Chapter 2 HYPOELLIPSE users guide

2.1 Introduction

HYPOELLIPSE has been developed to meet some of the research needs of the USGS and is in a constant state of modification and revision to meet new needs and implement new ideas. There are many subtle uses of the various options, and a complete description of these would expand the current work to book length. The program and manual are not error-free, and the author would greatly appreciate feedback on any errors or problems encountered.

The number of "options" available is large, and hence a new user may have trouble deciding where to begin and which to use. The easiest course is to start out by specifying only the minimum amount of information necessary to run the program, including station locations, velocity model, and a few sets of earthquake arrival times. Then review section 2.2 for modifications to the default parameters or additional calculations which your data set require. After the run, refer to section 2.3 to interpret the printed output.

The choice of which velocity model and variable layer thickness options to use will depend upon how much information one has about the region of study. Some of the possible choices are described below.

1. Very little is known about velocity structure.

   In this case a single simple model consistent with available information could be used. The linear increase with depth over a half-space model might be chosen, in that few assumptions need to be made.

2. Detailed information is available about upper sediment layer thickness.

   In this case a single simple model could be used with the thickness of the upper layer varying from station to station. VMOD of section 2.2.3.5 would be set equal to 0.0. On the STATION LIST records (section 2.2.5) layer thickness for variable layer model 1 would be filled out for each station, and the preferred layer thickness model for each station would be set equal to 1.

3. The region covered by the network includes two or more distinct velocity structures which are well known.

   In this case the multiple velocity structure option could be used. Each station would be assigned to one of the velocity models, and that model will always be used to calculate traveltimes to that station. Note that ray tracing is not done so that a shallow earthquake whose waves pass through a number of different velocity structures in the earth will be poorly modeled. However, events deeper than the velocity variations will be modeled relatively well.

4. Alaskan data

   In the case of Alaskan data, three different velocity models are used, depending upon the location of the earthquake, and the station delays are also a function of earthquake location (see Chapter 7). Selection of the correct velocity model and station delay is done by subroutine USEDLY (see 2.2.3.6), which has been set up specifically for the Alaskan region. This subroutine would need to be modified for use with data from another region. These options allow all of the events from a very large area to be run in chronological order without pre-sorting by source area.

5. Fault zone time delays

   Work in California indicates that there is a low velocity zone along the San Andreas fault. To model this situation, two delays are assigned to each station, one termed delay model 1 and the other termed model 2. In addition, stations on the east side of the fault are assigned the delay model preference number 1, while those on the west side are assigned number 2. The delay model used (1 or 2) in locating a particular earthquake is determined by the delay model preference number of the closest station to the event. For example, an earthquakes near station XYZ on the west side of the fault would use delay model 2. Delay model 2 has fault zone delays added to the delays of stations on the east side of the fault. The reverse would be true for earthquakes on the east side of the fault.

6. Poisson ratio variation between velocity models and with depth

   If desired, the ratio of P-velocity to S-velocity may be specified independently for each velocity model and for each model layer. A simple use of this option would be to specify a different Vp/Vs ratio for each velocity model, but constant within each model. A more complex use would be to vary the Vp/Vs ratio within each model.

2.2 Specifications for data input records

The input records for this program provide three types of information:

1. Parameters specific to each user and required for program operation such as the four-letter code and location of each station and the velocity model(s) to be used in traveltime calculations;

2. Parameters that control the iterative location procedure or that specify which of the available output options are to be used;

3. Arrival time data to be used in the location of each earthquake.

Except where otherwise noted, items 1 and 2 above have the following format: Columns 1 through 18 contain a keyword which is scanned to determine the number and type of free format variables on the remainder of the record. The directions for each input item indicate how many variables are required and whether they are real, integer, or character. For example,

Format:VELOCITY real, real, real

would indicate that the keyword is VELOCITY and that three real variables must be specified. All columns beginning with an ! mark are ignored, so comments may be placed on any input parameter record. Records starting with C* are processed as comments, and the contents are written to the output file. Note that the number of variables on each record must agree with the instructions, so leaving columns 19 and above blank is not equivalent to specifying a value of 0.0, but instead will generate an error message. If two records with the same keyword in columns 1 through 18 are found, the second one encountered will update the value(s) specified by the first.

Each of the input items is described below. In many cases parameters have default values, which are enclosed in brackets []. If the default is desired, then the record does not need to be included in the input file. The order of sections 2.2.1 through 2.2.5 makes no difference except that RESET TEST(1), which specifies the VpVs ratio, must precede the VELOCITY model records (see 2.2.5).

2.2.1 Jump record - Format:JUMP character

If a record of the form JUMP FILENAME is encountered, where JUMP begins in column 1 and filename is in columns 6-55, then input is switched to file 'FILENAME'. Input resumes from the original input file after an end-of-file is reached. The jump file may not include any additional JUMP records. A JUMP record may not be imbedded within the STATION LIST records or within an earthquake's PHASE records. A JUMP record after the ARRIVAL TIMES NEXT record or between earthquakes may optionally contain in columns 56-65 the contents of the start of the next record to be processed. For example, if columns 56-65 contain the character string '7901' followed by 6 blanks, then all records will be skipped until one beginning with '7901' is found. All records encountered prior to that one will be skipped.

2.2.2 Travel time calculations

Both velocity models and travel time tables may be used by HYPOELLIPSE in computing travel times.

2.2.2.1) Computed velocity model specifications (Models 1-10)

Format:VELOCITY real, real, real

Velocity models are specified by up to a total of 48 records. There are three types of model that may be specified and up to 10 models may be defined. Models are placed in order starting with model 1. For these models a reference elevation, Eo (see Test(8) in section 2.2.4), is specified for the highest elevation in the region in kilometers above sea level. The "top" of the model is set to Eo. Earthquake depths are still computed with respect to sea level, so negative depths, up to -Eo km are allowed. Station elevations on the station records must be specified in meters above sea level. Specification of Eo allows for the correct location of earthquakes within a region of great topographic relief, such as within a volcano; travel times and take-off angles are computed correctly, even to stations that are at a lower elevation than the hypocenter.

a) Constant velocity in each layer.

The three real variables to be specified are P-phase velocity (km/sec), depth to top of layer (km), and Vp/Vs ratio. The first record of each model must have a depth of 0.0 km specified. The model may consist of from 1 to 11 layers over a half space. Embedded low velocity zones are allowed. For example, a 5 km thick layer with velocity of 5.2 km/s and a Vp/Vs ratio of 1.85 over a 7.0 km/s half space with Vp/Vs ratio of 1.78 would be specified by the following two records:

```
VELOCITY        5.2     0.0     1.85
VELOCITY        7.0     5.0     1.78
```

b) Linear increase in velocity over a half space.

For this model the velocity increases linearly from Vo at the surface by K km/s per km until the half space is reached at a depth of D km. Velocity within the halfspace is Vh km/s. To use this type of model, the VELOCITY records are defined as follows:

```
VELOCITY        Vo      0.0     Vp/Vs
VELOCITY        K       1.0     Vp/Vs
VELOCITY        D       2.0     Vp/Vs
VELOCITY        Vh      3.0     Vp/Vs
VELOCITY        200.    4.0     Vp/Vs
```

c) Linear increase in velocity.

For this model the velocity begins at Vo km/s and increases at a rate of K km/s per km. To use this type of model, the VELOCITY records are defined as follows:

```
VELOCITY        Vo      0.0     Vp/Vs
VELOCITY        K       1.0     Vp/Vs
VELOCITY        300.    3.0     Vp/Vs
```

Vp/Vs must be specified on each record and remain constant.

d) As an example, to specify two models, the first model with 20 km of 6.0 km/sec over a half space of 7.5 km/sec and the second model with a linear increase with depth starting at 4.0 km/sec at the surface, increasing 0.11 km/sec per km of depth down to 30 km, overlying a half space with a velocity of 8.1 km/sec, the following records would be used:

```
VELOCITY        6.0     0.0     0.0
VELOCITY        7.5     20.0    0.0

VELOCITY        4.0     0.0     0.0
VELOCITY        0.11    1.0     0.0
VELOCITY        30.0    2.0     0.0
VELOCITY        8.1     3.0     0.0
VELOCITY        200.0   4.0     0.0
```

A blank record between models is optional. See the next section (2.2.2.2) for more discussion of Vp/Vs ratios.

2.2.2.2) Vp/Vs ratios

The Vp/Vs ratio must be specified for each velocity layer. If specified as 0.0 then the current value of TEST(1) will be used. Use of this feature will be described by considering various cases:

You wish for all models to use the same Vp/Vs ratio
In this case set TEST(1) to the desired value before the VELOCITY model is input to the program and set the Vp/Vs ratio to zero on all of the VELOCITY records.

You wish for different models to use different Vp/Vs ratios
Specify Vp/Vs ratio on each VELOCITY model record. Do not vary Vp/Vs within a given model.

Variation in Vp/Vs ratio within a given model
This feature is allowed only for models with constant velocity layers (not for the linear-increase models). If the Vp/Vs ratio changes within a given model, then a separate S-velocity model is defined and used for S-phase traveltimes. The S-phase model is assigned a number one higher then the corresponding P-phase model. For example, if two models are specified in the input stream, and the first model has variable Vp/Vs ratio, then three models will be defined and used as follows:

	P-Phase Travel Times	S-Phase Travel Times
Stations Using Model 1	Model 1	Model 2
Stations Using Model 3	Model 3	Model 3

In this example, no PRIMARY STATION parameter record should specify velocity model 2. (See section 2.2.5)

One limitation of this feature is that S-P interval times (See section 2.2.9) do not use the S model, but instead assume the constant Vp/Vs ratio defined by TEST(1). Another limitation is that each variable Vp/Vs ratio model uses up two models, so that a maximum of five models with variable Vp/Vs may be specified.

2.2.2.3) Travel-time table specification (Models 11 - 13)

In addition to the 10 models previously described, up to three velocity models may be specified by travel-time tables. The first, which will be model number 11, is read from file number 21. The second and third are model numbers 12 and 13 and are read from file numbers 22 and 23, respectively. The program prompts for the names of the travel-time tables. See Chapter 6 for the operation of the program TTGEN that may be used to generate a travel time table. This option used portions of the code written by Klein (1985) for HYPOINVERSE. Note that the elevation of the top of the models (TEST(8)) must be zero when travel time tables are in use.

The Vp/Vs velocity ratio is specified for each travel time model (see section 6.5), and is used for computing S-phase travel times. However, if the specified Vp/Vs ratio is negative, then the next model will be used for computing S-phase travel times. For example, if model 11 specifies a negative Vp/Vs ratio, then model 12 will be use for S-phase travel times for stations that use model 11, and in this case no station may be assigned to use model 12.

2.2.2.4) Elevation corrections

If the elevation of the surface of the layer models is zero, as set by TEST(8), and for travel-time tables, elevation delay is computed from the station elevation (E) divided by the apparent vertical velocity within a surface layer with velocity VS. VS is specified by TEST(2) (see section 2.2.4). By using apparent velocity, the elevation correction will vary from a maximum of E/VS for vertical incidence to a minimum of zero for a horizontal direct path. This formulation is reasonable for refracted ray paths but will underestimate the elevation delay for direct ray paths with non-vertical incidence at the surface.
The elevation (in km above sea level) of the surface of computed travel-time models is set by TEST(8). Stations with lower elevations are "embedded" within the model, while earthquakes with higher elevations are fixed at the surface. In this case elevation corrections are not needed and the value of TEST(2) is ignored. Note that earthquakes may occur above the "embedded" stations, and that in this case travel times and angles of incidence are correctly computed.

Earthquakes which occur above sea level will be have negative depths, which will be so indicated on the printed output. If TEST(9) is 0.0 then the summary and archive files will also indicate negative depths for events above sea level. However, if TEST(9) is not equal to 0.0, then negative depths will be reported as -00 in the summary and archive files.

2.2.3 Option records

This set of records is optional. Include only those required.

2.2.3.1) Printer option record - Format:PRINTER OPTION Integer

Code	Printed output
-2	Only warning messages.
-1	Date and time of each earthquake and warning messages.
0	Final solution for each event showing residuals at each station.
[1]	Above plus one line per iteration
2	Above plus residuals at each station each iteration
3, 4, or 5	Above plus details from many subroutines. Used for debug purposes only.

2.2.3.2) Summary option record - Format:SUMMARY OPTION Integer

See section 2.4.1 for SUMMARY record format and 2.2.15 for archive format.

Code	SUMMARY record output
0	No SUMMARY records
[1]	SUMMARY records on FILE4
2	SUMMARY records on FILE4 and ARCHIVE-PHASE FILE on FILE11.
3	ARCHIVE-PHASE FILE on FILE11
4	PHASE records in input format with "fake" arrival times on FILE11. See section 2.2.14 for example of use.

2.2.3.3) Magnitude option record - Format:MAGNITUDE OPTION Integer

Local magnitude (XMAG) and coda magnitude (FMAG) are computed from formulas given in Chapter 4.

Code	Preferred magnitude used on SUMMARY record and in final line output (See sections 2.2.17, 2.3.5 and 2.4.1)
[0]	XMAG (Amplitude magnitude)
1	FMAG (coda length magnitude)
2	(XMAG + FMAG)/2
3	Prefer FMAG but use XMAG if FMAG is not calculated
4	Prefer XMAG but use FMAG if XMAG is not calculated

(Add ten to code for median rather than average value to be used as preferred magnitude.)

MAGTYP on SUMMARY record is set to X, F, or A, (corresponding to XMAG, FMAG, and average) to denote which type of magnitude was used. If no location can be obtained, then the magnitude is left blank and MAGTYP is set to K.

If code is negative, the calculation will be based on F minus S (F - S) rather than F minus P (F - P) time. F - P is still entered on ARRIVAL TIME records as coda length, but the S-P interval is subtracted. If S has not been read, the S residual is greater than (F - P)/10., or the computed S weight is zero, then the calculated rather than observed S-P interval is subtracted. See section 2.2.17 for the use of magnitudes computed outside of HYPOELLIPSE.

2.2.3.4) Tabulation option record - Format:TABULATION OPTION Integer

The tabulation at the very end of each run gives statistics such as average residual for each station.

Code	Events included in final tabulation
0	No tabulation
±1	Tabulation for A quality only
[+2]	Tabulation for A and B quality
-2	Tabulation for A and B quality
±3	Tabulation for A, B, and C quality
±4	Tabulation for A, B, C, and D quality

Positive for quality based on error ellipsoid.
Negative for quality defined in HYPO71 (Lee and Lahr, 1972).
See section 2.3.5 for definition of A, B, C, and D.

2.2.3.5) Variable layer option record -

Format:VARIABLE LAYER	Integer	Integer	Integer
	NLAY	VMOD	LOWV

This record is required for the variable layer thickness option. NLAY is the number of the layer to be varied, VMOD determines how the layer thickness model is chosen, and LOWV is set to 1 if an equal and opposite change in the thickness of the layer below the variable layer is to be made.

For each station two thickness are specified for the variable layer, a model 1 thickness and a model 2 thickness. In the calculation of each travel-time two stations are considered, the closest station to the epicenter and the receiving station. VMOD is used to specify which of three options is desired:

VMOD

+1.0 The thickness specified for the receiving station's preferred model (1 or 2) is used. For example, station STA has the layer thickness for variable-layer model 1 equal to 3 km, and model 1 is its preferred layer-thickness model. Then all traveltimes to station STA will use 3 km as the variable layer thickness. With this option only one thickness need be specified for each station.

0.0 The depth to the lower boundary of the variable layer is calculated for the receiving and closest station. If the hypocentral depth is below the average of the two lower boundary depths, then the receiving station's variable layer thickness is used. For shallower depths, the lower boundary depth is set to the average of the receiving and closest station's lower boundary depths.

-1.0 The thickness model (1 or 2) preferred by the closest station to the epicenter is used to determine the variable layer thickness used at each station.

Example of variable-layer-model velocity in the case where the first layer thickness is variable and LOWV equals 1:

CRUSTAL MODEL AS SPECIFIED ON CRUSTAL STRUCTURE RECORDS	CRUSTAL STRUCTURE WHEN VARIABLE LAYER THICKNESS EQUALS 5KM
Z	Z
0----------	0----------
5 km/sec	5 km/sec
	5----------
10----------	
6 km/sec	6 km/sec
15----------	15----------
7 km/sec	7 km/sec

Note that in this example no station should be given a variable layer thickness greater than 15 km.

2.2.3.6) Crustal delay, velocity model, and starting depth option record

Format:SELECT DELAY Integer

If code is positive, the default, the delay model used (1-9) is the one preferred by the closest station. If code is less than or equal to zero, then the subroutine USEDLY is used to control the delays, velocity model and starting depth of each event. Subroutine USEDLY, as distributed, has been tailored for use in processing data from Alaska, and would need to be modified for another region. The current Alaskan algorithm in USEDLY, which is used when code is negative, does the following:

1) Reads the first record following the SELECT DELAY record for the name of a file defining cylindrical delay regions.

2) Selects one of three velocity models depending upon the earthquake location. The velocity model is updated before each iteration.

3) Selects one of up to 10 delay models depending upon the earthquake location with respect to cylindrical delay regions. The delay selection is updated each iteration. Chapter 7 describes the use of cylindrical regions in more detail.

4) Sets an upper limit on the maximum starting depth depending on each event's starting location. Section 2.2.12 summarizes how the first trial depth is determined.

5) For events in the Gulf of Alaska, fixes depth at 10 km.

2.2.3.7) Missing stations option record - Format:MISSING STATIONS Integer

Code	Effect
0	The station list will be searched after each event for stations that would probably improve the earthquake solution quality. Those stations which are closer than the third closest station used or that would reduce the GAP by 30^{o} or more are listed.
[1]	A search for "missing" stations is not conducted.

Searching for missing stations requires that the entire station list be initialize, so this option can not be used with a negative code on the BEGIN STATION LIST record. (See 2.2.5)

2.2.3.8) Sort option record - Format:SORT OPTION Integer

Code	Effect
[0]	Stations are listed in the output in order of increasing epicentral distance.
1	Stations are listed in the same order as the input ARRIVAL TIME records.

2.2.3.9) Compress option record - Format:COMPRESS OPTION Integer

Code	Effect
0	Printout is compressed by not skipping to the top of a new page for each solution.
[1]	Printout for each earthquake starts on a new page.

2.2.3.10) Debug option record - Format:DEBUG OPTION Integer

Code	Effect
[0]	This option is not called into play and no additional record is needed.
1	This option is used and the next record must be included:

Debug limits record - the following format must be used:

(10X,F5.2, 5X,F5.2, 5X,F5.2, 5X, I5, 5X, I5, 5X, I5)

For example:
MAX RMS 0.65 PRES 1.00 SRES 1.00NWOUT 2 NMAX 8 SEMX 25

The words are typed only for your convenience and the order of the variables is fixed. The value of any variable not specified will be read as zero. This setup would give a detailed printout of traveltime, residuals, etc., for each station only for "Debug events" defined by:
RMS > MAX RMS, 0.65 sec, or
Largest P-Res with computed weight greater than 0.2 > PRES = 1 sec, or
Largest S-Res with computed weight greater than 0.2 > SRES = 1 sec, or
The combined number of P and S readings weighted out by the program
(does not include readings assigned weight code 4) > NWOUT = 2, or
Total number of iterations > NMAX = 8, or
The maximum error estimate > SEMX = 25 km.
The DEBUG OPTION can be used with the COMPRESS OPTION so that each event will not start on a new page.

TABLE OF DEBUG OPTIONS

CODE	EVENT PRINTOUT	SUMMARY RECORD
[0]	Controlled by PRINT OPTION.	Controlled by SUMMARY OPTION
+1	Summary line for good events. Detailed for debug events.	For both good and debug events
-1	Same as +1.	Only for good events
+2	No print for good events. Detailed for debug events.	For both good and debug events
-2	Same as +2.	Only for good events
±3	Detailed for all events. To rerun debug events with only critical stations set TEST(44) = 1.0.	For both good and debug events

2.2.3.11) Find global minimum in depth - Format:GLOBAL OPTION Integer

This option is now set up to find the best solution in regions where depths vary from the surface to 100 km or more. This option can not be used if the hypocenter is fixed on a plane, so TEST(47) must be set to 0.0.

Code Effect

[1] GLOBAL OPTION is turned off.

0 Global search option is turned on. The "global" search begins by solving fixed depth solutions with z = 0 and z = DEEPZ = TEST(42) km below sea level. Then a free depth solution starting at z = DEEPZ km is found. If the latter solution has z < CUTZ = TEST(27) km below sea level and significantly lower RMS than at z = 0, then it is taken as the final solution. If z = 0 has

significantly lower RMS, then a free depth solution starting at z = 0 is used as the final solution. If neither has significantly lower RMS, both solutions are reported to the output and that with the lower RMS is considered the best. If the solution starting at DEEPZ km depth has z greater than or equal CUTZ km then a solution with z fixed at SHALZ = (CUTZ - TEST(8))/2.0 km below sea level is computed. Of the 0 and SHALZ fixed depth solutions, the one with lower RMS is used as a starting location for free depth solution. If the latter solution is within DEEPZ/10.0 km of the free solution that started at DEEPZ km, then the solution with the lower RMS is reported as final. If the solutions are more than DEEPZ/10.0 km apart, then the one with significantly lower RMS is reported as final. If neither has significantly lower RMS, both are reported to the output, and the one with the lower RMS is taken as the final solution.

Error limits reported to the output and to the SUMMARY record are the greatest deviations of depth with RMS less than RMSLIM (See Chapter 3 for the definition of RMSLIM), even if there are intervening peaks in the RMS. This limit is approximately equivalent to one standard deviation in depth.

For different networks and regions, the values of DEEPZ and CUTZ may need to be adjusted for best results.

2.2.3.12) Residual option record - Format:RESIDUAL OPTION Integer

After the initial location of an earthquake the printed output can be checked for large residuals. When the original seismograms are reviewed to correct errors, inexperienced processors can be influenced in their revisions by the printed computer residual. This is very hazardous and <u>not</u> recommended because in many cases the true error, if any, is not reflected by the individual residuals.

To prevent this ill-advised feedback, the "preliminary option" may be used.

Code	Effect
0	Print output in residual form as described below.
[1]	Print output in normal form.

Residual output form consists of the following:

1) P and S residuals less than 2.25 seconds are shown only in absolute value and are rounded to the nearest 0.5 second. The printed residual (Rp) is related to the absolute value of the calculated residual (R) as follows:

$0 < R \leq .25$ Rp = 0
$.25 < R \leq .75$ Rp = 0.5
$.75 < R \leq 1.25$ Rp = 1.0
$1.25 < R \leq 1.75$ Rp = 1.5
$1.75 < R \leq 2.25$ Rp = 2.0

2) Flag large residuals: For residuals that have not been weighted out automatically by the program, an * is placed after the residual if it meets one of the following criteria:

P Residuals

R > .6 for one of closest five stations
R > .9 for distance less than 150 km
R > 1.5 for distance less than 350 km

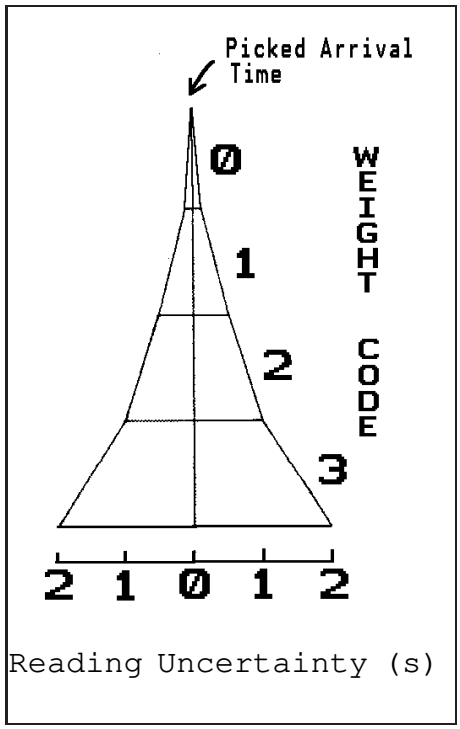
S Residuals

R > .9 for one of closest five stations
R > 1.5 for distance less than 150 km
R > 2.0 for distance less than 350 km

2.2.3.13) Weight assignment option

Format:WEIGHT OPTION Real Real Real

The relative weight assigned to each reading is dependent upon an integer weight-code, which can range from 0 for the most impulsive to 4 for readings that are too uncertain to be used in the hypocentral solution. It is recommended that RESET TEST(29) (see 2.2.4) be set to minus the standard error of the best readings, and that these readings be assigned zero weight code. Less certain readings are then assigned larger weight codes. If, for example, 1, 2, and 3 weight codes are to be assigned to readings that have standard errors that are 5, 10, and 20 times less certain than the best, respectively, then the three WEIGHT OPTION parameters should be set to 5, 10, and 20. For processing Alaskan seismic data, 0, 1, 2, and 3 weight codes are assigned to readings with standard errors ranging up to 0.1, 0.5, 1.0, and 2.0 seconds, respectively. The graph below is used to assign weight codes according to these limits.



The default weight and corresponding relative standard error corresponding to each weight code is given in the table below:

WEIGHT CODE	STANDARD ERROR (SEC)	STANDARD ERROR RELATIVE TO READINGS WITH WEIGHT CODE ZERO	COMPUTED WEIGHT
0	0.1	1.0	1.0
1	0.5	5.0	1/25
2	1.0	10.0	1/100
3	2.0	20.0	1/400
4	INFINITE	INFINITE	0.0

To change the default weight assignments, include a record with WEIGHT OPTION starting in Column 1 followed by the relative standard errors for weight codes of 1, 2, and 3. For example, the default weights that used to be set in older versions of HYPOELLIPSE could be reset with:

WEIGHT OPTION 1.33 2. 4.

2.2.3.14) Ignore summary records - Format:IGNORE SUMMARY REC Integer

Code Effect

[1] Starting location parameters (latitude, longitude, depth, and origin time) may be taken from the SUMMARY record. (See section 2.2.12)

0 The SUMMARY record will be ignored in determining the starting location parameters.

2.2.3.15) Header content record - Format:HEADER OPTION Any alphanumeric heading.

Used to write a heading of up to 50 characters above each earthquake in the output.

2.2.3.16) Comment records - Format:C* Any Comment

Any record with C* in columns 1-2 will be printed out during program execution but is otherwise ignored. Comments may not be imbedded within the station list.

2.2.3.17) Relocate after revising delays - Format:RELOCATE Integer

This will cause the input file to be rewound and rerun N = Code times. Prior to each rerun, the station delays for delay model 1 will be revised by adding the event-weighted average station residual. At the end of the job a file is generated on Unit 13 with one record for each station used. These records are in the format of the primary station records. (See section 2.2.5) The P- and S-delay field for delay model 1 will contain the revised stations delays. The field for delay models 2 through 5 will be blank. The default is Code = 0.

2.2.3.18) Uofacal option - Format:UOFACAL OPTION Filename

Used to specify the name of the file that contains calibration data in the format used by the U. of Alaska. (See section 4.2.3). Type UOFACAL beginning in column 1 and filename in columns 19-68.

2.2.3.19) Reset all control parameters to the initial default values - Format:STANDARD TEST

2.2.3.20) Constants noprint option - Format:CONSTANTS NOPRINT Integer

Controls whether the station list, user specified constants, and control options will written to the output file.

Code	Effect
0	Do not write out these items.
[1]	Write out these items.

2.2.3.21) Blank source option - Format:BLANK SOURCE One-Character Code

The stations list may contain calibration, polarity, and telemetry delay information for various sources of data. The arrival-time records have columns to specify the source of the P- and S-arrival times, the first motion, and the amplitude. However, some sets of arrival-time data may not have any source code entries. The BLANK SOURCE code specified on this record will be used whenever the arrival-time source code is blank in computing delays, magnitudes and corrected polarities.

2.2.4 Reset test records - Format:RESET TEST Integer Real

These records have RESET TEST typed starting in column 1 and beginning in column 19 the test number and the new value for the test variable. All of these records are optional and need be included only if a non-default value is required.

Test Number	Default Test Value		Description
1	1.78	---	Ratio of P-wave to S-wave velocity
2	5.0	---	P-wave velocity for elevation (correction) (km/sec). If negative, make no elevation corrections. If zero, use first layer velocity for elevation corrections. If greater than zero, use this for elevation corrections. In the latter case, value must be less than first layer P-phase velocity. Used with computed models if TEST(8) = 0 and with travel-time tables.
		---	Trial Location
3	0.0		First trial latitude (degrees). North positive. If TEST(3) or (4) .eq. 0, then ignore. See 2.2.12 for use.
4	0.0		First trial longitude (degrees). West positive. If TEST(3) or (4) .eq. 0, the ignore. See 2.2.12 for use.
5	-99.0		Used for first trial depth (km with respect to sea level) unless equal -99. See 2.2.12 for use.

Test Number	Default Value	Test	Description
6	0.0	---	RMS calculation at additional points. Radius of sphere for auxiliary RMS values (km). If zero, no auxiliary RMS values are calculated. If negative, continue iteration once starting at most neg point.
7	10.0	---	Focal Mechanism Plot Minimum number of first motions for a first motion plot to be made. If negative, make a second plot showing station names.
8	0.0	---	Elevation of top of computed models with respect to sea level (km).
9	0.0	---	If 0, allow negative depths in summary and archive file, else reset negative depths to -00.
		---	Distance Weighting
10	50.0		Apply distance weighting on this iteration. See also TEST(11) and (12).
11	50.0		XNEAR = Greatest distance with weight of 1.0 (km)
12	100.0		XFAR = Least distance with weight of 0.0 (km). See also TEST(46).
13	50.0	---	Azimuthal Weighting Apply azimuthal weighting on this iteration. Warning: this option has not been tested.
		---	Truncation Weighting
14	50.0		If there are 6 or more phases, then weight out large residuals on this iteration. See also TEST(15).
15	10.0		Give zero weight to residuals greater than this (sec).
		---	Boxcar Weighting
16	50.0		If there are 6 or more phases, then apply boxcar weighting on this iteration. See also TEST(17), (34) and (35).
17	2.0		Give zero weight to residuals greater than this times the standard deviation (sec).

Test Number	Default Test Value		Description
		---	Jeffrey's Weighting
18	50.0		Begin Jeffrey's weighting on this iteration. (See also TEST(34) and (35)).
19	0.05		Use Jeffrey's weighting only if RMS is greater than this (sec).
20	0.05		Mu of Jeffrey's weighting function
21	9.0	---	Maximum number of iterations
22	35.0	---	Limit change in focal depth to approximately this amount (km).
23	0.7	---	If move would take earthquake above surface, move this proportion of the way to the surface.
24	35.0	---	Limit change in epicenter to approximately this amount (km).
25	40.0	---	Fix depth if epicentral change is greater than this (km).
26	0.0025	---	Stop iterations if adjustment squared is less than this (km).
27	20.0	---	Global solution: if deep solution converges below this depth with respect to sea level, continue at a depth one half way between this depth and the surface of the crustal models. See also TEST(42).
28	0.0	---	To fix the hypocenter on a plane, set absolute value of this equal to azimuth of plunge line of plane (0 to 360 degrees measured clockwise from North). If negative, then a free solution will be determined starting at the best location on the plane. See also TEST(30) and TEST(47).
29	-0.1	---	If TEST(29) is positive, the standard error of zero weight-code readings is set equal to the RMS residual, unless there are zero degrees of freedom or the estimated reading standard error falls below TEST(29). In that case TEST(29) is used for the standard error of the readings. If TEST(29) is negative, the standard error of the zero weight-code readings is always set equal to minus TEST(29). (Also see 2.2.3.13)
30	0.0	---	If positive -- dip of plunge vector for hypocenter on plane. See also TEST(28) and TEST(47). If negative -- fix epicenter and solve only for depth and origin time. Ignore TEST(47). If TEST(28) is negative, then determine free solution starting at best depth.

Test Number	Default Value	Test	Description
		---	Duration Magnitude (See also TEST(40) and (43))
31	-1.15		C1, constant
32	2.0		C2, *log((F-P) * FMGC)
33	0.0		C3, *DELTA
34	0.0	---	If not equal 0, scale the normal equations.
35	0.001	---	Minimum damping of normal equations.
36	100.0	---	Maximum first trial depth, if computed from P-arrival times.
37	3.0	---	If termination occurs before this iteration, set iteration number to this and continue. Prevents iteration from stopping before all forms of weighting have been applied.
38	0.0	---	If 0, use of S depends upon S data indicator on INSTRUCTION record. If 1, locate all with & without S. If 2, locate all with S. If 3, locate all without S. If 4, fix all at starting hypocenter, and use S. If negative, use S readings only to fix origin time.
39	1.0	---	Multiply the S and S-P weight-code weights by this factor.
40	0.007	---	Duration magnitude C4, *DEPTH (see also TEST(31)-(33) and TEST(43))
41	0.0	---	If equal 1, PRINT OPTION greater than or equal 1, and SUMMARY OPTION equals plus or minus 1, then write a new SUMMARY record after each iteration.
42	75.0	---	Global solution: deep starting depth (km wrt sea level). See also TEST(27).

Test Number	Default Value	Test	Description
43	0.0	---	Duration magnitude (see also TEST(31)-(33) and TEST(40)) C5, *(log ((F-P) *FMGC)**2)
44	0.0	---	If 1, rerun "debug events" again (See 2.2.3.10) with critical stations; if 2, make a second run for all events with critical stations See note below for definition of critical stations.
45	0.1379	---	X scale factor for focal mechanism plots. Adjust for printer in use. (See 2.3.9)
46	0.0	---	If TEST(46) not equal 0.0, distance weighting constant XFAR (see TEST(12)) will be set to a minimum of 10 km beyond the distance of the TEST(46)th station. If TEST(46) is negative then any station beyond XFAR that would reduce a gap greater than 90 degrees by 45 degrees or more is given a distance weight of 0.5.
47	0.0	---	Constraint equation weight for hypocenter fixed on plane. A large value, such as 1000, will prevent out-of-plane movement. If equal 0, option is not used. See also TEST(28) and (30). This option may not be used with the GLOBAL OPTION (see 2.2.3.11).
48	0.0	---	Not used.
49	0.0	---	If abs value equal 1 compute Vp/Vs and origin time; if equal 2, also make printer plot of S-P vs P. If negative, use this origin time for earthquake location.
50	0.0	---	Compute this number of fixed depth solutions, starting with Z(1) = 0.0 and continuing with Z(i+1) = 1.2*Z(i) + 1.0. The maximum this value can be is 22., which produces a maximum depth of 225 km.

Note on TEST(44) - critical stations

In an effort to speed up the identification of reading errors during preliminary runs of data, the to rerun each event, using only the most important arrivals, was developed. In some cases reading errors can be identified by comparing the solution using only critical stations with the normal solution. In the printed output for critical station reruns, readings that are not used are marked with an 'X' between the residual and the weight. Critical stations are defined to be:

a) The closest four stations with P-phase readings;

b) Additional stations with P- or S-phase readings are considered one at a time and added only if they reduce a gap of greater than 72° by 5° or more;

c) S-arrivals are used when available at "critical" stations. If there is no S-arrival at any critical station, then S is used from the closest non-critical station.

2.2.5 Station list

The station list is set up so that a complex history of station changes can be maintained, such as starting and closing dates and changes in gain and polarity. (See discussion in 2.2.7) For the southern Alaska seismic network, a complex history beginning in 1971 has been developed, however in situations where this information is not needed, the station list may consist of just two entries for each station, with many fields left blank. Comment records that begin with C* in columns 1 and 2 may be included within the station list.

2.2.5.1) Begin station list - Format:BEGIN STATION LIST Integer Integer

The first record has BEGIN STATION LIST typed in columns 1-18, followed by Code and date of the first event to be run in free format. The date includes year, month, and day (for example: 821028). If the station list contains many stations that expired before the time of the first event, specifying the correct starting date will eliminate the expired stations from the initial printed station list. The date may be set to 0, but information for stations expired prior to first event will be printed depending on Code.

If the CODE is: 0 or 1 STATION records follow BEGIN STATION LIST record. Print station list updated to date specified.

-1 Same as one but do not print station list or print new station parameters when a station is updated during run.

2.2.5.2) Primary station parameters - Formatted as indicated below.

For each station there is one entry with PRIMARY STATION PARAMETERS, such as latitude and longitude, and one or more entries with TIME-DEPENDENT STATION PARAMETERS, including calibration parameters and polarity indicator. To speed up the search for station parameters, the current version of HYPOELLIPSE requires the station list to be in alphabetical order. The 3-letter codes must be grouped together preceding the 4-letter codes.

Alphabetical order is not required if the alternate version of subroutine PHAIDX, which is included in with the source code, is used. In either case, the first station should be near the center of the network, as it is used as a reference location for calculating the azimuth of approach of a plane wave. A fake station with the name AAA can be used as the first station. See section 1.3 for the maximum of number of stations allowed.

Format for PRIMARY STATION PARAMETER records:

Item	Col. Nos.	Format
Station Name	1 - 4	A4
Latitude (Degrees)	5 - 6	I2
N or blank for North, S for South	7	A1
Latitude (Minutes)	8 - 12	F5.3
Longitude (Degrees)	14 - 16	I3
W or blank for West, E for East	17	A1
Longitude (Minutes)	18 - 22	F5.3

THE FOLLOWING ITEMS ARE OPTIONAL, AND IF LEFT BLANK THE DEFAULT VALUES WILL BE USED.

Item	Default Value	Col. Nos.	Format
Elevation (Meters)	0	24 - 27	I4
Preferred velocity model (1-10)	1	28 - 29	I2
Preferred layer thickness model (1-2)	1	30	I1
Layer thickness for model 1	0.0	31 - 34	F4.2
Layer thickness for model 2	0.0	35 - 38	F4.2
Preferred delay model (1-9)	1	39	I1
P-delay for model 1	0.0	40 - 43	F4.2
S-delay for model 1	0.0	44 - 47	F4.2
P-delay for model 2	0.0	48 - 51	F4.2
S-delay for model 2	0.0	52 - 55	F4.2
P-delay for model 3	0.0	56 - 59	F4.2
S-delay for model 3	0.0	60 - 63	F4.2
P-delay for model 4	0.0	64 - 67	F4.2
S-delay for model 4	0.0	68 - 71	F4.2
P-delay for model 5	0.0	72 - 75	F4.2
S-delay for model 5	0.0	76 - 79	F4.2
*Component, Blank or Z, N, or E Corresponds to Vertical, North-South and East-West.		80	A1

*Stations with N or E component are currently ignored by HYPOELLIPSE.

NOTE ON DELAYS: The total delay used for the S-phase is just the S-delay given on the STATION record. [Some earlier versions of HYPOELLIPSE added a term equal to (VpVs ratio)*(P-delay) to the S-delay.]

2.2.5.3) Time-dependent station parameters

Format for TIME-DEPENDENT STATION PARAMETER records:

Item	Default Value	Col. Nos.	Format
Station name		1 - 4	A4
*		5	A1
If any of the following items are left blank, default values will be used.			
Station weight (Multiplies the weight derived from weight code. See section 2.2.6.)	1.0	6 - 9	F4.2
Primary system response code: 0 for Wood-Anderson 1 USGS Central California Network Standard 2 EV-17 and Develco 3 EV-17 and Teledyne 4 HS-10 and Develco 5 L-4C and Develco 6 L-4C and Teledyne 7 L-4C replacing HS-10 and Develco 8 Ten-day Recorders 9-17 User specified calibration curve (See 2.2.10 and Chapter 4) 18 Use U. of Alaska magnitude calculation (See 4.2.3)	1	10 - 11	I2
A1VCO 5 Hz Calibration (mm ptp - not used by HYPOELLIPSE)		12 - 15	F4.0
XMAG calibration constant-C10 (See 4.2)	0.0	16 - 20	F5.2
XMAG correction (added to amplitude magnitude)	0.0	21 - 24	F4.2
NOTE: If the number typed is the actual magnitude correction plus 10, the magnitude for this station will be computed and listed but not used in computing the average magnitude. For example, if XMAG correction = 10.2, a correction of +0.2 is applied to all XMAG's for this station, but none are used in the average magnitude for each event.			
XMAGWT magnitude weight (If zero, exclude xmag's from this station from mean and median xmag magnitude. Print "e" next to xmag value in output.	1	25 - 25	I1
FMAGWT magnitude weight (If zero, exclude fmag's from this station from mean and median fmag magnitude. Print "e" next to fmag value in output.	1	27 - 27	I1

Item	Default Value	Col. Nos.	Format
FMAG correction (Multiplies the observed coda).	1.0	28 - 31	F4.2
P weight code replacement For this station, an ARRIVAL TIME record with P weight code of 0, 1, 2, or 3 will be replaced by this code. If blank, use assigned weight.	none	32	I1
S weight code replacement For this station an ARRIVAL TIME record with an S weight code of 0, 1, 2, or 3 will be replaced by this code. If blank, use assigned weight.	none	33	I1
Field gain setting (Not used by HYPOELLIPSE)	0	35 - 36	I2
Palmer attenuator setting (0, 1, or 2 Not used by HYPOELLIPSE)	0	37	I1
Year, month, and day	990000	38 - 43	I6
Hour and minute Time of expiration of information in these entries. If another entry with revised time dependent parameters does not follow, then this is time of station expiration.	0	44 - 47	I4

Two telemetry delays are specified. The primary delay is used unless (1) the source of data is one of those specified for the alternate delay or (2) the source is "T" or "N", both of which have already been corrected. Certain source codes are equivalent for the purposes of telemetry delays. For example, the USGS film viewer is equivalent to the USGS one-film digitizer. A complete list of source codes is given in section 4.2.2.2. The following table shows delay-equivalent codes. Only one code from a set of equivalents need be included as an alternate delay code.

Source of data	Equivalent codes
USGS Film	V, *, 1, 4
USGS Tape	S, E, 2
UAGI Film	%, A, a, F
UAGI DAQ/DAN	d, D, J, X

Item	Default Value	Col. Nos.	Format
Primary telemetry delay	0.0	48 - 51	F4.2
Source codes of arrival times that will use the alternate telemetry delay		52 - 55	4A1
Alternate telemetry delay	0.0	56 - 59	F4.2

Polarity reversal indicators may be any of the following:

Indicator Value:	Focal Mechanism Symbol:
N Normal	Same as phase record
R Reversed	Reverse of phase record
+ Probably normal	Same as phase record
- Probably reversed	Same as phase record
? Unknown	Question Mark

Item		Col. Nos.	Format
Five reversal indicators may be specified, one for each of the following sources of Alaskan data:			
Source of data	Source codes effected		
USGS Film	V, *, 1, 4	60	A1
USGS Tape or PCELOG	S, E, 2, P	61	A1
ATWC Film	W	62	A1
UAGI Film	%, A, a, F	63	A1
UAGI DAQ/DAN	d, D, J, X	64	A1
Other sources	any other code, including blank	65	A1

The following items allow amplitude measurements for a given station to be made on up to four additional recording systems, each with a different frequency response:

System response code	72 - 73	I2
A1VCO 5 Hz, Calibration (mm ptp - not used by HYPOELLIPSE)	74 - 77	F4.0
XMAG Calibration constant-C10	78 - 82	F5.2
System response code	84 - 85	I2
A1VCO 5 Hz, Calibration (mm ptp - not used by HYPOELLIPSE)	86 - 89	F4.0
XMAG Calibration constant-C10	90 - 94	F5.2
System response code	96 - 97	I2
A1VCO 5 Hz, Calibration (mm ptp - not used by HYPOELLIPSE)	98 - 101	F4.0
XMAG Calibration constant-C10	102- 106	F5.2
System response code	108- 109	I2
A1VCO 5 Hz, Calibration (mm ptp - not used by HYPOELLIPSE)	110- 113	F4.0
Calibration constant-C10	114- 118	F5.2
Coordinates of new station location:		
Revised minutes of latitude	119- 123	F5.2
Revised minutes of longitude	124- 128	F5.2
Revised elevation	129- 132	I4

2.2.5.4) End station list - Format:END STATION LIST

A record with END typed starting in column 1 follows the last STATION record. The record immediately following the BEGIN STATION LIST record may be of the form JUMP FILENAME, where the STATION records are contained in the file 'FILENAME'. In this case, no END record is used in either the original input file or the jump file.

2.2.5.5) Additional delays

Delays may be specified for 5 additional models (#'s 6-10). Each set of additional delays begins with a record with DELAY typed in columns 1-5 and a delay model number (6-10), an integer, beginning after column 18. This record is followed by a set of records with station name in columns 1-4, followed by P-Delay and S-Delay (seconds) in free format. After the last station, a record with END starting in column 1 ends the set of delays. The stations need not be in alphabetical order, and stations not included will be given delays of zero.

2.2.6 Arrival times

2.2.6.1) Arrival times next record

A record with ARRIVAL TIMES NEXT starting in column 1 signals the start of the ARRIVAL TIME records. Each earthquake consists of four types of records: SUMMARY ('/' or '\' in column 81), ARRIVAL TIME, COMMENT ('C*' in columns 1-2) and INSTRUCTION. If any SUMMARY records are present, the first record of the event must be the primary SUMMARY record ('/' in column 81) and this record provides the starting location for the event unless the IGNORE SUMMARY records is in effect (See sections 2.2.3.14 and 2.2.12). Each event must end with a series of one or more INSTRUCTION records. A maximum of 256 records may be associated with each event.

2.2.6.2) Arrival time record format

For each seismograph station recording the earthquake, an ARRIVAL TIME record is typed as follows. A maximum of 256 phases, counting P and S phases, may be used for each earthquake.

Item	Col. Nos.	Format
Station name	1 - 4	A4
Alphanumeric symbol describing P-phase arrival (for example, I or E)	5	A1
Phase descriptor P - P-arrival read on vertical component N - P-arrival read on North-South component E - P-arrival read on East-West component If N or E is used, then neither the coda duration nor the maximum amplitude will be used and the first motion direction will not be plotted.	6	A1
First motion direction of P-arrival	7	A1
c, C, u, or U Compression d, D Dilatation + Poor compression - Poor dilatation Z Nodal, and not clearly up or down N Noisy . or Blank Not readable		

Item	Col. Nos.	Format
P-phase weight code 0 or blank Full weight 1 Partial weight 2 Partial weight 3 Partial weight 4, 5, 6, 7, 8 No weight	8	F1.0
If the P phase is a secondary arrival refracted along the bottom of the Ith layer, type the value of I here. If event is in the (I + 1)th layer, direct wave calculation is made. If the event is deeper than the (I + 1)th layer or the distance is too short for this refraction to be possible, then the computed weight is reset to zero. This option only operates with computed layer models with constant velocity (see section 2.2.2.1.a).	9	I1
Year, month, day, hour, minute	10 - 19	I10
Seconds of P arrival. If left blank, the assigned weight code will be set to 8 both during this run and on the ARCHIVE ARRIVAL TIME record.	20 - 24	F5.2
Seconds of S arrival	32 - 36	F5.2
S remark	37 - 39	A3
S phase weight code	40	F1.0
Maximum peak-to-peak amplitude. Values from .001 to 9,999 are entered as positive. Negative entries are multiplied by -10,000 to allow for values of 10,000 to 9,990,000.	44 - 47	F4.0
Period of maximum amplitude in hundredths of sec. If left blank, 0.1 will be used.	48 - 50	F3.2
Siemens gain state: 0 = high; 1 = low (X1/4)	61	I1
A1VCO gain range state. 0 = high; 1 = X 1/10; 2 = X 1/500	62	I1
Any remark	63 - 64	A2
Time correction in seconds	66 - 70	F5.2
F-P time interval, in sec, for FMAG calculation. In USGS practice, one measures the time between the first P-arrival and the point where the peak-to-peak amplitude of the signal drops below 1 cm on a Geotech Develocorder film viewer (X 20 magnification). If the F-P is less than 1.25 times the S-P time, then FMAG is not calculated.	71 - 75	F5.0
Polarity source code	* 105	A1
P Arrival source code	* 106	A1
S Arrival source code	* 107	A1
Amplitude source code	* 108	A1
Coda duration source code	* 109	A1

* See 4.2.2.2 for a listing of source codes used in Alaska.

2.2.6.3) Instruction record

After each set of ARRIVAL TIME records for a particular earthquake, at least one INSTRUCTION record follows.

Item	Col. Nos.	Format
MORE Indicator for another INSTRUCTION record following this one. Leave blank if no additional INSTRUCTION records follow. Type MORE if another one follows. The earthquake will be processed once for each INSTRUCTION record.	1 - 4	A4
Processing Status	9	A1
Event Type See section 2.4.1 for definition of Processing Status and Event type. If an event is not preceded by a SUMMARY record, then the Processing Status and Event Type from the INSTRUCTION record are placed in columns 72 and 90 of the SUMMARY record generated when HYPOELLIPSE is run. If the event is in Archive Format, and is therefore already preceded by a SUMMARY record, then the event type and processing status on the INSTRUCTION record are ignored.	10	A1
S data indicator 0 if S data is not to be used 1 for use of S data in solution	18	I1
Fixed location indicator 0 implies nothing fixed. 1 implies depth fixed at trial depth. 7 implies hypocenter fixed but origin time free. 8 implies origin time fixed at trial origin time. 9 implies location fixed at trial latitude, longitude, and depth. If origin time is entered on this record (cols. 74-80), or on a SUMMARY record, then origin time will also be fixed. (See 2.2.12)	19	I1
Trial depth	20 - 24	F5.2
Trial latitude (Degrees)	41 - 42	F2.0
N or blank for North S for South	43	A1
Trial latitude (Minutes)	44 - 48	F5.2
Trial Longitude (Degrees)	54 - 56	F3.0
W or blank for West and E for East	57	A1
Trial longitude (Minutes)	58 - 62	F5.2

Item	Col. Nos.	Format
CUSP ID (not used by HYPOELLIPSE)	63 - 73	A11
Trial origin time (Minutes)	74 - 75	F2.0
Trial origin time (Seconds)	76 - 80	F5.2
Sequence Number - will be transferred to columns 92-96 of SUMMARY record.	92 - 96	A5

2.2.6.4) Comment records

Any phase record with C* in columns 1-2 will be printed out during program execution but otherwise ignored. There is no limit to the number of COMMENT records per event, except that they count along with SUMMARY records, ARRIVAL TIME records, and the INSTRUCTION record toward the maximum number of records per event - currently set at 256. In this way a comment can be made, for example:
C* Station XYZ may have cross-feed or
C* these readings may be from two earthquakes.

2.2.6.5) Jump records

If a record with 'JUMP FILENAME' beginning in column 1 is encountered then input is transferred to file 'FILENAME'. When an end-of-file is reached on the subsidiary input file, input resumes from the original file.

2.2.7 Station parameter changes during run (see sections 2.2.5.2 and 2.2.5.3)

The station list record file may be set up so that station parameter changes will automatically be made as a set of data is run. Each STATION record has an expiration date and time. If left blank the year is set to 1999. But if, for example, the station calibration changed on 760120 at 1432 from 5.1 to 8.3, then two STATION records would be included in the file. The first would have 5.1 for calibration and an expiration of 7601201432. The second, which must directly follow the first, would be identical except 8.3 would replace 5.1 and the expiration date and time would be updated. As many STATION records as required can be grouped together like this. The expiration date of each station is checked against the current event time before each event is processed.

CAUTION: In order to use this system of automatic updating of station parameters, the earthquake data set must be run in chronological order. All updates for a particular station must also be in chronological order. Note that if the events are rerun, as described in section 2.2.11, then they will not be run in chronological order, so station parameter updating will not operate correctly and errors may result.

2.2.8 Change input items 2.2.1 through 2.2.5 during run

Any or all of these items may be changed as follows:

2.2.8.1) Reset record

Type RESET starting in column 1. This record is placed following the last INSTRUCTION record of an event or set of events, and it switches the program to the input mode in which items 2.2.1 through 2.2.5 may be entered. All location parameters will remain in effect except those for which new 2.2.1-2.2.5 records are included. To switch back to reading PHASE records, terminate the 2.2.1-2.2.5 items with an ARRIVAL TIMES NEXT record.

2.2.8.2) Reset S record

Type RESET S starting in column 1. This is the same as RESET described above except that (1) a tabulation of average residuals will be printed for the set of events preceding the RESET S record, and (2) tabulation will begin anew on the events that follow.

2.2.8.3) Standard test record

A record with STANDARD TEST starting in column 1 will reset input items 2.2.3 and 2.2.4 to default values. This record is placed after a RESET or RESET S record.

2.2.9 Use of S-P intervals

If the same time base is not available for some stations, it is still possible to use the recorded S-P intervals in the hypocentral solution. To do this, set the weight code assigned to the P-arrival (column 8) to 9, and the weight code assigned to the S-arrival (column 40) to that desired for the S-P interval. This will only work with velocity models that have the same ratio of P-wave to S-wave velocity in each layer.

2.2.10 How to add your own calibration curves -
Format:CALIBRATION Integer

In addition to the 8 system response tables stored with HYPOELLIPSE, the user may supply tables for up to nine additional seismic systems, corresponding to system numbers 9 through 17. To do this, place a record with CALIBRATION starting in column 1 and the number of additional system calibration tables to be added beginning in column 19 in free format. Each table consists of two records with the values of RSPA for n = 1,20 on the first and n = 21,40 on the second. The format is (20F4.2). The first two records correspond to system number 9, the second two to number 10, etc., up to the total number of tables to be added. See Chapter 4 for the definition of RSPA(n).

2.2.11 How to run the same data more than once

A set of ARRIVAL TIME records may be run with a variety of velocity models, station lists, trial depths, or any other of the variable parameters defined in 2.2.1 through 2.2.5. First, place the ARRIVAL TIME records in a separate file (named PHDATA in the example below). Then set up the input file as in the this example:

```
Items 2.2.1 through 2.2.5 as desired for 1st run
ARRIVAL TIMES NEXT
JUMP PHDATA
RESET
New items 2.2.1 through 2.2.5 as desired for second run
ARRIVAL TIMES NEXT
JUMP PHDATA
```

* HYPOELLIPSE always assumes that the earthquakes being processed are in chronological order when keeping the station parameters up-to-date. Therefore, if the events being rerun span any changes in the station parameters, the station file will have to be included again prior rerunning the data.

2.2.12 Summary of first trial location specifications

For each parameter, the sources are given in order of decreasing priority.
LATITUDE AND LONGITUDE

1) INSTRUCTION record, if specified (columns 41-44 contain some non-blank characters), else
2) SUMMARY record, if specified (columns 15-18 contain some non-blank characters) - (See 2.2.3.14 to ignore SUMMARY records), else
3) TEST(3) and (4), if both not equal zero, else

4) Inversion of up to the first 10 P-arrival times.

DEPTH

1) INSTRUCTION record, if specified (columns 21-24 contain some non-blank characters), else
2) SUMMARY record, if specified (columns 31-34 contain some non-blank characters) - (See 2.2.3.14 to ignore SUMMARY records), else
3) Trial depth specified in SUBROUTINE USEDLY if the SELECT DELAY code is not zero and USEDLY sets a depth not equal to 99999. (See 2.2.3.6), else
4) TEST(5), if not equal -99.0, else
5) Inversion of up to the first 10 P-arrival times, rounded to nearest 5 km and not less than 15 km or greater than TEST(36).

ORIGIN TIME

1) Computed from distribution of S vs P if TEST(49) equals -1 or -2 and the number of pairs of S and P times is greater than 2.
2) INSTRUCTION record, if specified (columns 74-77 contain some non-blank characters), else
3) SUMMARY record, if specified (columns 9-12 contain some non-blank characters) - (See 2.2.3.14 to ignore SUMMARY records), else
4) Computed from distribution of S vs P if TEST(49) equals 1 or 2 and the number of pairs of S and P times is greater than 2.
5) Define TO(i) = TP(i) - (TS(i) - TP(i))/(TEST(1) - 1.0) where
   TP(i) is the P arrival time at the i th station,
   TS(i) is the S arrival time at the i th station,
   TEST(1) is the Vp/Vs ratio
   Use the average value of TO(i) if at least one station has both P- and S- arrivals, else
6) Inversion of up to the first 10 P-arrival times.

NOTE: If TEST(38) is negative, then the origin time will be fixed at the average value of TO(i), unless TEST(49) is negative, in which case it will be fixed at the value determined by the Wadati plot (extrapolation of the (TS - TP) vs TP curve to the point where (TS - TP) equals zero).

NOTE: Starting parameters will not be taken from the SUMMARY record if the IGNORE SUMMARY RECORD is in effect (See 2.2.3.14).

2.2.13 Run data with random errors added

In order to study the effectiveness of this inversion program for varying station distributions or earthquake distributions and for data corrupted by random errors, the following method may be used:

a) Generate a "fake" set of perfect phase data for the desired earthquake distribution. This can be done by setting up a group of ARRIVAL TIME records with the stations of interest and including arbitrary P- and S-phase data for each station. Then use a series of INSTRUCTION records, each with a fixed location indicator and one of the desired test earthquake locations (See 2.2.6.3). Run this data with SUMMARY OPTION 5 in order to generate the "fake" set of arrival time data. If these data were fed back into the program, the result should be the desired test earthquake locations, each with zero RMS residual.

b) In order to have random errors added to each arrival time, type a record with SCATTER starting in column 1, P standard error starting in column 20 (F5.2), and S standard error starting in column 32 (F5.2). Note that this format is fixed. These should be the standard errors for readings with 0 weight code. For readings with weight codes of 1, 2, and 3, larger deviations will be added, based on the WEIGHT parameters (see 2.2.3.13). Place this record directly before the first ARRIVAL TIME record of the fake data set. If an archive phase file is being generated, the arrival times will reflect the added random errors. Each time this job is run a new series of random numbers will be generated because the random number seed is initialized by the time, month, and year of the run.

If the velocity model is also changed, then one can also simulate the systematic errors introduced by not knowing the true earth structure.

Note that an archive file written when SCATTER is in effect will have all of the original arrival times perturbated by random errors.

c) To simulate a non-gaussian distribution, add a record with NONGAUS starting in column 1, fraction of readings with larger error starting in column 20 (f5.2), and factor by which to increase P & S standard errors starting in column 32 (f5.2). for example, to randomly increase P & S standard errors by a factor of 5 10% of the time, use:

```
NONGAUS          0.1          5.0
```

2.2.14 Define a MASTER event for random location study.

To test the hypothesis that all of the events in a set of locations are located at the same hypocenter, and are only apparently shifted due to random reading errors and variations in which phases were read for each event, this option may be used. Set up a "perfect" event (an event with zero RMS residual) located at the hypothesized hypocenter. Place this as the first a set and precede it with a record that has MASTER starting in column 1. Specify the reading errors with a SCATTER record next (see 2.2.13). All events following the first will have their minutes and seconds of P and S replaced with the "master" values. Due to the SCATTER option, the computed locations will vary randomly. The spatial distribution of the resulting random distribution and the summary statistics at the end of the run can be compared with the actual data set to test the hypothesis.

2.2.15 How to generate an ARCHIVE-PHASE FILE

HYPOELLIPSE can be used in a mode that utilizes and generates data in a data base that combines the raw data measurements of the PHASE records, the SUMMARY record, and certain derived parameters for each station such as distance, azimuth, and angle of incidence (Figure 2-1). To set up HYPOELLIPSE to generate this file, simply set SUMMARY equal to 2 or 3. When HYPOELLIPSE is run, FILE11 will be generated with input and derived parameters for each event. See 2.4.2 for format. The ARCHIVE-PHASE FILE for each event is generated as follows:

1) Write out SUMMARY record(s).
   Case 1. The input event included either zero or one SUMMARY records.
      Case 1a. A new earthquake solution was generated. Then: Write a SUMMARY record for the new solution and discard the previous SUMMARY record, if there was one.
      Case 1b. A new solution was not generated. This could happen, for example, if all of the arrivals are weighted out. Then: Write out a FAKE SUMMARY record followed by the SUMMARY record previously associated with the event, if there was one.

   Case 2. The input event included two or more SUMMARY records.
      Case 2a. A new earthquake solution was generated. Then: Write out the new SUMMARY record followed by all but the first of the SUMMARY records previously associated with the event.
      Case 2b. A new solution was not generated. Then: Write out a FAKE SUMMARY record followed by all of the SUMMARY records previously associated with the event.

2) For each station, write out an augmented PHASE record with original phase data and computed data.

3) Write out the original INSTRUCTION record.

The generation of archive-phase files is not compatible with option of running events with more than one INSTRUCTION record (see 2.2.6.3, 'MORE').

OLD DATA BASE	NEW DATA BASE
PHASE records with: raw data measurements.	Archive-phase file with: raw and derived information for each station as well as the derived earthquake solution parameters.
Summary records with: derived earthquake solution parameters, such as location depth, origin time and magnitude.	
Printed listings with: derived station information, such as distance, azimuth, angle of incidence, and magnitude.	

Figure 2-1. Organization of the old and new data base structures. Raw and derived data that were previously stored in three files are now combined into a single ARCHIVE-PHASE FILE.

The ARCHIVE-PHASE FILE may be used as a HYPOELLIPSE input phase file. In that case, the starting location, depth, and origin time will be taken from the first SUMMARY record associated with the event unless overridden by a location, depth, or origin time on the INSTRUCTION record (section 2.2.6.3). The format specification for reading an ARCHIVE ARRIVAL TIME record is as follows:

Item	Col. Nos.	Format
Station name	1 - 4	A4
Any two alphanumeric symbols to describe P phases	5 - 6	A2
First motion direction of P-arrival	7	A1
C or U Compression		
D Dilatation		
+ Poor compression		
- Poor dilatation		
N Noisy		
Blank Not readable		
Z Nodal, and not clearly up or down		
P-phase weight code	8	F1.0
O or blank full weight		
1 Partial weight		
2 Partial weight		
3 Partial weight		
4, 5, 6, 7, 8 No weight		

Item (continued)	Col. Nos.	Format
If the P phase is a secondary arrival refracted along the bottom of the Ith layer, type the value of I here. If event is in the (I + 1)th layer, a direct wave calculation will be made. Below that, the weight is reset to zero.	9	I1
Year, month, day, hour, minute	10 - 19	I10
Seconds of P arrival	20 - 24	F5.2
Distance (km)	*25 - 28	F4.1
AZM - Azimuth from epicenter to station	*29 - 31	F3.0
Seconds of S arrival	32 - 36	F5.2
S remark	37 - 39	A3
S-phase weight code	40	F1.0
AIN - Angle of ray leaving hypocenter	*41 - 43	F3.0
Maximum peak-to-peak amplitude	44 - 47	F4.0
Period of maximum amplitude in sec. If left blank, the standard period as specified in the station list will be used.	48 - 50	F3.2
P travel time computed	*51 - 54	F4.2
P standard error	*55 - 57	F3.2
D, B, M, J, X, R, G, or * weight code (See 2.3.7 for definition)	* 58	A1
Siemens gain state: 0 = high; 1 = low (X1/4)	61	I1
A1VCO gain range state. 0 = high; 1 = X1/10; 2 = X1/500	62	I1
Remark	63 - 64	A2
Corrected first motion symbol	* 65	A1
Time correction in seconds	66 - 70	F5.2
F-P time interval in sec. for FMAG	71 - 75	F5.0
P:RES - Residual of P-arrival in seconds	*76 - 80	F5.2
S standard error	*81 - 83	F3.2
D, B, M, J, X, R, G, or * weight code	* 84	A1
S:RES - Residual of S-arrival in seconds	*85 - 89	F5.2
P delay	*90 - 92	F3.2
S delay	*93 - 95	F3.2
P elevation delay	*96 - 98	F3.2
System response code	*99 - 100	I2
XMAG	*101- 102	F2.1
FMAG	*103- 104	F2.1
Polarity source code	** 105	A1
P arrival source code	** 106	A1
S arrival source code	** 107	A1
Amplitude source code	** 108	A1
Coda duration source code	** 109	A1

Item (continued)	Col. Nos.	Format
Number of satellite hops (NHOP) in telemetry path, each producing a delay of 0.27 seconds. (If a record includes both a P-arrival and an S-arrival, this only applies to the P-arrival source.)	110	I1

* These items are added to the original ARRIVAL TIME record.
** See 4.2.2.2 for a listing of source codes.

Use of Polarity Source Code by HYPOELLIPSE:
STATION records have two fields for keeping track of station polarity (see 2.2.5), the Polarity-Reversal-Indicator in column 34 and the Tape-Polarity-Reversal-Indicator in column 48, and these two indicators do not always agree. The Polarity-Reversal-Indicator is used in correcting the observed first motion unless the polarity source code is S, in which case the Tape-Polarity-Reversal-Indicator is used.

2.2.16 Close current ARCHIVE-PHASE FILE and open new one

In some situations it is desirable to close the archive-phase file specified when the program was started and to open a new file with a different name. To do this, use a record with ARC in columns 1-3 and the new file name in columns 19-68. The ARC record must either be included with the initial input data or follow a RESET record. The following example illustrates a run in which P1.ARC corresponds to P1.PHA and P2.ARC corresponds to P2.PHA.

```
{Items 2.2.1 through 2.2.5}
ARC                 P1.ARC
ARRIVAL TIMES NEXT
JUMP P1.PHA
RESET
ARC                 P2.ARC
ARRIVAL TIMES NEXT
JUMP P2.PHA
```

2.2.17 Use of magnitudes not determined by HYPOELLIPSE

For some earthquakes it is desirable to use a magnitude calculated by another organization, and to enter this magnitude in columns 35-36 of the SUMMARY record as the preferred magnitude. In this situation MAGTYP in column 78 is also set to some code other than F, X, or A. For example, in Alaska we use the following codes:

B PDE mb	H Helicorder
C Canadian ML	S PDE M_S
G Geophysical Institute	O Other
P Palmer ML	

When earthquakes are being rerun, if the SUMMARY record precedes the phase data (See 2.2.15) and has MAGTYP not equal to F, X, or A, then the preferred magnitude and MAGTYP on the newly generated SUMMARY record will not be changed. Thus, the preferred magnitude is preserved through repeated runs of HYPOELLIPSE.

2.3 Printed output

The line-printer outputs of HYPOELLIPSE are generally self-explanatory. The following explanations may be helpful for first time users.

2.3.1 List of stations available (each station uses two lines in the printout)

Heading	Explanation
P THK	Preferred variable layer thickness. Either 1 or 2.
VAR LAYER THICKNESS 1 and 2	Two thicknesses may be specified for the variable layer.
P MOD	Number of velocity model to be used with this station. 1 through 10.
P DLY	Preferred delay. 1 through 5.
PDLY1, SDLY1	Model 1 time delays for P and S arrivals Followed by delays for models 2 through 5.
SYS	System response code. See 2.2.5 on station list for code number assignments.
CALR	Standard calibration for XMAG
XMGC	Amplitude magnitude correction
FMWT	Weight for F-P magnitudes
FMGC	F-P magnitude correction. Multiplies observed F-P interval.
WT P	Replace P-weight code of 0, 1, 2, or 3 with this. Ignored of equal to 10.
WT S	Replace S-weight code of 0, 1, 2, or 3 with this. Ignored of equal to 10.
POL	Two codes are printed, the first for develocorder and the second for tape. If 1, then reverse observed polarity before plotting on focal-sphere. If .GT. 1, plot as question mark.

Heading	Explanation
STAWT	The reading weight is multiplied by STAWT.
TLDLY	Correction to be added to the observed time Used for satellite delays for USGS Alaska data.
YRMODY	Year, month, and day of expiration of time-dependent station parameters.
HRMN	Hour and minute of expiration

2.3.2 Program specifications

The TEST variables and abbreviated definitions are printed out so that each run is well documented. The s used and the velocity models are also printed out.

2.3.3 Vp/Vs ratio

If the Vp/Vs-value is in effect (see TEST(49), section 2.2.4) the computed Vp/Vs ratios are printed out. See Chapter 5 for an explanation of the calculations.

2.3.4 Iteration output

It is recommended that PRINTER 1 be used. One line will then be printed per iteration as follows:

Heading	Explanation
I	Iteration step. If a particular step is repeated, I is also repeated.
LAT	Minutes of latitude
LON	Minutes of longitude
DEPTH	In kilometers
*	If depth constrained.
RMS	If the residuals are R_i and the weights are W_i, i = 1, N, then

$$RMS = \left[\frac{\sum_1^N W_i R_i^2}{\sum_1^N W_i} \right]^{\frac{1}{2}}$$

Heading	Explanation
NO	Number of P, S and S-P readings used
PRMS	RMS predicted for after the next step. See section 4.4 for discussion.
DAMP	Value of damping constant in use. See section 4.
EIGENVALUES	The three eigenvalues of the spatial normal equations.
ADJUSTMENTS DLAT DLON DZ	The adjustments in the principal directions are converted into changes in latitude, longitude, and depth.
ADJST. TAKEN DLAT DLON DZ	This adjustment will be taken to reach the next iterative location. The limits imposed by the TEST variables have been applied.

2.3.5 Quality

2.3.5.1 Based on error estimates

This quality is based on SEH (the horizontal 68 percent confidence limit in the least well constrained direction) and SEZ (the 68 percent confidence limit for depth). See Chapter 3 for further explanation of SEH and SEZ. Note that the following limits are modified from those used previous to April 1984 to reflect revised definitions of ERH and ERZ.

Quality	Larger of SEH and SEZ
A	$\leq$ 1.34
B	$\leq$ 2.67
C	$\leq$ 5.35
D	> 5.35

2.3.5.2 Quality based on many parameters

SQD-HYPO71 Quality

S is the solution quality as defined in HYPO 71:

S	RMS	SEH*	SEZ**
A	< 0.15	≤ 1.0	≤ 2.0
B	< 0.30	≤ 2.5	≤ 5.0
C	< 0.50	≤ 5.0	
D	Others		

* SEH is the horizontal 68 percent confidence limit in the least well constrained direction.

** SEZ is 68 percent confidence limit for depth.

Q is used just as a spacer between S and D qualities.

D is the station distribution quality as defined in HYPO71:

D	NO	GAP	DMIN
A	≥ 6	≤ 90	≤ DEPTH or 5 km
B	≥ 6	≤ 135	≤ 2*DEPTH or 10 km
C	≥ 6	≤ 180	≤ 50 km
D	Others		

DMIN is the distance to the nearest station.

2.3.6 Final summary output lines

Heading	Explanation
SE OF ORIG	Standard deviation of origin time.
EVENT TYPE	Column 90 of SUMMARY record (see section 2.4.1).
EVENT STATUS	Column 72 of SUMMARY record (see section 2.4.1).
DMAX	Final value of XFAR, based on TEST(12) and TEST(46).
SEQ NO	Sequence number - taken from columns 92-96 of SUMMARY record preceding this event.
Date Origin Lat Lon Depth	If solution based only on S-P data, an * will follow date.

Heading	Explanation
MAG	Preferred magnitude. Also entered on SUMMARY record in columns 35-36. See 2.2.3.3, 2.2.17, and 2.4.1.
NO	Number of P, S, and S-P readings used in the solution.
D1	Distance to the closest station used in the solution.
GAP	Largest azimuthal separation in degrees between stations as seen from the epicenter.
D	Number of delay model used (1 to 5)
RMS	If the residuals are R_i and the weights are W_i, i = 1, N, then $$RMS = \left[\frac{\sum_1^N W_i R_i^2}{\sum_1^N W_i} \right]^{\frac{1}{2}}$$
AVWT	Weights are normalized so that their sum equals NO by dividing each weight by the average weight, AVWT.
SEH	Horizontal 68 percent confidence limit for the least well constrained direction.
SEZ	68 percent confidence limit for depth.
Q - HYPO71	Average of S and D qualities defined in C.4. Rounded to lower quality when necessary.
SQD	S and D qualities defined in C.4.
ADJ	Length (km) of final adjustment of hypocenter.
I	S data indicator. O - S not used 1 - S is used
N	Fixed location indicator. O - nothing fixed 1 - depth fixed at trial depth 8 - origin time fixed at trial origin time 9 - location fixed at trial hypocenter

Heading	Explanation
NR	Total number of P, S, and S-P readings
AVR	Average weighted residual.
AAR	Average of the absolute value of the weighted residuals.
NM	Number of stations at which amplitude magnitude (SMAG) was calculated.
AVXM	Average XMAG.
MDXM	Median XMAG.
SDXM	Standard deviation of XMAG's calculated, with respect to AVXM.
NF	Number of stations at which F-P magnitude (FMAG) was calculated.
AVFM	Average FMAG.
MDFM	Median FMAG
SDFM	Standard deviation of FMAG's calculated, with respect to AVFM.

2.3.7 Detailed station output: TRAVEL TIMES AND DELAYS:

Heading	Explanation
STN	Station name
C	Component blank - vertical N - north-south horizontal E - east-west horizontal
PHA	Phase P - P-phase S - S-phase SMP - S minus P interval
REMK	Phase remark (columns 508 of PHASE record)
P	First motion polarity, corrected as per station history
PSEC	Seconds of P-arrival as typed on ARRIVAL TIME record
SSEC	Seconds of S-arrival as typed on ARRIVAL TIME record

Heading	Explanation
RESID	Residual in seconds If a character follows the residual the meaning is: D Weight reduced to zero by distance weighting. B Weight reduced to zero by boxcar weighting. M Weight reduced to zero by truncation weighting. J Residual is greater than 3 standard deviations from the mean. Used with Jeffrey's weighting. X Weight reduced to zero during critical station run (see TEST(44)). R Computed weight less than 0.0005, so set to zero. G Beyond distance weighting cutoff but included in order to reduce gap (See TEST(46)). * Large residual flagged by RESIDUAL OPTION (See 2.2.3.12).
STD-ER	Standard error(s) used for this arrival in hypocentral solution. The weight assigned to each phase is proportional to the inverse square of the standard error of the phase.
DIST	Epicentral distance of station (km)
AZM	Azimuth of station from epicenter (degree)
AIN	Angle of ray leaving hypocenter measured with respect to downward vertical (degree)
TC	Station clock correction in sec. from ARRIVAL TIME record. Added to observed arrival time.
C	Velocity model used for this travel time
VTHK	This is the thickness of the variable layer in km for the velocity model used.
TTOB	Travel time observed (sec)
TTCAL	Travel time calculated (sec)
DELAY	Station delay in seconds for model preferred by closest station
EDLY	Elevation delay (sec)
RMK	Remark from columns 63-64 of PHASE record
STN	Station name

Heading	Explanation
SOURCES	Phase data sources followed by number of satellite hops, columns 105-110 of original PHASE record.
MAGNITUDE DATA:	
SOURCE	Amplitude source code from column 108 of ARRIVAL TIME record
SYS	System response used in computing magnitude
C10	XMAG calibration constant
AMX	Maximum amplitude in mm from input data
GR	A1VC0 gain range state, 0 = normal; 1 = X1/10; 2 = X1/500
INK	Siemens playback gain, 0 = high; 1 = low (X1/4)
AMF	Maximum amplitude, corrected for gain state and Siemens gain
PER	Period of wave where maximum amplitude was read. If PR is not given on ARRIVAL TIME record, then standard period from station archive is used. The default is 0.1s.
XMAG	Amplitude magnitude. An 'e' (for Excluded) follows if XMAGWT = 0; if not, an '*' follows XMAG if XMAG - AVXM > 0.5.
FMP	F-P time interval in seconds.
FMAG	Coda magnitude. An S follows if the coda was too short with respect to the S-P time for a coda magnitude to be computed; if not, an 'e' (for Excluded) follows if FMAGWT = 0; if not, an * follows FMAG if FMAG - AVFM > 0.5. An "e" follows the XMAG and FMAG value if the magnitude weight for this station is zero.

2.3.8 Auxiliary RMS sphere output

At times there may be a concern that the final iterative earthquake location is not the best one possible. If TEST(6) .NE. 0.0, then the RMS residual is calculated at 14 points on a sphere of radius = TEST(6) centered on the final hypocenter. If the hypocenter is at a minimum of RMS in space, then all the points on the sphere will have larger RMS values than the center point. The DRMS is the RMS on the sphere minus the RMS at the center and will be positive for good locations.

The average DRMS values at the ends of seven diagonals through the sphere are calculated. These are printed in order of poorest to greatest location control and are specified by their down dip azimuths.

If TEST(6) is negative and if a point on the sphere has lower RMS than the center of the sphere, iteration will resume at that point in order to improve the solution. This is allowed only once per earthquake solution to prevent an infinite loop condition from arising.

A tabulation is printed listing the number of readings used, the RMS at the center, the minimum DRMS, the average DRMS, and a quality based upon these values as follows:

Q	NUMBER	RMS	MIN DRMS	AVE DRMS
A	≥ 6	≤ 0.2	≥ 0.3	
B	≥ 5	≤ 0.4	≥ 0.15	
C	≥ 4	≤ 0.4		≥ 0.5
D	Others			

2.3.9 Focal mechanism plot

If the number of first motions is greater than or equal TEST(7) a focal mechanism plot will be made on the printer. The diagram is an equal-area projection of the lower hemisphere of the radiation field. The symbol printed is as follows:

+	1 or more +'s
C	1 compression
B	2 compressions
A	3 or more compressions
X	Any combination of compressions and dilatations
-	1 or more -'s
D	1 dilatation
E	2 dilatations
F	3 or more dilatations
?	Indicates that although a first motion was reported, the station polarity is uncertain.

A +, -, or ? is printed only if the position is not occupied by a compression or a dilatation.
If TEST(7) < 0 a second plot will be made showing station names on the focal sphere.
Use TEST(45) = .1379 for 8.5 inch paper and TEST(45) = .10106 for 11 inch paper.

2.3.10 Final Tabulation

At the end of each run of a set of earthquakes a table is printed which gives the number of earthquakes within each quality specification. There is also a table which shows for each station the number of times the station was used (N), the average weight (WT), the weighted average residual (AVE), and the standard deviation of the residuals about their mean (SD). The TABULATION option (see 2.2.3.4) controls the quality of the events included in this table.

For P- and S-arrivals there are sets of two columns in the table. The first bases the weight for the i^{th} residual from the k^{th} event only on the final weight prior to normalization, WT_{ik}, used in locating the k^{th} event. The second also includes an event weighting factor, F, based upon the number of arrivals and their weights used in locating each event. For the k^{th} event:

$F_k = SUMWT_k * (NRWT - 4)/NRWT_k$, $NRWT_k$ greater than 4

$F_k = 0.0$, $NRWT_k$ less than or equal 4

where $NRWT_k$ is the number of readings used in locating the k^{th} event, and SUMWTk is the sum of the weights (WT_{ik}) of the arrivals of the k^{th} event. Inclusion of the factor F in the weights used to compute the average station residual will bring the average residual into closer agreement with the modification in station correction that would be obtained from a joint inversion of all of the events for both location and station correction. Pavlis and Hokanson (1985) suggested using $SUMWT_k$ for this purpose. The addition of the degree of freedom term, (NRWT - 4)/NRWT should further improve the technique, in that the residual pattern for an event with few degrees of freedom will be unlikely to reflect the true station residuals. For data sets consisting of a large number of events, iterative modification of the station corrections using this table of averages and then relocating the earthquakes will give approximately the same results as joint inversion for both locations and station corrections (Pavlis and Booker, 1983; Pavlis and Hokanson, 1985).

If a station is given zero weight on its STATION record (section 2.2.5) it will be included in the tabulation even though it has not been used in any of the solutions. In this case the station name will be proceeded by a 'W'. If a station is assigned a P-weight code replacement of 4-8 on the TIME-DEPENDENT STATION parameter record (section 2.2.5.3), then the summary will include average P-residual information even though the P-arrivals were not used, and the P-residual standard deviation will be followed by a 'P'. The S-residual standard deviation will be followed by an 'S' in analogous situations. In either this case or the case where the station weight is zero the weight used in tabulation is based on the P-weight-code on the ARRIVAL TIME record (See section 2.2.6).

WARNING: The station weight and the P- and S-weight replacement codes are time dependent parameters specified in the station list. The final tabulation assumes, however, that the station weight for a given station was either zero or non-zero during the entire run, and similarly, that the weight code replacements either were or were not within the range 4-8 or not during the entire run. If these assumptions are not correct, the tabulation will be in error.

2.4 Summary record output

The SUMMARY record output is controlled by the SUMMARY OPTION record described in section C.3. The STATION records are generated in the same format as the input STATION records. The other formats are given below.

2.4.1 Summary record

To save space no decimal points are used. Use the format for reading given below.

Item	Col. Nos.	Format for Reading
Origin Time:		
KDATE - year, month, day	1 - 6	I6
KHRMN - hour, minute,	7 - 10	I4
seconds	11 - 14	F4.2
LAT degrees	15 - 16	I2
N or S	17	A1
LAT minutes	18 - 21	F4.2
LON degrees	22 - 24	I3
E or W	25	A1
LON minutes	26 - 29	F4.2
DEPTH (km)	30 - 34	F5.2
PREFERRED MAGNITUDE	35 - 36	F2.1
NO - Number of P, S, and S-P readings used in the solution	37 - 39	I3
GAP - Largest azimuthal separation in degrees between stations as seen from the epicenter (deg.)	40 - 42	I3
D1 - Distance to closest station used in solution (km)	43 - 45	F3.0
RMS (sec)	46 - 49	F4.2
Azimuth of axis 1 of error ellipsoid (deg)	50 - 52	I3
Dip of axis 1 (deg)	53 - 54	I2
SE - length of ellipsoid semi-axis 1 (km)	55 - 58	F4.2
Azimuth of axis 2 of error ellipsoid (deg)	59 - 61	I3
Dip of axis 2 (deg)	62 - 63	I2
SE - length of ellipsoid semi-axis 2 (km)	64 - 67	F4.2
Average XMAG	68 - 69	F2.1
Average FMAG	70 - 71	F2.1
Processing state (not used by HYPOELLIPSE)	72	A1
* - More data available to be added		
P - Preliminary, but location not finalized		
F - Final location determined		
G - NEIS solution		
I - Insufficient data to determine a hypocenter		
N - Not of principal interest		
SE - length of ellipsoid semi-axis 3 (km)	73 - 76	F4.2

Item	Col. Nos.	Format for Reading
Quality - either error ellipsoid quality or HYPO quality depending upon QUALITY OPTION record. (See section 2.2.3.4)	77	A1
MAGTYP - F, X, A, or K to indicate which type of magnitude is entered in columns 35-36. (See sections 2.2.3.3 and 2.2.17)	78	A1
NSWT - Number of S-phase arrivals used in solution.	79 - 80	I2
/ or \ [The primary SUMMARY record is always first and has a / in column 81. If an archive file has more than one SUMMARY record, the second and subsequent records will have a \ in column 81.]	81	A1
First 4 characters of INSTRUCTION record	82 - 85	A4
Month data was run	86 - 87	I2
Year data was run	88 - 89	I2
Event type:	90	A1

E or blank	local or regional earthquake
T	teleseism
N	nuclear explosion
G	glacial event
X	emergent, low frequency, near volcano
Q	quarry shot
A	artificial explosive source other than quarry
O	other non-earthquake (eg sonic boom)
C	calibration signal

Once the event type has been placed on the SUMMARY record of an earthquake in archive format, it will be transferred to succeeding SUMMARY records generated by later runs of HYPOELLIPSE.

Fixed location indicator, from column 19 of INSTRUCTION record	91	I1
Sequence number	92 - 96	A5
S-P time at closest station used in solution. Blank if either P or S is not used. Set to 9999 if S-P .GE. 100.	97 - 100	F4.2
ZUP - Computed with GLOBAL OPTION.	101- 102	F2.0
ZDN - Computed with GLOBAL OPTION.	103- 104	F2.0
Vp/Vs - Computed slope of Ts vs Tp. Only computed if TEST(49) is not equal 0.	105- 108	F4.2
Number of readings weighted out due to Jeffrey's, truncation, or boxcar weighting.	109- 110	I2

2.4.2 Phase records in input format with corrected arrival times

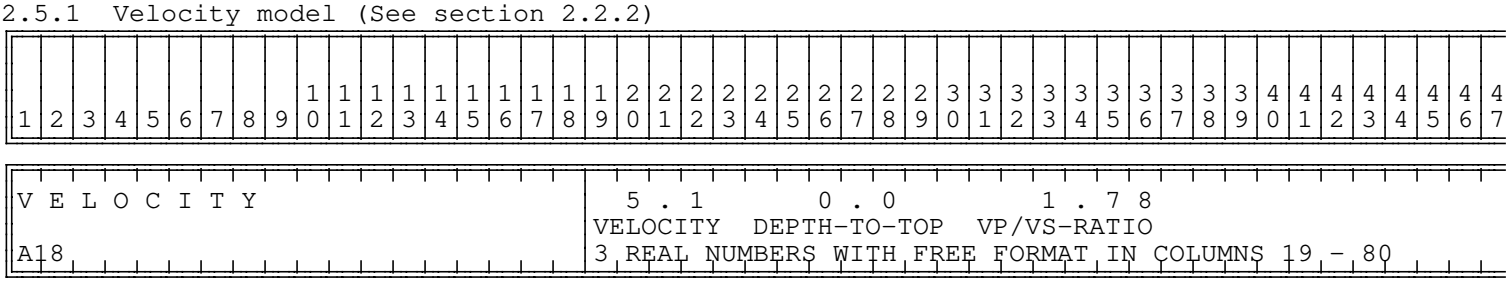
This option will create a "perfect" set of data which then may be used to check the HYPOELLIPSE program. For example, one might want to know how well the program would work on events in some particular region. Fixed solutions specifying this epicentral region could be run with SUMMARY OPTION 5 and test earthquakes would be generated. The "perfect" data will be generated as follows:

Item	Col. Nos.	Format for Reading
Station name	1 - 4	A4
KDATE	10 - 15	I6
KHRMN	16 - 19	I4
SPEC - P - arrival time	20 - 24	F5.2
SSEC - S - arrival time	32 - 36	F5.2

2.5 Summary of important formats

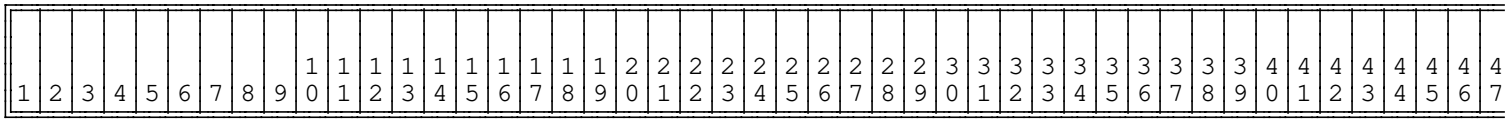
Formats are illustrated here for many of the input and output items. Each field includes a typical entry, an abbreviated explanation, and the format for reading the field. For more details, refer to the sections indicated.

2.5.1 Velocity model (See section 2.2.2)



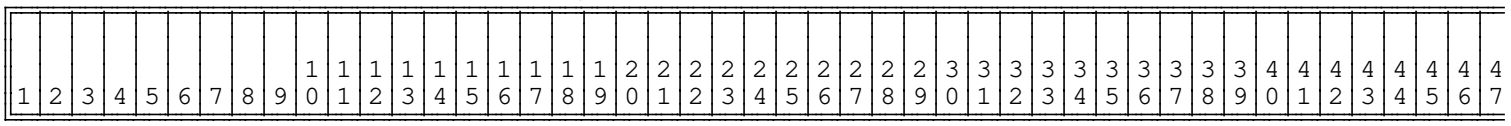
V E L O C I T Y A18	5 . 1 0 . 0 1 . 7 8 VELOCITY DEPTH-TO-TOP VP/VS-RATIO 3 REAL NUMBERS WITH FREE FORMAT IN COLUMNS 19 - 80

2.5.2 Header (See section 2.2.3.15)



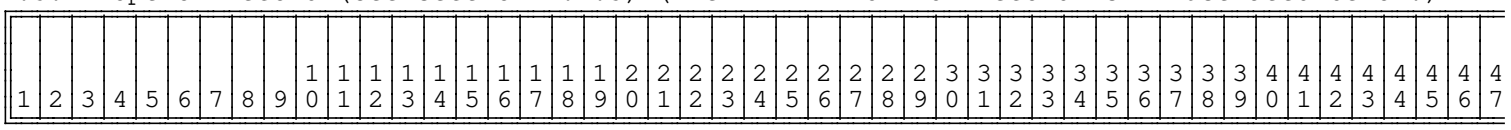
H E A D E R A18	ANY HEADING IN COLUMNS 19 - 68 A50

2.5.3 Reset test (See section 2.2.4)



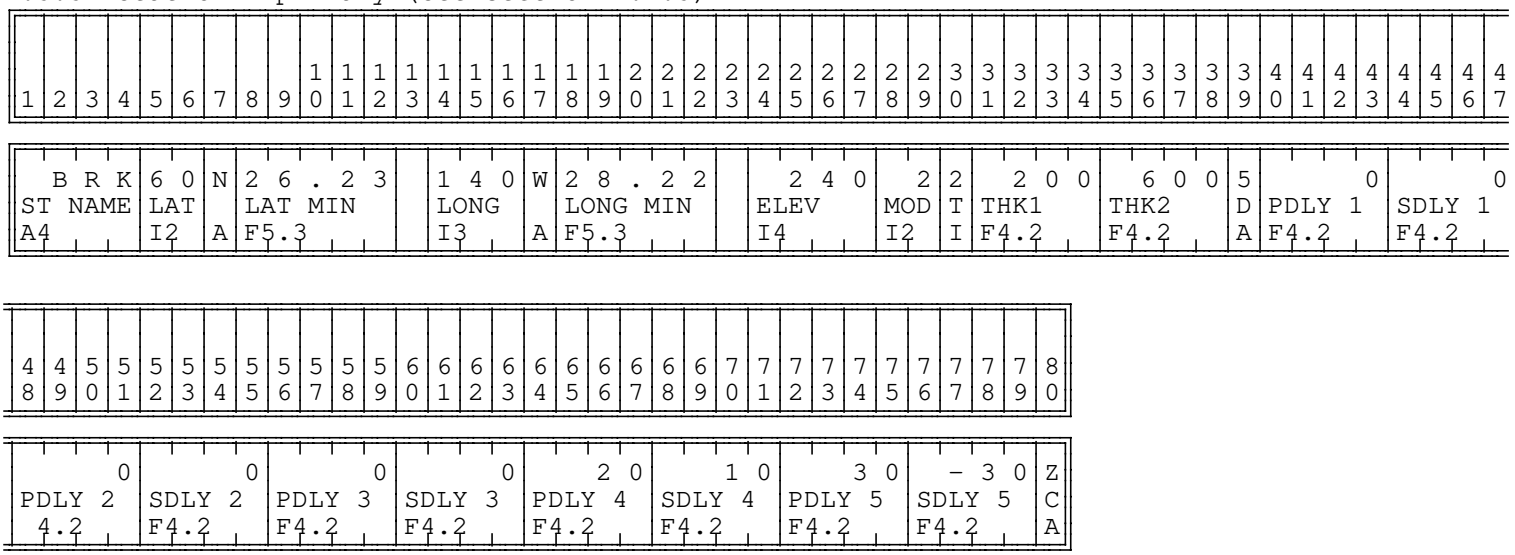
R E S E T T E S T A18	2 1 1 5 . TEST # NEW VALUE 2 REAL NUMBERS WITH FREE FORMAT IN COLUMNS 19 - 80

2.5.4 Option record (See section 2.2.3) (The PRINTER OPTION record is illustrated below.)



P R I N T E R O P T I O N A18	2 PRINTER OPTION NUMBER 1 INTEGER NUMBERS WITH FREE FORMAT IN COLUMNS 19 - 80

2.5.5 Station – primary (See section 2.2.5)



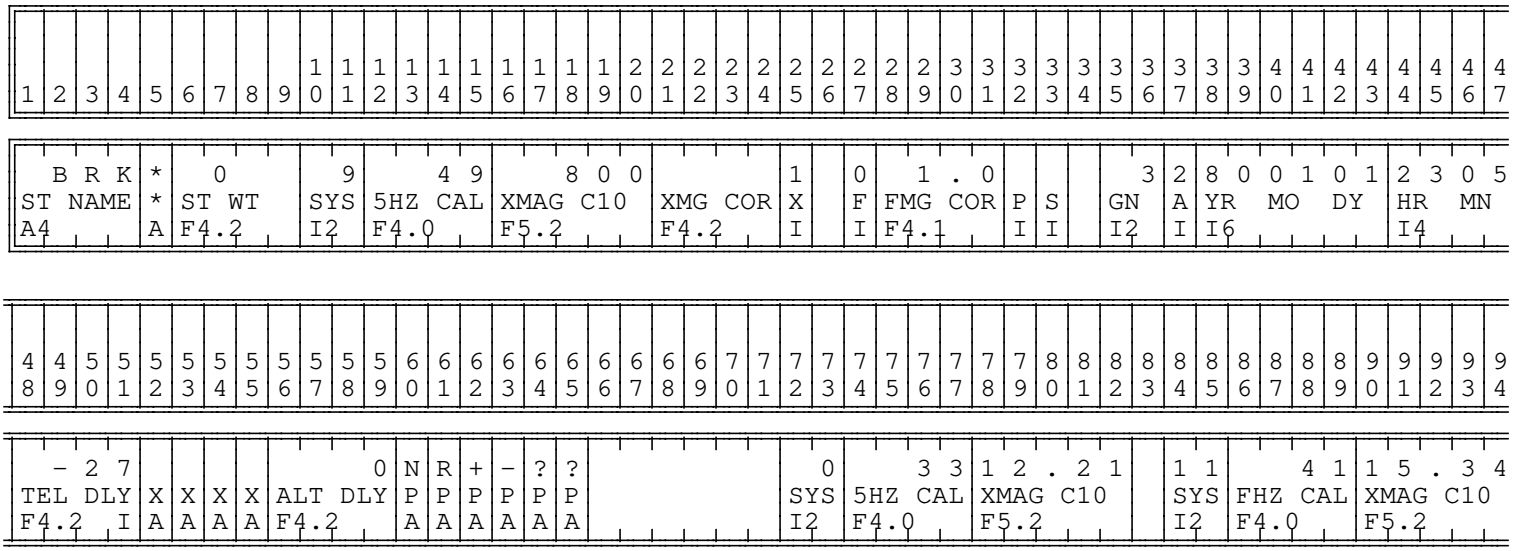
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

BRK ST NAME A4	60 LAT I2	N A	26.23 LAT MIN F5.3		140 LONG I3	W A	28.22 LONG MIN F5.3		240 ELEV I4	2 MOD I2	2 TI	200 THK1 F4.2	600 THK2 F4.2	5 DA	0 PDLY 1 F4.2	0 SDLY 1 F4.2

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

0 PDLY 2 4.2	0 SDLY 2 F4.2	0 PDLY 3 F4.2	0 SDLY 3 F4.2	20 PDLY 4 F4.2	10 SDLY 4 F4.2	30 PDLY 5 F4.2	-30 SDLY 5 F4.2	ZCA

2.5.6 Station – time dependent (See section 2.2.5)



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

BRK ST NAME A4	* * A	0 ST WT F4.2	9 SYS I2	49 5HZ CAL F4.0	800 XMAG C10 F5.2	XMG COR F4.2	1 XI	0 FI	1.0 FMG COR F4.1	PI	SI	3 GN I2	2 AI	80010101 YR MO DY I6	2305 HR MN I4

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94

-27 TEL DLY F4.2 I	X A	X A	X A	X A	0 ALT DLY F4.2	N PA	R PA	+ PA	- PA	? PA	? PA		0 SYS I2	33 5HZ CAL F4.0	12.21 XMAG C10 F5.2		11 SYS I2	41 FHZ CAL F4.0	15.34 XMAG C10 F5.2

95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132

	12 SYS I2	78 FHZ CAL F4.0	8.76 XMAG C10 F5.2		13 SYS I2	154 FHZ CAL F4.0	5.21 XMAG C10 F5.2	58.21 REVIS LAT F5.3	58.21 REV LON F5.3	390 REV ELE I4

2.5.7 Arrival time (See section 2.2.6.2)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

BRK ST NAME A4	IP A2	UMA	2WI	I	7908 YR MO	0610 DY HR	41 MN	15.31 SEC F5.2		19.38 S-SEC F5.2	ES SRMK A3	3WI		22 MX AMP F4.0

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75

1 PER F3.2			OSI	OVI	TL RMK A2		0 TIME COR F5.2	200 F-P TIME F5.0

2.5.8 Instruction (See section 2.2.6.3)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

MORE IPRO A4		*SA	ETA			1SI	0FI	TRIAL Z F5.2			61 LAT 2,0	N A	31.5 LAT MIN F5.2

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80

2		142 LON F3.0	W	59.01 LON MIN F5.2		CUSP ID A10			42 MIN 2,0	40.13 SECONDS F5.2

2.5.9 Archive arrival time (See section 2.2.15)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

B R K	I P	U	2		7 9 0 8 0 6 1 0 4 1	1 5 . 3 1	6 2	2 9	1 9 . 3 8	E S	3	1 0 5	2 2
ST NAME		M	W		YR MO DY HR MN	SEC	DIST	AZIM	S-SEC	SRMK	W	A INC	MX AMP
A4	A2	A	I	I	I10	F5.2	F4.1	I3	F5.2	A3	I	I3	F4.0

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92

1	2 1 3 8	9 0	M		0	0	T L	D	0	2 0 0	6 2 1	1 3 1		8 2	0
PER	PTT CAL	P SE	R		S	V	RMK	M	TIM COR	F-P TIME	P RESIDU	S SE	R	S RESIDU	PDLY
F3.2	F4.2	F3.2	A		I	I	A2	A	F5.2	F5.0	F5.2	F3.2	A	F5.2	F3.1

93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110

0	2 9	1	1 6	2 3	E	E	E	E	E	1
SDLY	EDLY	SYS	XMG	FMG	P	P	S	A	C	H
F3.1	F3.1	I2	2,1	2,1	A	A	A	A	A	I

2.5.10 Summary (See section 2.4.1)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47

7 9 0 8 0 6	1 0 4 1	0 5 1 E	4 3	N	1 6 3 2	1 2 2	W	4 9 5 3	5 3 2	4 2	1 5	2 2 0	8 2	
YR MO DY	HR MN	SEC	LAT		LAT MIN	LON		LON MIN	DEPTH	MAG	N PHA	GAP	DIST1	RMS
I6	I4	F4.2	I2	A	F4.2	I3	A	F4.2	F5.2	2,1	I3	I3	F3.0	F4.

48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94

4 9	3 1	2	8 2 2	1 2 1	4	6 3 8	2 0	2 2	F	1 2 5 7	C	F	3	/	M O R E	1 0 7 9	E	0	E 0 1
	AZIM	DIP	STD ER	AZIM	DIP	STD ER	XMG	FMG	P	STD ER	Q	M	N S	/	INST	MO YR	T	F	SEQ
2	I3	I2	F4.2	I3	I2	F4.2	2,1	2,1	A	F4.2	A	A	I2	A	A4	A4	A	I	A5

95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110

9 3	7 8 1	5	4	1 7 7	3
NUM	S-P TIM	ZUP	ZDN	VP/VS	WTO
	F4.2	2,0	2,0	F4.2	I2