FEASIBILITY OF COMPLETELY AUTOMATED MICROFOSSIL IDENTIFICATION IN PETROLEUM EXPLORATION

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ABSTRACT

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By

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The purpose of this study is to explore the possiblity of eliminating the time-consuming aspect involved in conventional methods of identifying ostracodes. Using computerized methods, this work can be accomplished with greatly increased rapidity and productivity in identification. Initially, this study attempts to differentiate 91 species of Mesozoic and Cenozoic ostracodes that have been selected on the basis of their proven usefulness in biostratigraphic correlation and identify them on the basis of shape using Fourier shape analysis. This method, developed by Ehrlich and Weinberg (1970), exactly describes two-dimensional shape in a multivariate fashion.

The Fourier series generated 55 shape variables for use in the identification process. The objective of this study was to find the optimum combination of the variables generated by the Fourier series and the optimum clustering methods for the identification of ostracode

guide fossils. Parks' (1970) program using simple distance based on principal component values with results illustrated in dendrogram form enables interpretation of specimen clustering.

Twenty specimens (12 species) were added later for species-level identification. After 53 specimens associated with sampling design error were omitted, a final cluster analysis was run with the remaining 58 specimens. Of these 58 specimens, 9 were replicated at the species level. Using the most optimal clustering method, the results indicated that only one specimen, *Bythocypris* (?) *gibsonensis*, was misidentified at the species level. This specimen was doubtfully assigned to the species *gibsonensis* and may belong to some other species.

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Dedicated to my wife, Sue, for her assistance and support throughout this study.

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INTRODUCTION

Microfossils are useful in petroleum exploration for three basic reasons: (1) biostratigraphic correlation; (2) environmental analysis in depositional basins; and (3) they are retrievable from the subsurface in well cuttings. Therefore, microfossils are economically useful. One major problem is that they have been difficult to use because conventional identification is tedious and time-consuming and the identifier must search through a prolific literature beset with some degree of taxonomic chaos. Even present practices by competent professionals do not insure complete accuracy in all taxonomic assignments. Greater efficiency and productivity in such work could be obtained by utilizing trained specialists in the development of highly automated identification systems that could be operated by nonpaleontologists and still yield a significant proportion of accurate identifications.

The purpose of this study is to explore the possibility of eliminating the time-consuming aspect of identification by creating a completely automated system for the identification of microfossils. Through the automation of large portions of the identification process, such work can be accomplished by less highly skilled workers with extreme rapidity of identification and prodigiously increased output. Needless to say, such an increase in productivity could be of great economic value.

Fourier analysis has been proven successful in "automatically" identifying a wide range of different types of microfossils from both two-dimensional outlines and photographic images of the complete fossil. Developed in an optimal way by Ehrlich and Weinberg (1970), who applied it successfully to inorganic forms, this shape analysis method exactly describes two-dimensional shape. In a controlled experiment, two Soviet workers, Mirkin and Bagdasaryan (1972), successfully identified unknown micro-paleontological objects, using an optical Fourier series taken from photographed images of the entire microfossil. Their samples included spore and pollen grains, diatoms, and phytoplankton. Successful results in ostracode identification using Ehrlich and Weinberg's method have been achieved by Younker (1971, 1974) and Kaesler and Waters (1972). Christopher and Waters (1975) demonstrate the utility of the same method for palynomorphs. These studies suggest that with the use of an optical scanner to obtain the two-dimensional outlines automatically, and a minicomputer programmed to calculate the Fourier series (and having memory capacity sufficient to store the Fourier amplitudes of a wide range of known forms), the identification process could be accomplished with extreme rapidity and productivity with a minimal loss of accuracy.

As a means of seeking quantitative solutions to the mass identification of microfossils for use in petroleum exploration, this study attempts to differentiate 91 species of Mesozoic and Cenozoic ostracodes and identify them on the basis of shape using the Fourier series. These 91 species have been selected on the basis of their proven usefulness in biostratigraphic correlation. Thus this study, unlike previous studies, specifically emphasizes the machine identification of taxa having potential economic importance. Automated identification poses several problems in that a great variety of options are available to any investigator desirous of building such a system. It is known that the Fourier method is operational, but the precise combination of options for optimal machine-processing is not clearly defined. Thus, the objective of this study is to search for the optimum combination of the variables generaged by the Fourier series and the optimum clustering methods for the identification of ostracode guide fossils.

Complete automation of this method is desired if it is to eliminate the time-consuming aspects. This study includes in its equipage a sonic digitizer interfaced to computers that contain the necessary programs for the ultimate clustering analysis. This thesis, however, introduces some degree of human error because the digitizing of the estracode outline is done semi-manually. A device made by Visicon, Inc., called the GC-3A, is a fast, accurate, compact, and inexpensive terminal for the completely automatic conversion of graphic data to digital data. The Visicon GC-3A uses a raster scan type of optical/electronic digitizing. The GC-3A automatically scans and digitizes the information. This device, coupled to the stage of a microscope, such as the automatic coordinate recorder discussed by Scott (1975), would achieve great accuracy because the raster scan would more accurately depict the outline boundaries, the human error in digitizing would be eliminated. The only limitations in this process involve the (minimal) time factor necessary to present the prepared specimens to the optical scanner. Thus this study proposes to test the usefulness of Fourier analysis in a wide variety of Mesozoic and Cenozoic ostracode species that have been proven to be successful index or guide fossils to petroliferous horizons. The results obtained will provide a direct test of the economic usefulness of these computer-based techniques, and will determine, as a first approximation, the feasibility of completely automated identification systems in industrial applications.

METHODS

Material

Photographs of 91 different species of ostracodes, all guide fossils from the Cenozoic and Mesozoic, were collected from published literature for preliminary study at the family and generic levels. The majority of these are Cenozoic and are common to the Gulf Coast area of the United States and its petroliferous horizons. Illustrations of 20 additional specimens of 12 of the same species were obtained for comparison and identification at the species level.

Outlines were drawn from projections of published photographs (Shimer & Shrock, 1944; Ellis & Messina, 1952-1971; McLean, 1957; Moore, 1961). The photographs of these 11 ostracode specimens were the experimental units for this study. When possible the right valve view was selected. Of these 111 photographs, 53 were later eliminated because they were known to be females (8), juvenile instars (7), and improper views (38). Improper views include left valve images and other views that were not right valves. The reason for their elimination is because these sources of potential error occurred in a majority of specimens that were misidentified in the final clustering of the total 111 specimens. Of the remaining 58 specimens (51 species), nine are of species that have multiple representatives for use in testing species-level identification (Table 1).

Fourier Shape Analysis

The Fourier method of shape characterization (harmonic analysis) was first developed and used in studies of closed forms in geology by Ehrlich and Weinberg (1970). Fourier descriptors are very good shape discriminators; the proof of the optimality of Fourier series has been established (Zahn & Roskies, 1972). To obtain the Fourier series of each shape, the origin of a set of polar coordinates was centered over the projected photograph such that the valve length corresponded to the 0°-180° axis, and the breadth to the 90°-270° axis. In this way, all shapes were orientated in a consistent manner. The radii of each shape (measured from the approximate center of gravity of each form to the valve periphery) were spaced at 6° intervals yielding 60 radiating lines in a sunburst pattern. The intersection points of the traced outline and the sunburst grid were digitized in Cartesian coordinates. The punched coordinates of the 111 outlines were used as input to program Fourier (Appendix I). The measurements were used to compute a Fourier series including calculation of the mean radius (the mean radius is

Table 1.--Classification of specimens used in shape analysis and the geologic horizons of which they are indices.

I. Order Podocopida	
A. Suborder Metacopina	
Superfamily Healdiacea	
Family Bairdiocyprididae	
Bairdiocypris morrisonensis Roth, 1933	Lower Morrison Fm.
B. Suborder Platycopina	
Family Cytherellidae	
Cytherella marlboroensis Ulrich, 1901	Aquia Fm., Paspotansa Mb.
Cytherella ovata (Roemer, 1840)	Navarro Group
C. Suborder Podocopina	
Superfamily Bairdiacea	
Family Bairdiidae	
Bythocypris gibsonensis Howe and Chambers, 1935	L. Jackson--L. Chickasawhay Marl
Bythocypris goodlandensis Alexander, 1929	Fredericksburg Group, Goodland Fm.
Bythocypris subaequata Ulrich, 1901	Aquia Fm., Paspotansa Mb.
Superfamily Cypridacea	
Family Paracyprididae	
Paracypris perapiculata Alexander, 1934	Midway Group, Wills Point and L. Kincaid Fms.
Superfamily Cytheracea	
Family Brachycytheridae	
Brachycythere interrasilis Alexander, 1934	Midway Group, Kincaid and Wills Point Fms.
Brachycythere ledaforma (Israelsky, 1929)	Navarro Group
Brachycythere ledaforma erugata Crane, 1965	L. Taylor Marl--Austin Chalk
Brachycythere sphenoides (Reuss, 1854)	Taylor Marl--Austin Chalk
Digmocythere russelli (Howe and Law, 1936)	Claiborne--Vicksburg Fms.
Pterygocythereis cornuta americana Ulrich and Bassler, 1904	Calbert Fm., L. Plum Point Marl Mb.
Family Bythocytheridae	
Monoceratina pedata (Marsson, 1880)	U. Cret. (Wide Range)
Monoceratina rossae Alexander, 1934	Midway Group, U. Wills Point Fm.
Family Cytherideidae	
Subfamily Cytherideinae	
Anomocytheridea floridana (Howe and Hough, 1935)	Choctawhatchee Fm.
Clithrocytheridea garretti Howe and Chambers, 1935	Lowermost Jackson Fm.
Haplocytheridea blanpiedi Stephenson, 1936	Vicksburg Group
Haplocytheridea monmouthensis Berry, 1925	Monmouth Fm.
Subfamily Eucytherinae	
Eucythere brightseatensis (Berry, 1925)	Monmouth Fm.
Eucythere brownstowensis Alexander, 1936	Uppermost Austin Chalk, L. Brownstown Marl
Eucythere chickasawhayensis Howe, 1936	Vicksburg Group--L. Chickasawhay Marl
Eucythere woodwardensis Howe, 1936	Uppermost Vicksburg Group, Byram Marl
Subfamily Neocytherideidinae	
Neocytherideis ashermani Ulrich and Bassler, 1904	Calvert Fm., L. Plum Point Marl Mb.
Family Cytheruridae	
Cytheropteron galericulum Howe and Law, 1936	Uppermost Vicksburg Group, Byram Marl
Cytheropteron midwayensis Alexander, 1934	Midway Group, Lowermost Wills Point Fm.
Cytheropteron montgomeryensis Howe and Chambers, 1935	L. Jackson Fm.
Cytheropteron navarroense Alexander, 1929	Navarro Group
Cytherura byramensis Howe and Law, 1936	Uppermost Vicksburg Group, Byram Marl
Cytherura cretecea Alexander, 1936	Uppermost Taylor Marl--Navarro Group
Cytherura wardensis Howe and Brown, 1935	Choctawhatchee Fm.
Eocytheropteron bilobatum Alexander, 1929	Washita Group, Weno Equivalent
Eocytheropteron trinitiensis (Vanderpool, 1928)	Trinity Sands
Eucytherura murdercreekensis Howe and Law, 1936	Uppermost Vicksburg Group, Byram Marl
Orthonotacythere cristata Alexander, 1934	Midway Group, Kincaid and Wills Point Fms.
Orthonotacythere hannai (Israelsky, 1929)	Ozan Fm.--Lowermost Navarro Group
Family Loxoconchidae	
Loxoconcha claibornensis Murray, 1938	Claiborne Fm.
Loxoconcha fletcheri Israelsky, 1929	Taylor Marl--Navarro Group
Loxoconcha perdecora Alexander, 1934	Midway Group
Family Schizocytheridae	
Amphicytherura dubia (Marsson, 1880)	Taylor Marl--Navarro Group
Family Trachyleberididae	
Actinocythereis exanthemata (Ulrich and Bassler, 1904)	Calvert Fm., L. Plum Point Marl Mb.
Actinocythereis exanthemata marylandica Howe and Hough, 1935	Calvert Fm., L. Plum Point Marl Mb.
Cythereis bassleri Ulrich, 1901	Wilcox Fm.--Claiborne Group
Cythereis bassleri lata Jennings, 1936	Upper Monmouth Group, Navesink Fm.
Cythereis bassleri reticulolira Schmidt, 1948	Lower Pamunkey Group, Lowermost Aquia Fm.
Cythereis bassleri vacuitatis Schmidt, 1948	Upper Matawan Group, Marshalltown Fm.
Cythereis communis retivesca Crane, 1965	Navarro Group, Corsicana Marl
Cythereis pustulosissima Alexander, 1929	Washita Group
Cythereis semiplicata Reuss, 1846	Austin Chalk--Taylor Marl
Cythereis vaughani (Ulrich and Bassler, 1904)	Duplin Marl
Echinocythereis garretti (Howe and McGuirt, 1935)	Lowermost Choctawhatchee Fm.
Echinocythereis jacksonensis (Howe and Pyeatt, 1935)	Jackson Fm. and Vicksburg Group

calculated as the average of the 60 measured radii drawn from the exact center of gravity of each specimen), 29 harmonic amplitudes, and 29 harmonic phase angles. The maximum number of harmonics that may be computed is one less than the Nyquist frequency, n/2, where n is the number of measured data points (Gevirtz, 1975). In addition, the normalized roughness coefficient was calculated from selected harmonic amplitudes (Program Rough, Appendix II). The roughness coefficient is the average squared deviation of the grain perimeter from a circle of equal area or simply the square root of one-half the sum of the squared normalized harmonic amplitudes (Ehrlich & Weinberg, 1970).

A root mean square error comparison of harmonics (Program Redraw, Appendix III), combined with a modified analysis of variance design and Snedecor's F-test (Table 2), permits identification of significant harmonic amplitudes (Gevirtz, 1975). The harmonic amplitudes insignificant at α = .002 level were tabulated for the entire data set. The F-test indicates that harmonics 1, 28, and 29 make significant contributions to the total shape in less than 50 percent of all the specimens studied.

Because phase angles are expressed as angular rather than linear variables, the stability of each angle can be determined by letting each individual phase angle represent a vector of unit length (Table 3), and calculating (Program Angle, Appendix IV) the length of the vector which is formed from the sum of all unit vectors for that

Table 2.--Results of analysis of variance in determination of significant harmonic amplitudes based on the original 91 specimens (Appendix III).

Harmonic Number	Percent Specimens Having Insignificant F-ratios at $\alpha = .002$
1	100
2-24	0
25	1
26	2
27	13
28	53
29	100

harmonic (Christopher & Waters, 1975). The median value of 12.12 was used as the cutoff value reflecting the stability of the phase relationship within the total sample. Angles with resultant vector values below the median have highly variable phase relationships. These variable angles might reflect lack of homology among species. Evolution might represent change in either the magnitude (amplitudes) of a structure or in its angular position (phase angles). Changes in angular position should not generally be great in homologous structures; therefore, very highly variable phase angles probably reflect non-homologous structures that are contributing to the same harmonic amplitude. All phase angles are calculated from the position of the second harmonic. The results of

Table 3.--Results of Program Angle (Appendix IV) with resultant vector lengths of phase angles for their respective harmonic amplitudes based on 91 specimens. Maximum vector length is 91.00.

Harmonic Number	Resultant Vector Length	Average Phase Angle in Degrees
1	25.04*	53.16
2	91.00*	.00
3	52.07*	246.95
4	70.37*	.89
5	56.09	249.90
6	16.47*	164.86
7	32.04*	344.70
8	29.64*	135.44
9	7.23	285.32
10	16.72*	102.19
11	5.33	4.96
12	6.79	296.89
13	13.95*	161.82
14	8.87	359.93
15	8.56	114.11
16	13.93*	301.81
17	14.05*	185.98
18	12.79*	303.26
19	9.19	108.55
20	2.89	3.46
21	9.67	114.96
22	7.16	289.64

Table 3.--Continued.

Harmonic Number	Resultant Vector Length	Average Phase Angle in Degrees
23	8.30	77.01
24	4.54	352.08
25	8.93	216.39
26	12.12*	197.28
27	9.95	76.60
28	23.24*	185.98
29	14.78*	8.79

*Values greater than the median.

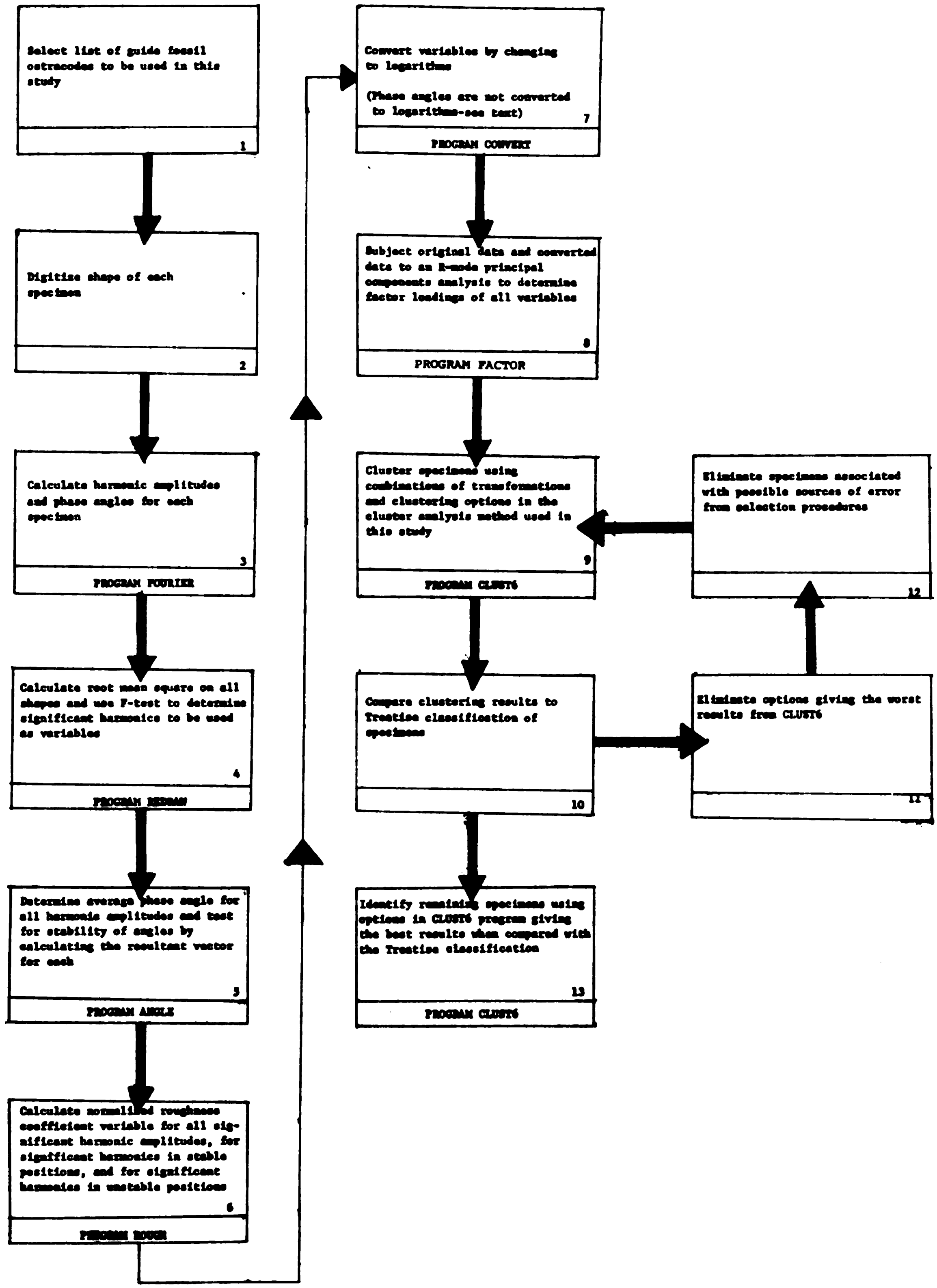
Program Angle were used as input to Program Rough. Roughness coefficients were calculated for harmonic amplitudes having stable phase angles (stable RC) and for harmonic amplitudes having unstable phase angles (unstable RC); RC-ALL refers to roughness coefficients calculated from all harmonic amplitudes. A flow chart (Figure 1) illustrates the methods and sequence of computer programs used in this study.

Factor Analysis

The phase angles, σ_n, greater than 180° were converted (Program Convert, Appendix V) to $360°-\sigma_n$ in order to represent the absolute magnitude of a phase shift irrespective of direction (referred to as "upper quadrants conversion" hereafter). Also all other variables were converted (Program Convert, Appendix V) to logarithms to represent better possible logarithmic growth relationships. The total data set generated consisted of 26 harmonic amplitudes, 25 phase angles, three roughness coefficients, and the mean radius.

All 55 original variables and their log-transforms (except for phase angles) were subjected to separate R-mode principal components analyses. This analysis was carried out by means of program FACTOR using the PA1 and VARIMAX rotation options (Nie, Bent, & Hull, 1970). Examination reveals that 50 of the 55 variables in the transformed data have their highest loadings in the first 10 factors

Figure 1. Flow chart of study methods illustrating sequence of computer programs used.


Select list of guide fossil ostracodes to be used in this study
1
Digitize shape of each specimen
2
Calculate harmonic amplitudes and phase angles for each specimen
3
PROGRAM FOURIER
Calculate root mean square on all shapes and use F-test to determine significant harmonics to be used as variables
4
PROGRAM REDRAW
Determine average phase angle for all harmonic amplitudes and test for stability of angles by calculating the resultant vector for each
5
PROGRAM ANGLE
Calculate normalized roughness coefficient variable for all significant harmonic amplitudes, for significant harmonics in stable positions, and for significant harmonics in unstable positions
6
PROGRAM ROUGH
Convert variables by changing to logarithms
(Phase angles are not converted to logarithms-see text)
7
PROGRAM CONVERT
Subject original data and converted data to an R-mode principal components analysis to determine factor loadings of all variables
8
PROGRAM FACTOR
Cluster specimens using combinations of transformations and clustering options in the cluster analysis method used in this study
9
PROGRAM CLUST6
Compare clustering results to Treatise classification of specimens
10
Eliminate options giving the worst results from CLUST6
11
Eliminate specimens associated with possible sources of error from selection procedures
12
Identify remaining specimens using options in CLUST6 program giving the best results when compared with the Treatise classification
13
PROGRAM CLUST6

as compared to 43 of the 55 untransformed variables that load on the first 10 factors (Table 4). This result indicates that the transformed data shows higher intercorrelations than the untransformed data. This result indicates nonlinear or allometric relationships among the variables studied.

Optimal Clustering Methods

Parks' (1970) CLUST6 program, designed for use with either qualitative and/or quantitative data, which uses simple distance as a measure of Q-mode association, was used to cluster and identify the original 91 specimens at the family and genus level. It performs an R-mode principal components analysis on the data, using either simple distance or the correlation coefficient, and extracts the principal components which explain 80 percent or more of the variation in the data unless otherwise specified. Principal component loadinds are calculated from the original data to produce orthogonal coordinate values that are normalized to a 1.0 scale. A final Q-mode cluster analysis based on the principal components is displayed as a line printed dendrogram.

The following clustering methods are used to determine which options available from the cluster program when used with combinations of Fourier shape variables give the most optimal clustering result when comparing the line printed dendrogram with the Treatise (Moore, 1961) classification at the various taxonomic levels.

Table 4.--Eigenvalues of transformed and untransformed data.

Variable Number	Eigenvalues of Transformed Data	Eigenvalues of Untransformed Data
1	13.15547	11.79944
2	4.90825	4.81495
3	3.87711	3.64735
4	3.19030	3.08630
5	2.64294	2.80417
6	2.43407	2.45225
7	2.00441	2.25828
8	1.71222	1.98235
9	1.52071	1.65244
10	1.43024	1.52393
11	1.33053	1.34448
12	1.18217	1.21724
13	1.14911	1.17134
14	1.08280	1.12514
15	1.01988	1.01836
16	.91185	.95694
17	.82179	.89009
18	.80150	.84799
19	.73487	.77741
20	.70612	.75604
21	.64459	.70645
22	.64142	.66545
23	.61181	.62150
24	.52450	.60003
25	.50122	.53275
26	.48557	.50152
27	.42351	.46047
28	.41048	.39386
29	.39136	.36749
30	.35792	.36120
31	.33056	.35221
32	.32281	.31108
33	.29705	.30032
34	.25150	.27942
35	.24381	.24908
36	.21248	.22594
37	.19504	.21725
38	.17796	.21287
39	.16800	.19227
40	.15349	.17067
41	.14380	.15815
42	.13746	.14564
43	.12007	.13828
44	.10464	.12842

Table 4.--Continued.

Variable Number	Eigenvalues of Transformed Data	Eigenvalues of Untransformed Data
45	.09053	.11215
46	.08092	.10063
47	.07275	.08509
48	.06666	.07783
49	.05296	.06550
50	.05067	.05924
51	.03884	.04978
52	.03137	.04026
53	.02048	.03799
54	.01857	.03150
55	.00974	.00925

Clustering options include varying the number of principal components used in the computation and weighting of the principal components in proportion to the amount of the variance they explain. Results of the various combinations of analytical options are given in Table 5.

In the comparison of the results of the 20 combinations of variables used for clustering, two methods were used in calculating the similarity to the Treatise classification. One method used is to compare the total percent of pairwise comparisons that match the conventional (Treatise) taxonomy in the observed clustering results at the family and genus levels. The other method is to take the percent of all specimens that do not fall within the main cluster, irrespective of small clusters outside the main cluster. The results of pairwise comparisons were calculated only if the latter method produced results of 41 percent misidentification or less at the generic level (Table 5).

All combinations incorporating harmonic phase angles gave the worst clustering results (all combinations except 2 and 11). Of the combinations using harmonic phase angles, the ones incorporating unstable harmonic phase angles (1 and 4-9) gave significantly more misidentifications at the generic level than did combinations containing only stable angles (3, 10). Therefore, it may be concluded that phase information is not generally taxonomically useful in ostracodes. The combinations

Table 5.--Comparisons of various clustering methods via results at genus and family level using the original 91 specimens.

Variable Combination*	Similarity Measure	Data Transform	Principal Components Weighted	No. of Principal Components Extracted	No. of Variables	Percent Pairwise Comparisons @ Generic Level	Percent Misidentifications Within All Families	Percent Misidentifications Within All Genera
1	CC**	L,U**		10	55		60.67	50.52
2	CC	L		6	28	92.70	47.92	36.71
3	CC	L,U		6	15		51.58	43.57
4	CC	L,U		4	15		49.00	47.47
5	CC	U		9	25		57.42	46.67
6	CC	U		6	13		66.25	56.10
7	CC	L,U		10	28		57.92	49.05
8	CC	L,U		10	41		53.50	49.57
9	CC	L,U		10	28		60.33	55.14
10	CC	L,U		9	40	90.35	45.75	40.10
2	CC	L		7	28	93.24	51.35	35.86
2	DF**	L		1	28		49.08	44.98
2	CC	NL**		5	28	89.72	44.25	37.49
2	DF	NL		1	28		49.75	45.44
2	CC	L	X	10	28	86.64	44.42	40.85
2	DF	L	X	10	28		54.25	48.06
2	CC	NL	X	10	28		54.58	41.41

Table 5.--Continued.

Variable Combination*	Similarity Measure	Data Transform	Principal Components Weighted	No. of Principal Components Extracted	No. of Variables	Percent Pairwise Comparisons @ Generic Level	Percent Misidentifications Within All Families	Percent Misidenticiations Within All Genera
2	DF	NL	X	10	28		51.00	41.85
11	CC	NL		7	26		48.17	45.47
12	CC	L		7	28		51.83	45.79

**L = Logarithmic; NL = nonlogarithmic; CC = correlation coefficient; DF = distance function; U = upper quadrants conversion.

*Variable combinations list (HAR = harmonic; RC = roughness coefficient).

1 HAR2-HAR27, all phase angles and amplitudes; RC-ALL; stable RC; unstable RC; and RADIUS.

2 HAR2-HAR27 amplitudes; RC-ALL; and RADIUS.

3 Harmonic amplitudes with stable angles, stable RC, and RADIUS.

4 Harmonic amplitudes with unstable angles, unstable RC, and RADIUS.

5 Phase angles (HAR3-HAR27).

6 All unstable phase angles.

7 Harmonic amplitudes with stable angles, stable RC, unstable phase angles, and RADIUS.

8 HAR2-HAR27, all unstable phase angles, RC-ALL, and RADIUS.

9 Harmonic amplitudes with unstable angles, unstable RC, and RADIUS.

10 HAR2-HAR27, all stable phase angles, RC-ALL, and RADIUS.

11 Same as 2 without HAR2 and RADIUS.

12 Same as 2 deleting first factor score variable.

using the correlation matrix computation to produce principal components appear to give slightly better clustering results than does the distance function matrix. Weighting the principal components used in variable combination 2 did not significantly improve results of the clustering. Choosing the proper number of principal components to be computed for the cluster analysis is critical. Using seven principal components computed from principal component loading results of combination 1 (all 55 variables) produced better results than when six components were used. The combination 2 using seven principal components gave a 93.24 percent pairwise comparison compared with combination 2 using six principal components which gave a 92.70 percent pairwise comparison at the generic level. Combination 11 deletes harmonic amplitude 2 and the mean radius (size) in hopes of eliminating the possible effects of ontogeny. Younker (1971) found that a continuous increase in the second harmonic through molt stage eight in Cypridopsis vidua. The deletion of these variables in this cluster analysis increased the number of misidentifications in the clustering. Therefore, it can be stated that the second harmonic and the carapace size, although partially reflecting ontogeny, also carry valuable taxonomic information.

Another combination eliminating the first factor score variable from the analysis was run. This was done in an attempt to eliminate noise caused by the intercorrelation of the variables loading on the first component. As this clustering result also gave a large number of misidentifications, the noise was not eliminated.

The best result is combination 2 using unweighted, logarithmic variables, a correlation coefficient matrix, and computing seven principal components. The 28 variables used were harmonic amplitudes two through twenty-seven, the radius, and the roughness coefficient computed from all harmonic amplitudes. For this combination of 28 Fourier shape variables (Table 6) the total percent variance extracted by the seven principal components is 79.856. All characters loaded highest on the first five components.

The results of this optimal clustering method yielded a 93.24 percent pairwise comparison at the generic level. Biologically, the results indicate that these specimens can be identified quite successfully at the generic level using only these 28 shape variables.

Table 6.--Principal component loading of Fourier shape character set for initial R-mode analysis of Parks' CLUST6 program. Character 1, RC-ALL; 2, RADIUS; 3-28, harmonic amplitudes 2-27. Total percent of variance extracted by the seven components is 79.856. F1-7 indicates principal components 1-7.

	F1	F2	F3	F4	F5	F6	F7
1	.240	-.313	-.077	-.355	.518	.082	-.332
2	-.205	-.024	.582	.625	.374	-.025	-.013
3	.425	.225	.446	-.134	-.374	-.088	.139
4	.156	.442	.585	-.277	.294	.035	.087
5	.430	.529	-.045	.219	-.258	.105	-.051
6	.441	.544	.598	-.055	-.018	-.133	-.050
7	.516	.487	-.231	.126	.041	.470	-.155
8	.629	.458	.016	-.153	.105	-.024	-.295
9	.702	.495	.012	.007	.135	-.154	.013
10	.760	.297	-.139	-.022	.360	.066	.057
11	.776	.268	-.169	-.021	-.294	.125	-.037
12	.710	.281	.045	.211	-.115	.073	.188
13	.705	.106	-.202	.124	.028	.297	.078
14	.780	.169	-.097	-.202	.055	-.140	.001
15	.735	-.023	-.157	-.087	.030	-.343	.301
16	.846	.093	-.191	.015	-.006	-.099	.055
17	.826	-.050	-.129	.084	.174	-.154	.091
18	.799	-.292	-.125	.115	.122	-.203	-.020
19	.726	-.271	-.223	.055	.119	-.017	.092
20	.760	.012	-.241	.021	.091	.058	-.043
21	.775	-.347	.047	.024	-.048	-.225	.016
22	.699	-.234	.213	.105	-.095	-.244	-.315
23	.559	-.455	.155	.041	-.152	.107	-.302
24	.675	-.365	.123	-.193	-.273	-.015	-.302
25	.725	-.440	.077	-.034	-.120	.063	.052
26	.611	-.397	.381	-.134	-.034	.441	.018
27	.599	-.391	.200	.473	.065	.088	.085
28	.468	-.434	.218	-.295	.068	.263	.475
Eigenvalues	11.643	3.388	2.098	1.218	1.173	1.016	.930
Percent of Variance Explained	41.583	12.100	7.492	4.350	4.191	3.629	3.323

SPECIES IDENTIFICATION

For species-level identification 20 replicates (12 species) were added to the cluster analysis. After the sources of sampling design error were detected 53 specimens (40 species) were eliminated and a final cluster analysis (Appendix VI) using Parks' CLUST6 program was run using the remaining 58 specimens (51 species), including 9 replicates at the species level. Results of the percent pairwise comparisons at the specific, generic, and family levels are given in Table 7 for the optimal combination of options. These results show that this method of identification works best at the specific level. The only misidentified specimen, *Bythocypris* (?) *gibsonensis*, was doubtfully assigned to the species *gibsonensis*, and may belong to some other species. The generated dendrogram (Figure 2) illustrates the clustering of the 58 specimens. A triangular plot (Figure 3) computed from components 1, 2, and 3 shows clustering of the specimens at the generic level. These figures show that sources of biological noise such as sexual dimorphism and ontogenetic variation are causing these misidentifications in the clustering results, especially at the higher levels.

Table 7.--Evaluation of final clustering results in terms of percent of pairwise comparisons and calculated chi-square results for same.

Taxonomic Level	Sample Size	Percent Pairwise Comparison	Calculated Chi-Square Results
Specific	9	94.44	22.49*
Generic	49	91.33	77.97*
Family	56	86.95	132.08*

*Values exceed critical chi-square value of 10.83 at α = 0.001.

One way to test the degree of association between the conventional classification (Treatise) and the generated dedrogram of the cluster analysis used in this study is by use of the chi-square method. This test is designed to reveal a degree of association statistically greater than is likely to occur by chance. A two by two contingency table is used wherein the conventional classification is compared to that generated by cluster analysis. Contingency tables were set up for specific, generic, and familial taxa. The null hypothesis is that no association exists between the two methods of classification. If the selected level is .001, a significant chi-square result indicates the interaction observed between the two types of classification will occur only once in a thousand times if they are not in some way associated. Results of the pairwise comparisons and their corresponding chi-square calculations are given in Table 7.

Significant chi-square results indicate association between the dendrogram generated by the cluster method and the Treatise classification is greater than would be expected by chance. All three (specific, generic, and family) taxonomic levels yielded significant chi-square results; each calculated chi-square value exceeds the critical value of 10.83 set prior to construction of the tables at the .001 level.

Figure 2. Q-mode dendrogram illustrating phenetic affinities of 58 specimens of Mesozoic and Cenozoic ostracodes based on 7 principal components extracted from 28 shape variables.

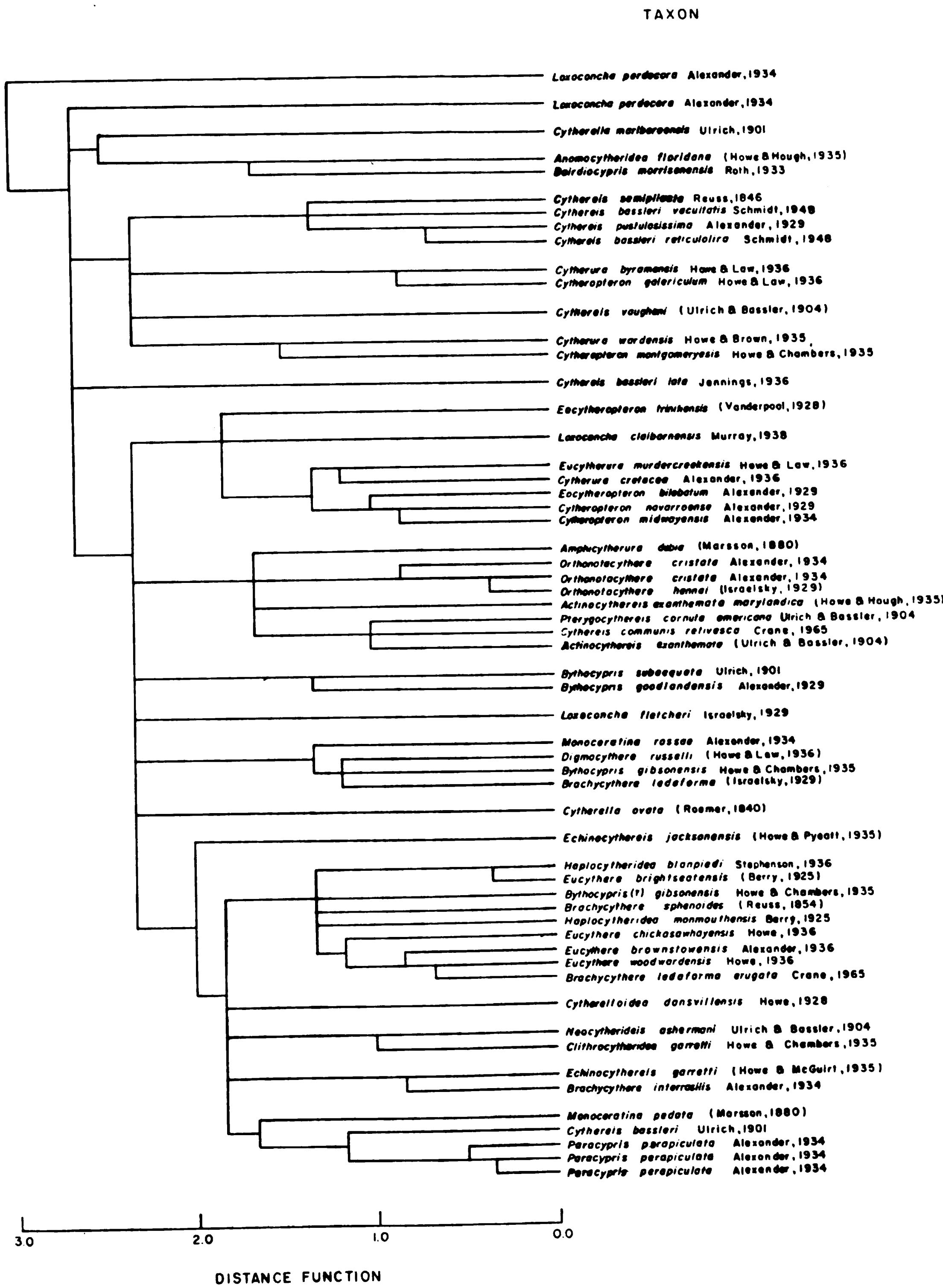

TAXON
Laxoconcha perdecora Alexander, 1934
Laxoconcha perdecora Alexander, 1934
Cytherella marlboroensis Ulrich, 1901
Anomocytheridea floridana (Howe & Hough, 1935)
Bairdiocypris morrisonensis Roth, 1933
Cythereis semiplicata Reuss, 1846
Cythereis bassleri vaculatis Schmidt, 1948
Cythereis pustulosissima Alexander, 1929
Cythereis bassleri reticulolira Schmidt, 1948
Cytherura byramensis Howe & Law, 1936
Cytheropteron galericulum Howe & Law, 1936
Cythereis vaughani (Ulrich & Bassler, 1904)
Cytherura wardensis Howe & Brown, 1935
Cytheropteron montgomeryesis Howe & Chambers, 1935
Cythereis bassleri lata Jennings, 1936
Eocytheropteron trinitensis (Vanderpool, 1928)
Loxoconcha claibornensis Murray, 1938
Eucytherura murdercreekensis Howe & Law, 1936
Cytherura cretacea Alexander, 1936
Eocytheropteron bilobatum Alexander, 1929
Cytheropteron navarroense Alexander, 1929
Cytheropteron midwayensis Alexander, 1934
Amphicytherura dubia (Marsson, 1880)
Orthonotacythere cristata Alexander, 1934
Orthonotacythere cristata Alexander, 1934
Orthonotacythere hannai (Israelsky, 1929)
Actinocythereis exanthemata marylandica (Howe & Hough, 1935)
Pterygocythereis cornuta americana Ulrich & Bassler, 1904
Cythereis communis retivesca Crane, 1965
Actinocythereis exanthemata (Ulrich & Bassler, 1904)
Bythocypris subaequata Ulrich, 1901
Bythocypris goodlandensis Alexander, 1929
Loxoconcha fletcheri Israelsky, 1929
Monoceratina rossae Alexander, 1934
Digmocythere russelli (Howe & Law, 1936)
Bythocypris gibsonensis Howe & Chambers, 1935
Brachycythere ledaforma (Israelsky, 1929)
Cytherella ovata (Roemer, 1840)
Echinocythereis jacksonensis (Howe & Pyeatt, 1935)
Haplocytheridea blanpiedi Stephenson, 1936
Eucythere brightseatensis (Berry, 1925)
Bythocypris(?) gibsonensis Howe & Chambers, 1935
Brachycythere sphenoides (Reuss, 1854)
Haplocytheridea monmouthensis Berry, 1925
Eucythere chickasawhayensis Howe, 1936
Eucythere brownstowensis Alexander, 1936
Eucythere woodwardensis Howe, 1936
Brachycythere ledaforma erugata Crane, 1965
Cytherelloidea dansvillensis Howe, 1928
Neocytherideis ashermani Ulrich & Bassler, 1904
Clithrocytheridea garretti Howe & Chambers, 1935
Echinocythereis garretti (Howe & McGuirt, 1935)
Brachycythere interrasilis Alexander, 1934
Monoceratina pedata (Marsson, 1880)
Cythereis bassleri Ulrich, 1901
Paracypris perapiculata Alexander, 1934
Paracypris perapiculata Alexander, 1934
Paracypris perapiculata Alexander, 1934
3.0
2.0
1.0
0.0
DISTANCE FUNCTION

Figure 3. Triangular plot indicating clustering of specimens at the generic level. (Computed from principal components 1, 2, and 3 of final cluster analysis).

Genus

A *Cythereis*
B *Bythocypris*
C *Brachycythere*
D *Eucythere*
E *Loxoconcha*
F *Cytheropteron*
G *Paracypris*
H *Orthonotacythere*

SUMMARY AND CONCLUSIONS

1. The method used in this study is highly successful for species-level identification.
2. The method only works with partial success for identification purposes at higher taxonomic levels. The differences in ontogeny and sexual dimorphism must be more fully known and studied by a competent investigator. The effects of these differences could be filtered from the cluster analysis using the Fourier series.
3. The method works somewhat successfully for classification purposes at the higher taxonomic levels.
4. Additional work is required due to the morphological convergence at the higher taxonomic levels. When the work in this area and the work in ontogeny and sexual dimorphism is complete, the optimal clustering method discussed in this study will represent a technique for identification and classification of specimens at the higher levels as well as at the species level.

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APPENDICES

APPENDIX I

LISTING OF PROGRAM FOURIER

```
      PROGRAM FOURIFP (INPUT,OUTPUT,PUNCH)
C     EXPLANATION OF METHOD GIVEN BY EHRLICH + WEINBERG, 1970, JOUR.
C     SED. PETROLOGY, V. 40, P. 205-212.
C     REVISIONS TO ORIGINAL PROGRAM BY ROBERT L. ANSTEY, NOV. 20, 1972
C     ADDITIONAL REVISIONS BY F. EWALD, 2/11/75.
C     DECK STRUCTURE...
C             1. CONTROL CARD - NUMBER OF HARMONIC COEFFICIENTS DESIRED,
C             COLS. 1-2. IF DATA IS FROM AN OPEN CURVE, PUNCH 1 IN COL. 4.
C             2. TITLE CARD (FOR SAMPLE GROUP) - ANY ALPHANUMERIC SYMBOLS,
C             LIMITED TO ONE CARD
C             3. DATA CARDS
C             ALL VALUES MUST BE RECORDED AS 4 DIGIT INTEGER NUMBERS, 20 TO
C             A CARD. VALUES FROM A CLOSED SHAPE MUST BE RECORDED AS X, Y
C             IN A COUNTERCLOCKWISE SEQUENCE STARTING FROM THE POINT
C             X=XMAX. VALUES FROM AN OPEN CURVE MUST BE RECORDED AS X, Y IN
C             ORDER OF DECEASING X STARTING FROM THE POINT X=XMAX.
C             Y AT X=XMAX MUST EQUAL Y AT X=XMIN.
C             IN A CLOSED SHAPE, NO VALUE OF THETA SHOULD HAVE MORE THAN
C             ONE VALUE OF R. IN AN OPEN CURVE, NO VALUE OF X SHOULD HAVE
C             MORE THAN ONE VALUE OF Y.
C             (ALL VALUES MUST BE LESS THAN 9999)
C             LAST 8 COLUMNS OF LAST CARD FOR EACH SAMPLE MUST BE BLANK OR
C             ZERO-FILLED (OTHERWISE A BLANK CARD MUST BE INSERTED)
C             4. FLAG CARD - 9999 IN COLS. 1-4 (SIGNALS END OF EACH SAMPLE
C             GROUP)
C             5. CONTINUATION CARD - CONT OR FINI IN COLS. 1-4
C             IF CONT, NEXT SAMPLE GROUP IS EXECUTED
C             IF FINI, PROGRAM TERMINATES
C             6. REPEAT DECK STRUCTURE, STEPS 2-5, FOR EACH SAMPLE GROUP
C     SIZE LIMITATIONS AND RESTRICTIONS...
C             1. LESS THAN 70 POINTS PER SAMPLE. FOR MORE POINTS, CHANGE
C             DIMENSIONS OF X, Y, RAD, THETA, IX, AND IY.
C             2. LESS THAN 100 SAMPLES PER SAMPLE GROUP. FOR MORE SAMPLES
C             , CHANGE DIMENSIONS OF ARRAY, CARRAY AND ARAD.
C             3. NUMBER OF SAMPLE GROUPS IS UNLIMITED
C             4. ALL HARMONICS ARE DIVIDED BY THE VALUE OF THE ZEROTH
C             HARMONIC, MAKING ITS VALUE UNITY. UP TO 29 HARMONICS CAN
C             BE CALCULATED.  TO OBTAIN MORE THAN 29 HARMONICS, INCREASE
C             THE DIMENSIONS OF A, B, C, AMP, ARRAY, AND CARRAY. ALSO
C             CHANGE FORMATS 960, 980, AND 872.
C             5. PHASE ANGLES ARE NORMALIZED TO THE ORIENTATION OF THE
C             SECOND HARMONIC.
C             6. STATISTICAL ESTIMATES WILL NOT BE CALCULATED, NOR WILL
C             DATA BE NORMALIZED FOR SAMPLE SIZES SMALLER THAN 20.
C             NORMALIZED VALUES ARE THOSE DIVIDED BY THE MEAN OF THE SAMPLE
C             GROUP.
C             7. NORMALITY IS TESTED ONLY FOR SAMPLE SIZES GREATER THAN 35
      COMMON NUM(2000),NN,KV,FVAR,FMED,FMEAN,FKS
      DIMENSION X(70), Y(70), RAD(70), THETA(70)
      DIMENSION A(30), B(30), C(30), AMP(30), NAME(10)
      DIMENSION ARRAY(100,30), CARRAY(100,30), ARAD(100)
      DIMENSION IX(70), IY(70)
      EQUIVALENCE (X,IX), (Y,IY)
      LOGICAL TRBL
      BETA=4HCONT
      IFLAG=9999
      READ 1030, NHARM, NOPEN
   20 READ 1000, NAME
      DO 1060 N=1,NHARM
 1060 AMP(N) = 0.
      AMPSUM=0.
      NOGOOD=0
      ISEQ=0
      LTOTAL=0
      NN=0
      PRINT 940, NAME
   30 JL=1
      JU=10
      TRBL=.FALSE.
   40 READ 950, (IX(J),IY(J),J=JL,JU)
      IF (IX(JL)-IFLAG) 50,810,860
   50 DO 60 K=JL,JU
      KWIT=IX(K)+IY(K)
      IF (KWIT) 60,70,60
   60 CONTINUE
      JL=JL+10
      JU=JU+10
      GO TO 40
```

```
 70 L=K-1
    IF(NOPEN) 71,71,72
 72 IXMAX=IX(1)
    DO 73 I=2,L
    IF(IXMAX-IX(I)) 74,73,73
 74 IXMAX=IX(I)
 73 CONTINUE
    IXMIN=IX(1)
    DO 75 I=2,L
    IF(IXMIN-IX(I)) 75,75,76
 76 IXMIN=IX(I)
 75 CONTINUE
    IXMAX=IXMAX-IXMIN
    DO 77 I=1,L
    X(I)=((IX(I)-IXMIN)*6.2832)/IXMAX
 77 Y(I)=IY(I)
    IYMAX=IY(1)
    DO 78 I=2,L
    IF(IYMAX-IY(I)) 79,78,78
 79 IYMAX=IY(I)
 78 CONTINUE
    DO 81 I=1,L
    IX(I)=(Y(I)*COS(X(I)))+IYMAX
 81 IY(I)=(Y(I)*SIN(X(I)))+IYMAX
    L=L-1
 71 ISEQ=ISEQ+1
    LTOTAL=LTOTAL+L
    DO 570 J=1,L
    X(J)=IX(J)
570 Y(J)=IY(J)
    MX=0
    MY=MX
    MMY=1
    MMX=MMY
    YMOM=0.
    XMOM=YMOM
    YAREA=XMOM
    XAREA=YAREA
580 MMX=MMX+1
    MX=MX+1
    IF (MX-L) 600,590,600
590 MMX=1
600 YAREA=YAREA+(X(MMX)-X(MX))*(Y(MMX)+Y(MX))
    YMOM=YMOM+(X(MMX)-X(MX))*((Y(MMX)+Y(MX))**2-Y(MMX)*Y(MX))
    IF (MX-L) 580,610,580
610 MMY=MMY+1
    MY=MY+1
    IF (MY-L) 630,620,630
620 MMY=1
630 XAREA=XAREA+(Y(MMY)-Y(MY))*(X(MMY)+X(MY))
    XMOM=XMOM+(Y(MMY)-Y(MY))*((X(MMY)+X(MY))**2-X(MMY)*X(MY))
    IF (MY-L) 610,640,610
640 YCEN=YMOM/(YAREA*3.)
    XCEN=XMOM/(XAREA*3.)
    DO 660 I=1,L
    THETA(I)=ATAN((Y(I)-YCEN)/(X(I)-XCEN))
    IF (X(I)-XCEN) 650,660,660
650 THETA(I)=THETA(I)+3.14159
660 RAD(I)=SQRT((Y(I)-YCEN)**2+(X(I)-XCEN)**2)
    DO 670 I=1,NHARM
670 A(I)=B(I)=0.
    AO=0.
    FL=L
    AJ=25./FL
    DO 760 I=1,L
    II=I+1
    IF (I-L) 690,680,690
680 II=1
690 ANGLE=THETA(II)-THETA(I)
    IF (ANGLE) 700,760,710
700 ANGLE=ANGLE+6.28138
710 IF (ANGLE-AJ) 730,720,720
720 TRBL=.TRUE.
    GO TO 760
730 IF(TRBL) 760,740
740 AO=AO+ANGLE*(RAD(II)+RAD(I))
    DO 750 N=1,NHARM
    FN=N
```

```
      COS2=COS(FN*THETA(II))
      COS1=COS(FN*THETA(I))
      SIN2=SIN(FN*THETA(II))
      SIN1=SIN(FN*THETA(I))
      A(N)=A(N)+((RAD(II)-RAD(I))*(COS2-COS1))/(ANGLE*FN*FN)+(RAD(II)*SI
     1N2-RAD(I)*SIN1)/FN
  750 B(N)=B(N)+((RAD(II)-RAD(I))*(SIN2-SIN1))/(ANGLE*FN*FN)-(RAD(II)*CO
     1S2-RAD(I)*COS1)/FN
  760 CONTINUE
      IF(TPBL) 770,780
  770 NOGOOD=NOGOOD+1
      PRINT 1050, ISEQ
      GO TO 30
  780 DO 31 N=1,NHARM
      IF (A(N)) 37,36,37
   36 C(N)=90.
      GO TO 33
   37 C(N)=57.2*ATAN(B(N)/A(N))
      IF (A(N)) 32,33,33
   32 C(N)=C(N)+180.
      GO TO 31
   33 IF (B(N)) 34,31,31
   34 C(N)=C(N)+360.
   31 CONTINUE
      DO 35 N=1,NHARM
      C(N)=C(N)-N*C(2)/2.0
   63 IF (C(N)-360.) 64,64,61
   64 IF (C(N)) 62,35,35
   61 C(N)=C(N)-360.
      GO TO 63
   62 C(N)=C(N)+360.
      GO TO 64
   35 CONTINUE
      DO 790 N=1,NHARM
  790 A(N)=(SQRT(A(N)**2+B(N)**2))*4./AO
      NN=NN+1
      DO 800 N=1,NHARM
      CARRAY(NN,N)=C(N)
  800 ARRAY(NN,N)=A(N)
      ARAD(NN)=AO/125.663
      ARAD(NN)=ARAD(NN)*0.254
      GO TO 30
  810 PRINT 900, NN
      IF (NN-20) 841,829,829
  829 DO 840 I=1,NHARM
      DO 830 J=1,NN
      F=ARRAY(J,I)*10000.
  830 NUM(J)=F+1
      PRINT 1040, I,NAME
      CALL STAT
      A(I)=(KV/100.)**2
      B(I)=FVAR
      C(I)=FMED
      AMP(I)=FMEAN
      RAD(I)=FKS
      IX(I)=KV
  840 CONTINUE
      PUNCH 1000, NAME
      PUNCH 1002
      PUNCH 990, (AMP(N),N=1,NHARM)
      PUNCH 1001
      PUNCH 990, (C(N),N=1,NHARM)
      PRINT 1003
      DO 1004 I=1,NHARM
 1004 PRINT 1005,I,AMP(I),C(I),RAD(I),IX(I)
  841 PRINT 970
      PRINT 980, (N,N=1,NHARM)
      DO 850 M=1,NN
      PRINT 960, M,(ARRAY(M,N),N=1,NHARM),ARAD(M)
      PUNCH 990, (ARRAY(M,N),N=1,NHARM)
  850 CONTINUF
      IF(NN-20) 855,856,856
  856 PRINT 874
      PRINT 980, (N,N=1,NHARM)
      DO 853 M=1,NN
      ARAD(M)=0.0
      DO 854 N=1,NHARM
      ARRAY(M,N)=ARRAY(M,N)/AMP(N)
```

```
854 ARAD(M)=ARAD(M)+(APRAY(M,N)**2)
    ARAD(M)=SQRT(APAD(M)/2.)
    PRINT 960, M,(ARRAY(M,N),N=1,NHARM),ARAD(M)
853 CONTINUE
    RCMN=0.0
    DO 857 N=1,NN
857 RCMN=RCMN+ARAD(N)
    RCMN=RCMN/NN
    PRINT 875, RCMN
    PRINT 2000
    DO 871 M=1,NN
    PRINT 872,M,(CARRAY(M,N),N=1,NHARM)
    PUNCH 873,(CARRAY(M,N),N=1,NHARM)
871 CONTINUE
855 READ 1010, ALPHA
    IF (ALPHA-BETA) 860,20,860
860 CONTINUE
874 FORMAT(1H0,42X,30HNORMALIZED HARMONIC AMPLITUDES,44X,15HNORMALIZED
   + R.C.)
875 FORMAT(1H0,2X,40HMEAN NORMALIZED ROUGHNESS COEFFICIENT IS,F9.5)
900 FORMAT(22H USABLE SAMPLE SIZE IS,I4)
940 FORMAT(1H1,10(1H*),10A8,10(1H*)/37H THE FOLLOWING SAMPLES CANNOT B
   +E USED)
950 FORMAT (20I4)
960 FORMAT(1H ,I3,19F6.4/57X,10F6.4,F9.4/)
970 FORMAT(1H0,53X,19HHARMONIC AMPLITUDES,45X,10HRADIUS(MM))
980 FORMAT(6X,19(I2,4X)/57X,10(I2,4X)/)
990 FORMAT (10F7.4)
1000 FORMAT(10A8)
1001 FORMAT(16HMEDIAN HARMONICS)
1002 FORMAT(14HMEAN HARMONICS)
1003 FORMAT(9H0HARMONIC,4X,4HMEAN,4X,6HMEDIAN,4X,8HSTD.DEV.,4X,10HCOEFF
   +.VAR.)
1005 FORMAT(1H0,2X,I2,7X,F6.4,3X,F6.4,5X,F6.4,8X,I4)
1010 FORMAT (A4)
1030 FORMAT(2I2)
1040 FORMAT(1X,3(1H*),15HHARMONIC NUMBER,I3,3(1H*),10A8)
1050 FORMAT (21X,6HNUMBER,I5)
872 FORMAT(1H ,I3,2X,19F6.1/57X,10F6.1/)
873 FORMAT(10F7.2)
2000 FORMAT(1H0,12HPHASE ANGLES)
    END
```

```
      SUBROUTINE STAT
C     CALCULATIONS ARE VALID FOR 4 SIGNIFICANT FIGURES
C     NORMALITY IS TESTED BY THE KOLMOGOROV-SMIRNOV VALUE OF D AT THE
C     .05 LEVEL OF SIGNIFICANCE. FOR OTHER PROBABILITY LEVELS OF D,
C     CONSULT TABLE E OF SIEGEL, 1956, NONPARAMETRIC STATISTICS FOR THE
C     BEHAVIORAL SCIENCES, MCGRAW-HILL.
      COMMON NUM(2000),NN,KV,FVAR,FMED,FMEAN,FKS
      DIMENSION NBR(10000),NHIST(20),KHIST(20,100),ID(20)
      EQUIVALENCE (NUM,KHIST)
      DO 10 I=1,10000
   10 NBR(I)=0
      DO 20 I=1,NN
   20 NBR(NUM(I))=NBR(NUM(I))+1
      DO 30 I=1,10000
      IF (NBR(I)) 30,30,40
   30 CONTINUE
   40 MIN=I
      DO 50 I=1,10000
      J=10001-I
      IF (NBR(J)) 50,50,60
   50 CONTINUE
   60 MAX=J
      KR=MAX-MIN
      MM=0
      DO 65 I=MIN,MAX
      M=(NN/2)+1
      MM=MM+(NBR(I))
      IF(MM-M) 65,66,66
   65 CONTINUE
   66 MED=I
      INT=(KR/20)+1
      MF=MIN+(INT*19)
      DO 67 M=MIN,MF,INT
      I=((M-MIN)/INT)+1
      NHIST(I)=0
      L=M+INT
      ID(I)=M
      DO 68 J=M,L
   68 NHIST(I)=NHIST(I)+NBR(J)
   67 CONTINUE
      NSUM=0
      DO 70 I=MIN,MAX
   70 NSUM=NSUM+(I*NBR(I))
      MEAN=NSUM/NN
      MM=NN-1
      KVAR=0
      DO 90 I=1,NN
   90 KVAR=KVAR+((MEAN-NUM(I))**2)
      KVAR=KVAR/MM
      FVAR=KVAR
      KS=SQRT(FVAR)
      IF (MEAN) 110,110,100
  100 KV=(KS*100)/MEAN
      FMEAN=MEAN/10000.
      FMED=MED/10000.
      FMIN=MIN/10000.
      FMAX=MAX/10000.
      FKR=KR/10000.
      FKS=KS/10000.
      FVAR=FKS**2
      DO 101 I=1,20
      DO 101 J=1,100
  101 KHIST(I,J)=1H
      DO 102 I=1,20
      IF(NHIST(I)) 102,102,103
  103 K=NHIST(I)
      IF(K-100) 104,104,105
  105 K=99
      KHIST(I,100)=1H+
  104 DO 106 J=1,K
  106 KHIST(I,J)=1H*
  102 CONTINUE
      FINT=INT/10000.
      PRINT 140,FINT
      DO 107 I=1,20
      FID=ID(I)/10000.
  107 PRINT 150, FID,NHIST(I),(KHIST(I,J),J=1,100)
      IF(NN-35) 110,110,5
```

```
    5 DO 1 I=1,20
      J=(INT/2)+1
      NUM(I)=MIN+(I*INT)-J
      NBR(I)=(INT*100)/(KS*SQRT(6.2832))
      F=-(((NUM(I)-MEAN)/KS)**2)/2.
    1 NBR(I)=NBR(I)*(2.7183**F)
      ID(1)=IABS(NBR(1)-((NHIST(1)*100)/NN))
      DO 2 I=2,20
      J=I-1
      NBR(I)=NBR(I)+NBR(J)
      NHIST(I)=NHIST(I)+NHIST(J)
    2 ID(I)=IABS(NBR(I)-((NHIST(I)*100)/NN))
      IDMAX=ID(1)
      DO 3 I=2,20
      IF(IDMAX-ID(I)) 4,3,3
    4 IDMAX=ID(I)
    3 CONTINUE
      DMAX=IDMAX/100.
      FNN=NN
      DTEST=1.36/SQRT(FNN)
      IF(DMAX-DTEST) 6,7,7
    6 PRINT 8, DMAX
      GO TO 110
    7 PRINT 9, DMAX
  110 PRINT 160
      RETURN
    8 FORMAT(32H DATA FIT A NORMAL DISTRIBUTION.,24H KOLMOGOROV-SMIRNOV
     +D IS,F5.3)
    9 FORMAT(39H DATA DO NOT FIT A NORMAL DISTRIBUTION.,24H KOLMOGOROV-S
     +MIRNOV D IS,F5.3)
  140 FORMAT(101H HISTOGRAM OF DATA FREQUENCIES IN 20 EQUAL SIZE CLASSES
     + RANGING FROM THE MINIMUM TO THE MAXIMUM VALUE/25H   SIZE CLASS IN
     +TERVAL IS,F6.4)
  150 FORMAT(3X,F6.4,I5,2X,100A1)
  160 FORMAT(1X,100(1H+))
      END
```

APPENDIX II

LISTING OF PROGRAM ROUGH

```
      PROGRAM ROUGH (INPUT,OUTPUT,PUNCH)
      DIMENSION A(26,91), B(3,91), C(26), N(13), M(13)
      DO 1 I=1,91
      READ 2,(A(J,I),J=1,26)
    1 CONTINUE
      DO 3 J=1,26
      SUM=0.0
      DO 4 I=1,91
      SUM=SUM+A(J,I)
    4 CONTINUE
      C(J)=SUM/91.
      DO 5 I=1,91
      A(J,I)=A(J,I)/C(J)
    5 CONTINUE
    3 CONTINUE
      DO 8 K=1,7
    8 N(K)=K
      N(8)=10 $ N(9)=13 $ N(10)=16
      N(11)=17 $ N(12)=18 $ N(13)=26
      M(1)=9 $ M(2)=11 $ M(3)=12
      M(4)=14 $ M(5)=15 $ M(13)=27
      DO 9 K=6,12
    9 M(K)=K
      DO 6 I=1,91
      SUM=0.0
      DO 7 J=1,26
      SUM=SUM+A(J,I)*A(J,I)
    7 CONTINUE
      SUM=SUM/2.
      B(1,I)=SQRT(SUM)
      SUM=0.0
      DO 10 K=1,13
      SUM=SUM+A(N(K),I)*A(N(K),I)
   10 CONTINUE
      SUM=SUM/2.
      B(2,I)=SQRT(SUM)
      SUM=0.0
      DO 11 K=1,13
      SUM=SUM+A(M(K),I)*A(M(K),I)
   11 CONTINUE
      SUM=SUM/2.
      B(3,I)=SQRT(SUM)
    6 CONTINUE
      PRINT 14
      DO 12 I=1,91
      PRINT 13, I,(B(J,I),J=1,3)
      PUNCH 15, I,(B(J,I),J=1,3)
   12 CONTINUE
    2 FORMAT (7X,9F7.4/10F7.4/7F7.4)
   13 FORMAT (1X,I4,3F10.4)
   14 FORMAT (1H1,2X,3HNO.,3X,6HRC-ALL,3X,9HRC-STABLE,1X,11HRC-UNSTABLE
     1,//)
   15 FORMAT (I4,3F10.4)
      END
```

APPENDIX III

LISTING OF PROGRAM REDRAW

```
      PROGRAM FEDRAW (INPUT,OUTPUT)
C     INPUT STRUCTURE SAME AS THAT OF PROGRAM FOURIER-VERSION 2/11/75.
      COMMON X(70), Y(70), RAD(70), THETA(70)
      COMMON/MAIN/NHARM,L,AO,NN
      COMMON A(30), B(30), C(30), NAME(10)
      DIMENSION IX(70), IY(70)
      EQUIVALENCE (X,IX), (Y,IY)
      LOGICAL TRBL
      BETA=4HCONT
      IFLAG=9999
      READ 1.30, NHARM, NOPEN
   20 READ 1.00, NAME
      NOGOOD=0
      ISEQ=0
      LTOTAL=0
      NN=0
      PRINT 940, NAME
   30 JL=1
      JU=10
      TRBL=.FALSE.
   40 READ 950, (IX(J),IY(J),J=JL,JU)
      IF (IX(JL)-IFLAG) 50,810,860
   50 DO 60 K=JL,JU
      KWIT=IX(K)+IY(K)
      IF (KWIT) 60,70,60
   60 CONTINUE
      JL=JL+10
      JU=JU+10
      GO TO 40
   70 L=K-1
      IF(NOPEN) 71,71,72
   72 IXMAX=IX(1)
      DO 73 I=2,L
      IF(IXMAX-IX(I)) 74,73,73
   74 IXMAX=IX(I)
   73 CONTINUE
      IXMIN=IX(1)
      DO 75 I=2,L
      IF(IXMIN-IX(I)) 75,75,76
   76 IXMIN=IX(I)
   75 CONTINUE
      IXMAX=IXMAX-IXMIN
      DO 77 I=1,L
      X(I)=((IX(I)-IXMIN)*6.2832)/IXMAX
   77 Y(I)=IY(I)
      IYMAX=IY(1)
      DO 78 I=2,L
      IF(IYMAX-IY(I)) 79,78,78
   79 IYMAX=IY(I)
   78 CONTINUE
      DO 81 I=1,L
      IX(I)=(Y(I)*COS(X(I)))+IYMAX
   81 IY(I)=(Y(I)*SIN(X(I)))+IYMAX
      L=L-1
   71 ISEQ=ISEQ+1
      LTOTAL=LTOTAL+L
      DO 570 J=1,L
      X(J)=IX(J)
  570 Y(J)=IY(J)
      MX=0
      MY=MX
      MMY=1
      MMX=MMY
      YMOM=0.
      XMOM=YMOM
      YAREA=XMOM
      XAREA=YAREA
  580 MMX=MMX+1
      MX=MX+1
      IF (MX-L) 600,590,600
  590 MMX=1
  600 YAREA=YAREA+(X(MMX)-X(MX))*(Y(MMX)+Y(MX))
      YMOM=YMOM+(X(MMX)-X(MX))*((Y(MMX)+Y(MX))**2-Y(MMX)*Y(MX))
      IF (MX-L) 580,610,580
  610 MMY=MMY+1
      MY=MY+1
      IF (MY-L) 630,620,630
  620 MMY=1
```

```
 630 XAREA=XAREA+(Y(MMY)-Y(MY))*(X(MMY)+X(MY))
     XMOM=XMOM+(Y(MMY)-Y(MY))*((X(MMY)+X(MY))**2-X(MMY)*X(MY))
     IF (MY-L) 610,640,610
 640 YCEN=YMOM/(YAREA*3.)
     XCEN=XMOM/(XAREA*3.)
     DO 660 I=1,L
     THETA(I)=ATAN((Y(I)-YCEN)/(X(I)-XCEN))
     IF (X(I)-XCEN) 650,660,660
 650 THETA(I)=THETA(I)+3.14159
 660 RAD(I)=SQRT((Y(I)-YCEN)**2+(X(I)-XCEN)**2)
     DO 670 I=1,NHARM
 670 A(I)=B(I)=0.
     AO=0.
     FL=L
     AJ=25./FL
     DO 750 I=1,L
     II=I+1
     IF (I-L) 690,680,690
 680 II=1
 690 ANGLE=THETA(II)-THETA(I)
     IF (ANGLE) 700,760,710
 700 ANGLE=ANGLE+6.28318
 710 IF (ANGLE-AJ) 730,720,720
 720 TRBL=.TRUE.
     GO TO 760
 730 IF(TRBL) 760,740
 740 AO=AO+ANGLE*(RAD(II)+RAD(I))
     DO 750 N=1,NHARM
     FN=N
     COS2=COS(FN*THETA(II))
     COS1=COS(FN*THETA(I))
     SIN2=SIN(FN*THETA(II))
     SIN1=SIN(FN*THETA(I))
     A(N)=A(N)+((RAD(II)-RAD(I))*(COS2-COS1))/(ANGLE*FN*FN)+(RAD(II)*SI
    1N2-RAD(I)*SIN1)/FN
 750 B(N)=B(N)+((RAD(II)-RAD(I))*(SIN2-SIN1))/(ANGLE*FN*FN)-(RAD(II)*CO
    1S2-RAD(I)*COS1)/FN
 760 CONTINUE
     IF(TRBL) 770,780
 770 NOGOOD=NOGOOD+1
     PRINT 1050, ISEQ
     GO TO 30
 780 DO 31 N=1,NHARM
     IF (A(N)) 37,36,37
  36 C(N)=90.
     GO TO 33
  37 C(N)=57.296*ATAN(B(N)/A(N))
     IF (A(N)) 32,33,33
  32 C(N)=C(N)+180.
     GO TO 31
  33 IF (B(N)) 34,31,31
  34 C(N)=C(N)+360.
  31 CONTINUE
     DO 35 N=1,NHARM
     C(N)=C(N)-N*C(2)/2.0
  63 IF (C(N)-360.) 64,64,61
  64 IF (C(N)) 62,35,35
  61 C(N)=C(N)-360.
     GO TO 63
  62 C(N)=C(N)+360.
     GO TO 64
  35 CONTINUE
     DO 790 N=1,NHARM
 790 A(N)=(SQRT(A(N)**2+B(N)**2))*4./AO
     AO=AO/12.5663
     NN=NN+1
     CALL RMS
     GO TO 30
 810 PRINT 900,NN
 855 READ 1010,ALPHA
     IF (ALPHA-BETA) 860,20,860
 860 CONTINUE
 900 FORMAT(22H USABLE SAMPLE SIZE IS,I4)
 940 FORMAT(1H1,10(1H+),10A8,10(1H+)/37H THE FOLLOWING SAMPLES CANNOT B
    +E USED)
 950 FORMAT (20I4)
1000 FORMAT(10A8)
1010 FORMAT (A4)
```

```
1030 FORMAT(2I2)
1050 FORMAT (21X,6HNUMBER,I5)
     END

     SUBROUTINE RMS
     COMMON/MAIN/NHARM,L,AO,NN
     COMMON X(70), Y(70), RAD(70), THETA(70)
     COMMON A(30), B(30), C(30), NAME(10)
     DIMENSION RADN(70), R(30), F(30), DFN(30), DFD(30)
     DO 3 J=1,L
   3 RADN(J)=AO
     OLDSUM=0.0
     DO 8 I=1,L
     OLDSUM=OLDSUM+(RAD(I)-AO)**2
   8 CONTINUE
     DO 1 I=1,NHARM
     A(I)=A(I)*AO
     SUM=0.0
     DO 2 J=1,L
     PHI=(I*THETA(J))-(C(I)*0.01745)
     RADN(J)=RADN(J)+A(I)*COS(PHI)
     SUM=SUM+(RADN(J)-RAD(J))**2
     SUM2=OLDSUM-SUM
   2 CONTINUE
     DFD(I)=L-(I*2.)-1.
     XM1=SUM2/2.
     XM2=SUM/DFD(I)
     F(I)=XM1/XM2
     R(I)=(SQRT(SUM/(L-1)))/AO
   1 CONTINUE
     PRINT 4, NN,(I,I=1,15)
     PRINT 5, (DFD(I),I=1,15)
     PRINT 6, (F(I),I=1,15)
     PRINT 7, (R(I),I=1,15)
     PRINT 4, NN,(I,I=16,NHARM)
     PRINT 5, (DFD(I),I=16,NHARM)
     PRINT 6, (F(I),I=16,NHARM)
     PRINT 7, (R(I),I=16,NHARM)
   4 FORMAT (1H0,10HSAMPLE NO.,I2,2X,15HHARMONIC NUMBER/1X,15(I6,2X))
   5 FORMAT (1H0,30HDENOMINATOR DEGREES OF FREEDOM/1X,15F8.0)
   6 FORMAT (1H0,8HF RATIOS/1X,15F8.2)
   7 FORMAT (1H0,17HROOT MEAN SQUARES/1X,15F8.4)
     END
```

APPENDIX IV

LISTING OF PROGRAM ANGLE

```
      PROGRAM ANGLE (INPUT,OUTPUT)
      DIMENSION PHI(91,29)
      DO 2 J=1,91
      READ 1,(PHI(J,K),K=1,29)
    2 CONTINUE
      DO 3 I=1,29
      SUM1=0.0
      SUM2=0.0
      DO 4 L=1,91
      PHI(L,I)=PHI(L,I)*0.01745
      SUM1=SUM1+COS(PHI(L,I))
      SUM2=SUM2+SIN(PHI(L,I))
    4 CONTINUE
      RESULT1=SUM2/SUM1
      SUM1=SUM1**2
      SUM4=SUM2
      SUM2=SUM2**2
      SUM3=SUM1+SUM2
      R=SQRT(SUM3)
      RESULT2=SUM4/R
      A1=ATAN(RESULT1)*57.296
      A2=ASIN(RESULT2)*57.296
      PRINT 5,I,R,A1,A2
    3 CONTINUE
    1 FORMAT (10F7.2)
    5 FORMAT (1X,8HHARMONIC,I4,3F10.4)
      END
```

APPENDIX V

LISTING OF PROGRAM CONVERT

```
      PROGRAM CONVERT (INPUT,OUTPUT,PUNCH)
      DIMENSION AMP(30),ANGLE(25)
      DO 1 I=1,91
      READ 2,(AMP(J),J=1,30)
      READ 3,(ANGLE(J),J=1,25)
      DO 4 J=1,30
      AMP(J)=ALOG(AMP(J))
    4 CONTINUE
      DO 5 J=1,25
      IF (ANGLE(J).GT.180.) GO TO 6
      GO TO 5
    6 ANGLE(J)=360.-ANGLE(J)
    5 CONTINUE
      PUNCH 7, I,(AMP(J),J=1,30)
      PUNCH 8, (ANGLE(J),J=1,25)
    1 CONTINUE
    2 FORMAT (7X,F7.4,2F10.4,F10.3/7X,9F7.4/10F7.4/7F7.4)
    3 FORMAT (14X,8F7.2/10F7.2/7F7.2)
    7 FORMAT (I6,6X,8F8.3/10F8.3/10F8.3/2F8.3)
    8 FORMAT (10F7.2)
      END
```

APPENDIX VI

LISTING OF CLUST6 PROGRAM WITH FINAL CLUSTER RESULTS

```
*IDENT C 46     Q-MODE CLUSTER ON DISTANCE FUNCTION      CDC 6400     F  IV
      OVERLAY(JPCL,0,0)
      PROGRAM CLUSTR(INPUT,TAPE3=INPUT,OUTPUT,TAPE4=OUTPUT,TAPE6,TAPE7,
     1TAPE8,TAPE5,PUNCH)
C     CLUSTER PROGRAM - LIMIT 100 VARIABLES,  200 SAMPLES
C
C       200 SAMPLE 100 VARIABLE PROGRAM RUNS ON 65010  CENTRAL MEMORY
C       BY CHANGING INDICATED DIMENSIONS, CAPACITY OF PROGRAM CAN BE
C       INCREASED TO 1000 SAMPLES BY 200 VARIABLES, BUT IT WILL THEN
C       REQUIRE 140K
C       REQUIRED DIMENSION CHANGES ARE INDICATED BY COMMENT CARDS, MAINLY
C       THE BEGINNING OF EACH OVERLAY PROGRAM, BUT THERE ARE A FEW OTHER
C       ALSO INDICATED BY COMMENT CARDS
C
C     PERFORMS R-MODE PRINCIPAL COMPONENTS ANALYSIS ON VARIABLES
C         LIMIT 10 FACTORS OR PRINCIPAL COMPONENTS, EITHER ON
C          CORRELATION COEFFICIENT MATRIX OR DISTANCE FUNCTION MATRIX
C
C     CARD 1 --- TITLE CARD     80 COLUMNS ALPHANUMERIC
C     CARD 2 --- COLUMNS 1-4 = NUMBER OF VARIABLES (RIGHT JUSTIFIED)
C                COLS 5-6 = I, NUMBER OF ALPHANUMERIC CHARACTERS IN
C                   FIRST A-FIELD OF SAMPLE DESIGNATION (RIGHT JUSTIFIED)
C                   IF  LEFT BLANK, DEFAULT VALUE IS  5
C
C                COLS 7-8 = IFM, MAXIMUM NUMBER OF FACTORS DESIRED
C                   (RIGHT JUSTIFIED))  IF LEFT BLANK, DEFAULT VALUE
C                   IS 10 TO ALLOW OTHER CRITERIA TO CONTROL NUMBER OF
C                   FACTORS (ECD OR ECK)
C                COLS 9-10 = JKL, WEIGHTING CODE FOR FACTOR
C                   MEASUREMENTS   IF ZERO OR LEFT BLANK, FACTOR
C                   MEASUREMENTS ARE UNWEIGHTED
C                   IF JKL = 1, FACTOR MEASUREMENTS ARE WEIGHTED
C                         ACCORDING TO PERCENT VARIANCE ACCOUNTED FOR
C
C                COLS 11-14= EPSI, CRITERION FOR ACCURACY OF SELECTING
C                   FACTORS)  IF LEFT BLANK, DEFAULT VALUE IS 0.005
C
C                COLS 15-24 = ECK, THE SMALLEST PERCENT VARIANCE
C                   ACCEPTED FOR FURTHER CALCULATIONS
C                      IF LEFT BLANK, DEFAULT VALUE IS 3.0
C                COLS 25-34 = ECH, VALUE OF DISTANCE FUNCTION ON CLUSTER
C                   DIAGRAM AT WHICH CLUSTERS ARE DOUBLE SPACED
C                   IF LEFT BLANK, DEFAULT VALUE IS 1/2 LARGEST DISTANCE
C                COLS 35-44 = ECD, MINIMUM TOTAL PERCENT VARIANCE
C                   ACCEPTED FOR TOTAL NUMBER OF FACTORS TO BE USED
C                   IF LEFT BLANK, DEFAULT VALUE IS 80.0
C               .COLS 45-48 = ICH, (RIGHT JUSTIFIED)
C                   IF COL 48 = 1, FACTOR MATRIX ON VARIABLES IS COMPUTED
C                   ON SIMPLE DISTANCE FUNCTION MATRIX OF VARIABLES
C
C                   IF COL 48 = 2, FACTOR MATRIX OF VARIABLES IS COMPUTED
C                   ON CORRELATION COEFFICIENT MATRIX
C                   IF COL 48 LEFT BLANK, DEFAULT VALUE = 1 (FOR
C                  .DISTANCE FUNCTION MATRIX)
C
C
C                COL 50 = MN
C                   IF COL 50 = 2, FIRST FACTOR SCORE VARIABLE IS
C                   DELETED FROM CLUSTER ANALYSIS
C
C                   IF COL 50 IS LEFT BLANK, DEFAULT VALUE = 1
C
C                COL 52 = NR
C                  IF NR IS SET TO 1, FACTOR MEASUREMENTS ARE NORMALIZED
C                   AND ARE PUNCHED OUT FOR FOR PLOTTING ON TRIANGULAR DI
C
C
C     CARD 3 --- VARIABLE FORMAT CARD, MUST BEGIN WITH 2 A-FIELDS
C                   FIRST A-FIELD MUST BE A5
C                   EXAMPLE VARIABLE FORMAT = (2A6,10F5.0/(12X,10F5.0))
C
C     CARD 4 --- DATA CARDS, USUALLY
C                   COLS 1-12 ALPHANUMERIC SAMPLE DESIGNATION
C                   COLS 13-80 DATA (ACCORDING TO VARIABLE FORMAT CARD 3)
C
C     CARD 5 --- END OF DATA IS INDICATED BY 999999 IN COLS 1-5
C         CARD TYPE 5 MUST BE FOLLOWED BY AS MANY BLANK CARDS AS NEEDED
C         TO EQUAL NUMBER OF CARDS IN DATA SET FOR EACH SAMPLE
```

```
C
C        TWO OR MORE JOBS MAY BE DONE IN SEQUENCE, STARTING WITH CARD 1
C        THROUGH CARD 5
C
C     LAST CARD IN DATA DECK MUST HAVE IN COLS 1-6 FINISH
C
C     FACTOR MEASUREMENTS ARE COMPUTED FOR EACH SAMPLE, WHICH ARE THEN
C        NORMALIZED, AND USED AS INPUT INTO CLUSTERING ROUTINE BASED ON
C        DISTANCE FUNCTION
C
C     CLUSTERING OF SAMPLES IS PERFORMED ON SIMPLE DISTANCE FUNCTION
C         DATA ARE NORMALIZED ( NOT STANDARDIZED) BY VARIABLES
C
C     CLUSTER DIAGRAM IS PRINTED OUT BY COMPUTER PRINTER, WITH
C        SEQUENTIAL SAMPLE NUMBER IN FIRST COLUMN, THEN ACTUAL
C        ALPHANUMERIC SAMPLE DESIGNATOR IN SECOND COLUMN
C
C
      COMMON/BLOCKA/M,N,MP,NN,IECK,JPCL,IP,CHAR(16),ECH,ECD,EPSI,ECK,IFM
     1,JKL,MN,BENO,IMT(16),I,ICH,NR
      COMMON/BLB/IO(200),IS(200),RCOEF(200),IC(200,2),IY(200),IWYE(200)
      COMMON/BLC/TX(200)
C  ****************************************
C      FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     COMMON/BLB/IO(1000),IS(1000),RCOEF(1000),IC(1000,2),IY(1000),IWYE(
C    11000)
C     COMMON/BLC/TX(1000)
C
      COMMON/BLD/PC(10)
      JPCL=4LJPCL
      FINI=(5HFINIS)
    3 CONTINUE
      REWIND 5
      REWIND 6
      REWIND 7
      REWIND 8
      READ(3,201) (CHAR(I),I=1,16)
  201 FORMAT(16A5)
      IF(CHAR(1).EQ.FINI) GO TO 4
      READ(3,202)M,I,IFM,JKL,EPSI,ECK,ECH,ECD,ICH,MN,NR
  202 FORMAT(I4,3I2,F4.0,3F10.0,T4,2I2)
      IF(MN.LE.0) MN=1
      IF(ICH.LE.0) ICH=1
      CALL OVERLAY(JPCL,5,0)
      CALL OVERLAY(JPCL,1,0)
      CALL OVERLAY(JPCL,2,0)
      CALL OVERLAY(JPCL,3,0)
      CALL OVERLAY(JPCL,4,0)
      GO TO 3
    4 CONTINUE
      END
```

```
      OVERLAY(JPCL,1,0)
      PROGRAM FACMES
C    TO CALCULATE FACTOR MEASUREMENTS FROM RAW DATA MATRIX
C       INPUT, 100 VARIABLES BY 200 SAMPLES
C       NORMALIZES VARIABLES
C       CALCULATES CORRELATION COEFFICIENT MATRIX BY VARIABLES
C       EXTRACTS PRINCIPAL FACTORS LARGER THAN 5 PERCENT OF VARIANCE
C       TAKES SQUARE ROOT OF FACTOR MATRIX
C       CALCULATES BETA COEFFICIENTS
C       ESTIMATES FACTOR MEASUREMENTS
C       READY FOR INPUT TO CLUSTER BY DISTANCE
C
C
C     FUNCTION ISYMM TO FIND LINEAR SUBSCRIPT IN HALF OF A
C     SYMMETRIC MATRIX WITH ITS PRINCIPAL DIAGONAL STORED IN ROW-WISE
C     ORDER, GIVEN ROW(I) AND COLUMN(J) AND SIZE OF MATRIX(M)
C
      DIMENSION RTT( 50),VEE( 60),R( 3030),X( 60),TT( 60),T( 50),F
     1( 60,10),VV(10),H(10),AR( 60) ,SUMASQ(10),HSQ( 50),TN( 50)
C   ******************************************
C     SET THE DIMENSIONS OF ARRAY R TO THE
C     QUANTITY 50.5 X NO. OF VARIABLES.
C     FOR A 50 VARIABLE PROBLEM CHANGE THE R( 5050) IN THE DIMENSION STATMENT
C     TO R( 1275)
C      FOR 200 VARIABLE PROBLEM, CHANGE TO FOLLOWING
C     DIMENSION RTT(200),VEE(200),R(10100),X(200),TT(200),T(200),F(200,1
C    10),VV(10),H(10),AR(200),SUMASQ(10),HSQ(200),TN(200)
C
      COMMON/BLOCKA/M,N,MP,MN,IFCK,JPCL,IP,CHAR(16),ECH,ECD,EPSI,ECK,IFM
     1,JKL,MN,REND,IMT(16),I,ICH,NR
      COMMON/BLD/PC(10)
      EMM=M
      NNN=(M*M+M)/2
      PCO=0.0
      DO 296 J=1,10
      SUMASQ(J)=0.0
      VV(J)=0.0
  296 PC(J)=0.0
      DO 417 J=1,M
      HSQ(J)=0.0
      DO 417 K=1,10
  417 F(J,K)=0.0
      WRITE(4,300)
  300 FORMAT(25X,38HPRINCIPAL FACTOR ANALYSIS OF VARIABLES//)
      READ(8) (R(I),I=1,NNN)
      REWIND 8
      PEPSI=EPSI
  412 DO 401 MP=1,10
      KIP=MP
      DO 324 J=1,M
  324 VEE(J)=0.0
      SUV=0.0
      LLL=0
      NQ=0
      LL=1
  400 CONTINUE
      DO 313 J=1,M
      TT(J)=0.0
  313 T(J)=0.0
      DO 6001 K=1,M
      DO 6003 J=1,M
 6003 AR(J)=0.0
      MK=M-K+1
      L=1
      DO 6005 I=K,M
      DO 6002 J=1,M
      MJ=ISYMM(J,K,M)
      MI=ISYMM(J,I,M)
      AR(L)=AR(L)+R(MI)*R(MJ)
 6002 CONTINUE
      L=L+1
 6005 CONTINUE
      WRITE(7) (AR(L),L=1,MK)
 6001 CONTINUE
      REWIND 7
      K=M
      L=1
      DO 6006 I=1,M
```

```
      READ(7) (R(J),J=L,K)
      L=K+1
 6006 K=K+M-T
      REWIND 7
      DO 101 J=1,NNN
      IF(R(J).NE.0.0) GO TO 102
  101 CONTINUE
      READ(5)(R(J),J=1,NNN)
      REWIND 5
      NQ=1
  102 CONTINUE
      DO 314 J=1,M
      DO 314 I=1,M
      IA=ISYMM(I,J,M)
  314 T(J)=T(J)+R(IA)
      TM=0.0
      DO 315 J=1,M
      IF(ABS(TM).LT.ABS(T(J))) TM=T(J)
  315 CONTINUE
      DO 316 J=1,M
      TN(J)=T(J)/TM
      IF(T(J).EQ.0.0) TN(J)=0.0
  316 CONTINUE
   43 DO 317 J=1,M
  317 TT(J)=0.0
      DO 318 J=1,M
      DO 318 I=1,M
      IA=ISYMM(I,J,M)
  318 TT(J)=TT(J)+R(IA)*TN(I)
      TM=0.C
      DO 319 J=1,M
      IF(ABS(TM).LT.ABS(TT(J))) TM=TT(J)
  319 CONTINUE
      DO 320 J=1,M
      RTT(J)=TT(J)/TM
      IF(TT(J).EQ.0.0) RTT(J)=0.0
  320 CONTINUE
  414 DO 321 J=1,M
      TEST1=RTT(J)+EPSI
      TEST2=RTT(J)-EPSI
      IF(TN(J).LT.TEST1.AND.TN(J).GT.TEST2) GO TO 321
      LLL=LLL+1
      IF(LL.EQ.0) GO TO 413
      LL=LL+1
      IF(LL-4 )413,413,411
  411 EPSI=EPSI+EPSI/5.0
      LL=0
      GO TO 414
  413 CONTINUE
      IF(LLL.GT.8) GO TO 40
      IF(NQ.EQ.1) GO TO 40
      GO TO 41
   40 DO 42 K=1,M
      TN(K)=RTT(K)
   42 CONTINUE
      GO TO 43
   41 GO TO 400
  321 CONTINUE
      EPSI=REPSI
      READ(5) (R(J),J=1,NNN)
      REWIND 5
      DO 326 J=1,M
      DO 326 I=1,M
      IA=ISYMM(I,J,M)
  326 VEE(J)=VEE(J)+RTT(I)*R(IA)
      DO 327 I=1,M
  327 SUV=SUV+RTT(I)*VEE(I)
      SUV=ABS(SUV)
      SUV=SQRT(SUV)
      WRITE(4,301) MP
  301 FORMAT(1H ,5X,6HFACTOR,I5)
      DO 328 J=1,M
      F(J,MP)=VEE(J)/SUV
  328 IF(VEE(J).EQ.0.0.AND.SUV.EQ.0.0) F(J,MP)=0.0
      IA=0
      DO 329 J=1,M
      DO 329 K=J,M
      IA=IA+1
```

```
329 R(IA)=R(IA)-F(J,MP)*F(K,MP)
    WRITE (5)  (R(J),J=1,NNN)
    REWIND 5
    DO 330 J=1,M
330 SUMASQ(MP)=SUMASQ(MP)+F(J,MP)*F(J,MP)
    WRITE(4,302) LLL
302 FORMAT(15X,27HNUMBER OF ITERATIONS EQUALS,I7)
    WRITE(4,303) SUMASQ(MP)
303 FORMAT(15X,25HVARIANCE EXTRACTED EQUALS,F9.3//)
    PC(MP)=SUMASQ(MP)*100./EMM
    PCO=PCO+PC(MP)
    IF(MP.LT.IFM) GO TO 401
    IF(MP.GT.IFM) GO TO 331
    IF(PCO.GT.ECO) GO TO 415
    IF(PCO.GT.50.0.AND.PC(MP).LT.EC<)GO TO 331
401 CONTINUE
    MP=KIP
    GO TO 415
331 MP=MP-1
415 DO 332 J=1,M
    DO 332 K=1,MP
332 HSQ(J)=HSQ(J)+F(J,K)*F(J,K)
    WRITE(4,304)
304 FORMAT(1H1,5X,30HPRINCIPAL AXIS FACTOR LOADINGS//)
    WRITE(4,305)
305 FORMAT(12X,3HF 1,7X,3HF 2,7X,3HF 3,7X,3HF 4,7X,3HF 5,7X,3HF 6,7X,3
   1HF 7,7X,3HF 8,7X,3HF 9,5X,4HF 10,9X,3HHSQ//)
    DO 333 K=1,M
    DO 334 J=1,MP
334 VV(J)=F(K,J)
333 WRITE(4,306) K,(VV(I),I=1,10),HSQ(K)
306 FORMAT(2X,I4,11F10.3)
    WRITE(4,307) (SUMASQ(I),I=1,MP)
307 FORMAT(1H0,5X,10F10.3)
    WRITE(4,307) (PC(J),J=1,MP)
    WRITE(4,307) PCO
    READ(8) (R(J),J=1,NNN)
    REWIND 8
    DO 336 J=2,M
    LJ=J-1
    II=ISYMM(J,J,M)
    DO 337 L=1,LJ
    IL=ISYMM(L,J,M)
337 R(II)=R(II)-R(IL)*R(IL)
    IF (R(II).LE.0.0) GO TO 7021
    R(II)=SQRT(R(II))
    KJ=J+1
    IF(KJ.GT.M)GO TO 339
    DO 336 K=KJ,M
    LJ=J-1
    IJ=ISYMM(J,K,M)
    DO 338 L=1,LJ
    IK=ISYMM(L,K,M)
    IL=ISYMM(L,J,M)
338 R(IJ)=R(IJ)-R(IK)*R(IL)
336 R(IJ)=R(IJ)/R(II)
339 CONTINUE
    DO 342 K=1,MP
    DO 342 J=1,M
    DO 343 L=1,J
    IF(L.EQ.J) GO TO 416
    IL=ISYMM(L,J,M)
343 F(J,K)=F(J,K)-F(L,K)*R(IL)
416 IJ=ISYMM(J,J,M)
342 F(J,K)=F(J,K)/R(IJ)
    WRITE(4,309)
    WRITE(4,305)
309 FORMAT(1H1,5X,28HSQUARE ROOT OF FACTOR MATRIX//)
    DO 344 K=1,M
    DO 345 J=1,MP
345 VV(J)=F(K,J)
344 WRITE(4,306) K,(VV(I),I=1,MP)
    DO 346 K=1,MP
    DO 347 J=1,M
    JJ=M+1-J
    JK=ISYMM(JJ,JJ,M)
    DO 348 I=1,M
    II=M+1-I
```

```
      IF(II.EQ.JJ) GO TO 347
      JI=ISYMM(JJ,II,M)
  348 F(JJ,K)=F(JJ,K)-R(JI)*F(II,K)
  347 F(JJ,K)=F(JJ,K)/R(JK)
  346 CONTINUE
      WRITE(4,119)
  119 FORMAT(1H1,10X,17HBETA COEFFICIENTS//)
      WRITE(4,311)
  311 FORMAT(9X,3HF 1,8X,3HF 2,8X,3HF 3,8X,3HF 4,8X,3HF 5,8X,3HF 6,8X,3H
     1F 7,8X,3HF 8,8X,3HF 9,8X,4HF 10//)
      DO 349 K=1,M
  349 WRITE(4,350) K,(F(K,J),J=1,MP)
  350 FORMAT(1X,I4,10F11.5)
      DO 551 I=1,N
  551 READ(6) Q1,Q2
      DO 352  J=1,N
      READ(6)  (X(I),I=1,M)
      DO 353 K=1,MP
      RTT(K)=0.0
      DO 353 I=1,M
      RTT(K)=RTT(K)+F(I,K)*X(I)
  353 CONTINUE
      WRITE(8)  (RTT(K),K=1,MP)
  352 CONTINUE
      END FILE 8
      REWIND 8
      REWIND 6
      GO TO 7019
 7021 PRINT 7020,II,IL
 7020 FORMAT(1X,* INDEX II=*,I5,*INDEX IL=*,I5,* VARIABLES ARE
     1 PERFECTLY CORRELATED PROGRAM TERMINATED*)
 7019 CONTINUE
      END

      FUNCTION ISYMM(I,J,M)
      IF(I.GT.J) GO TO 111
  110 ISYMM=(I-1)*M-((I-1)*I)/2+J
      RETURN
  111 ISYMM=(J-1)*M-((J-1)*J)/2+I
      RETURN
      END
```

```
      OVERLAY(JPCL,2,0)
      PROGRAM CLUSTE
      DIMENSION TT(10),PT(10),X(10,200),Y(200),L(200,2),XX(10)
      COMMON/BLOCKA/M,N,MP,NN,IFCK,JPCL,IP,CHAR(16),FCH,FCD,EPSI,FCK,IFM
     1,JKL,MN,RENO,TMT(16),I,ICH,NR
      COMMON/BLB/IO(200),IS(200),RCOEF(200),IC(200,2),IY(200),IHYE(200)
      COMMON/BLC/IX(200)
C     ****************************************
C     FOR A 70 SAMPLE SIZE PROBLEM CHANGE X(10, 200) IN THE ABOVE DIMENS
C     STATEMENT TO X(10,  70)
C      FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     DIMENSION TT(10),PT(10),X(10,1000),Y(1000),L(1000,2),XX(10)
C     COMMON/BLB/IO(1000),IS(1000),RCOEF(1000),IC(1000,2),IY(1000),IHYE(
C    11000)
C     COMMON/BLC/IX(1000)
C
      COMMON/BLD/PC(10)
      INTEGER P
      NN=N-1
      M=MP
      DO 41 J=1,M
      TT(J)=999999.
   41 PT(J)=-99999.
      DO 33 J=1,N
      READ(8) (X(I,J),I=1,M)
      DO 32 I=1,MP
      IF(X(I,J).LT.TT(I)) TT(I)=X(I,J)
   32 IF(X(I,J).GT.PT(I)) PT(I)=X(I,J)
   33 CONTINUE
      REWIND 8
      IF(JKL.GE.1) GO TO 538
      WRITE(4,410)
  410 FORMAT(1H1,42HNORMALIZED FACTOR MEASUREMENTS, UNWEIGHTED//)
      DO 541 K=1,MP
  541 PT(K)=PT(K)-TT(K)
      GO TO 539
  538 CONTINUE
      WRITE(4,537)
  537 FORMAT(1H1, 40HNORMALIZED FACTOR MEASUREMENTS, WEIGHTED//)
      DO 46 K=1,MP
   46 PT(K)=(PT(K)-TT(K))*100./PC(K)
  539 CONTINUE
      DO 47 J=1,MP
      DO 47 I=1,N
   47 X(J,I)=(X(J,I)-TT(J))/PT(J)
      DO 412 J=1,N
  412 WRITE(4,411) J,(X(I,J),I=1,MP)
      IF(NR.EQ.1) 566,565
  566 CONTINUE
      WRITE(4,563)
  563 FORMAT(1H1,*FACTOR MEASUREMENTS NORMALIZED ROW-WISE*//)
      DO 561 I=1,N
      SX=0.0
      DO 560 J=1,MP
      XX(J)=X(J,I)*X(J,I)
  560 SX=SX+XX(J)
      DO 562 J=1,MP
  562 XX(J)=XX(J)/SX
      WRITE(4,411) I,(XX(J),J=1,MP),SX
      PUNCH 564,I,(XX(J),J=1,MP)
  564 FORMAT(I8,10F7.5)
  561 CONTINUE
  565 CONTINUE
  411 FORMAT(1X,I4,10F11.5)
      EM=M
      IF(MN.EQ.2) EM=EM-1.0
      IF(MN.EQ.2) WRITE(4,540)
  540 FORMAT(10X,*FIRST FACTOR SCORE ELIMINATED FROM CLUSTER*,//)
      DO 191 J=1,N
      IC(J,1)=1
      IC(J,2)=1
      IO(J)=0
      IS(J)=0
  191 RCOEF(J)=0.0
      IP=1
      NT=N/2
   19 CONTINUE
      JI=1
```

```
      DO 11 I=1,N
      Y(I)=1.0
      DO 11 J=1,2
      L(I,J)=0
   11 CONTINUE
      DO 215 J=1,NN
      IF(X(1,J).LT.0.0) GO TO 215
      IJ=J+1
      DO 216 K=IJ,N
      IF(X(1,K).LT.0.0) GO TO 216
      R=0.0
      DO 122 I=MN,M
  122 R=R+(X(I,K)-X(I,J))*(X(I,K)-X(I,J))
      R=R/EM
      DO 12 I=1,JI
      IF(R.GT.Y(I)) GO TO 12
      II=I
      GO TO 13
   12 CONTINUE
      II=JI+1
   13 TEMP=Y(II)
      JEMP=L(II,1)
      KEMP=L(II,2)
      IB=II
      IF(IB.EQ.1) GO TO 16
      DO 14 I=1,IB
      IF(K.EQ.L(I,2).OR.J.EQ.L(I,2))GO TO 216
   14 CONTINUE
   16 Y(II)=R
      L(II,1)=J
      L(II,2)=K
      JI=JI+1
      IB=II+1
      IF(IB.GT.JI) GO TO 216
      DO 15 I=IB,JI
      IF(K.EQ.KEMP) GO TO 17
   21 TTEMP=Y(I)
      JTEMP=L(I,1)
      KTEMP=L(I,2)
      Y(I)=TEMP
      L(I,1)=JEMP
      L(I,2)=KEMP
      TEMP=TTEMP
      JEMP=JTEMP
      KEMP=KTEMP
   15 CONTINUE
      GO TO 216
   17 JI=JI-1
  216 CONTINUE
  215 CONTINUE
      II=1
      DO 211 P=IP,NI
      KP=P
      LP=P-1
      RCOEF(P)=Y(II)
      IF(LP.EQ.0) GO TO 210
      IF(NI.LT.(N-N/5).AND.RCOEF(P).GT.(RCOEF(LP)+0.002)) GO TO 212
  210 CONTINUE
      IQ(P)=L(II,1)
      IS(P)=L(II,2)
      J=P-1
  147 IF(J.EQ.0) GO TO 59
      DO 703 I=1,J
      K=P-I
      IF(IQ(K).EQ.IQ(P)) GO TO 707
  703 CONTINUE
      GO TO 704
  707 IC(P,1)=IC(K,1)+IC(K,2)
  704 J=P-1
      DO 706 I=1,J
      K=P-I
      IF(IQ(K).EQ.IS(P)) GO TO 705
  706 CONTINUE
      GO TO 59
  705 IC(P,2)=IC(K,1)+IC(K,2)
   59 TEMPJ=0
      TJ=0
      IF(IC(P,1).GE.IC(P,2)) GO TO 62
```

```
261  TEMPJ=IQ(P)
     IQ(P)=IS(P)
     IS(P)=TEMPJ
     TEMPJ=IC(P,1)
     IC(P,1)=IC(P,2)
     IC(P,2)=TEMPJ
     TEMPJ=L(II,1)
     L(II,1)=L(II,2)
     L(II,2)=TEMPJ
     IJ=II+1
     IF(IJ.GT.JI) GO TO 62
     DO 262 I=IJ,JI
     IF(L(II,2).EQ.L(I,1)) L(I,1)=L(II,1)
     IF(L(II,2).EQ.L(I,2)) L(I,2)=L(II,1)
262  CONTINUE
 62  AK=IC(P,1)
     BK=IC(P,2)
     JA=IQ(P)
     JB=IS(P)
     DO 63 J=MN,M
     X(J,JA)=(X(J,JA)*AK+X(J,JB)*BK)/(AK+BK)
 63  CONTINUE
     X(1,JB)=-9.0
     K=II+1
     IF(K.GT.JI) GO TO 212
     R=0.0
     DO 64 J=K,JI
     JB=J
     IF(JA.EQ.L(J,2)) GO TO 66
     IF(JA.EQ.L(J,1))GO TO 65
 64  CONTINUE
     GO TO 232
 65  JC=L(JB,2)
     GO TO 67
 66  JC=L(JB,1)
 67  DO 222 I=MN,M
     R=R+(X(I,JA)-X(I,JC))*(X(I,JA)-X(I,JC))
222  CONTINUE
     R=R/EM
     Y(JB)=R
232  CONTINUE
     II=II+1
     IF(KP.EQ.NN) GO TO 20
211  CONTINUE
     KP=KP+1
212  IP=KP
     IF(IP.LE.(2*N/3)) GO TO 9
     NI=NN
     GO TO 19
  9  NI=N-N/5
     GO TO 19
 20  WRITE(4,10)   (CHAR(J),J=1,16)
 10  FORMAT(1H1,16A5)
     END
```

```
      OVERLAY(JPOL,3,0)
      PROGRAM PLPLIT
      DIMENSION BO(11),B(24)
      DIMENSION KEY(200),LE(200),IL(200)
      COMMON/BLOCKA/M,N,MP,NN,IECK,JPOL,IP,CHAR(16),ECH,ECO,EPSI,ECK,IFM
     1,JKL,MN,BEND,IMT(16),I,ICH,NP
      COMMON/BLB/IO(200),IS(200),RCOEF(200),IC(200,2),IY(200),IWYE(200)
      COMMON/BLC/IX(200)
C  ****************************************
C       FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     DIMENSION KEY(1000),LE(1000),IL(1000)
C     COMMON/BLB/IO(1000),IS(1000),RCOEF(1000),IC(1000,2),IY(1000),IWYE(
C    11000)
C     COMMON/BLC/IX(1000)
C
      DATA BOX/4H    /
      DATA (BO(J),J=1,11)/4H 0.0,4H 0.1,4H 0.2,4H 0.3,4H 0.4,4H 0.5,4H 0
     1.6,4H 0.7,4H 0.8,4H 0.9,4H 1.0/
      WRITE(4,550) N
  550 FORMAT(5X,I6,2X,7HSAMPLES//)
      WRITE(4,106)
  106 FORMAT(//30X,23HCLUSTER TYPE 6 ANALYSIS/)
      WRITE(4,108)
  108 FORMAT(1X,59H   LEFT SAMPLE   RIGHT SAMPLE   DISTANCE  NO. IN
     1NO. IN)
      WRITE(4,109)
  109 FORMAT(1X,59H     NUMBER         NUMBER        FUNCTION   LEFT
     1 RIGHT/)
      DO 381 J=1,NN
      RCOEF(J)=SQRT (RCOEF(J))
  381 WRITE(4,110) IO(J),IS(J),RCOEF(J),IC(J,1),IC(J,2)
  110 FORMAT(1X,I10,I15,F12.7,2I8)
      RCOEFO =0.0
      J=NN
      DO 5 K=1,10
      IF(RCOEFO-RCOEF(J))6,5,5
    6 RCOEFO=RCOEF(J)
      IJ=J
    5 J=J-1
      DO 4 L=IJ,NN
    4 RCOEF(L)=RCOEFO
      COP=1.0
      DO 7 K=1,10
      IF(RCOEFO-COP)7,7,8
    7 COP=COP-0.1
    8 RCOEFO=COP+0.1
      IF(ECH)911,911,912
  911 ECH=RCOEFO/2.0
  912 COP=24./RCOEFO
      IECK=ECH*COP
      DO 9 J=1,NN
      IX(J)=RCOEF(J)*COP
      IF(IX(J).LT.1) IX(J)=1
    9 CONTINUE
      NNN=NN-1
      WRITE(4,205)
      WRITE(4,207)
      DO 41 J=1,24
   41 B(J)=BOX
      I=24.0/(RCOEFO*10.0)+.2
      L=1
      DO 42 J=1,11
      B(L)=BO(J)
      L=L+I
      IF(L-24)42,42,43
   42 CONTINUE
   43 CONTINUE
      WRITE(4,204) (B(J),J=1,24)
      DO 15 J=1,NNN
      NNNN=NNN-J
      JAY=IX(J)
      DO 15 I=1,NNNN
      IF(IO(J+I).NE.IO(J)) GO TO 13
      IF(IX(J+I).LT.JAY) IX(J+I)=JAY
      JAY=IX(J+I)
   13 IF(IS(J+I).NE.IO(J)) GO TO 15
      IF(IX(J+I).LT.JAY) IX(J+I)=JAY
      JAY=IX(J+I)
```

```
   15 CONTINUE
  206 FORMAT(1H1,15X,15HCLUSTER DIAGRAM/)
  207 FORMAT(10X,20HVALUE OF COEFFICIENT/)
  204 FORMAT(30X,2,A4//)
      DO 3 J=1,N
    3 IWYE(J)=0
      DO 1 J=1,200
C     *******************************************
C       FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     DO 1 J=1,1000
C
      IY(J)=0
      KEY(J)=0
      IL(J)=0
    1 LE(J)=0
      I=1
      IP=1
      IY(IP)=IQ(I)
      IP=IP+1
      IF(IX(I)-IECK) 901,901,902
  902 IP=IP+1
  901 IY(IP)=IS(I)
      IWYE(I)=IP
      IP=IP+1
      KEY(I)=IQ(I)
      IQ(I)=-IQ(I)
      IS(I)=-IS(I)
      LP=1
      K=2
      IL(I)=N
   21 CONTINUE
      DO 20 J=K,NN
      IF(IQ(J)-KEY(I))24,23,24
   23 LE(I)=IC(J,2)
  128 IF(IX(J)-IECK)25,26,25
   25 IP=IP+1
   26 IY(IP)=IS(J)
      IWYE(J)=IP
      LP=LP+1
      IP=IP+1
      IL(I)=IL(I)-LE(I)
      IF(IC(J,2)-1)20,27,32
   27 IQ(J)=-IQ(J)
      IS(J)=-IS(J)
   31 IF(IL(I)-1)29,201,201
  201 IF(J-NN)20,21,45
   29 IF(I-1)21,21,30
   30 I=I-1
      GO TO 31
   32 I=I+1
      IL(I)=IC(J,2)-1
      KEY(I)=IS(J)
      IQ(J)=-IQ(J)
      IS(J)=-IS(J)
      GO TO 21
   24 IF(IS(J)-KEY(I))20,33,20
   33 CONTINUE
   28 IF(IX(J)-IECK)35,35,34
   34 IP=IP+1
   35 I=1
      KEY(I)=IQ(J)
      IY(IP)=IQ(J)
      IWYE(J)=IP
      LP=LP+1
      IP=IP+1
      IQ(J)=-IQ(J)
      IS(J)=-IS(J)
      IL(I)=IC(J,1)-1
      GO TO 21
   20 CONTINUE
      IF(LP.LT.NN) GO TO 21
   45 CONTINUE
      END
```

```
      OVERLAY(JPCL,4,0)
      PROGRAM CLPLAT
      DIMENSION A(24,250),C(200,2)
      COMMON/BLOCKA/M,N,MP,NM,IECK,JPCL,IP,CHAR(16),ECH,ECD,EPSI,ECK,IFM
     1,JKL,MM,BEND,IMT(16),T,TCH,NR
      COMMON/BLB/IQ(200),IS(200),RCOEF(200),IC(200,2),IY(200),IWYE(200)
      COMMON/PLC/TX(200)
C    ******************************************
C       FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     DIMENSION A(24,1500),C(1001,2)
C     COMMON/BLB/IQ(1000),IS(1000),RCOEF(1000),IC(1000,2),IY(1000),IWYE(
C    11000)
C     COMMON/BLC/TX(1000)
C
      EQUIVALENCE (IC,C)
      DATA BOX,BKD,BSD,BLB/4H    ,4H----,4HI   ,4HI---/
      DO 340 I=1,24
      DO 340 J=1,250
C    ******************************************
C       FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     DO 340 J=1,1000
C
  340 A(I,J)=BOX
      K=0
      JT=0
      JK=0
      JL=0
      LL=0
C     JK= ROW FOR UPPER LINE
C     K = COLUMN START FOR UPPER LINE
C     JI = COLUMN END FOR UPPER LINE
C     JL = ROW FOR LOWER LINE
C      LL = CLOUMN START FOR LOWER LINE
C     JT = CLOUMN END FOR LOWER LINE
      DO 1000 I=1,NN
      LK=IC(I,1)
      JM= IC(I,2)
      KK=I
      JJ=JM
      IF(LK-1)45,46,47
   46 IF(JJ-1)45,60,45
   47 IF(JJ-1)45,62,63
   60 K=1
      JI=IX(KK)
      LL=1
      JL=IWYE(KK)
      JK=IWYE(KK)-1
      IF(IX(KK)-IECK)72,72,71
   71 JK=JK-1
   72 GO TO 70
   62 L=KK-1
      LL=1
      DO 85 IJ=1,N
      IF(IQ(KK)-IQ(L))85,86,85
   86 JK=IWYE(L)
      K=IX(L)
      IF(IX(L)-IX(KK))87,88,88
   88 K=IX(KK)
   87 JI=IX(KK)
   89 JL=IWYE(KK)
      IWYE(KK)=(IWYE(KK)+IWYE(L))/2
      GO TO 70
   85 L=L- 1
   63 L=KK-1
      DO 95 IJ=1,N
      IF(IQ(KK)-IQ(L))95,96,95
   96 JK=IWYE(L)
      K=IX(L)
      IF(IX(L)-IX(KK))97,98,98
   98 K=IX(KK)
   97 JI=IX(KK)
   99 LK=KK-1
      DO 101 II=1,N
      IF(IQ(LK)-IS(KK))101,102,101
  102 JL=IWYE(LK)
      LL=IX(LK)
      IF(IX(LK)-IX(KK))103,105,103
  105 LL=IY(KK)
```

```
 103 IHYE(KK)=(IWYF(L)+IWYF(LK))/2
     GO TO 70
 101 LK=LK-1
  95 L=L-1
  70 CONTINUE
  45 CONTINUE
     IF(JI-1)449,455,449
 449 IF(K-JT)411,445,445
 411 IF(A(K,JK)-BSD)476,477,476
 477 A(K,JK)=BLD
     K=K+1
 476 IF(K-JT)446,446,445
 445 JT=K
     IX(I)=JT
 446 IF(LL-JT)412,447,447
 412 IF(A(LL,JL)-BSD)478,479,478
 479 A(LL,JL)=BLD
     LL=LL+1
 478 IF(LL-JT)448,448,447
 447 JT=LL
     IX(I)=JT
 448 DO 376 L=K,JT
 376 A(L,JK)=BKD
     DO 375 L=LL,JI
 375 A(L,JL)=BKD
 455 IF(JL-JK)485,486,486
 485 MM=JL
     JL=JK
     JK=MM
 486 CONTINUE
     DO 374 L=JK,JL
 374 A(JI,L)=BSD
1000 CONTINUE
     DO 561 I=1,N
 561 READ(6) C(I,1),C(I,2)
     REWIND 5
     M=TP
     DO 365 J=1,M
     IF(IY(J)-1)366,357,357
 356 WRITE(4,115) (A(K,J),K=1,24)
     GO TO 365
 357 IK=IY(J)
     WRITE(4,116) IY(J),(C(IK,I),I=1,2),(A(K,J),K=1,24)
 365 CONTINUE
 116 FORMAT(3X,I4,3X,2A6,1X,24A4)
 115 FORMAT(23X,24A4)
     END
```

```
      OVERLAY(JPCL,5,0)
      PROGRAM DISSYM
      DIMENSION RTT( 60),VEE( 60),R( 3030),X( 60),TT( 60),T( 60)
C     ******************************************
C     FOR A 50 VARIABLE PROBLEM CHANGE R( 5050) TO R(  1275) IN ABOVE DIM STATEM
C      FOR 1000 SAMPLE PROBLEM, CHANGE TO FOLLOWING
C     DIMENSION RTT(200),VEE(200),R(10100),X(200),TT(200),T(200)
C
      COMMON/BLOCKA/M,N,MP,NN,TECK,JPCL,IP,CHAR(16),ECH,ECO,EPSI,ECK,IFM
     1,JKL,MN,BEND,IMT(16),I,ICH,NP
      IF(JKL.LE.0) JKL=0
      IF(I.LE.0) GO TO 46
      IF(I.EQ.1) GO TO 47
      IF(I.EQ.3) GO TO 48
      IF(I.EQ.10) GO TO 49
      IF(I.EQ.5) GO TO 2038
      GO TO 46
   47 BEND=(1H9)
      GO TO 50
   48 BEND=(3H999)
      GO TO 50
 2038 BEND=(5H99999)
      GO TO 50
   49 BEND=(10H9999999999)
      GO TO 50
   46 BEND=(6H999999)
   50 CONTINUE
      READ(3,103) (IMT(I),I=1,16)
  103 FORMAT(8A10/,8A10)
      IF(IFM.LE.0) IFM=0
      IF(EPSI.LE.0.0)EPSI=0.005
      IF(ECK.LE.0.0) ECK=3.0
      IF(ECO.LE.0.0) ECO=80.0
      DO 203 J=1,M
      TT(J)=999999.
  203 T(J)=-999999.
C     ***************************************************
      DO 291 J=1,1001
      READ(3,IMT) C1,C2,(X(I),I=1,M)
      IF(C1.EQ.BEND) GO TO 299
      WRITE(6) C1,C2
      DO 292 K=1,M
      IF(X(K).LT.TT(K))TT(K)=X(K)
      IF(X(K).GT.T(K))T(K)=X(K)
  292 CONTINUE
  291 WRITE(8) (X(I),I=1,M)
  299 N=J-1
      END FILE 8
      REWIND 8
      DO 293 K=1,M
  293 T(K)=T(K)-TT(K)
      DO 294 J=1,N
      READ(8) (X(I),I=1,M)
      DO 295 K=1,M
      X(K)=(X(K)-TT(K))/T(K)
  295 CONTINUE
  294 WRITE(6) (X(I),I=1,M)
      END FILE 6
      REWIND 6
      REWIND 8
      WRITE(4,10)(CHAR(I),I=1,16)
   10 FORMAT (1H1,16A5)
      DO 393 K=1,M
      RTT(K)=0.0
  393 VEE(K)=0.0
      NNN=(M*M+M)/2
      DO 310 J=1,NNN
  310 R(J)=0.0
      DO 561 I=1,N
  561 READ(6) D1,D2
      IF(ICH.EQ.2) GO TO 400
      FMM=N
      DO 494 J=1,N
      READ(6) (X(I),I=1,M)
      IJ=1
      DO 497 I=1,M
      R(IJ)=C.0
      IJ=IJ+1
```

```
      L=T+1
      IF(L.GT.M) GO TO 494
      DO 497 K=L,M
      R(IJ)=R(IJ)+(X(I)-X(K))*(X(I)-X(K))
  497 IJ=IJ+1
  494 CONTINUE
      REWIND 5
      IJ=1
      DO 413 J=1,M
      R(IJ)=0.0
      IJ=IJ+1
      KJ=J+1
      IF(KJ.GT.M) GO TO 413
      DO 412 K=KJ,M
      R(IJ)=SQRT(R(IJ)/EMM)
  412 IJ=IJ+1
  413 CONTINUE
      DO 313 J=1,NNN
      R(J)=1.0-R(J)
  313 CONTINUE
      GO TO 401
  400 EM=N
      DO 394 J=1,N
      READ(6) (X(I),I=1,M)
      IJ=1
      DO 395 K=1,M
      RTT(K)=RTT(K)+X(K)
      VEE(K)=VEE(K)+X(K)*X(K)
  395 CONTINUE
      DO 297 I=1,M
      DO 297 K=I,M
      R(IJ)=R(IJ)+X(I)*X(K)
  297 IJ=IJ+1
  394 CONTINUE
      REWIND 6
      IJ=1
      DO 312 J=1,M
      R(IJ)=1.0
      IJ=IJ+1
      KJ=J+1
      IF(KJ.GT.M) GO TO 401
      DO 312 K=KJ,M
      EMR=EM    *R(IJ)-(RTT(K)*RTT(J))
      EMVJ=EM    *VEE(J)-(RTT(J)*RTT(J))
      EMVK=EM    *VEE(K)-(RTT(K)*RTT(K))
      R(IJ)=EMR/SQRT(EMVJ*EMVK)
  312 IJ=IJ+1
  401 WRITE(8) (R(J),J=1,NNN)
      END FILE 8
      REWIND 8
      WRITE(5) (R(J),J=1,NNN)
      END FILE 5
      REWIND 5
      IF(ICH.EQ.2) GO TO 402
      WRITE(4,300)
  300 FORMAT(1H0,5X,64HR-MODE PRINCIPAL COMPONENTS ANALYSIS ON DISTANCE
     1FUNCTION MATRIX//)
      GO TO 600
  402 WRITE(4,301)
  301 FORMAT(1H0,5X,70HR-MODE PRINCIPAL COMPONENTS ANALYSIS ON CORRELATI
     1ON COEFFICIENT MATRIX//)
  600 CONTINUE
      END
```

NO.2 ALL AMPS. AND RC-ALL + RADIUS

R-MODE PRINCIPAL COMPONENTS ANALYSIS ON CORRELATION COEFFICIENT MATRIX

PRINCIPAL FACTOR ANALYSIS OF VARIABLES

```
FACTOR     1
           NUMBER OF ITERATIONS EQUALS         1
           VARIANCE EXTRACTED EQUALS      11.643

FACTOR     2
           NUMBER OF ITERATIONS EQUALS         3
           VARIANCE EXTRACTED EQUALS       3.388

FACTOR     3
           NUMBER OF ITERATIONS EQUALS         3
           VARIANCE EXTRACTED EQUALS       2.098

FACTOR     4
           NUMBER OF ITERATIONS EQUALS         8
           VARIANCE EXTRACTED EQUALS       1.218

FACTOR     5
           NUMBER OF ITERATIONS EQUALS         5
           VARIANCE EXTRACTED EQUALS       1.173

FACTOR     6
           NUMBER OF ITERATIONS EQUALS         6
           VARIANCE EXTRACTED EQUALS       1.016

FACTOR     7
           NUMBER OF ITERATIONS EQUALS         8
           VARIANCE EXTRACTED EQUALS        .930

FACTOR     8
           NUMBER OF ITERATIONS EQUALS         4
           VARIANCE EXTRACTED EQUALS        .893
```

PRINCIPAL AXIS FACTOR LOADINGS

	F 1	F 2	F 3	F 4	F 5	F 6	F 7
1	.240	-.313	-.077	-.365	.518	.082	-.332
2	-.205	-.024	.582	.625	.374	-.026	-.313
3	.426	.225	.446	-.184	-.374	-.098	.139
4	.156	.442	.585	-.277	.294	.075	.087
5	.430	.629	-.045	.219	-.259	.105	-.051
6	.441	.544	.598	-.065	-.010	-.133	-.050
7	.516	.487	-.231	.176	.041	.470	-.155
8	.529	.459	.015	-.163	.106	-.024	-.295
9	.702	.495	.012	.007	.135	-.154	.013
10	.760	.297	-.139	-.022	.350	.055	.057
11	.776	.269	-.159	-.071	-.294	.125	-.037
12	.710	.231	.046	.211	-.115	.073	.188
13	.705	.105	-.202	.124	.029	.297	.079
14	.780	.169	-.097	-.202	.055	-.143	.001
15	.735	-.023	-.157	-.387	.000	-.343	.301
16	.846	.098	-.191	.015	-.036	-.099	.055
17	.826	-.050	-.129	.094	.174	-.154	.091
18	.799	-.292	-.126	.116	.122	-.203	-.320
19	.726	-.271	-.223	.065	.119	-.017	.092
20	.760	.012	-.241	.071	.091	.059	-.343
21	.775	-.347	.047	.026	-.049	-.225	.015
22	.699	-.234	.218	.105	-.096	-.244	-.316
23	.659	-.455	.155	.041	-.162	.107	-.302
24	.575	-.365	.234	-.103	-.278	-.016	-.302
25	.725	-.440	.077	-.034	-.120	.063	.052
26	.511	-.397	.381	-.134	-.034	.441	.019
27	.599	-.391	.200	.473	.055	.088	.085
28	.468	-.434	.219	-.296	.058	.263	.475
	11.643	3.389	2.098	1.218	1.173	1.018	.930
	41.583	12.100	7.492	4.350	4.191	3.629	3.323
	79.956						

SQUARE ROOT OF FACTOR MATRIX

	F 1	F 2	F 3	F 4	F 5	F 6	F 7
1	.240	-.313	-.077	-.366	.518	.092	-.332
2	-.183	-.055	.377	.592	.426	-.018	-.045
3	.409	.225	.493	-.133	-.351	-.091	.141
4	.068	.415	.394	-.438	.350	.082	.049
5	.332	.506	-.223	.324	-.052	.151	-.169
6	.249	.099	.128	-.013	-.026	-.275	-.215
7	.288	.155	-.158	.202	.173	.497	-.109
8	.277	.009	-.039	-.047	.086	-.314	-.273
9	.209	.068	-.155	.089	.310	-.254	.344
10	.320	-.087	-.113	.118	.176	.052	.315
11	.260	-.219	.039	.069	-.233	.150	.027
12	.107	-.025	.047	.141	-.037	-.102	.174
13	.129	-.071	-.070	.009	-.004	.141	.109
14	.170	-.125	-.013	-.008	.021	-.166	-.015
15	.164	-.153	-.088	-.039	.039	-.315	.339
16	.141	-.135	.019	.096	-.020	-.029	-.047
17	.161	-.223	.063	.134	.042	-.064	.047
18	.118	-.162	-.003	.152	.025	-.132	-.145
19	.110	-.207	.091	.007	-.040	.143	-.309
20	.071	-.075	.003	.025	-.010	.122	-.395
21	.109	-.216	.152	.025	-.114	.041	-.029
22	.066	-.106	.114	.025	-.137	-.111	-.375
23	.058	-.152	.117	-.086	-.107	.214	-.093
24	.076	-.160	.145	-.003	-.134	.155	-.056
25	.044	-.098	.058	-.055	-.046	.125	.097
26	.049	-.124	.143	-.101	.016	.328	-.226
27	.025	-.058	.048	.142	.029	.057	.079
28	.021	-.069	.055	-.128	.030	.135	.270

BETA COEFFICIENTS

	F 1	F 2	F 3	F 4	F 5	F 6	F 7
1	.02063	-.09224	-.03687	-.30059	.44170	.08060	-.35693
2	-.01763	-.00715	.27748	.51312	.31985	-.02568	-.01393
3	.03659	.06636	.21265	-.15106	-.31912	-.08707	.14896
4	.01343	.13034	.32659	-.22748	.25021	.03397	.09312
5	.03696	.19534	-.02134	.17957	-.21997	.10365	-.05433
6	.03791	.16056	.25496	-.05311	-.00855	-.13066	-.05395
7	.04435	.14394	-.11015	.10353	.03512	.46271	-.16659
8	.05405	.13516	.00742	-.13362	.09033	-.02333	-.31658
9	.06031	.14639	.03550	.00531	.11532	-.15152	.01394
10	.06525	.08771	-.06619	-.01908	.30556	.06529	.06131
11	.06563	.07919	-.08044	-.01716	-.25089	.12400	-.03956
12	.05100	.08301	.02205	.17311	-.09319	.07165	.20234
13	.06055	.03128	-.09571	.10188	.02465	.29130	.09352
14	.06702	.04991	-.04615	-.15565	.04567	-.13900	.00103
15	.06310	-.00696	-.07504	-.07110	.00040	-.33739	.32312
16	.07262	.02749	-.09099	.01236	-.00551	-.09781	.05895
17	.07194	-.01495	-.05149	.05923	.14903	-.15127	.03755
18	.05959	-.08606	-.06002	.09546	.10423	-.19995	-.02160
19	.06235	-.09033	-.12635	.05303	.10151	-.01654	.09889
20	.06525	.00351	-.11498	.01706	.07756	.05714	-.04591
21	.06552	-.10246	.02245	.01994	-.04096	-.22102	.01717
22	.06307	-.06917	.10389	.08592	-.08203	-.24005	-.33954
23	.04903	-.13473	.07349	.03392	-.13774	.10551	-.32451
24	.05797	-.10790	.11149	-.08492	-.23717	-.01537	-.32504
25	.06226	-.12992	.03654	-.07915	-.10218	.06154	.05589
26	.05244	-.11724	.18141	-.10957	-.02987	.43766	.01950
27	.05143	-.11550	.09546	.39803	.05580	.08517	.09142
28	.04018	-.12801	.10391	-.24287	.05771	.25845	.51072

NORMALIZED FACTOR MEASUREMENTS, UNWEIGHTED

1	.73960	.25191	.75229	.57555	.53959	.68064	.31027
2	.56738	.17459	.31972	.39755	.60471	.79474	.23709
3	.24411	.90076	.77315	.95444	.90921	.93435	.54214
4	.31709	.59957	.69594	.65346	.41371	.51137	.43433
5	.50777	.78538	.55320	.85799	.55723	.24242	.75429
6	.38136	.91509	.67828	.52091	.57203	.83751	.41472
7	.37646	.90351	.55799	.81030	.64069	.66599	.42909
8	.36934	.92343	.71472	.72952	.42166	.37282	.07909
9	.50187	.88931	.74056	.49178	.19364	.56019	.15607
10	.44492	.69336	1.00000	.65426	.27680	.65867	.00000
11	.44097	.96263	.92175	.55763	.41595	.27435	.41856
12	.30174	.50080	.56075	.67937	1.00000	.73215	.37142
13	.70175	.55426	.56246	.73528	.29547	.57050	.53036
14	.39611	.35172	.66855	.00000	.55305	.49520	.06519
15	.54622	.42191	.76574	.62554	.42552	.00000	.76959
16	.62047	.44599	.52473	.67566	.69099	.16194	.76315
17	.72400	.43100	.30930	.59535	.45397	.70496	.15634
18	.74511	.00000	.92144	.60548	.69127	.38559	.41924
19	.57193	.52104	.81100	.62976	.37311	.21119	.75317
20	.49640	.59517	.51324	.49053	.57973	.10789	.51332
21	.46394	.76307	.65964	.54249	.55572	.82127	.35605
22	.12679	.44334	.25081	.70995	.75981	.32585	.56517
23	.00000	.54699	.45242	.77948	.25246	.45529	.51095
24	.44729	1.00000	.30739	.61570	.60205	.15259	.97535
25	.57919	.60776	.13930	.76717	.47911	.48737	.39022
26	.44750	.82059	.26416	.56553	.69999	.60917	.77651
27	.68955	.59179	.14335	1.00000	.52720	.45794	.33445
28	.57038	.99291	.16592	.62908	.61137	.22939	.70971
29	.75264	.72415	.20319	.59371	.54617	.61218	.53011
30	.44566	.71493	.11367	.33999	.71353	.47893	.43432
31	.25155	.81653	.53042	.66627	.41996	.88949	.05327
32	.32533	.43135	.75935	.85370	.37931	.61964	.39395
33	.32967	.39040	.73369	.73951	.17778	.67535	.75637
34	.63497	.50144	.35506	.67011	.53323	.62171	.33555
35	.69760	.49055	.00000	.90418	.49355	.59073	.04732
36	.53270	.79173	.52540	.36166	.61921	.53147	.39697
37	.38977	.96456	.63997	.42377	.60024	.66155	.31723
38	.28154	.62222	.90590	.51993	.54047	.84474	.22249
39	.29049	.89974	.93227	.53072	.57932	.72987	.52579
40	.70032	.59003	.34299	.39720	.36495	.64087	.42995
41	.57762	.74359	.57869	.44923	.57325	.49993	.30729
42	.47002	.77845	.54729	.55369	.67417	.88593	.54051
43	.27477	.57501	.10561	.84203	.33326	.24588	.36997
44	.42161	.74939	.47273	.52026	.14059	.63713	.59341
45	.21352	.45853	.16271	.72950	.00000	.65759	.30743
46	.66960	.56891	.71510	.75971	.79325	.85402	.74659
47	.51720	.92563	.22983	.64339	.57359	.20303	.12323
48	.51713	.69737	.97554	.49516	.40777	.09519	.30254
49	.69552	.45061	.49755	.83295	.54593	.79013	.17672
50	.56374	.45331	.37334	.63736	.64376	.67002	.39029
51	1.00000	.69414	.77210	.68531	.43701	.62059	.44015
52	.73793	.37051	.81851	.69169	.55079	.41597	.10729
53	.95026	.70249	.76775	.79307	.37252	.45843	.35394
54	.99019	.74252	.74321	.76405	.39545	.52487	.48039
55	.34537	.94522	.69195	.30097	.54479	.59893	.54559
56	.35457	.25460	.52422	.63259	.50050	.44743	.29757
57	.37364	.41637	.25565	.59192	.39523	1.00000	1.00000
58	.53742	.46760	.45313	.66087	.55029	.63333	.14187

FACTOR MEASUREMENTS NORMALIZED ROW-WISE

1	.26929	.32492	.25791	.12598	.12372	.16461	.36397	2.19429
2	.19763	.01938	.05155	.09318	.22022	.39939	.33395	1.46949
3	.01775	.19637	.13796	.21468	.19090	.15467	.39517	4.33276
4	.05659	.19027	.25364	.21297	.09511	.13157	.39491	1.98756
5	.10039	.26206	.13456	.31278	.12935	.22493	.32743	3.35731
6	.05317	.24291	.15921	.09917	.11956	.25591	.35299	3.73507
7	.05972	.23113	.11142	.23496	.14375	.15915	.35599	2.79439
8	.05792	.36206	.21539	.22597	.07563	.05902	.30255	2.35519
9	.11392	.35796	.24793	.10929	.01596	.14183	.31245	2.71295
10	.07568	.19379	.39229	.16363	.02987	.15575	.30033	3.51583
11	.09296	.31639	.28731	.13256	.07370	.03206	.37657	2.34747
12	.02066	.11580	.10175	.14936	.32357	.17344	.10553	3.09055
13	.19356	.12469	.17782	.21996	.03325	.13199	.11397	2.46792
14	.11561	.03550	.36931	.00330	.24319	.19148	.30332	1.28066
15	.13339	.37993	.26379	.17559	.08168	.00003	.25575	3.72964
16	.16568	.09256	.11473	.19073	.19319	.01937	.34261	3.43059
17	.19396	.37093	.31526	.13515	.09057	.19931	.30937	3.52266
18	.21769	.00330	.33172	.16323	.19090	.05909	.35857	2.55956
19	.13321	.11222	.27189	.15396	.05756	.01966	.24079	2.41914
20	.13198	.19460	.23539	.13219	.19399	.00533	.16496	1.92219
21	.06611	.16779	.12539	.09567	.08969	.19599	.27193	3.64316
22	.00999	.10934	.03805	.29194	.32793	.05947	.17357	1.79772
23	.00630	.17036	.11659	.34597	.03530	.11907	.21252	1.75565
24	.06363	.35435	.03369	.13433	.12466	.00925	.27152	2.92210
25	.17371	.19127	.01005	.30476	.11937	.12309	.37893	1.93117
26	.07363	.24690	.02959	.11727	.17951	.13507	.22116	3.72729
27	.19540	.13950	.03947	.41216	.11655	.09791	.34510	2.42627
28	.13047	.32595	.01104	.15971	.14330	.02092	.23200	3.49347
29	.22712	.21325	.01685	.13551	.11351	.15026	.13952	3.69415
30	.11241	.25932	.00731	.06563	.24925	.12372	.13755	1.76677
31	.03945	.49714	.17095	.26973	.10713	.00497	.03172	1.54581
32	.04365	.09313	.25973	.31431	.06205	.16559	.25333	3.31975
33	.04512	.05335	.22374	.27730	.01313	.18957	.23773	3.40594
34	.19975	.17029	.35969	.21140	.13335	.19197	.05334	2.12414
35	.22347	.10317	.00003	.38631	.11310	.16499	.22133	2.11626
36	.13262	.29295	.12901	.05117	.17962	.13301	.37353	3.13958
37	.05992	.35217	.15943	.46399	.14029	.17033	.33917	3.56944
38	.03267	.15958	.26502	.11072	.11365	.29229	.32027	3.44140
39	.03039	.27288	.23401	.09515	.09433	.17397	.33373	2.96005
40	.26516	.18893	.05384	.08552	.07229	.22299	.10027	1.94269
41	.15023	.24937	.15079	.09097	.23410	.11252	.34252	2.22036
42	.07283	.13233	.09507	.09935	.14434	.24911	.14539	3.15075
43	.05256	.23015	.00775	.49356	.07926	.04243	.33523	1.43652
44	.08306	.26242	.13445	.12569	.08926	.18767	.22459	2.14001
45	.03491	.15659	.01972	.39634	[illegible]	.32203	.37079	1.34272
46	.13382	.13351	.15253	.17226	.02395	.21769	.15635	3.35040
47	.13519	.43300	.02570	.20320	.16901	.02322	.00757	1.97870
48	.12269	.21949	.42952	.11956	.07505	.00329	.34131	3.21566
49	.19351	.37913	.39547	.27037	.11516	.23720	.31217	2.55511
50	.16289	.10464	.07170	.20026	.22956	.23199	.00329	1.96501
51	.30131	.14519	.17962	.14102	.05756	.11504	.25937	3.31983
52	.23382	.03834	.28754	.20349	.13502	.07425	.00435	2.32916
53	.29756	.15953	.19067	.19856	.04489	.06799	.34050	3.09141
54	.29369	.16519	.16545	.17485	.04554	.08252	.37145	3.33950
55	.34731	.35229	.18379	.03572	.11739	.14165	.11741	2.53606
56	.09972	.06636	.19612	.29559	.17977	.14331	.15323	1.49123
57	.04839	.06039	.02266	.12141	.05615	.34664	.34654	3.99483
58	.15417	.11651	.10969	.23313	.16164	.21419	.31074	1.97342

NO.2 ALL AMPS. AND RC-ALL + RADIUS
58 SAMPLES

CLUSTER TYPE 6 ANALYSIS

LEFT SAMPLE NUMBER	RIGHT SAMPLE NUMBER	DISTANCE FUNCTION	NO. IN LEFT	NO. IN RIGHT
51	54	.0567440	1	1
36	41	.0620060	1	1
50	58	.0621632	1	1
51	53	.0673485	2	1
15	19	.0925126	1	1
5	39	.0944891	1	1
6	37	.1055586	2	1
25	27	.1026163	1	1
24	29	.1062529	1	1
25	34	.1290880	2	1
50	49	.1117799	2	1
4	32	.1156497	1	1
6	38	.1402135	3	1
1	17	.1205299	1	1
11	48	.1254296	1	1
5	42	.1630304	4	1
1	52	.1159913	2	1
6	7	.1357414	5	1
29	40	.1385630	1	1
51	13	.1410967	3	1
6	55	.1353753	6	1
25	29	.1504963	3	2
5	8	.1425632	1	1
51	45	.1891246	4	1
15	16	.1511939	2	1
4	11	.2144130	2	2
6	36	.1395842	7	2
15	28	.1351243	3	1
1	18	.1874792	3	1
25	43	.2162313	5	1
9	10	.1600925	1	1
4	56	.1949701	4	1
5	31	.1358774	2	1
4	51	.2139924	5	5
25	35	.1875151	5	1
5	47	.1553012	3	1
4	5	.1765772	10	9
26	30	.1764512	1	1
4	33	.2302372	19	1
4	23	.2599865	20	1
3	12	.1852947	1	1
1	50	.1987653	4	3
4	3	.2142099	21	4
4	44	.1905161	25	1
26	21	.2559187	2	1
4	9	.1771389	26	2
1	2	.1975266	7	1
4	1	.1920968	29	8
26	24	.1990306	3	2
4	25	.1904922	36	7
26	15	.2400231	5	4
4	14	.2951898	43	1
3	22	.2782231	2	1
4	26	.1957663	44	9
4	3	.2157047	53	3
4	45	.2886999	56	1
4	57	.3246192	57	1

CLUSTER DIAGRAM

VALUE OF COEFFICIENT