below cutoff as computed in Sec. 3.5, rather than as in Sec. 3.4, is that both calculations agree to the same order of accuracy as would be expected for the approximations inherent in the method of Sec. 3.4. Consequently, we expect the values from the computer run to be the more nearly accurate. Of course, the values of k_I have to be computed by the method of Sec. 3.4 since the computer program in its present form does not compute these directly.

In Fig.14 we show CALCOMP plots of modal and total waveforms obtained before and after the inclusion of leaking modes. (This is for our running example, 15,000 km from a 50 megaton burst at 3 km altitude, the receiver being on the ground.) One may note that the inclusion of the leaking modes eliminates the spurious precursor in the waveform and raises the amplitude of the first peak. It is also important to note that the waveform with leaking modes included begins with a pressure rise. This is what one would probably expect from intuition alone, and would also appear to be more realistic.

3.7 FURTHER EXAMPLE (HOUSATONIC)

To further explore the effects of inclusion of leaking modes, we chose the case of waveforms observed at Berkeley, California, following the Hausatonic detonation at Johnson Island on October 30, 1962. A previous comparison of theoretical and observed waveforms for this event is given in the Geophysical Journal article by Pierce and Posey.¹⁵ This case is also the central example in the 1970 AFCRL report by Pierce and

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Figure 13. Sample input data for synthesis of infrasonic waveform including leaking modes. The data for the NAM51 input list is as derived from previous computations described in the present chapter.

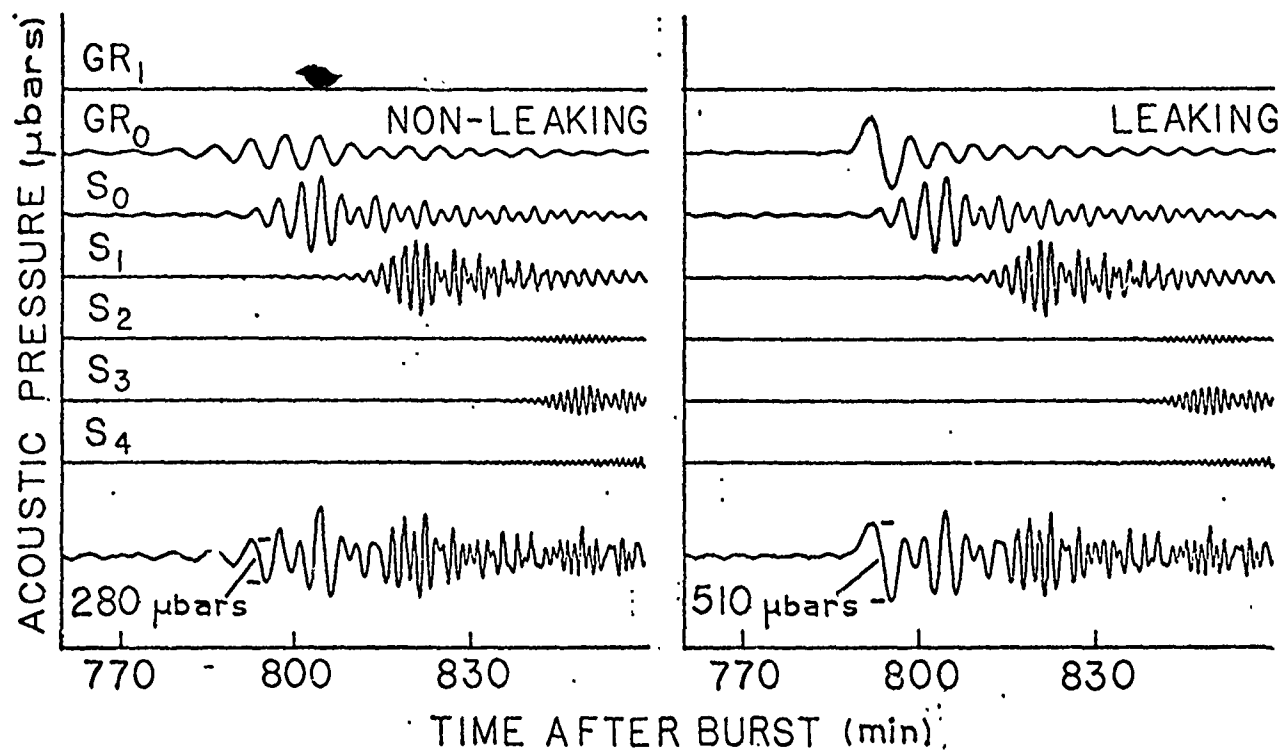


Figure 14. CALCOMP plots of modal and total waveforms before and after inclusion of leaking modes. Example is for the case of a 50 megaton burst at 3 km altitude in the atmosphere of Fig. 2; receiver is at distance of 15,000 km.

Posey¹, and is discussed within the Lamb edge mode theory context in some detail in Posey's thesis.¹⁶

The model atmosphere assumed for the computation is exactly the same as in Fig. 3-12 of the 1970 report, only we let the upper half space begin at 125 km ($IMAX = 24$). Rather than repeat the tedious calculations of the k_I for the GR_0 and GR_1 modes for this model atmosphere, we assumed that they would be essentially the same as for the running example in the previous section. Thus the steps in Secs. 3.5 and 3.6 needed only to be carried out to obtain a waveform synthesis.

In Fig. 15, we give comparisons of the CALCOMP plots for this event before and after the inclusion of leaking modes. One may note that the first of these does not agree with the comparable CALCOMP plots in Fig. 3-10 of the 1970 AFCRL report. This is of course because we have here taken the upper halfspace to begin at a lower altitude. This choice of where the upper halfspace begins is of little consequence when leaking modes are included, and consequently the agreement of the old computation with the leaking mode included case is quite substantial. Further, the new computation is regarded as an improvement in that the spurious initial pressure drop has been eliminated.

On the basis of the calculations described above, we have redrawn the Fig. 7 in the Geophysical Journal article which compares observed and theoretical pressure waveforms for the Housatonic-Berkeley event. This revised figure is given here as Fig. 16. The only difference is in the center waveform. The precursor is now absent and the first peak to trough amplitude has been changed from 157 μ bar to 170 μ bar (less than 10% increase); the remainder of the waveform is virtually unchanged. The discrepancy with the edge mode synthesis hasn't been diminished and remains a topic for future study. (It was not addressed during the present study.)

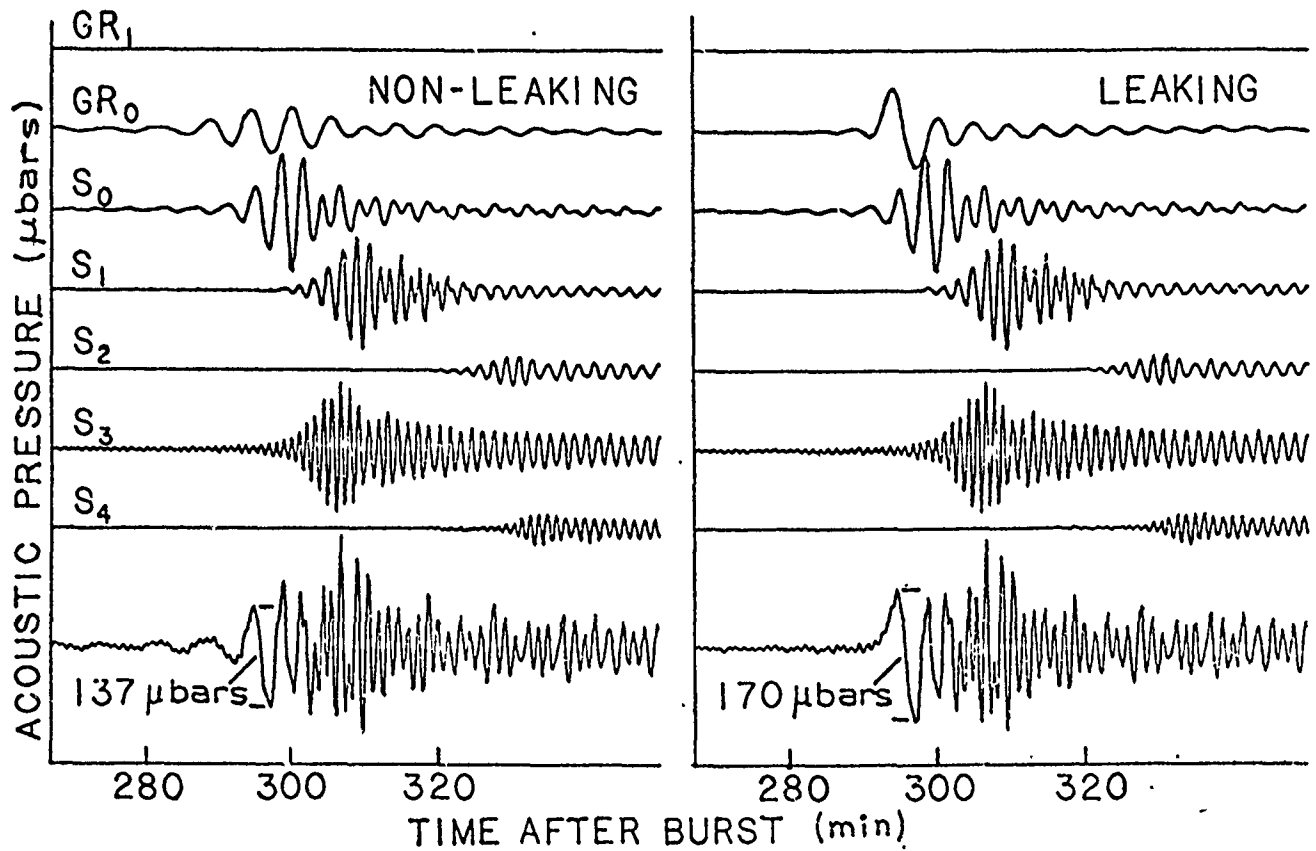


Figure 15. CALCOMP plots of modal and total waveforms before and after the inclusion of leaking modes. The observations were made at Berkeley, California, following the Housatonic detonation at Johnson Island on 30 October 1962. The energy yield assumed in the theoretical computations was 10 megaton. The model atmosphere is as previously used by Pierce and Posey in AFRL-70-0134, only the upper halfspace begins at 125 km.

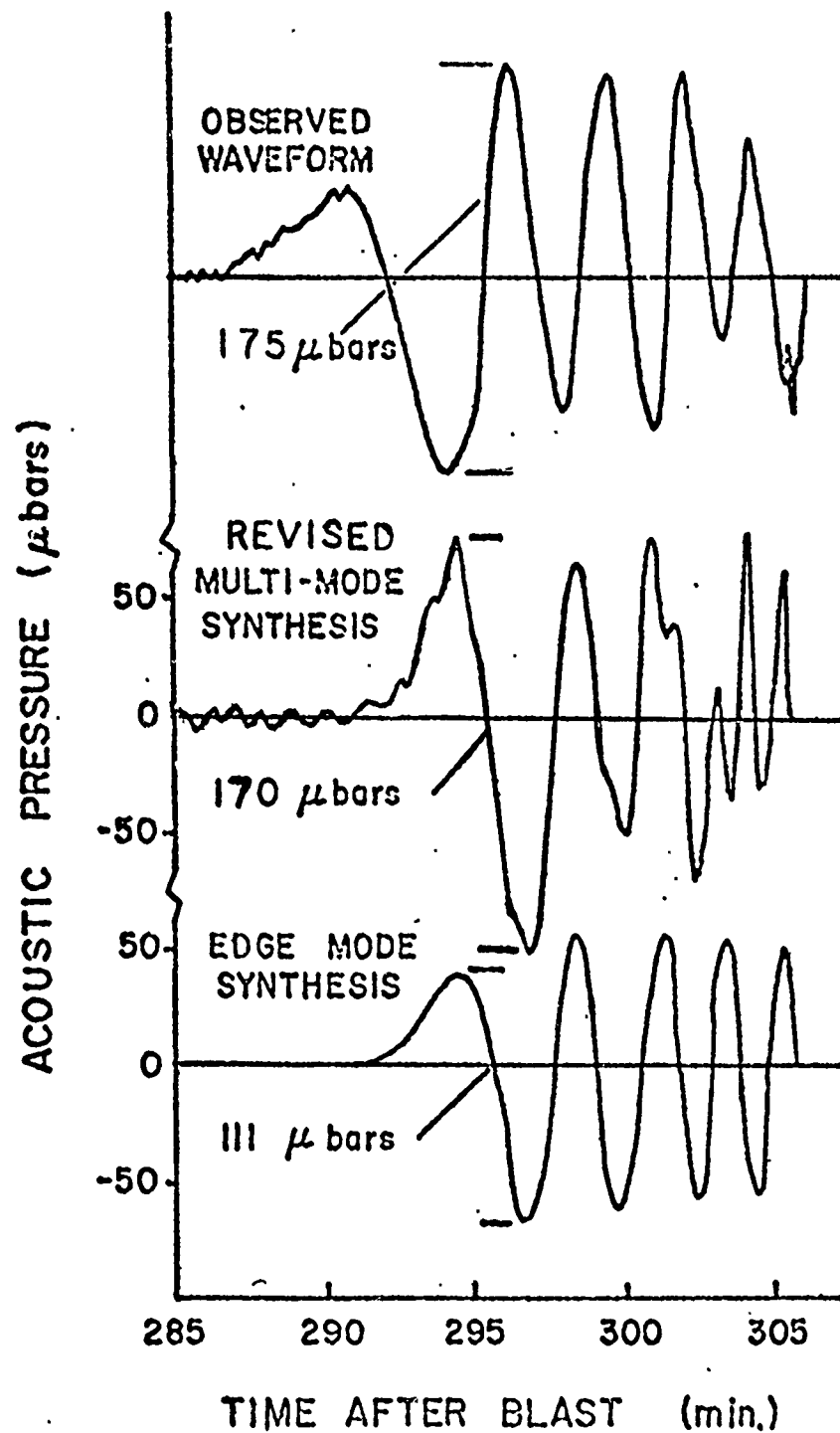


Figure 16. Observed and theoretical pressure waveforms at Berkeley, California, following the Housatonic detonation at Johnson Island on 30 October 1962. The observed waveform is taken from Donn and Shaw (1967). The energy yield assumed in the theoretical computations was 10 megatons. This is a revised version of the Fig. 7 in the 1971 paper by Pierce and Posey (Geophys. J. Roy. Astron. Soc. 26, 341-368). The original multi-mode synthesis figure has been replaced by one including leaking modes.

Chapter IV

ASYMPTOTIC HIGH-FREQUENCY BEHAVIOR OF GUIDED MODES

4.1 INTRODUCTION

Due to temperature and wind stratification, the earth's atmosphere possesses sound speed channels with associated relative sound speed minima. Fig.17 shows a standard reference atmosphere wherein two such sound speed channels are indicated; one with a minimum occurring at approximately 16 km altitude and the second with a minimum occurring at approximately 86 km altitude. Given the presence of such a channel, an acoustic ducting phenomenon can occur, as is demonstrated in Fig.18, wherein the energy associated with an acoustic disturbance can become trapped in the region of a relative sound speed minimum. It is this mechanism of ducting only that is of interest here.

In the computer program INFRASONIC WAVEFORMS, the computation of modal waveforms involves the numerical integration over angular frequency of a Fourier transform of acoustic pressure where this integration is truncated at the high-frequency end. It has been speculated that this abrupt truncation leads to the generation of what might be called "numerical noise" in the computer output. It was felt useful, therefore, to extend this integration beyond the heretofore upper angular frequency limit by means of some appropriate high-frequency approximation. In the case of an atmosphere with just one sound channel, the technique for doing this is well known and dates back to a paper published by N. Haskell¹⁷ in 1951. Haskell's method is the W.K.B.J. (Wentzel, Kramers, Brillouin, Jeffreys) method, then in common use in quantum mechanics, although its invention dates back to Carlini¹⁸ and Green¹⁹ in the early 19th century.

The approximations associated with the W.K.B.J. method of solution apply to the analytical model on which the computer program is based at

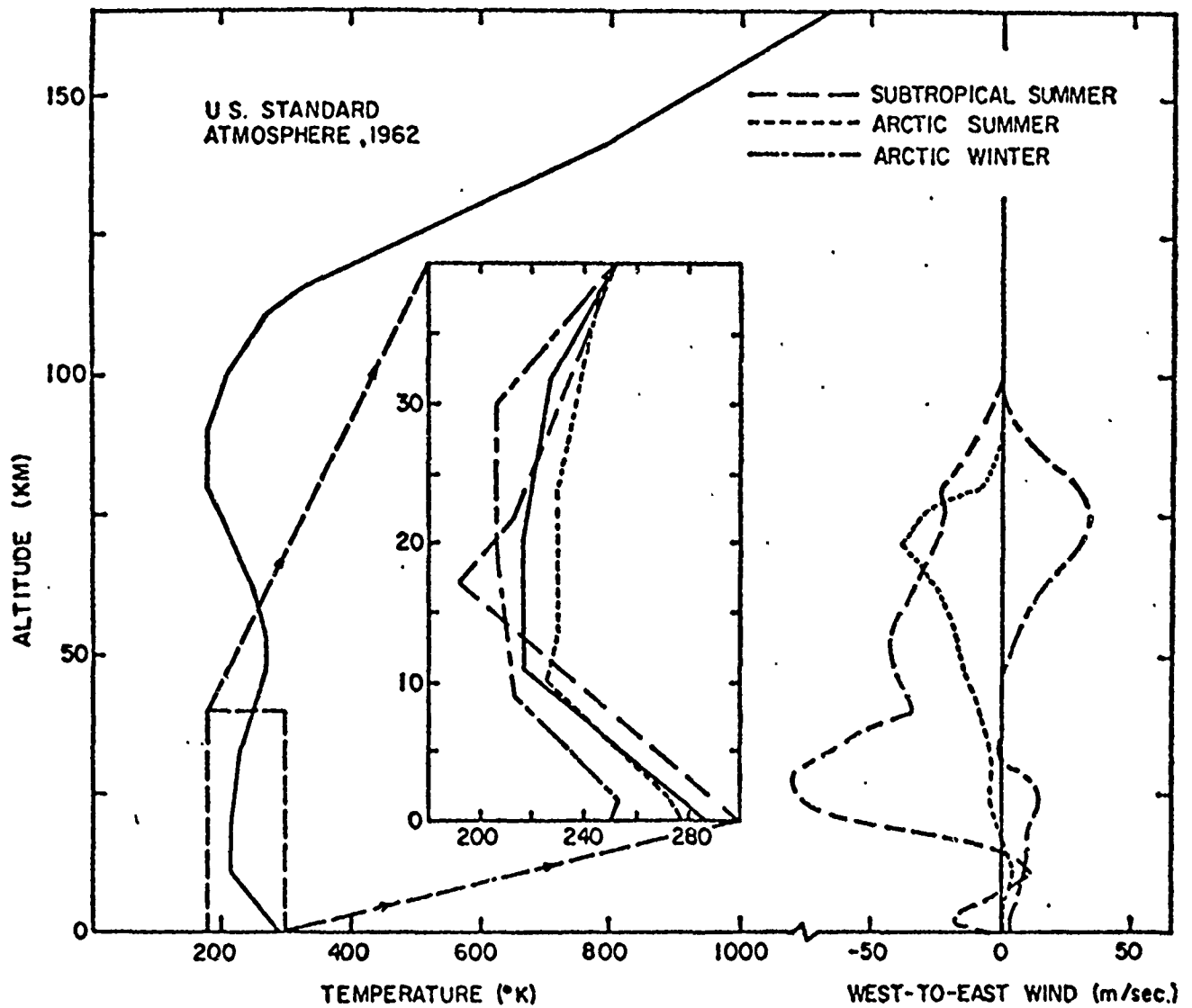


Figure 17. Temperature and wind speed versus height profiles for standard reference atmospheres. Calculations in present chapter are for U. S. Standard Atmosphere 1962 without winds. The presence of two temperature minima indicates two sound speed channels.

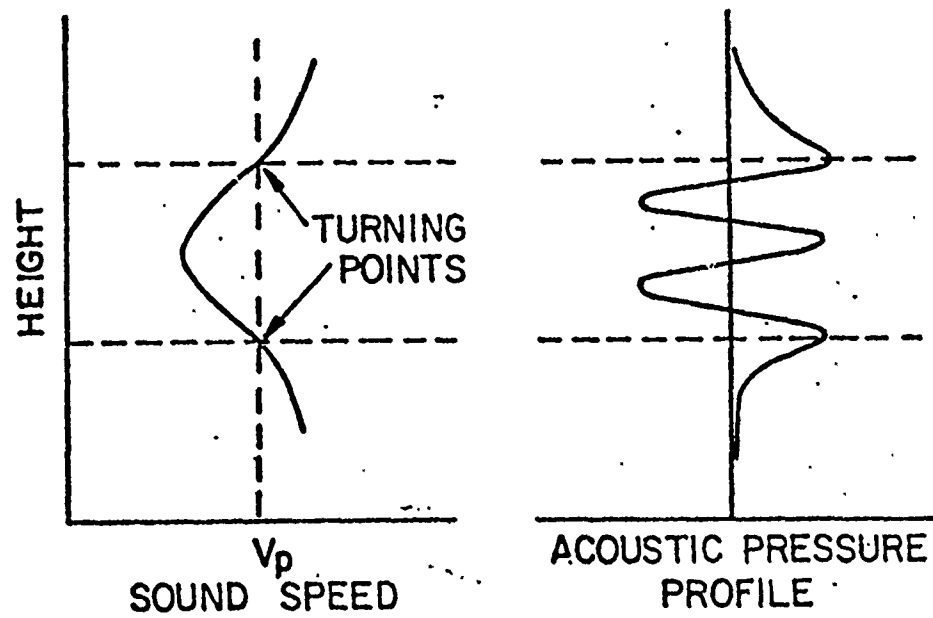


Figure 18. Sketches of sound speed versus height and acoustic pressure amplitude versus height for a guided mode illustrating the mechanism of acoustic ducting in a sound speed channel centered at a region of minimum sound speed. The energy of the disturbance may be considered as concentrated in the height region between turning points.

frequencies above approximately 0.05 radian/sec (periods less than 2 minutes). Below that limit, effects due to density stratification in the atmosphere and gravitational forces cannot be neglected. Such effects therefore are not germane to the discussion here.

The application of the W.K.B.J. method of solution to the problem of describing propagation of acoustic disturbances in an atmosphere that contains two adjacent sound speed channels has previously been discussed in the literature by Eckart,²⁰ who invented the simple method of seeking a W.K.B.J. model for each of the sound speed channels separately, then combining the results rather than treating the problem with a single model. In the present chapter, Eckart's method is applied and numerically verified for the case of infrasonic waves in the atmosphere.

4.2 THE W.K.B.J. MODEL

The W.K.B.J. model for propagation of acoustic disturbances in a single sound speed channel may be considered as an approximation for the acoustic pressure divided by the square root of the ambient density, which in general may be expressed as

$$\frac{P}{\sqrt{\rho_0}} = \psi(z) e^{-i\omega t} e^{ikx} \quad (4.1)$$

where ω is angular frequency, k is the wave number associated with the horizontal dimension x , z is altitude. Here $\psi(z)$ satisfies the reduced wave equation,

$$\left[\frac{d^2}{dz^2} + \frac{\omega^2}{c^2(z)} - k^2 \right] \psi = 0 \quad (4.2)$$

where $c(z)$ is sound speed as a function of altitude. The W.K.B.J. approximation applies in general to all differential equations of this type if the coefficient of ψ is sufficiently "slowly varying." It would appear in particular to be valid in the present context provided

$$\left| \frac{c}{\nabla c} \right| \ll \lambda \quad (4.3)$$

where λ is some representative wavelength of interest. This approximation states that substantial changes in sound speed should not occur within distances corresponding to a typical wavelength of interest if the model is to apply.

A particular result of the W.K.B.J. approximation is that dispersion curves (v_p vs. ω) of guided modes are given by the equation

$$\int_{z_{\text{bottom}}}^{z_{\text{top}}} \left[c^{-2} - v_p^{-2} \right]^{1/2} dz = \frac{(2n+1)\pi}{2\omega} \quad (4.4)$$

where v_p is phase velocity, $n = 0, 1, 2, 3, \dots$, and where z_{bottom} and z_{top} identify the lower and upper bounds of the sound speed channel, respectively. This integral is a direct result of the W.K.B.J. method of solution²¹, and its numerical solution enables the plotting of dispersion curves.

4.3 COMPARISON OF DISPERSION CURVES

Particular insight into the high-frequency behavior of guided infrasonic modes was gained when the above integral was solved numerically by computer for both the upper and lower channels, the model atmosphere being that given in Fig.17. The resulting dispersion curves computed in this manner are shown in the lower portion of Fig 19. One set of curves (the dashed curves) is appropriate to the W.K.B.J. model for the lower channel and the other set (the solid curves) is appropriate to the W.K.B.J. model for the upper channel. In the upper portion of the same figure are shown again dispersion curves as generated by the computer model INFRASONIC WAVEFORMS. It should be mentioned that the computer model solves a more complex problem in the sense that the simplifications inherent in the W.K.B.J. model are not present.

As is illustrated in the lower portion of Fig.19, the two sets of dispersion curves generated by the W.K.B.J. models intersect with one another at various points. A comparison of the dispersion curves shown in both the upper and lower portions of Fig. 19 reveals that these points

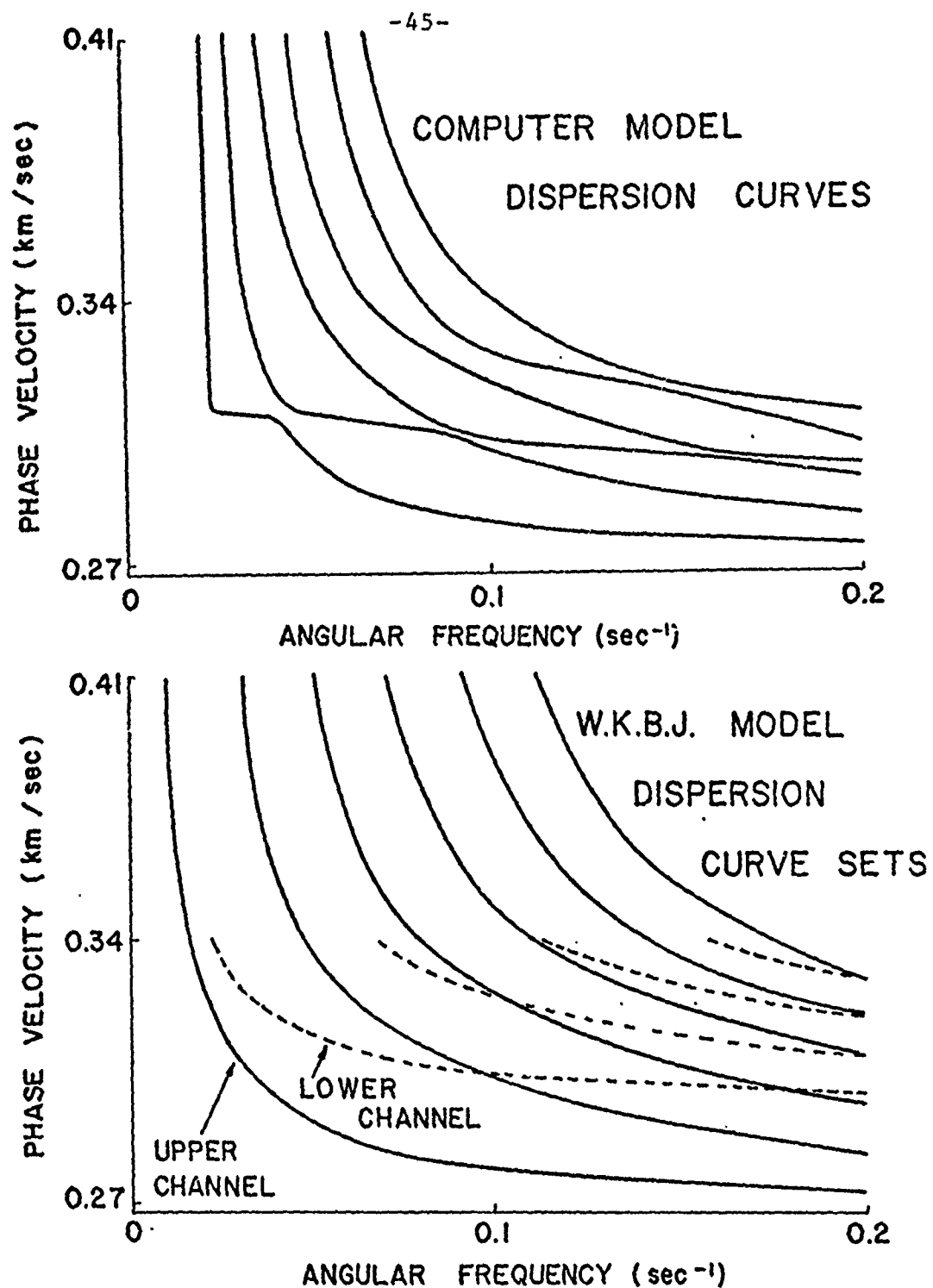


Figure 19. A comparison of theoretical guided mode dispersion curves for the U. S. Standard Atmosphere 1962. The upper set of curves were generated by full wave calculations with the multi-modal synthesis program INFRASONIC WAVEFORMS. The lower sets were obtained by applying the W.K.B.J. method to the upper sound channel (solid lines) and the lower sound channel (dashed lines), respectively.

of intersection mark regions of resonant interaction in the phase velocity-angular frequency plane between adjacent modes of the computer model. To better illustrate this observation, in the right hand portion of Fig. 20 is shown one such region of interaction with its corresponding point of intersection between two dispersion curves of the W.K.B.J. models shown to the left. It should be mentioned that the dispersion curves of the computer model never intersect with one another. An analytical explanation of this fact has previously been given by Pierce²².

4.4 INFERENCES CONCERNING ENERGY VERSUS HEIGHT DISTRIBUTION

The above observation may be stated differently by saying that, for relatively high angular frequencies, the dispersion curve corresponding to a given mode of the computer model is comprised of portions of dispersion curves from both sets of the curves generated by the W.K.B.J. models. Two important inferences about the asymptotic high-frequency behavior of guided infrasonic modes can be drawn from this statement. First, for some frequency ranges, and depending on how dispersion curve portions match between curves of the computer model and the W.K.B.J. models, it can be inferred that the acoustic energy associated with a given mode is comprised of energy associated more with propagation of acoustic disturbances in one sound speed channel than in the other. Also, as frequency increases, this association alternates back and forth between channels. To illustrate, if, for a small range of frequencies, a portion of a dispersion curve of the computer model matches (in the phase velocity-angular frequency plane) a portion of one of the W.K.B.J. model curves for the upper channel, then that implies that, for that mode and for that small frequency range, the acoustic energy density associated with that mode is greater in the upper channel than in the lower channel. Secondly, in the standard reference atmosphere, the sound speed minimum for the upper channel is less in magnitude than the sound speed minimum for the lower channel. It can be inferred, therefore, that those acoustic disturbances for which phase velocities are less in magnitude than the sound speed minimum for the lower channel are associated more with acoustic energy trapped in the upper channel than in the lower channel, and thus, for this reason, do not contribute significantly to the acoustic energy at the ground. This inference implies that care must

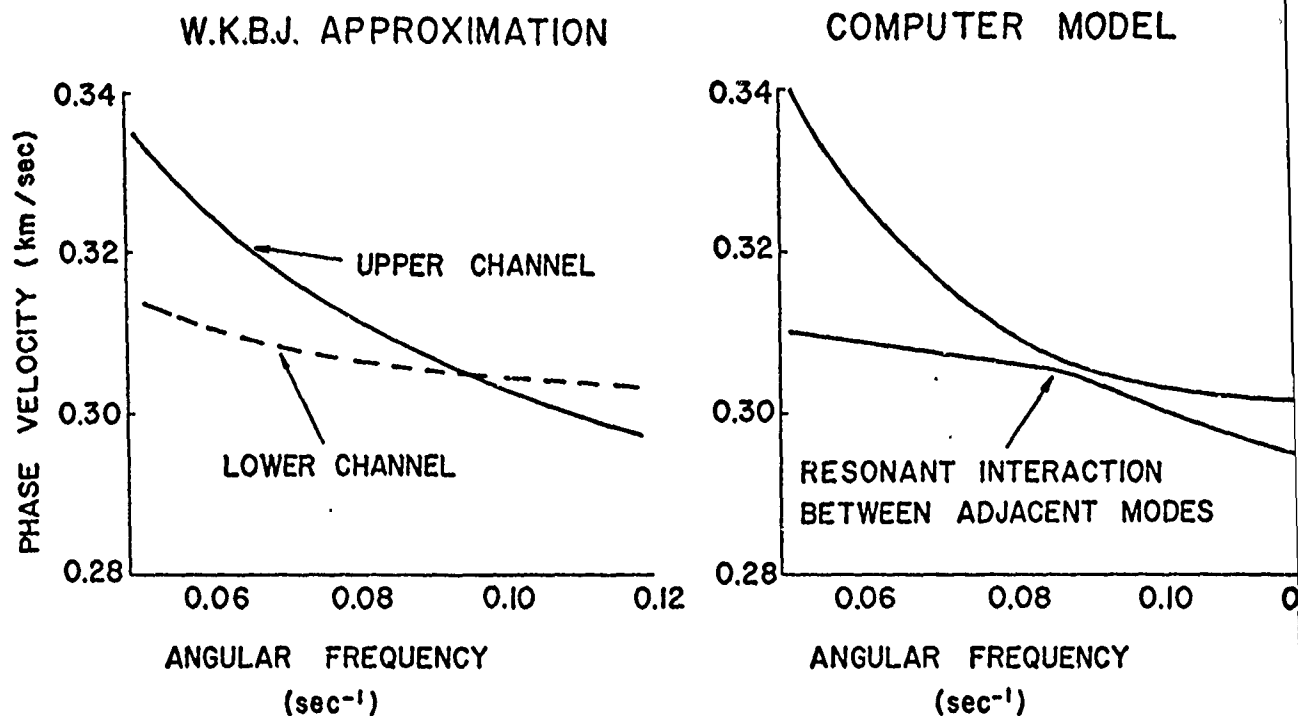


Figure 20. A detailed (blown-up) plot of a section of Fig. 19 showing a region of resonant interaction between two modes, one ducted in the upper channel, the other ducted in the lower channel. The full wave calculation (computer model) indicates that the two modes interact such that the actual dispersion curves do not cross, but indicates that the W.K.B.J. and computer model curves are nearly the same except in the region of resonant interaction.

be taken as to which modes are chosen to superpose in the attainment of the final pressure waveform at the ground, as some may not contribute.

4.5 IMPLICATIONS FOR WAVEFORM SYNTHESIS

In the previous synthesis of guided pressure waveforms at long distances, the acoustic modes were numbered in order of increasing phase velocity (i.e., $S_0, S_1, S_2, \dots$, etc.) and the sum over modes was truncated at a finite maximum number of modes. The analysis given here indicates that this may be a very poor approximation for synthesizing high frequency portions of waveforms observed near the ground since there is always some frequency above which the first, say, N modes all correspond to channelling in the upper sound speed channel.

The preferable alternative would appear to be (for synthesis of ground level arrivals from sources below 50 km altitude) to ignore the upper sound speed channel completely for frequencies above, say, at least 0.2 rad/sec (possibly 0.1 rad/sec) corresponding to periods below at most 30 sec (possibly 1 min). The dispersion curves could then be taken as given by the W.K.B.J. approximation and the mode amplitude versus height profiles could be computed by the method outlined by Haskell. The dispersion curves and amplitudes so computed would fit directly into the general scheme outlined by Pierce and Posey¹ which forms the theoretical basis for the current version of INFRASONIC WAVEFORMS.

Chapter V

EXTENSION OF INFRASONIC WAVEFORMS TO INCLUDE DISTANCES BEYOND THE ANTIPODE

5.1 INTRODUCTION

Previous theoretical considerations incorporated into the digital computer program INFRASONIC WAVEFORMS restricted synthesis to waves that had traveled less than one-half the distance around the earth. The purpose of this chapter is to further exemplify techniques to enable computer synthesis of acoustic-gravity pressure waveforms at points whose distances are greater than halfway around the world from a nuclear explosion. Extension of prior theory shows that for wave propagation past a point on a spherical earth, one-half the great circle distance away from the point of detonation (i.e., the antipode), a phase shift of $\pi/2$ radians to the Fourier transforms of each modal wave is incurred. Modification to the computer program necessitates the reinterpretation of the great circle distance r , the inclusion of the $\pi/2$ phase shift, and a modification to the earth curvature correction factor. Computations are presented for pre and post antipodal waveforms.

5.2 THEORETICAL CONSIDERATIONS FOR POST-ANTIPODAL WAVEFORMS

In considering acoustic-gravity waves that have passed beyond the antipode, certain specific definitions for the various waveforms must be adopted. To an observer located on the surface of a spherical earth between the source and the antipode the pressure waveform that is first observed is the direct arrival or A_1 arrival. The A_1 arrival has traveled the shortest great circle distance r to reach the observation point. The next waveform observed at the above observation point is the A_2 or antipodal arrival. The A_2 arrival has traveled the longer great circle distance from the explosion point around the globe passing through the antipode to reach the observation point. The A_3 arrival is the A_1 pressure waveform that has traveled completely around the globe with respect

to the observation point. Further arrivals exist but are not considered here. The distance r is measured in kilometers and is the great circle distance measured from the detonation point to the final observation point. Figure 21 shows some typical pressure waveforms recorded in suburban New York for the Russian explosion of 58 megatons at Novaya Zemlya on 30 October 1961.²³

Previous numerical syntheses of acoustic-gravity waveforms have only considered direct arrivals. The extension of this theory to include waveform prediction for antipodal arrivals is described here. An investigation of a small region of the earth's surface in the vicinity of the antipode where prior theory breaks down yields certain waveform characteristics that enable waveform synthesis to be extended to ranges past the antipode. By taking the antipodal region smaller in area than say 1/100th of the earth's area as a whole we can consider this region to be flat. Then the equation governing propagation of any frequency in any guided mode near the antipode is the cylindrical wave equation in the form of

$$\partial^2 F / \partial r_A^2 + (1/r_A) \partial F / \partial r_A - (1/V_p^2) \partial^2 F / \partial t^2 = 0 \quad (5.1)$$

where F would represent the r_A and t dependent part of the integration kernel for synthesization (i.e., integration over frequency of any given modal waveform where the height dependent part is omitted here). The quantity V_p is the corresponding phase velocity. The assumed circular symmetry of the wave about the antipode is inherent in the absence of the angular derivative terms in the above equation. The distance r_A is measured positive out from the antipode. The wave solution to Eq. (5.1) for the total acoustic pressure p and small r_A can be written for time t as

$$F \approx DJ_0(kr_A) \cos(\omega t + \epsilon) \quad (5.2)$$

For the above, $k = \omega/V_p$ represents the horizontal wave number, ω the angular frequency, and ϵ some phase angle. The quantity D is some arbitrary constant while $J_0(kr_A)$ is the Bessel function of zero order.

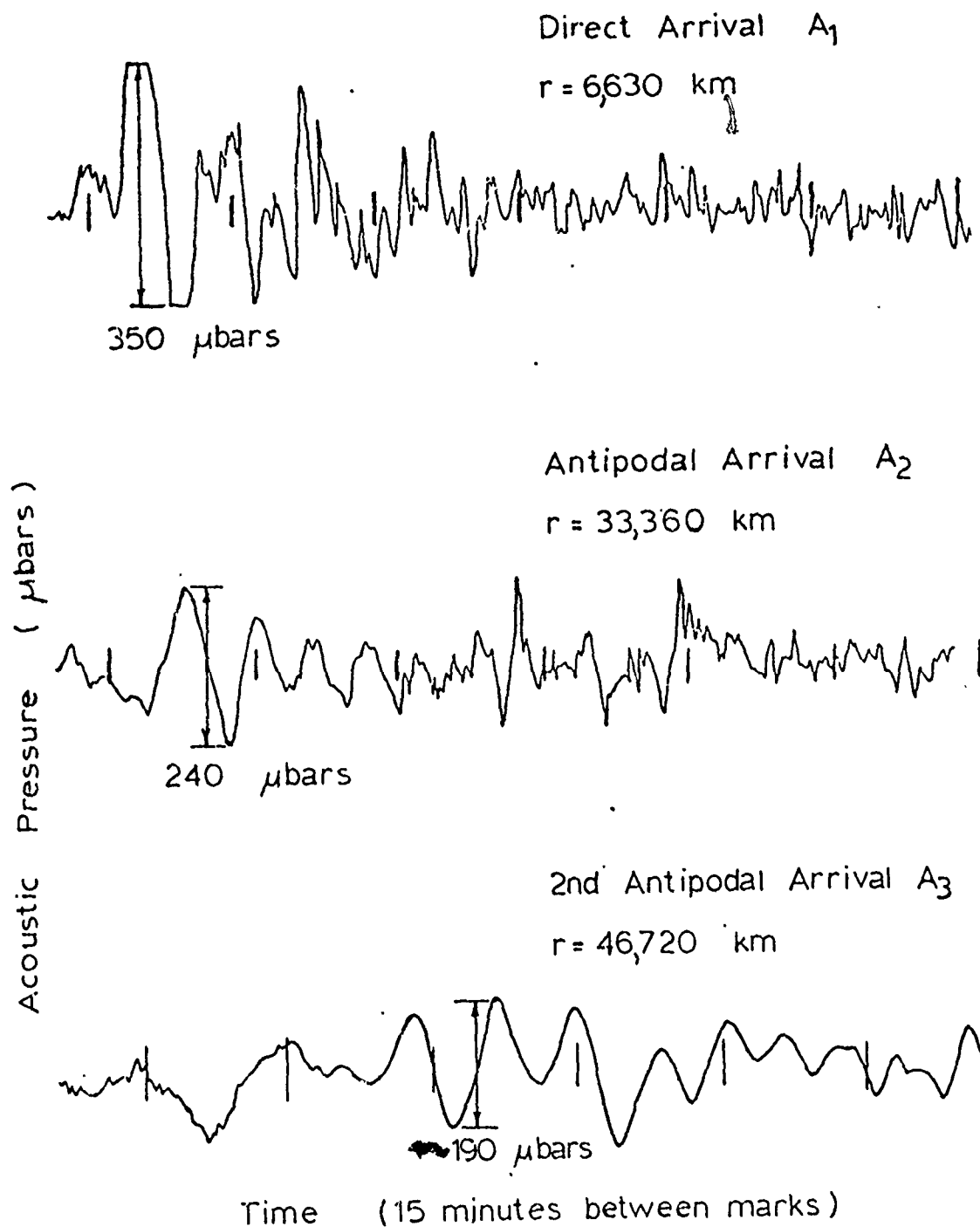


Figure 21. Infrasonic pressure waveforms recorded in suburban New York following the detonation of a 58 megaton yield nuclear device in Novaya Zemlya USSR on 30 October 1961. [Extracted from Donn and Shaw, Rev. of Geophys. 5, 53-82 (1967).]

When r_A is sufficiently large (i.e., greater than three wavelengths) a solution for the total acoustic pressure p can be considered as a sum of ingoing and outgoing waves with respect to the antipodal region. The asymptotic solution for large kr_A can be written for time t as

$$F = A(r_A)^{-1/2} \cos(\omega t + kr_A + \phi_{in}) + B(r_A)^{-1/2} \cos(\omega t - kr_A + \phi_{out}) \quad (5.3)$$

In Eq. (5.3) ϕ is some phase angle while ω and k are as previously defined. The plus sign in the argument of the cosine denotes an ingoing wave. Equation (5.3) is not defined at $r_A = 0$ and, as r_A approaches zero, wave amplification is predicted. Figure 22 illustrates waveform amplification approaching the antipode for three different values of r for a ten megaton nuclear explosion. The antipode is reached when $r = 20,000$ km.

Realizing that Eqs. (5.2) and (5.3) should represent the same pressure waveform at large r_A we can now show the existence of a phase difference between waveforms approaching and leaving the antipode. For large r_A , the Bessel function $J_0(kr_A)$ can be represented by its asymptotic approximation such that Eq. (5.2) becomes

$$F = D(2/\pi r_A k)^{1/2} \cos(kr_A - \pi/4) \cos(\omega t + \epsilon) \quad (5.4)$$

or with the aid of trigonometric identities as

$$F = \frac{1}{2} D(2/\pi r_A k)^{1/2} [\cos(\omega t + \epsilon + kr_A - \pi/4) + \cos(\omega t + \epsilon - kr_A + \pi/4)] \quad (5.5)$$

Equating (5.3) to (5.5) then requires that

$$A = B = D/(2\pi k)^{1/2} \quad (5.6a)$$

$$\phi_{in} = \epsilon - \pi/4 \quad (5.6b)$$

$$\phi_{out} = \epsilon + \pi/4 \quad (5.6c)$$

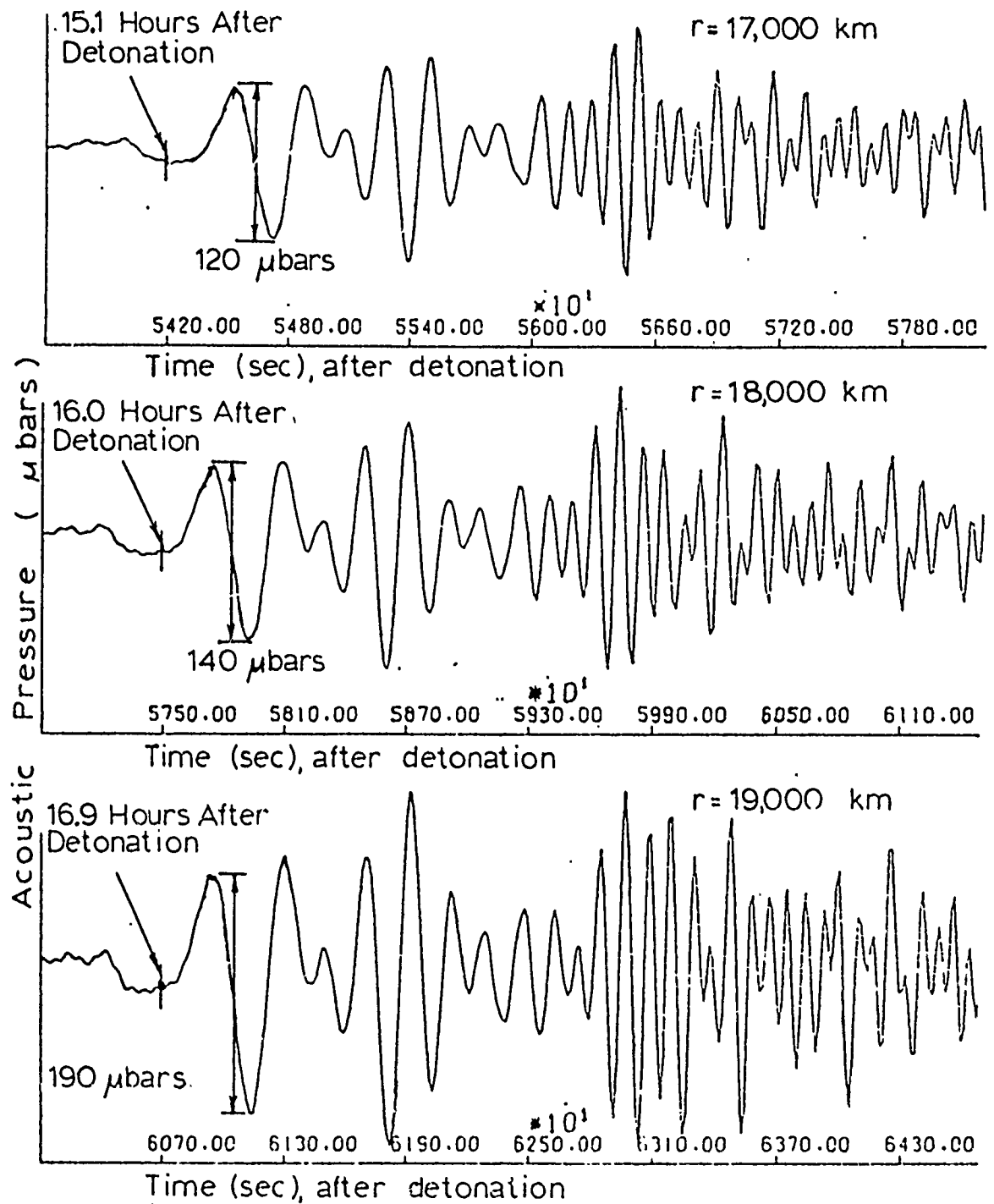


Figure 22. Theoretical pressure waveforms of a pulse propagating towards the antipode (corresponding to a great circle distance r of 20,000 km). Computations presented are for a 10 megaton burst in a standard atmosphere without winds. Note the amplification in amplitude for values of r successively closer to 20,000 km.

so

$$\phi_{out} = \phi_{in} + \pi/2 \quad (5.7)$$

The latter shows that a pressure waveform undergoes a phase shift of 90 degrees. Based on this knowledge the computer program has been altered to synthesize pressure waveforms for the A_2 arrival that passes through the antipode.

5.3 MODIFICATIONS TO INFRASONIC WAVEFORMS FOR POST ANTIPODAL WAVEFORMS

Waveform synthesis for ranges beyond the antipode necessitates only minor adjustments to the computer program. By considering the theoretical development of Brune, Nafe, and Alsop (1961)²⁴ for circular spreading of waves over a spherical surface of radius r_e (i.e., $r_e = 6374$ km for earth) the amplitude correction factor for the curvature of a spherical earth, appearing in subroutine TMPT, is altered for post antipodal waveforms by replacing the term $\sin(r/r_e)$ by its absolute magnitude, where r is interpreted as the total distance the wave has traveled from the point of detonation. For post antipodal arrivals considered here r would be between πr_e and $2\pi r_e$ kilometers. The earth curvature correction factor in subroutine TMPT appearing as

$$CF = (1./(6374. * SIN(RAD)))*0.5 \quad (5.8)$$

is replaced for post antipodal waveforms by

$$CF = (1./(6374.*ABS(SIN(RAD))))*0.5 \quad (5.9)$$

where ROBS = r and

$$RAD = ROBS/6374. \quad (5.10)$$

To accomodate the change in phase as the waveforms pass through the antipode two computer cards of the form

$$PH2 = PH2 + 1.570796 \quad (5.11)$$

are inserted in the deck listing of subroutine TMPT after lines 160 and 177.

After incorporating the above modifications into subroutine TMPT the computer program was then utilized to synthesize various theoretical waveforms. Using the Soviet shot of 30 October 1961 as the source, a phase shift upon passing through the antipode is exhibited in Fig. 23 for two observation ranges of a synthesized pressure waveform. Further dispersion beyond the antipode of the pressure waveform is shown in Fig. 24 for a ten megaton explosion. A comparison of antipodal arrivals for a computer synthesized pressure waveform and a microbarograph recorded by Donn and Shaw in suburban New York⁵ for the 58 megaton Soviet test is presented in Fig. 25. Considering the scattering in waveforms that can occur at such large arrival distances, it is not unreasonable to say that the amplitudes and typical periods of the two plots are of the same order of magnitude.

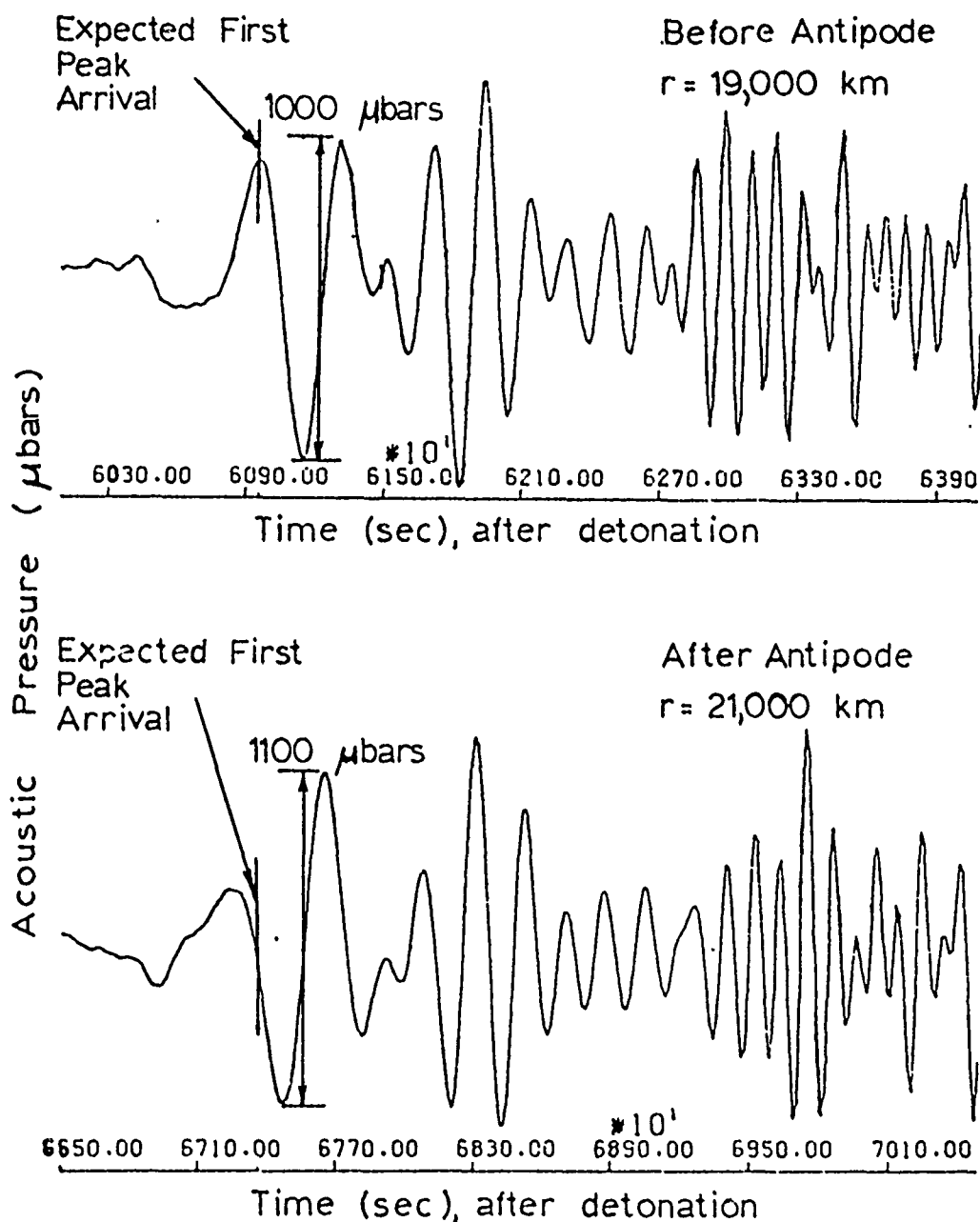


Figure 23. Theoretical pressure waveforms just before (great circle distance r of 19,000 km) and just after (r of 21,000 km) passing through the antipode (20,000 km). The $\pi/2$ phase shift after the antipodal passage is evidenced by the second figure. Time of expected first peak arrival derived from linear extrapolation of computed time of first peak arrival versus great circle distance for $r < 20,000$ km to case of $r > 20,000$ km. Source is the 58 megaton Soviet test in Novaya Zemlya.

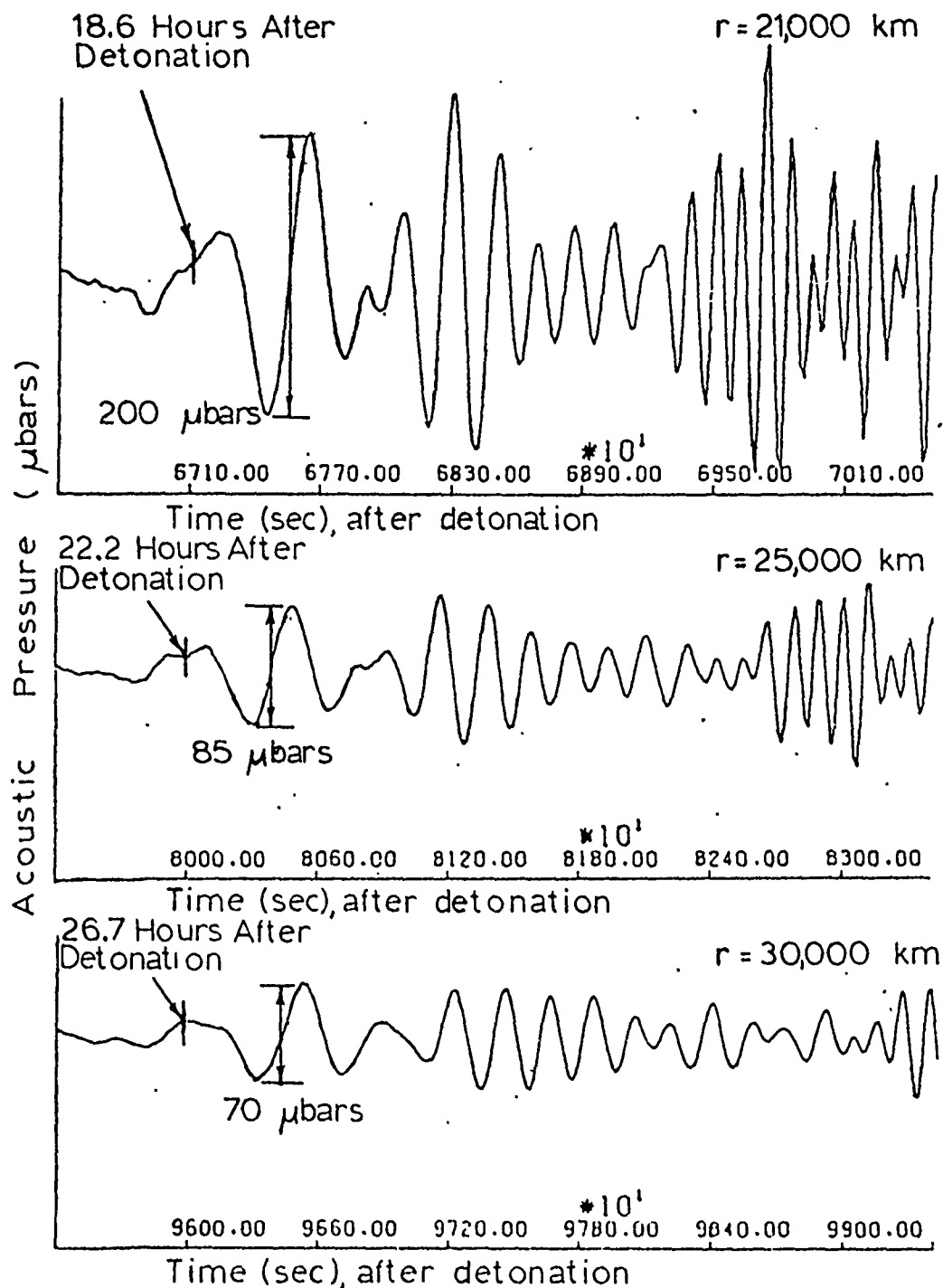


Figure 24. Theoretical pressure waveform for a pulse propagating away from the antipode. Decrease of amplitude and increased frequency dispersion occurs with increasing great circle distance r . The source is a 10 megaton nuclear explosion in a standard atmosphere without winds.

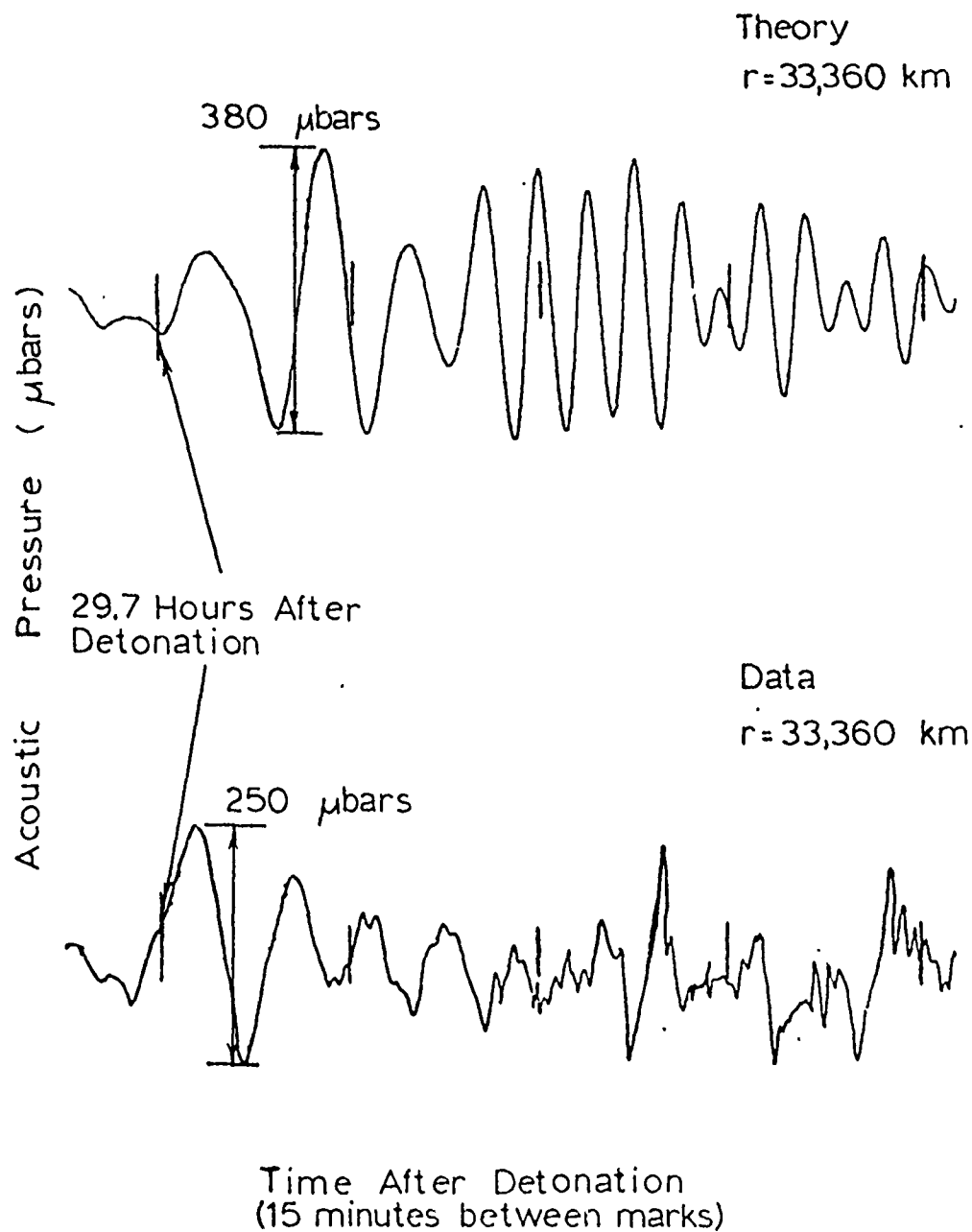


Figure 25. A comparison of theoretical and observed antipodal (A_2) arrivals for pressure wave recorded in suburban New York following the detonation of a 58 megaton yield nuclear device in Novaya Zemlya USSR on 30 October 1961. Note that the amplitude scales for the two records are not the same. Observed waveform taken from Donn and Shaw, *Revs. of Geophys.* 5, 53-82 (1967).

Chapter VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 REMARKS CONCERNING INFRASONIC WAVEFORMS

The new version of INFRASONIC WAVEFORMS contained in this report (Appendix A) allows for the computation of waveforms which have propagated past the antipode and for the computation of waveforms including leaking modes. Our remarks here concentrate on the latter modification.

If one chooses a model atmosphere in which the sound speed is constant above some arbitrary large height, it is inevitable that the GR_0 and GR_1 modes should have lower cutoff frequencies and be leaking below that altitude. Beyond a certain point, one would expect that the computations should be independent of this choice of height, provided the analysis were carried through with some degree of exactitude. If there were a genuine sensitivity, this would indicate that these modes carry an appreciable fraction of their energies at high altitudes and this would in turn suggest that the neglect of physical dissipative mechanisms (such as viscosity and thermal conduction, Joule heating, etc.), which increase dramatically at extremely large heights for the frequencies of interest here, is not a valid approximation.

The reason we cannot take the bottom of our upper halfspace to be arbitrarily large is that some modal height-amplitudes decrease exponentially at large altitudes. This exponential decrease implies that, if one attempts to calculate the transmission matrix $[R]$ connecting variables at the bottom of the upper halfspace to those at the ground, then the elements of $[R]$ are going to be extremely large and the mathematical theorem that the determinant of $[R]$ be 1, while true in principle, is not going to be satisfied for the actual numerical values computed because of the loss of significant figures. The net result is such large fluctuations in the eigenmode dispersion function due to round-off errors that it is impossible to determine its roots. This problem

always arises at sufficiently high frequencies when the upper halfspace bottom is taken too high.

In Chapter III, a simple expedient for circumventing this difficulty is implicitly described. One uses one atmosphere for low frequencies, another atmosphere for higher frequencies. The atmosphere for the higher frequency calculations has its halfspace beginning at, say, 125 km altitude while the atmosphere for the lower frequency calculations has its upper halfspace beginning at, say, 225 km. Given the premise that, for the GR_0 and GR_1 modes (which appear to be the only modes for which we have problems at low frequencies), the energy is ducted below 125 km, the temperature above 225 km can be made as large as one desires without changing the answers. Thus one simply chooses this temperature to be so large that the lower cutoff frequencies for the two modes are, for all practical purposes, zero. In this manner one can construct the phase velocities and source free amplitude functions versus frequency for these modes down to arbitrarily small frequencies.

Another question is whether or not the k_I (imaginary part of wave-number) for the leaking modes are physically meaningful. They obviously would be meaningful were the actual atmosphere terminated by an upper halfspace and were there no physical dissipation mechanisms. However, the actual atmosphere is more complicated than this model and one has to accept the fact that (1) an approximate atmosphere is going to give rise to approximate answers and (2) that the values of the k_I are going to depend on the choice of the bottom height of the upper halfspace. Thus the k_I are really somewhat arbitrary. Fortunately, the values of the k_I so derived are very small, at least for the example we have numerically carried out, that the computed waveforms are almost the same as if the k_I were identically zero.

With the above remarks in mind, it is recommended that the calculations of the k_I for the GR_0 and GR_1 modes below cutoff not be carried out in the synthesizing of waveforms. Rather, one should either set the k_I for frequencies below cutoff as given in our numerical example or to 2×10^{-10} (i.e., for all intents and purposes, zero). The reason the k_I

should not be set identically to zero is that the computer program uses the nonzeroness of k_I as a flag to decide whether to look for an input value of AMP (source free amplitude) or to compute the number internally (it can't do this at frequencies below cutoff and will consequently return $AMP = 0$). While this may seem a rather simple thing to do, considering the elaborate mathematical theory developed² in Scientific Report No. 1, the analysis and computations which preceded the formulations of this recommendation were necessary, if only to establish that the procedure has some rigorous mathematical basis.

In any event, it is evident that one must and should include contributions from the frequencies below the nominal low frequency cutoff (determined by the upper halfspace) if one is to adequately synthesize the initial portions of waveforms. The present report shows how this may be done. The procedure, although requiring several (three, in general) runs of the program rather than just one run to accomplish this, is relatively straightforward. It is obviously feasible to automate this so that only one run is necessary, but the time limitations of the present study precluded our doing so.

6.2 DISCREPANCY WITH LAMB EDGE MODE THEORY

It was hoped that the inclusion of leaking modes into the multi-mode synthesis would eliminate the discrepancy between the numerical predictions of the Lamb edge mode theory and the multi-mode theory. It is evident, however, from Fig. 16 in the present report that this has not turned out to be the case. The cause of the discrepancy has not been resolved and time limitations precluded its resolution. There is always the possibility that either program may have a mistake. However, barring this, it should be pointed out that the modified multimode theory should be the more nearly correct. The Lamb edge mode theory¹⁵ contains a number of approximations which the multi-mode theory does not contain. Consequently, it is recommended that the multi-mode model as modified here be used in preference to the Lamb edge mode model.

The relative simplicity of the edge mode model still retains an intrinsic appeal and, consequently, it is recommended that some future effort be expended in revising the model (possibly by including higher order terms in the dispersion relation) such that the discrepancy is resolved.

6.3 GUIDED MODES AT HIGHER FREQUENCIES

The procedure outlined in Chapter IV for using a modified W.K.B.J. approximation to order the modes and to compute modal parameter at high frequencies looks eminently feasible and is recommended for inclusion into the multi-mode synthesis program INFRASONIC WAVEFORMS. Although, again, time limitations precluded this, we regret not having done so in the present study. The motivation for doing this, however, is not as strong as for the low frequency modifications because the commonly available data in the open literature is markedly poor as regards high frequency arrivals. If and when such a modification is carried out, one should ideally have appropriate data with which to compare the numerical predictions.

Another problem is that there is some question as to whether a multi-modal theory with a finite number of modes (even when judiciously selected) can ever adequately synthesize higher frequency arrivals. In many respects, we believe that an appropriate modification of a geometrical acoustics theory would be preferable.

6.4 GEOMETRICAL ACOUSTICS MODEL

The geometrical acoustics model described³ in Scientific Report No. 2, although still incompletely developed, appears to hold considerable promise for the understanding of higher frequency arrivals. We know now how to take the edge mode into account and how to handle the problem of caustics. Problems of aretes, lacunae, and wave diffusion from channel to channel still remain, but we believe these can be overcome with only a modest amount of additional theoretical effort.

The ultimate objective of the analysis should be to develop the simplest possible theory sufficient to explain and interpret available data. In this respect, we would suggest that both the multi-mode and geometrical acoustical models, while perhaps more elaborate than should be ideally required, could be used as research tools to conduct numerical experiments which test simpler models. The statistical models developed by P. Smith²⁵ for underwater acoustics appear especially attractive in this regard and we believe that one should be able to test his models using the geometrical acoustics model described in Scientific Report No. 2. Also, the types of numerical experiments envisioned should provide the inspiration and support required to refine Smith's models such that they be capable of a more nearly precise description of infrasonic waveforms.

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APPENDIX A

SOURCE DECK LISTING OF THE PRESENT
VERSION OF INFRASONIC WAVEFORMS

This supercedes the source deck listing originally given by Pierce and Posey in AFCRL-70-0134. Changes incorporated include those described by Pierce, Moo, and Posey in AFCRL-TR-73-0135 and those described in the present report.

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PROGRAM INFR (INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT,
1PUNCH, TAPE7=PUNCH, TAPE2)
MAIN PROGRAM 7/23/69
C
C *****
C
C PROGRAM TO SYNTHESIZE PRESSURE WAVEFORMS OF ACOUSTIC
C GRAVITY WAVES GENERATED BY NUCLEAR EXPLOSIONS IN THE
C ATMOSPHERE
C
C *****
C
C -----ABSTRACT-----
C
C TITLE - MAIN PROGRAM
C GENERAL PURPOSE PROGRAM FOR STUDYING THE PROPAGATION OF NUCLEAR
C EXPLOSION GENERATED ACOUSTIC GRAVITY WAVES IN THE ATMOSPHERE.
C
C THE ATMOSPHERE IS APPROXIMATED BY A MULTILAYER ATMOSPHERE
C WITH CONSTANT WIND VELOCITY AND TEMPERATURE IN EACH LAYER.
C THE NUMBER OF LAYERS, WIDTHS OF LAYERS, AND PROPERTIES OF
C LAYERS MAY BE SELECTED BY THE USER. THE GROUND AT Z=0 IS
C ASSUMED FLAT AND RIGID. THE UPPERMOST LAYER OF THE
C ATMOSPHERE IS ASSUMED TO BE UNBOUNDED FROM ABOVE.
C
C THE SOURCE IS SPECIFIED BY ITS HEIGHT OF BURST AND ENERGY
C YIELD. IT IS APPROXIMATED AS A POINT ENERGY SOURCE WITH
C TIME DEPENDENCE CONFORMING TO CURE FOOT (HYCRODYNAMIC)
C SCALING DERIVED FROM THE EFFECTS OF NUCLEAR WEAPONS
C (U.S. GOVERNMENT PRINTING OFFICE, 1952).
C
C THE OBSERVER LOCATION MAY BE SPECIFIED ARBITRARILY.
C HOWEVER, THE COMPUTATION INCLUDES ONLY CONTRIBUTIONS FROM
C FULLY DUCTED GUIDED MODES AND ACCORDINGLY GIVES A SOLUTION
C VALID (AT BEST) ONLY AT LARGE HORIZONTAL DISTANCES.
C ALSO, THE PROGRAMMING IS BASED ON THE PREMISE THAT ONLY
C PORTIONS OF MODES WITH PHASE VELOCITIES GREATER THAN THE
C MAXIMUM WIND SPEED ARE TO BE INCLUDED INTO THE COMPUTATION.
C THE PROGRAM CANNOT THEREFORE BE APPLIED TO THE STUDY OF
C CRITICAL LAYER EFFECTS.
C
C LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4)
C
C AUTHORS - A.D. PIERCE AND J. POSEY, M.I.T., JUNE, 1968
C
C -----USAGE-----
C
C ALL DATA IS INPUT IN THE NAMELIST FORMAT. EACH SEQUENCE OF DATA
C MUST INCLUDE A NAME GROUP AT THE BEGINNING.
C
C CENAM1 NSTART= , NPRNT= , NPUNCH= &END
C
C THE REMAINDER OF THE DATA TO BE SUPPLIED DEPENDS ON THE VALUE
C OF NSTART.
C
C *****NSTART=1*****
C CENAM2 LANG= , IMAX= , T= , , , , VKNTX= , , , , ETC. &
C CENAM4 THETK= , V1= , V2= , OM1= , ETC. &
C CENAM6 ZSOURCE= , ZOBSS= &END
C CENAM9 YIELD= &END
C CENAM10 YFIRST= , YEND= , DELTY= , ROSS= , IOPT= &END
C
C *****NSTART=2*****
C CENAM3 IMAX= , CI= , , , , VXi= , , , , ETC. &END
C CENAM4 THETK= , V1= , V2= , OM1= , ETC. &END
C CENAM6 ZSOURCE= , ZOBSS= &END
C CENAM9 YIELD= &END
C CENAM10 YFIRST= , YEND= , DELTY= , ROSS= , IOPT= &END
C
C *****NSTART=3*****

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CINAM5  IMAX= , CI= , .... VXI= , , .... ETC. . . . . IEND      MAIN      71
CINAM6  ZSRCE= , ZORS= , IEND      MAIN      72
CINAM8  YIELD= IEND      MAIN      73
CINAM10 TFIRST= , TEND= , DELTT= , ROSS= , IOPT= IEND      MAIN      74
C      MAIN      75
C      *****NSTART=4*****
CINAM7  OMMOD= , , .... VPMOD= , , .... MODFNO= , ETC.      MAIN      76
CINAM8  YIELD= IEND      MAIN      77
CINAM10 TFIRST= , TEND= , DELTT= , ROSS= , IOPT= IEND      MAIN      78
C      MAIN      79
C      *****NSTART=5*****
CINAM9  MODFNO= , KST= , , .... KFIN= , , .... OMMOD= , , ETC.      MAIN      80
CINAM10 TFIRST= , TEND= , DELTT= , ROSS= , IOPT= IEND      MAIN      81
C      MAIN      82
C      *****NSTART=6*****
C      MAIN      83
C      (NO ADDITIONAL DATA IS NEEDED. COMPUTATION TERMINATES.)      MAIN      84
C      MAIN      85
C      FOR A COMPLETE LIST OF VARIABLES THAT ARE INCLUDED IN A GIVEN      MAIN      86
C      NAMELIST GROUP, SEE NAMELIST STATEMENTS IN PROGRAM. NOTE THAT      MAIN      87
C      DATA INPUT BY READ(5,NAM1), READ(5,NAM2), ETC., NEED NOT INCLUDE      MAIN      88
C      VALUES OF ALL VARIABLES IN THE CORRESPONDING NAMELIST GROUP. ONE      MAIN      89
C      NEED ONLY INPUT THOSE VALUES NEEDED FOR THE CALCULATION AND WHICH      MAIN      90
C      ARE NOT ALREADY IN STORAGE.      MAIN      91
C      MAIN      92
C      DATA ASSOCIATED WITH NAM3, NAM5, NAM7, AND NAM9 SHOULD IN GENERAL      MAIN      93
C      NOT BE SUPPLIED ARBITRARILY, BUT MAY BE OBTAINED FROM PREVIOUS      MAIN      94
C      RUNS OF THE PROGRAM. IF NSTART=1, NPNCH=1, DATA CARDS FOR NAM3,      MAIN      95
C      NAM5, NAM7, AND NAM9 ARE AUTOMATICALLY PUNCHED. IF NSTART=2,      MAIN      96
C      NPNCH=1, DATA CARDS FOR NAM5, NAM7, AND NAM9 ARE PUNCHED. IF      MAIN      97
C      NSTART=3, NPNCH=1, DATA CARDS FOR NAM7 AND NAM9 ARE PUNCHED. IF      MAIN      98
C      NSTART=4, NPNCH=1, DATA CARDS FOR NAM9 ARE PUNCHED.      MAIN      99
C      MAIN      100
C      THE NEXT BATCH OF DATA AFTER NAM10 SHOULD BE NAM1. THE LAST DATA      MAIN      101
C      CARD SHOULD BE NAM1 WITH NSTART=6.      MAIN      102
C      MAIN      103
C      MAIN      104
C      MAIN      105
C      -----EXTERNAL SUBROUTINES REQUIRED-----      MAIN      106
C      SUBROUTINE      TYPE      CALLED BY      MAIN      107
C      AAAA      SUB      ELINT,PPPM,NAMPDE,NMODF      MAIN      108
C      AKI      SUB      THPT      MAIN      109
C      ALLMOD      SUB      MAIN      110
C      AMENT      SUB      PAMPDE      MAIN      111
C      ATMOS      SUB      MAIN      112
C      AXIS1      SUB      THPT (M.I.T. CALCOMP ROUTINE)      MAIN      113
C      B998      SUB      ELINT      MAIN      114
C      CAI      FUNC      B998,MMMM      MAIN      115
C      OXOY1      SUB      THPT (M.I.T. CALCOMP ROUTINE)      MAIN      116
C      ELINT      SUB      TOTINT      MAIN      117
C      ENOPLT      SUB      THPT (M.I.T. CALCOMP ROUTINE)      MAIN      118
C      FNM001      FUNC      MODCTR (EXTERNAL FOR ARG. OF RTMI)      MAIN      119
C      FNM002      FUNC      MODCTR (EXTERNAL FOR ARG. OF RTMI)      MAIN      120
C      LNGLTHN      SUB      TABLE      MAIN      121
C      MMMM      SUB      NAMPDE,RRRR      MAIN      122
C      MODCTR      SUB      ALLMOD      MAIN      123
C      MODLST      SUB      MAIN      MAIN      124
C      MPOUT      SUB      TABLE      MAIN      125
C      NAMPDE      SUB      PAMPDE      MAIN      126
C      NEWPLT      SUB      THPT (M.I.T. CALCOMP ROUTINE)      MAIN      127
C      NMODFN      SUB      FNM001,FNM002,LNGLTHN,MPOUT,WIGEN      MAIN      128
C      NUMBRI      SUB      THPT (M.I.T. CALCOMP ROUTINE)      MAIN      129
C      NXMODE      SUB      ALLMOD      MAIN      130
C      NXPNT      SUB      MODCTR      MAIN      131
C      PAMPDE      SUB      MAIN      MAIN      132
C      PHASE      SUB      SOURCE      MAIN      133
C      PLOT1      SUB      THPT (M.I.T. CALCOMP ROUTINE)      MAIN      134
C      PPAMP      SUB      MAIN      MAIN      135
C      PRATMO      SUB      MAIN      MAIN      136
C      RRRR      SUB      NMODFN      MAIN      137
C      RTMI      SUB      MODCTR (IBM SCIENTIFIC SUBROUTINE)      MAIN      138

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C	SAI	FUNC	R09B,MMHM	MAIN	141
C	SCLGPH	SUB	TMPT (M.I.T. CALCOMP ROUTINE)	MAIN	142
C	SOURCE	SUB	PPAMP	MAIN	143
C	SUSPCT	SUB	TAPLE	MAIN	144
C	SYNOLS	SUB	TMPT (M.I.T. CALCOMP ROUTINE)	MAIN	145
C	TARLE	SUB	MAIN	MAIN	146
C	TABPRT	SUB	MAIN	MAIN	147
C	TMPT	SUB	MAIN	MAIN	148
C	TOTINT	SUB	NAMPDE	MAIN	149
C	UPINT	SUB	TOTINT	MAIN	150
C	USEAS	SUB	TOTINT	MAIN	151
C	WIDEN	SUB	TAELE	MAIN	152
C				MAIN	153
C			----INPUTS THROUGH NAMELIST READ STATEMENTS----	MAIN	154
C				MAIN	155
C	NAM1 -- NAMELIST GROUP 1			MAIN	156
C				MAIN	157
C	NSTART		=FLAG DENOTING POINT IN MAIN PROGRAM AT WHICH COMPUTA	MAIN	158
C			TION BEGINS. POSSIBLE VALUES OF 1 THROUGH 5 CAUSE	MAIN	159
C			NAM2, NAM3, NAM5, NAM7, OR NAM9 TO BE READ. NSTART=	MAIN	160
C			CAUSES TERMINATION OF PROGRAM EXECUTION.	MAIN	161
C	NPRNT		=FLAG FOR PRINTING OPTION. IF NPRNT .LE. 0, A MINIMA	MAIN	162
C			AMOUNT OF PRINTOUT WILL BE RETURNED.	MAIN	163
C	NPNCN		=FLAG FOR PUNCHING OPTION. IF NPNCN .LE. 0, NO INFO	MAIN	164
C			WILL BE PUNCHED ON CARDS.	MAIN	165
C				MAIN	166
C	NAM2 -- NAMELIST GROUP 2			MAIN	167
C				MAIN	168
C	LANGLE		=INTEGER WHICH SPECIFIES WHICH TYPE OF ATMOSPHERIC DA	MAIN	169
C			IS INPUT. IF LANGLE .LE. 0, THE WIND COMPONENTS IN	MAIN	170
C			KNOTS ARE SPECIFIED, WHILE IF LANGLE .GT. 0, THE WIND	MAIN	171
C			MAGNITUDE AND DIRECTION ARE SPECIFIED FOR EACH LAYER	MAIN	172
C	IMAX		=NUMBER OF LAYERS OF FINITE THICKNESS IN MULTILAYER	MAIN	173
C			ATMOSPHERE.	MAIN	174
C	T(I)		=TEMPERATURE IN DEGREES KELVIN IN THE I-TH LAYER.	MAIN	175
C	VKNTX(I)		=X (WEST TO EAST) COMPONENT OF WIND VELOCITY IN I-TH	MAIN	176
C			LAYER.	MAIN	177
C	VKNTY(I)		=Y (SOUTH TO NORTH) COMPONENT OF WIND VELOCITY IN I-TH	MAIN	178
C			LAYER.	MAIN	179
C	WINDV(I)		=WIND VELOCITY MAGNITUDE IN KNOTS IN I-TH LAYER.	MAIN	180
C	WANGLE(I)		=WIND VELOCITY DIRECTION IN DEGREES, RECKONED COUNTER	MAIN	181
C			CLOCKWISE FROM X-AXIS.	MAIN	182
C	ZI(I)		=HEIGHT IN KILOMETERS OF THE TOP OF THE I-TH LAYER OF	MAIN	183
C			FINITE THICKNESS.	MAIN	184
C				MAIN	185
C	NAM3 -- NAMELIST GROUP 3			MAIN	186
C				MAIN	187
C	IMAX		=NUMBER OF LAYERS OF FINITE THICKNESS.	MAIN	188
C	CI(I)		=SOUND SPEED IN KM/SEC IN I-TH LAYER.	MAIN	189
C	VXI(I)		=X COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC).	MAIN	190
C	VYI(I)		=Y COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC).	MAIN	191
C	HI(I)		=THICKNESS IN KM OF I-TH LAYER OF FINITE THICKNESS.	MAIN	192
C				MAIN	193
C	NAM4 -- NAMELIST GROUP 4			MAIN	194
C				MAIN	195
C	THETKO		=DIRECTION IN DEGREES TO OBSERVER, RECKONED COUNTER	MAIN	196
C			CLOCKWISE FROM X AXIS.	MAIN	197
C	V1		=LOWER BOUND IN KM/SEC OF PHASE VELOCITY INTERVAL CON	MAIN	198
C			SIDERED FOR NONPAL MODE TABULATION	MAIN	199
C	V2		=UPPER BOUND IN KM/SEC OF PHASE VELOCITY INTERVAL CON	MAIN	200
C			SIDERED FOR NONPAL MODE TABULATION	MAIN	201
C	OM1		=MINIMUM ANGULAR FREQUENCY IN RAD/SEC CONSIDERED FOR	MAIN	202
C			NONPAL MODE TABULATION.	MAIN	203
C	OM2		=MAXIMUM ANGULAR FREQUENCY IN RAD/SEC CONSIDERED FOR	MAIN	204

C		NORMAL MODE TABULATION.	MAIN	205
C	NOMI	=INITIAL NUMBER OF DISCRETE FREQUENCIES BETWEEN CM1	MAIN	206
C		AND CM2, INCLUSIVE, AT WHICH NORMAL MODE DISPERSION	MAIN	207
C		FUNCTION IS STUDIED.	MAIN	208
C	NVPI	=INITIAL NUMBER OF DISCRETE PHASE VELOCITIES BETWEEN	MAIN	209
C		V1 AND V2, INCLUSIVE, AT WHICH NORMAL MODE DISPERSION	MAIN	210
C		FUNCTION IS STUDIED.	MAIN	211
C	MAXMOD	=MAXIMUM NUMBER OF MODES TO BE TABULATED.	MAIN	212
C			MAIN	213
C	NAM5 -- NAMELIST GROUP 5		MAIN	214
C			MAIN	215
C	IMAX	=NUMBER OF LAYERS OF FINITE THICKNESS	MAIN	216
C	CI(I)	=SOUND SPEED IN KM/SEC IN I-TH LAYER	MAIN	217
C	VXI(I)	=X COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)	MAIN	218
C	VYI(I)	=Y COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)	MAIN	219
C	HI(I)	=THICKNESS IN KM OF I-TH LAYER OF FINITE THICKNESS	MAIN	220
C	THETKO	=DIRECTION IN DEGREES TO OBSERVER, RECKONED COUNTER	MAIN	221
C		CLOCKWISE FROM X AXIS	MAIN	222
C	MOFNO	=NUMBER OF NORMAL MODES FOUND	MAIN	223
C	KST(N)	=INDEX OF FIRST TABULATED POINT IN N-TH MODE	MAIN	224
C	KFIN(N)	=INDEX OF LAST TABULATED POINT IN N-TH MODE. IN	MAIN	225
C		GENERAL, KFIN(N)=KST(N+1)-1.	MAIN	226
C	OMMOD(N)	=ARRAY STORING ANGULAR FREQUENCY ORDINATE (RAD/SEC) OF	MAIN	227
C		POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR	MAIN	228
C		FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).	MAIN	229
C	VPMOD(N)	=ARRAY STORING PHASE VELOCITY ORDINATE (KM/SEC) OF	MAIN	230
C		POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR	MAIN	231
C		FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).	MAIN	232
C			MAIN	233
C	NAM6 -- NAMELIST GROUP 6		MAIN	234
C			MAIN	235
C	ZSCRCE	=HEIGHT IN KM OF BURST ABOVE GROUND	MAIN	236
C	ZOBS	=HEIGHT IN KM OF OBSERVER ABOVE GROUND	MAIN	237
C			MAIN	238
C	NAM7 -- NAMELIST GROUP 7		MAIN	239
C			MAIN	240
C	OMMOD(N)	=ARRAY STORING ANGULAR FREQUENCY ORDINATE (RAD/SEC) OF	MAIN	241
C		POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR	MAIN	242
C		FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).	MAIN	243
C	VPMOD(N)	=ARRAY STORING PHASE VELOCITY ORDINATE (KM/SEC) OF	MAIN	244
C		POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR	MAIN	245
C		FOR N BETWEEN KST(NMODE) AND KFIN(NMODE)	MAIN	246
C	MOFNO	=NUMBER OF NORMAL MODES FOUND	MAIN	247
C	KST(N)	=INDEX OF FIRST TABULATED POINT IN N-TH MODE	MAIN	248
C	KFIN(N)	=INDEX OF LAST TABULATED POINT IN N-TH MODE. IN	MAIN	249
C		GENERAL, KFIN(N)=KST(N+1)-1.	MAIN	250
C	AMP(J)	=AMPLITUDE FACTOR FOR GUIDED WAVE EXCITED BY POINT	MAIN	251
C		ENERGY SOURCE. UNITS ARE KM**(-1). THE J-TH ELEMENT	MAIN	252
C		CORRESPONDS TO ANGULAR FREQUENCY OMMOD(J) AND PHASE	MAIN	253
C		VELOCITY VPMOD(J). THE AMPLITUDE FACTOR IS APPROPRI	MAIN	254
C		TO THE NMODE-TH MODE IF J.GE. KST(NMODE) AND J.LE.	MAIN	255
C		KFIN(NMODE). A DETAILED DEFINITION OF AMP(J) IS GIV	MAIN	256
C		IN THE LISTING OF SUBROUTINE NAMODE.	MAIN	257
C	ALAM	=A SCALING FACTOR DEPENDENT ON HEIGHT OF BURST. EQUAL	MAIN	258
C		TO CUBE ROOT OF (PRESSURE AT GROUND)/(PRESSURE AT	MAIN	259
C		BURST HEIGHT) TIMES (SOUND SPEED AT GROUND)/(SOUND	MAIN	260
C		SPEED AT BURST HEIGHT). SEE SUBROUTINE PAMODE.	MAIN	261
C	FACT	=A GENERAL AMPLITUDE FACTOR DEPENDENT ON BURST HEIGHT	MAIN	262
C		AND OBSERVER HEIGHT. A PRECISE DEFINITION IS GIVEN	MAIN	263
C		IN THE LISTING OF SUBROUTINE PAMODE.	MAIN	264
C			MAIN	265
C	NAM8 -- NAMELIST GROUP 8		MAIN	266
C			MAIN	267
C	YIELD	=ENERGY YIELD OF EXPLOSION IN EQUIVALENT KILOTONS (KT	MAIN	268

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C      ... OF TNT. 1 KT = 4.2X(10)**19 ERGS. MAIN 269
C      MAIN 270
C NAM9 -- NAMELIST GROUP 9 MAIN 271
C      MAIN 272
C      MOFND =NUMBER OF NORMAL MODES FOUND MAIN 273
C      KST(N) =INDEX OF FIRST TABULATED POINT IN N-TH MODE MAIN 274
C      KFIN(N) =INDEX OF LAST TABULATED POINT IN N-TH MODE. IN MAIN 275
C      GENERAL, KFIN(N)=KST(N+1)-1 MAIN 276
C      OMNOD(N) =ARRAY STORING ANGULAR FREQUENCY ORDINATE (RAD/SEC) O MAIN 277
C      POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR MAIN 278
C      FOR N BETWEEN KST(NMODE) AND KFIN(NMODE). MAIN 279
C      VPHOD(N) =ARRAY STORING PHASE VELOCITY ORDINATE (KM/SEC) OF MAIN 280
C      POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR MAIN 281
C      FOR N BETWEEN KST(NMODE) AND KFIN(NMODE). MAIN 282
C      AMPLTO(N) =AMPLITUDE FACTOR REPRESENTING TOTAL MAGNITUDE OF MAIN 283
C      FOURIER TRANSFORM OF WAVEFORM CONTRIBUTION OF SINGLE MAIN 284
C      GUIDED MODE AT FREQUENCY OMNOD(N). IT REPRESENTS TH MAIN 285
C      AMPLITUDE OF NMODE-TH MODE IF N IS BETWEEN KST(NMODE) MAIN 286
C      AND KFIN(NMODE), INCLUSIVE. FOR PRECISE DEFINITION, MAIN 287
C      SEE SUBROUTINE PPAMP. MAIN 288
C      PHASQ(N) =PHASE LAG AT FREQUENCY OMNOD(N) FOR NMODE MODE WHEN MAIN 289
C      N BETWEEN KST(NMODE) AND KFIN(NMODE), RESPECTIVELY. MAIN 290
C      THE INTEGRAND IS UNDERSTOOD TO HAVE THE FORM MAIN 291
C      , AMPLTC*COS(OMNOD*(TIME-DISTANCE/VPHOD)+PHASQ). FOR MAIN 292
C      PRECISE DEFINITION OF PHASQ, SEE SUBROUTINES TMPT MAIN 293
C      AND PPAMP. MAIN 294
C      MAIN 295
C NAM10 -- NAMELIST GROUP 10 MAIN 296
C      MAIN 297
C      TFIRST =FIRST TIME RELATIVE TO TIME OF DETONATION FOR WHICH MAIN 298
C      WAVEFORM IS COMPUTED. UNITS ARE IN SECONDS. MAIN 299
C      TEND =APPROXIMATE TIME VALUE CORRESPONDING TO LAST POINT MAIN 300
C      TABULATED FOR WAVEFORM (RELATIVE TO TIME OF DETONATI MAIN 301
C      FOR PRECISE DEFINITION. SEE SUBROUTINE TMPT. MAIN 302
C      DELTT =INCREMENT OF TIME VALUES IN SECONDS FOR WHICH SUCCES MAIN 303
C      SIVE WAVEFORM POINTS ARE TABULATED. MAIN 304
C      ROBS =MAGNITUDE OF HORIZONTAL DISTANCE IN KM BETWEEN SOURC MAIN 305
C      AND OBSERVER. MAIN 306
C      IOPT =INTEGER CONTROLLING WHICH MODES ARE INCLUDED IN THE MAIN 307
C      COMPUTED WAVEFORM. FOR PRECISE DEFINITION, SEE MAIN 308
C      SUBROUTINE TMPT. MAIN 309
C      MAIN 310
C      MAIN 311
C      ----PROGRAM FOLLOWS BELOWS ---- MAIN 312
C      MAIN 313
C      MAIN 314
C DIMENSION STATEMENTS MAIN 315
C      DIMENSION CI(100),VXI(100),VYI(100),HI(100),AMP(1000),AMPLTO(1000) MAIN 316
C      DIMENSION T(100),VKNTX(100),VKNTY(100),ZI(100),PHASQ(1000) MAIN 317
C      DIMENSION WANGLE(100),WINDY(100) MAIN 318
C      DIMENSION OM(100),VP(100),INMODE(10000) MAIN 319
C      DIMENSION KST(10),KFIN(10),OMMCO(1000) MAIN 320
C      1VP400(1000),AKI(1000),I4UF(1400) MAIN 321
C      DIMENSION OMGR1(50),VFGRI(50),AKIGRI(50),OMGRP(50), MAIN 322
C      1VPGRI(50),AKIGRO(50),AMPGR(50),AMPGR1(50) MAIN 323
C      MAIN 324
C ALLOCATION OF VARIABLES TO COMMON STORAGE MAIN 325
C      COMMON IMAX,CI,VXI,VYI,HI MAIN 326
C      MAIN 327
C NAMELIST STATEMENTS MAIN 328
C      NAMELIST /NAM1/ NSTAPT,NPENT,NPNCH,NCHPL MAIN 329
C      NAMELIST /NAM2/ LANGLE,IMAX,T,VKNTX,VKNTY,WINDY,WANGLE,ZI MAIN 330
C      NAMELIST /NAM3/ IMAX,CI,VXI,VYI,HI MAIN 331
C      NAMELIST /NAM4/ THETK0,V1,V2,OM1,OM2,NOMI,AVPI,HAXMCO MAIN 332

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NAMELIST /NAM5/ INAX,CI,VXI,VYI,HI,THEYKO,MOFNO,KST,KFIN,OMH07,	MAIN	333
1 VPH00	MAIN	334
NAMELIST /NAM6/ ZSCRCE,Z09S	MAIN	335
NAMELIST /NAM7/ CHMOO,VPH00,MOFNO,KST,KFIN,AMP,ALAM,FACT	MAIN	336
NAMELIST /NAM8/ YIELD	MAIN	337
NAMELIST /NAM9/ MOFNO,KST,KFIN,OMH00,VPH00,AMP,LTO,PHASQ	MAIN	338
NAMELIST /NAM10/ TFIRST,TEND,DELTT,RO9S,IOPT	MAIN	339
NAMELIST /NAM51/ HNGR1,AMPGR1,HNGR0,N0GR0,OMGR1,VFGR1,OMGR0,	MAIN	340
1VPGR0,AKIGR1,AKIGR0,AMPGR0,AMPGR1	MAIN	341
	MAIN	342
	MAIN	343
C	MAIN	344
C BEFORE ANY DATA IS READ IN. ALL NAMELIST VALUES ARE PRESET TO ZERO.	MAIN	345
C THIS IS DONE SIMPLY TO MAKE NAMELIST PRINTOUT EASIER TO READ.	MAIN	346
NSTART=0	MAIN	347
NPRNT=0	MAIN	348
NPNCH=0	MAIN	349
NCHPL=0	MAIN	350
LANGLE=0	MAIN	351
INAX=0	MAIN	352
THEYKO=0.0	MAIN	353
V1=0.0	MAIN	354
V2=0.0	MAIN	355
OM1=0.0	MAIN	356
OM2=0.0	MAIN	357
NOMI=0	MAIN	358
NVPI=0	MAIN	359
MAXH00=0	MAIN	360
MOFNO=0	MAIN	361
ZSCRCE=0.0	MAIN	362
Z09S=0.0	MAIN	363
ALAM=0.0	MAIN	364
FACT=0.0	MAIN	365
YIELD=0.0	MAIN	366
TFIRST=0.0	MAIN	367
TEND=0.0	MAIN	368
DELTT=0.0	MAIN	369
RO9S=0.0	MAIN	370
IOPT=0	MAIN	371
DO 21 IPR=1,100	MAIN	372
CI(IPR)=0.0	MAIN	373
VXI(IPR)=0.0	MAIN	374
VYI(IPR)=0.0	MAIN	375
HI(IPR)=0.0	MAIN	376
T(IPR)=0.0	MAIN	377
VKNTX(IPR)=0.0	MAIN	378
VKNTY(IPR)=0.0	MAIN	379
ZI(IPR)=0.0	MAIN	380
WANGLE(IPR)=0.0	MAIN	381
WINDY(IPR)=0.0	MAIN	382
OM(IPR)=0.0	MAIN	383
21 VP(IPR)=0.0	MAIN	384
DO 31 IPR=1,10	MAIN	385
KST(IPR)=0	MAIN	386
31 KFIN(IPR)=0	MAIN	387
DO 41 IPR=1,1000	MAIN	388
AMP(IPR)=0.0	MAIN	389
AMP,LTO(IPR)=0.0	MAIN	390
PHASQ(IPR)=0.0	MAIN	391
OMH00(IPR)=0.0	MAIN	392
AKI(IPR)=0.0	MAIN	393
41 VPH00(IPR)=0.0	MAIN	394
	MAIN	395
	MAIN	396
C		
C		
C START OF EXECUTABLE PORTION OF PROGRAM		

C	NEWPLY IS A CALCOMP SUBROUTINE WHICH INITIATES THE CALCOMP PLOTTER	MAIN	397
C	TAPE FILE. 5640 IS THE M.I.T. COMPUTATION CENTER PROBLEM NO. 5923 I	MAIN	398
C	THE PROGRAMMER NO. GRAPH PAPER WITH BLACK INK IS REQUESTED.	MAIN	399
	CALL PLOTS(IRUF,1400,2,00)	MAIN	400
C		MAIN	401
	1 READ (5,NAM1)	MAIN	402
C		MAIN	403
C	IT IS CONSIDERED GOOD PRACTICE TO HAVE INPUT DATA PRINTED ON OUTPUT	MAIN	404
	WRITE (6,37)	MAIN	405
	37 FORMAT(1H ///// 27H1NAM1 HAS JUST BEEN READ IN)	MAIN	406
	WRITE (6,NAM1)	MAIN	407
C		MAIN	408
C	CURRENT VALUE OF NSTART CONTROLS THE STAGE AT WHICH COMPUTATION BEGIN	MAIN	409
C	SINCE COMPUTED GO TO STATEMENTS SOMETIMES DO NOT COMPILE CORRECTLY IF	MAIN	410
C	INDEX IS NOT EXPLICITLY DEFINED, WE PLAY IT SAFE WITH REDUNDANT	MAIN	411
C	STATEMENT.	MAIN	412
	NSTART=NSTART	MAIN	413
C		MAIN	414
	GO TO (200,300,400,500,600,999),NSTART	MAIN	415
C		MAIN	416
C	WE ARRIVE HERE IF NSTART=1	MAIN	417
	200 READ (5,NAM2)	MAIN	418
C		MAIN	419
	WRITE (6,237)	MAIN	420
	237 FORMAT(1H ///// 27H NAM2 HAS JUST BEEN READ IN)	MAIN	421
	WRITE (6,NAM2)	MAIN	422
C		MAIN	423
C	CONVERT ATMOSPHERIC DATA TO STANDARD FORM	MAIN	424
	CALL ATMOS(T,VKNTX,VKNTY,ZI,WANGLE,WINDY,LANGLE)	MAIN	425
	IF(NPRNT .LE. 0) GO TO 270	MAIN	426
C		MAIN	427
C	PRINT ATMOSPHERIC PROFILE IF NPRNT .GT. 0	MAIN	428
	CALL PRATHO	MAIN	429
C		MAIN	430
	270 IF(NPNCH .LE. 0) GO TO 305	MAIN	431
C		MAIN	432
C	PUNCH NAM3 DATA IF NPNCH .GT. 0	MAIN	433
	WRITE (7,271)	MAIN	434
	271 FORMAT (74 (NAM3)	MAIN	435
	IUHS = IMAX + 1	MAIN	436
	WRITE (7,272) IMAX, (CI(I),I=1,IUHS)	MAIN	437
	272 FORMAT (10H IMAX = ,I3,1H, / 9H CI = /	MAIN	438
	1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	439
	WRITE(7,274) (VXI(I),I=1,IUHS)	MAIN	440
	274 FORMAT(9H VXI = /	MAIN	441
	1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	442
	WRITE(7,275) (VYI(I),I=1,IUHS)	MAIN	443
	275 FORMAT(9H VYI = /	MAIN	444
	1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	445
	WRITE(7,276) (HI(I),I=1,IUHS)	MAIN	446
	276 FORMAT (8H HI = /	MAIN	447
	1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	448
	WRITE (7,279)	MAIN	449
	279 FORMAT (64 (END)	MAIN	450
	WRITE (6,583)	MAIN	451
	WRITE (6,271)	MAIN	452
	WRITE (6,272) IMAX, (CI(I),I=1,IUHS)	MAIN	453
	WRITE(6,274) (VXI(I),I=1,IUHS)	MAIN	454
	WRITE(6,276) (VYI(I),I=1,IUHS)	MAIN	455
	WRITE(6,278) (HI(I),I=1,IUHS)	MAIN	456
	WRITE (6,279)	MAIN	457
	280 GO TO 305	MAIN	458
C		MAIN	459
		MAIN	460

C WE ARRIVE HERE IF NSTART=2	MAIN	461
300 READ (5,NAM3)	MAIN	462
WRITE (6,302)	MAIN	463
302 FORMAT(1H ///// 27H NAM3 HAS JUST BEEN READ IN)	MAIN	464
WRITE (6,NAM3)	MAIN	465
IF(NPRNT .LE. 0) GO TO 305	MAIN	466
C PRINT ATMOSPHERIC PROFILE IF NPRNT .GT. 0	MAIN	467
CALL PPATMO	MAIN	468
C	MAIN	469
C CONTINUING FROM 270, 290, 302, OR 303	MAIN	470
305 READ (5,NAM4)	MAIN	471
WRITE (6,307)	MAIN	472
307 FORMAT(1H ///// 27H NAM4 HAS JUST BEEN READ IN)	MAIN	473
WRITE (6,NAM4)	MAIN	474
C	MAIN	475
C CONVERT THETKD FROM DEGREES TO RADIAN	MAIN	476
THETK = (3.14159) * THETKD / 180.0	MAIN	477
NOM = NOP1	MAIN	478
NVP = NVPI	MAIN	479
C	MAIN	480
C CONSTRUCT TABLE OF INMODE VALUES	MAIN	481
CALL TABLE(OM1,OM2,V1,V2,NCH,NVP,THETK,OM,VP,INMODE,NPRNT)	MAIN	482
C	MAIN	483
C COMPUTE DISPERSION CURVES OF GUIDED MODES	MAIN	484
CALL ALLMOD(NVP,NCH,PAXPCO,MOFNO,OM,VP,KST,KFIN,CHMOD,VPMOD,	MAIN	485
1 INMODE,THETK,KHOP)	MAIN	486
IF(NCHOL .LE. 0) GO TO 309	MAIN	487
READ(5,NAM51)	MAIN	488
KBEGIN = KST(MNGR1)	MAIN	489
KENDI = KFIN(MNGRO)	MAIN	490
KENDF = KBEGIN + NPGRO + NPGR1 - 1	MAIN	491
IF(KENDF .LE. KENDI) GO TO 3085	MAIN	492
KFINP1 = KENDI + 1	MAIN	493
KFINMO = KFIN(MOFNO)	MAIN	494
DO 3081 LL = KFINP1,KFINMO	MAIN	495
L = KFINMO + KFINP1 - LL	MAIN	496
LNEW = L + KENDF - KENDI	MAIN	497
OMMOD(LNEW) = OMMOD(L)	MAIN	498
VPMOD(LNEW) = VPMOD(L)	MAIN	499
AKI(LNEW) = AKI(L)	MAIN	500
AMP(LNEW) = AMP(L)	MAIN	501
3081 CONTINUE	MAIN	502
MNGROP1 = MNGRO + 1	MAIN	503
DO 3082 KKL = MNGROP1,MCFNO	MAIN	504
KL = MNGROP1 + MOFNO - KKL	MAIN	505
KFIN(KL) = KFIN(KL) + KENDF - KENDI	MAIN	506
3082 KST(KL) = KST(KL) + KENDF - KENDI	MAIN	507
GO TO 3088	MAIN	508
3085 CONTINUE	MAIN	509
KFINP1 = KFIN(MNGRO) + 1	MAIN	510
KFINMO = KFIN(MOFNO)	MAIN	511
DO 3086 L = KFINP1,KFINMO	MAIN	512
LNEW = L + KENDF - KENDI	MAIN	513
OMMOD(LNEW) = OMMOD(L)	MAIN	514
VPMOD(LNEW) = VPMOD(L)	MAIN	515
AKI(LNEW) = AKI(L)	MAIN	516
AMP(LNEW) = AMP(L)	MAIN	517
3086 CONTINUE	MAIN	518
MNGROP1 = MNGRO + 1	MAIN	519
DO 3087 KKL = MNGROP1,MCFNO	MAIN	520
KL = MNGROP1 + MOFNO - KKL	MAIN	521
KFIN(KL) = KFIN(KL) + KENDF - KENDI	MAIN	522
3087 KST(KL) = KST(KL) + KENDF - KENDI	MAIN	523
3088 CONTINUE	MAIN	524

KST(MNGR1) = KBEGIN	MAIN	525
KFIN(MNGR1) = KST(MNGR1) + NPGR1 - 1	MAIN	526
KST(MNGR0) = KFIN(MNGR1) + 1	MAIN	527
KFIN(MNGR0) = KST(MNGR0) + NPGRO - 1	MAIN	528
DO 3189 L = 1, NPGR1	MAIN	529
LNEW = KST(MNGR1) + L - 1	MAIN	530
OMMOD(LNEW) = OMGR1(L)	MAIN	531
VPMOD(LNEW) = VPGR1(L)	MAIN	532
AKI(LNEW) = AKIGR1(L)	MAIN	533
AMP(LNEW) = AMPGR1(L)	MAIN	534
3188 CONTINUE	MAIN	535
DO 3089 L = 1, NPGRO	MAIN	536
LNEW = KST(MNGR0) + L - 1	MAIN	537
OMMOD(LNEW) = OMGR0(L)	MAIN	538
VPMOD(LNEW) = VPGR0(L)	MAIN	539
AKI(LNEW) = AKIGR0(L)	MAIN	540
AMP(LNEW) = AMPGR0(L)	MAIN	541
3089 CONTINUE	MAIN	542
309 CONTINUE	MAIN	543
C	MAIN	544
C CHECK TO SEE IF ANY MODES WERE FOUND	MAIN	545
IF(KWOP .GE. 0) GO TO 320	MAIN	546
C	MAIN	547
C EXIT IF KWOP .LT. 0	MAIN	548
WRITE (6,321) KWOP	MAIN	549
311 FORMAT(1H , 5HKWOP=, I3)	MAIN	550
CALL EXIT	MAIN	551
C	MAIN	552
C CONTINUING WITH KWOP .GE. 0 FROM 308	MAIN	553
IF (NPRNT .LE. 0) GO TO 350	MAIN	554
C PRINT NORMAL MODE DISPERSION CURVES	MAIN	555
CALL MODLST(MOFNO,OMMOD,VPMOD,AKI,KST,KFIN)	MAIN	556
C	MAIN	557
C CONTINUING FROM 320 OR 321	MAIN	558
350 IF(NPNCH .LE. 0) GO TO 360	MAIN	559
C	MAIN	560
C PUNCH NAME DATA IF NPNCH .GT. 0	MAIN	561
WRITE (7,351)	MAIN	562
351 FORMAT (7H NAME)	MAIN	563
IUMS = IMAX + 1	MAIN	564
WRITE (7,272) IMAX, (CI(I), I=1, IUMS)	MAIN	565
WRITE (7,274) (VXI(I), I=1, IUMS)	MAIN	566
WRITE (7,276) (VYI(I), I=1, IUMS)	MAIN	567
WRITE (7,279) (HI(I), I=1, IUMS)	MAIN	568
WRITE (7,352) THETKO, MOFNO, (KST(I), I=1, MOFNO)	MAIN	569
352 FORMAT (11H THETKO =, G15.8, 1H, /10H MOFNO =, I3, 1H, /8H KST =,	MAIN	570
1 (6X, G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H,))	MAIN	571
WRITE (7,355) (KFIN(I), I=1, MOFNO)	MAIN	572
355 FORMAT (10H KFIN = /	MAIN	573
1 (6X, G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H,))	MAIN	574
KLAST = KFIN(MOFNO)	MAIN	575
WRITE (7,357) (OMMOD(I), I=1, KLAST)	MAIN	576
357 FORMAT (11H OMMOD = /	MAIN	577
1 (6X, G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H,))	MAIN	578
WRITE (7,359) (VPMOD(I), I=1, KLAST)	MAIN	579
359 FORMAT (11H VPMOD = /	MAIN	580
1 (6X, G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H, ., G15.8, 1H,))	MAIN	581
WRITE (7,279)	MAIN	582
WRITE (6,583)	MAIN	583
WRITE (6,351)	MAIN	584
WRITE (6,272) IMAX, (CI(I), I=1, IUMS)	MAIN	585
WRITE (6,274) (VXI(I), I=1, IUMS)	MAIN	586
WRITE (6,276) (VYI(I), I=1, IUMS)	MAIN	587
WRITE (6,279) (HI(I), I=1, IUMS)	MAIN	588

WRITE (6,352) THETKD,MCFND,(KST(I),I=1,MCFND)	MAIN	589
WRITE(6,355) (KFIN(I),I=1,MCFND)	MAIN	590
WRITE (6,357) (CMHOD(I),I=1,KLAST)	MAIN	591
WRITE(6,359) (VPMOD(I),I=1,KLAST)	MAIN	592
WRITE (6,279)	MAIN	593
C	MAIN	594
C CONTINUING FROM 350 OR 351	MAIN	595
360 GO TO 415	MAIN	596
C	MAIN	597
C	MAIN	598
C WE ARRIVE HERE IF NSTART=3	MAIN	599
400 READ (5,NAM5)	MAIN	600
WRITE (6,403)	MAIN	601
403 FORMAT(1H ///// 27H NAM5 HAS JUST BEEN READ IN)	MAIN	602
WRITE (6,NAM5)	MAIN	603
C	MAIN	604
C CONVERT THETKD FROM DEGREES TO RADIANS	MAIN	605
THETK = (3.14159) * THETKD / 180.0	MAIN	606
C	MAIN	607
C CONTINUING FROM 360 OR 402	MAIN	608
415 READ (5,NAM6)	MAIN	609
WRITE (6,417)	MAIN	610
417 FORMAT(1H ///// 27H NAM6 HAS JUST BEEN READ IN)	MAIN	611
WRITE (6,NAM6)	MAIN	612
C	MAIN	613
C COMPUTE YIELD INDEPENDENT AMPLITUDE FACTORS FOR GUIDED MODES	MAIN	614
CALL PAMFOE(ZSCRC,ZCBS,MCFND,KST,KFIN,CMHOD,VPMOD,AKI,	MAIN	615
1AMP,ALAM,FACT,THETK,NPRNT)	MAIN	616
C	MAIN	617
450 IF(NPMCH .LE. 0) GO TO 450	MAIN	618
C	MAIN	619
C PUNCH NAM7 DATA IF NPMCH .GT. 0	MAIN	620
KLAST = KFIN(MCFND)	MAIN	621
WRITE (7,451) (AMP(I),I=1,KLAST)	MAIN	622
451 FORMAT (7H 1NAM7 / 9H AMP = /	MAIN	623
1 (6X,G15.9,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	624
WRITE (7,452) ALAM,FACT	MAIN	625
452 FORMAT (10H ALAM = ,G16.8,1H, / 10H FACT = ,G16.8,1H,)	MAIN	626
WRITE (7,455) MCFND,(KST(I),I=1,MCFND)	MAIN	627
455 FORMAT (10H MCFND = ,I3,1H,/8H KST = /	MAIN	628
1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	629
WRITE(7,355) (KFIN(I),I=1,MCFND)	MAIN	630
WRITE (7,357) (CMHOD(I),I=1,KLAST)	MAIN	631
WRITE(7,359) (VPMOD(I),I=1,KLAST)	MAIN	632
WRITE (7,279)	MAIN	633
WRITE (6,583)	MAIN	634
WRITE (6,451) (AMP(I),I=1,KLAST)	MAIN	635
WRITE (6,452) ALAM,FACT	MAIN	636
WRITE (6,455) MCFND,(KST(I),I=1,MCFND)	MAIN	637
WRITE(6,355) (KFIN(I),I=1,MCFND)	MAIN	638
WRITE (6,357) (CMHOD(I),I=1,KLAST)	MAIN	639
WRITE(6,359) (VPMOD(I),I=1,KLAST)	MAIN	640
459 WRITE (6,279)	MAIN	641
C	MAIN	642
C CONTINUING FROM 450 OR 459	MAIN	643
460 GO TO 515	MAIN	644
C	MAIN	645
C	MAIN	646
C WE ARRIVE HERE IF NSTART=4	MAIN	647
500 READ (5,NAM7)	MAIN	648
WRITE (6,501)	MAIN	649
501 FORMAT(1H ///// 27H NAM7 HAS JUST BEEN READ IN)	MAIN	650
502 WRITE (6,NAM7)	MAIN	651
C	MAIN	652

C CONTINUING FROM 460 OR 502	MAIN	653
515 READ (5,NAM8)	MAIN	654
WRITE (6,516)	MAIN	655
516 FORMAT(1H // 27H NAM8 HAS JUST BEEN READ IN)	MAIN	656
517 WRITE (6,NAM8)	MAIN	657
C	MAIN	658
C COMPUTE YIELD DEPENDENT AMPLITUDES AND PHASE TERMS OF GUIDED MODES	MAIN	659
CALL PPAMP(YIELD,MOFNO,KST,KFIN,OMMOD,VPMOD,	MAIN	660
1AMP,ALAM,FACT,AMPLTD,PHASQ)	MAIN	661
518 IF(NPRNT .LE. 0) GO TO 580	MAIN	662
C THE RESULTS OF CALLING PPAMP ARE PRINTED OUT BY CALLING TABPRT	MAIN	663
CALL TABPRT(YIELD,MOFNO,KST,KFIN,OMMOD,VPMOD,AMPLTD,PHASQ)	MAIN	664
C	MAIN	665
C CONTINUING FROM 519 OR 520	MAIN	666
590 IF(NPNCH .LE. 0) GO TO 590	MAIN	667
C	MAIN	668
C PUNCH NAM9 DATA IF NPNCH .GT. 0	MAIN	669
KLAST = KFIN(MOFNO)	MAIN	670
WRITE (7,581) (AMPLTD(I),I=1,KLAST)	MAIN	671
581 FORMAT (7H INAM9 / 12H AMPLTD = /	MAIN	672
1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	673
WRITE (7,582) (PHASQ(I),I=1,KLAST)	MAIN	674
582 FORMAT (11H PHASQ = /	MAIN	675
1 (6X,G15.8,1H,,G15.8,1H,,G15.8,1H,,G15.8,1H,))	MAIN	676
WRITE (7,455) MOFNC,(KST(I),I=1,MOFNO)	MAIN	677
WRITE(7,355) (KFIN(I),I=1,MOFNO)	MAIN	678
WRITE (7,357) (OMMOD(I),I=1,KLAST)	MAIN	679
WRITE(7,359) (VPMOD(I),I=1,KLAST)	MAIN	680
WRITE (7,279)	MAIN	681
WRITE (6,583)	MAIN	682
583 FORMAT(1H // 41H THE FOLLOWING DATA HAS JUST BEEN PUNCHED)	MAIN	683
WRITE (6,581) (AMPLTD(I),I=1,KLAST)	MAIN	684
WRITE (6,582) (PHASQ(I),I=1,KLAST)	MAIN	685
WRITE (6,455) MOFNC,(KST(I),I=1,MOFNO)	MAIN	686
WRITE(6,355) (KFIN(I),I=1,MOFNO)	MAIN	687
WRITE (6,357) (OMMOD(I),I=1,KLAST)	MAIN	688
WRITE(6,359) (VPMOD(I),I=1,KLAST)	MAIN	689
584 WRITE (6,279)	MAIN	690
C	MAIN	691
C CONTINUING FROM 580 OR 584	MAIN	692
590 GO TO 615	MAIN	693
C	MAIN	694
C	MAIN	695
C WE ARRIVE HERE IF ISTART=5	MAIN	696
600 READ (5,NAM9)	MAIN	697
IF(NPRNT .LE. 0) GO TO 615	MAIN	698
WRITE (6,601)	MAIN	699
601 FORMAT(1H // 27H NAM9 HAS JUST BEEN READ IN)	MAIN	700
602 WRITE (6,NAM9)	MAIN	701
C	MAIN	702
C CONTINUING FROM 590 OR 602	MAIN	703
615 READ (5,NAM10)	MAIN	704
WRITE (6,616)	MAIN	705
616 FORMAT(1H // 28H NAM10 HAS JUST BEEN READ IN)	MAIN	706
WRITE (6,NAM10)	MAIN	707
C	MAIN	708
C COMPUTATION OF WAVEFORM	MAIN	709
CALL TPPT(TFIRST,TEND,DELTT,ROBS,MOFNO,KST,KFIN,OMMOD,VPMOD,AKI,	MAIN	710
1AMPLTD,PHASQ,IOPT)	MAIN	711
C	MAIN	712
C REPEAT FOR NEXT WAVEFORM	MAIN	713
GO TO 1	MAIN	714
C	MAIN	715
C WE ARRIVE HERE IF ISTART = 6.	MAIN	716
C ENOPLT TERMINATES THE CALCCMP TAPE FILE.	MAIN	717
CALL PLOT(0.,0.,999)	MAIN	718
CALL EXIT	MAIN	719
END	MAIN	720

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SUBROUTINE AAAAA(OMEGA,AKX,AKY,C,VX,VY,A)
AAAA (SUBROUTINE) 7/25/68 LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - AAAAA
THIS SUBROUTINE COMPUTES THE 2-BY-2 MATRIX A OF COEFFICIENTS
IN THE RESIDUAL EQUATIONS
D(PHI1)/OZ = (A11)*PHI1 + (A12)*PHI2
D(PHI2)/OZ = (A21)*PHI1 + (A22)*PHI2
DERIVED BY A. PIERCE, J. COMP. PHYS., VOL. 1, NO. 3, 343-366,
1967. (SEE EGN. (19) OF THE PAPER.) THE EXPLICIT EXPRESSIONS
FOR THE A(I,J) ARE
A(1,1) = G*(K/ROM)**2 - GAMMA*G/(2*C**2)
A(1,2) = 1 - (C*K/ROM)**2
A(2,1) = ((G*K)/(ROM*C))**2 - (ROM/C)**2
A(2,2) = -A(1,1)
WHERE GAMMA=1.4 IS THE SPECIFIC HEAT RATIO, G=.0098 KM/SEC**2
IS THE ACCELERATION OF GRAVITY, C IS THE SOUND SPEED, K IS THE
HORIZONTAL WAVE NUMBER AND ROM IS THE DOPPLER SHIFTED ANGULAR
FREQUENCY
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)
AUTHOR - A.D.PIERCE, M.I.T., JULY, 1968
-----CALLING SEQUENCE-----
SEE SUBROUTINES ELINT, PMMP, NAMPOE, NHOFN
DIMENSION A(2,2)
CALL AAAAA(OMEGA,AKX,AKY,C,VX,VY,A)
NO EXTERNAL SUBROUTINES ARE REQUIRED
-----ARGUMENT LIST-----
OMEGA R*4 NO INP
AKX R*4 NO INP
AKY R*4 NO INP
C R*4 NO INP
VX R*4 NO INP
VY R*4 NO INP
A R*4 2-BY-2 OUT
NO COMMON STORAGE IS USED
-----INPUTS-----
OMEGA =ANGULAR FREQUENCY IN RAD/SEC
AKX =X COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM
AKY =Y COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM
C =SOUND SPEED IN KM/SEC
VX =X COMPONENT OF WIND VELOCITY IN KM/SEC
VY =Y COMPONENT OF WIND VELOCITY IN KM/SEC
-----OUTPUTS-----
A(I,J) =(I,J)-TH ELEMENT OF MATRIX A OF COEFFICIENTS IN THE
RESIDUAL EQUATIONS AS DEFINED IN THE ABSTRACT.

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C          -----PROGRAM FOLLOWS BELOW
C
C
      DIMENSION A(2,2)
      BOMSQ=(OMEGA-AXX*VX-AXY*VY)**2
      CSQ=C*C
      T=(AXX**2+AXY**2)/BOMSQ
      A(1,1)=.6098*T-.00686/CSQ
C GAMMA*C/2 IS .00686
      A(1,2)=1.0-CSQ*T
      A(2,1)=((96.04E-6)*T-BOMSQ)/CSQ
C G**2 IS 96.04E-6 KM**2/SEC**4
      A(2,2)=-A(1,1)
      RETURN
      END.

```

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AAAA 65
AAAA 66
AAAA 67
AAAA 68
AAAA 69
AAAA 70
AAAA 71
AAAA 72
AAAA 73
AAAA 74
AAAA 75
AAAA 76
AAAA 77
AAAA 78
AAAA 79

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SUBROUTINE AKI(OM1,OM2,A1,A2,CTRIG1,STRIG1,CTRIG2,
1 STRIG2,DELPH,AKIINT)
AKI (SUBROUTINE)
8/15/68 LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - AKI
EVALUATION OF INTEGRAL OF A(OMEGA)*COS(PHI(OMEGA)) FROM OM1 TO
OM2
A(OMEGA) AND PHI(OMEGA) ARE ASSUMED TO BE LINEAR BETWEEN
OM1 AND OM2, FOLLOWING THE METHOD OF AKI ( J. GEOPHYS.
RES., VOL. 65 (1960), PP. 729-740 ). THE INTEGRAL IS
READILY EVALUATED AS
(PHI**(-1) * (AI + A***(OM2-OM1)) * SIN(PHII+X)
+ PHI**(-2) * A** * COS(PHII + X)
- PHI**(-1) * (AI - A** * (OM2 - OM1)) * SIN(PHII-X)
- PHI**(-2) * A** * COS(PHII - X)
WHERE
AI = AVERAGE VALUE OF A IN INTERVAL
PHII = AVERAGE VALUE OF PHI IN INTERVAL
A** = D(A) / D(OMEGA)
PHI** = D(PHI) / D(OMEGA)
X = PHI** * (OM2 - OM1) / 2
A SOMEWHAT MORE CONVENIENT FORMULA OBTAINABLE BY TRIGONO
METRIC IDENTITIES IS
AKIINT = 2 * PHI**(-1) * AI * SIN(X) * COS(PHII)
+ 2 * PHI**(-2) * A** * (X * COS(X) - SIN(X))
* SIN(PHII)
WHENEVER X IS SMALL, SIN(X)/X AND COS(X) ARE EVALUATED B
USING THEIR POWER SERIES REPRESENTATIONS.
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)
AUTHORS - A.D.PIERCE AND J.POSEY, M.I.T., AUGUST,1968
-----USAGE-----
NO SUBROUTINES ARE CALLED
FORTRAN USAGE
CALL AKI(OM1,OM2,A1,A2,CTRIG1,STRIG1,CTRIG2,STRIG2,
1 DELPH,AKIINT)
INPUTS
OM1 LOWER LIMIT OF INTEGRATION OVER ANGULAR FREQUENCY
R*4 (RADIAN)
OM2 UPPER LIMIT OF INTEGRATION (RADIAN)

```

C	R*4		AKI	65
C	A1	VALUE OF A AT OMEGA = OM1	AKI	66
C	R*4		AKI	67
C	A2	VALUE OF A AT OMEGA = OM2	AKI	68
C	R*4		AKI	69
C	CTRIG1	COS(PHI) WHERE OMEGA = OM1	AKI	70
C	R*4		AKI	71
C	STRIG1	SIN(PHI) WHERE OMEGA = OM1	AKI	72
C	R*4		AKI	73
C	DELPH	CHANGE IN PHI OVER THE INTERVAL (PHI(OM2) - PHI(OM1))	AKI	74
C	R*4	(RADIAN)	AKI	75
C			AKI	76
C	OUTPUTS		AKI	77
C			AKI	78
C	CTRIG2	COS(PHI) WHERE OMEGA = OM2	AKI	79
C	R*4		AKI	80
C	STRIG2	SIN(PHI) WHERE OMEGA = OM2	AKI	81
C	R*4		AKI	82
C	AKIINT	VALUE OF INTEGRAL DEFINED IN ABSTRACT IN UNITS OF A*OMEG	AKI	83
C	R*4		AKI	84
C			AKI	85
C		----PROGRAM FOLLOWS BELOW----	AKI	86
C			AKI	87
C	DELOH=OM2-OM1		AKI	88
C	DELAA=A2-A1		AKI	89
C			AKI	90
C	AI=(A2+A1)/2.0		AKI	91
C	X=DELPH/2.0		AKI	92
C	CTRX=COS(X)		AKI	93
C	STRX=SIN(X)		AKI	94
C	CTRIG1=CTRIG1*CTRX-STRIG1*STRX		AKI	95
C	STRIG1=STRIG1*CTRX+CTRIG1*STRX		AKI	96
C	CTRIG2=CTRIG1*CTRX-STRIG1*STRX		AKI	97
C	STRIG2=STRIG1*CTRX+CTRIG1*STRX		AKI	98
C	IF(ABS(X)-1.0E-2) 20,20,10		AKI	99
C	10 S1=STRX/X		AKI	100
C	S2=(S1-CTRX)/X**2		AKI	101
C	GO TO 30		AKI	102
C	20 S1=1.0-(1.0/6.0)*X**2+(1.0/120.0)*X**4		AKI	103
C	S2=(1.0/3.0)-(1.0/30.0)*X**2+(1.0/840.0)*X**4		AKI	104
C	30 AKIINT=(AI*S1*CTRIG1-DELAA*DELPH*0.25*S2*STRIG1)*DELOH		AKI	105
C	RETURN		AKI	106
C	END		AKI	107
			AKI	108
			AKI	109
			AKI	110
			AKI	111
			AKI	112
			AKI	113
			AKI	114
			AKI	115
			AKI	116

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SUBROUTINE ALLMOD(NROW,NCOL,MAXMOD,MDFND,OM,VP,KST,KFIN,OPMOD, ALLMOD 1
1 VPMOD,INMODE,THETK,KWOP) ALLMOD 2
ALLMOD (SUBROUTINE) 6/25/68 LAST CARD IN DECK IS ALLMOD 3
TITLE - ALLMOD ALLMOD 4
PROGRAM TO TABULATE DISPERSION CURVES OF UP TO MAXMOD GUIDED ALLMOD 5
MODES. ONLY PORTIONS OF CURVES WITH OMEGA BETWEEN OM(1) AND ALLMOD 6
OM(NCOL) AND WITH PHASE VELOCITY BETWEEN VP(NCOL) AND VP(1) ALLMOD 7
ARE TABULATED. THE ANGULAR DEVIATION OF GROUP VELOCITY DIREC- ALLMOD 8
TION FROM PHASE VELOCITY DIRECTION THETK IS NEGLECTED. ALLMOD 9
SUCCESSIVE MODES NUMBERED FROM 1 TO MDFND ARE EACH TABULATED BY ALLMOD 10
CALLING SUBROUTINE MODETR. STARTING POINTS FOR EACH MODE ARE ALLMOD 11
FOUND BY CALLING SUBROUTINE NXMODE. THE NORMAL MODE DISPERSIO ALLMOD 12
FUNCTION (NPDF) SHOULD BE NEARLY ZERO FOR EVERY TABULATED POINT ALLMOD 13
ON EACH DISPERSION CURVE. THE COMPUTATIONAL METHOD IS BASED ALLMOD 14
ON THE PREVIOUSLY COMPUTED VALUES OF THE NPDF SIGN ALLMOD 15
INMODE((J-1)*NROW+I) AT POINTS (I,J) IN A RECTANGULAR ARRAY OF ALLMOD 16
NROW ROWS AND NCOL COLUMNS. DIFFERENT COLUMNS (J) CORRESPOND ALLMOD 17
TO DIFFERENT ANGULAR FREQUENCIES OM(J) WHILE DIFFERENT ROWS (I ALLMOD 18
CORRESPOND TO DIFFERENT PHASE VELOCITIES VP(I). IT IS ASSUMED ALLMOD 19
THAT VP(1) .GT. VP(2) .GT. VP(3), ETC. DISPERSION CURVES ALLMOD 20
OF VARIOUS MODES APPEAR ON THIS ARRAY AS LINES OF DEMARCATION ALLMOD 21
BETWEEN ADJACENT REGIONS WITH OPPOSITE INMODES. IT IS ASSUMED ALLMOD 22
THAT DISPERSION CURVES SLOPE DOWNWARDS. MODES ARE NUMBERED ALLMOD 23
STARTING FROM LOWER LEFT OF INMODE ARRAY. ALLMOD 24
PROGRAM NOTES ALLMOD 25
THE ARRAYS OPMOD AND VPMOD ARE USED TO STORE DISPERSION ALLMOD 26
CURVES FOR ALL THE MODES TO CONSERVE STORAGE. FOR THE ALLMOD 27
NMODE-TH MODE, VPMOD(KST(NMODE)+K-1) IS THE PHASE VELOCITY ALLMOD 28
CORRESPONDING TO ANGULAR FREQUENCY OF OMOD(KST(NMODE)+ ALLMOD 29
K-1). THE PAIR OF VALUES CORRESPONDS TO THE K-TH TABULA ALLMOD 30
POINT FOR THE MODE. THE LAST TABULATED POINT FOR THE ALLMOD 31
NMODE-TH MODE IS LABELED BY THE PAIR VPMOD(KFIN(NMODE)), ALLMOD 32
OMMOD(KFIN(NMODE)). THUS OMMOD(K), VPMOD(K) FOR ALLMOD 33
K .GE. KST(NMODE) AND K .LT. KFIN(NMODE) DESCRIBE THE ALLMOD 34
NMODE-TH MODE'S DISPERSION CURVE. ALLMOD 35
THE FLAG KWOP IS NORMALLY RETURNED AS 1. HOWEVER, IF ALLMOD 36
NO DISPERSION CURVES ARE TABULATED, KWOP IS RETURNED AS ALLMOD 37
-1. ALLMOD 38
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4) ALLMOD 39
AUTHOR - A.D.PIERCE, M.I.T., JUNE, 1968 ALLMOD 40
-----CALLING SEQUENCE----- ALLMOD 41
SEE MAIN PROGRAM ALLMOD 42
DIMENSION OM(100),VP(100),KST(10),KFIN(10),OMMOD(1000),VPMOD(1000) ALLMOD 43
DIMENSION INMODE(10000) ALLMOD 44
DIMENSION CI(100),VXI(100),VYI(100),HI(100) ALLMOD 45
THE SUBROUTINE USES VARIABLE DIMENSIONING. THE ASSIGNMENTS ABOVE ARE ALLMOD 46
THOSE GIVEN BY MAIN PROGRAM ALLMOD 47
COMMON IMAX,CI,VYI,VXI,HI ALLMOD 48
ATMOSPHERIC VARIABLES MUST BE IN COMMON BEFORE ALLMOD IS CALLED. ALLMOD 49
CALL ALLMOD(NROW,NCOL,MAXMOD,MDFND,OM,VP,KST,KFIN,OPMOD,VPMOD, ALLMOD 50
1 INMODE,THETK,KWOP) ALLMOD 51
IF(KWOP .NE. 1) GO SOMEWHERE ALLMOD 52
-----EXTERNAL SUBROUTINES REQUIRED----- ALLMOD 53
NXMODE,MODETR,XTPTNT,RTMI,FNPOO1,FNMOD2,NMDFN,AAAA,RRRR,HMMH,CAI, ALLMOD 54
NXMODE AND MODETR ARE EXPLICITLY CALLED. THE REST ARE ALLMOD 55
IMPLICITLY CALLED BY CALLING MODETR. FOR FURTHER INFORMATION ALLMOD 56
ON IBM SCIENTIFIC SUBROUTINE PACKAGE ROUTINE RTMI, SEE DOCU- ALLMOD 57
MENTATION OF MODETR. ALLMOD 58
-----ARGUMENT LIST----- ALLMOD 59
NROW I*4 NO INP ALLMOD 60
NCOL I*4 NO INP ALLMOD 61

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C	MAXMOD	I*4	NO	INP	ALLMOD	75
C	MODNO	I*4	NO	OUT	ALLMOD	76
C	OM	R*4	VAR	INP	ALLMOD	77
C	VP	R*4	VAR	INP	ALLMOD	78
C	KST	I*4	VAR	OUT	ALLMOD	79
C	KFIN	I*4	VAR	OUT	ALLMOD	80
C	OMMOD	R*4	VAR	OUT	ALLMOD	81
C	VPMOD	R*4	VAR	OUT	ALLMOD	82
C	INMODE	I*4	VAR	INP	ALLMOD	83
C	THETK	R*4	NO	INP	ALLMOD	84
C	KNOP	I*4	NO	OUT	ALLMOD	85
C	COMMON STORAGE USED					86
C	COMMON IMAX,CI,VXI,VYI,HI,OMEGAC,VPHSEC,THETKP					87
C	IMAX	I*4	NO	INP	ALLMOD	89
C	CI	R*4	100	INP	ALLMOD	90
C	VXI	R*4	100	INP	ALLMOD	91
C	VYI	R*4	100	INP	ALLMOD	92
C	HI	R*4	100	INP	ALLMOD	93
C	OMEGAC	R*4	NO	CUT (USED INTERNALLY)	ALLMOD	94
C	VPHSEC	R*4	NO	OUT (USED INTERNALLY)	ALLMOD	95
C	THETKP	R*4	NO	OUT (USED INTERNALLY)	ALLMOD	96
C	-----INPUTS-----					98
C	NROW	*NUMBER OF ROWS IN INMODE ARRAY. MAXIMUM INDEX OF VP(N).			ALLMOD	99
C	NCOL	*NUMBER OF COLUMNS IN INMODE ARRAY. MAXIMUM INDEX OF OM(N).			ALLMOD	100
C	MAXMOD	*MAXIMUM NUMBER OF MODES TO BE TABULATED			ALLMOD	101
C	OM(N)	*ANGULAR FREQUENCY OF N-TH COLUMN IN INMODE ARRAY			ALLMOD	102
C	VP(N)	*PHASE VELOCITY OF N-TH ROW IN INMODE ARRAY			ALLMOD	103
C	INMODE	*1, -1, OR 5 DEPENDING ON WHETHER SIGN OF NORMAL MODE DISPERSION FUNCTION IS + OR -, 5 IF NPCF DOESNT EXIST			ALLMOD	104
C	THETK	*PHASE VELOCITY DIRECTION IN RADIANS RECKONED COUNTER CLOCKWISE WITH RESPECT TO X AXIS.			ALLMOD	105
C	IMAX	*NUMBER OF ATMOSPHERIC LAYERS OF FINITE THICKNESS			ALLMOD	106
C	CI(I)	*SOUND SPEED IN I-TH LAYER			ALLMOD	107
C	VXI(I)	*X COMPONENT OF WIND VELOCITY IN I-TH LAYER			ALLMOD	108
C	VYI(I)	*Y COMPONENT OF WIND VELOCITY IN I-TH LAYER			ALLMOD	109
C	HI(I)	*THICKNESS OF I-TH LAYER			ALLMOD	110
C	-----OUTPUTS-----					111
C	MODNO	*NUMBER OF MODES FOUND			ALLMOD	112
C	KST(N)	*INDEX OF FIRST TABULATED POINT IN N-TH MODE			ALLMOD	113
C	KFIN(N)	*INDEX OF LAST TABULATED POINT IN N-TH MODE. IN GENERAL, KFIN(N)=KST(N+1)-1.			ALLMOD	114
C	OMMOD(N)	*ARRAY STORING ANGULAR FREQUENCY ORDINATE OF POINTS ON DISPERSION CURVES. THE NMODE MODE IS STORED FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).			ALLMOD	115
C	VPMOD(N)	*ARRAY STORING PHASE VELOCITY ORDINATE OF POINTS ON DISPERSION CURVES. THE NMODE-TH MODE IS STORED FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).			ALLMOD	116
C	KNOP	*-1 IF NO MODES ARE TABULATED. OTHERWISE IT IS 1.			ALLMOD	117
C	OMEGAC	*INTERNALLY USED FREQUENCY TRANSMITTED AMONG SUBROUTINES THROUGH COMMON			ALLMOD	118
C	VPHSEC	*INTERNALLY USED PHASE VELOCITY TRANSMITTED AMONG SUBROUTINES THROUGH COMMON			ALLMOD	119
C	THETKP	*SAME AS THETK			ALLMOD	120
C	-----EXAMPLE-----					121
C	SUPPOSE THE TABLE OF INMODE VALUES IS AS SHOWN BELOW WITH					122
C	+++++----- NROW=6, NCOL=10					123
C	+++++-----					124

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C      +---+-----+ IF MAXMOD=10, YOU SHOULD FIND MODNO=6. ALLMOD 145
C      5---+---+--- ALLMOD 146
C      5---+---+--- KST(1)=1 KFIN(1)=4 OMNO(1-36) SHOULD E ALLMOD 147
C      5---+---+--- KST(2)=5 KFIN(2)=10 VPMOD(1-36) TABULATE ALLMOD 148
C      5---+---+--- KST(3)=11 KFIN(3)=21 ALLMOD 149
C      KST(4)=22 KFIN(4)=29 ALLMOD 150
C      KST(5)=30 KFIN(5)=34 ALLMOD 151
C      KST(6)=35 KFIN(6)=36 ALLMOD 152
C      ALLMOD 153
C      ALLMOD 154
C      ----PROGRAM FOLLOWS BELOW---- ALLMOD 155
C      ALLMOD 156
C      ALLMOD 157
C      ALLMOD 158
C      DIMENSION CI(100),VXI(100),VYI(100),HI(100) ALLMOD 159
C      DIMENSION OM(1),VP(1),KST(1),KFIN(1),OMNO(1),VPMOD(1),INMODE(1) ALLMOD 160
C      COMMON IMAX,CI,VXI,VYI,HI,OMEGAC,VPMSEC,THETKP ALLMOD 161
C      ALLMOD 162
C      C STORE THETK IN COMMON ALLMOD 163
C      THETKP=THETK ALLMOD 164
C      ALLMOD 165
C      C AT THIS POINT, WE HAVEN-T FOUND ANY MODES ALLMOD 166
C      MODNO=0 ALLMOD 167
C      ALLMOD 168
C      C WE START SEARCH FOR FIRST MODE IN LOWER LEFT CORNER OF INMODE ARRAY. ALLMOD 169
C      C WE SEEK A POINT WITH INMODE .NE. 5 WHERE THE MOD EXISTS. ALLMOD 170
C      NMODE=1 ALLMOD 171
C      KST(NMODE)=1 ALLMOD 172
C      IST=NROW ALLMOD 173
C      ALLMOD 174
C      C THE SEARCH GOES TO THE RIGHT. IF WE DON-T FIND A POINT IN THE BOTTOM ALLMOD 175
C      ROW, WE TRY THE (NROW-1)-TH ROW, ETC. AT STATEMENT 2 WE ARE STARTING ALLMOD 176
C      C AT THE LEFT OF A GIVEN ROW. ALLMOD 177
C      2 JST=1 ALLMOD 178
C      3 J50=(JST-1)*NROW+IST ALLMOD 179
C      10=INMODE(J50) ALLMOD 180
C      IF(10 .NE. 5) GO TO 10 ALLMOD 181
C      ALLMOD 182
C      C IF JST IS NOT NCOL WE GO TO THE RIGHT. ALLMOD 183
C      IF(JST .EQ. NCOL) GO TO 5 ALLMOD 184
C      JST=JST+1 ALLMOD 185
C      GO TO 3 ALLMOD 186
C      ALLMOD 187
C      C AT THIS POINT WE HAVE EXHAUSTED AN ENTIRE ROW. WE GO TO THE NEXT ALLMOD 188
C      C HIGHER ROW PROVIDED IST .NE. 1. IF IST IS 1, THE ENTIRE SET OF ALLMOD 189
C      C INMODES ARE 5. ALLMOD 190
C      5 IF(IST .EQ. 1) GO TO 7 ALLMOD 191
C      IST=IST-1 ALLMOD 192
C      GO TO 2 ALLMOD 193
C      ALLMOD 194
C      7 WRITE (6,6) ALLMOD 195
C      8 FORMAT(1H0,51HTHE NORMAL MODE DISPERSION FUNCTION DOES NOT EXIST ALLMOD 196
C      1 26HFOR ANY POINT IN THE ARRAY / 1H .22HALLMOD RETURNS KHOP=-1) ALLMOD 197
C      9 KHOP=-1 ALLMOD 198
C      RETURN ALLMOD 199
C      ALLMOD 200
C      C STATEMENT 10 IS START OF LOOP. EACH PASSAGE THROUGH LOOP CORRESPONDS ALLMOD 201
C      C TO A GIVEN MODE. ALLMOD 202
C      10 CALL NXMODE(IST,JST,NCOL,NROW,INMODE,IFNO,JFNO,KEX) ALLMOD 203
C      ALLMOD 204
C      C IF YOU CANNOT FIND THE FIRST MODE YOU ARE IN TROUBLE ALLMOD 205
C      IF(NMODE .NE. 1) GO TO 15 ALLMOD 206
C      IF(KEX .EQ. 1) GO TO 15 ALLMOD 207
C      WRITE (6,11) ALLMOD 208

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11	FORMAT(1H,36HNP0000 COULD NOT FIND THE FIRST MODE/ 1H ,	ALLMOD	209
122	HALLMOD RETURNS KNOP=-1)	ALLMOD	210
	GO TO 9	ALLMOD	211
C		ALLMOD	212
C	IF THE MODE SOUGHT IS NOT THE FIRST AND YOU CANNOT FIND IT, THEN THE	ALLMOD	213
C	RETURN IS CONSIDERED SATISFACTORY.	ALLMOD	214
	15 IF (KEK .EQ. -1) GO TO 50	ALLMOD	215
C		ALLMOD	216
C	WE NOW TABULATE THE KMODE-TH MODE	ALLMOD	217
	CALL MCODETR(IFND,JFND,NPCOE,KST,KFIN,OMMOD,VPMOD,NROW,NCOL,INMODE	ALLMOD	218
	1 OM,VP,KRUD)	ALLMOD	219
C		ALLMOD	220
C	IT IS DOUBFUL THAT KRUD COULD BE -1. HOWEVER, IF IT DID HAPPEN, WE	ALLMOD	221
C	WOULD LIKE TO KNOW THAT IT DID.	ALLMOD	222
	IF (KRUD .EQ. 1) GO TO 30	ALLMOD	223
	WRITE (6,21) NPOCE,IFND,JFND	ALLMOD	224
	21 FORMAT(1H,23HMOCE TR RETURNS KPUD=-1,2X,25HCURRENT VALUE OF NMOD	ALLMOD	225
	1 IS, I4, 3H. , 5HIFND=, I4,3H, , 5HJFND=, I4/ 1H ,27HSEE COCUM	ALLMOD	226
	2NTATION OF ALLMOD)	ALLMOD	227
C		ALLMOD	228
C	WE KEEP NMODE THE SAME AND TRANSFER CONTROL TO STATEMENT 35	ALLMOD	229
	GO TO 35	ALLMOD	230
	30 MCFND=PCFND+1	ALLMOD	231
C		ALLMOD	232
C	THIS IS THE CURRENT NUMBER OF MODES FOUND.	ALLMOD	233
C	WE NOW CHECK IF THIS IS MAXMOD. IF IT IS, THE RETURN IS WITH KNOP=1.	ALLMOD	234
	IF (MCFND .EQ. MAXMOD) GO TO 50	ALLMOD	235
	NMODE=NMODE+1	ALLMOD	236
	KST(NMODE)=KFIN(NMODE-1)+1	ALLMOD	237
C		ALLMOD	238
C	WE SEEK NEW IST AND JST BEFORE CALLING NXMODE.	ALLMOD	239
	35 J52=(JFND-1)*NROW+IFND	ALLMOD	240
	I0=INMODE(J52)	ALLMOD	241
	IF (IFND .EQ. 1) GO TO 40	ALLMOD	242
C		ALLMOD	243
C	WE CHECK INMODE OF POINT ABOVE	ALLMOD	244
	J3=(JFND-1)*NROW+IFND-1	ALLMOD	245
	IUP=INMODE(J3)	ALLMOD	246
C		ALLMOD	247
C	IF THIS IS -I0, THE POINT ABOVE IS THE ONE DESIRED	ALLMOD	248
	IF (IUP .NE. -I0) GO TO 40	ALLMOD	249
	IST=IFND-1	ALLMOD	250
	JST=JFND	ALLMOD	251
	GO TO 10	ALLMOD	252
C		ALLMOD	253
C	WE CHECK INMODE OF POINT TO RIGHT. THERE IS NO PLACE TO GO IF JFND=	ALLMOD	254
C	NCOL. THIS IS INTERPRETED AS SUCCESS PROVIDING MCFND .NE. 0.	ALLMOD	255
	40 IF (JFND .NE. NCOL) GO TO 43	ALLMOD	256
	GO TO 50	ALLMOD	257
C		ALLMOD	258
C	IRT IS INMODE OF POINT TO RIGHT	ALLMOD	259
	J4=(JFND)*NPOW+IFND	ALLMOD	260
	IRT=INMODE(J4)	ALLMOD	261
	IF (IRT .NE. -I0) GO TO 50	ALLMOD	262
	IST=IFND	ALLMOD	263
	JST=JFND+1	ALLMOD	264
	GO TO 10	ALLMOD	265
C		ALLMOD	266
C	THE SEARCH HAS TERMINATED. IF MCFND=0, WE HAVE BEEN UNSUCCESSFUL.	ALLMOD	267
	50 IF (MCFND .EQ. 0) GO TO 9	ALLMOD	268
	KNOP=1	ALLMOD	269
	RETURN	ALLMOD	270
	END	ALLMOD	271

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SUBROUTINE AMBNT(Z,PRESUR,I)
AMNT (SUBROUTINE)
7/27/68 LAST CARD IN DECK IS AMNT
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TITLE - AMNT
 THIS SUBROUTINE COMPUTES THE AMBIENT PRESSURE IN CMES/CM**2
 AT A GIVEN ALTITUDE Z KM BY USE OF THE EQUATION

$$PRESUR = (1.E6)*EXP(-INTEGRAL FROM 0 TO Z OF GAMMA*G/C**2)$$

 WHERE 1.E6 CMES/CM**2 IS THE AMBIENT PRESSURE AT THE GROUND,
 GAMMA=1.4 IS THE SPECIFIC HEAT RATIO FOR AIR, G=.0098 KM/SEC**2
 IS THE ACCELERATION OF GRAVITY, AND C IS THE ALTITUDE DEPENDENT
 SOUND SPEED IN KM/SEC. THE ABOVE EQUATION FOLLOWS FROM THE
 HYDROSTATIC EQUATION $D(P)/DZ = -G/RH00$ AND THE IDEAL GAS LAW
 $C**2 = GAMMA*P/RH00$.
 THE SOUND SPEED PROFILE IS THAT OF A MULTILAYER ATMOSPHERE AND
 IS PRESUMED TO BE STORED IN COMMON BEFORE EXECUTION. THE
 PROGRAM ALSO RETURNS THE INDEX I OF THE LAYER IN WHICH Z LIES.

PROGRAM NOTES
 IN THE EVENT THAT THE INPUT VALUE OF Z SHOULD BE NEGATIVE
 THE FIRST LAYER IS ASSUMED TO HOLD FOR Z .LT. 0 WITH THE
 AMBIENT PRESSURE STILL EQUAL TO 1.E6 AT Z=0. THE PROGRAM
 RETURNS PRESUR .GT. 1.E6 AND I=1.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)
 AUTHOR - A.D.PIERCE, P.I.T., JULY,1968

----CALLING SEQUENCE----

SEE SUBROUTINE PAMPOS
 DIMENSION CI(100),VXI(100),VYI(100),HI(100)
 COMMON IMAX,CI,VXI,VYI,HI (THESE MUST BE STORED IN COMMON)
 CALL AMBNT(Z,PRESUR,I)

----EXTERNAL SUBROUTINES REQUIRED----
 NO EXTERNAL SUBROUTINES ARE REQUIRED.

----ARGUMENT LIST----

NAME	TYPE	MODE	DESCRIPTION
Z	R*4	NO	INP
PRESUR	R*4	NO	OUT
I	I*4	NO	OUT

COMMON STORAGE USED
 COMMON IMAX,CI,VXI,VYI,HI

NAME	TYPE	MODE	DESCRIPTION
IMAX	I*4	NO	INP
CI	R*4	100	INP
VXI	R*4	100	INP (NOT USED BY THIS SUBROUTINE)
VYI	R*4	100	INP (NOT USED BY THIS SUBROUTINE)
HI	R*4	100	INP

----INPUTS----
 Z = HEIGHT IN KM

C	IMAX	=NUMBER OF ATMOSPHERIC LAYERS WITH FINITE THICKNESS	AMNT	62
C	CI(I)	=SOUND SPEED (KM/SEC) IN I-TH LAYER	AMNT	63
C	VXI(I)	=X COMPONENT OF WIND VELOCITY (KM/SEC) IN I-TH LAYER	AMNT	64
C	VYI(I)	=Y COMPONENT OF WIND VELOCITY (KM/SEC) IN I-TH LAYER	AMNT	65
C	HI(I)	=THICKNESS IN KM OF I-TH LAYER	AMNT	66
C			AMNT	67
C		----OUTPUTS----	AMNT	68
C			AMNT	69
C	PRESUR	=AMBIENT PRESSURE IN DYNES/CM**2 AT ALTITUDE Z	AMNT	70
C	I	=INDEX OF LAYER IN WHICH Z LIES	AMNT	71
C			AMNT	72
C		----PROGRAM FOLLOWS BELOW----	AMNT	73
C			AMNT	74
C			AMNT	75
C	DIMENSION AND COMMON STATEMENTS		AMNT	76
	DIMENSION CI(100),VXI(100),VYI(100),HI(100)		AMNT	77
	COMMON IPAX,CI,VXI,VYI,HI		AMNT	78
C			AMNT	79
C	THE FINAL VALUE OF ENPON WILL BE THE INTEGRAL FROM 0 TO Z OF		AMNT	80
C	-GAMMA*G/C**2. THE RUNNING VALUE WILL BE THE SUBTOYAL.		AMNT	81
	ENPON=0.0		AMNT	82
C			AMNT	83
C	THE RUNNING VALUE OF I WILL BE THE LAYER BEING CONSIDERED		AMNT	84
	I=1		AMNT	85
C	Z LIES IN LAYER 1 IF IMAX=0.		AMNT	86
	ZT=0.0		AMNT	87
	IF(IMAX .EQ. 0) GO TO 30		AMNT	88
C			AMNT	89
C	TOP OF FIRST LAYER		AMNT	90
	ZT=HI(1)		AMNT	91
C			AMNT	92
C	THE START OF A LOOP. THE CURRENT ZT DENOTES THE TOP OF THE I-TH LAYER		AMNT	93
	10 IF(Z .GT. ZT) GO TO 20		AMNT	94
C			AMNT	95
C	Z LIES IN I-TH LAYER		AMNT	96
C	ZT-HI(I) IS HEIGHT OF BOTTOM OF I-TH LAYER		AMNT	97
C	Z-ZT+HI(I) IS DISTANCE OF Z ABOVE BOTTOM OF I-TH LAYER		AMNT	98
	ENPON=ENPON-1.4*(.0098/CI(I)**2)*(Z-ZT+HI(I))		AMNT	99
	12 GO TO 40		AMNT	100
C			AMNT	101
C	Z LIES ABOVE TOP OF I-TH LAYER		AMNT	102
	20 ENPON=ENPON-1.4*(.0098/CI(I)**2)*HI(I)		AMNT	103
C	THE CURRENT ENPON IS THE INTEGRAL OF -1.4*G/C**2 UP TO THE TOP		AMNT	104
C	OF THE I-TH LAYER		AMNT	105
	I=I+1		AMNT	106
	IF(I .GT. IMAX) GO TO 30		AMNT	107
	ZT=ZT+HI(I)		AMNT	108
C	ZT IS THE TOP OF THE NEW I-TH LAYER		AMNT	109
	GO TO 10		AMNT	110
C	END OF LOOP		AMNT	111
C			AMNT	112
C	Z LIES IN UPPER HALFSpace		AMNT	113
	30 ENPON=ENPON-1.4*(.0098/CI(I)**2)*(Z-ZT)		AMNT	114
C			AMNT	115
C	CONTINUING FROM 12 OR 30		AMNT	116
	40 PRESUR=1.E6*EXP(ENPON)		AMNT	117
	RETURN		AMNT	118
	END		AMNT	119

C	SUBROUTINE ATMOS(T,VKNTX,VKNTY,ZI,WANGLE,WINDY,LANGLE)	ATMOS	1
C	ATMOS (SUBROUTINE)	ATMOS	2
C	6/19/68 LAST CARD IN DECK IS	ATMOS	3
C		ATMOS	4
C	----	ATMOS	5
C		ATMOS	6
C		ATMOS	7
C	TITLE - ATMOS	ATMOS	8
C	TABULATION OF WIND VELOCITY COMPONENTS AND SPEED OF SOUND FOR	ATMOS	9
C	ALL LAYERS OF MODEL ATMOSPHERES	ATMOS	10
C		ATMOS	11
C	THE MODEL ATMOSPHERE CONSISTS OF UP TO 100 ISOTHERMAL	ATMOS	12
C	LAYERS (THE TOP LAYER BEING INFINITE). EACH LAYER MAY	ATMOS	13
C	HAVE A UNIQUE TEMPERATURE, THICKNESS AND WIND VELOCITY.	ATMOS	14
C	SUBROUTINE ATMOS CONVERTS AN INPUT DESCRIPTION OF THE	ATMOS	15
C	ATMOSPHERE'S PROPERTIES INTO ONE MORE APPROPRIATE FOR THE	ATMOS	16
C	CALCULATIONS TO FOLLOW (SUCH AS EVALUATION OF THE NORMAL	ATMOS	17
C	MODE DISPERSION FUNCTION IN NMODFN, DESCRIBED ELSEWHERE IN	ATMOS	18
C	THIS SERIES).	ATMOS	19
C		ATMOS	20
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4)	ATMOS	21
C		ATMOS	22
C	AUTHORS - A.D.PIERCE AND J.POSEY, M.I.T., JUNE,1968	ATMOS	23
C		ATMOS	24
C		ATMOS	25
C	----	ATMOS	26
C		ATMOS	27
C	IMAX MUST BE STORED AS THE FIRST VARIABLE IN UNLABELED COMMON WHEN	ATMOS	28
C	ATMOS IS CALLED.	ATMOS	29
C		ATMOS	30
C	NO FORTRAN SUBROUTINES ARE CALLED.	ATMOS	31
C		ATMOS	32
C	FORTRAN USAGE	ATMOS	33
C		ATMOS	34
C	CALL ATMOS(T,VKNTX,VKNTY,ZI,WANGLE,WINDY,LANGLE)	ATMOS	35
C		ATMOS	36
C	INPUTS	ATMOS	37
C		ATMOS	38
C	IMAX NUMBER OF LAYERS OF FINITE THICKNESS IN THE MODEL ATMOS-	ATMOS	39
C	I*4 PHERE. (1.LE.IMAX.LE.99)	ATMOS	40
C		ATMOS	41
C	T T(I) IS TEMPERATURE OF LAYER I IN MODEL ATMOSPHERE.	ATMOS	42
C	R*4(I) (DEGREES KELVIN)	ATMOS	43
C		ATMOS	44
C	VKNTX VKNTX(I) IS WIND VELOCITY COMPONENT IN X-DIRECTION (WEST	ATMOS	45
C	R*4(I) TO EAST) FOR LAYER I. (KNOTS)	ATMOS	46
C		ATMOS	47
C	VKNTY VKNTY(I) IS WIND VELOCITY COMPONENT IN Y-DIRECTION (SOUTH	ATMOS	48
C	R*4(I) TO NORTH) FOR LAYER I. (KNOTS)	ATMOS	49
C		ATMOS	50
C	ZI ZI(I) IS THE HEIGHT ABOVE THE GROUND OF THE TOP OF LAYER	ATMOS	51
C	R*4(I) I. (KM)	ATMOS	52
C		ATMOS	53
C	WANGLE WANGLE(I) IS WIND VELOCITY DIRECTION FOR LAYER I, RECKON	ATMOS	54
C	R*4(I) COUNTER CLOCKWISE FROM THE X-AXIS. (DEGREES)	ATMOS	55
C		ATMOS	56
C	WINDY WINDY(I) IS MAGNITUDE OF WIND VELOCITY IN LAYER I.	ATMOS	57
C	R*4(I) (KNOTS)	ATMOS	58
C		ATMOS	59
C	LANGLE SPECIFIES WHICH SORT OF WIND DATA IS INPUT.	ATMOS	60
C	I*4 IF LANGLE.LE.0 , VKNTX AND VKNTY ARE INPUT.	ATMOS	61
C		ATMOS	62
C	IF LANGLE.GT.0 , WANGLE AND WINDY ARE INPUT.	ATMOS	63
C		ATMOS	64
C	OUTPUTS	ATMOS	65
C		ATMOS	66
C	THE OUTPUTS ARE STORED IN UNLABELED COMMON IN THE FOLLOWING	ATMOS	67
C	ORDER, BEGINNING IN POSITION 2.	ATMOS	68
C	CI(100),VXI(100),VYI(100),HI(100)	ATMOS	69
C		ATMOS	70
C	CI CI(I) IS THE SPEED OF SOUND IN LAYER I OF THE MODEL ATMOS	ATMOS	71
C	R*4(I) PHERE. (KM/SEC)	ATMOS	72

C			ATHOS	71
C	VXI	VXI(I) IS WIND VELOCITY COMPONENT IN X-DIRECTION (WEST T	ATHOS	72
C	R*4(10)	EAST) FOR LAYER I. (KM/SEC)	ATHOS	73
C			ATHOS	74
C	VYI	VYI(I) IS WIND VELOCITY COMPONENT IN Y-DIRECTION (SOUTH	ATHOS	75
C	R*4(10)	TO NORTH) FOR LAYER I. (KM/SEC)	ATHOS	76
C			ATHOS	77
C	HI	HI(I) IS THE THICKNESS OF LAYER I. (KM)	ATHOS	78
C	R*4(10)		ATHOS	79
C			ATHOS	80
C		-----PROGRAM FOLLOWS BELOW-----	ATHOS	81
C			ATHOS	82
C			ATHOS	83
C			ATHOS	84
C			ATHOS	85
C		DIMENSION CI(100),VXI(100),VYI(100),HI(100)	ATHOS	86
C		DIMENSION T(100),VKNTX(100),VKNTY(100),ZI(100)	ATHOS	87
C		DIMENSION WANGLE(100),WINDY(100)	ATHOS	88
C		COMMON IMAX,CI,VXI,VYI,HI	ATHOS	89
C			ATHOS	90
C	JET	IS TOTAL NUMBER OF LAYERS.	ATHOS	91
C		JET = IMAX + 1	ATHOS	92
C		IMAX = JET - 1	ATHOS	93
C		IF (WANGLE .LE. 0) GO TO 20	ATHOS	94
C		D3 = 3.1415927 / 180.0	ATHOS	95
C	D3	IS THE NUMBER OF RADIAN IN A DEGREE	ATHOS	96
C			ATHOS	97
C		IF VKNTX AND VKNTY WERE NOT INPUT, THEY ARE NOW DETERMINED FROM WINDY	ATHOS	98
C	AND WANGLE.		ATHOS	99
C		DO 5 I=1,JET	ATHOS	100
C		VKNTX(I) = WINDY(I) * COS(D3*WANGLE(I))	ATHOS	101
C		VKNTY(I) = WINDY(I) * SIN(D3*WANGLE(I))	ATHOS	102
C		*20 D1 = 1.4 * 8.3144 * 0.001 / 29.0	ATHOS	103
C	D2	IS THE NUMBER OF KM/SEC PER KNOT.	ATHOS	104
C		D2 = 0.005148	ATHOS	105
C			ATHOS	106
C		DO 30 I = 1,JET	ATHOS	107
C			ATHOS	108
C		THE SPEED OF SOUND = (GAMMA * P / RHO) FOR PERFECT GAS, AND (P/RHO	ATHOS	109
C		= (R * T)	ATHOS	110
C	R	IS THE (UNIVERSAL GAS CONSTANT)/(MOLECULAR WEIGHT)	ATHOS	111
C		CI(I) = SQRT(D1*T(I))	ATHOS	112
C			ATHOS	113
C		(D2 * V(KNOTS)) = V(KM/SEC)	ATHOS	114
C		ZI(I) = D2 * VKNTX(I)	ATHOS	115
C		30 VYI(I) = D2 * VKNTY(I)	ATHOS	116
C		IF(IMAX .EQ. 0) RETURN	ATHOS	117
C		HI(1) = ZI(1)	ATHOS	118
C		IF(IMAX .EQ. 1) RETURN	ATHOS	119
C		DO 40 I=2,IMAX	ATHOS	120
C		40 HI(I) = ZI(I) - ZI(I-1)	ATHOS	121
C		RETURN	ATHOS	122
C		END	ATHOS	123

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SUBROUTINE B888(X,R1,R2,R3)
B888 (SUBROUTINE)
7/25/68 LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - B888
THIS SUBROUTINE COMPUTES THREE FUNCTIONS R1,R2,R3 OF A VARIABLE
X. THESE ARE DEFINED FOR X .GE. 0 BY THE FORMULAS

R1= 1.0 +SINH(2Y)/(2Y)
R2= (SINH(2Y)/2Y - 1.6)/Y**2
R3= (COSH(2Y)-1.0)/Y**2

WHERE Y= SQRT(X). FORMULAS FOR NEGATIVE X MAY BE OBTAINED BY
ANALYTIC CONTINUATION. FOR SMALL VALUES OF X, THE FUNCTIONS
ARE COMPUTABLE BY THE POWER SERIES

R1= 2 + 4X/(3FACT) + (4X)**2/(5FACT) + (4X)**3/(7FACT) +...
R2= 4/(3FACT) + 4*(4X)/(5FACT) + 4*(4X)**2/(7FACT) +...
R3= 4/(2FACT) + 4*(4X)/(4FACT) + 4*(4X)**2/(6FACT) +...

THE MANNER IN WHICH THESE PARTICULAR FUNCTIONS ARISE IN THE
THEORY COMES FROM INTEGRATIONS OVER VARIOUS PRODUCTS OF CAI(X)
AND SAI(X). IN PARTICULAR, FOR X POSITIVE,

R1= (2/Y)(INTEGRAL ON Y FROM 0 TO Y OF (COSH(Y))**2)
R2= (2/Y**3)(INTEGRAL ON Y FROM 0 TO Y OF (SINH(Y))**2)
R3= (4/Y**2)(INTEGRAL ON Y FROM 0 TO Y OF SINH(Y)*COSH(Y))

WITH Y=SQRT(X). THE CORRESPONDING FORMULAS FOR X NEGATIVE CAN
BE OBTAINED BY REPLACING SINH AND COSH BY SIN AND COS, RESPEC-
TIVELY, AND BY REINTERPRETING Y AS SQRT(-X).

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)
AUTHOR - A.D.PIERCE, M.I.T., JULY,1968

-----CALLING SEQUENCE-----
SEE SUBROUTINE ELINT
X=
CALL B888(X,R1,R2,R3)

-----EXTERNAL SUBROUTINES REQUIRED-----
CAI, SAI

-----ARGUMENT LIST-----
X      R*4    NO    INP
R1     R*4    NO    OUT
R2     R*4    NO    OUT
R3     R*4    NO    OUT

NO COMMON STORAGE IS USED

-----PROGRAM FOLLOWS BELOW-----
S=SAI(4.0*X)

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IF(ABS(X) .GT. 1.E-2) GO TO 3	0000	65
C	0000	66
C COMPUTATION FOR SMALL X	0000	67
R2=2.0/3.0+(2.0/15.0)*X+(4.0/315.0)*X**2+(2.0/9.0)*X**3/315.0	0000	68
R3=2.0+2.0*X/3.0+4.0*X**2/45.0+2.0*X**3/315.0	0000	69
GO TO 4	0000	70
C	0000	71
C COMPUTATION FOR X NOT NEAR ZERO	0000	72
3 R2=(S-1.0)/X	0000	73
R3=(CAI(4.0*X)-1.0)/X	0000	74
C	0000	75
C COMPUTATION OF R1 FOR ARBITRARY X	0000	76
4 R1=1.0+S	0000	77
RETURN	0000	78
END	0000	79

C	FUNCTION CAI(X)	7/25/68	LAST CARD IN DECK IS	CAI	1
C	CAI (FUNCTION)			CAI	2
C				CAI	3
C	-----ABSTRACT-----			CAI	4
C				CAI	5
C	TITLE - CAI			CAI	6
C	PROGRAM TO EVALUATE FUNCTION CAI(X) FOR GIVEN VARIABLE X.			CAI	7
C	IF X IS NEGATIVE, CAI(X)=COS(SQRT(-X)). IF X IS POSITIVE,			CAI	8
C	CAI(X)=COSH(SQRT(+X)). THE FUNCTION IS ALSO REPRESENTABLE			CAI	9
C	BY THE POWER SERIES			CAI	10
C				CAI	11
C	CAI(X)= 1 + X/(2FACT) + X**2/(4FACT) + X**3/(6FACT) + ...			CAI	12
C				CAI	13
C	LANGUAGE - FORTRAN IV (360. REFERENCE MANUAL C-2-6515-4)			CAI	14
C				CAI	15
C	AUTHOR - A.D. PIERCE, M.I.T., JULY, 1968			CAI	16
C	-----CALLING SEQUENCE-----			CAI	17
C				CAI	18
C	CAI(ANY P*4 ARGUMENT) MAY BE USED IN ARITHMETIC EXPRESSIONS			CAI	19
C				CAI	20
C	-----EXTERNAL SUBROUTINES REQUIRED-----			CAI	21
C				CAI	22
C	NO EXTERNAL SUBROUTINES ARE REQUIRED			CAI	23
C				CAI	24
C	-----ARGUMENT LIST-----			CAI	25
C				CAI	26
C	X R*4 NO INP			CAI	27
C	CAI R*4 NO OUT			CAI	28
C				CAI	29
C	NO COMMON STORAGE IS USED			CAI	30
C				CAI	31
C	-----PROGRAM FOLLOWS BELOW-----			CAI	32
C				CAI	33
C	IF(X .GE. 0.0) GO TO 11			CAI	34
C				CAI	35
C	X IS LESS THAN 0			CAI	36
C	10 CAI=COS(SQRT(-X))			CAI	37
C	RETURN			CAI	38
C				CAI	39
C	X IS GREATER OR EQUAL TO 0			CAI	40
C	11 E=EXP(SQRT(X))			CAI	41
C	THE HYPERBOLIC COSINE IS COMPUTED			CAI	42
C	CAI=0.5*(E+1./E)			CAI	43
C	RETURN			CAI	44
C	END			CAI	45
C				CAI	46

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SUBROUTINE OMEGA,AKX,AKY,C,VX,VY,DAOM,DAKX,DAKY)
DAQR (SUBROUTINE) MODIFIED 7/11/74 LAST CARD IN DECK IS NO.

      ----ABSTRACT----

TITLE - DAQR
THE FUNCTION OF THIS SUBROUTINE IS TO COMPUTE THE COMPONENTS
OF THE MATRICES DAOM,DAKX, AND DA KY WHICH REPRESENT THE
PARTIAL DERIVATIVES OF THE MATRIX A WHICH WOULD BE
COMPUTED BY SUBROUTINE AAAA.
      DAOM IS THE PARTIAL DERIVATIVE MATRIX OF A WRT OMEGA
      DAKX IS THE PARTIAL DERIVATIVE MATRIX OF A WRT AKX
      DA KY IS THE PARTIAL DERIVATIVE MATRIX OF A WRT AKY
      LIKE A, ALL ARE 2-BY-2 MATRICES.

LANGUAGE - FORTRAN V (UNIVAC 1100, REFERENCE MANUAL UC-7536 REV. 1)
AUTHORS - ALLAN D. PIERCE, CHRISTOPHER KAPFER, G.I.T., JULY, 1974

      ----CALLING SEQUENCE----

SEE SUBROUTINE COMPK
      DIMENSION D(2,2),DAOM(2,2),DAKX(2,2),DAKY(2,2)
      CALL DAQR(OMEGA,AKX,AKY,C,VX,VY,DAOM,DAKX,DAKY)

NO EXTERNAL SUBROUTINES REQUIRED

      ----ARGUMENT LIST----

      OMEGA      R*4      NO      INP
      AKX        R*4      NO      INP
      AKY        R*4      NO      INP
      C          R*4      NO      INP
      VX         R*4      NO      INP
      VY         R*4      NO      INP
      DAOM       R*4      2-BY-2 OUT
      DAKX       R*4      2-BY-2 OUT
      DA KY     R*4      2-BY-2 OUT

NO COMMON STORAGE USED

      ----INPUTS----

      OMEGA      =ANGULAR FREQUENCY RAD/SEC
      AKX        =X COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM
      AKY        =Y COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM
      C          =SOUND SPEED IN KM/SEC
      VX         =X COMPONENT OF WIND VELOCITY IN KM/SEC
      VY         =Y COMPONENT OF WIND VELOCITY IN KM/SEC

      ----OUTPUTS----

      DAOM(I,J)  =(I,J)-TH ELEMENT OF DAOM MATRIX
      DAKX(I,J)  =(I,J)-TH ELEMENT OF DAKX MATRIX
      DA KY(I,J) =(I,J)-TH ELEMENT OF DA KY MATRIX

      ----PROGRAM FOLLOWS BELOW----

      DAOM,DAKX,DAKY ARE MATRIX DERIVATIVES OF A WITH RESPECT TO

```

OMEGA,AKX,AKY, WHERE A IS AS COMPUTED BY AAAA.	OAOQR	60
DIMENSION D(2,2),DADOM(2,2),DADKX(2,2),DADKY(2,2)	OAOQR	61
CSQ=C*C	OAOQR	62
D(1,1)=.0098	OAOQR	63
D(1,2)=-CSQ	OAOQR	64
D(2,1)=(96.04E-6)/CSQ	OAOQR	65
D(2,2)=-.0098	OAOQR	66
BOM=OMEGA-AXX*VX-AXY*VY	OAOQR	67
BOMSQ=BOM**2	OAOQR	68
C T IS AKSQ/BOMSQ	OAOQR	69
OTDOM=-2.0*(AKX**2+AKY**2)/(BOMSC*BOM)	OAOQR	70
OTDKX=-OTDOM*VX+2.0*AKX/BOMSQ	OAOQR	71
OTDKY=-OTDOM*VY+2.0*AKY/BOMSQ	OAOQR	72
DO 90 I=1,2	OAOQR	73
DO 90 J=1,2	OAOQR	74
DADOM(I,J)=OTOCY*D(I,J)	OAOQR	75
DADKX(I,J)=OTDKX*D(I,J)	OAOQR	76
90 DADKY(I,J)=OTDKY*D(I,J)	OAOQR	77
C THE ABOVE ELEMENTS ARE CORRECT EXCEPT FOR (2,1) ELEMENTS	OAOQR	78
XAT=2.0*BOM/CSQ	OAOQR	79
C XAT IS THE DERIVATIVE WITH RESPECT TO OMEGA OF BOMSQ/CSQ	OAOQR	80
DADOM(2,1)=DADOM(2,1)-XAT	OAOQR	81
DADKX(2,1)=DADKX(2,1)+XAT*VX	OAOQR	82
DADKY(2,1)=DADKY(2,1)+XAT*VY	OAOQR	83
RETURN	OAOQR	84
END	OAOQR	85

C	DFOKX	=PARTIAL DERIVATIVE OF FPP WRT AKX	DFOQR	65
C	DFOKY	=PARTIAL DERIVATIVE OF FPP WRT AKY	DFOQR	66
C			DFOQR	67
C		----PROGRAM FOLLOWS BELOW----	DFOQR	68
C			DFOQR	69
	DIMENSION A(2,2),DADOM(2,2),DACKX(2,2),DAOKY(2,2)		DFOQR	70
	DIMENSION RPP(2,2),DRODM(2,2),DROKX(2,2),CROKY(2,2)		DFOQR	71
	GU=GI		DFOQR	72
	CALL DADQR(OMEGA,AKX,AKY,C,VX,VY,DADOM,DACKX,DAOKY)		DFOQR	73
	DGDOM=(2.0*A(1,1)*DADOM(1,1)+A(1,2)*DADOM(2,1)+A(2,1)*DADOM(1,2))		DFOQR	74
	1(2.0*GU)		DFOQR	75
	DGOKX=(2.0*A(1,1)*DACKX(1,1)+A(1,2)*DACKX(2,1)+A(2,1)*DACKX(1,2))		DFOQR	76
	1(2.0*GU)		DFOQR	77
	DGOKY=(2.0*A(1,1)*DAOKY(1,1)+A(1,2)*DAOKY(2,1)+A(2,1)*DAOKY(1,2))		DFOQR	78
	1(2.0*GU)		DFOQR	79
	CALL DROQR(OMEGA,AKX,AKY,RPP,A,CRODM,DROKX,CROKY)		DFOQR	80
C	F IS R(1,1)*A(1,2)-P(1,2)*(GU+A(1,1))		DFOQR	81
	DFOOM=CRODM(1,1)*A(1,2)-CRODM(1,2)*(GU+A(1,1))+RPP(1,1)*DADOM(1,2)		DFOQR	82
	1-RPP(1,2)*(DGDOM+DADOM(1,1))		DFOQR	83
	DFOKX=DROKX(1,1)*A(1,2)-CROKX(1,2)*(GU+A(1,1))+RPP(1,1)*DACKX(1,2)		DFOQR	84
	1-RPP(1,2)*(DGOKX+DACKX(1,1))		DFOQR	85
	DFOKY=DROKY(1,1)*A(1,2)-CROKY(1,2)*(GU+A(1,1))+RPP(1,1)*DAOKY(1,2)		DFOQR	86
	1-RPP(1,2)*(DGOKY+DAOKY(1,1))		DFOQR	87
	RETURN		DFOQR	88
	END		DFOQR	89

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SUBROUTINE OMOQR(OMEGA,AKX,AKY,C,VX,VY,H,A,EM,OMDOM,OMOKX,OMOKY)  OMOQR 1
OMOQR (SUBROUTINE) MODIFIED 7/11/74 LAST CARD IN DECK IS NO.  OMOQR 2
C  OMOQR 3
C  OMOQR 4
C  OMOQR 5
C  OMOQR 6
C  OMOQR 7
C  TITLE - OMOQR  OMOQR 8
C  THE FUNCTION OF THIS SUBROUTINE IS TO COMPUTE THE COMPONENTS  OMOQR 9
C  OF THE MATRICES OMOCP,OMOKX, AND OMOKY WHICH REPRESENT THE  OMOQR 10
C  PARTIAL DERIVATIVES OF THE EM MATRIX WHICH WOULD BE  OMOQR 11
C  COMPUTED BY SUBROUTINE PPMH.  OMOQR 12
C  OMDOM IS THE PARTIAL DERIVATIVE MATRIX OF EM WRT OMEGA  OMOQR 13
C  OMOKX IS THE PARTIAL DERIVATIVE MATRIX OF EM WRT AKX  OMOQR 14
C  OMOKY IS THE PARTIAL DERIVATIVE MATRIX OF EM WRT AKY  OMOQR 15
C  MATRIX EM IS ALSO COMPUTED IN THIS SUBROUTINE.  OMOQR 16
C  LANGUAGE - FORTRAN V (UNIVAC 1106,REFERENCE MANUAL UP-7536 REV.1)  OMOQR 17
C  AUTHORS - ALLAN D FIERCE,CHRISTOPHER KAPPER, G.I.T., JULY, 1974  OMOQR 18
C  OMOQR 19
C  OMOQR 20
C  OMOQR 21
C  OMOQR 22
C  SEE SUBROUTINE COMPK  OMOQR 23
C  DIMENSION A(2,2),EM(2,2),OMDX(2,2),OMDOM(2,2),OMOKX(2,2)  OMOQR 24
C  DIMENSION OMOKY(2,2),OMDOM(2,2),OMOKX(2,2),OMOKY(2,2)  OMOQR 25
C  CALL OMOQR(OMEGA,AKX,AKY,C,VX,VY,H,A,EM,OMDOM,OMOKX,OMOKY)  OMOQR 26
C  OMOQR 27
C  OMOQR 28
C  OMOQR 29
C  OMOQR 30
C  OMOQR 31
C  OMOQR 32
C  OMOQR 33
C  OMOQR 34
C  OMOQR 35
C  OMOQR 36
C  OMOQR 37
C  OMOQR 38
C  OMOQR 39
C  OMOQR 40
C  OMOQR 41
C  OMOQR 42
C  OMOQR 43
C  OMOQR 44
C  OMOQR 45
C  OMOQR 46
C  NO COMMON STORAGE USED  OMOQR 47
C  OMOQR 48
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C  OMOQR 61
C  OMOQR 62
C  OMOQR 63
C  OMOQR 64

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-----ABSTRACT-----

TITLE - OMOQR

THE FUNCTION OF THIS SUBROUTINE IS TO COMPUTE THE COMPONENTS OF THE MATRICES OMOCP,OMOKX, AND OMOKY WHICH REPRESENT THE PARTIAL DERIVATIVES OF THE EM MATRIX WHICH WOULD BE COMPUTED BY SUBROUTINE PPMH.

OMDOM IS THE PARTIAL DERIVATIVE MATRIX OF EM WRT OMEGA

OMOKX IS THE PARTIAL DERIVATIVE MATRIX OF EM WRT AKX

OMOKY IS THE PARTIAL DERIVATIVE MATRIX OF EM WRT AKY

MATRIX EM IS ALSO COMPUTED IN THIS SUBROUTINE.

LANGUAGE - FORTRAN V (UNIVAC 1106,REFERENCE MANUAL UP-7536 REV.1)

AUTHORS - ALLAN D FIERCE,CHRISTOPHER KAPPER, G.I.T., JULY, 1974

-----CALLING SEQUENCE-----

SEE SUBROUTINE COMPK

DIMENSION A(2,2),EM(2,2),OMDX(2,2),OMDOM(2,2),OMOKX(2,2)

DIMENSION OMOKY(2,2),OMDOM(2,2),OMOKX(2,2),OMOKY(2,2)

CALL OMOQR(OMEGA,AKX,AKY,C,VX,VY,H,A,EM,OMDOM,OMOKX,OMOKY)

-----EXTERNAL SUBROUTINES REQUIRED-----

OMODR,CAI,SAI

-----ARGUMENT LIST-----

NAME	MODE	VALUE	UNIT
OMEGA	R*	NO	INP
AKX	R*	NO	INP
AKY	R*	NO	INP
C	R*	NO	INP
VX	R*	NO	INP
VY	R*	NO	INP
H	R*	NO	INP
A	R*	2-BY-2	INP
EM	R*	2-BY-2	OUT
OMDOM	R*	2-BY-2	OUT
OMOKX	R*	2-BY-2	OUT
OMOKY	R*	2-BY-2	OUT

NO COMMON STORAGE USED

-----INPUTS-----

OMEGA =ANGULAR FREQUENCY RAD/SEC

AKX =X COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM

AKY =Y COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM

C =SOUND SPEED IN KM/SEC

VX =X COMPONENT OF WIND VELOCITY IN KM/SEC

VY =Y COMPONENT OF WIND VELOCITY IN KM/SEC

H =THICKNESS IN KM OF LAYER

A(I,J) =(I,J)-TH ELEMENT OF MATRIX A FOR UHS

-----OUTPUTS-----

EM =2-BY-2 TRANSFER MATRIX WHICH RELATES THE SOLUTIONS OF THE RESIDUAL EQUATIONS AT THE TOP OF A LAYER TO THOSE AT THE BOTTOM OF THE LAYER.

C	OMDOM(I,J) =(I,J)-TH ELEMENT OF MATRIX OMDOM	OMDQR	65
C	OMOKX(I,J) =(I,J)-TH ELEMENT OF MATRIX OMOKX	OMDQR	66
C	OMOKY(I,J) =(I,J)-TH ELEMENT OF MATRIX OMOKY	OMDQR	67
C		OMDQR	68
C	-----PROGRAM FOLLOWS BELOW-----	OMDQR	69
C		OMDQR	70
	DIMENSION EM(2,2),OMCX(2,2),OMCCP(2,2),OMOKX(2,2),OMOKY(2,2)	OMDQR	71
	DIMENSION A(2,2),OADM(2,2),OACKX(2,2),OACKY(2,2)	OMDQR	72
	CALL OADR(OMEGA,AKX,AKY,C,VX,VY,OADM,OACKX,OACKY)	OMDQR	73
	HSQ=H*H	OMDQR	74
	X=(A(1,1)**2+A(1,2)*A(2,1))*HSQ	OMDQR	75
	CA=CAI(X)	OMDQR	76
	SA=SAI(X)	OMDQR	77
	DCAIX=0.5*SA	OMDQR	78
	Y=ABS(X)	OMDQR	79
	IF(Y-1.0E-2) 3,3,4	OMDQR	80
	3 OSAIX=1.0/6.6+X/60.0+X**2/1680.0+X**3/90720.0	OMDQR	81
	GO TO 5	OMDQR	82
	4 OSAIX=0.5*(CA-SA)/X	OMDQR	83
	5 GEN=H*OSAIX	OMDQR	84
	DO 20 I=1,2	OMDQR	85
	DO 20 J=1,2	OMDQR	86
	20 OMDX(I,J)=-GEN*A(I,J)	OMDQR	87
	DO 30 I=1,2	OMDQR	88
	30 OMDX(I,I)=OMDX(I,I)+DCAIX	OMDQR	89
	OADM=(2.0*A(1,1)*OADM(1,1)+A(1,2)*OADM(2,1)+A(2,1)*OADM(1,2))	OMDQR	90
	1HSQ	OMDQR	91
	OACKX=(2.0*A(1,1)*OACKX(1,1)+A(1,2)*OACKX(2,1)+A(2,1)*OACKX(1,2))	OMDQR	92
	1HSQ	OMDQR	93
	OACKY=(2.0*A(1,1)*OACKY(1,1)+A(1,2)*OACKY(2,1)+A(2,1)*OACKY(1,2))	OMDQR	94
	1HSQ	OMDQR	95
	T=H*SA	OMDQR	96
	DO 90 I=1,2	OMDQR	97
	DO 90 J=1,2	OMDQR	98
	OMDOM(I,J)=OMDX(I,J)*OADM-T*OADM(I,J)	OMDQR	99
	OMOKX(I,J)=OMDX(I,J)*OACKX-T*OACKX(I,J)	OMDQR	100
	OMOKY(I,J)=OMDX(I,J)*OACKY-T*OACKY(I,J)	OMDQR	101
	90 EM(I,J)=-T*A(I,J)	OMDQR	102
	DO 190 I=1,2	OMDQR	103
	190 EM(I,I)=EM(I,I)+CA	OMDQR	104
	RETURN	OMDQR	105
	END	OMDQR	106

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C      SUBROUTINE DRDQR(OMEGA,AKX,AKY,RPP,A,ORDOM,ORDKX,ORDKY)
C      DRDQR (SUBROUTINE)  MODIFIED 7/11/74  LAST CARD IN DECK IS NO.
C
C      -----ABSTRACT-----
C
C  TITLE - DRDQR
C      THE PURPOSE OF THIS SUBROUTINE IS TO COMPUTE THE COMPONENTS
C      OF THE MATRICES ORDOM,ORDKX, AND ORDKY WHICH REPRESENT THE
C      PARTIAL DERIVATIVES OF THE RPP MATRIX WHICH WOULD BE
C      COMPUTED BY SUBROUTINE PPPR.
C      ORDOM IS THE PARTIAL DERIVATIVE MATRIX OF RPP WRT OMEGA
C      ORDKX IS THE PARTIAL DERIVATIVE MATRIX OF RPP WRT AKX
C      ORDKY IS THE PARTIAL DERIVATIVE MATRIX OF RPP WRT AKY
C
C  LANGUAGE - FORTRAN V (UNIVAC 1108, REFERENCE MANUAL UP-7536 REV. 1)
C  AUTHORS - A.D. PIERCE, CHRISTOPHER KAPPER, G.I.T., JULY, 1974
C
C      -----CALLING SEQUENCE-----
C
C  SEE SUBROUTINE COMPK
C      DIMENSION CI(100),VXI(100),VYI(100),HI(100)
C      DIMENSION RPP(2,2),A(2,2),ORDOM(2,2),ORDKX(2,2),ORDKY(2,2)
C      DIMENSION EM(2,2),OMGOM(2,2),OMOKX(191),OMOKY(2,2)
C      DIMENSION UPP(2,2),OPF(2,2),AINT(2,2)
C      COMMON IMAX,CI,VXI,VYI,HI
C      CALL DRDQR(OMEGA,AKX,AKY,RPP,A,ORDOM,ORDKX,ORDKY)
C
C      -----EXTERNAL SUBROUTINES REQUIRED-----
C
C      DRDQR (DRDQR CALLS CACCR,CAI,SAI)
C
C      -----ARGUMENT LIST-----
C
C      OMEGA      R*4      NO      INP
C      AKX        R*4      NO      INP
C      AKY        R*4      NO      INP
C      RPP        R*4      2-BY-2 INP
C      A          R*4      2-BY-2 INP
C      ORDOM      R*4      2-BY-2 OUT
C      ORDKX      R*4      2-BY-2 OUT
C      ORDKY      R*4      2-BY-2 OUT
C
C      COMMON STORAGE USED
C      COMMON IMAX,CI,VXI,VYI,HI
C
C      IMAX      I*4      NO      INP
C      CI        R*4      100     INP
C      VXI       R*4      100     INP
C      VYI       R*4      100     INP
C      HI        R*4      100     INP
C
C      -----INPUTS-----
C
C      OMEGA      =ANGULAR FREQUENCY  RAD/SEC
C      AKX        =X COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM
C      AKY        =Y COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM
C      RPP        =2-BY-2 TRANSFER MATRIX WHICH CONNECTS SOLUTIONS
C                  OF THE RESIDUAL EQUATIONS AT THE BOTTOM OF THE
C                  UPPER HALFSpace TO SOLUTIONS AT THE GROUND.
C      A          =MATRIX A OF COEFFICIENTS
C
C      -----OUTPUTS-----

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C	OROOM(I,J) =(I,J)-TH ELEMENT OF MATRIX OROOM	ORQQR	65
C	OROKX(I,J) =(I,J)-TH ELEMENT OF MATRIX OROKX	ORQQR	66
C	ORDKY(I,J) =(I,J)-TH ELEMENT OF MATRIX ORDKY	ORQQR	67
C		ORQQR	68
C	-----PROGRAM FOLLOWS BELLOW-----	ORQQR	69
C		ORQQR	70
	DIMENSION CI(100),VXI(100),VYI(100),HI(100)	ORQQR	71
	DIMENSION RPP(2,2),A(2,2),C=DOM(2,2),OROKX(2,2),ORDKY(2,2)	ORQQR	72
	DIMENSION EM(2,2),OMCOM(2,2),OMCKX(2,2),OMOKY(2,2)	ORQQR	73
	DIMENSION UPP(2,2),OPF(2,2),AINT(2,2)	ORQQR	74
	COMMON IMAX,CI,VXI,VYI,HI	ORQQR	75
	DO 10 I=1,2	ORQQR	76
	DO 10 J=1,2	ORQQR	77
	OROOM(I,J)=0.0	ORQQR	78
	OROKX(I,J)=0.0	ORQQR	79
10	ORDKY(I,J)=0.0	ORQQR	80
	UPP(1,1)=1.0	ORQQR	81
	UPP(1,2)=0.0	ORQQR	82
	UPP(2,1)=0.0	ORQQR	83
	UPP(2,2)=1.0	ORQQR	84
	DO 15 I=1,2	ORQQR	85
	DO 15 J=1,2	ORQQR	86
15	OPP(I,J)=RPP(I,J)	ORQQR	87
	DO 100 J=1,IMAX	ORQQR	88
	I=IMAX+1-J	ORQQR	89
	C=CI(I)	ORQQR	90
	VX=VXI(I)	ORQQR	91
	VY=VYI(I)	ORQQR	92
	H=HI(I)	ORQQR	93
	CALL OMQOR(OMEGA,AKX,AKY,C,VX,VY,H,A,EM,OMCOM,OMCKX,OMOKY)	ORQQR	94
	MULTIPLY OPP TIMES THE INVERSE OF EM	ORQQR	95
	AINT(1,1)=OPP(1,1)*EM(2,2)-OPP(1,2)*EM(2,1)	ORQQR	96
	AINT(1,2)=-OPP(1,1)*EM(1,2)+OPP(1,2)*EM(1,1)	ORQQR	97
	AINT(2,1)=OPP(2,1)*EM(2,2)-OPP(2,2)*EM(2,1)	ORQQR	98
	AINT(2,2)=-OPP(2,1)*EM(1,2)+OPP(2,2)*EM(1,1)	ORQQR	99
	DO 20 II=1,2	ORQQR	100
	DO 20 JJ=1,2	ORQQR	101
20	OPP(II,JJ)=AINT(II,JJ)	ORQQR	102
	DO 30 II=1,2	ORQQR	103
	DO 30 JJ=1,2	ORQQR	104
	DO 30 KK=1,2	ORQQR	105
	DO 30 LL=1,2	ORQQR	106
	OROP(II,JJ)=OROC(II,JJ)+OPP(II,KK)*OMCOM(KK,LL)*UPP(LL,JJ)	ORQQR	107
	OROKX(II,JJ)=OROKX(II,JJ)+OPP(II,KK)*OMCKX(KK,LL)*UPP(LL,JJ)	ORQQR	108
30	ORDKY(II,JJ)=ORDKY(II,JJ)+OPP(II,KK)*OMOKY(KK,LL)*UPP(LL,JJ)	ORQQR	109
	DO 40 II=1,2	ORQQR	110
	DO 40 JJ=1,2	ORQQR	111
40	AINT(II,JJ)=EM(II,1)*UPP(1,JJ)+EM(II,2)*UPP(2,JJ)	ORQQR	112
	DO 50 II=1,2	ORQQR	113
	DO 50 JJ=1,2	ORQQR	114
50	UPP(II,JJ)=AINT(II,JJ)	ORQQR	115
100	CONTINUE	ORQQR	116
	RETURN	ORQQR	117
	END	ORQQR	118

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SUBROUTINE ELINT(OMEGA,AKX,AKY,C,VX,VY,H,F1H,F2H,A1,A2,AINT)
ELINT (SUBROUTINE)
7/25/68 LAST CARD IN DECK IS

-----ABSTRACT-----

TITLE - ELINT
THIS SUBROUTINE COMPUTES THE INTEGRAL
      AINT = INTEGRAL OVER Z FROM 0 TO H OF
      (A1*F1(Z) + A2*F2(Z))**2
THE FUNCTIONS F1(Z) AND F2(Z) ARE THE SOLUTIONS OF THE COUPLED
ORDINARY DIFFERENTIAL EQUATIONS
      DF1/DZ = A11*F1 + A12*F2
      DF2/DZ = A21*F1 + A22*F2
WHERE THE ELEMENTS OF THE MATRIX A ARE INDEPENDENT OF Z.
FOR GIVEN SQUAD SPEED C, WIND VELOCITY COMPONENTS VX AND VY,
ANGULAR FREQUENCY OMEGA, AND WAVE NUMBER COMPONENTS AKX AND AK
THE A(I,J) ARE COMPUTED BY CALLING AAAA. THE SOLUTION TO THE
DIFFERENTIAL EQUATIONS IS FIXED BY SPECIFICATION OF F1 AND F2
AT Z=H.

PROGRAM NOTES

THE GENERAL SOLUTION OF EQNS. (2) IS
      F1(Z) = CAI(X)*F1(H)-(H-Z)*SAI(X)*(A11*F1(H)+A12*F2(H)
      F2(Z) = CAI(X)*F2(H)-(H-Z)*SAI(X)*(A21*F1(H)+A22*F2(H)
WITH X=(A11**2+A12*A21)*(H-Z)**2 SINCE A22=-A11. WE LET
      R1 =(INTEGRAL OF (CAI(X))**2)*(Z/H)
      R2 =(INTEGRAL OF ((H-Z)*SAI(X))**2)*(Z/H**3)
      R3 =(INTEGRAL OF ((H-Z)*SAI(X)*CAI(X)))*(4/H**2)
WHERE IN EACH CASE THE INTEGRATION IS OVER Z FROM 0 TO H
THE QUANTITIES R1,R2,R3 ARE COMPUTED BY CALLING BBBB.
THEN
      AINT=(H/2)*(FP1)**2+R1+(H**3/2)*(FP2)**2+R2
      -(H**2/2)*(FP1)*(FP2)*R3
WITH
      FP1= A1*F1(H)+A2*F2(H)
      FP2= A1*(A11*F1(H)+A12*F2(H))+A2*(A21*F1(H)+A22*F2(H)
THE LATTER TWO QUANTITIES REPRESENT THE COEFFICIENTS OF
CAI(X) AND (H-Z)*SAI(X) IN A1*F1+A2*F2.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)

AUTHOR - A.O.PIERCE, P.I.T., JULY,1968

-----CALLING SEQUENCE-----

SEE SUBROUTINE TOTINT
NO DIMENSION STATEMENTS REQUIRED
CALL ELINT(OMEGA,AKX,AKY,C,VX,VY,H,F1H,F2H,A1,A2,AINT)

-----EXTERNAL SUBROUTINES REQUIRED-----

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C      AAAA, 8800
C
C      ----ARGUMENT LIST----
C      OMEGA      R*4      NO      INP
C      AKX        R*4      NO      INP
C      AKY        R*4      NO      INP
C      C          R*4      NO      INP
C      VX         R*4      NO      INP
C      VY         R*4      NO      INP
C      H          R*4      NO      INP
C      F1H        R*4      NO      INP
C      F2H        R*4      NO      INP
C      A1         R*4      NO      INP
C      A2         R*4      NO      INP
C      AINT       R*4      NO      OUT
C
C      NO COMMON STORAGE USED
C
C      ----INPUTS----
C      OMEGA      =ANGULAR FREQUENCY IN RAD/SEC
C      AKX        =X COMPONENT OF WAVE NUMBER VECTOR IN KM**(-1)
C      AKY        =Y COMPONENT OF WAVE NUMBER VECTOR IN KM**(-1)
C      C          =SOUND SPEED IN KM/SEC
C      VX         =X COMPONENT OF WIND VELOCITY IN KM/SEC
C      VY         =Y COMPONENT OF WIND VELOCITY IN KM/SEC
C      H          =INTEGRATION INTERVAL (LAYER THICKNESS) IN KM
C      F1H        =VALUE OF F1(Z) AT UPPER LIMIT OF INTEGRAL
C      F2H        =VALUE OF F2(Z) AT UPPER LIMIT OF INTEGRAL
C      A1         =COEFFICIENT OF F1(Z) IN INTEGRAND
C      A2         =COEFFICIENT OF F2(Z) IN INTEGRAND
C
C      ----OUTPUTS----
C      AINT       =INTEGRAL OVER HEIGHT WITH RANGE H OF THE QUANTITY
C      (A1*F1(Z)+A2*F2(Z))**2 WHERE F1(Z) AND F2(Z) ARE
C      EQUAL TO F1H AND F2H, RESPECTIVELY, AT THE UPPER
C      LIMIT AND SATISFY THE RESIDUAL DIFFERENTIAL EQUATION
C
C      ----PROGRAM FOLLOWS BELOW----
C
C      DIMENSION A(2,2)
C      CALL AAAA(OMEGA,AKX,AKY,C,VX,VY,A)
C
C      COMPUTATION OF FP1 AND FP2
C      FP1=A1*F1H+A2*F2H
C      FP2=A1*(A(1,1)*F1H+A(1,2)*F2H)+A2*(A(2,1)*F1H+A(2,2)*F2H)
C
C      COMPUTATION OF COEFFICIENTS OF R1,R2,R3
C      S1=0.5*H*FP1**2
C      S2=0.5*(H**3)*FP2**2
C      S3=-0.5*(H**2)*FP1*FP2
C
C      COMPUTATION OF R1,R2,R3
C      X=(A(1,1)**2+A(1,2)*A(2,1))*H**2
C      CALL 8800(X,R1,R2,R3)
C
C      COMPUTATION OF AINT
C      AINT=S1*R1+S2*R2+S3*R3
C      RETURN
C      END

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ELINT 125
ELINT 126

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C	FUNCTION FNM001(V)	FNM001	1
C	FNM001 (FUNCTION)	FNM001	2
C	6/19/68 LAST CARD IN DECK IS	FNM001	3
C	---- <td>FNM001</td> <td>4</td>	FNM001	4
C	TITLE - FNM001	FNM001	5
C	EVALUATION OF NORMAL MODE DISPERSION FUNCTION AS FUNCTION OF	FNM001	6
C	PHASE VELOCITY V	FNM001	7
C	THE NORMAL MODE DISPERSION FUNCTION DEPENDS ON THREE VAR	FNM001	8
C	ABLES. ANGULAR FREQUENCY OMEGA, PHASE VELOCITY V, AND	FNM001	9
C	DIRECTION OF PROPAGATION THETK. FNM001 OBTAINS V THROUG	FNM001	10
C	ITS ARGUMENT, OMEGA AND THETK FROM COMMON. SUBROUTINE	FNM001	11
C	NMDFN IS THEN CALLED TO EVALUATE THE FUNCTION. (SEE	FNM001	12
C	PIERCE, J.COMF.PHYSICS, FEB.,1967, P.343-366 FOR DEFINI-	FNM001	13
C	TION OF NORMAL MODE DISPERSION FUNCTION.)	FNM001	14
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)	FNM001	15
C	AUTHORS - A.O.PIERCE AND J.ROSEY, M.I.T., JUNE,1968	FNM001	16
C	---- <td>FNM001</td> <td>17</td>	FNM001	17
C	OMEGA MUST BE STORED IN WORD POSITION 402 OF UNLABELED COMMON, AN	FNM001	18
C	THETK MUST BE IN POSITION 404.	FNM001	19
C	FNM001 CALLS SUBROUTINE NMDFN WHICH CALLS AAAA AND RRRR. RRRR	FNM001	20
C	CALLS AAAA AND MPMH. ALL THESE SUBROUTINES ARE DESCRIBED ELSE-	FNM001	21
C	WHERE IN THIS SERIES.	FNM001	22
C	CALLING SEQUENCE	FNM001	23
C	COMMON CM1(401),OMEGA,CM2,THETK	FNM001	24
C	OMEGA = XXX	FNM001	25
C	THETK = XXX	FNM001	26
C	V = XXX	FNM001	27
C	FUNCTN = FNM001(V)	FNM001	28
C	INPUTS	FNM001	29
C	V PHASE VELOCITY (KM/SEC).	FNM001	30
C	R*4	FNM001	31
C	OMEGA ANGULAR FREQUENCY (RADIANS/SEC).	FNM001	32
C	R*4	FNM001	33
C	THETK PHASE VELOCITY DIRECTION MEASURED COUNTER-CLOCKWISE FROM	FNM001	34
C	R*4 X-AXIS.	FNM001	35
C	OUTPUTS	FNM001	36
C	THE ONLY OUTPUT IS THE VALUE OF THE NORMAL MODE DISPERSION FUNCTIO	FNM001	37
C	FOR THE VALUES OF V, OMEGA, AND THETK WHICH HAVE BEEN INPUT.	FNM001	38
C	---- <td>FNM001</td> <td>39</td>	FNM001	39
C	DIMENSION CI(100),VXI(100),VYI(100),HI(100)	FNM001	40
C	COMMON IPAX,CI,VXI,VYI,HI,OMEGAC,VPHSEC,THETK	FNM001	41
C	OMEGA AND THETK OBTAINED FROM COMMON	FNM001	42
C	OMEGA=OMEGAC	FNM001	43
C	CALL NMDFN(OMEGA,V,THETK,L,FPP,K)	FNM001	44
C	FNM001=FPP	FNM001	45
C	RETURN	FNM001	46
C	END	FNM001	47
C		FNM001	48
C		FNM001	49
C		FNM001	50
C		FNM001	51
C		FNM001	52
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C		FNM001	62
C		FNM001	63
C		FNM001	64
C		FNM001	65
C		FNM001	66
C		FNM001	67
C		FNM001	68
C		FNM001	69
C		FNM001	70

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SUBROUTINE(LNGTHN(OH,V,INMODE,NOP,NVP,NVPP,N1,KL,THETK)
LNGTHN(SUBROUTINE)      7/19/68    LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - LNGTHN
LENGTHEN THE MATRIX INMODE BY ADDING KL ROWS BETWEEN THE N1 AND
N1+1 ROWS
        LNGTHN ADDS KL ELEMENTS TO THE VECTOR OF PHASE VELOCITIES
        V , DIVIDING THE INTERVAL BETWEEN V(N1) AND V(N1+1) INTO
        KL+1 EQUAL PARTS. FOR EACH NEW PHASE VELOCITY, A NEW ROW
        IS ADDED TO THE INMODE MATRIX (DEFINED IN SUBROUTINE
        MPOUT). INMODE IS STORED COLUMN BY COLUMN IN VECTOR FOR
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4)
AUTHOR - J.W.POSEY, M.I.T., JUNE, 1968
-----USAGE-----
OH,V,INMODE MUST BE DIMENSIONED IN THE CALLING PROGRAM
MPOFN IS ONLY SUBROUTINE CALLED
FORTRAN USAGE
CALL LNGTHN(OH,V,INMODE,NOP,NVP,NVPP,N1,KL,THETK)
INPUTS
OH      VECTOR WHOSE ELEMENTS ARE THE VALUES OF ANGULAR FRE-
R*(OI) QUENCY CORRESPONDING TO THE COLUMNS OF THE INMODE MATRIX
V       VECTOR WHOSE ELEMENTS ARE THE VALUES OF PHASE VELOCITY
R*(OI) CORRESPONDING TO THE ROWS OF THE INMODE MATRIX.
INMODE  EACH ELEMENT OF THIS MATRIX CORRESPONDS TO A POINT IN THE
I*(OI) FREQUENCY (OH) - PHASE VELOCITY (V) PLANE. IF THE NORMA
MODE DISPERSION FUNCTION (FPF) IS POSITIVE AT THAT POINT
THE ELEMENT IS +1. IF FPF IS NEGATIVE, THE ELEMENT IS
-1. IF FPF DOES NOT EXIST, THE ELEMENT IS 0. INMODE HAS
NVP ROWS (INCREASED TO NVPP), AND NOP COLUMNS. MATRIX IS
STORED IN VECTOR FORM COLUMN AFTER COLUMN.
NOP     THE NUMBER OF ELEMENTS IN OH.
I*(O)   THE NUMBER OF ELEMENTS IN V (WHEN LNGTHN IS CALLED).
NVP     THE NUMBER OF ELEMENTS IN V (WHEN LNGTHN IS CALLED).
I*(O)   THE NUMBER OF ELEMENTS IN V (WHEN LNGTHN IS CALLED).
N1      NUMBER OF INMODE ROW IMMEDIATELY ABOVE SPACE IN WHICH NE
I*(O)   ROWS ARE TO BE ADDED
KL      NUMBER OF ROWS TO BE ADDED
I*(O)   NUMBER OF ROWS TO BE ADDED
THETK   PHASE VELOCITY DIRECTION (RADIAN)
R*(O)   PHASE VELOCITY DIRECTION (RADIAN)
OUTPUTS
THE OUTPUTS ARE NVPP (= NVP + KL) AND REVISED VERSIONS OF V AND
INMODE.
-----EXAMPLE-----
VALUES OF INMODE NOT VALID -- FOR ILLUSTRATION PURPOSES ONLY
        Y=1.0,2.0
        OH=1.0,2.0
        INMODE=1,-1,-1,1

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C CALL LNGTHN(OM,V,INMODE,2,2,NVPP,1,3,THETK)
C
C UPON RETURN TO CALLING PROGRAM THE VALUES OF V AND NVPP ARE
C V=1.0,1.25,1.5,1.75,2.0
C NVPP=5
C
C INMODE WILL BE OF THE FORM
C INMODE=1,Y,Y,Y,-1,-1,Y,Y,1
C WHERE THE Y'S ARE NEW ELEMENTS, EACH OF WHICH MAY BE -1, 1,
C OR 5
C
C ORIGINAL MATRIX          EXPANDED MATRIX
C
C      +-
C      +-
C      YY
C      YY
C      YY
C      +-
C
C -----PROGRAM FOLLOWS BELOW-----
C
C VARIABLE DIMENSIONING
C DIMENSION OM(1),V(1),INMODE(1)
C COMMON IHAX,CI(100),VXI(100),VYI(100),HI(100)
C DELVP = (V(N1+1)-V(N1)) / (KL+1)
C DELVP IS THE INTERVAL OF PHAS VELOCITIES FOR THE ADDED ROWS.
C NVPP = NVPP + KL
C NVPP IS THE NEW NUMBER OF ROWS IN THE TOTAL MATRIX.
C
C N2 IS NEW NUMBER OF OLD ROW NO. (N1+1)
C N2 = N1 + KL + 1
C
C SHIFT OLD VALUES OF V(I) IN LOWER ROWS TO I+KL SPOTS ONE HAS TO
C SHIFT THE NVPP ELEMENT FIRST. NOTE THAT I RANGES FROM NVPP TO N2
C DOWNWARD WHILE I-KL RANGES FROM NVPP TO N1+1.
C DO 71 IP =N2,NVPP
C I = NVPP - (IP-N2)
C 71 V(I) = V(I-KL)
C
C NEW VALUES OF VP ARE INSERTED INTO V
C DO 72 IP=1,KL
C I = N1 + IP
C 72 V(I) = V(N1) + IP*DELVP
C
C BEGINNING AT THE RIGHT INMODE IS LENGTHENED COLUMN BY COLUMN
C DO 90 JP=1,NOM
C J = NOM - (JP-1)
C DO 90 IP=1,NVPP
C I = NVPP - (IP-1)
C
C THE IJ ELEMENT IN THE INMODE VECTOR IS THE J ELEMENT IN THE I ROW OF
C THE NEW INMODE MATRIX
C IJ = (J-1)*NVPP + I
C
C IF I CORRESPONDS TO A NEW ROW INMODE(IJ) MUST BE DETERMINED FROM NMOP
C IF (I.GT.N1.AND.I.LT.N2) GO TO 9
C
C IJOLD IS NO. OF ELEMENT IN OLD INMODE VECTOR WHICH IS TO BE MOVED INTO
C IJ POSITION OF NEW VECTOR
C IJOLD = (J-1)*NVPP + I
C
C NOTE THAT IOLD IS ALWAYS 1 IF I .LT. N1 BUT IOLD IS I-KL IF I .GE. N2
C IJOLD IS COMPUTED ON THE BASIS OF NVPP RATHER THAN NVPP ROWS.

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IF (I.GE.N2) IJOLD = IJCLO - KL	LNGETHN	133
INMODE(IJ) = INMCDE(IJOLD)	LNGETHN	134
GO TO 80	LNGETHN	135
C 9 CALL NMOFN(OH(J),V(I),THETK,L,FPP,K)	LNGETHN	136
C	LNGETHN	137
C IF FPP EXISTS L = 1 AND INMCDE(IJ) = (FPP/ABS(FPP))	LNGETHN	138
INMODE(IJ) = 1	LNGETHN	139
IF (L.EQ.1.AND.FPP.LE.0.0) INMODE(IJ) = -1	LNGETHN	140
C	LNGETHN	141
C IF FPP DOES NOT EXIST L = -1	LNGETHN	142
IF (L.EQ.-1) INMODE(IJ)=5	LNGETHN	143
C	LNGETHN	144
80 CONTINUE	LNGETHN	145
90 CONTINUE	LNGETHN	146
RETURN	LNGETHN	147
END	LNGETHN	148
	LNGETHN	149

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SUBROUTINE MMMP(OMEGA,AKX,AKY,C,VX,VY,H,EM)
MMMH (SUBROUTINE) 7/25/68 LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - MMHM
THIS SUBROUTINE COMPUTES THE 2-BY-2 TRANSFER MATRIX EM WHICH
CONNECTS THE SOLUTIONS OF THE RESIDUAL EQUATIONS AT THE TOP
OF A LAYER TO THOSE AT THE BOTTOM OF THE LAYER BY THE RELATION
PHI1(ZB) = EM(1,1)*PHI1(ZB+H) + EM(1,2)*PHI2(ZB+H)
PHI2(ZB) = EM(2,1)*PHI1(ZB+H) + EM(2,2)*PHI2(ZB+H)
WHERE ZB DENOTES THE HEIGHT OF THE BOTTOM OF AN ISOTHERMAL
LAYER (THICKNESS H) WITH CONSTANT WINDS. THE QUANTITIES
PHI1(Z) AND PHI2(Z) SATISFY THE RESIDUAL EQUATIONS.
D(PHI1)/DZ = A(1,1)*PHI1(Z) + A(1,2)*PHI2(Z)
D(PHI2)/DZ = A(2,1)*PHI1(Z) + A(2,2)*PHI2(Z)
WHERE THE A(I,J) ARE CONSTANT OVER THE LAYER AND WHERE
A(2,2) = -A(1,1). ON THIS BASIS, ONE CAN SHOW THAT
EM(I,J) = CAI(X)*KDELTA(I,J) - 4*SAI(X)*A(I,J)
WHERE
X = (A(1,1)**2 + A(1,2)*A(2,1))*H**2
AND WHERE KDELTA(I,J) IS THE KRONECKER DELTA (1 IF INDICES
EQUAL, 0 OTHERWISE). THE FUNCTIONS CAI AND SAI ARE DEFINED IN
THE DESCRIPTIONS OF THE CORRESPONDING FUNCTION SUBPROGRAMS.
THE MATRIX A IS COMPUTED FOR GIVEN FREQUENCY, WAVE NUMBER, SOUND
SPEED, AND WIND VELOCITY BY CALLING SUBROUTINE AAAA.
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)
AUTHOR - A.O.PIERCE, P.I.T., JULY, 1968.
-----CALLING SEQUENCE-----
SEE SUBROUTINES NAMPCE,RRRR
DIMENSION EM(2,2)
CALL MMMP(OMEGA,AKX,AKY,C,VX,VY,H,EM)
-----EXTERNAL SUBROUTINES REQUIRED-----
AAAA,CAI,SAI
-----ARGUMENT LIST-----
OMEGA R*4 NO INP
AKX R*4 NO INP
AKY R*4 NO INP
C R*4 NO INP
VX R*4 NO INP
VY R*4 NO INP
A R*4 NO INP
EM R*4 2-BY-2 OUT
NO COMMON STORAGE IS USED

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C		-----INPUTS-----	MMMM	65
C			MMMM	66
C	OMEGA	=ANGULAR FREQUENCY IN RAC/SEC	MMMM	67
C	AKX	=X COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM	MMMM	68
C	AKY	=Y COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM	MMMM	69
C	C	=SOUND SPEED IN KM/SEC	MMMM	70
C	VX	=X COMPONENT OF WIND VELOCITY IN KM/SEC	MMMM	71
C	VY	=Y COMPONENT OF WIND VELOCITY IN KM/SEC	MMMM	72
C	H	=THICKNESS IN KM OF LAYER	MMMM	73
C			MMMM	74
C		-----OUTPUTS-----	MMMM	75
C			MMMM	76
C	EM	=2-9Y-2 TRANSFER MATRIX WHICH RELATES THE SOLUTIONS OF	MMMM	77
C		THE RESIDUAL EQUATIONS AT THE TOP OF A LAYER TO THOSE	MMMM	78
C		AT THE BOTTOM OF THE LAYER	MMMM	79
C			MMMM	80
C		-----PROGRAM FOLLOWS BELOW-----	MMMM	81
C			MMMM	82
C			MMMM	83
C		DIMENSION A(2,2),EM(2,2)	MMMM	84
C			MMMM	85
C		COMPUTE A(I,J), CAI(X), AND SAI(X)	MMMM	86
C		CALL AAAA(OMEGA,AKX,AKY,C,VX,VY,A)	MMMM	87
C		X=(A(1,1)**2+A(1,2)*A(2,1))*H**2	MMMM	88
C		CA=CAI(X)	MMMM	89
C		SA=SAI(X)	MMMM	90
C			MMMM	91
C		COMPUTE THE TERMS -H*SAI(X)*A(I,J)	MMMM	92
C		TA=H*SA	MMMM	93
C		DO 90 I=1,2	MMMM	94
C		DO 90 J=1,2	MMMM	95
C		90 EM(I,J)=-TA*A(I,J)	MMMM	96
C			MMMM	97
C		ADD IN CAI(X)*KDELTA(I,J) TERMS BY ADDING CA TO DIAGONAL ELEMENTS	MMMM	98
C		DO 190 I=1,2	MMMM	99
C		190 EM(I,I)=EM(I,I)+CA	MMMM	100
C			MMMM	101
C		RETURN	MMMM	102
C		END	MMMM	103

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SUBROUTINE MODETR(IST,JST,NMODE,KST,KFIN,OMMOD,VPMOD,NROW,NCOL, MODETR 1
1 INMODE,OM,VP,KRUD) MODETR 2
MODETR (SUBROUTINE) 6/25/68 LAST CARD IN DECK IS MODETR 3
C MODETR 4
C MODETR 5
C MODETR 6
C MODETR 7
C MODETR 8
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C MODETR 64

SUBROUTINE MODETR(IST,JST,NMODE,KST,KFIN,OMMOD,VPMOD,NROW,NCOL,
1 INMODE,OM,VP,KRUD)
MODETR (SUBROUTINE)

-----ABSTRACT-----

TITLE - MODETR
PROGRAM TO TABULATE A TABLE OF PHASE VELOCITY VERSUS FREQUENCY
FOR A GIVEN GUIDED MODE. THE NORMAL MODE DISPERSION FUNCTION
IS ZERO FOR EACH LISTING OF THE TABLE. THE COMPUTATIONAL
METHOD IS BASED ON THE PREVIOUSLY COMPUTED VALUES OF THE NMODF
SIGN INMODE((J-1)*NROW+I) AT POINTS (I,J) IN A RECTANGULAR
ARRAY OF NROW ROWS AND NCOL COLUMNS. DIFFERENT COLUMNS (J)
CORRESPOND TO DIFFERENT FREQUENCIES WHILE DIFFERENT ROWS (I)
CORRESPOND TO DIFFERENT PHASE VELOCITIES. DISPERSION CURVES
OF VARIOUS MODES APPEAR ON THIS ARRAY AS LINES OF DEMARCATION
BETWEEN ADJACENT REGIONS WITH DIFFERENT INMODES. TWO ADJACENT
POINTS WITH INMODES OF OPPOSITE SIGN BRACKET A POINT ON THE
ACTUAL DISPERSION CURVE. IF THE POINTS CORRESPOND TO THE SAME
FREQUENCY, THEN THE PHASE VELOCITY CORRESPONDING TO THAT FREQUENCY
ON THE DISPERSION CURVE IS FOUND BY CALLING RTMI. A 360 PACKAG
ROUTINE FOR SOLVING NONLINEAR EQUATIONS, AND CONSIDERING THE
NMODF AS A FUNCTION OF VPMSE WITH OMEGA FIXED. SIMILARLY, IF
THE POINTS CORRESPOND TO THE SAME PHASE VELOCITY, THE APPROPRI
OMEGA CORRESPONDING TO THIS PHASE VELOCITY IS FOUND BY CALLING
RTMI WITH THE NMODF CONSIDERED AS A FUNCTION OF OMEGA WITH
VPMSE FIXED.

THE PROGRAM SUCCESSIVELY CONSIDERS EACH PAIR OF ADJACENT POINT
WITH OPPOSITE INMODES BRACKETING A LINE OF DEMARCATION AND
PROCEEDS IN THE DIRECTION OF INCREASING FREQUENCY UNDER THE
ASSUMPTION THAT THE PHASE VELOCITY CURVE SLOPES DOWNWARDS.

PROGRAM NOTES

THE MODES ARE NUMERED. THE INPUT INTEGER NMODE DESIGNATES
WHICH MODE IS BEING TABULATED. THE PAIRS OF FREQUENCY
AND PHASE VELOCITY VALUES ARE STORED AS OMMOD(KST(NMODE))
OMMOD(KST(NMODE)+1),OMMOD(KST(NMODE)+2),.....
OMMOD(KFIN(NMODE)),VPMOD(KST(NMODE)),VPMOD(KST(NMODE)+1)
.....VPMOD(KFIN(NMODE)). THE ARRAYS OMMOD AND VPMOD
ARE USED TO STORE DISPERSION CURVES FOR ALL MODES.

KST(NMODE) IS INPUT WHILE KFIN(NMODE) IS DETERMINED DURING
THE COMPUTATION. THE TOTAL NUMBER OF POINTS EXTRACTABLE
FROM THE ARRAY OF INMODE VALUES DETERMINES KFIN-KST+1.
IF A SINGLE POINT CANNOT BE CALCULATED, THE PROGRAM
RETURNS KRUD=-1. OTHERWISE IT RETURNS KRUD=1.

THE SUBROUTINE RTMI FOR SOLVING A NONLINEAR EQUATION
IS ALLOWED A MAXIMUM OF TEN ITERATIONS TO FIND THE
PHASE VELOCITY TO ACCURACY OF 1.E-5 KM/SEC OR THE
FREQUENCY TO FOUR SIGNIFICANT FIGURES. IF THE SEARCH IS
UNSUCCESSFUL A MESSAGE IS PRINTED AND THE POINT IS
SKIPPED OVER.

THE INPUT PARAMETERS IST,JST ARE COORDINATES OF A POINT
IN THE INMODE ARRAY. THIS POINT SHOULD BE THAT POINT FURTH
TO THE UPPER LEFT OF THOSE POINTS LYING BELOW THE LINE OF
DEMARCATION FOR THE MODE CONSIDERED, PROVIDING THAT POINT
DOES NOT HAVE INMODE=5.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)

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C AUTHOR      - A.D.PIERCE, M.I.T., JUNE,1968
C
C      ----CALLING SEQUENCE----
C
C SEE SUBROUTINE ALLMOD
C   DIMENSION KST(1),KFIN(1),OMMOD(1),VPMOD(1),INMODE(1),OM(1),VP(1)
C   (SUBROUTINE USES VARIABLE DIMENSIONING)
C   CALL MODETR(IST,JST,NPGCE,KST,KFIN,OMMOD,VPMOD,NROW,NCOL,INMODE,
C   1 OM,VP,KRUD)
C   IF( KRUD .EQ. 1 ) GO SOMEWHERE
C
C      ----EXTERNAL SUBROUTINES REQUIRED----
C
C   NXPNT, PTHI, FPMOD1, FPMOD2, NPGFN, AAAA, RRRR, MMMM,CAI,SAI
C   (FPMOD1 AND FPMOD2 CALL NPGFN, WHICH IN TURN CALLS AAAA AND RRR
C   RRRR CALLS AAAA AND MMMM. DESCRIPTIONS OF THESE PROGRAMS ARE
C   GIVEN ELSEWHERE IN THIS SERIES.)
C
C   RTHI IS A SUBROUTINE CODED BY IBM TO DETERMINE A ROOT OF A GENERA
C   NONLINEAR EQUATION F(X)=0 BY MEANS OF MUELLER-S ITERATION SCHEME
C   OF SUCCESSIVE BISECTION AND INVERSE PARABOLIC INTERPOLATION. A
C   COMPLETE DESCRIPTION AND DECK LISTING IS GIVEN ON PAGES 198-199 O
C   DOCUMENT M20-0205-2, SYSTEM/360 SCIENTIFIC SUBROUTINE PACKAGE
C   (360A-CM-03X) VERSION II, PROGRAMMER-S MANUAL, IBM, TECHNICAL
C   PUBLICATIONS DEPARTMENT, 112 EAST POST ROAD, WHITE PLAINS, N.Y.
C   10601. PUBLISHED 1966, 1967.
C
C      ----ARGUMENT LIST----
C
C   IST      I*4    NO    INP
C   JST      I*4    NO    INP
C   NMODE     I*4    NO    INP
C   KST       I*4    VAR   INP (ONLY KST(NMODE) NEEDED)
C   KFIN      I*4    VAR   OUT (ONLY KFIN(NMODE) COMPUTED)
C   OMMOD(N)  R*4    VAR   OUT (COMPUTED FOR N .GE. KST(NMODE))
C   VPMOD(N)  R*4    VAR   OUT (COMPUTED FOR N .GE. KST(NMODE))
C   NROW      I*4    NO    INP
C   NCOL      I*4    NO    INP
C   INMODE    I*4    VAR   INP
C   OM        R*4    VAR   INP
C   VP        R*4    VAR   INP
C   KRUD      I*4    NO    OUT
C
C   COMMON STORAGE USED
C   COMMON IMAX,CI,VXI,VYI,HI,OMEGAC,VPMSEC,THETK
C
C   IMAX      I*4    NO    INP
C   CI        R*4    100  INP
C   VXI       R*4    100  INP
C   VYI       R*4    100  INP
C   HI        R*4    100  INP
C   OMEGAC    R*4    NO    OUT (USED INTERNALLY)
C   VPMSEC    R*4    NO    OUT (USED INTERNALLY)
C   THETK     R*4    NO    INP
C
C      ----INPUTS----
C
C   IST      =ROW INDEX OF START POINT, WHICH MUST LIE BELOW LINE
C             OF DEMARCATION
C   JST      =COLUMN INDEX OF START POINT
C   NMODE     =NUMBER LABELLING MODE TO BE TABULATED
C   KST(NMODE) =INDEX OF CPMOD AND VPMOD CORRESPONDING TO FIRST
C             POINT TABULATED.
C   NROW      =NUMBER OF ROWS IN INMODE ARRAY

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MODETR 65
 MODETR 66
 MODETR 67
 MODETR 68
 MODETR 69
 MODETR 70
 MODETR 71
 MODETR 72
 MODETR 73
 MODETR 74
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 MODETR 116
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 MODETR 118
 MODETR 119
 MODETR 120
 MODETR 121
 MODETR 122
 MODETR 123
 MODETR 124
 MODETR 125
 MODETR 126
 MODETR 127
 MODETR 128

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C      NCOL      *NUMBER OF COLUMNS IN INMODE ARRAY      MODETR      129
C      INMODE    *ARRAY WHOSE (J-1)*NROW+I-TH ELEMENT IS THE SIGN OF      MODETR      130
C              THE NORMAL MODE DISPERSION FUNCTION WHEN OMEGA=OM(J)      MODETR      131
C              VPHSE=VP(I).      MODETR      132
C      OM        *VECTOR OF FREQUENCIES AT WHICH INMODE IS TABULATED.      MODETR      133
C      VP        *VECTOR OF PHASE VELOCITIES AT WHICH INMODE IS      MODETR      134
C              TABULATED.      MODETR      135
C      IMAX      *NUMBER OF ATMOSPHERIC LAYERS OF FINITE THICKNESS.      MODETR      136
C      CI(I)     *SOUND SPEED IN I-TH LAYER IN KM/SEC.      MODETR      137
C      VXI(I)    *X COMPONENT OF WIND VELOCITY IN I-TH LAYER IN KM/SEC      MODETR      138
C      VYI(I)    *Y COMPONENT OF WIND VELOCITY IN I-TH LAYER IN KM/SEC      MODETR      139
C      HI(I)     *THICKNESS IN KM OF I-TH LAYER      MODETR      140
C      THETK     *PHASE VELOCITY DIRECTION IN RADIANs W.R.T. X AXIS      MODETR      141
C              ----OUTPUTS----      MODETR      142
C      KFIN(NMODE) *INDEX OF CMOD AND VPMOD CORRESPONDING TO LAST      MODETR      143
C              POINT TABULATED.      MODETR      144
C      OMMOD(N)   *ANGULAR FREQUENCY OF POINTS ON DISPERSION CURVE.      MODETR      145
C              N=KST(NMODE) UP TO KFIN(NMODE) CORRESPONDS TO NMODE      MODETR      146
C              MODE.      MODETR      147
C      VPMOD(N)   *PHASE VELOCITY OF POINTS ON DISPERSION CURVE.      MODETR      148
C              N=KST(NMODE) UP TO KFIN(NMODE) CORRESPONDS TO NMODE      MODETR      149
C              MODE.      MODETR      150
C      KRUD      *FLAG INDICATING IF ANY POINTS ON DISPERSION CURVE      MODETR      151
C              HAVE BEEN FOUND. 1 IF YES, -1 IF NO.      MODETR      152
C      OMEGAC     *INTERNALLY USED FREQUENCY TRANSMITTED AMONG SUB-      MODETR      153
C              ROUTINES THROUGH COMMON      MODETR      154
C      VPMSEC     *INTERNALLY USED PHASE VELOCITY TRANSMITTED AMONG      MODETR      155
C              SUBROUTINES THROUGH COMMON.      MODETR      156
C              ----EXAMPLE----      MODETR      157
C              SUPPOSE THE TABLE OF INMODE VALUES IS AS SHOWN BELOW WITH      MODETR      158
C              ++++++ ARCH=7, NCOL=14      MODETR      159
C              ++++++      MODETR      160
C              ++++++ OM=.1,.2,.3,.4,.5,.6,.7,.8,.9,1.0,1.1,1.2,1.3      MODETR      161
C              ++++++ 1.4      MODETR      162
C              ++++++      MODETR      163
C              ++++++ VF=.5,.45,.40,.35,.30,.25,.20      MODETR      164
C              ++++++      MODETR      165
C              ++++++ NMODE=2, IST=3, JST=1, KST(L)=7      MODETR      166
C              THEN ONE MIGHT FIND KRUC=1, KFIN(2)=23, AND      MODETR      167
C              OMMOD(7)=.1 VPMOD(7)=.43 OMMOD(16)=.75 VPMOD(16)=.3      MODETR      168
C              OMMOD(8)=.2 VPMOD(8)=.42 OMMOD(17)=.8 VPMOD(17)=.29      MODETR      169
C              OMMOD(9)=.3 VPMOD(9)=.41 OMMOD(18)=.9 VPMOD(18)=.285      MODETR      170
C              OMMOD(10)=.33 VPMOD(10)=.4 OMMOD(19)=1.0 VPMOD(19)=.28      MODETR      171
C              OMMOD(11)=.36 VPMOD(11)=.35 OMMOD(20)=1.1 VPMOD(20)=.27      MODETR      172
C              OMMOD(12)=.40 VPMOD(12)=.34 OMMOD(21)=1.2 VPMOD(21)=.265      MODETR      173
C              OMMOD(13)=.50 VPMOD(13)=.33 OMMOD(22)=1.3 VPMOD(22)=.26      MODETR      174
C              OMMOD(14)=.60 VPMOD(14)=.32 OMMOD(23)=1.4 VPMOD(23)=.255      MODETR      175
C              OMMOD(15)=.70 VPMOD(15)=.31      MODETR      176
C              ----PROGRAM FOLLOWS BELOW----      MODETR      177
C              DIMENSION CI(100),VXI(100),VYI(100),HI(100)      MODETR      178
C              DIMENSION KST(1),KFIN(1),OMMOD(1),VPMOD(1),INMODE(1),OM(1),VF(1)      MODETR      179
C              COMMON IMAX,CI,VXI,VYI,HI,OMEGAC,VPMSEC,THETK      MODETR      180
C              MODETR      181
C              MODETR      182
C              MODETR      183
C              MODETR      184
C              MODETR      185
C              MODETR      186
C              MODETR      187
C              MODETR      188
C              MODETR      189
C              MODETR      190
C              MODETR      191
C              MODETR      192

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C		MOETR	193
C	FUNCTIONS FNM001 AND FNM002 ARE USED AS ARGUMENTS OF RTM1	MOETR	194
	EXTERNAL FNM001,FNM002	MOETR	195
C		MOETR	196
C	INDEX OF FIRST POINT ON DISPERSION CURVE IS LABELLED AS K	MOETR	197
	K=KST(INMODE)	MOETR	198
C		MOETR	199
	J5=(JST-1)*NROW+IST	MOETR	200
	I0=INMODE(J5)	MOETR	201
C		MOETR	202
C	WE CHECK TO SEE IF POINT ABOVE (IST,JST) HAS A DIFFERENT INMODE	MOETR	203
	2 IF(IST.EQ. 1) GO TO 5	MOETR	204
	J6=(JST-1)*NROW+IST-1	MOETR	205
	IUP=INMODE(J6)	MOETR	206
	IF(IUP.EQ. -I0) GO TO 10	MOETR	207
C		MOETR	208
C	IF IT DOESN'T, WE CHECK THE POINT ON THE RIGHT. WE CAN ALSO ARRIVE AT	MOETR	209
C	5 FROM 2 IF IST=1.	MOETR	210
	5 IF(JST.EQ. NCOL) GO TO 8	MOETR	211
	J7=(JST)*NROW+IST	MOETR	212
	ISIO=INMODE(J7)	MOETR	213
	IF(ISIO.EQ. -I0) GO TO 15	MOETR	214
C		MOETR	215
C	IF WE ARRIVE AT 8, WE CANNOT FIND A POINT EITHER ABOVE OR TO THE RIGHT	MOETR	216
C	OF (IST,JST) WHICH HAS A INMODE OF OPPOSITE SIGN.	MOETR	217
	8 KRU0=-1	MOETR	218
	RETURN	MOETR	219
C		MOETR	220
C	WE ASSIGN A TYPE INDEX TO THE POINT (IST,JST). SEE DESCRIPTION OF	MOETR	221
C	NXTPAT FOR DEFINITION OF TYPE INDEX.	MOETR	222
	10 ITP1=1	MOETR	223
C		MOETR	224
C	OPPOSITE SIGN ABOVE	MOETR	225
	GO TO 20	MOETR	226
C		MOETR	227
	15 ITP1=2	MOETR	228
C	OPPOSITE SIGN TO RIGHT	MOETR	229
C		MOETR	230
C	WE NOW CAN IDENTIFY OUR FIRST BRACKETING	MOETR	231
	20 I1=IST	MOETR	232
	J1=JST	MOETR	233
C		MOETR	234
C	STATEMENT 25 IS START OF LOOP TERMINATING AT 190. EACH PASSAGE THRU	MOETR	235
C	LOOP GENERATES A NEW POINT ON THE DISPERSION CURVE.	MOETR	236
	25 IF(ITP1.EQ. 2) GO TO 50	MOETR	237
C		MOETR	238
C	CALCULATION IF ITP1=1. STORE FREQUENCY IN COMMON. FIND PHASE VELO-	MOETR	239
C	CITY WITHIN BRACKETED INTERVAL.	MOETR	240
	OMEGAC=OM(J1)	MOETR	241
	VDOWN=VP(I1)	MOETR	242
	VUP=VP(I1-1)	MOETR	243
	EPS=1.E-6	MOETR	244
	CALL RTM1(VA,F,FNM001,VDOWN,VUP,EPS,6,IER)	MOETR	245
	OMMOD(K)=OMEGAC	MOETR	246
	VPHOD(K)=VA	MOETR	247
	GO TO 100	MOETR	248
C		MOETR	249
C	CALCULATION IF ITP1=2. STORE PHASE VELOCITY IN COMMON. FIND FREQUE	MOETR	250
C	IN BRACKETED INTERVAL.	MOETR	251
	50 VPHSEC=VP(I1)	MOETR	252
	OMLEF=OM(J1)	MOETR	253
	OMRIT=OM(J1+1)	MOETR	254
	EPS=(1.E-6)*OMRIT	MOETR	255
	CALL RTM1(OMA,F,FNM002,OMLEF,OMRIT,EPS,6,IER)	MOETR	256

OHMOD(K)=OMA	MODETR	257
VPMOD(K)=VPHSEC	MODETR	258
C	MODETR	259
100 CONTINUE	MODETR	260
C WE HAVE NOW FOUND THE K-TH POINT. WE DO NOT YET KNOW IF THIS IS THE	MODETR	261
C FINAL POINT FOR THE NMODE-TH MODE. HOWEVER, WE SET KFIN(NMODE)=K	MODETR	262
KFIN(NMODE)=K	MODETR	263
C WHEN THE SUBROUTINE RETURNS, THE CURRENT STORED KFIN(NMODE) WILL BE	MODETR	264
C THE CORRECT ONE.	MODETR	265
C	MODETR	266
C WE NOW PREPARE THE SEARCH FOR THE NEXT POINT.	MODETR	267
K=K+1	MODETR	268
179 CALL NXTPNT(I1,J1,ITYP1,I2,J2,ITYP2,NROW,NCOL,INMODE,KUCOS)	MODETR	269
190 IF(KUCOS .EQ. -1) GO TO 200	MODETR	270
I1=I2	MODETR	271
J1=J2	MODETR	272
ITYP1=ITYP2	MODETR	273
190 GO TO 25	MODETR	274
C	MODETR	275
200 CONTINUE	MODETR	276
C WE CONTINUE HERE AFTER AN UNSUCCESSFUL ATTEMPT TO FIND THE NEXT POINT	MODETR	277
C PROVIDING WE HAVE FOUND AT LEAST ONE POINT. WE CAN EXIT WITH KRUD=1.	MODETR	278
IF(K .LE. KST(NMODE)) GO TO 8.	MODETR	279
KRUD=1	MODETR	280
RETURN	MODETR	281
C	MODETR	282
END	MODETR	283

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SUBROUTINE MOOLST(MOFNO,OMMOD,VPMOD,AKI,KST,KFIN)
MOOLST (SUBROUTINE)      6/19/6A  LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - MOOLST
TABULATION OF SELECTED POINTS ON THE PHASE VELOCITY (VPHSE) VS
ANGULAR FREQUENCY (CMEGA) CURVES OF SELECTED MODES
NO COMPUTATION OR CHANGING OF UNITS IS PERFORMED BY SUB-
ROUTINE MOOLST, IT MERELY PRINTS OUT THE INPUT IN LARELE
AND ORDERED FASHION.
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL. C29-6515-4)
AUTHORS - A.D.PIERCE AND J.POSEY, M.I.T., JUNE,1968
-----USAGE-----
NO SUBROUTINES ARE CALLED.
KFIA, CPMOD, VPMOD, KST WILL ASSUME THE DIMENSIONS SPECIFIED IN
THE CALLING PROGRAM. (DIMENSION OF KST AND KFIN MUST BE .GE. NMF
FORTRAN USAGE
CALL MOOLST (MOFNO,OMMOD,VPMOD,KST,KFIN)
INPUTS
MOFNO NUMBER OF MODES TO BE PRINTED OUT.
I*4
OMMOD VECTOR STORING ANGULAR FREQUENCY COORDINATE OF POINTS ON
R*4(D) DISPERSION CURVES. MODE M IS STORED FROM ELEMENT KST(M)
THROUGH ELEMENT KFIN(M). ( RAD/SEC )
VPMOD VECTOR STORING PHASE VELOCITY COORDINATE OF POINTS ON
R*4(D) DISPERSION CURVES. MODE M IS STORED FROM ELEMENT KST(M)
THROUGH ELEMENT KFIN(M). ( KM/SEC )
KST SEE OPMOD AND VPMOD ABOVE.
I*4(D)
KFIN SEE OPMOD AND VPMOD ABOVE.
I*4(D)
OUTPUTS
THE OUTPUT IS AN ORDERED AND LAREELED PRINT OUT OF THE INPUTS, EX-
CLUDING KST AND KFIN. ( SEE EXAMPLE BELOW. )
-----EXAMPLE-----
CALLING PROGRAM
DIMENSION KST(2),KFIN(2),OPMOD(5),VPMOD(5)
MOFNO = 2
KST = 1,3
KFIN = 2,5

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C      OMHOD = 0.1,0.2,0.1,0.15,0.2
C      VPHOD = 1.0,2.0,2.0,2.5,3.0
C      CALL MODLST (MOFNO,OMHOD,VPHOD,KST,KFIN)
C
C      PRINT OUT
C
C      TABULATION OF FIRST      2 MODES
C
C      MODE 1
C
C      OMEGA (RAD/SEC)      VPHSE (KM/SEC)
C      0.100000      1.000000
C      0.200000      2.000000
C
C      MODE 2
C
C      OMEGA (RAD/SEC)      VPHSE (KM/SEC)
C      0.100000      2.000000
C      0.150000      2.500000
C      0.200000      3.000000
C
C      END OF EXAMPLE
C
C      ----PROGRAM FOLLOWS BELOW----
C
C      VARIABLE DIMENSIONING
C      DIMENSION KFIN(1),OMHOD(1),VPHOD(1),KST(1)
C      DIMENSION AKI(1000)
C      WRITE(6,11) MOFNO
C      11 FORMAT(1H1,25X,19HTABULATION OF FIRST, 16.6H MODES)
C      DO 100 II=1,MOFNO
C      WRITE (6,21) II
C      21 FORMAT(1H ///,1H ,35X, 5HMODE ,13//, 1H ,12X,15HOMEGA (RAD/SEC),
C      110X,14HVPHSE (KM/SEC),10X,15HAKI (NEPERS/KM) //)
C      K1=KST(II)
C      K2 =KFIN(II)
C      DO 100 J=K1,K2
C      OMEGA=OMHOD(J)
C      VPHSE=VPHOD(J)
C      AKIPR=AKI(J)
C      31 FORMAT (1H ,12X,F15.8,10X,F14.8,10X,5E12.5)
C      WRITE (6,31) OMEGA,VPHSE,AKIPR
C      100 CONTINUE
C      RETURN
C      END..

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MODLST 65
 MODLST 66
 MODLST 67
 MODLST 68
 MODLST 69
 MODLST 70
 MODLST 71
 MODLST 72
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 MODLST 119
 MODLST 120
 MODLST 121

SUBROUTINE MPOUT(OM1,OM2,V1,V2,NCH,NVP,INMODE,OM,V,THETK)
MPOUT (SUBROUTINE) 7/19/68 LAST CARD IN DECK IS

-----ABSTRACT-----

TITLE - MPOUT

TABULATION OF NORMAL MODE DISPERSION FUNCTION SIGN AT POINTS
IN A RECTANGULAR REGION OF FREQUENCY - PHASE VELOCITY PLANE

THE VECTOR V OF PHASE VELOCITIES IS CONSTRUCTED BY TAKING
VALUES AT INTERVALS OF $((V2-V1)/(NVP-1))$ FROM V2 DOWN TO
V1. SIMILARLY, VECTOR OM OF ANGULAR FREQUENCIES IS CON-
STRUCTED BY TAKING VALUES AT INTERVALS OF $((OM2-OM1)/(NCH-1))$
FROM OM1 UP TO OM2. NEXT, MATRIX INMODE IS CON-
STRUCTED WITH NVP ROWS AND NCH COLUMNS. SINCE INMODE IS
STORED IN VECTOR FORM, COLUMN AFTER COLUMN, ELEMENT J IN
ROW I IS REPRESENTED AS INMODE $((J-1)*NVP + I)$. THE VALUE
OF THIS ELEMENT IS DETERMINED BY CALLING SUBROUTINE NMOF
TO EVALUATE THE NORMAL MODE DISPERSION FUNCTION, FPP, FOR
FREQUENCY OM(J) AND PHASE VELOCITY V(I). IF FPP DOES NOT
EXIST, THE ELEMENT IS SET EQUAL TO 5. OTHERWISE THE ELE-
MENT WILL BE 1 TIMES THE SIGN OF FPP.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C23-6515-4)
AUTHORS - A.O.PIERCE AND J.POSEY, M.I.T., JUNE, 1968

-----USAGE-----

VARIABLES OM,V,INMODE MUST BE DIMENSIONED IN CALLING PROGRAM
FORTRAN SUBROUTINE NMOF (DESCRIBED ELSEWHERE IN THIS SERIES) IS
CALLED

FORTRAN USAGE

CALL MPOUT(OM1,OM2,V1,V2,NCH,NVP,INMODE,OM,V,THETK)

INPUTS

OM1 MINIMUM ANGULAR FREQUENCY TO BE CONSIDERED (RADIAN / SEC)
R*4
OM2 MAXIMUM ANGULAR FREQUENCY TO BE CONSIDERED (RADIAN / SEC)
R*4
V1 MINIMUM PHASE VELOCITY TO BE CONSIDERED (KM / SEC)
R*4
V2 MAXIMUM PHASE VELOCITY TO BE CONSIDERED (KM / SEC)
R*4
NCH NUMBER OF FREQUENCIES TO BE CONSIDERED (NO. OF ELEMENTS
IN OM AND NO. OF COLUMNS IN INMODE)
I*4
NVP NUMBER OF PHASE VELOCITIES TO BE CONSIDERED (NO. OF ELE-
MENTS IN V AND NO. OF ROWS IN INMODE)
I*4
THETK DIRECTION OF PHASE VELOCITY MEASURED COUNTER CLOCKWISE
FROM X-AXIS (RADIAN)
R*4

OUTPUTS

INMODE MATRIX OF NORMAL MODE DISPERSION FUNCTION SIGNS (SEE
I*4(D) ABSTRACT ABOVE FOR EXPLANATION OF ELEMENT VALUES)
OM VECTOR OF NCH VALUES OF ANGULAR FREQUENCY AT EQUAL INTER-
R*4(D) VALS FROM OM1 TO OM2 INCLUSIVE (RADIAN / SEC).
V VECTOR OF NVP VALUES OF PHASE VELOCITY AT EQUAL INTERVAL
R*4(D) FROM V2 TO V1 INCLUSIVE (KM / SEC)

-----EXAMPLE-----

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C CALLING PROGRAM	HPOUT	73
C DIMENSION OM(3),V(3),INMODE(9)	HPOUT	74
C OM1 = 1.0	HPOUT	75
C OM2 = 3.0	HPOUT	76
C V1 = 1.0	HPOUT	77
C V2 = 3.0	HPOUT	78
C NOM = 3	HPOUT	79
C NVP = 3	HPOUT	80
C THETK = 0.0	HPOUT	81
C CALL MPOUT (OM1,OM2,V1,V2,NOM,NVP,INMODE,OM,V,THETK)	HPOUT	82
C END	HPOUT	83
C UPON RETURN FROM MPOUT, OM AND V WILL HAVE THE FOLLOWING VALUES	HPOUT	84
C OM = 1.0 , 2.0 , 3.0	HPOUT	85
C V = 3.0 , 2.0 , 1.0	HPOUT	86
C EACH OF THE NINE ELEMENTS OF INMODE WILL BE -1, 1 OR 5 AS DETERMINED	HPOUT	87
C BY THE NORMAL MODE DISPERSION FUNCTION (SEE ABSTRACT ABOVE)	HPOUT	88
C	HPOUT	89
C	HPOUT	90
C	HPOUT	91
C	HPOUT	92
C	HPOUT	93
C	HPOUT	94
C	HPOUT	95
C VARIABLE DIMENSIONING	HPOUT	96
C DIMENSION OM(1),V(1),INMODE(1)	HPOUT	97
C COMMON IPAX,C1(100),VXI(100),VYI(100),MI(100)	HPOUT	98
C	HPOUT	99
C INTERVAL BETWEEN SUCCESSIVE ELEMENTS OF OM IS DETERMINED	HPOUT	100
C DELCM=(OM2-OM1)/(NOM-1)	HPOUT	101
C	HPOUT	102
C INTERVAL BETWEEN SUCCESSIVE ELEMENTS OF V IS DETERMINED	HPOUT	103
C DELV=(V2-V1)/(NVP-1)	HPOUT	104
C	HPOUT	105
C VECTOR V IS CONSTRUCTED WITH V(I) DROPPING FROM V2 TO V1 AS I GOES FROM	HPOUT	106
C 1 TO NVP	HPOUT	107
C V(1)=V2	HPOUT	108
C DO 10 I=2,NVP	HPOUT	109
C 10 V(I)=V(I-1)-DELV	HPOUT	110
C	HPOUT	111
C OM(J) GOES FROM OM1 TO OM2 AS J GOES FROM 1 TO NOM	HPOUT	112
C DO 90 J=1,NOM	HPOUT	113
C OM(J) = OM1 +(J-1)*DELCM	HPOUT	114
C	HPOUT	115
C FOR A FIXED VALUE OF J, ALL VALUES OF I FROM 1 THROUGH NVP ARE CONSID	HPOUT	116
C ERED, THUS EVALUATING COLUMN J OF INMODE	HPOUT	117
C DO 90 I=1,NVP	HPOUT	118
C	HPOUT	119
C IJ IS NO. OF ELEMENT IN VECTOR REPRESENTATION OF INMODE WHICH CORRES-	HPOUT	120
C POND TO ELEMENT J OF ROW I IN MATRIX FORM OF INMODE	HPOUT	121
C IJ=(J-1)*NVP + I	HPOUT	122
C VPHSE=V(I)	HPOUT	123
C	HPOUT	124
C NMOFN IS CALLED TO EVALUATE THE NORMAL MODE DISPERSION FUNCTION FOR	HPOUT	125
C FREQUENCY OM(J) AND PHASE VELOCITY V(I)	HPOUT	126
C CALL NMOFN(OM(J),VPHSE,THETK,L,FPP,K)	HPOUT	127
C	HPOUT	128
C WHEN NORMAL MODE DISPERSION FUNCTION DOES NOT EXIST (L.EQ.-1), INMODE	HPOUT	129
C (IJ) = 5	HPOUT	130
C IF(L.EQ.-1) GO TO 50	HPOUT	131
C	HPOUT	132
C WHEN THE FUNCTION DOES EXIST AND IS FPP, INMODE(IJ) = 1*FPP/ABS(FPP)	HPOUT	133
C INMODE(IJ) = 1	HPOUT	134
C IF (FPP.LE.0.0) INMODE(IJ) = -1	HPOUT	135
C GO TO 80	HPOUT	136
C 50 INMODE(IJ)=5	HPOUT	137
C 80 CONTINUE	HPOUT	138
C 90 CONTINUE	HPOUT	139
C RETURN	HPOUT	140
C END	HPOUT	141

SUBROUTINE NAMPOE(ZSCRC, ZOPS, OMEGA, VPHSE, AKI, THETK, AMPLTO, NFRNT) NAMPOE 1
NAMPOE (SUBROUTINE) 6/27/68 LAST CARD IN DECK IS NAMPOE 2

-----ABSTRACT-----

TITLE - NAMPOE

PROGRAM TO DETERMINE AN AMPLITUDE FACTOR AMPLTO OF A GUIDED
MODE EXCITED BY A POINT ENERGY SOURCE IN THE ATMOSPHERE. THE
SOURCE IS AT ALTITUDE ZSCRC KM AND THE OBSERVER IS AT ALTITUDE
ZOPS IN KM. THE PARTICULAR AMPLTO COMPUTED CORRESPONDS TO AN
ANGULAR FREQUENCY OMEGA (RAD/SEC), A PHASE VELOCITY VPHSE
(KM/SEC), AND A PHASE VELOCITY DIRECTION THETK (RADIAN) REC-
KONED COUNTER-CLOCKWISE FROM THE X AXIS. PARAMETERS DEFINING
THE AMBIENT ATMOSPHERE ARE PRESUMED TO BE STORED IN COMMON.
THE NORMAL MODE DISPERSION FUNCTION NMDF IS PRESUMED TO VANISH
FOR ARGUMENTS OMEGA, VPHSE, THETK, NAMPOE 17

THE ACTUAL DEFINITION OF AMPLTO IS AS FOLLOWS. LET S1(Z) AND
S2(Z) BE THE SOLUTIONS OF THE RESIDUAL EQUATIONS NAMPOE 18

$$\begin{aligned} O(S1)/OZ &= (A11)*S1 + (A12)*S2 & (1-A) \text{ NAMPOE } 22 \\ O(S2)/OZ &= (A21)*S1 + (A22)*S2 & (1-B) \text{ NAMPOE } 23 \end{aligned}$$

WHERE THE MATRIX A IS AS COMPUTED BY AAAA AND AS DEFINED BY
A.O. FIERCE, J. COMP. PHYS., VOL. 1, NO. 3, FEB., 1967, PP. 343-
366, EQS. 11. THE ELEMENTS OF A SHOULD BE CONSIDERED AS FUNC-
TIONS OF ALTITUDE. WE DEFINE THE REDUCED PRESSURE ZFN(Z) AS NAMPOE 24

$$ZFN(Z) = (G/C)*S1 - C*S2 \quad (2) \text{ NAMPOE } 25$$

WHERE G IS ACCELERATION OF GRAVITY AND C IS SOUND SPEED. THEN NAMPOE 26

$$\text{AMPLTO} = (1/2) * \frac{S2(ZSCRC)*ZFN(ZOPS)}{BOM(ZSCRC)*\text{INTEGRAL}} \quad (3) \text{ NAMPOE } 27$$

WHERE NAMPOE 28

$$BOM(Z) = OMEGA - KX*VX(Z) - KY*VY(Z) \quad (4) \text{ NAMPOE } 29$$

IS THE DOPPLER SHIFTED ANGULAR FREQUENCY. THE INTEGRAL IS 1/2
OF THE I-SUR1 DEFINED BY A.O. FIERCE, J. ACOUST. SOC. AMER.,
VOL. 37, NO. 2, FEB., 1965, PP. 214-227, EQ. (51). SPECIFICALLY NAMPOE 30

INTEGRAL = (INTEGRAL OVER Z FROM 0 TO INFINITY) OF NAMPOE 31

$$\begin{aligned} & (BOM*((KX*VX+KY*VY)/K)*YFN(Z)**2 \\ & + (K*OMEGA/BOM**3)*ZFN(Z)**2 \end{aligned} \quad (5) \text{ NAMPOE } 32$$

WHERE K IS THE MAGNITUDE OF THE WAVE-NUMBER VECTOR (KX, KY) AND NAMPOE 33

$$YFN(Z) = (1/C)*S1(Z) \quad (6) \text{ NAMPOE } 34$$

PROGRAM NOTES

THE INTEGRAL IS COMPUTED BY SUBROUTINE TOTINT IN TWO PAR
AS X3+X7. THE FIRST IS OBTAINED BY CALLING TOTINT WITH
IT=3, WHILE THE SECOND IS OBTAINED BY CALLING TOTINT WITH NAMPOE 35

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C      IT=7. THE IT PARAMETER GOVERNS THE CHOICE OF COEFFICIENTS NAMPOE 61
C      A1, A2, A3 RETURNED TO TOTINT BY SUBROUTINE USEAS. FOR NAMPOE 62
C      FURTHER INFORMATION, SEE THE DOCUMENTATION ON TOTINT AND NAMPOE 63
C      USEAS. NAMPOE 64
C      THE NORMALIZATION OF S1 AND S2 CANNOT AFFECT AMPLTD. NAMPOE 65
C      HOWEVER, TOTINT ADOPTS NORMALIZATION WHERE NAMPOE 66
C      S1 =-SQRT(GG)*A12 NAMPOE 67
C      S2 =SQRT(GG)*(GG+A11) NAMPOE 68
C      AT THE BOTTOM OF THE UPPER HALF SPACE. THE NUMERATOR OF NAMPOE 69
C      EQ.(3) IS ACCORDINGLY COMPUTED WITH SAME NORMALIZATION. NAMPOE 70
C      HERE GG=SQRT(A11**2+A12**2). NAMPOE 71
C      THE ONLY BOUNDARY CONDITION EXPLICITLY USED IS THE UPPER NAMPOE 72
C      BOUNDARY CONDITION WHEREBY BOTH S1(Z) AND S2(Z) DECREASE NAMPOE 73
C      EXPONENTIALLY WITH INCREASING HEIGHT IN THE UPPER NAMPOE 74
C      HALFSpace. IF THIS CANNOT BE SATISFIED, THE PROGRAM NAMPOE 75
C      RETURNS AMPLTD=0. THIS WOULD IMPLY THAT THE POINT NAMPOE 76
C      CONSIDERED IS PRACTICALLY IDENTICAL TO ONE WHERE OMEGA NAMPOE 77
C      IS THE CUTOFF FREQUENCY FOR THE GUIDED MODE UNDER NAMPOE 78
C      CONSIDERATION. NAMPOE 79
C      NAMPOE 80
C      NAMPOE 81
C      NAMPOE 82
C      LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4) NAMPOE 83
C      AUTHOR - A.O.PIERCE, P.I.T., JUNE,1968 NAMPOE 84
C      NAMPOE 85
C      ----CALLING SEQUENCE----- NAMPOE 86
C      SEE SUBROUTINE NAMPOE NAMPOE 87
C      DIMENSION CI(100),VXI(100),VYI(100),HI(100) NAMPOE 88
C      COMMON IMAX,CI,VXI,VYI,HI (THESE MUST BE IN COMMON) NAMPOE 89
C      CALL NAMPOE(ZSCRCE,ZOBS,OMEGA,VPHSE,THETK,AMPLTD,NPRNT) NAMPOE 90
C      NAMPOE 91
C      ----EXTERNAL SUBROUTINES REQUIRED----- NAMPOE 92
C      NAMPOE 93
C      TOTINT,MMMM,AAAA,USEAS,UPINT,ELINT,BBBS,CAI,SAI NAMPOE 94
C      NAMPOE 95
C      (THE FIRST THREE ARE EXPLICITLY CALLED. THE REMAINING SUBROUTINE NAMPOE 96
C      ARE IMPLICITLY CALLED WHEN TOTINT IS CALLED.) NAMPOE 97
C      NAMPOE 98
C      ----ARGUMENT LIST----- NAMPOE 99
C      NAMPOE 100
C      ZSCRCE R*4 NO INP NAMPOE 101
C      ZOBS R*4 NO INP NAMPOE 102
C      OMEGA R*4 NO INP NAMPOE 103
C      VPHSE R*4 NO INP NAMPOE 104
C      THETK R*4 NO INP NAMPOE 105
C      AMPLTD R*4 NO OUT NAMPOE 106
C      NPRNT I*4 NO INP NAMPOE 107
C      NAMPOE 108
C      COMMON STORAGE USED NAMPOE 109
C      COMMON IMAX,CI,VXI,VYI,HI NAMPOE 110
C      NAMPOE 111
C      IMAX I*4 NO INP NAMPOE 112
C      CI R*4 100 INP NAMPOE 113
C      VXI R*4 100 INP NAMPOE 114
C      VYI R*4 100 INP NAMPOE 115
C      HI R*4 100 INP NAMPOE 116
C      NAMPOE 117
C      NAMPOE 118
C      NAMPOE 119
C      ----INPUTS----- NAMPOE 120
C      NAMPOE 121
C      ZSCRCE =HEIGHT OF SOURCE IN KM NAMPOE 122
C      ZOBS =HEIGHT OF OBSERVER NAMPOE 123
C      OMEGA =ANGULAR FREQUENCY IN RAD/SEC NAMPOE 124

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C      VPHSE      =PHASE VELOCITY IN KM/SEC      NAMPOE      125
C      THETK      =PHASE VELOCITY DIRECTION (RADIAN) RECKONED      NAMPOE      126
C      NPRINT      =PRINT OPTIC INDICATOR (SEE NAME IN MAIN PROGRAM)      NAMPOE      127
C      COUNTER-CLOCKWISE FROM X AXIS.      NAMPOE      128
C      IMAX      =NUMBER OF ATMOSPHERIC LAYERS WITH FINITE THICKNESS      NAMPOE      129
C      CI(I)      =SOUND SPEED (KM/SEC) IN I-TH LAYER      NAMPOE      130
C      VXI(I)      =X COMPONENT OF WIND VELOCITY (KM/SEC) IN I-TH LAYER      NAMPOE      131
C      VYI(I)      =Y COMPONENT OF WIND VELOCITY (KM/SEC) IN I-TH LAYER      NAMPOE      132
C      HI(I)      =THICKNESS IN KM OF I-TH LAYER      NAMPOE      133
C      NAMPOE      134
C      NAMPOE      135
C      ----OUTPUTS----      NAMPOE      136
C      AMPLTO      =AMPLITUDE FACTOR FOR GUIDED WAVE EXCITED BY POINT      NAMPOE      137
C      ENERGY SOURCE. UNITS ARE KM**(-1).      NAMPOE      138
C      NAMPOE      139
C      ----EXAMPLE----      NAMPOE      140
C      SUPPOSE THE ATMOSPHERE IS ISOTHERMAL AND THERE ARE NO WINDS. THE      NAMPOE      141
C      THERE IS ONLY ONE MODE, FOR WHICH VPHSE=C. FURTHERMORE, YFN(Z)      NAMPOE      142
C      AND S1(Z) ARE BOTH ZERO. THE ZFN(Z) DECREASES EXPONENTIALLY      NAMPOE      143
C      WITH HEIGHT AS EXP(-(0.3*G/C**2)). THE RESULTING AMPLTO      NAMPOE      144
C      SHOULD BE      NAMPOE      145
C      AMPLTO=-(.3*G/C**2)*EXP(-(0.3*(G/C**2)*(Z OBS+ZSRC))      NAMPOE      146
C      REGARDLESS OF VALUES OF CMEGA AND THETK. IF C=1/3 KM/SEC,      NAMPOE      147
C      G=.01 KM/SEC**2, Z OBS=0, ZSRC=0, THEN AMPLTO=.027 KM**(-1).      NAMPOE      148
C      NAMPOE      149
C      NAMPOE      150
C      NAMPOE      151
C      ----PROGRAM FOLLOWS BELOW----      NAMPOE      152
C      NAMPOE      153
C      NAMPOE      154
C      NAMPOE      155
C      DIMENSION CI(100),VXI(100),VYI(100),HI(100)      NAMPOE      156
C      DIMENSION A(2,2),EM(2,2)      NAMPOE      157
C      DIMENSION ZIJZ(2),S1(2),S2(2),VXIJZ(2),VYIJZ(2),CIJZ(2)      NAMPOE      158
C DIMENSION STATEMENTS ADDED IN THE DEBUG PROCESS      NAMPOE      159
C      DIMENSION LAYJZ(2),GFLI(2),POP(2,2),EMP(100,2,2),DUNNY(2,2)      NAMPOE      160
C      DIMENSION PHI1(100),PHI2(100)      NAMPOE      161
C      COMMON IMAX,CI,VXI,VYI,HI      NAMPOE      162
C      SAVE = CI(IMAX)      NAMPOE      163
C      IF(AKI .GE. 1.E-10) RETURN      NAMPOE      164
C      NAMPOE      165
C      C COMPUTE HAVE NUMBER VECTOR COMPONENTS      NAMPOE      166
C      1 CONTINUE      NAMPOE      167
C      AKX=(OMEGA/VPHSE)*COS(THETK)      NAMPOE      168
C      AKY=(OMEGA/VPHSE)*SIN(THETK)      NAMPOE      169
C      NAMPOE      170
C      C THE SOURCE AND OBSERVER LOCATIONS ARE NUMBERED ACCORDING TO HEIGHT      NAMPOE      171
C      IF(ZSRC .GT. ZOBS) GO TO 10      NAMPOE      172
C      ZIJZ(1)=ZSRC      NAMPOE      173
C      ZIJZ(2)=ZOBS      NAMPOE      174
C      NSRC=1      NAMPOE      175
C      NOBS=2      NAMPOE      176
C      GO TO 20      NAMPOE      177
C      10 ZIJZ(1)=ZOBS      NAMPOE      178
C      ZIJZ(2)=ZSRC      NAMPOE      179
C      NOBS=1      NAMPOE      180
C      NSRC=2      NAMPOE      181
C      NAMPOE      182
C      C WE DENOTE S1 AND S2 AT BOTTOM OF UPPER HALFSpace BY F1 AND F2. THEIR      NAMPOE      183
C      COMPUTATION IS AS FOLLOWS.      NAMPOE      184
C      20 IZMAX=2      NAMPOE      185
C      J=IZMAX+1      NAMPOE      186
C      C=CI(J)      NAMPOE      187
C      VX=VXI(J)      NAMPOE      188

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VY=VYI(J)	NAMPDE	189
CALL AAAA(OMFGA,AKX,AKY,C,VX,VY,A)	NAMPDE	190
X=A(1,1)**2+A(1,2)*A(2,1)	NAMPDE	191
IF(X.LE.0.C) GO TO 200	NAMPDE	192
G=SQRT(X)	NAMPDE	193
GRT=SQRT(G)	NAMPDE	194
F1=-GRT*A(1,2)	NAMPDE	195
F2=GRT*(A(1,1)+G)	NAMPDE	196
C	NAMPDE	197
C WE COMPUTE ZM REPRESENTING THE BOTTOM OF THE UPPER HALFSpace	NAMPDE	198
ZM=0.0	NAMPDE	199
IF(IMAX.EQ.0) GO TO 31	NAMPDE	200
DO 30 IC=1,IMAX	NAMPDE	201
30 ZM=ZM+HI(IC)	NAMPDE	202
C	NAMPDE	203
C WE STORE F1P,F2P,ZMP	NAMPDE	204
31 F1P=F1	NAMPDE	205
F2P=F2	NAMPDE	206
ZMP=ZM	NAMPDE	207
C	NAMPDE	208
C COMPUTATION OF LAYJZ(JZ) AND DELT(JZ)	NAMPDE	209
C LAYJZ(JZ) IS THE INDEX OF THE LAYER IN WHICH ZIJZ(JZ) LIES.	NAMPDE	210
C WHILE DELT(JZ) IS THE DISTANCE OF ZIJZ(JZ) ABOVE THE BOTTOM EDGE OF	NAMPDE	211
C THE LAYER	NAMPDE	212
DO 35 JZ=1,2	NAMPDE	213
LAYJZ(JZ)=IMAX+1	NAMPDE	214
32 DELT(JZ)=ZIJZ(JZ)-ZM	NAMPDE	215
IF(DELT(JZ).GT.0.0) GO TO 35	NAMPDE	216
IF(LAYJZ(JZ).EQ.1) GO TO 35	NAMPDE	217
LAYJZ(JZ)=LAYJZ(JZ)-1	NAMPDE	218
J8=LAYJZ(JZ)	NAMPDE	219
ZM=ZM+HI(J8)	NAMPDE	220
C AT THIS POINT ZM DENOTES THE BOTTOM OF THE LAYJZ(JZ) LAYER	NAMPDE	221
GO TO 32	NAMPDE	222
35 ZM=ZMP	NAMPDE	223
C	NAMPDE	224
C COMPUTATION OF EM MATRICES FOR ALL IMAX LAYERS OF FINITE THICKNESS	NAMPDE	225
C EM(IP,JP) FOR I-TH LAYER IS STORED AS EMP(I,IP,JP)	NAMPDE	226
DO 36 I=1,IMAX	NAMPDE	227
C=C(I)	NAMPDE	228
VX=VXI(I)	NAMPDE	229
VY=VYI(I)	NAMPDE	230
H=HI(I)	NAMPDE	231
CALL MPM(OMEGA,AKX,AKY,C,VX,VY,H,EM)	NAMPDE	232
DO 36 IP=1,2	NAMPDE	233
DO 36 JP=1,2	NAMPDE	234
36 EMP(I,IP,JP)=EM(IP,JP)	NAMPDE	235
C	NAMPDE	236
C COMPUTATION OF RPP MATRIX. THIS ACCOMPLISHES THE SAME AS CALLING	NAMPDE	237
C SUBROUTINE RRRR	NAMPDE	238
RPP(1,1)=1.0	NAMPDE	239
RPP(1,2)=0.0	NAMPDE	240
RPP(2,1)=0.0	NAMPDE	241
RPP(2,2)=1.0	NAMPDE	242
DO 38 I=1,IMAX	NAMPDE	243
JASA=IMAX+1-I	NAMPDE	244
DO 37 IP=1,2	NAMPDE	245
DO 37 JP=1,2	NAMPDE	246
37 QUHMY(IP,JP)=EMP(JASA,IP,1)*RPP(1,JP)+EMP(JASA,IP,2)*RPP(2,JP)	NAMPDE	247
DO 38 IP=1,2	NAMPDE	248
DO 38 JP=1,2	NAMPDE	249
38 RPP(IP,JP)=QUHMY(IP,JP)	NAMPDE	250
C	NAMPDE	251
QUOT = ABS(RPP(1,1))/(ABS(RPP(1,1))+ABS(RPP(1,2))+ABS(RPP(2,1)))	NAMPDE	252

1 +ABS(RPP(2,2))	NAMPOE	253
IF (QUOT .LT. 0.1) GO TO 120	NAMPOE	254
F290T=F2P/RPP(1,1)	NAMPOE	255
GO TO 150	NAMPOE	256
120 QUOT = ABS(RPP(1,2))/(ABS(RPP(1,1))+ABS(RPP(1,2))+ABS(RPP(2,1)))	NAMPOE	257
1 +ABS(RPP(2,2))	NAMPOE	258
IF (QUOT .LT. 0.1) GO TO 130	NAMPOE	259
F290T=-F1P/RPP(1,2)	NAMPOE	260
GO TO 150	NAMPOE	261
130 F290T=RPP(2,1)*F1P+RPP(2,2)*F2P	NAMPOE	262
150 F290T=F290T	NAMPOE	263
PHI1(1)=0.0	NAMPOE	264
PHI2(1)=F290T	NAMPOE	265
KTOUP=1	NAMPOE	266
K=IMAX+1	NAMPOE	267
PHI1(K)=F1P	NAMPOE	268
PHI2(K)=F2P	NAMPOE	269
331 T1=PHI1(K)	NAMPOE	270
T2=PHI2(K)	NAMPOE	271
K=K-1	NAMPOE	272
IF (K .EQ. 1) GO TO 400	NAMPOE	273
C=CI(K)	NAMPOE	274
VX=VXI(K)	NAMPOE	275
VY=VYI(K)	NAMPOE	276
CALL AAAA(OMEGA,AKX,AKY,C,VX,VY,A)	NAMPOE	277
X=A(1,1)*2+A(1,2)*A(2,1)	NAMPOE	278
IF (X .GT. 0.0) GO TO 340	NAMPOE	279
333 PHI1(K)=EMP(K,1,1)*T1+EMP(K,1,2)*T2	NAMPOE	280
PHI2(K)=EMP(K,2,1)*T1+EMP(K,2,2)*T2	NAMPOE	281
GO TO 331	NAMPOE	282
340 O1=A(1,1)*T1+A(1,2)*T2	NAMPOE	283
O2=A(2,1)*T1+A(2,2)*T2	NAMPOE	284
IF (O1 .LT. 0.0 .AND. T1 .LT. 0.0) GO TO 341	NAMPOE	285
IF (O1 .GT. 0.0 .AND. T1 .GT. 0.0) GO TO 341	NAMPOE	286
IF (O2 .LT. 0.0 .AND. T2 .LT. 0.0) GO TO 341	NAMPOE	287
IF (O2 .GT. 0.0 .AND. T2 .GT. 0.0) GO TO 341	NAMPOE	288
GO TO 333	NAMPOE	289
341 CONTINUE	NAMPOE	290
C AT THIS POINT THE CURRENT VALUE OF K IS NOT ZERO OR ONE	NAMPOE	291
KTOUP=K	NAMPOE	292
GO 360 K=2,KTOUP	NAMPOE	293
JET=K-1	NAMPOE	294
T1=PHI1(JET)	NAMPOE	295
T2=PHI2(JET)	NAMPOE	296
PHI1(K)=EMP(JET,2,2)*T1-EMP(JET,1,2)*T2	NAMPOE	297
360 PHI2(K)=-EMP(JET,2,1)*T1+EMP(JET,1,1)*T2	NAMPOE	298
400 NZC1 = 0	NAMPOE	299
NZC2 = 0	NAMPOE	300
IAP1MX = 1	NAMPOE	301
IA02MX = 1	NAMPOE	302
AP1MX = ABS(PHI1(1))	NAMPOE	303
AP2MX = ABS(PHI2(1))	NAMPOE	304
GO 407 LNMI=1,IMAX	NAMPOE	305
LN = LNMI + 1	NAMPOE	306
AP1P = ABS(PHI1(LN))	NAMPOE	307
IF (AP1P.LE.AP1MX) GO TO 403	NAMPOE	308
IAP1MX = LN	NAMPOE	309
AP1MX = AP1P	NAMPOE	310
403 AP2P = ABS(PHI2(LN))	NAMPOE	311
IF (AP2P.LE.AP2MX) GO TO 405	NAMPOE	312
AP2MX = AP2P	NAMPOE	313
IAP2MX = LN	NAMPOE	314
405 IF ((PHI1(LNMI)*PHI1(LN)).LT.0.0) NZC1 = NZC1 + 1	NAMPOE	315
IF ((PHI2(LNMI)*PHI2(LN)).LT.0.0) NZC2 = NZC2 + 1	NAMPOE	316

407 CONTINUE	NANPOE	317
R1 = PHI1(IAP1MX)/AP2MX	NANPOE	318
R2 = PHI2(IAP2MX)/AP2MX	NANPOE	319
R3 = PHI2(1)/AP2MX	NANPOE	320
WRITE (6,409) OMEGA,VPHSE,IAP1MX,R1,NZC1,IAP2MX,R2,NZC2,R3	NANPOE	321
409 FORMAT (1H,2F12.5,9X,I3,F12.5,9X,I3,9X,I3,F12.5,9X,I3,F12.5)	NANPOE	322
415 DO 450 JZ=1,2	NANPOE	323
IDA=LAYJZ(JZ)	NANPOE	324
C=CI(IDA)	NANPOE	325
VX=VXI(IDA)	NANPOE	326
VY=VYI(IDA)	NANPOE	327
CIJZ(JZ)=CI(IDA)	NANPOE	328
VXIJZ(JZ)=VXI(IDA)	NANPOE	329
VYIJZ(JZ)=VYI(IDA)	NANPOE	330
IF(IDA.EQ.IMAX+1) GO TO 420	NANPOE	331
IF(IDA.LE.KTOUF) GO TO 430	NANPOE	332
JET=IDA+1	NANPOE	333
H=HI(IDA)-DELT(JZ)	NANPOE	334
CALL MPM(OMEGA,AKX,AKY,C,VX,VY,H,EM)	NANPOE	335
S1(JZ)=EM(1,1)*PHI1(JET)+EM(1,2)*PHI2(JET)	NANPOE	336
S2(JZ)=EM(2,1)*PHI1(JET)+EM(2,2)*PHI2(JET)	NANPOE	337
GO TO 450	NANPOE	338
420 EON=EXP(-G*DELT(JZ))	NANPOE	339
S1(JZ)=F1P*EON	NANPOE	340
S2(JZ)=F2P*EON	NANPOE	341
GO TO 450	NANPOE	342
430 H=DELT(JZ)	NANPOE	343
CALL MPM(OMEGA,AKX,AKY,C,VX,VY,H,EM)	NANPOE	344
S1(JZ)=EM(2,2)*PHI1(IDA)-EM(1,2)*PHI2(IDA)	NANPOE	345
S2(JZ)=-EM(2,1)*PHI1(IDA)+EM(1,1)*PHI2(IDA)	NANPOE	346
450 CONTINUE	NANPOE	347
C AT THIS POINT S1(JZ),S2(JZ),CIJZ(JZ), ETC. ARE STORED FOR JZ=1 AND 2.	NANPOE	348
C WE COMPUTE THE DOPPLER SHIFTED ANGULAR FREQUENCY AT SOURCE ALTITUDE.	NANPOE	349
100 BOM=OMEGA-AXX*VXIJZ(NSCRCE)-AKY*VYIJZ(NSCRCE)	NANPOE	350
C WE COMPUTE ZFN AT OBSERVER ALTITUDE	NANPOE	351
ZFN=(.0098/CIJZ(NOBS))*S1(NOBS)-CIJZ(NOBS)*S2(NOBS)	NANPOE	352
C HERE WE TAKE THE ACCELERATION OF GRAVITY TO BE .0098 KM/SEC**2.	NANPOE	353
C COMPUTATION OF INTEGRALS	NANPOE	354
IT=3	NANPOE	355
CALL TOTINT(OMEGA,AKX,AKY,IT,L,X3,PHI1,PHI2)	NANPOE	356
IF(L.EQ.-1) GO TO 200	NANPOE	357
IT=7	NANPOE	358
CALL TOTINT(OMEGA,AKX,AKY,IT,L,X7,PHI1,PHI2)	NANPOE	359
IF(L.EQ.-1) GO TO 200	NANPOE	360
C FINAL ANSWER	NANPOE	361
AMPLTD= 0.5*S2(NSCRCE)*ZFN/((X3+X7)*90M)	NANPOE	362
CI(IMAX) = SAVE	NANPOE	363
RETURN	NANPOE	364
C IF YOU ARRIVE HERE, THE UPPER BOUNDARY CONDITION COULD NOT BE SATISFI	NANPOE	365
200 AMPLTD=0.0	NANPOE	366
CI(IMAX) = 1.E5	NANPOE	367
GO TO 1	NANPOE	368
C	NANPOE	369
END	NANPOE	370
	NANPOE	371
	NANPOE	372
	NANPOE	373
	NANPOE	374
	NANPOE	375
	NANPOE	376

C	SUBROUTINE NMOFNI(OMEGA,VPHSE,THETK,L,FPP,K)	NMOFNI	1
C	NMOFNI (SUBROUTINE) 7/25/68 LAST CARD IN DECK IS	NMOFNI	2
C	---- <td>NMOFNI</td> <td>3</td>	NMOFNI	3
C	TITLE - NMOFNI	NMOFNI	4
C	SUBROUTINE TO COMPUTE THE NORMAL MODE DISPERSION FUNCTION FPP	NMOFNI	5
C	FOR GIVEN ANGULAR FREQUENCY OMEGA, PHASE VELOCITY MAGNITUDE	NMOFNI	6
C	VPHSE AND PHASE VELOCITY DIRECTION THETK. FPP SHOULD VANISH	NMOFNI	7
C	IF BOTH UPPER AND LOWER BOUNDARY CONDITIONS ARE SATISFIED FOR	NMOFNI	8
C	THE SOLUTIONS OF THE RESIDUAL EQUATIONS	NMOFNI	9
C		NMOFNI	10
C	$D(PHI1)/DZ = A(1,1)*PHI1(Z) + A(1,2)*PHI2(Z)$	NMOFNI	11
C		NMOFNI	12
C	$D(PHI2)/DZ = A(2,1)*PHI1(Z) + A(2,2)*PHI2(Z)$	NMOFNI	13
C		NMOFNI	14
C	WHERE THE ELEMENTS OF THE MATRIX A VARY WITH HEIGHT Z, BUT ARE	NMOFNI	15
C	CONSTANT IN EACH LAYER OF A MULTILAYER ATMOSPHERE. THE ELEMENTS	NMOFNI	16
C	OF A ARE FUNCTIONS OF OMEGA, AKX AND AKY, AS DESCRIBED IN	NMOFNI	17
C	SUBROUTINE AAAA WHERE	NMOFNI	18
C		NMOFNI	19
C	AKX=OMEGA*COS(THETK)/VPHSE	NMOFNI	20
C		NMOFNI	21
C	AKY=OMEGA*SIN(THETK)/VPHSE	NMOFNI	22
C		NMOFNI	23
C	THE FUNCTION FPP IS DEFINED AS THE VALUE OF PHI1 AT THE GROUND	NMOFNI	24
C	(Z=0) WHEN (1) THE UPPER BOUNDARY CONDITION OF PHI1 AND PHI2	NMOFNI	25
C	DECREASING EXPONENTIALLY WITH HEIGHT IN THE UPPER HALFSpace	NMOFNI	26
C	IS SATISFIED, AND (2) PHI1 AND PHI2 AT THE BOTTOM OF THE UPPER	NMOFNI	27
C	HALFSpace ARE GIVEN BY $A(1,2)$ AND $-(G+A(1,1))$ WHERE	NMOFNI	28
C	$G=2*sqrt(A(1,1)^2+A(1,2)^2)$. THE ELEMENTS OF A HERE ARE	NMOFNI	29
C	THOSE APPROPRIATE TO THE UPPER HALFSpace. CONDITIONS (1) AND	NMOFNI	30
C	(2) ARE NOT INDEPENDENT. "CONDITION (1) IMPLIES THAT $G^2 > 0$,	NMOFNI	31
C	AND CONDITION (2) WITH G^2 POSITIVE IMPLIES (1). IF G^2 IS	NMOFNI	32
C	NEGATIVE, FPP DOES NOT EXIST AND L=-1 IS RETURNED. OTHERWISE	NMOFNI	33
C	L=1 IS RETURNED.	NMOFNI	34
C	PROGRAM NOTES	NMOFNI	35
C		NMOFNI	36
C	THE PARAMETERS DEFINING THE MULTILAYER MODEL ATMOSPHERE	NMOFNI	37
C	ARE PRESUMED TO BE STORED IN COMMON.	NMOFNI	38
C		NMOFNI	39
C	THE SUBROUTINE RRRR IS USED TO GENERATE THE MATRIX RPP	NMOFNI	40
C	WHICH CONNECTS SOLUTIONS OF THE RESIDUAL EQUATIONS AT	NMOFNI	41
C	THE BOTTOM OF THE UPPER HALFSpace TO SOLUTIONS AT THE	NMOFNI	42
C	GROUND. IN TERMS OF THIS MATRIX, THE NPOF IS GIVEN BY	NMOFNI	43
C		NMOFNI	44
C	$FPP = RPP(1,1)*A(1,2) - RPP(1,2)*(G+A(1,1))$	NMOFNI	45
C		NMOFNI	46
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C22-6515-4)	NMOFNI	47
C		NMOFNI	48
C	AUTHOR - A.D. PIERCE, P.I.T., AUGUST, 1968	NMOFNI	49
C		NMOFNI	50
C	-----CALLING SEQUENCE-----	NMOFNI	51
C	SEE SUBROUTINES LNSTMN, WIGEN, MPOUT	NMOFNI	52
C	DIMENSION CI(100), VXI(100), VYI(100), HI(100)	NMOFNI	53
C	COMMON IPAX, CI, VYI, VYI, HI. (THESE MUST BE STORED IN COMMON)	NMOFNI	54
C	CALL NMOFNI(OMEGA, VPHSE, THETK, L, FPP, K)	NMOFNI	55
C		NMOFNI	56
C	-----EXTERNAL SUBROUTINES REQUIRED-----	NMOFNI	57
C		NMOFNI	58
C	RRRR, MMMM, AAAA, CAI, SAI	NMOFNI	59
C		NMOFNI	60
C		NMOFNI	61
C		NMOFNI	62
C		NMOFNI	63
C		NMOFNI	64

C	-----ARGUMENT LIST-----				NMOFEN	65
C	OMEGA	R*4	NO	INP	NMOFEN	66
C	VPHSE	R*4	NO	INP	NMOFEN	67
C	THETK	R*4	NO	INP	NMOFEN	68
C	L	I*4	NO	OUT	NMOFEN	69
C	FPP	R*4	NO	OUT	NMOFEN	70
C	K	I*4	NO	OUT (ALWAYS RETURNED AS K=0)	NMOFEN	71
C	COMMON STORAGE USED				NMOFEN	72
C	COMMON IMAX,CI,VXI,VYI,HI				NMOFEN	73
C	IMAX	I*4	NO	INP	NMOFEN	74
C	CI	R*4	100	INP	NMOFEN	75
C	VXI	R*4	100	INP	NMOFEN	76
C	VYI	R*4	100	INP	NMOFEN	77
C	HI	R*4	100	INP	NMOFEN	78
C	-----INPUTS-----				NMOFEN	79
C	OMEGA	=ANGLLAR FREQUENCY IN RAD/SEC			NMOFEN	80
C	VPHSE	=PHASE VELCCITY MAGNITUDE IN KM/SEC			NMOFEN	81
C	THETK	=PHASE VELCCITY DIPECTION RECKONED COUNTER CLOCKWISE			NMOFEN	82
C		FROM THE X AXIS IN PADIAN			NMOFEN	83
C	IMAX	=NUMBER OF LAYERS OF FINITE THICKNESS			NMOFEN	84
C	CI(I)	=SOUND SPEED IN KM/SEC IN I-TH LAYER			NMOFEN	85
C	VXI(I)	=X COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)			NMOFEN	86
C	VYI(I)	=Y COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)			NMOFEN	87
C	HI(I)	=THICKNESS IN KM OF I-TH LAYER OF I-TH THICKNESS			NMOFEN	88
C	-----OUTPUTS-----				NMOFEN	89
C	L	=1 IF NORPAL MODE DISPERSION FUNCTION EXISTS, -1 IF IT DOES NOT.			NMOFEN	90
C	FPP	=NCRPAL MCEE DISPERSION FUNCTION			NMOFEN	91
C	K	=DUMHY PARAPETEP ALWAYS RETURNED AS K=0.			NMOFEN	92
C	-----PROGRAM FOLLOWS BELOW-----				NMOFEN	93
C	DIMENSION AND COMMON STATEMENTS LOCATING PARAMETERS CEFINING MODEL				NMOFEN	94
C	MULTILAYER ATMOSPHERE				NMOFEN	95
C	DIMENSION CI(100),VXI(100),VYI(100),HI(100)				NMOFEN	96
C	COMMON IMAX,CI,VXI,VYI,HI				NMOFEN	97
C	DIMENSION A(2,2),RPP(2,2).				NMOFEN	98
C	COMPUTATION CF AKX AND AKY				NMOFEN	99
C	AKX=OMEGA*COS(THETK)/VPHSE				NMOFEN	100
C	AKY=OMEGA*SIN(THETK)/VPHSE				NMOFEN	101
C	COMPUTATION CF MATRIX A AND C**2 FOR UPPER HALFSPACE.				NMOFEN	102
C	J=IMAX+1				NMOFEN	103
C	C=CI(J)				NMOFEN	104
C	VX=VXI(J)				NMOFEN	105
C	VY=VYI(J)				NMOFEN	106
C	CALL AAAA(OMEGA,AKX,AKY,C,VX,VY,A)				NMOFEN	107
C	GUSQ=A(1,1)**2+A(1,2)*A(2,1)				NMOFEN	108
C	IF(GUSQ.GT. 0.0) GO TO 11				NMOFEN	109
C	GUSQ IS LESS THAN ZERO				NMOFEN	110
C	L=-1				NMOFEN	111

```
      RETURN
C
C GUSQ IS GREATER THAN ZERO
  11 L=1
      GU=SQRT(GUSQ)
C
C COMPUTATION OF RPP MATRIX
      CALL RPPR(OMEGA,AKX,AKY,OPP,K)
C
C COMPUTATION OF FPP
      FPP = RPP(1,1)*A(1,2) - PPP(1,2)*(GU+A(1,1))
C
      RETURN
      END
```

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NHOFN 128
NHOFN 129
NHOFN 130
NHOFN 131
NHOFN 132
NHOFN 133
NHOFN 134
NHOFN 135
NHOFN 136
NHOFN 137
NHOFN 138
NHOFN 139
NHOFN 140
NHOFN 141
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SUBROUTINE NXMCCF(IST,JST,NOM,NV#,INMODE,IFNO,JFNO,K)
DIMENSION INMODE(1)
NXMODE (SUBROUTINE)

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6/24/68 LAST CARD

6/24/68 LAST CARD IN DECK IS

-----ABSTRACT-----

TITLE - NXMODE

PROGRAM TO FIND A POINT WITH COORDINATES I=IFNO,J=JFNO IN AN
ARRAY WITH NPM COLUMNS AND NVP ROWS. FOUND PCINT CORRESPONDING
TO STARTING POSITION FOR CALCULATION OF PHASE VELOCITY VERSUS
FREQUENCY OF A PARTICULAR GUIDED MODE. A TABLE OF VALUES OF
THE SIGN OF THE NORMAL MODE DISPERSION FUNCTION IS PRESUMED
TO BE STORED AS INMODE(J-1)*NVP+I FOR EACH POINT (I,J) IN THE
ARRAY. DIFFERENT COLUMNS (J) CORRESPOND TO DIFFERENT FREQUEN-
CIES WHILE DIFFERENT ROWS (I) CORRESPOND TO DIFFERENT PHASE
VELOCITIES. THE SEARCH PROCEEDS FROM AN INITIAL POINT (IST,JS
TO SUCCESSIVE ADJACENT POINTS HAVING THE SAME INMODE AS THE
STARTING POINT. THE DETERMINATION OF (IFNO,JFNO) IS SUBJECT TO
THE FOLLOWING RULES.

1. IT MUST LIE BELOW OR TO THE LEFT OF A POINT WITH OPPOSITE INPOCE
2. IF MUST BE THE HIGHEST POINT (LOWEST I) IN THE REGIO SATISFYING CONDIICN 1
3. IF MORE THAN 1 POINT SATISFY 1 AND 2, THEN THE POINT DETERMINED IS THAT FURTEST TO THE LEFT.
4. ONLY POINTS IN THE RECTANGLE ARE CONSIDERED

THE COMPUTATION ASSUMES REGION OF SUCCESSIVELY ADJACENT POINTS HAVING SAME INMODE IS SIMPLY CONNECTED AND THAT PHASE VELOCITY CURVES BEND DOWNWARDS, I.E., $C(VP)/D(OM) \leq 0$. (THIS CAN BE THE CASE PROVIDING VP IS GREATER THAN THE MAXIMUM WIND VELOCITY.) IF THE FCINT IS FOUND, $K=1$, IF NOT FOUND, $K=-1$.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)
AUTHOR - A.D. PIERCE, R.I.T., JUNE, 1968.

-----CALLING SEQUENCE-----

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SEE SUBROUTINE ALLMOD
  DIMENSION INHMOD(11)          (VARIABLE DIMENSIONING)
  CALL NXMOD(IST,JST,NCF,NVP,INHMOD,IFNO,JFNO,K)
```

NO EXTERNAL SUBROUTINES ARE REQUIRED.

---ARGUMENT LIST---

IST	I*4	NO	INP
JST	I*4	NO	INP
NOM	I*4	NO	INP
NVP	I*4	NO	INP
INMODE	I*4	VAR	INP
IFNO	I*4	NO	OUT
JFNO	I*4	NO	OUT
K	I*4	NO	OUT

NO COMMON STORAGE USED

---INPUTS---

IST **=ROW INDEX OF START POINT**

NXMOOE	1
NXMOOE	2
NXMOOE	3
NXMOOE	4
NXMOOE	5
NXMOOE	6
NXMOOE	7
NXMOOE	8
NXMOOE	9
NXMOOE	10
NXMOOE	11
NXMOOE	12
NXMOOE	13
NXMOOE	14
NXMOOE	15
NXMOOE	16
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NXMOOE	57
NXMOOE	58
NXMOOE	59
NXMOOE	60
NXMOOE	61
NXMOOE	62
NXMOOE	63
NXMOOE	64
NXMOOE	65

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C      JST      =COLUMN INDEX OF START POINT      NXMODE 66
C      NOM      =NO. OF COLUMNS OF ARRAY      NXMODE 67
C      NVP      =NO. OF ROWS OF ARRAY      NXMODE 68
C      INMODE(L) =SIGN OF NORMAL MODE DISPERSION FUNCTION, 1 IF POS.,
C      -1 IF NEG., 5 IF IT DOESN'T EXIST. LET I=L MOD NVP,
C      J=(L-I)/NVP+1. INMODE(I) IS SIGN OF NMOD FOR
C      OMEGA=OM(J), PHASE VEL.=VP(I), WHERE OM(J) .GE. OM(
C      AND VP(I) .LE. VP(I-1).      NXMODE 73
C      -----OUTPUTS-----      NXMODE 74
C      IFND      =ROW INDEX OF FOUND POINT      NXMODE 75
C      JFND      =COLUMN INDEX OF FOUND POINT      NXMODE 76
C      K          =FLAG INDICATING IF POINT (IFND,JFND) IS FOUND, 1 IF
C      YES, -1 IF NO.      NXMODE 77
C      -----EXAMPLE-----      NXMODE 78
C      SUPPOSE THE ARRAY OF INMODE VALUES IS AS SHOWN BELOW      NXMODE 79
C      ++++++--      NVP=8, NOM=11      NXMODE 80
C      ++++++--      NXMODE 81
C      5-----++ IF IST=2,JST=5 THEN IFND=3,JFND=2,K=1      NXMODE 82
C      55-----++ IF IST=2,JST=5 THEN IFND=1,JFND=9,K=1.      NXMODE 83
C      55-----++ IF IST=3,JST=7 THEN IFND=3,JFND=2,K=-1      NXMODE 84
C      55-----++ IF IST=8,JST=2 THEN K=-1      NXMODE 85
C      55-----++ IF IST=2,JST=11 THEN K=-1      NXMODE 86
C      55-----++      NXMODE 87
C      -----PROGRAM FOLLOWS BELOW-----      NXMODE 88
C      1 IF( IST .GT. NVP .OR. JST .GT. NOM) GO TO 100      NXMODE 89
C      J9=(JST-1)*NVP+IST      NXMODE 90
C      I0=INMODE(J9)      NXMODE 91
C      3 IF( I0 .NE. 1 .AND. I0 .NE. -1) GO TO 100      NXMODE 92
C      C THE POINT (IST,JST) LIES IN THE ARRAY AND THE NORMAL MODE DISPERSION
C      C FUNCTION EXISTS AT THIS POINT WITH A SIGN I0. WE FIRST GO UP UNTIL
C      C A DIFFERENT INMODE IS ENCOUNTERED OR UNTIL WE REACH I=1      NXMODE 93
C      I=IST      NXMODE 94
C      J=JST      NXMODE 95
C      10 IF( I .EQ. 1) GO TO 30      NXMODE 96
C      I=I-1      NXMODE 97
C      J10=(J-1)*NVP+I      NXMODE 98
C      ICHK=INMODE(J10)      NXMODE 99
C      IF( ICHK .EQ. I0) GO TO 10      NXMODE 100
C      I=I+1      NXMODE 101
C      C THE CURRENT I IS NOT 1. IF THE ICHK OF THE POINT ABOVE IS NOT 5, WE
C      C MOVE TO THE LEFT.      NXMODE 102
C      15 IF( ICHK .EQ. 5) GO TO 50      NXMODE 103
C      IF( J .EQ. 1) GO TO 20      NXMODE 104
C      J=J-1      NXMODE 105
C      J10=(J-1)*NVP+I      NXMODE 106
C      ICHK=INMODE(J10)      NXMODE 107
C      C IF THE ICHK OF THE CONSIDERED NEW POINT IS I0, WE TRY TO GO HIGHER
C      C AGAIN.      NXMODE 108
C      IF( ICHK .EQ. I0) GO TO 10      NXMODE 109
C      J=J+1      NXMODE 110
C      C      NXMODE 111
C      C      NXMODE 112
C      C      NXMODE 113
C      C      NXMODE 114
C      C      NXMODE 115
C      C      NXMODE 116
C      C      NXMODE 117
C      C      NXMODE 118
C      C      NXMODE 119
C      C      NXMODE 120
C      C      NXMODE 121
C      C      NXMODE 122
C      C      NXMODE 123
C      C      NXMODE 124
C      C      NXMODE 125
C      C      NXMODE 126
C      C      NXMODE 127
C      C      NXMODE 128
C      C      NXMODE 129

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C WE HAVE -10 ABOVE THE CURRENT POINT AND ARE EITHER ON THE FAR LEFT OF	NXMODE	130
C THE TABLE OR ELSE HAVE A DIFFERENT SIGN AT THE POINT TO THE LEFT.	NXMODE	131
C THIS IS INTERPRETED AS SUCCESS.	NXMODE	132
20 K=1	NXMODE	133
IFND=I	NXMODE	134
JFND=J	NXMODE	135
RETURN	NXMODE	136
C	NXMODE	137
C THE CONSIDERED NEW POINT IS ON THE FIRST ROW. WE GO TO THE RIGHT.	NXMODE	138
30 IF(J .EQ. NOM) GO TO 60	NXMODE	139
J=J+1	NXMODE	140
J10=(J-1)*NVP+I	NXMODE	141
ICLK=INMODE(J10)	NXMODE	142
IF(ICLK .EQ. 10) GO TO 30	NXMODE	143
J=J-1	NXMODE	144
C	NXMODE	145
C IF THE POINT AT THE RIGHT OF CURRENT (I,J) IS -10, WE HAVE SUCCESS	NXMODE	146
IF(ICLK .EQ. -10) GO TO 20	NXMODE	147
C	NXMODE	148
C IF IT IS NOT -10, WE ALLOW FOR POSSIBILITY OF INMODE=5 IN UPPER RIGHT	NXMODE	149
C HAND CORNER OF THE TABLE AND TRY TO SKIRT THESE FIVES BY MOVING EITHER	NXMODE	150
C DOWNWARDS OR TO THE RIGHT.	NXMODE	151
40 IF(I .EQ. NVP) GO TO 70	NXMODE	152
I=I+1	NXMODE	153
J10=(J-1)*NVP+I	NXMODE	154
ICLK=INMODE(J10)	NXMODE	155
C	NXMODE	156
C IF THIS ICLK IS +10 WE ARE IN A POSITION TO MAKE A TRY OF MOVING TO	NXMODE	157
C THE RIGHT.	NXMODE	158
44 IF(ICLK .NE. 10) GO TO 90	NXMODE	159
C	NXMODE	160
C IF WE ARE ON THE RIGHT HAND SIDE OF THE TABLE THE DESIRED POINT CANNOT	NXMODE	161
C BE FOUND. WE RETURN WITH K=-1	NXMODE	162
45 IF(J .EQ. NOM) GO TO 100	NXMODE	163
J=J+1	NXMODE	164
C	NXMODE	165
C IT IS TAKEN FOR GRANTED THAT THE INMODE OF POINT ABOVE CURRENT (I,J)	NXMODE	166
C IS 5 SINCE IT HAS FOUND TO BE 5 TO THE LEFT AND ABOVE. THE INMODE OF	NXMODE	167
C THE POINT TO THE LEFT IS 10. IF THE NEW INMODE IS +10, WE HAVE TO TRY	NXMODE	168
C TO MOVE FURTHER TO THE RIGHT.	NXMODE	169
J10=(J-1)*NVP+I	NXMODE	170
ICLK=INMODE(J10)	NXMODE	171
IF(ICLK .EQ. 10) GO TO 45	NXMODE	172
J=J-1	NXMODE	173
C	NXMODE	174
C IF THE CURRENT ICLK IS 5, WE TRY TO GO DOWN AGAIN. THE OTHER POSS-	NXMODE	175
C IBILITY, ICLK=-10 INDICATES SUCCESS	NXMODE	176
IF(ICLK .EQ. -10) GO TO 20	NXMODE	177
GO TO 40	NXMODE	178
C	NXMODE	179
C WE CONTINUE HERE FROM 15. THE POINT ABOVE THE CURRENT (I,J) HAS	NXMODE	180
C ICLK .EQ. 5. THE SITUATION IS SUCH THAT WE CAN RESUME CALCULATION	NXMODE	181
C AT 45 AND TRY TO MOVE FURTHER TO THE RIGHT.	NXMODE	182
50 GO TO 45	NXMODE	183
C	NXMODE	184
C WE CONTINUE HERE WITH I=1, J=NOM FROM STATEMENT 30. SINCE WE HAVE NO	NXMODE	185
C PLACE TO GO THE SEARCH IS UNSUCCESSFUL. WE RETURN WITH K=-1.	NXMODE	186
60 GO TO 100	NXMODE	187
C	NXMODE	188
C WE CONTINUE HERE FROM STATEMENT 40 WITH I .EQ. NVP AND INMODE=5 TO THE	NXMODE	189
C RIGHT OF THE CURRENT (I,J). WE RETURN WITH K=-1.	NXMODE	190
70 GO TO 100	NXMODE	191
C	NXMODE	192
C WE CONTINUE HERE FROM STATEMENT 44 WITH THE POINT BELOW HAVING	NXMODE	193

C ICHK .NE. 10. THE POINT AT THE RIGHT HAS ICHK .EQ. 5. WE CANNOT
C SKIRT THE FIVES AND HENCE WE RETURN WITH K=-1.
80 GO TO 100

C
C WE CONTINUE HERE FROM 1,3,45,60,70,OR 80. THE SEARCH WAS UNSUCCESSFU
100 K=-1
RETURN
END

NXMODE 194
NXMODE 195
NXMODE 196
NXMODE 197
NXMODE 198
NXMODE 199
NXMODE 200
NXMODE 201

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C      SUBROUTINE NXTFNT(I1,J1,ITYP1,I2,J2,ITYP2,NROW,NCOL,INM,K)      NXTFNT      1
C      NXTFNT (SUBROUTINE)      6/24/69  LAST CARD IN DECK IS NXTFNT      2
C      . . . . .      NXTFNT      3
C      . . . . .      NXTFNT      4
C      . . . . .      NXTFNT      5
C      . . . . .      NXTFNT      6
C      . . . . .      NXTFNT      7
C      TITLE - NXTFNT      8
C      PROGRAM TO FIND THE NEXT POINT (I2,J2) OF AN ARRAY OF NROW ROW NXTFNT      9
C      AND NCOL COLUMNS GIVEN THE PRECEDING POINT (I1,J1). POINT WILL NXTFNT     10
C      BE USED IN SUBSEQUENT CALCULATION OF A PARTICULAR POINT ON THE NXTFNT     11
C      PHASE VELOCITY VERSUS FREQUENCY CURVE OF A GIVEN GUIDED MODE. NXTFNT     12
C      A TABLE OF VALUES OF THE SIGN OF THE NORMAL MODE DISPERSION NXTFNT     13
C      FUNCTION IS PRESUMED TO BE STORED AS INM((J-1)*NVP+I) FOR EACH NXTFNT     14
C      POINT (I,J) IN THE ARRAY. DIFFERENT COLUMNS (J) CORRESPOND TO NXTFNT     15
C      DIFFERENT FREQUENCIES WHILE DIFFERENT ROWS (I) CORRESPOND TO NXTFNT     16
C      DIFFERENT PHASE VELOCITIES. SUCCESSIVE POINTS ARE CHARACTERIZ NXTFNT     17
C      BY A TYPE, ITYP1 IS TYPE OF (I1,J1) WHILE ITYP2 IS TYPE OF NXTFNT     18
C      SECOND POINT. THE TYPE INDEX IS 1 IF THE POINT DIRECTLY ABOVE NXTFNT     19
C      THE CONSIDERED POINT HAS AN INM OF OPPOSITE SIGN. IT IS 2 IF NXTFNT     20
C      THE POINT TO THE RIGHT HAS INM OF OPPOSITE SIGN. SINCE BOTH NXTFNT     21
C      POSSIBILITIES CAN OCCUR, THE DESIGNATED TYPE INDEX ITYP1 CANNOT NXTFNT     22
C      THE PREVIOUS USE OF THE POINT (I1,J1) IN COMPUTATION. THE VAL NXTFNT     23
C      ITYP2 WILL IN GENERAL DEPEND ON THE PREVIOUS VALUE ITYP1. NXTFNT     24
C      THE DERIVED VALUES OF I2,J2,ITYP2 ARE CALCULATED AS FOLLOWS. NXTFNT     25
C      . . . . .      NXTFNT     26
C      1. IF ITYP1 IS 1 AND INM OF POINT TO RIGHT IS OPPOSITE      NXTFNT     27
C      OF IO=INM((J-1)*NVP+I), THEN I2=I1,J2=J1,ITYP2=2.      NXTFNT     28
C      . . . . .      NXTFNT     29
C      2. THE POINT (I2,J2) MUST EITHER BE THE DIRECTLY ADJACE      NXTFNT     30
C      POINT TO THE RIGHT (I1,J1+1), THE POINT DIRECTLY BEL      NXTFNT     31
C      (I1+1,J1), OR THE ADJACENT POINT TO THE LOWER RIGHT      NXTFNT     32
C      (I1+1,J1+1) IF CONDITION 1 DOES NOT HOLD      NXTFNT     33
C      . . . . .      NXTFNT     34
C      3. THE CHOSEN POINT MUST HAVE THE SAME INM AS (I1,J1)      NXTFNT     35
C      AND HAVE A POINT EITHER DIRECTLY ABOVE OR DIRECTLY T      NXTFNT     36
C      THE RIGHT WITH OPPOSITE INM.      NXTFNT     37
C      . . . . .      NXTFNT     38
C      4. IN THE EVENT MORE THAN ONE POINT SATISFY CONDITIONS      NXTFNT     39
C      2 AND 3, PRIORITY OF SELECTION IS (1) THE POINT TO      NXTFNT     40
C      THE RIGHT, (2) THE POINT DIRECTLY BELOW, (3) THE POI      NXTFNT     41
C      TO THE LOWER RIGHT. IF THE SELECTED POINT SATISFIES      NXTFNT     42
C      CRITERIA FOR BOTH ITYP2=1 OR 2, ITYP2=1 IS RETURNED.      NXTFNT     43
C      OTHERWISE, THE APPROPRIATE ITYP2 IS RETURNED DEPENDI      NXTFNT     44
C      ON WHICH CRITERION IS SATISFIED.      NXTFNT     45
C      . . . . .      NXTFNT     46
C      THE COMPUTATION ASSUMES REGION OF SUCCESSIVELY ADJACENT POINTS      NXTFNT     47
C      HAVING SAME INM TO BE SIMPLY CONNECTED AND THAT PHASE VELOCITY      NXTFNT     48
C      CURVES BEND DOWNWARDS, I.E., D(V)/D(OH) .LT. 0. IF NEW POIN      NXTFNT     49
C      IS FOUND, K=+1. IF IT IS NOT FOUND, K=-1.      NXTFNT     50
C      . . . . .      NXTFNT     51
C      LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4)      NXTFNT     52
C      AUTHOR - A.D. PIERCE, M.I.T., JUNE, 1968      NXTFNT     53
C      . . . . .      NXTFNT     54
C      . . . . .      NXTFNT     55
C      . . . . .      NXTFNT     56
C      SEE SUBROUTINE MOOETR      NXTFNT     57
C      DIMENSION INMOE(1) (INMOE IS SAME AS INM)      NXTFNT     58
C      CALL NXTFNT(I1,J1,ITYP1,I2,J2,ITYP2,NROW,NCOL,INMOE,K)      NXTFNT     59
C      IF (K.EQ. -1) GO SOMEWHERE      NXTFNT     60
C      USE I2,J2,ITYP2      NXTFNT     61
C      . . . . .      NXTFNT     62
C      NO EXTERNAL LIBRARY SUBROUTINES ARE REQUIRED      NXTFNT     63
C      . . . . .      NXTFNT     64
C      . . . . .      NXTFNT     65
C      . . . . .      NXTFNT     66

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C      I1      I*4      NO      INP      NXPNT      65
C      J1      I*4      NO      INP      NXPNT      66
C      ITYP1     I*4      NO      INP      NXPNT      67
C      I2      I*4      NO      OUT      NXPNT      68
C      J2      I*4      NO      OUT      NXPNT      69
C      ITYP2     I*4      NO      OUT      NXPNT      70
C      NROW     I*4      NO      INP      NXPNT      71
C      NCOL     I*4      NO      INP      NXPNT      72
C      INH      I*4      VAR     INP      NXPNT      73
C      K        I*4      NO      OUT      NXPNT      74
C      NO COMMON STORAGE USED      NXPNT      75
C      ----INPUTS----      NXPNT      76
C      I1      =ROW INDEX OF START POINT      NXPNT      77
C      J2      =COLUMN INDEX OF START POINT      NXPNT      78
C      ITYP1     =TYPE INDEX OF START POINT. 1 MEANS POINT ABOVE HAS      NXPNT      79
C      DIFFERENT IAM, 2 MEANS POINT TO RIGHT HAS DIFFERENT      NXPNT      80
C      INH.      NXPNT      81
C      NROW     =NUMBER OF ROWS IN ARRAY      NXPNT      82
C      NCOL     =NUMBER OF COLUMNS IN ARRAY      NXPNT      83
C      INH      =SIGN OF NORMAL MODE DISPERSION FUNCTION. 1 IF PCS.,      NXPNT      84
C      -1 IF NEG., 5 IF IT DOESN'T EXIST. LET I=L MOD NVP,      NXPNT      85
C      J=(L-I)/NVP+1. INHCODE(L) IS SIGN OF AMOD FOR      NXPNT      86
C      OMEGA=OM(J), PHASE VEL. =VP(I), WHERE OM(J) .GE. OM(I)      NXPNT      87
C      AND VP(I) .LE. VP(I-1)      NXPNT      88
C      ----OUTPUTS----      NXPNT      89
C      I2      =ROW INDEX OF FOUND POINT      NXPNT      90
C      J2      =COLUMN INDEX OF FOUND POINT      NXPNT      91
C      ITYP2     =TYPE INDEX OF FOUND POINT      NXPNT      92
C      K        =FLAG INDICATING IF POINT (I2,J2) IS FOUND, 1 IF YES,      NXPNT      93
C      -1 IF NO      NXPNT      94
C      ----EXAMPLE----      NXPNT      95
C      SUPPOSE THE ARRAY OF INH VALUES IS AS SHOWN: 6LUM      NXPNT      96
C      ++++++---      NXPNT      97
C      ++++++---      NXPNT      98
C      5-----++      NXPNT      99
C      55-----++      NXPNT      100
C      55-----++      NXPNT      101
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C      55-----++      NXPNT      29
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C IR IS INM OF POINT TO THE RIGHT. IO IS INM OF POINT (I1,J1).	NXTPNT	129
5 J12=(J1)*NROW+I1	NXTPNT	130
IR=INM(J12)	NXTPNT	131
6 IF(IR .NE. IO) GO TO 15	NXTPNT	132
7 IF(I1 .EQ. 1) GO TO 30	NXTPNT	133
C	NXTPNT	134
C IR HAS THE SAME SIGN AS IO. WE CHECK IRU REPRESENTING INM OF UPPER	NXTPNT	135
C RIGHT POINT. IF THIS IS -IO, THE RIGHT POINT IS THE DESIRED POINT.	NXTPNT	136
C IF IT IS NOT -IO, WE CANNOT FIND (I2,J2).	NXTPNT	137
10 J13=(J1)*NROW+I1-1	NXTPNT	138
IRU=INM(J13)	NXTPNT	139
11 IF(IRU .NE. -IO) GO TO 30	NXTPNT	140
ITYP2=1	NXTPNT	141
I2=I1	NXTPNT	142
J2=J1+1	NXTPNT	143
K=1	NXTPNT	144
RETURN	NXTPNT	145
C	NXTPNT	146
C WE ARRIVE HERE FROM STATEMENT 6. THE POINT TO THE RIGHT HAS A	NXTPNT	147
C DIFFERENT INM. IF THIS IS -IO AND ITP1=1, WE HAVE (I2,J2)=(I1,J1)	NXTPNT	148
C WITH ITP2=2. IF THIS IS 5, WE CANNOT FIND (I2,J2).	NXTPNT	149
15 IF(IR .EQ. 5) GO TO 30	NXTPNT	150
C	NXTPNT	151
C IR=-IO AT THIS POINT	NXTPNT	152
IF(ITP1 .NE. 1) GO TO 25	NXTPNT	153
I2=I1	NXTPNT	154
J2=J1	NXTPNT	155
ITYP2=2	NXTPNT	156
K=1	NXTPNT	157
RETURN	NXTPNT	158
C	NXTPNT	159
C IR=-IO. ITP1 IS 2. WE CONTINUE FROM STATEMENT 15. IF WE ARE ON THE	NXTPNT	160
C BOTTOM ROW, WE CANNOT FIND NEW POINT	NXTPNT	161
25 IF(I1.EQ.NROW) GO TO 30	NXTPNT	162
C	NXTPNT	163
C WE CONSIDER POINTS BELOW AND TO LOWER RIGHT	NXTPNT	164
J14=(J1-1)*NROW+I1+1	NXTPNT	165
ID=INM(J14)	NXTPNT	166
J15=(J1)*NROW+I1+1	NXTPNT	167
IDR=INM(J15)	NXTPNT	168
C	NXTPNT	169
C IF IDR IS 5, WE CANNOT FIND THE NEW POINT	NXTPNT	170
26 IF(IDR .EQ. -5) GO TO 30	NXTPNT	171
C	NXTPNT	172
C IF IDR IS IO, THE NEXT POINT IS THE CR POINT	NXTPNT	173
27 IF(IDR .NE. IO) GO TO 28	NXTPNT	174
I2=I1+1	NXTPNT	175
J2=J1+1	NXTPNT	176
ITYP2=1	NXTPNT	177
K=1	NXTPNT	178
RETURN	NXTPNT	179
C	NXTPNT	180
C IR=-IO. ITP1 IS 2. IDR IS -IO. WE CONTINUE FROM STATEMENT 27.	NXTPNT	181
28 IF(IO .NE. IO) GO TO 30	NXTPNT	182
C	NXTPNT	183
C THE NEXT POINT IS THE DOWN POINT	NXTPNT	184
I2=I1+1	NXTPNT	185
J2=J1	NXTPNT	186
ITYP2=2	NXTPNT	187
K=1	NXTPNT	188
RETURN	NXTPNT	189
C	NXTPNT	190
C WE ARRIVE HERE FROM 1,7,11,15,25,26. THE NEXT POINT CANNOT BE FOUND	NXTPNT	191
30 K=-1	NXTPNT	192
RETURN	NXTPNT	193
END	NXTPNT	194

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SUBROUTINE PAMPCE(ZSCRCE,ZORS,PDFND,KST,KFIN,OMMOD,VPMOD,AKI,
1AMP,ALAM,FACT,THETK,NPNT)
PAMPCE (SUBROUTINE)
7/30/66 LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - PAMPCE
PROGRAM TO COMPUTE AND STORE AMPLITUDE FACTORS AMP(J) AND FACT
AND SCALING FACTOR ALAM. THE QUANTITY AMP(J) IS THE QUANTITY
AMPLTD COMPUTED BY SUBROUTINE NAMPDE WHEN THE ANGULAR FREQUENC
IS OMMOD(J) AND THE PHASE VELOCITY IS VPMOD(J). IT CORRESPOND
TO THE NMODE-TH GUIDED MODE WHEN J IS BETWEEN KST(NMODE) AND
KFIN(NMODE), INCLUSIVE. THE QUANTITY FACT IS DEPENDENT ON
SOURCE ALTITUDE ZSCRCE AND OBSERVER ALTITUDE ZOBS AND IS GIVEN
FACT = CONST*CI(1)*UEC*(PSCRCE/1.26)**0.333333
WHERE CONST=4.3/SORT(2*PI), CI(1) IS THE SOUND SPEED AT THE
GROUND, (PSCRCE/1.26) IS THE AMBIENT PRESSURE AT ZSCRCE DIVIDE
BY THE AMBIENT PRESSURE AT THE GROUND. THE QUANTITY UED IS
THE SQUARE ROOT OF (AMBIENT DENSITY AT ZOBS)/(AMBIENT DENSITY
ZSCRCE). THE SCALING FACTOR ALAM IS GIVEN BY
ALAM = (1.26/PSCRCE)**(0.333333)*(CI(1)/CI(ISCR))
WHERE CI(ISCR) IS THE SOUND SPEED AT THE SOURCE ALTITUDE. THE
SIGNIFICANCE OF THESE QUANTITIES IS EXPLAINED IN SUBROUTINE
PPAMP.
PROGRAM NOTES
THE PARAMETERS IMAX,CI,VXI,VYI,HI DEFINING THE MULTILAYER
ATMOSPHERE ARE PRESUMED STORED IN COMMON. THE AMBIENT
PRESSURES ARE COMPUTED BY CALLING SUBROUTINE AMENT WHICH
ALSO COMPUTES THE INDICES IOBS AND ISCR OF THE LAYERS
IN WHICH OBSERVER AND SOURCE, RESPECTIVELY, LIE.
IN COMPUTING AMBIENT DENSITIES, THE IDEAL GAS LAW
RMO= GAMMA*P/C**2 IS USED. THUS UED = (CI(ISCR)/CI(IOBS))
SQRT(POBS/PSCRCE).
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4)
AUTHORS - A.D.PIERCE AND J.POSEY, M.I.T., JULY,1968
-----CALLING SEQUENCE-----
SEE THE MAIN PROGRAM
DIMENSION CI(100),VXI(100),VYI(100),HI(100)
DIMENSION KST(1),KFIN(1),OMMOD(1),VPMOD(1),AMP(1)
THE PROGRAM USES VARIABLE DIMENSIONING FOR QUANTITIES IN ITS
ARGUMENT LIST.
COMMON IMAX,CI,VXI,VYI,HI THESE MUST BE STORED IN COMMON)
CALL PAMPCE(ZSCRCE,ZORS,PDFND,KST,KFIN,OMMOD,VPMOD,AMP,ALAM,
1 FACT,THETK,NPNT)
-----EXTERNAL SUBROUTINES REQUIRED-----
AMENT,NAMPDE,TCINT,MMFM,AAAA,USEAS,UPINT,ELINT,SOBB,CAI,SAI
-----ARGUMENT LIST-----
ZSCRCE R*4 NO INP
ZOBS R*4 NO INP

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C	MOFNO	I*4	NO	INP	PANPOE	65
C	KST	I*4	VAR	INP	PANPOE	66
C	KFIN	I*4	VAR	INP	PANPOE	67
C	OMMOD	R*4	VAR	INP	PANPOE	68
C	VPHOD	R*4	VAR	INP	PANPOE	69
C	AMP	R*4	VAR	OUT	PANPOE	70
C	ALAM	R*4	NO	OUT	PANPOE	71
C	FACT	R*4	NO	OUT	PANPOE	72
C	THETK	R*4	NO	INP	PANPOE	73
C	NPRNT	I*4	NO	INP	PANPOE	74
C	COMMON STORAGE USED				PANPOE	75
C	COMMON IPAX,CI,VXI,VYI,HI				PANPOE	76
C	INAX	I*4	NO	INP	PANPOE	77
C	CI	R*4	100	INP	PANPOE	78
C	VXI	R*4	100	INP	PANPOE	79
C	VYI	R*4	100	INP	PANPOE	80
C	HI	R*4	100	INP	PANPOE	81
C	-----INPUTS-----				PANPOE	82
C	ZSCRCE	=HEIGHT IN KM OF BURST ABOVE GROUND			PANPOE	83
C	ZTBS	=HEIGHT IN KM OF OBSERVER ABOVE GROUND			PANPOE	84
C	MOFNO	=NUMBER OF GUIDED MODES FOUND			PANPOE	85
C	KST(N)	=INDEX OF FIRST TABULATED POINT IN N-TH MODE			PANPOE	86
C	KFIN(N)	=INDEX OF LAST TABULATED POINT IN N-TH MODE. IN			PANPOE	87
C		GENERAL, KFIN(N)=KST(N+1)-1.			PANPOE	88
C	OMMOD(N)	=ARRAY STORING ANGULAR FREQUENCY ORDINATE (RAD/SEC) OF			PANPOE	89
C		POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR			PANPOE	90
C		FOR N BETWEEN KST(NMODE) AND KFIN(NMODE), INCLUSIVE.			PANPOE	91
C	VPHOD(N)	=ARRAY STORING PHASE VELOCITY ORDINATE (KM/SEC) OF			PANPOE	92
C		POINTS ON DISPERSION CURVES. THE NMODE MODE IS STOR			PANPOE	93
C		FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).			PANPOE	94
C	THETK	=DIRECTION IN RADIANS TO OBSERVER FROM SOURCE, RECKON			PANPOE	95
C		COUNTER CLOCKWISE FROM X AXIS.			PANPOE	96
C	NPRNT	=PRINT OPTION INDICATOR (SEE NAME IN MAIN PROGRAM).			PANPOE	97
C	INAX	=NUMBER OF LAYERS OF FINITE THICKNESS.			PANPOE	98
C	CI(I)	=SOUND SPEED IN KM/SEC IN I-TH LAYER			PANPOE	99
C	VXI(I)	=X COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)			PANPOE	100
C	VYI(I)	=Y COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)			PANPOE	101
C	HI(I)	=THICKNESS IN KM OF I-TH LAYER OF FINITE THICKNESS			PANPOE	102
C	-----OUTPUTS-----				PANPOE	103
C	AMP(J)	=AMPLITUDE FACTOR FOR GUIDED WAVE EXCITED BY POINT			PANPOE	104
C		ENERGY SOURCE. UNITS ARE KM**(1/2). THE J-TH ELEMEN			PANPOE	105
C		CORRESPONDS TO ANGULAR FREQUENCY OMMOD(J) AND PHASE			PANPOE	106
C		VELOCITY VPHOD(J). THE AMPLITUDE FACTOR IS APPROPRI			PANPOE	107
C		TO THE NMODE-TH MODE IF J.GE. KST(NMODE) AND J.LE.			PANPOE	108
C		KFIN(NMODE). THE AMP(J) IS THE SAME AS AMPLTD COMPU			PANPOE	109
C		BY SUBROUTINE HAMPDE.			PANPOE	110
C	ALAM	=A SCALING FACTOR DEPENDENT ON HEIGHT OF BURST, EQUAL			PANPOE	111
C		TO CUBE ROOT OF (PRESSURE AT GROUND)/(PRESSURE AT			PANPOE	112
C		BURST HEIGHT) TIMES (SOUND SPEED AT GROUND)/(SOUND			PANPOE	113
C		SPEED AT BURST HEIGHT).			PANPOE	114
C	FACT	=A GENERAL AMPLITUDE FACTOR DEPENDENT ON BURST HEIGHT			PANPOE	115
C		AND OBSERVER HEIGHT. A PRECISE DEFINITION IS GIVEN			PANPOE	116
C		IN THE ABSTRACT.			PANPOE	117
C	-----PROGRAM FOLLOWS BELOW-----				PANPOE	118
C	DIMENSION AND COMMON STATEMENTS				PANPOE	119
C	DIMENSION CI(100),VXI(100),VYI(100),HI(100)				PANPOE	120

```

DIMENSION KST(10),KFIN(10),OMHOD(1000),VPHOD(1000),AMP(1000)
DIMENSION AKI(1000)
COMMON IMAX,CI,VXI,VYI,HI
C
MOFNO = MOFNO
IF (NPRNT.LT.0) GO TO 20
C PRINT HEADING FOR PHI1 AND PHI2 PROFILE DATA TO BE PRINTED BY NAMPOE
WRITE (6,19)
19 FORMAT (1H1,41X,26HFI1 AND PHI2 PROFILE DATA ///63H0IAP1MX = NO.
10F LAYER FOR WHICH ABS(PHI1(IAF1MX)) IS A MAXIMUM/63H IAP2MX = NO.
2 OF LAYER FOR WHICH ABS(PHI2(IAF2MX)) IS A MAXIMUM/42H R1 = P
3I1(IAF1MX) / ABS(PHI2(IAF2MX)) /42H R2 = PHI2(IAF2MX) / ABS(P
4I2(IAF2MX)) /37H R3 = PHI2(1) / ABS(PHI2(IAF2MX)) /40H NZC1
5= NO. OF TIMES PHI1 CHANGES SIGN /40H NZC2 = NO. OF TIMES PHI2
6CHANGES SIGN)
20 CONTINUE
C DO LOOP TO COMPUTE AMP(J)
DO 25 II=1,MOFNO
DO 25 J=1,MOFNO
IF (NPRNT.LT.0) GO TO 23
WRITE (6,22) II
22 FORMAT (1H //111111 1H ,51X,5HMOFNO ,I2 /// 1H ,7X,5HOMEGA,7X,5HVPHS
1,6X,6HIAP1MX,10X,2HR1,3X,4HNZC1,6X,6HIAP2MX,10X,2HR2,8X,4HNZC2,10
2,2HR3 //)
23 J1=KST(II)
J2=KFIN(II)
DO 25 J=J1,J2
K = J
OMEGA = OMHOD(K)
VPHSE = VPHOD(K)
AKITR = AKI(K)
X = AMP(K)
CALL NAMPOE(ZSCRCE,ZOBS,OMEGA,VPHSE,AKITR,THETK,X,NPRNT)
AMP(K) = X
25 CONTINUE
WRITE (6,251)
251 FORMAT(1H //111111 16H AMENT IS CALLED).
C END OF DO LOOP
C
C COMPUTATION OF AMBIENT PRESSURES
CALL AMBNT(ZSCRCE,PSCRCE,ISCR)
CALL AMBNT(ZOBS,POBS,ICBS)
WRITE (6,252) PSCRCE,ISCR,POBS,ICBS
252 FORMAT (1H ,E16.5,I10,E16.5,I10)
C
C COMPUTATION OF SORT(CEMSTY RATIO)
UED = (CI(ISCR)/CI(ICBS)) * SORT(POBS/PSCRCE)
C
C COMPUTATION OF ALAM AND FACT
ALAM=(1.E6/PSCRCE)**(0.333333)*(CI(1)/CI(ISCR))
C NOTE THAT CI(1) IS SOUND SPEED AT THE GROUND
CONST = 4.0/SORT(2.0*3.141593)
FACT = CONST*(CI(1)*UED*(PSCRCE/1.E6)**(0.333333))
WRITE (6,253) FACT
253 FORMAT (1H ,5HFACT=E16.5)
IF(NPRNT.NE.1) RETURN
WRITE (6,31) ZSCRCE,ZOBS,FACT,ALAM
31 FORMAT(1H1, 20X, 36HTABULATION OF SOURCE FREE AMPLITUDES,
1 23H FROM SUBROUTINE NAMPOE //21X, 19HHEIGHT OF BURST =,
1 F8.3, 3H KM / 21X, 19HHEIGHT OF OBSERVER=, F8.3, 3H KM/
1,21X, 4HFACT, 14X, 1H=, F8.3, 7H KM/SEC/ 21X,4HALAM,14X, 1H=,
1 F8.3)
DO 50 II =1,MOFNO
WRITE (6,41) II
41 FORMAT( 1H /// 1H , 5HMOFNO , I3/ 1H , 20X,5HOMEGA,
1 15X, 5HVPHSE,15X, 3HAKI, 17X, 3HAMPI)

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NAMPOE 130
NAMPOE 131
NAMPOE 132
NAMPOE 133
NAMPOE 134
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NAMPOE 136
NAMPOE 137
NAMPOE 138
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NAMPOE 144
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NAMPOE 192
NAMPOE 193
NAMPOE 194

```
K1=KST(II)
K2=KFIN(II)
DO 50 J=K1,K2
50 WRITE (6,51) OPMOD(J),VPHOC(J),AKI(J),AMP(J)
51 FORMAT(1H ,4X,F20.5,F20.5,F20.9,F20.9)
RETURN
ENC
```

```
PANPOE 195
PANPOE 196
PANPOE 197
PANPOE 198
PANPOE 199
PANPOE 200
PANPOE 201
```

SUBROUTINE PHASE(RR,RI,R,PHI)	8/15/68	LAST CARD IN DECK IS	PHASE	1
PHASE (SUBROUTINE)			PHASE	2
			PHASE	3
			PHASE	4
-----ABSTRACT-----			PHASE	5
			PHASE	6
TITLE - PHASE			PHASE	7
CONVERSION OF A COMPLEX NUMBER FROM RECTANGULAR FORM TO POLAR			PHASE	8
FORM			PHASE	9
			PHASE	10
GIVEN TWO REAL NUMBERS RR AND RI, A MAGNITUDE R AND AN			PHASE	11
ANGLE PHI ARE COMPUTED SUCH THAT			PHASE	12
			PHASE	13
$RR + I*RI = R * \exp(I*PHI)$			PHASE	14
			PHASE	15
WHERE $I = (-1)**0.5$			PHASE	16
			PHASE	17
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)			PHASE	18
			PHASE	19
AUTHORS - A.D.PIERCE AND J.POSEY, M.I.T., AUGUST, 1968			PHASE	20
			PHASE	21
			PHASE	22
-----USAGE-----			PHASE	23
			PHASE	24
NO SUBROUTINES ARE CALLED			PHASE	25
			PHASE	26
FORTRAN USAGE			PHASE	27
			PHASE	28
CALL PHASE(RR,RI,R,PHI)			PHASE	29
			PHASE	30
INPUTS			PHASE	31
			PHASE	32
RR REAL PART OF THE COMPLEX NUMBER BEING CONVERTED			PHASE	33
R*4			PHASE	34
			PHASE	35
RI IMAGINARY PART OF COMPLEX NUMBER BEING CONVERTED			PHASE	36
R*4			PHASE	37
			PHASE	38
OUTPUTS			PHASE	39
			PHASE	40
R MAGNITUDE OF THE COMPLEX NUMBER			PHASE	41
R*4			PHASE	42
			PHASE	43
PHI PHASE OF THE COMPLEX NUMBER (RADIANS) (-PI.LE.PHI.LE.PI)			PHASE	44
R*4			PHASE	45
			PHASE	46
			PHASE	47
-----EXAMPLES-----			PHASE	48
			PHASE	49
CALL PHASE(0.0,1.0,R,PHI)			PHASE	50
			PHASE	51
R = 1.0 AND PHI = 1.570796 ARE RETURNED			PHASE	52
			PHASE	53
CALL PHASE(1.0,-1.0,R,PHI)			PHASE	54
			PHASE	55
R = 1.414214 AND PHI = -0.7853982 ARE RETURNED			PHASE	56
			PHASE	57
			PHASE	58
-----PROGRAM FOLLOWS BELOW-----			PHASE	59
			PHASE	60
			PHASE	61
			PHASE	62
Q=ABS(RR)+ABS(RI)			PHASE	63
IF(Q-1.E-25) 1,1,30			PHASE	64

```
1 R=0.0
  PHI=0.0
  RETURN
30 AR=RR/Q
  AI=RI/Q
  A=SQRT(AR**2+AI**2)
  R=Q*A
  PHI=ASIN(ABS(AI)/A)
  IF(RR) 50,60,60
50 IF(RI) 300,300,200
60 IF(RI) 400,400,100
100 PHI=PHI
  RETURN
200 PHI=3.1415927-PHI
  RETURN
300 PHI=PHI-3.1415927
  RETURN
400 PHI=-PHI
  RETURN
  END
```

PHASE	65
PHASE	66
PHASE	67
PHASE	68
PHASE	69
PHASE	70
PHASE	71
PHASE	72
PHASE	73
PHASE	74
PHASE	75
PHASE	76
PHASE	77
PHASE	78
PHASE	79
PHASE	80
PHASE	81
PHASE	82
PHASE	83
PHASE	84

SUBROUTINE PPAMP(YIELD,RCFAD,KST,KFIN,OMHOD,VFHOD,
 1AMP,ALAM,FACT,AMPLTD,PHASQ)
 PPAMP (SUBROUTINE) 7/30/68 LAST CARD IN DECK IS

-----ABSTRACT-----

TITLE - PPAMP
 PROGRAM TO COMPUTE AND STORE AMPLITUDE ARRAY AMPLTD AND PHASE
 ARRAY PHASQ FOR GUIDED WAVES EXCITED BY A POINT ENERGY SOURCE
 WITH TIME DEPENDENCE CORRESPONDING TO A NUCLEAR EXPLOSION OF
 ENERGY DENOTED BY YIELD IN KT. THE VALUES FOUND ARE TO BE
 SUBSEQUENTLY USED BY TMPT ACCORDING TO THE RELATION
 (PRESSURE IN GYNES/CM**2 FOR A GIVEN MODE)*SORT(R)
 = INTEGRAL OVER CMGA OF AMPLTD*COS(OMEGA*(T-R/VP)+PHASQ)
 THE QUANTITIES AMPLTD AND PHASQ ARE BOTH DEPENDENT ON ANGULAR
 FREQUENCY AND ARE DIFFERENT FOR DIFFERENT MODES.

PROGRAM NOTES

IN THE FORMULATION FOR A POINT ENERGY SOURCE, THE ENERGY
 EQUATION IS WRITTEN

$$\partial P / \partial T - (C^2/2) \partial^2 (RHO) / \partial T^2 = 4 \cdot \pi \cdot C^2 \cdot F(T) \cdot (\Delta \text{FNCTN})$$

 AN EXPRESSION FOR F(T) IS

$$F(T) = ((L^2/CS) \cdot POS \cdot (\text{INTEGRAL OVER X FROM 0 TO CS} \cdot T/L \text{ OF UNIVERSAL FUNCTION FUNIV(X)}))$$

 WITH $L = (\text{ENERGY}/POS)^{2/3}$ AND POS, CS REPRESENTING PRESS
 AND SOUND SPEED AT THE SOURCE. IF F(T) IS THE PRESSU
 AT A DISTANCE OF 1 KM FROM A 1 KT EXPLOSION AT SEA LEVEL
 AND WITH TIME ORIGIN CORRESPONDING TO BLAST WAVE ONSET,
 THEN

$$\text{FUNIV(X)} = ((L^2/POS)^{2/3} \cdot (-1)) \cdot \text{FIKT}(L^2 \cdot X/CS)$$

 THE FOURIER TRANSFORM OF F(T) IS ACCORDINGLY FOUND TO BE

$$G(\Omega) = (1/(2 \cdot \pi)) \cdot (Y^{2/3}) \cdot (CS/POS) \cdot (POS/POS)^{2/3} \cdot (1/3) \cdot (1/(-I \cdot \Omega)) \cdot \text{FTMAG}(\Omega \cdot \text{ERAT}) \cdot \text{EXP}(I \cdot \text{FTPHSE}(\Omega \cdot \text{ERAT}))$$

 WHERE Y IS YIELD IN KT, $I = \sqrt{-1}$, AND $\Omega \cdot \text{ERAT} = \text{ALAM} \cdot \Omega \cdot Y^{2/3}$. THE FUNCTIONS FTMAG AND FTFHSE ARE AS
 COMPUTED BY SUBROUTINE SOURCE. THE QUANTITY ALAM IS
 $(CS/POS) \cdot (POS/POS)^{2/3}$ AS COMPUTED BY SUBROUTINE
 PAMPDE.
 A LENGTHY DERIVATION NOT GIVEN HERE INDICATES THAT

$$\text{AMPLTD} \cdot \text{EXP}(-I \cdot \text{PHASQ})$$

$$= -4 \cdot \text{SORT}(K) \cdot G(\Omega) \cdot CS \cdot \text{UED} \cdot \text{SORT}(2 \cdot \pi) \cdot \text{AMP}$$

$$\cdot \text{EXP}(-I \cdot \pi/4)$$

 WHERE AMP IS THE SAME AS THE AMPLTD COMPUTED BY PAMPDE A
 WHERE UED IS THE DENSITY FACTOR $(CS/COBS) \cdot \text{SORT}(PSCRC/PO$
 COMPUTED IN SUBROUTINE PAMPDE. INSERTING G(OMEGA) INTO
 THE ABOVE, WE IDENTIFY

$$\text{PHASQ} = (3/4) \cdot \pi - \text{FTPHSE}(\Omega \cdot \text{ERAT})$$

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C          AMPLTO=FACT*AMP*(Y**(2/3))*FTHAG(OMERAT)*SQRT(K)/OMEGA PPAMP 65
C          WHERE FACT IS 4/SQRT(2*PI)*C1*U2D*(PS/P1)**(1/3) AND IS PPAMP 66
C          COMPUTED BY SUBROUTINE FAMPDE. PPAMP 67
C          THE QUANTITIES FACT, ALAM, AND AMP ARE IN THE INPUT LIST PPAMP 68
C          OF THE SUBROUTINE. NOTE THAT THESE ARE YIELD INDEPENDENT PPAMP 69
C          THE SCHEME OF STORAGE FOR AMPLTO(J) AND PHASQ(J) IS THE PPAMP 70
C          SAME AS FOR OMMOD(J) AND VPMOD(J). SEE SUBROUTINE ALLMO PPAMP 71
C          PPAMP 72
C          PPAMP 73
C          PPAMP 74
C          PPAMP 75
C LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4) PPAMP 76
C          PPAMP 77
C AUTHORS - A.O.PIERCE AND J.POSEY, M.I.T., JULY, 1968 PPAMP 78
C          PPAMP 79
C          -----CALLING SEQUENCE----- PPAMP 80
C          SEE THE MAIN PROGRAM PPAMP 81
C          DIMENSION KST(1),KFIN(1),OMMOD(1),VPMOD(1),AMP(1) PPAMP 82
C          DIMENSION AMPLTO(1),PHASQ(1) PPAMP 83
C          THESE QUANTITIES MUST BE DIMENSIONED. THE PROGRAM USES VARIABLE PPAMP 84
C          DIMENSIONING. FOR ACTUAL DIMENSIONS ASSIGNED, SEE THE MAIN PROGRAM. PPAMP 85
C          CALL PPAMP(YIELD,MCFAC,KST,KFIN,OMMOD,VPMOD,AMP,ALAM,FACT, PPAMP 86
C          1 AMPLTO,PHASQ) PPAMP 87
C          PPAMP 88
C          PPAMP 89
C          -----EXTERNAL SUBROUTINES REQUIRED----- PPAMP 90
C          SOURCE, PHASE (PHASE IS CALLED BY SOURCE) PPAMP 91
C          PPAMP 92
C          PPAMP 93
C          -----ARGUMENT LIST----- PPAMP 94
C          PPAMP 95
C          YIELD R*4 NO INP PPAMP 96
C          MCFND I*4 NO INP PPAMP 97
C          KST I*4 VAR INP PPAMP 98
C          KFIN I*4 VAR INP PPAMP 99
C          OMMOD R*4 VAR INP PPAMP 100
C          VPMOD R*4 VAR INP PPAMP 101
C          AMP R*4 VAR INP PPAMP 102
C          ALAM R*4 NO INP PPAMP 103
C          FACT R*4 NO INP PPAMP 104
C          AMPLTO R*4 VAR OUT PPAMP 105
C          PHASQ R*4 VAR OUT PPAMP 106
C          PPAMP 107
C          NO COMMON STORAGE IS USED PPAMP 108
C          PPAMP 109
C          PPAMP 110
C          PPAMP 111
C          -----INPUTS----- PPAMP 112
C          YIELD =ENERGY RELEASE OF EXPLOSION IN EQUIVALENT KILOTONS OF PPAMP 113
C          TNT, 1 KT = 4.2E19 ERGS. PPAMP 114
C          MCFND =NUMBER OF MODES FOUND IN PREVIOUS TABULATION OF PPAMP 115
C          DISPERSION CURVES. PPAMP 116
C          KST(N) =INDEX OF FIRST TABULATED POINT IN N-TH MODE. PPAMP 117
C          KFIN(N) =INDEX OF LAST TABULATED POINT IN N-TH MODE. IN PPAMP 118
C          GENERAL, KFIN(N)=KST(N+1)-1. PPAMP 119
C          OMMOD(N) =ARRAY STORING ANGULAR FREQUENCY ORDINATE OF POINTS PPAMP 120
C          ON DISPERSION CURVES. THE NMODE MODE IS STORED FOR PPAMP 121
C          N BETWEEN KST(NMODE) AND KFIN(NMODE). PPAMP 122
C          VPMOD(N) =ARRAY STORING PHASE VELOCITY ORDINATE OF POINTS ON PPAMP 123
C          DISPERSION CURVES. THE NMODE MODE IS STORED FOR PPAMP 124
C          N BETWEEN KST(NMODE) AND KFIN(NMODE). PPAMP 125
C          AMP(N) =AMPLITUDE FACTOR INDEPENDENT OF YIELD COMPUTED BY PPAMP 126
C          SUBROUTINE FAMPDE CORRESPONDING TO ANGULAR FREQUENCY PPAMP 127
C          OMMOD(N) AND PHASE VELOCITY VPMOD(N). PPAMP 128
C          ALAM =A SCALING FACTOR DEPENDENT ON HEIGHT OF BURST, EQUAL PPAMP

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C		TO CUBE ROOT OF (PRESSURE AT GROUND)/(PRESSURE AT	PPAMP	129
C		BURST HEIGHT) TIMES (SOUND SPEED AT GROUND)/SOUND	PPAMP	130
C		SPEED AT BURST HEIGHT).	PPAMP	131
C	FACT	=A GENERAL AMPLITUDE FACTOR DEPENDENT ON BURST HEIGHT	PPAMP	132
C		AND OBSERVER HEIGHT. A PRECISE DEFINITION IS GIVEN	PPAMP	133
C		IN THE LISTING OF SUBROUTINE PAMPOE.	PPAMP	134
C		----	PPAMP	135
C		-----OUTPUTS-----	PPAMP	136
C			PPAMP	137
C	AMPLTD(N)	=AMPLITUDE FACTOR REPRESENTING TOTAL MAGNITUDE OF	PPAMP	138
C		FOURIER TRANSFORM OF THE CONTRIBUTION TO THE WAVEFOR	PPAMP	139
C		OF A SINGLE GUIDED MODE AT FREQUENCY OMMOD(N). IT	PPAMP	140
C		REPRESENTS THE AMPLITUDE OF THE NMODE-TH MODE IF N I	PPAMP	141
C		BETWEEN KST(NMODE) AND KFIN(NMODE), INCLUSIVE. THE	PPAMP	142
C		PRECISE DEFINITION IS GIVEN IN THE ABSTRACT.	PPAMP	143
C	PHASQ(N)	=PHASE LAG AT FREQUENCY OMMOD(N) FOR NMODE-TH MODE WH	PPAMP	144
C		N IS BETWEEN KST(NMODE) AND KFIN(NMODE), INCLUSIVE.	PPAMP	145
C		THE INTEGRAND IS UNDERSTOOD TO HAVE THE FORM	PPAMP	146
C		APPLTG*CGS(OMMOD*(TIME-DISTANCE/VPMOD)+PHASQ).	PPAMP	147
C			PPAMP	148
C		-----PROGRAM FOLLOWS BELOW-----	PPAMP	149
C			PPAMP	150
C			PPAMP	151
C	DIMENSION STATEMENTS USING VARIABLE DIMENSIONING		PPAMP	152
C		DIMENSION KST(1),KFIN(1),OMMOD(1),VPMOD(1),AMP(1)	PPAMP	153
C		DIMENSION AMPLTD(1),PHASQ(1)	PPAMP	154
C			PPAMP	155
C		O=(YIELD)**(0.333333)	PPAMP	156
C		ALAMP=O*ALAM	PPAMP	157
C			PPAMP	158
C	START OF DO LOOP. II IS NMODE NUMBER		PPAMP	159
C		DO 20 II=1,NMODE	PPAMP	160
C		K1=KST(II)	PPAMP	161
C		K2=KFIN(II)	PPAMP	162
C			PPAMP	163
C		DO 20 J=K1,K2	PPAMP	164
C	COMPUTATION OF SCALED FREQUENCY OPERAT		PPAMP	165
C		OPERAT=OMMOD(J)*ALAMP	PPAMP	166
C	COMPUTATION OF SORT(K)		PPAMP	167
C		AKAYSQ = ABS(OMMOD(J)/VPMOD(J))	PPAMP	168
C		AKAY = SORT(AKAYSQ)	PPAMP	169
C			PPAMP	170
C		CALL SOURCE(OPERAT,FTMAG,FTPHSE,CMAG,OPHSE)	PPAMP	171
C		AMPLTD(J)=(O**2)*FACT*FTMAG*AMP(J)*AKAY/OMMOD(J)	PPAMP	172
C	20 PHASQ(J)=.75*3.14159-FTPHSE		PPAMP	173
C	END OF DO LOOP		PPAMP	174
C			PPAMP	175
C		RETURN	PPAMP	176
C		END	PPAMP	177

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SUBROUTINE PRATHO
PRATHO (SUBROUTINE)
9/1/68 LAST CARD IN DECK IS
-----ABSTRACT-----
TITLE - PRATHO
PROGRAM TO PRINT OUT PARAMETERS DEFINING THE MODEL MULTILAYER
ATMOSPHERE. A LISTING IS PRINTED OF LAYER NUMBER, HEIGHT OF
LAYER BOTTOM, HEIGHT OF LAYER TOP, LAYER THICKNESS, SOUND SPEED
AND OF X AND Y COMPONENTS OF WIND VELOCITY.
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)
AUTHORS - A.O.PIERCE AND J.FOSEY, M.I.T., AUGUST, 1968
-----CALLING SEQUENCE-----
SEE THE MAIN PROGRAM
DIMENSION CI(100),VXI(100),VYI(100),HI(100)
COMMON IMAX,CI,VXI,VYI,HI (THESE MUST BE IN COMMON)
CALL PRATHO
-----EXTERNAL SUBROUTINES REQUIRED-----
NO EXTERNAL SUBROUTINES ARE REQUIRED.
-----ARGUMENT LIST-----
COMMON STORAGE USED
COMMON IMAX,CI,VXI,VYI,HI
IMAX      I*4      NO      INP
CI         R*4      100     INP
VXI        R*4      100     INP
VYI        R*4      100     INP
HI         R*4      100     INP
-----INPUTS-----
IMAX      =NUMBER OF LAYERS OF FINITE THICKNESS
CI(I)     =SOUND SPEED IN KM/SEC IN I-TH LAYER
VXI(I)    =X COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)
VYI(I)    =Y COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)
HI(I)     =THICKNESS IN KM OF I-TH LAYER OF FINITE THICKNESS
-----OUTPUTS-----
THE ONLY OUTPUT IS A PRINTOUT
-----EXAMPLE-----
MODEL ATMOSPHERE OF 10 LAYERS (TOP OF NEW PAGE)
(IMAX = 9)
LAYER      Z9      Z7      H      C      VX
10      22.50      INFINITE      INFINITE      0.2972      0.0042
9        20.00      22.50      2.50      0.2958      0.0093
8        17.50      20.00      2.50      0.2938      0.0118
7        15.00      17.50      2.50      0.2931      0.0144
6        12.50      15.00      2.50      0.2931      0.0165
5        10.00      12.50      2.50      0.2951      0.0160
4         7.50      10.00      2.50      0.3012      0.0149
3         5.00       7.50      2.50      0.3117      0.0118
2         2.50       5.00      2.50      0.3268      0.0098

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C      1      0.      2.50      2.50      0.3394      0.0057      PRATHO      65
C      PRATHO      66
C      ZB=HEIGHT OF LAYER BOTTOM IN KM      PRATHO      67
C      ZT=HEIGHT OF LAYER TOP IN KM      (THE VY COLUMN IS PRATHO      68
C      H =WIDTH OF LAYER IN KM      NOT SHOWN BECAUS PRATHO      69
C      C =SOUND SPEED IN KM/SEC      OF LACK OF SPACE PRATHO      70
C      VX=X COMP. OF WIND VEL. IN KM/SEC      IT DOES APPEAR O PRATHO      71
C      VY=Y COMP. OF WIND VEL. IN KM/SEC      PRINTOUT.) PRATHO      72
C      PRATHO      73
C      ----PROGRAM FOLLOWS BELOW----      PRATHO      74
C      PRATHO      75
C      PRATHO      76
C DIMENSION AND COMMON STATEMENTS LOCATING INPUT      PRATHO      77
C      DIMENSION CI(100),VXI(100),VYI(100),HI(100),ZI(100)      PRATHO      78
C      COMMON IPAX,CI,VXI,VYI,HI      PRATHO      79
C      PRATHO      80
C LET JET DENOTE THE INDEX OF THE UPPER HALFSpace      PRATHO      81
C      JET=IMAX+1      PRATHO      82
C      PRATHO      83
C PRINTING OF HEADING      PRATHO      84
C      WRITE (6,11) JET      PRATHO      85
C      11 FORMAT(1H,14X,15HMODEL ATMOSPHERE OF,14,7H LAYERS//)      PRATHO      86
C      WRITE (6,21)      PRATHO      87
C      21 FORMAT(1H ,2X,5H LAYER,7X,2HZB,10X,2HZT,11X,1HH,11X,1HC,11X,2HVX,      PRATHO      88
C      110X,2HVV)      PRATHO      89
C      PRATHO      90
C      IF(IMAX .EQ. 0) GO TO 33      PRATHO      91
C      PRATHO      92
C ZI(I) DENOTES THE HEIGHT OF TOP OF I-TH LAYER OF FINITE THICKNESS      PRATHO      93
C      ZI(1)=HI(1)      PRATHO      94
C      IF(IMAX .EQ. 1) GO TO 31      PRATHO      95
C      DO 30 I=2,IMAX      PRATHO      96
C      30 ZI(I)=ZI(I-1)+HI(I)      PRATHO      97
C      31 CONTINUE      PRATHO      98
C      PRATHO      99
C PRINTOUT FOR UPPER HALFSpace      PRATHO      100
C      XUV=ZI(IMAX)      PRATHO      101
C      33 IF(IMAX .EQ. 0) XUV=0.0      PRATHO      102
C      C=CI(JET)      PRATHO      103
C      VX=VXI(JET)      PRATHO      104
C      VY=VYI(JET)      PRATHO      105
C      WRITE (6,41) JET,XUV,C,VX,VY      PRATHO      106
C      41 FORMAT(1H ,17,F12.2,4X,8HINFINITE,4X,8HINFINITE,3F12.4)      PRATHO      107
C      PRATHO      108
C      IF(IMAX .EQ. 0) GO TO 60      PRATHO      109
C      IF(IMAX .EQ. 1) GO TO 52      PRATHO      110
C      PRATHO      111
C TABULATION FOR LAYERS 2 THROUGH IMAX      PRATHO      112
C      DO 50 J=2,IMAX      PRATHO      113
C      I=IMAX+2-J      PRATHO      114
C      IL=I-1      PRATHO      115
C      50 WRITE (6,51) I,ZI(IL),ZI(I),HI(I),CI(I),VXI(I),VYI(I)      PRATHO      116
C      51 FORMAT(1H ,17,3F12.2,3F12.4)      PRATHO      117
C      PRATHO      118
C TABULATION FOR LAYER 1      PRATHO      119
C      52 I=1      PRATHO      120
C      USTE0=0.0      PRATHO      121
C      WRITE (6,51) I,USTE0,ZI(I),HI(I),CI(I),VXI(I),VYI(I)      PRATHO      122
C      PRATHO      123
C PRINTOUT OF EXPLANATIONS      PRATHO      124
C      60 WRITE (6,61)      PRATHO      125
C      61 FORMAT(1HG,15X,31HZB=HEIGHT OF LAYER BOTTOM IN KM/ 1H ,15X,2HZT=      PRATHO      126
C      1EIGHT OF LAYER TOP IN KM/1H ,15X,23HH =WIDTH OF LAYER IN KM/1H ,      PRATHO      127
C      215X,24HC =SOUND SPEED IN KM/SEC/1H ,15X,33HVX=X COMP. OF WIND VEL      PRATHO      128
C      3 IN KM/SEC/1H ,15X,33HVV=Y COMP. OF WIND VEL. IN KM/SEC)      PRATHO      129
C      PRATHO      130
C      RETURN      PRATHO      131
C      ENO      PRATHO      132

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SUBROUTINE RRRR(OMEGA,AKX,AKY,RPP,K)
RRRR (SUBROUTINE)      8/1/68    LAST CARD IN DECK IS
C
C      ----ABSTRACT----
C
C  TITLE - RRRR
C  THIS SUBROUTINE COMPUTES A 2-BY-2 TRANSFER MATRIX WHICH CONNEC
C  SOLUTIONS OF THE RESIDUAL EQUATIONS AT THE BOTTOM OF THE UPPER
C  HALFSpace TO SOLUTIONS AT THE GROUND BY THE RELATIONS
C
C      PHI1(GROUND)= RPP(1,1)*PHI1(ZT(IMAX))+RPP(1,2)*PHI2(ZT(IM
C      PHI2(GROUND)= RPP(2,1)*PHI1(ZT(IMAX))+RPP(2,2)*PHI2(ZT(IM
C
C  WHERE ZT(IMAX) IS THE HEIGHT OF THE TOP OF THE IMAX LAYER AND
C  CONSEQUENTLY THE HEIGHT OF THE BOTTOM OF THE UPPER HALFSpace.
C  THE FUNCTIONS PHI1(Z) AND PHI2(Z) SATISFY THE RESIDUAL EQUATION
C
C      D(PHI1)/DZ = A(1,1)*PHI1(Z) + A(1,2)*PHI2(Z)
C      D(PHI2)/DZ = A(2,1)*PHI1(Z) + A(2,2)*PHI2(Z)
C
C  WHERE THE A(I,J) ARE FUNCTIONS OF ALTITUDE BUT CONSTANT IN EAC
C  LAYER.
C
C  IF WE LET EM(I) BE THE EM MATRIX (COMPUTED BY SUBROUTINE MMMM)
C  FOR THE I-TH LAYER, THEN (IN MATRIX NOTATION)
C
C      RPP = EM(1)*EM(2)*.....*EM(IMAX-1)*EM(IMAX)
C
C  THE ABOVE FORMULA IS USED TO COMPUTE THE RPP(I,J).
C
C  THE PARAMETERS DEFINING THE MULTILAYER ATMOSPHERE ARE PRESUMED
C  TO BE STORED IN COMMON.
C
C  LANGUAGE - FORTRAN IV (36J, REFERENCE MANUAL C23-6515-4)
C  AUTHOR - A.D.PIERCE, P.I.T., AUGUST, 1968
C
C      ----CALLING SEQUENCE----
C
C  SEE SUBROUTINE NMOFN
C  DIMENSION CI(100),VXI(100),VYI(100),HI(100)
C  COMMON IMAX,CI,VXI,VYI,HI (THESE MUST BE STORED IN COMMON)
C  DIMENSION RPP(2,2)
C  CALL RRRR(OMEGA,AKX,AKY,RPP,K)
C
C      ----EXTERNAL SUBROUTINES REQUIRED----
C
C  MMMM,AAAA,CAI,SAT
C
C      ----ARGUMENT LIST----
C
C  OMEGA      R*4      NO      INP
C  AKX        R*4      NO      INP
C  AKY        R*4      NO      INP
C  RPP        R*4      2-BY-2 OUT
C  K          I*4      NO      OUT (ALWAYS OUTPUT AS K=0)
C
C  COMMON STORAGE USED
C  COMMON IMAX,CI,VXI,VYI,HI
C
C  IMAX      I*4      NO      INP
C  CI        R*4      100     INP

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C	VXI	R*4	100	IMP	RRRR	65
C	VYI	R*4	100	IMP	RRRR	66
C	HI	R*4	100	IMP	RRRR	67
C					RRRR	68
C					RRRR	69
C					RRRR	70
C					RRRR	71
C	OMEGA			=ANGULAR FREQUENCY IN RAD/SEC	RRRR	72
C	AKX			=X COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM	RRRR	73
C	AKY			=Y COMPONENT OF HORIZONTAL WAVE NUMBER VECTOR IN 1/KM	RRRR	74
C	IMAX			=NUMBER OF LAYERS OF FINITE THICKNESS	RRRR	75
C	CI(I)			=SOUND SPEED IN KM/SEC IN I-TH LAYER	RRRR	76
C	VXI(I)			=X COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)	RRRR	77
C	VYI(I)			=Y COMPONENT OF WIND VELOCITY IN I-TH LAYER (KM/SEC)	RRRR	78
C	HI(I)			=THICKNESS IN KM OF I-TH LAYER OF FINITE THICKNESS	RRRR	79
C					RRRR	80
C					RRRR	81
C	RPP			=2-BY-2 TRANSFER MATRIX WHICH CONNECTS SOLUTIONS OF	RRRR	82
C				THE RESIDUAL EQUATIONS AT THE BOTTOM OF THE UPPER	RRRR	83
C				HALFSPACE TO SOLUTIONS AT THE GROUND.	RRRR	84
C	K			=DUMMY PARAMETER ALWAYS RETURNED AS 0.	RRRR	85
C					RRRR	86
C					RRRR	87
C					RRRR	88
C					RRRR	89
C					RRRR	90
C					RRRR	91
C					RRRR	92
C					RRRR	93
C					RRRR	94
C					RRRR	95
C					RRRR	96
C					RRRR	97
C					RRRR	98
C					RRRR	99
C					RRRR	100
C					RRRR	101
C					RRRR	102
C					RRRR	103
C					RRRR	104
C					RRRR	105
C					RRRR	106
C					RRRR	107
C					RRRR	108
C					RRRR	109
C					RRRR	110
C					RRRR	111
C					RRRR	112
C					RRRR	113
C					RRRR	114
C					RRRR	115
C					RRRR	116
C					RRRR	117
C					RRRR	118
C					RRRR	119
C					RRRR	120
C					RRRR	121
C					RRRR	122
C					RRRR	123
C					RRRR	124
C					RRRR	125
C					RRRR	126
C					RRRR	127
C					RRRR	128
C					RRRR	129
C					RRRR	130
C					RRRR	131

C	SUBROUTINE RTHI(X,F,FCT,XLI,XRI,EPS,IEND,IER)	RTHI	1
C		RTHI	2
C		RTHI	3
C	SUBROUTINE RTHI	RTHI	4
C		RTHI	5
C	PURPOSE	RTHI	6
C	TO SOLVE GENERAL NONLINEAR EQUATIONS OF THE FORM FCT(X)=0	RTHI	7
C	BY MEANS OF MUELLER-S ITERATION METHOD.	RTHI	8
C		RTHI	9
C	USAGE	RTHI	10
C	CALL RTHI (X,F,FCT,XLI,XRI,EPS,IEND,IER)	RTHI	11
C	PARAMETER FCT REQUIRES AN EXTERNAL STATEMENT.	RTHI	12
C		RTHI	13
C	DESCRIPTION OF PARAMETERPS	RTHI	14
C	X - RESULTANT ROOT OF EQUATION FCT(X)=0.	RTHI	15
C	F - RESULTANT FUNCTION VALUE AT ROOT X.	RTHI	16
C	FCT - NAME OF THE EXTERNAL FUNCTION SUBPROGRAM USED.	RTHI	17
C	XLI - INPUT VALUE WHICH SPECIFIES THE INITIAL LEFT BOUND	RTHI	18
C	OF THE ROOT X.	RTHI	19
C	XRI - INPUT VALUE WHICH SPECIFIES THE INITIAL RIGHT BOUND	RTHI	20
C	OF THE ROOT X.	RTHI	21
C	EPS - INPUT VALUE WHICH SPECIFIES THE UPPER BOUND OF THE	RTHI	22
C	ERROR OF RESULT X.	RTHI	23
C	IEND - MAXIMUM NUMBER OF ITERATION STEPS SPECIFIED.	RTHI	24
C	IER - RESULTANT ERROR PARAMETER CODED AS FOLLOWS	RTHI	25
C	IER=0 - NO ERROR.	RTHI	26
C	IER=1 - NO CONVERGENCE AFTER IEND ITERATION STEPS	RTHI	27
C	FOLLOWED BY IEND SUCCESSIVE STEPS OF	RTHI	28
C	BISECTION.	RTHI	29
C	IER=2 - BASIC ASSUMPTION FCT(XLI)*FCT(XRI) LESS	RTHI	30
C	THAN OR EQUAL TO ZERO IS NOT SATISFIED.	RTHI	31
C		RTHI	32
C	REMARKS	RTHI	33
C	THE PROCEDURE ASSUMES THAT FUNCTION VALUES AT INITIAL	RTHI	34
C	BOUNDS XLI AND XRI HAVE NOT THE SAME SIGN. IF THIS BASIC	RTHI	35
C	ASSUMPTION IS NOT SATISFIED BY INPUT VALUES XLI AND XRI, THE	RTHI	36
C	PROCEDURE IS BYPASSED AND GIVES THE ERROR MESSAGE IER=2.	RTHI	37
C		RTHI	38
C	SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED	RTHI	39
C	THE EXTERNAL FUNCTION SUBPROGRAM FCT(X) MUST BE FURNISHED	RTHI	40
C	BY THE USER.	RTHI	41
C		RTHI	42
C	METHOD	RTHI	43
C	SOLUTION OF EQUATION FCT(X)=0 IS DONE BY MEANS OF MUELLER-S	RTHI	44
C	ITERATION METHOD OF SUCCESSIVE BISECTIONS AND INVERSE	RTHI	45
C	PARABOLIC INTERPOLATION, WHICH STARTS AT THE INITIAL BOUNDS	RTHI	46
C	XLI AND XRI. CONVERGENCE IS QUADRATIC IF THE DERIVATIVE OF	RTHI	47
C	FCT(X) AT ROOT X IS NOT EQUAL TO ZERO. ONE ITERATION STEP	RTHI	48
C	REQUIRES TWO EVALUATIONS OF FCT(X). FOR TEST ON SATISFACTOR	RTHI	49
C	ACCURACY SEE FORMULAE (3,4) OF MATHEMATICAL DESCRIPTION.	RTHI	50
C	FOR REFERENCE, SEE G. K. KRISTIANSEN, ZERO OF ARBITRARY	RTHI	51
C	FUNCTION, BIT, VOL. 3 (1963), PP.205-206.	RTHI	52
C		RTHI	53
C		RTHI	54
C		RTHI	55
C		RTHI	56
C		RTHI	57
C	PREPARE ITERATION	RTHI	58
C	IER=0	RTHI	59
C	XL=XLI	RTHI	60
C	XR=XRI	RTHI	61
C	X=XL	RTHI	62
C	TOL=X	RTHI	63
C		RTHI	64

F=FCT(TOL)	RTMI	65
IF(F)1,16,1	RTMI	66
1 CONTINUE	RTMI	67
CONV=ABS(F)	RTMI	68
F=FCT(TOL)/CONV	RTMI	69
FL=F	RTMI	70
X=XR	RTMI	71
TOL=X	RTMI	72
F=FCT(TOL)/CONV	RTMI	73
IF(F)2,16,2	RTMI	74
2 FR=F	RTMI	75
IF(SIGN(1.,FL)+SIGN(1.,FR)) 25,3,25	RTMI	76
C BASIC ASSUMPTION FL*FR LESS THAN 0 IS SATISFIED.	RTMI	77
C GENERATE TOLERANCE FOR FUNCTION VALUES.	RTMI	78
3 I=0	RTMI	79
TOLF=EPS*(ABS(F)+1.0)*100.0	RTMI	80
C	RTMI	81
C	RTMI	82
C	RTMI	83
C START ITERATION LOOP	RTMI	84
4 I=I+1	RTMI	85
C	RTMI	86
C START BISECTION LOOP	RTMI	87
DO 13 K=1,IEND	RTMI	88
X=.5*(XL+XR)	RTMI	89
TOL=X	RTMI	90
F=FCT(TOL)/CONV	RTMI	91
IF(F)5,16,5	RTMI	92
5 IF(SIGN(1.,F)+SIGN(1.,FR)) 7,6,7	RTMI	93
C INTERCHANGE XL AND XR IN ORDER TO GET THE SAME SIGN IN F AND FR	RTMI	94
C	RTMI	95
6 TOL=XL	RTMI	96
XL=XR	RTMI	97
XR=TOL	RTMI	98
TOL=FL	RTMI	99
FL=FR	RTMI	100
FR=TOL	RTMI	101
7 TOL=F-FL	RTMI	102
A=F*TOL	RTMI	103
A=A+A	RTMI	104
IF(ABS(A)-1.0E35) 71,71,130	RTMI	105
71 CONTINUE	RTMI	106
QUEST=FR*(FR-FL)	RTMI	107
IF(ABS(QUEST)-1.0E35) 72,72,130	RTMI	108
72 CONTINUE	RTMI	109
IF(A-FR*(FR-FL)) 8,9,9	RTMI	110
8 IF(I-IEND)17,17,9	RTMI	111
9 XR=X	RTMI	112
FR=F	RTMI	113
C	RTMI	114
C TEST ON SATISFACTORY ACCURACY IN BISECTION LOOP	RTMI	115
TOL=EPS	RTMI	116
A=ABS(XR)	RTMI	117
IF(A-1.)11,11,10	RTMI	118
10 TOL=TOL*A	RTMI	119
11 IF(ABS(XR-XL)-TOL)12,12,13	RTMI	120
12 IF(ABS(FR-FL)-TOLF)14,14,13	RTMI	121
13 CONTINUE	RTMI	122
C END OF BISECTION LOOP	RTMI	123
C	RTMI	124
C NO CONVERGENCE AFTER IEND ITERATION STEPS FOLLOWED BY IEND	RTMI	125
C SUCCESSIVE STEPS OF BISECTION OR STEADILY INCREASING FUNCTION	RTMI	126
C VALUES AT RIGHT BOUNDS. ERROR RETURN.	RTMI	127
130 CONTINUE	RTMI	128

IER=1	RTHI	129
F=CONV*F	RTHI	130
FR=CONV*FR	RTHI	131
FL=CONV*FL	RTHI	132
Q=2.*(XL-XR)/(XL+XR)	RTHI	133
QA=ABS(Q)	RTHI	134
IF (QA .LT. 1.0E-4) GO TO 16	RTHI	135
IER = 1	RTHI	136
WRITE(6,723) IER,X	RTHI	137
WRITE(6,724) F,XLI,XRI	RTHI	138
WRITE(6,725) FR,FL,FR,FL,QA	RTHI	139
GO TO 16	RTHI	140
14 IF (ABS(FR)-ABS(FL))16,16,15	RTHI	141
15 X=XL	RTHI	142
F=FL	RTHI	143
FL=CONV*FR	RTHI	144
FR=CONV*FR	RTHI	145
F=CONV*F	RTHI	146
16 RETURN	RTHI	147
C COMPUTATION OF ITERATED X-VALUE BY INVERSE PARABOLIC INTERPOLATIO	RTHI	148
C 17 A=FR-F	RTHI	149
DX=(X-XL)*FL*(1.+F*(A-TOL)/(1*(FR-FL)))/TOL	RTHI	150
XH=X	RTHI	151
FH=F	RTHI	152
X=XL-DX	RTHI	153
TOL=X	RTHI	154
F=FCT(TOL)/CONV	RTHI	155
IF(F)18,16,18	RTHI	156
C TEST ON SATISFACTORY ACCURACY IN ITERATION LGCP	RTHI	157
C 19 TOL=EPS	RTHI	158
A=ABS(X)	RTHI	159
IF (A-1.)20,20,19	RTHI	160
19 TOL=TOL*A	RTHI	161
20 IF (ABS(DX)-TOL)21,21,22	RTHI	162
21 IF (ABS(F)-TOLF)16,16,22	RTHI	163
C PREPARATION OF NEXT BISECTION LGCP	RTHI	164
C 22 IF (SIGN(1.,F)+SIGN(1.,FL)) 24,23,24	RTHI	165
23 XR=X	RTHI	166
FR=F	RTHI	167
GO TO 4	RTHI	168
24 XL=X	RTHI	169
FL=F	RTHI	170
XR=XH	RTHI	171
FR=FH	RTHI	172
GO TO 4	RTHI	173
C END OF ITERATION LOOP	RTHI	174
C 25 IER=2	RTHI	175
FL=CONV*FL	RTHI	176
FR=CONV*FR	RTHI	177
F=CONV*F	RTHI	178
IER = 2	RTHI	179
WRITE(6,723) IER,X	RTHI	180
WRITE(6,724) F,XLI,XRI	RTHI	181
WRITE(6,725) FR,FL,FR,FL,QA	RTHI	182
723 FORMAT(1H ,4X,15HTROUBLE IN RTMI,3X,4HIER=,16,3X,2HX=,G15.8)	RTHI	183
724 FORMAT(1H ,3X,2HF=,G15.8,3X,4HXL,XRI=,2G15.9)	RTHI	184
725 FORMAT(1H ,3X,6HFR,FL=,2G15.8,3X,6HXR,XL=,2G15.8,3X,3HQA=,G15.8)	RTHI	185
RETURN	RTHI	186
END	RTHI	187
	RTHI	188
	RTHI	189
	RTHI	190
	RTHI	191
	RTHI	192
	RTHI	193

FUNCTION SAI(X)	SAI	1
SAI (FUNCTION)	SAI	2
7/25/68 LAST CARD IN DECK IS	SAI	3
---- <td>SAI</td> <td>4</td>	SAI	4
TITLE - SAI	SAI	5
PROGRAM TO EVALUATE FUNCTION SAI(X) FOR GIVEN VARIABLE X.	SAI	6
IF X IS NEGATIVE, SAI(X)=SIN(Y)/Y WITH Y=SQRT(-X). IF X IS	SAI	7
POSITIVE, SAI(X)=SINH(Y)/Y WITH Y=SQRT(X). THE FUNCTION IS	SAI	8
ALSO REPRESENTABLE BY THE POWER SERIES	SAI	9
SAI(X)= 1 + X/(3FACT) + X**2/(5FACT) + X**3/(7FACT) + ...	SAI	10
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C24-6515-4)	SAI	11
AUTHOR - A.D.PIERCE, M.I.T., JULY, 1968	SAI	12
---- <td>SAI</td> <td>13</td>	SAI	13
SAI(ANY R*4 ARGUMENT) MAY BE USED IN ARITHMETIC EXPRESSIONS	SAI	14
---- <td>SAI</td> <td>15</td>	SAI	15
NO EXTERNAL SUBROUTINES ARE REQUIRED	SAI	16
---- <td>SAI</td> <td>17</td>	SAI	17
X R*4 NO INP	SAI	18
SAI R*4 NO OUT	SAI	19
NO COMMON STORAGE IS USED	SAI	20
---- <td>SAI</td> <td>21</td>	SAI	21
1 IF(ABS(X) .GT. 1.E-15) GO TO 9	SAI	22
ABS(X) IS SO SMALL THAT SAI IS VIRTUALLY 1.0	SAI	23
SAI=1.0	SAI	24
RETURN	SAI	25
CONTINUING FROM 1	SAI	26
9 Y=SQRT(ABS(X))	SAI	27
IF(X) 10,10,11	SAI	28
X IS LESS THAN 0.	SAI	29
10 SAI=SIN(Y)/Y	SAI	30
RETURN	SAI	31
X IS POSITIVE. SAI= SINH(Y)/Y.	SAI	32
11 E=EXP(Y)	SAI	33
SAI=0.5*(E-1./E)/Y	SAI	34
RETURN	SAI	35
END	SAI	36

SUBROUTINE SOURCE(OMEGA,FTMAG,FTPHSE,DMAG,DPHSE)	SOURCE	1
SOURCE (SUBROUTINE) 8/15/68	SOURCE	2
	SOURCE	3
	SOURCE	4
-----ABSTRACT-----	SOURCE	5
	SOURCE	6
TITLE - SOURCE	SOURCE	7
EVALUATION OF FOURIER TRANSFORM OF NEAR FIELD ACOUSTIC RESPONSE	SOURCE	8
TO EXPLOSIVE SOURCE	SOURCE	9
	SOURCE	10
SOURCE COMPUTES THE FOURIER TRANSFORM OF THE NEAR FIELD	SOURCE	11
PRESSURE AT 1 KM FROM A 1 KT EXPLOSION AT SEA LEVEL. THE	SOURCE	12
AMBIENT PRESSURE IS ASSUMED TO BE 1.56 DYNES/CM**2 AND	SOURCE	13
THE TIME LAPSE FROM TIME ZERO IS NEGLECTED. AN EMPIRICAL	SOURCE	14
FORMULA FOR THIS PRESSURE IS	SOURCE	15
	SOURCE	16
$P(T) = P_{AS} * (1 - (T/T_{AS})) * \exp(-T/T_{AS}) \quad , T \geq T_{AS}$	SOURCE	17
$= 0 \quad , T < T_{AS}$	SOURCE	18
	SOURCE	19
WITH $P_{AS} = (34.45E+3) * (1.61) \text{ DYNES/CM**2}$	SOURCE	20
AND $T_{AS} = 0.33 \text{ SEC}$	SOURCE	21
	SOURCE	22
THEREFORE, ITS FOURIER TRANSFORM IS	SOURCE	23
	SOURCE	24
$FT(OMEGA) = -I * OMEGA * P_{AS} / (1/T_{AS} - I * OMEGA)**2$	SOURCE	25
	SOURCE	26
WHERE $I = (-1)**0.5$	SOURCE	27
	SOURCE	28
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C21-6515-4)	SOURCE	29
	SOURCE	30
AUTHORS - A.G. PIERCE AND J. POSEY, M.I.T., AUGUST, 1968	SOURCE	31
	SOURCE	32
	SOURCE	33
-----USAGE-----	SOURCE	34
	SOURCE	35
SUBROUTINE PHASE IS CALLED	SOURCE	36
	SOURCE	37
FORTRAN USAGE	SOURCE	38
	SOURCE	39
CALL SOURCE(OMEGA,FTMAG,FTPHSE,DMAG,DPHSE)	SOURCE	40
	SOURCE	41
INPUTS	SOURCE	42
	SOURCE	43
OMEGA ANGULAR FREQUENCY (RAD/SEC)	SOURCE	44
R*4	SOURCE	45
	SOURCE	46
OUTPUTS	SOURCE	47
	SOURCE	48
FTMAG MAGNITUDE OF FT(OMEGA) DEFINED ABOVE IN SUBROUTINE ABSTR	SOURCE	49
R*4 ((DYNES/CM**2) / (PAC/SEC))	SOURCE	50
	SOURCE	51
FTPHSE PHASE OF FT(OMEGA) DEFINED ABOVE IN SUBROUTINE ABSTRACT	SOURCE	52
R*4 (RAD/SEC)	SOURCE	53
	SOURCE	54
DMAG DERIVATIVE OF FTMAG WITH RESPECT TO OMEGA ((DYNES/CM**2	SOURCE	55
R*4 / (RAD/SEC)**2)	SOURCE	56
	SOURCE	57
DPHSE DERIVATIVE OF FTPHSE WITH RESPECT TO OMEGA (RAD / (RAD/	SOURCE	58
R*4 SEC))	SOURCE	59
	SOURCE	60
	SOURCE	61
	SOURCE	62
-----PROGRAM FOLLOWS BELOW-----	SOURCE	63
	SOURCE	64

C		SOURCE	65
C	WE ASSUME INVERSE R DEPENDENCE	SOURCE	66
	PAS=(34.45E+3/1.0)*(1.61)	SOURCE	67
C	PAS IS IN DYNES/CM**2	SOURCE	68
C	THIS IS THE PEAK OVERPRESSURE AT 1 KM	SOURCE	69
	TAS=0.33	SOURCE	70
C	TAS IS THE LENGTH OF THE POSITIVE PHASE	SOURCE	71
	OMO=1.0/TAS	SOURCE	72
	DENOM=OMEGA**2+OMO**2	SOURCE	73
	FTMAG=PAS*OMEGA/DENOM	SOURCE	74
	OMAG=PAS/DENOM-2.0*PAS*OMEGA**2/DENOM**2	SOURCE	75
	CALL PHASE(OMO,OMEGA,X,PHI)	SOURCE	76
C	PHI IS THE ARCTAN OF OMEGA/OMO	SOURCE	77
	FTPHSE=-3.1415927/2.0+2.0*PHI	SOURCE	78
	DPHSE=2.0*OMO/DENOM	SOURCE	79
C	THE DERIVATIVE OF THE ARCTAN IS 1./(1.+Y**2)	SOURCE	80
	RETURN	SOURCE	81
	END	SOURCE	82

SUBROUTINE SUSFCT(N,M,NROW,INMODE,ISUS)	SUSPCT	1
SUSPCT (SUBROUTINE)	7/19/68	2
	LAST CARD IN DECK IS	3
		4
-----ABSTRACT-----		5
TITLE - SUSPCT		6
EVALUATION OF SUSPICION INDEX OF ELEMENT (N,M) OF MATRIX INMODE		7
		8
		9
SUSPCT EVALUATES THE SUSPICION INDEX, ISUS, OF THE ELEMENT		10
IN ROW N, COLUMN M OF THE MATRIX INMODE ((N,M) MUST BE		11
AN INTERIOR ELEMENT). THE NEIGHBORS OF (N,M) ARE DEFINED		12
TO BE THE EIGHT ELEMENTS WHICH FORM THE THREE BY THREE		13
ELEMENT SQUARE WHICH HAS (N,M) AT ITS CENTER. THEY ARE		14
NUMBERED FROM ONE TO NINE BEGINNING IN THE UPPER LEFT AND		15
PROCEEDING CLOCKWISE (NO. 1 AND NO. 9 ARE SAME ELEMENT).		16
EACH ELEMENT OF MATRIX INMODE MUST HAVE ONE OF THREE		17
VALUES, -1, 1, OR 5. (N,M) IS NOT SUSPICIOUS AND ISUS >		18
0 IF ANY ONE OF THE FOLLOWING CONDITIONS HOLDS.		19
1. ELEMENT (N,M) > 5		20
2. ANY OF ITS NEIGHBORS > 5		21
3. NOWHERE IN THE 3X3 ARRAY OF (N,M) AND ITS NEIGHBORS		22
DOES THERE APPEAR TO BE A DISPERSION CURVE		23
WITH POSITIVE SLOPE		24
		25
		26
OTHERWISE ISUS IS SET EQUAL TO THE NUMBER OF THE QUADRANT		27
IN WHICH THE POSITIVE SLOPE APPEARS. THE QUADRANTS ARE		28
NUMBERED BEGINNING IN THE UPPER LEFT AND PROCEEDING CLOCK		29
WISE.		30
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)		31
AUTHORS - A.O. PIERCE AND J. POSEY, M.I.T., JUNE, 1968		32
		33
-----USAGE-----		34
NO FORTRAN SUBROUTINES ARE CALLED		35
		36
FORTRAN USAGE		37
CALL SUSFCT(N,M,NROW,INMODE,ISUS)		38
		39
INPUTS		40
		41
N	ROW NUMBER OF ELEMENT UNDER CONSIDERATION (MAY NOT BE	42
I*4	FIRST OR LAST ROW)	43
		44
M	COLUMN NUMBER OF ELEMENT UNDER CONSIDERATION (MAY NOT BE	45
I*4	FIRST OR LAST COLUMN)	46
		47
NROW	TOTAL NUMBER OF ROWS IN INMODE	48
I*4		49
		50
INMODE	MATRIX UNDER CONSIDERATION STORED IN VECTOR FORM, COLUMN	51
I*4(10)	AFTER COLUMN. EACH ELEMENT MUST BE -1, 1, OR 5.	52
		53
OUTPUTS		54
		55
ISUS	SUSPICION INDEX OF ELEMENT (N,M). SEE ABSTRACT ABOVE FOR	56
I*4	DEFINITION.	57
		58
		59
		60
		61
		62
-----EXAMPLES-----		63
		64
CALLING PROGRAM		65
		66
DIMENSION INMODE(9)		67
INMODE = -1, -1, 1, 1, -1, 1, 1, 1, -1		68

```

C      CALL SUSPCT(2,2,3,INMODE,ISUS)
C      WRITE (6,200) ISUS
C 200  FORMAT (10H EXAMPLE 1,EX, 6MISUS >.I2)
C      INMODE > -1, -1, 1, 1, -1, -1, 1, 1, 1
C      CALL SUSPCT(2,2,3,INMODE,ISUS)
C      WRITE (6,300) ISUS
C 300  FORMAT (10H EXAMPLE 2,EX, 6MISUS >.I2)
C      END

C  TABLES OF INMODE
C
C      EXAMPLE 1      EXAMPLE 2
C
C      -+-          -+-
C      --+          --+
C      +-+          +-+
C
C  PRINTOUT
C
C      EXAMPLE 1      ISUS = 3
C      EXAMPLE 2      ISUS = 0
C
C      -----PROGRAM FOLLOWS BELOW-----
C
C  VARIABLE DIMENSIONING OF INMODE
C      DIMENSION IPP(9),INMODE(1)
C
C  ELEMENT (N,M) OF INMODE IS ICEN
C      J16=(M-1)*NROW+N
C      ICEN=INMODE(J16)
C      ISUS= 0
C
C  IF ICEN IS 5, IT IS NOT SUSPICIOUS AND ISUS = 0.
C      IF(ICEN .EQ. 5) RETURN
C
C  IPP(N) IS NEIGHBOR NO. N (SEE ABSTRACT ABOVE FOR NUMBERING SCHEME)
C      J17=(M-2)*NROW+(M-1)
C      IPP(1)=INMODE(J17)
C      J18=(M-1)*NROW+(M-1)
C      IPP(2)=INMODE(J18)
C      J19=(M-0)*NROW+(M-1)
C      IPP(3)=INMODE(J19)
C      J20=(M-0)*NROW+(M-0)
C      IPP(4)=INMODE(J20)
C      J21=(M-0)*NROW+(M+1)
C      IPP(5)=INMODE(J21)
C      J22=(M-1)*NROW+(M+1)
C      IPP(6)=INMODE(J22)
C      J23=(M-2)*NROW+(M+1)
C      IPP(7)=INMODE(J23)
C      J24=(M-2)*NROW+(M+0)
C      IPP(8)=INMODE(J24)
C      IPP(9)= IPP(1)
C      NX = 0
C      DO 10 I=1,9
C      IF(IPP(I) .EQ. 5) NX=NX+1
C  10 CONTINUE
C  NX IS THE NUMBER OF NEIGHBORS WHICH EQUAL +5
C
C  IF MORE THAN ONE NEIGHBOR IS EQUAL TO +5, THEN ISUS=0
C      IF (NX .GT. 1) RETURN

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SUSPCT 69
SUSPCT 70
SUSPCT 71
SUSPCT 72
SUSPCT 73
SUSPCT 74
SUSPCT 75
SUSPCT 76
SUSPCT 77
SUSPCT 78
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SUSPCT 80
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SUSPCT 116
SUSPCT 117
SUSPCT 118
SUSPCT 119
SUSPCT 120
SUSPCT 121
SUSPCT 122
SUSPCT 123
SUSPCT 124
SUSPCT 125
SUSPCT 126
SUSPCT 127
SUSPCT 128
SUSPCT 129
SUSPCT 130
SUSPCT 131
SUSPCT 132

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C		SUSPCT	133
C	IF NEIGHBOR 3 IS THE ONLY ONE EQUAL TO +5 AND EITHER NEIGHBOR 2 OR	SUSPCT	134
C	NEIGHBOR 4 DOES NOT AGREE WITH ICEN, THEN ISUS=2	SUSPCT	135
	ISUM = IABS(ICEN + IPP(2) + IPP(4))	SUSPCT	136
	IF (IPP(3).EQ.5 .AND. ISUM.NE.3) ISUS=2	SUSPCT	137
	IF (NX.GT.0) RETURN	SUSPCT	138
30	DO 50 I=1,9	SUSPCT	139
50	IPP(I)=(IABS(IPP(I)+ICEN))/2	SUSPCT	140
C	IPP(I) IS 1 IF NEIGHBOR I AGREES WITH ICEN, IT IS 0 IF THEY DISAGREE	SUSPCT	141
C	(TO REACH THIS POINT, NEITHER ICEN NOR ANY OF ITS NEIGHBORS COULD BE	SUSPCT	142
C		SUSPCT	143
	ISUS = 1	SUSPCT	144
	IF(IPP(1) .EQ. 0 .AND. IPP(2) .EQ. 1 .AND. IPP(8) .EQ. 1)	SUSPCT	145
1	RETURN	SUSPCT	146
	IF(IPP(9) .EQ. 0 .AND. IPP(2) .EQ. 0) RETURN	SUSPCT	147
	ISUS = 2	SUSPCT	148
	IF(IPP(2) .EQ. 0 .AND. IPP(7) .EQ. 1) RETURN	SUSPCT	149
	IF(IPP(3) .EQ. 1 .AND. IPP(4) .EQ. 0) RETURN	SUSPCT	150
	ISUS = 3	SUSPCT	151
	IF(IPP(5) .EQ. 0 .AND. IPP(4) .EQ. 1 .AND. IPP(6) .EQ. 1)	SUSPCT	152
1	RETURN	SUSPCT	153
	IF(IPP(4) .EQ. 0 .AND. IPP(6) .EQ. 0) RETURN	SUSPCT	154
	ISUS = 4	SUSPCT	155
	IF(IPP(6) .EQ. 0 .AND. IPP(7) .EQ. 1) RETURN	SUSPCT	156
	IF(IPP(7) .EQ. 1 .AND. IPP(9) .EQ. 0) RETURN	SUSPCT	157
	ISUS = 0	SUSPCT	158
	RETURN	SUSPCT	159
	END	SUSPCT	160

C	SUBROUTINE TABLE(OM1,OM2,V1,V2,NCH,NVP,THETK,OM,V,INMODE,NOPT)	TABLE	1
C	TABLE (SUBROUTINE)	TABLE	2
C	7/19/64 LAST CARD IN DECK IS	TABLE	3
C	----	TABLE	4
C	-----ABSTRACT	TABLE	5
C	TITLE - TABLE	TABLE	6
C	GENERATION OF SUSPICIONLESS TABLE OF NORMAL MODE DISPERSION	TABLE	7
C	FUNCTION SIGNS	TABLE	8
C		TABLE	9
C		TABLE	10
C	TABLE CALLS SUBROUTINE MPOUT TO CONSTRUCT THE MATRIX OF	TABLE	11
C	NORMAL MODE DISPERSION FUNCTION SIGNS INMODE (STORED IN	TABLE	12
C	VECTOR FORM COLUMN AFTER COLUMN) FOR REGION IN FREQUENCY	TABLE	13
C	PHASE VELOCITY PLANE (OM1.LE.OMEGA.LE.OM2.AND.V1.LE.VP.L	TABLE	14
C	.V2). SUBROUTINE SUSPCT IS CALLED TO EVALUATE THE SUSPI	TABLE	15
C	CTION INDEX ,ISUS, OF EACH INTERIOR ELEMENT IN THE MATRIX	TABLE	16
C	SCANNING FROM LEFT TO RIGHT, TOP TO BOTTOM. IF ISUS .NE.	TABLE	17
C	0 , INMODE IS ALTERED AS FOLLOWS.	TABLE	18
C	ISUS=1 ROW ADDED ABOVE SUSPICIOUS ELEMENT AND COLUMN	TABLE	19
C	ADDED TO ITS LEFT	TABLE	20
C	=2 COLUMN ADDED TO RIGHT OF SUSPICIOUS ELEMENT	TABLE	21
C	AND ROW ADDED ABOVE IT	TABLE	22
C	=3 ROW ADDED BELOW SUSPICIOUS ELEMENT AND COLUMN	TABLE	23
C	ADDED TO ITS RIGHT	TABLE	24
C	=4 COLUMN ADDED TO LEFT OF SUSPICIOUS ELEMENT	TABLE	25
C	AND ROW ADDED BELOW IT	TABLE	26
C	HOWEVER, NEITHER THE NUMBER OF ROWS NVP NOR THE NUMBER OF	TABLE	27
C	COLUMNS NOM WILL BE INCREASED BEYOND 100. IF ISUS CALLS	TABLE	28
C	FOR AN ADDITIONAL ROW WHEN NVP = 100 , THE MESSAGE	TABLE	29
C	(NVP = 100 N = XX M = XX) WILL BE PRINTED.	TABLE	30
C	N IS ROW NO. OF SUSPICIOUS ELEMENT. M IS COLUMN NO. IF	TABLE	31
C	ISUS CALLS FOR ADDITION OF A COLUMN WHEN NOM = 100, THE	TABLE	32
C	MESSAGE (NOM = 100 N = XX M = XX) IS PRINT	TABLE	33
C	WHEN INMODE HAS BEEN EXPANDED SCANNING IS RESUMED AT THE	TABLE	34
C	ELEMENT IN NEW MATRIX WITH SAME ROW AND COLUMN NOS. AS	TABLE	35
C	THOSE OF SUSPICIOUS ELEMENT IN OLD MATRIX. IF NOPT IS	TABLE	36
C	POSITIVE INMODE WILL BE PRINTED AS IT IS RETURNED FROM	TABLE	37
C	MPOUT AND IN ITS FINAL FORM.	TABLE	38
C		TABLE	39
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL - C28-6515-4)	TABLE	40
C		TABLE	41
C	AUTHOR - J.W.POSEY, M.I.T., JUNE,1968	TABLE	42
C		TABLE	43
C	----	TABLE	44
C	-----USAGE-----	TABLE	45
C		TABLE	46
C	SUBROUTINES MPOUT,SUSFCT,LNGTHN,WIDEN,NMODN ARE CALLED IN TABLE.	TABLE	47
C		TABLE	48
C	FORTRAN USAGE	TABLE	49
C	CALL TABLE(OM1,OM2,V1,V2,NCH,NVP,THETK,OM,V,INMODE,NOPT)	TABLE	50
C		TABLE	51
C	INFUTS	TABLE	52
C		TABLE	53
C	OM1 MINIMUM VALUE OF FREQUENCY TO BE CONSIDERED.	TABLE	54
C	R*4	TABLE	55
C	OM2 MAXIMUM VALUE OF FREQUENCY TO BE CONSIDERED	TABLE	56
C	R*4	TABLE	57
C	V1 MINIMUM VALUE OF PHASE VELOCITY TO BE CONSIDERED	TABLE	58
C	R*4	TABLE	59
C	V2 MAXIMUM VALUE OF PHASE VELOCITY TO BE CONSIDERED	TABLE	60

C	R*4		TABLE	61
C	NOM	INITIAL NO. OF FREQUENCIES TO BE CONSIDERED	TABLE	62
C	I*4		TABLE	63
C	NVP	INITIAL NO. OF PHASE VELOCITIES TO BE CONSIDERED	TABLE	64
C	I*4		TABLE	65
C	THETK	PHASE VELOCITY DIRECTION (RADIAN)	TABLE	66
C	R*4		TABLE	67
C	NOPT	PRINT OUT OPTICAL. IF NOPT = -1, NO PRINT. IF NOPT = 1,	TABLE	68
C	I*4	INMODE IS PRINTED IN ITS INITIAL FORM (GENERATED BY MPOU	TABLE	69
C		AND IN ITS FINAL FORM.	TABLE	70
C			TABLE	71
C	OUTPUTS		TABLE	72
C			TABLE	73
C	NOM	TOTAL NO. OF FREQUENCIES CONSIDERED	TABLE	74
C	I*4		TABLE	75
C	NVP	TOTAL NO. OF PHASE VELOCITIES CONSIDERED	TABLE	76
C	I*4		TABLE	77
C	OM	VECTOR WHOSE ELEMENTS ARE THE VALUES OF ANGULAR FREQUENCY	TABLE	78
C	R*4(10)	CORRESPONDING TO THE COLUMNS OF THE INMODE MATRIX	TABLE	79
C			TABLE	80
C	V	VECTOR WHOSE ELEMENTS ARE THE VALUES OF PHASE VELOCITY	TABLE	81
C	R*4(10)	CORRESPONDING TO THE ROWS OF THE INMODE MATRIX	TABLE	82
C			TABLE	83
C	INMODE	EACH ELEMENT OF THIS MATRIX CORRESPONDS TO A POINT IN THE	TABLE	84
C	I*4(10)	FREQUENCY (CM) - PHASE VELOCITY (V) PLANE. IF THE NORMAL	TABLE	85
C		MODE DISPERSION FUNCTION (FPP) IS POSITIVE AT THAT POINT	TABLE	86
C		THE ELEMENT IS +1, IF FPP IS NEGATIVE, THE ELEMENT IS -1	TABLE	87
C		IF FPP DOES NOT EXIST, THE ELEMENT IS 5. INMODE HAS NVP	TABLE	88
C		ROWS AND NOM COLUMNS. MATRIX IS STORED AS A VECTOR,	TABLE	89
C		COLUMN AFTER COLUMN.	TABLE	90
C			TABLE	91
C			TABLE	92
C		----EXAMPLE----	TABLE	93
C			TABLE	94
C	LET INMODE =	-1.5,5.5,1,-1,-1,-1,1,1,-1,-1,1,1,1	TABLE	95
C	WITH NOM =	NVP = 4	TABLE	96
C	AND OM =	1.0,1.5,2.0,2.5	TABLE	97
C		THETK = 3.14159	TABLE	98
C	V =	1.0,2.0,3.0,4.0	TABLE	99
C	(VALUES NOT CORRECT, FOR ILLUSTRATION ONLY)		TABLE	100
C	THEN THE TABLE WILL BE PRINTED AS FOLLOWS.		TABLE	101
C			TABLE	102
C	VPHASE	NORMAL MODE DISPERSION FUNCTION SIGN	TABLE	103
C	1.00000	-+++	TABLE	104
C	2.00000	X-++	TABLE	105
C	3.00000	X--+	TABLE	106
C	4.00000	X---	TABLE	107
C			TABLE	108
C	OMEGA 1234		TABLE	109
C		PHASE VELOCITY DIRECTION IS 90.0000DEGREES	TABLE	110
C			TABLE	111
C	OMEGA =		TABLE	112
C	0.10000E 01	0.15000E 01 0.20000E 01 0.25000E 01	TABLE	113
C			TABLE	114
C			TABLE	115
C		----PROGRAM FOLLOWS BELOW----	TABLE	116
C			TABLE	117
C			TABLE	118
C			TABLE	119
C		DIMENSION OM(100),V(100),INMODE(10000),JORN(100),KORN(100)	TABLE	120
C		COMMON IMAX,CI(100),VXI(100),VYI(100),MI(100)	TABLE	121
C			TABLE	122
C		MPOUT IS CALLED TO PRODUCE INMODE MATRIX AND OM AND V VECTORS.	TABLE	123
C		CALL MPOUT(OM1,OM2,V1,V2,NOM,NVP,INMODE,OM,V,THETK)	TABLE	124

C	IFLAG = 1 INDICATES FIRST TIME THROUGH WRITE PROCEDURE	TABLE	125
C	IFLAG = 1	TABLE	126
C		TABLE	127
C	INMODE IS PRINTED IF NOPT IS POSITIVE	TABLE	128
C	IF (NOPT.GE.0) GO TO 123	TABLE	129
C	5 IFLAG = 0	TABLE	130
C	NOPT=0	TABLE	131
C	NOPT IS THE NUMBER OF EXPANSION OPERATIONS PERFORMED IN THE PRESENT	TABLE	132
C	SCAN OF THE MATRIX. THUS, NOPT IS THE NUMBER OF SUSPICIOUS POINTS	TABLE	133
C	FOUND IN THE PRESENT SCAN.	TABLE	134
C		TABLE	135
C	BEGIN SCANNING OF INTERIOR ELEMENTS OF INMODE IN UPPER LEFT CORNER	TABLE	136
C	N = 2	TABLE	137
C	M = 2	TABLE	138
C	10 CALL SUSPCT(N,M,NVP,INMODE,ISUS)	TABLE	139
C		TABLE	140
C	POINT (N,M) IS SUSPICIOUS IF ISUS.NE.0	TABLE	141
C	IF(ISUS.NE.0) GO TO 60	TABLE	142
C		TABLE	143
C	CHECK FOR END OF ROW	TABLE	144
C	20 IF (M.LT.(NOM-1)) GO TO 30	TABLE	145
C		TABLE	146
C	CHECK FOR LAST ROW	TABLE	147
C	IF (M.LT.(NVP-1)) GO TO 40	TABLE	148
C	GO TO 121	TABLE	149
C		TABLE	150
C	MOVE ONE COLUMN TO RIGHT	TABLE	151
C	30 M = M+1	TABLE	152
C	GO TO 10	TABLE	153
C		TABLE	154
C	ADVANCE ONE ROW AND START AT COLUMN TWO	TABLE	155
C	40. N = N+1	TABLE	156
C	M = 2	TABLE	157
C	GO TO 10	TABLE	158
C		TABLE	159
C	CHECK FOR MAXIMUM VALUE OF NVP	TABLE	160
C	60 IF(NVP.LT.100) GO TO 62	TABLE	161
C	61 FORMAT (24H NVP = 100	TABLE	162
C	WRITE (6,61) N,M	TABLE	163
C	GO TO 20	TABLE	164
C	62 IF(NOM .LT. 100) GO TO 70	TABLE	165
C	63 FORMAT(24HNOM = 100	TABLE	166
C	64 WRITE(6,63) N,M	TABLE	167
C	GO TO 20	TABLE	168
C	70 IF(ISUS .NE. 1) GO TO 75	TABLE	169
C		TABLE	170
C	ADD ROW ABOVE SUSPICIOUS POINT	TABLE	171
C	N1=N-1	TABLE	172
C		TABLE	173
C	ADD A COLUMN TO LEFT OF SUSPICIOUS POINT	TABLE	174
C	M1=M-1	TABLE	175
C	GO TO 100	TABLE	176
C	75 IF(ISUS .NE. 2) GO TO 80	TABLE	177
C		TABLE	178
C	ADD A COLUMN TO RIGHT OF SUSPICIOUS POINT	TABLE	179
C	M1=M	TABLE	180
C		TABLE	181
C	ADD ROW ABOVE SUSPICIOUS POINT	TABLE	182
C	N1=N-1	TABLE	183
C	GO TO 100	TABLE	184
C	80 IF(ISUS .NE. 3) GO TO 85	TABLE	185
C		TABLE	186
C	ADD A COLUMN TO RIGHT OF SUSPICIOUS POINT	TABLE	187
C		TABLE	188

	M1=M	TABLE	189
C	ADD ROW BELOW SUSPICIOUS POINT	TABLE	190
	N1=N	TABLE	191
	GO TO 100	TABLE	192
C	ADD ROW BELOW SUSPICIOUS POINT	TABLE	193
	65 N1=N	TABLE	194
C	ADD A COLUMN TO LEFT OF SUSPICIOUS POINT	TABLE	195
	M1=M-1	TABLE	196
100	CONTINUE	TABLE	197
	CALL LGTHN(OM,V,INMODE,NOM,NVP,NVPP,N1,1,THETK)	TABLE	198
	CALL WIDEN(OM,V,INMODE,NOM,NOMP,NVPP,M1,1,THETK)	TABLE	199
	NVP=NVP	TABLE	200
	NOM=NOMP	TABLE	201
	NOPER=NOPER+1	TABLE	202
	GO TO 10	TABLE	203
121	CONTINUE	TABLE	204
	IF(NOPER.GT.0.AND.NVP.LT.100.AND.NOM.LT.100) GO TO 5	TABLE	205
C	DO NOT PRINT INMODE IF NOPT IS NEGATIVE	TABLE	206
	IF(NOPT.LT.0) RETURN	TABLE	207
C	LABELING	TABLE	208
122	FORMAT (6H1VPHSE,6X,36HNORMAL MODE DISPERSION FUNCTION SIGN/)	TABLE	209
123	WRITE (6,122)	TABLE	210
	DO 133 I=1,NVP	TABLE	211
	DO 128 J=1,NOM	TABLE	212
	J88=(J-1)*NVP+I	TABLE	213
	J89=INMODE(J88)-1	TABLE	214
	IF (J89) 126,125,124	TABLE	215
124	CONTINUE	TABLE	216
C	IF INMODE = 5, DORN = 1HX.	TABLE	217
	DATA Q1/1HX/	TABLE	218
	DORN(J) = Q1	TABLE	219
	GO TO 127	TABLE	220
125	CONTINUE	TABLE	221
C	IF INMODE = 1, DORN = 1H+	TABLE	222
	DATA Q2/1H+/	TABLE	223
	DORN(J) = Q2	TABLE	224
	GO TO 127	TABLE	225
126	CONTINUE	TABLE	226
C	IF INMODE = -1, DORN = 1H-	TABLE	227
	DATA Q3/1H-/	TABLE	228
	DORN(J) = Q3	TABLE	229
127	CONTINUE	TABLE	230
128	CONTINUE	TABLE	231
C	PRINT ROW I OF TABLE	TABLE	232
	WRITE (6,130)V(I),(DORN(J), J=1,NOM)	TABLE	233
130	FORMAT(1H,F8.5,3X,100A1)	TABLE	234
133	CONTINUE	TABLE	235
	J10 = 10	TABLE	236
	DO 150 J=1,NOM	TABLE	237
C	NUMBER COLUMNS	TABLE	238
150	KORN(J) = MOD(J,J10)	TABLE	239
	WRITE (6,213) (KORN(J), J=1,NOM)	TABLE	240
213	FORMAT (6H00MEGA,6X,100I1)	TABLE	241
C		TABLE	242
		TABLE	243
		TABLE	244
		TABLE	245
		TABLE	246
		TABLE	247
		TABLE	248
		TABLE	249
		TABLE	250
		TABLE	251
		TABLE	252

C CONVERT THETA FROM RADIANS TO DEGREES	TABLE	253
X = THETA*180/3.14159	TABLE	254
WRITE (6,413) X	TABLE	255
413 FORMAT (1H ,11X,27H PHASE VELOCITY DIRECTION IS.F9.3,	TABLE	256
1 8H DEGREES)	TABLE	257
WRITE (6,513)	TABLE	258
513 FORMAT (8H OMEGA =)	TABLE	259
C	TABLE	260
C LIST VALUES OF OMEGA WHICH CORRESPOND TO COLUMNS OF TABLE	TABLE	261
WRITE (6,613) (OM(I),I=1,NOM)	TABLE	262
613 FORMAT (1H ,5E14.5)	TABLE	263
C	TABLE	264
C IF SUSPICION ELIMINATION HAS NOT BEEN PERFORMED, BEGIN IT AT THIS TIME	TABLE	265
IF(IFLAG.EQ.1) GO TO 5	TABLE	266
RETURN	TABLE	267
END	TABLE	268

```
SUBROUTINE TADPRT(YIELC,MDFNO,KST,KFIN,OHMOG,VPHOO,
1AMPLTO,FHASQ)
TADPRT (SUBROUTINE)                                7/31/68    LAST C
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7/31/68 LAST CARD IN DECK IS

---ABSTRACT---

TITLE - TARPPT

PROGRAM TO PRINT CUT LISTS OF FREQUENCY, PHASE VELOCITY, AMPLITUDE, AND PHASE FOR EACH GUIDED MODE EXCITED BY A NUCLEAR EXPLOSION OF GIVEN YIELD. THE SIMULTANEOUS LISTING OF FREQUENCY AND PHASE VELOCITY REPRESENTS THE DISPERSION CURVE FOR THE GUIDED MODE. THE QUANTITIES AMPLTD AND PHASE DEPEND ON SOURCE AND OBSERVER HEIGHTS AS WELL AS THE MODEL ATMOSPHERE. HOWEVER THE LATTER INFORMATION IS NOT LISTED BY TABPRT AND IS PRESUMED TO BE LISTED BY ANOTHER SUBROUTINE. THE SUBROUTINE TABPRT SHOULD NOT BE CALLED UNTIL ALL THE QUANTITIES TO BE LISTED HAVE BEEN COMPUTED AND STORED IN THE MACHINE. NORMALLY, ATMOS, TABLE, ALLMCD, PAMPDE, AND PPAMP WOULD BE CALLED BEFORE TABPRT.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C24-6515-4)
AUTHORS - A.O. PIERCE AND J. POSEY, M.I.T., JULY, 1968

---CALLING SEQUENCE---

DIMENSION KST(1),KFIN(1),OMMCO(1),VPMOD(1),AMPLTD(1),PHASQ(1)
 THE SUBROUTINE USES VARIABLE DIMENSIONING. THE TRUE DIMENSIONS MUST
 BE GIVEN IN THE PROGRAM WHICH DEFINES THESE QUANTITIES. SEE THE
 DIMENSION STATEMENTS IN THE MAIN PROGRAM.
 CALL TABPRT(YIELD,MOFNC,KST,KFIN,OMMCO,VPMOD,AMPLTD,PHASQ)

NO EXTERNAL SUBROUTINES ARE REQUIRED

---ARGUMENT LIST---

YIELD	R*4	NO	INO
PDFNO	I*4	NO	INO
KST	I*4	VAR	INO
KFIN	I*4	VAR	INO
OMHOO	R*4	VAR	INO
VPHOO	R*4	VAR	INO
AMFLTO	R*4	VAR	INO
PHASO	R*4	VAR	INO

NO COMMON STORAGE USED

---INPUTS---

YIELD	=ENERGY YIELD OF EXPLOSION IN EQUIVALENT KILOTONS (KT OF TNT. 1 KT = $4.2 \times (10)^{19}$ ERGS.	TABPR1
NOFND	=NUMBER OF NORMAL MODES FOUND	TABPR2
KST(N)	=INDEX OF FIRST TABULATED POINT IN N-TH MODE	TABPR3
KFIN(N)	=INDEX OF LAST TABULATED POINT IN N-TH MODE. IN GENERAL, KFIN(N) = KST(N+1) - 1.	TABPR4
OMMOD(N)	=ARRAY STORING ANGULAR FREQUENCY ORDINATE (RAD/SEC) OF POINTS ON DISPERSION CURVES. THE NMODE MODE IS STORED FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).	TABPR5
VPHOD(N)	=ARRAY STORING PHASE VELOCITY ORDINATE (KM/SEC) OF POINTS ON DISPERSION CURVES. THE NMODE MODE IS STORED FOR N BETWEEN KST(NMODE) AND KFIN(NMODE).	TABPR6
AMPLTD(N)	=AMPLITUDE FACTOR REPRESENTING TOTAL MAGNITUDE OF FOURIER TRANSFORM OF THE CONTRIBUTION TO THE WAVEFORM FROM A SINGLE GUIDED MODE AT FREQUENCY CMOD(N). ITS UNITS SHOULD BE (DYNES/CM**2) * (KM**(1/2)) * SEC.	TABPR7

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C      IT REPRESENTS THE AMPLITUDE OF NMODE-TH MODE IF N IS TABPRT 65
C      BETWEEN KST(NMODE) AND KFIN(NMODE), INCLUSIVE. FOR TABPRT 66
C      PRECISE DEFINITION, SEE SUBROUTINE PPAMP. TABPRT 67
C      PHASQ(N) =PHASE LAG IN RADIANS AT FREQUENCY OMMCO(N) FOR THE TABPRT 68
C      NMODE-TH MODE WHEN N IS BETWEEN KST(NMODE) AND TABPRT 69
C      KFIN(NMODE), INCLUSIVE. THE INTEGRAND IS UNDERSTOOD TABPRT 70
C      TO HAVE THE FORM AMPLTO*COS(OMMOD*(TIME-DISTANCE/VPH TABPRT 71
C      +PHASQ). FOR A PRECISE DEFINITION, SEE SUBROUTINE TABPRT 72
C      PPAPP. TABPRT 73
C      TABPRT 74
C      TABPRT 75
C      TABPRT 76
C      PRINTOUT. THE ONLY FUNCTION OF TABPRT IS TO PRINT OUT RESULTS. TABPRT 77
C      TABPRT 78
C      TABPRT 79
C      TABPRT 80
C      TABPRT 81
C      THE OUTPUT FORMAT IS ILLUSTRATED BELOW. TABPRT 82
C      MODE TABULATION FOR Y= 100.00 KILOTONS TABPRT 83
C      TABPRT 84
C      TABPRT 85
C      TABPRT 86
C      MODE 1 TABPRT 87
C      TABPRT 88
C      OMEGA VPHSE AMPLTO PHASE TABPRT 89
C      .00100 0.33426 -7.01342E 20 -3.72139 TABPRT 90
C      .00200 0.24372 -8.02394E 20 -4.56028 TABPRT 91
C      TABPRT 92
C      TABPRT 93
C      TABPRT 94
C      TABPRT 95
C      MODE 2 TABPRT 96
C      TABPRT 97
C      OMEGA VPHSE AMPLTO PHASE TABPRT 98
C      .00100 0.55298 -7.95321E 10 -2.40799 TABPRT 99
C      .00200 0.48321 -1.23108E 11 -2.30524 TABPRT 100
C      TABPRT 101
C      TABPRT 102
C      ETC. TABPRT 103
C      TABPRT 104
C      TABPRT 105
C      TABPRT 106
C      TABPRT 107
C      TABPRT 108
C      TABPRT 109
C      TABPRT 110
C      TABPRT 111
C      11 FORMAT( 1H1 ,1H ,25X,22HMODE TABULATION FOR Y=F9.2,9H KILGTONS TABPRT 112
C      C START OF OUTER DO LOOP TABPRT 113
C      DO 50 II=1,MCFNC TABPRT 114
C      C TABPRT 115
C      C TABPRT 116
C      WRITE (6,21) II TABPRT 117
C      21 FORMAT(1H ///,1H ,4X, 5HMODE ,I3//, 1H ,9X,5HOMEGA,9X,5HVPHSE,9X, TABPRT 118
C      1 6HAMPLTO,8X,5HPHASE/ ) TABPRT 119
C      C TABPRT 120
C      K1=KST(II) TABPRT 121
C      K2=KFIN(II) TABPRT 122
C      C TABPRT 123
C      C START OF INNER DO LOOP TABPRT 124
C      DO 50 J=K1,K2 TABPRT 125
C      C TABPRT 126
C      50 WRITE (6,51) OMMCO(J),VPHOD(J),AMPLTO(J),PHASQ(J) TABPRT 127
C      51 FORMAT( 1H ,4X,F14.5,F14.5,1PG14.5,0PF14.5) TABPRT 128
C      C END OF LOOPS TABPRT 129
C      C TABPRT 130
C      RETURN TABPRT 131
C      ENO TABPRT 132

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	SUBROUTINE TMPT(TFIRST,TEND,DELTT,ROBS,	TMPT	1
	1MOFND,KST,KFIN,CMMD,VPMO,AKIS,AMPLD,PHASQ,IOPT)	TMPT	2
	TMPT (SUBROUTINE) 7/19/68	TMPT	3
C		TMPT	4
C		TMPT	5
C	-----ABSTRACT-----	TMPT	6
C		TMPT	7
C	TITLE - TMPT	TMPT	8
C	CALCULATION AND PLOTTING OF FAR-FIELD TRANSIENT RESPONSE TO A	TMPT	9
C	PRESSURE SOURCE IN THE ATMOSPHERE	TMPT	10
C		TMPT	11
C	THE RESPONSE OF MODE N IS FOUND BY INTEGRATING (AMPLD * COS(OMEGA * (T - R/VP) + PHASQ) OVER OMEGA FROM OMMD	TMPT	12
C	(KST(N)) TO CMMD(KFIN(N)) AND DIVIDING BY SQR(R). VP,	TMPT	13
C	PHASQ, AND AMPLD ARE FUNCTIONS OF BOTH N AND OMEGA. TH	TMPT	14
C	TOTAL RESPONSE IS THE SUM OF THE MODAL RESPONSES. THE	TMPT	15
C	RESPONSE IS CALCULATED FOR TIME TFIRST AND AT INTERVALS	TMPT	16
C	OF DELTT THEREAFTER UNTIL TEND IS REACHED. THE VALUE OF	TMPT	17
C	IOPT DETERMINES WHAT WILL BE CALCULATED, PRINTED AND	TMPT	18
C	PLOTTED. (SEE INPUT LIST FOR POSSIBLE IOPT VALUES.) THE	TMPT	19
C	RESULTS ARE TABULATED IN THE PRINTOUT AND GRAPHED BY THE	TMPT	20
C	CALCOMP PLOTTER.	TMPT	21
C		TMPT	22
C	THE CURRENT VERSION OF THIS SUBROUTINE DIFFERS FROM THAT	TMPT	23
C	REPORTED IN AFRL-70-0134 IN THAT THE RESULTING THEORETI	TMPT	24
C	CAL PRESSURE PERTURBATIONS INCLUDE THE EARTH CURVATURE	TMPT	25
C	CORRECTION FACTOR, (ROBS / (RE * SIN(ROBS/RE)))**0.5	TMPT	26
C		TMPT	27
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C24-6515-4)	TMPT	28
C	AUTHOR - J.W. POSEY, M.I.T., JUNE, 1968	TMPT	29
C		TMPT	30
C		TMPT	31
C	-----USAGE-----	TMPT	32
C		TMPT	33
C	FORTRAN SUBROUTINE AKI IS CALLED	TMPT	34
C		TMPT	35
C	CALCOMP PLOTTER SUBROUTINES PLOT1, AXIS1, NUMB1, SYMPL, AND	TMPT	36
C	SCLGPH ARE CALLED TO WRITE THE CALCOMP TAPE. SUBROUTINE NEWFLY	TMPT	37
C	MUST HAVE BEEN CALLED PRIOR TO CALLING TMPT, AND ENOFLT MUST BE	TMPT	38
C	CALLED AFTER RETURNING FROM TMPT. (SEE MAIN PROGRAM)	TMPT	39
C		TMPT	40
C	FORTRAN USAGE	TMPT	41
C	CALL TMPT(TFIRST,TEND,DELTT,ROBS,MOFND,KST,KFIN,CMMD,VPMO,AMPLD	TMPT	42
C	1,PHASQ,IOPT)	TMPT	43
C		TMPT	44
C	INPUTS	TMPT	45
C		TMPT	46
C	TFIRST TIME AT WHICH TABULATION AND PLOTTING OF RESPONSE IS TO	TMPT	47
C	R*4 BEGIN (SEC)	TMPT	48
C		TMPT	49
C	TEND TIME AT WHICH TABULATION AND PLOTTING OF RESPONSE IS TO	TMPT	50
C	R*4 END (I.E. (TFIRST+5400.)) (SEC)	TMPT	51
C		TMPT	52
C	DELTT TIME INTERVAL BETWEEN SUCCESSIVE CALCULATIONS OF THE	TMPT	53
C	R*4 RESPONSE (I.E. ((TEND-TFIRST)/1000)) (SEC)	TMPT	54
C		TMPT	55
C	ROBS DISTANCE OF THE OBSERVER FROM THE SOURCE OF THE DISTUR-	TMPT	56
C	R*4 BANCE (KM)	TMPT	57
C		TMPT	58
C	MOFND NUMBER OF MODES FOUND (I.E. 10)	TMPT	59
C	I*4	TMPT	60
C		TMPT	61
C	KST ELEMENT N OF THIS VECTOR IS NUMBER OF OMMD ELEMENT WHICH	TMPT	62
C	I*4(D) IS FIRST FREQUENCY CONSIDERED FOR MODE N	TMPT	63
C		TMPT	64

C			TMPT	65
C	KFIN	ELEMENT N OF THIS VECTOR IS NUMBER OF OHMOD ELEMENT WHICH	TMPT	66
C	I*4(10)	IS LAST FREQUENCY CONSIDERED FOR MODE N	TMPT	67
C			TMPT	68
C	OHMOD	ELEMENTS OF THIS VECTOR NUMBERED KST(N) THROUGH KFIN(N)	TMPT	69
C	R*4(10)	ARE THE VALUES OF FREQUENCY (IN INCREASING ORDER) FOR	TMPT	70
C		WHICH THE CORRESPONDING MODE N PHASE VELOCITIES HAVE BEEN	TMPT	71
C		DETERMINED	TMPT	72
C			TMPT	73
C	VPHOD	VECTOR OF PHASE VELOCITIES WHICH CORRESPOND TO THE FRE-	TMPT	74
C	R*4(10)	QUENCIES OF VECTOR OHMOD	TMPT	75
C			TMPT	76
C	AMPLTD	VALUES OF AMPLITUDE FUNCTION IN AKI INTEGRAL (ELEMENTS	TMPT	77
C	R*4(10)	CORRESPOND DIRECTLY TO ELEMENTS OF OHMOD) (DYNES/CM**2)	TMPT	78
C			TMPT	79
C	PHASQ	TERM IN ARGUMENT OF COS IN AKI INTEGRAL WHICH IS INDEPENDENT	TMPT	80
C	R*4(10)	OF TIME AND DISTANCE (ROGS)	TMPT	81
C			TMPT	82
C	IOPT	COMPUTATION AND PRINT OPTION INDICATOR	TMPT	83
C	I*4	= 1,2,....,10 CALCULATE, PRINT AND PLOT MODE NO. IOPT ON	TMPT	84
C		= 11 CALCULATE, PRINT AND PLOT ALL MODES AS WELL AS THE	TMPT	85
C		TOTAL RESPONSE	TMPT	86
C		= 12 CALCULATE ALL MODES, PRINT AND PLOT TOTAL RESPONSE	TMPT	87
C		ONLY	TMPT	88
C			TMPT	89
C	OUTPUTS		TMPT	90
C			TMPT	91
C		THE ONLY OUTPUTS ARE THE PRINTOUTS AND PLOTS CALLED FOR BY IOPT.	TMPT	92
C		ALL GRAPHS ARE DRAWN TO THE SAME SCALE. THE PRESSURE SCALE IS	TMPT	93
C		DETERMINED BY THE MAXIMUM AMPLITUDE OF THE TOTAL PRESSURE, AND THE	TMPT	94
C		TIME SCALE IS 600 SEC PER INCH. PRESSURE IS EXPRESSED IN DYNES/CM	TMPT	95
C			TMPT	96
C			TMPT	97
C		-----PROGRAM FOLLOWS BELOW-----	TMPT	98
C			TMPT	99
C			TMPT	100
C			TMPT	101
C			TMPT	102
C		DIMENSION KST(10),KFIN(10),OHMOD(1000),VPHOD(1000),AMPLTD(1000),	TMPT	103
C		1 PHASQ(1000),T(1001),TCTINT(1001),TNINT(10,1001),Y(1001)	TMPT	104
C		DIMENSION CKI(1000)	TMPT	105
C		DIMENSION AXIS(1000)	TMPT	106
C			TMPT	107
C	YAX	IS VECTOR OF LITERAL CONSTANTS. ELEMENT N IS THE EIGHT SPACE LAB	TMPT	108
C	FOR	THE PRESSURE AXIS ON THE GRAPH OF THE MODE N RESPONSE.	TMPT	109
C		DOUBLE PRECISION YAX(10)	TMPT	110
C		DATA YAX/8H MODE 1 ,8H MODE 2 ,8H MODE 3 ,8H MODE 4 ,8H MODE 5 ,	TMPT	111
C		1 8H MODE 6 ,8H MODE 7 ,8H MODE 8 ,8H MODE 9 ,8H MODE 10/	TMPT	112
C		IF(IOPT.NE. 11) GO TO 4	TMPT	113
C		WRITE (6,2)	TMPT	114
C		2 FORMAT (1H1, 40X,23HTABULATION OF RESPONSES//)	TMPT	115
C		WRITE (6,3)	TMPT	116
C		3 FORMAT (1H ,20X,4HTIME,12X,5HTOTAL,11X,6HMODE 1,10X,6HMODE 2,10X,	TMPT	117
C		1 6HMODE 3,10X,6HMODE 4,10X,6HMODE 5//)	TMPT	118
C		4 IF(IOPT.EQ.12) WRITE(6,753)	TMPT	119
C		753 FORMAT (1H1,45X,40HTABULATION OF ACOUSTIC PRESSURE RESPONSE///1H	TMPT	120
C		1 44X,10HTIME (SEC),9X,15HP (DYNES/CM**2)///)	TMPT	121
C			TMPT	122
C	L	IS NUMBER OF TIMES AT WHICH RESPONSE IS TO BE CALCULATED	TMPT	123
C		L = (TEND - TFIRST) / DELTT + 1	TMPT	124
C		L=MIN0(L,999)	TMPT	125
C			TMPT	126
C	SIZE	IS THE LENGTH OF THE TIME AXIS IN INCHES	TMPT	127
C		SIZE = (TEND - TFIRST) / 600.0	TMPT	128

C		THPT	129
C	PRESET ALL RESPONSE VALUES TO 0.0	THPT	130
	5 DO 7, K=1, L	THPT	131
	TOTINT(K) = 0.0	THPT	132
	DO 7 N=1, 10	THPT	133
	7 TNINT(N, K) = 0.0	THPT	134
C		THPT	135
C	SET UP TABLE OF TIMES BEGINNING AT TFIRST AND TAKING VALUES OF TIME A	THPT	136
C	INTERVALS OF DELTT UNTIL TEND IS REACHED	THPT	137
	9 DO 10 IT=1, L	THPT	138
	10 Y(IT) = TFIRST + (IT-1)*DELTT	THPT	139
C		THPT	140
C	BEGIN SET UP TO CALCULATE MODE 1 RESPONSE	THPT	141
	N = 1	THPT	142
C		THPT	143
C	IF IOPT.LE.10 CALCULATE ONLY MODE IOPT RESPONSE	THPT	144
	IF (IOPT.LE.10) N = IOPT	THPT	145
	11 NOST = KST(N) + 1	THPT	146
	NOFN = KFIN(N)	THPT	147
C		THPT	148
C	DETERMINE THE EARTH CURVATURE CORRECTION FACTOR TIMES ROBS*(-0.5).	THPT	149
	RAD = ROBS / 6374.	THPT	150
	CF = (1./(6374.*ABS(SIN(RAD))))*.5	THPT	151
C		THPT	152
C	THE MODE N RESPONSE IS FOUND FOR ALL VALUES OF T BEFORE NEXT MODE IS	THPT	153
C	CONSIDERED	THPT	154
	DO 51 IT=1, L	THPT	155
C		THPT	156
C	SET A2, PH2 EQUAL TO VALUES FOR A1, PH1 IN FIRST INTEGRATION INTERVAL	THPT	157
	J26 = KST(N)	THPT	158
	A2 = APPLTD(J26)	THPT	159
	A2 = A2*EXP(-AKIS(J26)*ROBS)	THPT	160
	NHWR = RAD/3.1415926535	THPT	161
	PHASQ(J26) = PHASQ(J26) + NHWR*(3.1415926535/2.0)	THPT	162
	S2=OMMCD(J26)/VPMOD(J26)-PHASQ(J26)/ROBS	THPT	163
	SLOW=T(IT)/ROBS	THPT	164
	OIOOLE=SLOW-1.0/VPMOD(J26)	THPT	165
	PH2=ROBS*(OMMCD(J26)*CICCLE+PHASQ(J26)/ROBS)	THPT	166
	PHASQ(J26) = PHASQ(J26) - NHWR*(3.1415926535/2.0)	THPT	167
	CTRIG2=COS(PH2)	THPT	168
	STRIG2=SIN(PH2)	THPT	169
C		THPT	170
C	THE INTEGRAL OF (APPLTD * COS(OMEGA * (T - ROBS/V) + PHASQ)) OVER TH	THPT	171
C	INTERVAL FROM OMMCD(KST(N)) TO OMMCD(KFIN(N)) IS FOUND BY SUMMING THE	THPT	172
C	INTEGRALS FROM OMMCD(NOM-1) TO OMMCD(NOM) FOR NOM FROM KST(N)+1 TO	THPT	173
C	KFIN(N)	THPT	174
	DO 50 NOM = NOST, NOFN	THPT	175
	A1 = A2	THPT	176
	PH1 = PH2	THPT	177
	CTRIG1=CTRIG2	THPT	178
	STRIG1=STRIG2	THPT	179
	S1=S2	THPT	180
	A2 = APPLTD(NOM)*EXP(-AKIS(NOM)*ROBS)	THPT	181
	NHWR = RAD/3.1415926535	THPT	182
	PHASQ(NOM) = PHASQ(NOM) + NHWR*(3.1415926535/2.0)	THPT	183
	S2=OMMCD(NOM)/VPMOD(NOM)-PHASQ(NOM)/ROBS	THPT	184
	OIOOLE=SLOW-1.0/VPMOD(NOM)	THPT	185
	PH2=ROBS*(OMMCD(NOM)*CICCLE+PHASQ(NOM)/ROBS)	THPT	186
	PHASQ(NOM) = PHASQ(NOM) - NHWR*(3.1415926535/2.0)	THPT	187
	OMEG1=OMMOD(NOM-1)	THPT	188
	OMEG2=OMMOD(NOM)	THPT	189
	DELPH = FOTS * (SLOW * (OMEG2 - OMEG1) - (S2 - S1))	THPT	190
	CALL AKI(OMEG1, OMEG2, A1, A2, CTRIG1, STRIG1, CTRIG2, STRIG2,	THPT	191
	1 DELPH, AKIINT)	THPT	192

50 TNINT(N,IT) = TNINT(N,IT) + AKIINT	THPT	193
C PRESSURE IS EQUAL TO CF * (VALUE OF OMEGA INTEGRAL)	THPT	194
51 TNINT(N,IT) = CF * TNINT(N,IT)	THPT	195
C	THPT	196
C IF IOPT.LE.10 ALL THAT IS REQUESTED IS THE MODE IOPT RESPONSE, WHICH	THPT	197
C HAS JUST BEEN CALCULATED	THPT	198
IF (IOPT.LE.10) GO TO 101	THPT	199
C	THPT	200
C INCREASE MODE NUMBER BY ONE	THPT	201
N = N + 1	THPT	202
C	THPT	203
C IF N IS GREATER THAN MODFN, ALL MODAL RESPONSES HAVE BEEN DETERMINED	THPT	204
IF (N.LE.MODFN) GO TO 11	THPT	205
C	THPT	206
C FOR EACH TIME IN T SET TOTAL PRESSURE EQUAL TO SUM OF MODAL PRESURES	THPT	207
DO 60 IT=1,L	THPT	208
DO 53 N = 1,MODFN	THPT	209
53 TOTINT(IT) = TOTINT(IT) + TNINT(N,IT)	THPT	210
IF (IOPT.EQ. 11) GO TO 55	THPT	211
C	THPT	212
C WRITE TIME AND CORRESPONDING TOTAL ACOUSTIC RESPONSE (DYNES/CM**2)	THPT	213
WRITE (6,54) T(IT),TOTINT(IT)	THPT	214
54 FORMAT (1H ,49X,F9.1,10X,F12.2)	THPT	215
C	THPT	216
C WHEN IOPT.EQ.12 ONLY TOTAL RESPONSE IS PRINTED	THPT	217
IF (IOPT.EQ.12) GO TO 59	THPT	218
C	THPT	219
C WHEN IOPT.EQ.11 ALL MODAL RESPONSES ARE ALSO PRINTED	THPT	220
55 NM = MIN0(MODFN,5)	THPT	221
WRITE (6,57) IT,T(IT),TOTINT(IT),(TNINT(N,IT),N=1,NM)	THPT	222
57 FORMAT (1H ,7X,I4,10X,F9.1,5X,F12.4,4X,F12.4,4X,F12.4,4X,F12.4,	THPT	223
1 4X,F12.4,4X,F12.4)	THPT	224
59 CONTINUE	THPT	225
60 CONTINUE	THPT	226
IF (MODFN .LE. 5 .OR. IOPT .NE. 11) GO TO 65	THPT	227
WRITE (6,61)	THPT	228
61 FORMAT (1H0,20X,4HTIME,12X,5HTOTAL,11X,6HMODE 6,10X,6HMODE 7,10X,	THPT	229
1 6HMODE 8,10X,6HMODE 9,10X,7HMODE 10/)	THPT	230
DO 63 IT=1,L	THPT	231
63 WRITE (6,57) IT,T(IT),TOTINT(IT),(TNINT(N,IT),N=5,MODFN)	THPT	232
C	THPT	233
65 CONTINUE	THPT	234
66 CALL PLOT(2...3,-3)	THPT	235
C SIZE IS THE NUMBER OF SECONDS PER INCH IN THE PLOT	THPT	236
SIZE = (T(L)-T(1))/600.	THPT	237
IF (IOPT.LE.10) GO TO 107	THPT	238
CALL SCALE(TOTINT,3.0,L,1)	THPT	239
C AFTER SCALE RETURNS, TOTINT(L+1) IS THE MINIMUM VALUE OF THE	THPT	240
C FIRST L VALUES.	THPT	241
C TOTINT(L+2) IS (MAX-MIN)/3.0 OF THE FIRST L VALUES OF TOTINT	THPT	242
C UMIN IS MAX-MIN OF TOTINT	THPT	243
UMIN=TOTINT(L+2)*3.0	THPT	244
UMIN = AINT(UMIN/25) * 25.0	THPT	245
UMIN=AMAX1(UMIN,25.)	THPT	246
C AT THIS POINT DY IS THE TOTAL RANGE IN TOTINT MOD25	THPT	247
DY = ABS(UMIN)	THPT	248
TOTINT(L+2)=DY/3.0	THPT	249
DY=DY/3.0	THPT	250
C	THPT	251
C IF IOPT.EQ.12 PLOT ONLY THE TOTAL ACCUSTIC RESPONSE	THPT	252
IF (IOPT.EQ.12) GO TO 70	THPT	253
C	THPT	254
C DRAW PRESSURE AXIS	THPT	255
	THPT	256

CALL PLOT(0.,0.,3)	THPT	257
ABC = MOFNO	THPT	258
CALL PLOT(ABC,0.,2)	THPT	259
DO 69 N=1,MOFNO	THPT	260
DO 67 J=1,L	THPT	261
67 Y(J) = -1 * TNINT(N,J)	THPT	262
68 CALL PLOT(1.,0.,-3)	THPT	263
C	THPT	264
C PLOT ACOUSTIC RESPONSE (DYNES/CM**2) OF MODE N VERSUS TIME (SEC)	THPT	265
Y(L+1)=0.0	THPT	266
Y(L+2)=TOTINT(L+2)	THPT	267
T(L+1)=T(1)	THPT	268
T(L+2)=600.	THPT	269
69 CALL LINE(Y,T,L,1,0,0)	THPT	270
C	THPT	271
70 DO 73 J=1,L	THPT	272
73 Y(J) = (-1) * TOTINT(J)	THPT	273
C	THPT	274
C DRAW PRESSURE AXIS	THPT	275
75 CALL PLOT(0.,0.,3)	THPT	276
CALL PLOT(3.,0.,2)	THPT	277
CALL PLOT(2.5,0.,-3)	THPT	278
CALL NUMBER(9.,-.15,.15,OY,180.,0)	THPT	279
CALL SYMBOL(.4.,-.15,.15,"MICROBARS PER INCH",180.,18)	THPT	280
CALL AXIS(1.5,0.," ",1,SIZE,90.,T(1),600.)	THPT	281
CALL SYMBOL(1.8,2.,.15,"TIME (SEC)",90.,10)	THPT	282
Y(L+1)=0.0	THPT	283
Y(L+2)=TOTINT(L+2)	THPT	284
T(L+1)=T(1)	THPT	285
T(L+2)=600.	THPT	286
CALL LINE(Y,T,L,1,0,0)	THPT	287
CALL PLOT(3.,-.3,-3)	THPT	288
GO TO 200.	THPT	289
C	THPT	290
C PRINT HISTORY OF MODE IOPT ONLY	THPT	291
101 WRITE (6,102) IOPT	THPT	292
102 FORMAT (1H1,45X,19HTABULATION OF MODE ,I2, 9H RESPONSE///1H ,48X,	THPT	293
1 IOPTIME (SEC),9X,15HF (DYNES/CM**2)///)	THPT	294
DO 103 IT=1,L	THPT	295
103 WRITE (6,104) T(IT),TNINT(IOPT,IT)	THPT	296
104 FORMAT (1H ,49X,F9.1,10X,F12.4)	THPT	297
GO TO 66	THPT	298
C	THPT	299
C IF IOPT.LT.11 PLOT ONLY ACOUSTIC RESPONSE OF MODE IOPT	THPT	300
107 DO 108 J=1,L	THPT	301
108 Y(J)=(-1)*TNINT(IOPT,J)	THPT	302
C	THPT	303
C DETERMINE SCALE FOR PRESSURE AXIS WHEN IOPT.LT.11	THPT	304
111 CALL SCALE(Y,2,C,L,1)	THPT	305
UMIN=Y(L+2)*2.0	THPT	306
UMIN=AMIN(UMIN/25)+25.0	THPT	307
UMIN=AMAX1(UMIN,25.)	THPT	308
OY=ABS(UMIN)	THPT	309
Y(L+2)=OY/2.0	THPT	310
OY=OY/2.0	THPT	311
GO TO 75	THPT	312
C	THPT	313
200 RETURN	THPT	314
END	THPT	315

SUBROUTINE TCTI(OMEGA,AKX,AKY,IT,L,XINT,PHI1,PHI2)	1
SUSPCT (SUBROUTINE)	2
7/19/68 LAST CARD IN DECK IS	3
-----ABSTRACT-----	4
TITLE - SUSPCT	5
EVALUATION OF SUSPICION INDEX OF ELEMENT (N,M) OF MATRIX INMODE	6
SUSPCT EVALUATES THE SUSPICION INDEX, ISUS, OF THE ELEMENT	7
IN ROW N, COLUMN M OF THE MATRIX INMODE ((N,M) MUST BE	8
AN INTERIOR ELEMENT). THE NEIGHBORS OF (N,M) ARE DEFINED	9
TO BE THE EIGHT ELEMENTS WHICH FORM THE THREE BY THREE	10
ELEMENT SQUARE WHICH HAS (N,M) AT ITS CENTER. THEY ARE	11
NUMBERED FROM ONE TO NINE BEGINNING IN THE UPPER LEFT AND	12
PROCEEDING CLOCKWISE (NO. 1 AND NO. 9 ARE SAME ELEMENT).	13
EACH ELEMENT OF MATRIX INMODE MUST HAVE ONE OF THREE	14
VALUES, -1, 1, OR 5. (N,M) IS NOT SUSPICIOUS AND ISUS =	15
0 IF ANY ONE OF THE FOLLOWING CONDITIONS HOLDS.	16
1. ELEMENT (N,M) = 5	17
2. ANY OF ITS NEIGHBORS = 5	18
3. NOWHERE IN THE 3X3 ARRAY OF (N,M) AND ITS NEIGH	19
BORS DOES THERE APPEAR TO BE A DISPERSION CURVE	20
WITH POSITIVE SLOPE	21
OTHERWISE ISUS IS SET EQUAL TO THE NUMBER OF THE QUADRANT	22
IN WHICH THE POSITIVE SLOPE APPEARS. THE QUADRANTS ARE	23
NUMBERED BEGINNING IN THE UPPER LEFT AND PROCEEDING CLOCK	24
WISE.	25
LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)	26
AUTHORS - A.D. PIERCE AND J. POSEY, M.I.T., JUNE, 1968	27
-----USAGE-----	28
NO FORTRAN SUBROUTINES ARE CALLED	29
FORTRAN USAGE	30
CALL SUSPCT(N,M,NROW,INMODE,ISUS)	31
INPUTS	32
N ROW NUMBER OF ELEMENT UNDER CONSIDERATION (MAY NOT BE	33
I*4 FIRST OR LAST ROW)	34
M COLUMN NUMBER OF ELEMENT UNDER CONSIDERATION (MAY NOT BE	35
I*4 FIRST OR LAST COLUMN)	36
NROW TOTAL NUMBER OF ROWS IN INMODE	37
I*4	38
INMODE MATRIX UNDER CONSIDERATION STORED IN VECTOR FORM, COLUMN	39
I*4(1) AFTER COLUMN. EACH ELEMENT MUST BE -1, 1, OR 5.	40
OUTPUTS	41
ISUS SUSPICION INDEX OF ELEMENT (N,M). SEE ABSTRACT ABOVE FOR	42
I*4 DEFINITION.	43
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C	CALLING PROGRAM	TOTINT	65
C		TOTINT	66
C	DIMENSION INHODE(9)	TOTINT	67
C	INHODE = -1, -1, 1, 1, -1, 1, 1, 1, -1	TOTINT	68
C	CALL SUSPCT(2,2,3,INHODE,ISUS)	TOTINT	69
C	WRITE (6,200) ISUS	TOTINT	70
C	200 FORMAT (10H EXAMPLE 1,EX, 6HISUS =,I2)	TOTINT	71
C	INHODE = -1, -1, 1, 1, -1, -1, 1, 1, 1	TOTINT	72
C	CALL SUSPCT(2,2,3,INHODE,ISUS)	TOTINT	73
C	WRITE (6,300) ISUS	TOTINT	74
C	300 FORMAT (10H EXAMPLE 2,EX, 6HISUS =,I2)	TOTINT	75
C	END	TOTINT	76
C		TOTINT	77
C	TMPT (SUBROUTINE)	TOTINT	78
C		TOTINT	79
C		TOTINT	80
C	-----ABSTRACT-----	TOTINT	81
C		TOTINT	82
C	TITLE - TMPT	TOTINT	83
C	CALCULATION AND PLOTTING OF FAR-FIELD TRANSIENT RESPONSE TO A	TOTINT	84
C	PRESSURE SOURCE IN THE ATMOSPHERE	TOTINT	85
C		TOTINT	86
C	THE RESPONSE OF MODE N IS FOUND BY INTEGRATING (AMPLTD * COS(OMEGA * (T - P/VF) + PHASQ) OVER OMEGA FROM OMPD0	TOTINT	87
C	(KST(N)) TO OMOD(KFIN(N)) AND DIVIDING BY SORT(R), VP,	TOTINT	88
C	PHASQ, AND AMPLTD ARE FUNCTIONS OF BOTH N AND OMEGA. TH	TOTINT	89
C	TOTAL RESPONSE IS THE SUM OF THE MODAL RESPONSES. THE	TOTINT	90
C	RESPONSE IS CALCULATED FOR TIME TFIRST AND AT INTERVALS	TOTINT	91
C	OF DELT THEREAFTER UNTIL TEND IS REACHED. THE VALUE OF	TOTINT	92
C	IOPT DETERMINES WHAT WILL BE CALCULATED, PLOTTED AND	TOTINT	93
C	PLOTTED. (SEE INPUT LIST FOR POSSIBLE IOPT VALUES.) THE	TOTINT	94
C	RESULTS ARE TABULATED IN THE PRINTOUT AND GRAPHED BY THE	TOTINT	95
C	CALCOMP PLOTTER.	TOTINT	96
C		TOTINT	97
C		TOTINT	98
C	THE CURRENT VERSION OF THIS SUBROUTINE DIFFERS FROM THAT	TOTINT	99
C	REPORTED IN AFCL-70-0134 IN THAT THE RESULTING THEORETI	TOTINT	100
C	CAL PRESSURE PERTURBATIONS INCLUDE THE EARTH CURVATURE	TOTINT	101
C	CORRECTION FACTOR. (ROBS / (RE * SIN(ROBS/RE))) **0.5	TOTINT	102
C		TOTINT	103
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C23-6515-4)	TOTINT	104
C	AUTHOR - J.W.POSEY, M.I.T., JUNE, 1969	TOTINT	105
C		TOTINT	106
C		TOTINT	107
C	-----USAGE-----	TOTINT	108
C		TOTINT	109
C	FORTRAN SUBROUTINE AKI IS CALLED	TOTINT	110
C		TOTINT	111
C	CALCOMP PLOTTER SUBROUTINES PLOT1, AXIS1, NUMB1, SYMB1, AND	TOTINT	112
C	SCLGPH ARE CALLED TO WRITE THE CALCOMP TAPE. SUBROUTINE NEWFLT	TOTINT	113
C	MUST HAVE BEEN CALLED PRIOR TO CALLING TMPT, AND ENDFLT MUST BE	TOTINT	114
C	CALLED AFTER RETURNING FROM TMPT. (SEE MAIN PROGRAM)	TOTINT	115
C		TOTINT	116
C	FORTRAN USAGE	TOTINT	117
C	CALL TMPT(TFIRST,TEND,DELTT,ROBS,MOFNO,KST,KFIN,CHMCC,VPHOC,AMPLT	TOTINT	118
C	1,PHASQ,IOPT)	TOTINT	119
C		TOTINT	120
C	INPUTS	TOTINT	121
C		TOTINT	122
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C	R*4 BEGIN (SEC)	TOTINT	124
C		TOTINT	125
C	TEND TIME AT WHICH TABULATION AND PLOTTING OF RESPONSE IS TO	TOTINT	126
C	TOTINT (SUBROUTINE)	TOTINT	127
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C	-----ABSTRACT-----	TOTINT	129
C		TOTINT	130
C	TITLE - TOTINT	TOTINT	131
C	THIS SUBROUTINE COMPUTES THE TOTAL INTEGRAL	TOTINT	132
C		TOTINT	133
C	XINT = INTEGRAL OVER Z FROM 0 TO INFINITY OF	TOTINT	134
C		TOTINT	135
C	A3(Z)*(A1(Z)*F1(Z) + A2(Z)*F2(Z))**2	(1 TOTINT	136
C		TOTINT	137
C	THE ATMOSPHERE IS ASSUMED TO BE REPRESENTED IN A MULTILAYER FO	TOTINT	138
C	WITH A1,A2, AND A3 CONSTANT IN EACH LAYER. THE INTEGRAL IS	TOTINT	139
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C	THE FUNCTIONS F1(Z) AND F2(Z) ARE CONTINUOUS ACROSS LAYER	TOTINT	142
C	BOUNDARIES AND SATISFY THE RESIDUAL EQUATIONS	TOTINT	143
C		TOTINT	144
C	OF1(Z)/DZ = A(1,1)*F1(Z) + A(1,2)*F2(Z)	(2 TOTINT	145
C	OF2(Z)/DZ = A(2,1)*F1(Z) + A(2,2)*F2(Z)	(2 TOTINT	146
C		TOTINT	147
C	WHERE THE ELEMENTS OF THE MATRIX A (COMPUTED BY SUBROUTINE AAA	TOTINT	148
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C		TOTINT	150
C	THE FUNCTIONS F1(Z) AND F2(Z) ARE ASSUMED TO SATISFY THE UPPER	TOTINT	151
C	BOUNDARY CONDITION THAT BOTH DECREASE EXPONENTIALLY WITH	TOTINT	152
C	INCREASING HEIGHT IN THE UPPER HALFSpace. THE NORMALIZATION	TOTINT	153
C	OF THE FUNCTIONS IS SUCH THAT AT THE LOWER BOUNDARY Z0 OF THE	TOTINT	154
C	UPPER HALFSpace	TOTINT	155
C		TOTINT	156
C	F1(Z0) = -SQRT(G)*A(1,2)	(3 TOTINT	157
C	F2(Z0) = SQRT(G)*(G+A(1,1))	(3 TOTINT	158
C		TOTINT	159
C	WITH	TOTINT	160
C		TOTINT	161
C	G = SQRT(A(1,1)**2 + A(1,2)*A(2,1))	(4 TOTINT	162
C		TOTINT	163
C	THE ELEMENTS A(I,J) IN EONS. (3) AND (4) ARE THOSE APPROPRIATE	TOTINT	164
C	TO THE UPPER HALFSpace. IF G**2 IS NEGATIVE, THE PROGRAM	TOTINT	165
C	RETURNS L=-1. OTHERWISE IT RETURNS L=1.	TOTINT	166
C		TOTINT	167
C	PROGRAM NOTES	TOTINT	168
C		TOTINT	169
C	THE INTEGRATION OVER THE UPPER HALFSpace IS PERFORMED BY	TOTINT	170
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C		TOTINT	173
C	THE PARAMETERS A1,A2,A3 DEPEND IN GENERAL ON ANGULAR	TOTINT	174
C	FREQUENCY OMEGA, HORIZONTAL WAVENUMBER COMPONENTS AKX	TOTINT	175
C	AND AKY, SOUND SPEED C, AND WIND VELOCITY COMPONENTS VX	TOTINT	176
C	AND VY. THE FORMULAS USED ARE CONTROLLED BY THE INPUT	TOTINT	177
C	PARAMETER IT WHICH IS TRANSMITTED TO SUBROUTINE USEAS.	TOTINT	178
C		TOTINT	179
C	THE PARAMETERS DEFINING THE MULTILAYER ATMOSPHERE ARE	TOTINT	180
C	PRESUMED STORED IN COMMON	TOTINT	181
C		TOTINT	182
C	LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C28-6515-4)	TOTINT	183
C		TOTINT	184
C	AUTHOR - A.O.PIERCE, P.I.T., JULY,1968	TOTINT	185
C		TOTINT	186
C	-----CALLING SEQUENCE-----	TOTINT	187
C		TOTINT	188
C	SEE SUBROUTINE NAMEOE	TOTINT	189
C	DIMENSION CI(100),VXI(100),VYI(100),HI(100),PHI1(100),PHI2(100)	TOTINT	190
C	COMMON I=AX,CI,VXI,VYI,HI (THESE MUST BE IN COMMON)	TOTINT	191
C	CALL TOTINT(OMEGA,AKX,AKY,IT,L,XINT,PHI1,PHI2)	TOTINT	192

C					TOTINT	193
C					TOTINT	194
C					TOTINT	195
C					TOTINT	196
C					TOTINT	197
C					TOTINT	198
C					TOTINT	199
C					TOTINT	200
C					TOTINT	201
C					TOTINT	202
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C					TOTINT	248
C					TOTINT	249
C					TOTINT	250
C					TOTINT	251
C					TOTINT	252
C					TOTINT	253
C					TOTINT	254
C					TOTINT	255
C					TOTINT	256

VY=VYI(J)	TOTINT	257
CALL USEAS(OMEGA,AKX,AKY,C,VX,VY,IT,A1,A2,A3)	TOTINT	258
CALL UPINT(OMEGA,AKX,AKY,C,VX,VY,A1,A2,L,F1,F2,UINT)	TOTINT	259
C	TOTINT	260
C CHECK IF L NEGATIVE	TOTINT	261
IF(L.LT.0) RETURN	TOTINT	262
C	TOTINT	263
C WE DENOTE THE CONTRIBUTION A3*UINT BY XINT. AS THE COMPUTATION CON-	TOTINT	264
C TINUES, XINT WILL SUCCESSIVELY REPRESENT THE VARIOUS SUBTOTALS UNTIL	TOTINT	265
C CONTRIBUTIONS FROM ALL THE LAYERS HAVE BEEN ADDED IN.	TOTINT	266
XINT=A3*UINT	TOTINT	267
C	TOTINT	268
C START OF DO LOOP	TOTINT	269
DO 90 I=1,IMAX	TOTINT	270
J=IMAX+1-I	TOTINT	271
C	TOTINT	272
C COMPUTATION OF CONTRIBUTION FROM J-TH LAYER OF FINITE THICKNESS.	TOTINT	273
C THE CURRENT VALUES F1 AND F2 REPRESENT F1(Z) AND F2(Z) AT TOP OF	TOTINT	274
C J-TH LAYER.	TOTINT	275
C=C1(J)	TOTINT	276
VX=VXI(J)	TOTINT	277
VY=VYI(J)	TOTINT	278
H=HI(J)	TOTINT	279
CALL USEAS(OMEGA,AKX,AKY,C,VX,VY,IT,A1,A2,A3)	TOTINT	280
CALL ELINT(OMEGA,AKX,AKY,C,VX,VY,H,F1,F2,A1,A2,AINT)	TOTINT	281
XINT=XINT+AINI*A3	TOTINT	282
C	TOTINT	283
C COMPUTATION OF F1 AND F2 APPROPRIATE TO TOP OF (J-1)-TH LAYER	TOTINT	284
F1 = PHI1(J)	TOTINT	285
90 F2 = PHI2(J)	TOTINT	286
C END OF DO LOOP	TOTINT	287
C	TOTINT	288
RETURN	TOTINT	289
END	TOTINT	290

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SUBROUTINE UPINT(OMEGA,AKX,AKY,C,VX,VY,A1,A2,L,F1,F2,UINT)
UPINT (SUBROUTINE)
7/25/68 LAST CARD IN DECK IS
UPINT 1
UPINT 2
UPINT 3
UPINT 4
UPINT 5
UPINT 6
UPINT 7
UPINT 8
UPINT 9
UPINT 10
UPINT 11
UPINT 12
UPINT 13
UPINT 14
UPINT 15
UPINT 16
UPINT 17
UPINT 18
UPINT 19
UPINT 20
UPINT 21
UPINT 22
UPINT 23
UPINT 24
UPINT 25
UPINT 26
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UPINT 28
UPINT 29
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UPINT 31
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UPINT 39
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UPINT 44
UPINT 45
UPINT 46
UPINT 47
UPINT 48
UPINT 49
UPINT 50
UPINT 51
UPINT 52
UPINT 53
UPINT 54
UPINT 55
UPINT 56
UPINT 57
UPINT 58
UPINT 59
UPINT 60
UPINT 61
UPINT 62
UPINT 63
UPINT 64

-----ABSTRACT-----

TITLE - UPINT
THIS SUBROUTINE COMPUTES AN INTEGRAL OF THE FORM

      UNT = INTEGRAL OVER Z FROM Z0 TO INFINITY OF

      (A1*F1(Z) + A2*F2(Z))**2

THE FUNCTIONS F1(Z) AND F2(Z) ARE THE SOLUTIONS OF THE COUPLED
ORDINARY DIFFERENTIAL EQUATIONS

      DF1/DZ = A11*F1 + A12*F2
      DF2/DZ = A21*F1 + A22*F2

WHERE THE ELEMENTS OF THE MATRIX A ARE INDEPENDENT OF Z. THE
FUNCTIONS F1(Z) AND F2(Z) ARE SUBJECT TO THE UPPER BOUNDARY
CONDITION THAT BOTH DECREASE EXPONENTIALLY WITH INCREASING
ALTITUDE. SINCE THE MATRIX A IS COMPUTED BY AAAA, INSURING
A(2,2)=-A(1,1), BOTH SHOULD VARY WITH HEIGHT AS EXP(-G*(Z-Z0))
WHERE

      G = SQRT(A(1,1)**2+A(1,2)*A(2,1))

IT IS ASSUMED G**2 IS POSITIVE. OTHERWISE L=-1 IS RETURNED.

THE EXPLICIT FORMS ADOPTED FOR F1 AND F2 WHICH SATISFY (2) ARE

      F1 = -SQRT(G)*A(1,2)*EXP(-G*(Z-Z0))
      F2 = SQRT(G)*(G+A(1,1))*EXP(-G*(Z-Z0))

THUS UNT IS GIVEN BY

      UNT = ((-A1*A(1,2)+A2*(G+A(1,1))**2)/2.0

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL G22-6515-4)
AUTHOR - A.D.PIERCE, M.I.T., JULY,1968

-----CALLING SEQUENCE-----

SEE SUBROUTINE TOTINT
NO DIMENSION STATEMENTS REQUIRED
CALL UPINT(OMEGA,AKX,AKY,C,VX,VY,A1,A2,L,F1,F2,UINT)

-----EXTERNAL SUBROUTINES REQUIRED-----

AAAA

-----ARGUMENT LIST-----

OMEGA      R%      NO      INP
AKX        R%      NO      INP
AKY        R%      NO      INP
C          R%      NO      INP
VX         R%      NO      INP
VY         R%      NO      INP
A1         R%      NO      INP
A2         R%      NO      INP
L          I%      NO      OUT
F1         R%      NO      OUT
F2         R%      NO      OUT

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C	UINT	R*4	NO	OUT	UPINT	65
C					UPINT	66
C	NO COMMON STORAGE USED				UPINT	67
C					UPINT	68
C		----INPUTS----			UPINT	69
C					UPINT	70
C	OMEGA	=ANGULAR FREQUENCY IN RADIANS/SEC			UPINT	71
C	AKX	=X COMPONENT OF WAVE NUMBER VECTOR IN KM**(-1)			UPINT	72
C	AKY	=Y COMPONENT OF WAVE NUMBER VECTOR IN KM**(-1)			UPINT	73
C	C	=SOUND SPEED IN KM/SEC			UPINT	74
C	VX	=X COMPONENT OF WIND VELOCITY IN KM/SEC			UPINT	75
C	VY	=Y COMPONENT OF WIND VELOCITY IN KM/SEC			UPINT	76
C	A1	=COEFFICIENT OF F1(Z) IN INTEGRAND			UPINT	77
C	A2	=COEFFICIENT OF F2(Z) IN INTEGRAND			UPINT	78
C					UPINT	79
C		----OUTPUTS----			UPINT	80
C					UPINT	81
C	L	=1 OR -1 DEPENDING ON WHETHER UPPER BOUNDARY CONDITIO			UPINT	82
C		OF F1(Z),F2(Z) DECREASING EXPONENTIALLY WITH INCREAS			UPINT	83
C		HEIGHT CAN OR CANNOT BE SATISFIED. IT REPRESENTS TH			UPINT	84
C		SIGN OF G**2 WHERE G-IS DEFINED IN THE ABSTRACT.			UPINT	85
C	F1	=VALUE OF F1(Z) AT BOTTOM OF HALFSpace, DEFINED AS			UPINT	86
C		-SQRT(G)*A(1,2) FROM EQN. (4A).			UPINT	87
C	F2	=VALUE OF F2(Z) AT BOTTOM OF HALFSpace, DEFINED AS			UPINT	88
C		SQRT(G)*(G+A(1,1)) FROM EQN. (4B)			UPINT	89
C	UINT	=THE INTEGRAL DEFINED BY EQNS. (1) AND (5) IN THE			UPINT	90
C		ABSTRACT			UPINT	91
C					UPINT	92
C					UPINT	93
C		----PROGRAM FOLLOWS BELOW----			UPINT	94
C					UPINT	95
C					UPINT	96
C		DIMENSION A(2,2)			UPINT	97
C					UPINT	98
C		COMPUTATION OF A MATRIX AND OF X=G**2			UPINT	99
C		CALL AAAA(OMEGA,AKX,AKY,C,VX,VY,A)			UPINT	100
C		X=A(1,1)**2+A(1,2)*A(2,1)			UPINT	101
C		CHECK ON SIGN OF X			UPINT	102
C		2 IF(X.GT. 0.0) GO TO 3			UPINT	103
C					UPINT	104
C		X IS NEGATIVE			UPINT	105
C		L=-1			UPINT	106
C		RETURN			UPINT	107
C		CONTINUING FROM 2 WITH X POSITIVE			UPINT	108
C		3 L=1			UPINT	109
C		G=SQRT(X)			UPINT	110
C		GRT=SQRT(G)			UPINT	111
C		F1=-GRT*A(1,2)			UPINT	112
C		F2=GRT*(G+A(1,1))			UPINT	113
C		COMPUTATION OF UINT			UPINT	114
C		UINT=(-A1*A(1,2)+A2*(G+A(1,1)))*2/2.0			UPINT	115
C		RETURN			UPINT	116
C		END			UPINT	117

```

C SUBROUTINE USEAS(OMEGA,AKX,AKY,C,VX,VY,IT,A1,A2,A3) USEAS 1
C USEAS (SUBROUTINE) 7/25/68 LAST CARD IN DECK IS USEAS 2
C
C -----ABSTRACT----- USEAS 3
C
C TITLE - USEAS USEAS 4
C THE PURPOSE OF THIS SUBROUTINE IS TO COMPUTE THE NUMBERS A1, A USEAS 5
C AND A2 WHICH DEPEND ON ANGULAR FREQUENCY OMEGA, HORIZONTAL WAV USEAS 6
C NUMBER COMPONENTS AKX AND AKY, THE SOUND SPEED C, AND THE WIND USEAS 7
C SPEED COMPONENTS VX AND VY. THE INTEGER IT DETERMINES WHICH USEAS 8
C FORMULAS ARE USED FOR A1, A2, AND A3 ACCORDING TO THE FOLLOWIN USEAS 9
C TABLE USEAS 10
C
C (IT) (A1) (A2) (A3) USEAS 11
C ----- USEAS 12
C 1 1 0 1 USEAS 13
C 2 0 1 1 USEAS 14
C 3 1 0 BOM*(KDOTV)/(C**2*K) USEAS 15
C 4 1 0 BOM/C**2 USEAS 16
C 5 1 0 VX*BOM/C**2 USEAS 17
C 6 1 0 VY*BOM/C**2 USEAS 18
C 7 G/C -C K*OMEGA/BOM**3 USEAS 19
C 8 G/C -C 1.0/BOM**2 USEAS 20
C 9 G/C -C K**2/BOM**3 USEAS 21
C 10 G/C -C VX*K**2/BOM**3 USEAS 22
C 11 G/C -C VY*K**2/BOM**3 USEAS 23
C
C HERE BOM=OMEGA-KDOTV IS THE DOPPLER SHIFTED ANGULAR FREQUENCY, USEAS 24
C KDOTV=AKX*VX+AKY*VY IS THE DOT PRODUCT OF WAVE NUMBER WITH USEAS 25
C THE WIND VELOCITY, AND K=SQRT(AKX**2+AKY**2) IS THE MAGNITUDE USEAS 26
C OF THE WAVE NUMBER VECTOR. THE ACCELERATION OF GRAVITY G IS USEAS 27
C TAKEN AS .0091 KM/SEC**2 IN THE COMPUTATION. COMPUTED VALUES USEAS 28
C SHOULD BE IN KM,SEC SYSTEM OF UNITS. USEAS 29
C
C LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL C29-6515-4) USEAS 30
C AUTHOR - A.O.PIERCE, M.I.T., JUNE,1968 USEAS 31
C
C -----CALLING SEQUENCE----- USEAS 32
C
C SEE SUBROUTINE TGTINT USEAS 33
C NO DIMENSION STATEMENTS ARE REQUIRED USEAS 34
C IT= USEAS 35
C CALL USEAS(OMEGA,AKX,AKY,C,VX,VY,IT,A1,A2,A3) USEAS 36
C A1,A2,A3 ARE NOW AVAILABLE FOR FUTURE COMPUTATIONS USEAS 37
C
C NO EXTERNAL LIBRARY SUBROUTINES ARE REQUIRED USEAS 38
C
C -----ARGUMENT LIST----- USEAS 39
C
C OMEGA R*4 NO INP USEAS 40
C AKX R*4 NO INP USEAS 41
C AKY R*4 NO INP USEAS 42
C C R*4 NO INP USEAS 43
C VX R*4 NO INP USEAS 44
C VY R*4 NO INP USEAS 45
C IT I*4 NO INP USEAS 46
C A1 R*4 NO OUT USEAS 47
C A2 R*4 NO OUT USEAS 48
C A3 R*4 NO OUT USEAS 49
C
C NO COMMON STORAGE USED USEAS 50
C
C -----INPUTS----- USEAS 51
C
C USEAS 52
C USEAS 53
C USEAS 54
C USEAS 55
C USEAS 56
C USEAS 57
C USEAS 58
C USEAS 59
C USEAS 60
C USEAS 61
C USEAS 62
C USEAS 63
C USEAS 64

```

C	OMEGA	=ANGULAR FREQUENCY IN RAD/SEC	USEAS	65
C	AKX	=X COMPONENT OF WAVE NUMBER VECTOR IN KM**(-1)	USEAS	66
C	AKY	=Y COMPONENT OF WAVE NUMBER VECTOR IN KM**(-1)	USEAS	67
C	C	=SOUND SPEED IN KM/SEC	USEAS	68
C	VX	=X COMPONENT OF WIND VELOCITY IN KM/SEC	USEAS	69
C	VY	=Y COMPONENT OF WIND VELOCITY IN KM/SEC	USEAS	70
C	IT	=CONTROL PARAMETER FOR SELECTION OF FORMULAS (SEE ABSTRACT).	USEAS	71
C			USEAS	72
C		----OUTPUTS----	USEAS	73
C			USEAS	74
C	A1	=PARAMETER DEFINED BY FORMULAS IN ABSTRACT	USEAS	75
C	A2	=PARAMETER DEFINED BY FORMULAS IN ABSTRACT	USEAS	76
C	A3	=PARAMETER DEFINED BY FORMULAS IN ABSTRACT	USEAS	77
C			USEAS	78
C			USEAS	79
C			USEAS	80
C		----PROGRAM FOLLOWS BELOW----	USEAS	81
C			USEAS	82
C			USEAS	83
C			USEAS	84
C	WE ASSIGN VALUES TO A1,A2,A3 WHICH WILL NOT NECESSARILY BE THEIR EXIT		USEAS	85
C	VALUES.		USEAS	86
	A1=1.0		USEAS	87
	A2=0.0		USEAS	88
	A3=1.0		USEAS	89
C	IF IT IS 1, THESE ARE CORRECT, HOWEVER.		USEAS	90
	IF(IT.EQ. 1) RETURN		USEAS	91
	IF(IT.GT. 2) GO TO 200		USEAS	92
C			USEAS	93
C	IT IS 2. THE CURRENT VALUES ARE 1.0,1. WE CHANGE THE FIRST TWO.		USEAS	94
	A1=0.0		USEAS	95
	A2=1.0		USEAS	96
	RETURN		USEAS	97
C			USEAS	98
C	IT IS .GT. 2. WE COMPUTE SOME QUANTITIES FOR FUTURE REFERENCE		USEAS	99
	200 AKV=AKX*VX+AKY*VY		USEAS	100
	AKSQ=AKX**2+AKY**2		USEAS	101
	BOM=OMEGA-AKV		USEAS	102
	AK=SQRT(AKSQ)		USEAS	103
C	THE CURRENT VALUES OF A1,A2,A3 ARE STILL 1.0,1.		USEAS	104
	IF(IT.GT. 3) GO TO 300		USEAS	105
C			USEAS	106
C	IT IS EQUAL TO 3. ONLY A3 NEED BE CHANGED.		USEAS	107
	A3=BOM/AKV/(C**2/AK)		USEAS	108
	RETURN		USEAS	109
C			USEAS	110
C	IT IS 4 OR GREATER. WE SET A3 TO VALUE APPROPRIATE FOR IT=4.		USEAS	111
	300 A3=BOM/C**2		USEAS	112
C	THE CURRENT VALUES OF A1 AND A2 ARE 1 AND 0.		USEAS	113
	IF(IT.EQ. 4) RETURN		USEAS	114
	IF(IT.EQ. 5) A3=VX*A3		USEAS	115
	IF(IT.EQ. 6) A3=VY*A3		USEAS	116
	IF(IT.EQ. 5 .OR. IT.EQ. 6) RETURN		USEAS	117
C			USEAS	118
C	IT IS 7 OR LARGER		USEAS	119
	A1=.0098/C		USEAS	120
	A2=-C		USEAS	121
C			USEAS	122
C	THE ONLY QUANTITY WE NEED DETERMINE IS A3		USEAS	123
C			USEAS	124
	IF(IT.GT. 7) GO TO 700		USEAS	125
C	IT=7		USEAS	126
	A3=AK*OMEGA/BOM**3		USEAS	127
	RETURN		USEAS	128

C	700 IF(IT .GT. 9) GO TO 800	USEAS	129
C	IT=8	USEAS	130
	A3=1.0/80M**2	USEAS	131
	RETURN	USEAS	132
C		USEAS	133
C	FOR IT=9,10,11 WE NEED THE FACTOR AKSQ/80M**3	USEAS	134
	800 A3=AKSQ/80M**3	USEAS	135
	IF(IT .EQ. 9) RETURN	USEAS	136
	IF(IT .GT. 10) GO TO 1000	USEAS	137
C	IT=10	USEAS	138
	A3=VX*A3	USCAS	139
	RETURN	USEAS	140
C		USEAS	141
C	IT=11 (YOU SHOULDN'T INPUT IT FOR VALUES OUTSIDE RANGE OF 1 TO 11.)	USEAS	142
	1000 A3=VY*A3	USEAS	143
	RETURN	USEAS	144
	END	USEAS	145
		USEAS	146

•

```

C AND THE NEW NUMBER OF COLUMNS IN INMODE) AND REVISED VERSIONS OF O WIDEN 65
C AND INMODE. WIDEN 66
C WIDEN 67
C WIDEN 68
C WIDEN 69
C WIDEN 70
C SUPPOSE OM = 1.0,2.0,3.0 AND WIDEN IS CALLED WITH KW = 3, AND N1 = WIDEN 71
C 2, THEN UPON RETURN TO CALLING PROGRAM, OM = 1.0,2.0,2.25,2.5,2.75 WIDEN 72
C 3.0, NOMP = 6, AND INMODE WILL HAVE THREE NEW ROWS CORRESPONDING T WIDEN 73
C THE NEW ELEMENTS OF OM. WIDEN 74
C WIDEN 75
C WIDEN 76
C WIDEN 77
C WIDEN 78
C WIDEN 79
C WIDEN 80
C VARIABLE DIMENSIONING WIDEN 81
C DIMENSION OM(1),V(1),INMODE(1) WIDEN 82
C COMMON IMAX,CI(100),VXI(100),VYI(100),HI(100) WIDEN 83
C WIDEN 84
C INTERVAL AT WHICH NEW VALUES OF OM ARE BE PLACED BETWEEN OM(N1) AND WIDEN 85
C OM(N1+1) IS DETERMINED WIDEN 86
C DELOM=(OM(N1+1)-OM(N1))/(KW+1) WIDEN 87
C WIDEN 88
C NOMP IS NUMBER OF ELEMENT IN EXPANDED OM WIDEN 89
C NOMP=NOM+KW WIDEN 90
C WIDEN 91
C NSTART IS THE NUMBER OF THE ELEMENT IN THE NEW OM WHICH CORRESPONDS T WIDEN 92
C ELEMENT N1+1 IN THE OLD OM VECTOR WIDEN 93
C NSTART=N1+1+KW WIDEN 94
C WIDEN 95
C MOVE ALL ELEMENTS OF OM BEYOND ELEMENT N1 TO THEIR NEW POSITIONS, BEG WIDEN 96
C NING WITH THE LAST ELEMENT WIDEN 97
C DO 90 NJ=NSTART,NOMP WIDEN 98
C J=NOMP-(NJ-NSTART) WIDEN 99
C JOLD=J-KW WIDEN 100
C WIDEN 101
C MOVE COLUMN JOLD OF INMODE INTO POSITION FOR COLUMN J WIDEN 102
C OM(J)=OM(JOLD) WIDEN 103
C DO 90 IP=1,NVP WIDEN 104
C IJ=(J-1)*NVP+(NVP-IP) + 1 WIDEN 105
C IJOLD=(JOLD-1)*NVP+(NVP-IP) + 1 WIDEN 106
C INMODE(IJ)=INMODE(IJOLD) WIDEN 107
C 90 CONTINUE WIDEN 108
C WIDEN 109
C NSTART IS NUMBER OF FIRST NEW COLUMN WIDEN 110
C NSTART=N1+1 WIDEN 111
C WIDEN 112
C NEND IS NUMBER OF LAST NEW COLUMN WIDEN 113
C NEND=N1+KW WIDEN 114
C WIDEN 115
C NEW VALUES OF OM ARE ESTABLISHED WIDEN 116
C OMEGA=OM(N1) WIDEN 117
C DO 190 J=NSTART,NEND WIDEN 118
C OM(J)=OMEGA + DELOM WIDEN 119
C OMEGA = OM(J) WIDEN 120
C DO 190 I=1,NVP WIDEN 121
C WIDEN 122
C IJ IS NUMBER OF ELEMENT IN VECTOR REPRESENTATION OF INMODE WHICH IS WIDEN 123
C ELEMENT J IN ROW I OF INMODE WIDEN 124
C IJ=(J-1)*NVP+I WIDEN 125
C VPHSE=V(I) WIDEN 126
C WIDEN 127
C CALL NMOFN TO EVALUATE THE NORMAL MODE DISPERSION FUNCTION (FPP) WIDEN 128

```

CALL NHDFN(OMEGA,VPHSE,THETK,L,FPP,K)	WIDEN	129
C	WIDEN	130
C IF FPP DOES NOT EXIST L = -1	WIDEN	131
IF(L .EQ. -1) GO TO 150	WIDEN	132
C	WIDEN	133
C IF FPP DOES EXIST L = 1 AND INMODE(IJ) = (FPP/ABS(FPP))	WIDEN	134
INMODE(IJ) = 1	WIDEN	135
IF (FPP.LE.0.0) INMODE(IJ) = -1	WIDEN	136
GO TO 180	WIDEN	137
150 INMODE(IJ)=5	WIDEN	138
180 CONTINUE	WIDEN	139
190 CONTINUE	WIDEN	140
RETURN	WIDEN	141
END	WIDEN	142

APPENDIX B

SOURCE DECK LISTING OF
AN ALTERNATE VERSION OF SUBROUTINE TABLE

This version of SUBROUTINE TABLE is used, as described in Chapter III of the present report, to tabulate listings of R_{11} and R_{12} versus angular frequency Ω and phase velocity V_{PHSE} which are used in calculating the parameter α and β for the GR_0 and GR_1 modes which in turn are used in calculating the values of the imaginary component k_I of horizontal wave-number for these modes at frequencies below cutoff. This version of TABLE should replace the version in Appendix A when a tabulation of R_{11} and R_{12} is desired.

SUBROUTINE TABLE(OM1,OM2,V1,V2,NOM,NVP,THETK,OM,V,INMODE,NUPT)
TABLE (SUBROUTINE) 7/19/68 LAST CARD IN DECK IS NO.

-----AESTRACT-----

TITLE - TABLE
GENERATION OF SUSPICIONLESS TABLE OF NORMAL MODE DISPERSION
FUNCTION SIGNS

TABLE CALLS SUBROUTINE MPOUT TO CONSTRUCT THE MATRIX OF
NORMAL MODE DISPERSION FUNCTION SIGNS INMODE (STORED IN
VECTOR FORM COLUMN AFTER COLUMN) FOR REGION IN FREQUENCY-
PHASE VELOCITY PLANE (OM1.LE.OMEGA.LE.OM2.AND.V1.LE.VP.LE
.V2). SUBROUTINE SUSPCT IS CALLED TO EVALUATE THE SUSPI-
CION INDEX ,ISUS, OF EACH INTERIOR ELEMENT IN THE MATRIX
SCANNING FROM LEFT TO RIGHT, TOP TO BOTTOM. IF ISUS .NE.
0 , INMODE IS ALTERED AS FOLLOWS.

ISUS=1 ROW ADDED ABOVE SUSPICIOUS ELEMENT AND COLUMN
ADDED TO ITS LEFT
=2 COLUMN ADDED TO RIGHT OF SUSPICIOUS ELEMENT
AND ROW ADDED ABOVE IT
=3 ROW ADDED BELOW SUSPICIOUS ELEMENT AND COLUMN
ADDED TO ITS RIGHT
=4 COLUMN ADDED TO LEFT OF SUSPICIOUS ELEMENT
AND ROW ADDED BELOW IT

HOWEVER, NEITHER THE NUMBER OF ROWS NVP NOR THE NUMBER OF
COLUMNS NOM WILL BE INCREASED BEYOND 100. IF ISUS CALLS
FOR AN ADDITIONAL ROW WHEN NVP = 100 , THE MESSAGE
(NVP = 100 N = XX M = XX) WILL BE PRINTED.
N IS ROW NO. OF SUSPICIOUS ELEMENT. M IS COLUMN NO. IF
ISUS CALLS FOR ADDITION OF A COLUMN WHEN NOM = 100, THE
MESSAGE (NOM = 100 N = XX M = XX) IS PRINTED.
WHEN INMODE HAS BEEN EXPANDED SCANNING IS RESUMED AT THE
ELEMENT IN NEW MATRIX WITH SAME ROW AND COLUMN NOS. AS
THOSE OF SUSPICIOUS ELEMENT IN OLD MATRIX. IF NUPT IS
POSITIVE INMODE WILL BE PRINTED AS IT IS RETURNED FROM
MPOUT AND IN ITS FINAL FORM.

LANGUAGE - FORTRAN IV (360, REFERENCE MANUAL - C28-6515-4)

AUTHOR - J.W.PCSEY, M.I.T., JUNE, 1968

-----USAGE-----

SUBROUTINES MPOUT,SUSPCT,LNGTHN,WIDEN,NMDFN ARE CALLED IN TABLE.

FORTRAN USAGE

CALL TABLE(OM1,OM2,V1,V2,NOM,NVP,THETK,OM,V,INMODE,NUPT)

INPUTS

OM1 MINIMUM VALUE OF FREQUENCY TO BE CONSIDERED.

R*4

OM2 MAXIMUM VALUE OF FREQUENCY TO BE CONSIDERED

R*4

```

C      V1      MINIMUM VALUE OF PHASE VELOCITY TO BE CONSIDERED
C      R*4
C      V2      MAXIMUM VALUE OF PHASE VELOCITY TO BE CONSIDERED
C      R*4
C      NOM      INITIAL NO. OF FREQUENCIES TO BE CONSIDERED
C      I*4
C      NVP      INITIAL NO. OF PHASE VELOCITIES TO BE CONSIDERED
C      I*4
C      THETK    PHASE VELOCITY DIRECTION (RADIAN)
C      R*4
C      NOPT     PRINT OUT OPTION. IF NOPT = -1, NO PRINT. IF NOPT = 1,
C      I*4     INMODE IS PRINTED IN ITS INITIAL FORM (GENERATED BY MPOUT)
C              AND IN ITS FINAL FORM.

```

C OUTPUTS

```

C      NOM      TOTAL NO. OF FREQUENCIES CONSIDERED
C      I*4
C      NVP      TOTAL NO. OF PHASE VELOCITIES CONSIDERED
C      I*4
C      OM       VECTOR WHOSE ELEMENTS ARE THE VALUES OF ANGULAR FREQUENCY
C      R*4(D)   CORRESPONDING TO THE COLUMNS OF THE INMODE MATRIX
C
C      V        VECTOR WHOSE ELEMENTS ARE THE VALUES OF PHASE VELOCITY
C      R*4(D)   CORRESPONDING TO THE ROWS OF THE INMODE MATRIX
C
C      INMODE   EACH ELEMENT OF THIS MATRIX CORRESPONDS TO A POINT IN THE
C      I*4(D)   FREQUENCY (OM) - PHASE VELOCITY (V) PLANE. IF THE NORMAL
C              MODE DISPERSION FUNCTION (FPP) IS POSITIVE AT THAT POINT,
C              THE ELEMENT IS +1, IF FPP IS NEGATIVE, THE ELEMENT IS -1,
C              IF FPP DOES NOT EXIST, THE ELEMENT IS 5. INMODE HAS NVP
C              ROWS AND NOM COLUMNS. MATRIX IS STORED AS A VECTOR,
C              COLUMN AFTER COLUMN.

```

-----EXAMPLE-----

```

C LET INMODE = -1,5,5,5,1,-1,-1,-1,1,1,-1,-1,1,1,1,1
C WITH NOM = NVP = 4
C AND OM = 1.0,1.5,2.0,2.5          THETK = 3.14159
C V = 1.0,2.0,3.0,4.0
C (VALUES NOT CORRECT, FOR ILLUSTRATION ONLY)

```

C THEN THE TABLE WILL BE PRINTED AS FOLLOWS.

```

C VPHASE      NORMAL MODE DISPERSION FUNCTION SIGN
C 1.00000    -+++
C 2.00000    X-+-
C 3.00000    X--+
C 4.00000    X--+

```

```

C      OMEGA 1234
C      PHASE VELOCITY DIRECTION IS 90.0000DEGREES

```

```

C OMEGA =
C 0.10000E 01  0.15000E 01  0.20000E 01  0.25000E 01
C

```

-----PROGRAM FOLLOWS BELOW-----

```

      DIMENSION OM(100),V(100),INMODE(10000),DORN(100),KORN(100)
      DIMENSION PPP(2,2)
      COMMON IMAX,C1(100),VXI(100),VYI(100),HI(100)
C
C MPOUT IS CALLED TO PRODUCE INMODE MATRIX AND OM AND V VECTORS.
      CALL MPOUT(OM1,OM2,V1,V2,NOM,NVP,INMODE,OM,V,THETK)
C
C IFLAG = 1 INDICATES FIRST TIME THROUGH WRITE PROCEDURE
      IFLAG = 1
C
C INMODE IS PRINTED IF NOPT IS POSITIVE
      IF (NUP1.GE.0) GO TO 123
      5 IFLAG = 0
      NOPER=0
C NOPER IS THE NUMBER OF EXPANSION OPERATIONS PERFORMED IN THE PRESENT
C SCAN OF THE MATRIX.  THUS, NOPER IS THE NUMBER OF SUSPICIOUS POINTS
C FOUND IN THE PRESENT SCAN.
C
C BEGIN SCANNING OF INTERIOR ELEMENTS OF INMODE IN UPPER LEFT CORNER
      N = 2
      M = 2
      10 CALL SUSPCT(N,M,NVP,INMODE,ISUS)
C
C POINT (N,M) IS SUSPICIOUS IF ISUS.NE.0
      IF(ISUS.NE.0) GO TO 60
C
C CHECK FOR END OF ROW
      20 IF (M.LT.(NOM-1)) GO TO 30
C
C CHECK FOR LAST ROW
      IF (N.LT.(NVP-1)) GO TO 40
      GO TO 121
C
C MOVE ONE COLUMN TO RIGHT
      30 M = M+1
      GO TO 10
C
C ADVANCE ONE ROW AND START AT COLUMN TWO
      40 N = N+1
      M = 2
      GO TO 10
C
C CHECK FOR MAXIMUM VALUE OF NVP
      50 IF(NVP.LT.100) GO TO 62
      61 FORMAT (24H NVP = 100)
      WRITE (6,61) N,M
      GO TO 20
      N =,I3,8H      M =,I3)
      62 IF(NOM .LT. 100) GO TO 70
      63 FORMAT(24HNOM = 100)
      WRITE(6,63) N,M
      GO TO 20
      N=,I3, 8H      M=,I3)
      70 IF(ISUS.NE. 1) GO TO 75

```

```
C
C ADD ROW ABOVE SUSPICIOUS POINT
  N1=N-1
C
C ADD A COLUMN TO LEFT OF SUSPICIOUS POINT
  M1=M-1
  GO TO 100
  75 IF (ISUS .NE. 2) GO TO 80
C
C ADD A COLUMN TO RIGHT OF SUSPICIOUS POINT
  M1=M
C
C ADD ROW ABOVE SUSPICIOUS POINT
  N1=N-1
  GO TO 100
  80 IF (ISUS .NE. 3) GO TO 85
C
C ADD A COLUMN TO RIGHT OF SUSPICIOUS POINT
  M1=M
C
C ADD ROW BELOW SUSPICIOUS POINT
  N1=N
  GO TO 100
C
C ADD ROW BELOW SUSPICIOUS POINT
  85 N1=N
C
C ADD A COLUMN TO LEFT OF SUSPICIOUS POINT
  M1=M-1
100 CONTINUE
  CALL LGTHN(OM,V,INMODE,NOM,NVP,NVPP,N1,1,THETK)
  CALL WIDEN(OM,V,INMODE,NOM,NOMP,NVPP,M1,1,THETK)
  NVP=NVPP
  NOM=NOMP
  NOPR=NOPR+1
  GO TO 10
121 CONTINUE
  IF (NOPR .GT. 0 .AND. NVP .LT. 100 .AND. NOM .LT. 100) GO TO 5
C
C DO NOT PRINT INMODE IF NOPT IS NEGATIVE
  IF (NOPT .LT. 0) RETURN
C
C LABELING
122 FORMAT (6H1VPHSE,6X,36HNORMAL MODE DISPERSION FUNCTION SIGN/)
123 WRITE (6,122)
  DO 133 I=1,NVP
  DO 128 J=1,NOM
  J88=(J-1)*NVP+I
  J89=INMODE(J88)-1
  IF (J89) 126,125,124
124 CONTINUE
C
C IF INMODE = 5, DORN = 1HX
  DATA Q1/1HX/
  DORN(J) = Q1
  GO TO 127
125 CONTINUE
```

