SEVERAL TECHNIQUES OF BANDWIDTH REDUCTION FOR COMPUTATIONAL EFFICIENCY

BY
A. D. PHILLIPS

Bachelor of Science
OKLAHOMA STATE UNIVERSITY
Stillwater, Oklahoma

Submitted to the faculty of the
School of Architecture of Oklahoma State University
In Partial Fulfillment of the Requirements
for the Degree of

MASTER OF ARCHITECTURAL ENGINEERING
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I would like to formally express my gratitude and sincere appreciation to Prof. Louis Bass for his time and effort spent with me throughout my college education. I would also like to thank Prof. John Bryant and the faculty of the School of Architecture for all their help and support.

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Finally I want to express my appreciation and thankfullness to my wife, Janet, for all her love and devotion.

I feel that without any one of these people my education would have been less meaningful and less successful.

A. D. Phillips

Preface . . . The main concern of this paper is with very large systems of algebraic linear equations, in which the number of variables appearing in any equation is small compared to the total number of variables in the system. Such problems frequently arise in engineering as the numerical solution of a large set of simultaneous physical and economic constraints. Compared with the first set of equations to be conceived for the solution of such a system, it is frequently possible to make a reduction in required computer time by further analysis. Such reductions in computer time would make tractable many problems presently considered intractable on small computers. One class of methods which is conerned with reduced computational time for the solution of a set of linear simultaneous equations is that of bandwidth reduction techniques.

When the non-zero coefficients of such a sparse matrix are concentrated in a narrow band centered along the principal diagonal, the representation of the matrix in a computer or on paper is concise, and the arithmetic entailed in the solution of the linear equations associated with it is condensed. Unfortunately, sparse matrices often do not display such a compact band structure. Considerable interest is attached to the development of techniques for rearranging the non-zero coefficients of a matrix by permuting its rows and columns to provide the narrowest band possible, under the assumption that narrow bands will yield efficient solutions for a particular set of simultaneous equations.

Several techniques of bandwidth reduction are presented in this paper. An algorithm is also developed and tested for one of the procedures cited in this paper.

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In the analysis of many structural problems a mathematical model is built in two or three-dimensional space using discrete points called nodes. The nodes are then connected together by one or more of the many types of finite elements, e.g., bar members, rectangular, triangular, etc.). From this geometric arrangement a stiffness matrix is created which is directly related to the nodal connectivity. For example, if two nodes are connected together by an element in the mathematical model then this will be represented in the stiffness matrix by diagonal and off diagonal non-zero terms which represents the interaction of these two nodes in the stiffness matrix. From the nodal connectivity of the mathematical model a set of linear simultaneous equations are created. The set of equations that make up the mathematical model can be abbreviated in matrix notation as:

$$[\beta] = [K][\lambda] \qquad (1)$$

where $[K]$ = the stiffness coefficient matrix.

$[\lambda]$ = the displacement vector.

$[\beta]$ = the load vector.

The solution of the model can be found by the use of many different techniques. Several of the fastest and most efficient methods belong to a class of elimination techniques (e.g., Gauss - Sidel iteration, Cholesky, Guassian elimination, etc.) These techniques involve basically two steps: (1) Decomposition (2) Backsubstitution. If, for example, Guass Factorization was used to solve the equations, the stiffness matrix, $[K]$, would be decomposed into a triple matrix product.

$$[K] = [L\cdot][D][L]^T$$

where $[L]$ = unit lower triangular matrix

$[D]$ = a diagonal matrix

The displacement vector, $[\lambda]$, would then be computed by (1) Forward Substitution and finally (2) Backsubstitution

$$(1)\ [A] = [L]^{-1}$$

$$(2)\ [\lambda] = [L^T]^{-1}[D]^{-1}[A]\,[B]$$

The time required to perform these operations is directly related to the size of the stiffness matrix and its bandwidth.

The bandwidth of the stiffness matrix is defined as the column-label difference of the last and the first non-zero entries in any one row of $[K]$. Because of the symmetry of the stiffness matrix, $[K]$, the half-bandwidth is usually referenced. The half-bandwidth is defined as the maximum difference in column labels of the main diagonal and the first non-zero term in that row. The time required to solve a linear system usually increases in proportion to the square of the half bandwidth; therefore, the need for bandwidth reduction in large scale structural problems becomes obvious.

The stiffness matrix, $[K]$, is typically sparse and always symmetric. By taking advantage of the symmetry and sparseness of the stiffness matrix, $[K]$, and rearranging the non-zero stiffness coefficients in a narrow band centered along the principal diagonal, a relatively large empty region in the matrix is created. By confining the computational operations to the compact region densely populated with non-zero coefficients and by omitting operations for the empty region in which the coefficients are zero, improved computational efficiency and a reduction in computer storage requirements are achieved. However, many structural related matrices do not display this type of banded structure. Therefore, this paper will investigate several techniques for reducing the bandwidth of sparsely populated symmetric and definite positive matrices. The methods to be discussed are, (1) Rosen method [1] ; (2) Levy Wavefront method[2] ;(3) Reverse Cuthill and Mckee method [3] .

ROSEN . . . The Rosen method of matrix bandwidth reduction was presented in 1966 in the Proceedings of the 23rd National Conference of the Association for Computing Machinery. The basic concept behind Rosen's scheme of matrix bandwidth reduction is the interchanging of specific nodes that will reduce the stiffness matrix bandwidth. The procedure is relativily simple.

The first step in the method is to determine the maximum bandwidth and the nodes causing the bandwidth in the original matrix. The nodes that cause the bandwidth are then inspected to see if an interchange between them and another node will serve to reduce the bandwidth. When an interchange between two nodes is determined to reduce the bandwidth the corresponding rows and columns are switched and the stiffness matrix is revised. Again, the maximum bandwidth and the corresponding nodal locations are searched for. The reduction is made and the matrix updated. This procedure is continued until there are no further interchanges which will reduce the bandwidth.

When two node numbers are interchanged, this changes the order in which their respective equations appear in the stiffness matrix, $[K]$, as well as interchanging the columns defining the coefficient of the variables in the displacement vector, $[\lambda]$. The transformation may be represented by the 'nodal change', $[NC]$, matrix, say for example, the ith node and the jth node are to be interchanged. Then the $[NC]$ matrix is defined by

$$[nc]_{K,K} = 1.0 \qquad \text{WHERE} \quad K \neq i \text{ or } K \neq j$$

$$[nc]_{i,j} = 1.0$$

$$[nc]_{j,i} = 1.0$$

With all other elements equal to zero, such that

$$[NC]_1 = [NC]_1^T = [NC]_1^{-1}$$

In terms of the original numbering system, the reordered vectors may be represented by

$$[\lambda]_1 = [NC]_1 [\lambda] \qquad (2)$$

$$[\beta]_1 = [NC]_1 [\beta] \qquad (3)$$

By making the proper substitution of equations (2) and (3) into equation (1) the reordered nodal numbering system becomes

$$[\beta] = [NC]_1 [K] [NC]_1 [\lambda]$$

If this process is continued for N such transformations the result will be

$$[\beta] = [NC]_N \ldots [NC]_1 [K] [NC]_1 \ldots [NC]_N [\lambda]$$

It is apparent that each single interchange merely performs a row and columns interchange for the two designated nodes. If we let the old sequence of node numbers be represented by $[O]$ and assume a continuous nodal numbering system then the revised numbering system $[N]$ after N transformations can be represented by

$$[N] = [NC]_N \ldots [NC]_1 [O]$$

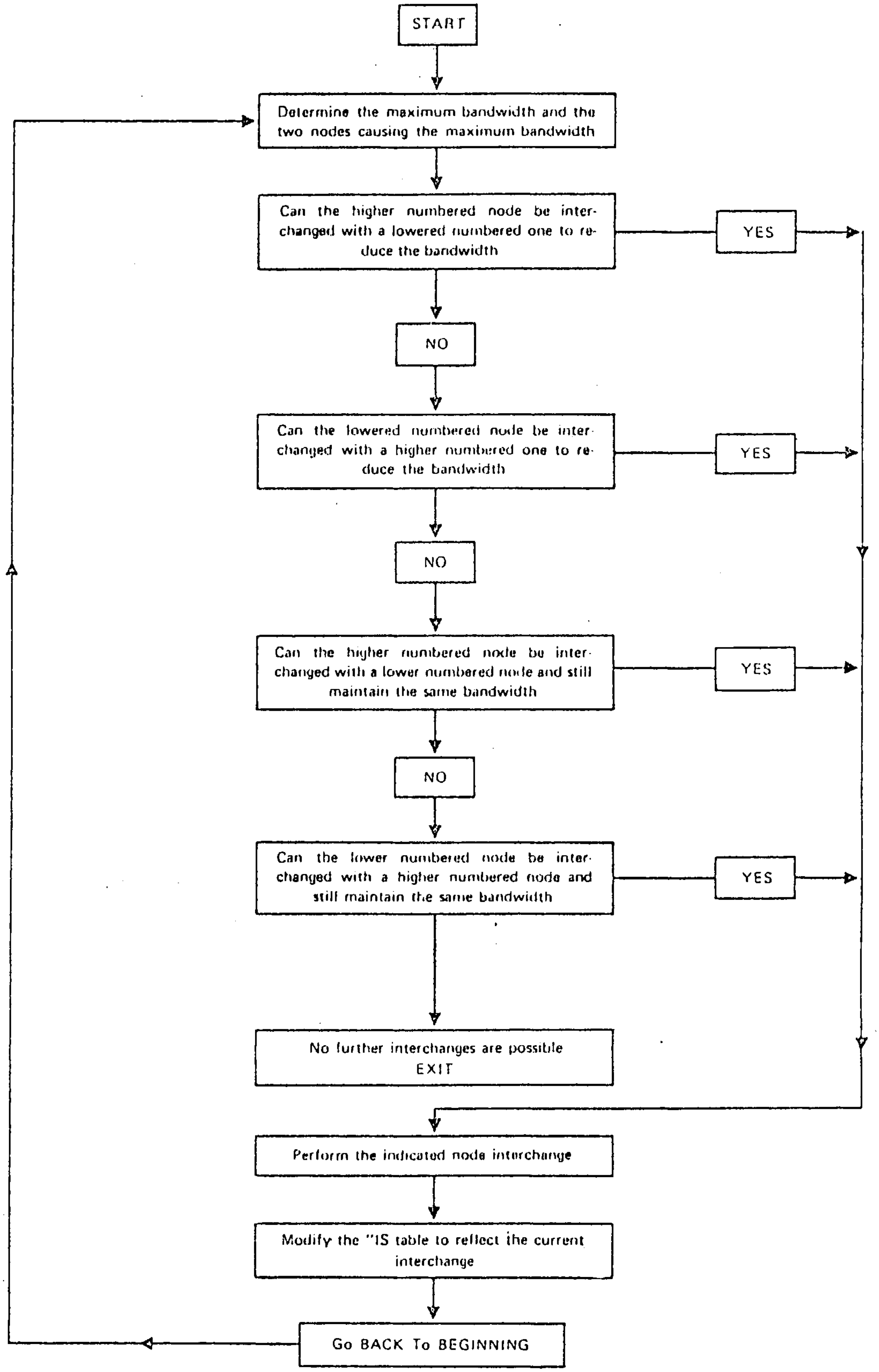
This relation of new to old node numbers will yield a nodal numbering system that will give the transformed stiffness matrix, $[TK]$.

$$[TK] = [NC]_N \ldots [NC]_1 [K] [NC]_1 \ldots [NC]_N$$

Rosen presents an iteration scheme for matrix bandwidth reduction. This scheme is based on a search for interchanges of two rows and the corresponding columns which will reduce or at worst not increase the bandwidth. The algorithm for the bandwidth reduction scheme is shown on page 6.

LEVY WAVEFRONT . . . The main goal of bandwidth reduction algorithms is to reorder a given stiffness matrix to make the region for computations as compact as possible and to make the empty region as large as possible. Generally it is considered that if the compactness of the stiffness matrix is dense, where density is evaluated by the matrix bandwidth, then computational operations and storage requirements are assumed to be rendered minimal. A consideration which is generally given little or no attention is that of wavefront reduction. The following procedure generates similar results as that of the Rosen method. However, its main objective is that of wavefront reduction opposed to Bandwidth reduction. The wavefront technique, which is to be discussed here, was presented by R. Levy in the JPL Quaterly Technical Review. The general concept behind Levy's procedure is that of wavefront

ROSEN GENERAL FLOW CHART



counting, as follows.

Given a matrix [A], such as stiffness or nodal connectivity, the wavefront at a row is the number of nonzero columns that follow the diagonal element. A column of matrix [A] becomes active at the row which contains the first non-zero element in that column. The column will remain active until it diminishes in proximity to the diagonal of the matrix. The wavefront at any row can be calculated by adding the wavefront of the previous row to the number of columns that become active in that row. If the column corresponding to the row is currently in the wavefront, then one is subtracted from the total to account for the column that leaves the wavefront by virtue of reaching the diagonal. Consider for example the structure in fig. 1a and its corresponding connectivity in matrix fig. 1b.

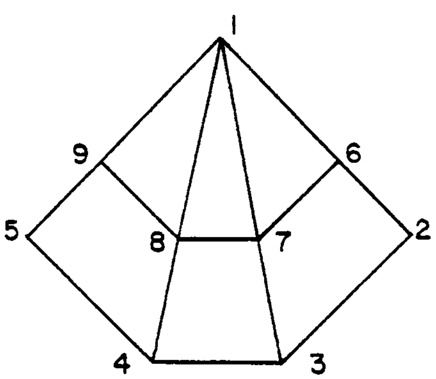


FIG. 1a

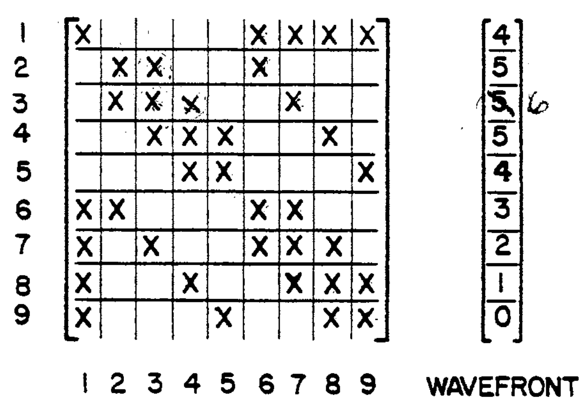


FIG. 1b

In the first row the wavefront is four, because rows six through nine are active and the wavefront at the non existing preceding row is considered to be zero. In the second row the wavefront is increased to five. The increase is accounted for by column three becoming active. In the third row column four becomes active which makes the wavefront 5 + 1 = 6. However, in row four column three diminishes into the diagonal and reduces the wavefront by one. Therefore the final wavefront of row four is 5 + 1 - 1 = 6. In rows 5 through nine all columns have been activated and no new columns can enter the wavefront. Therefore, at each row a column is subtracted from the preceeding wavefront, since one column always reaches the diagonal and leaves the wavefront. The tabulated wavefront values are shown in fig. 1b. Consider now, the proceedure of wavefront reduction.

In a resequencing approach, such as wavefront reduction, the first problem that must be confronted is that of choosing the first node in the sequence. The choice of the first node is somewhat arbitrary, however it can be based on any one of the following techniques.

1. Choose the node that has the smallest connectivity. This will give the smallest wavefront for the first row. Often, any one of several nodes will give the same minimum wavefront. The choice then, should be the first node encountered in the original sequence of node numbers. This tends to make the new numbering as close as possible to the original.
2. When the connectivity matrix contains n nodes, such that m nodes have the same minimum connectivity, perform resequencing m times, selecting each node in turn to be the first node. Then select the most favorable resequence.
3. Assign one particular node to be the first based on prior inspection and knowledge of wavefront reduction.

The next problem to be considered is the actual resequencing of the nodal numbers. The general procedure to be used for selection of the succesive nodes can be put into six steps, four of which are repetitive.

1. Tabulate the degree of connectivity of each row.
2. Choose the beginning node by one of the three above mentioned techniques.
3. Enter the number of the new node in the new sequencing, numbering it new node n + 1.
4. Refering to the original connectivity matrix, count the new number of connections at each row and tabulate the wavefront change. This is equal to the sum of the entries in the old connectivity matrix that do not occur at columns already in the wavefront. The change in wavefront at each row is the sum of the new connections. The change is reduced by one if the row is already in the wavefront.
5. Select the smallest change in wavefront from the column of wavefront changes. The row containing the smallest wavefront corresponds to the new node to be placed in the new sequencing list.
6. Add the change in wavefront to the preceeding wavefront and tabulate the value for use in step 4. Go to step 3.

This procedure is continued until all columns have been activated and no new columns may enter the wavefront. Then the remaining nodes are added to the new sequencing list in order of connectivity; ties are broken arbitrarily. Tabular resequencing will be demonstrated for the structure of Fig. 1.a.

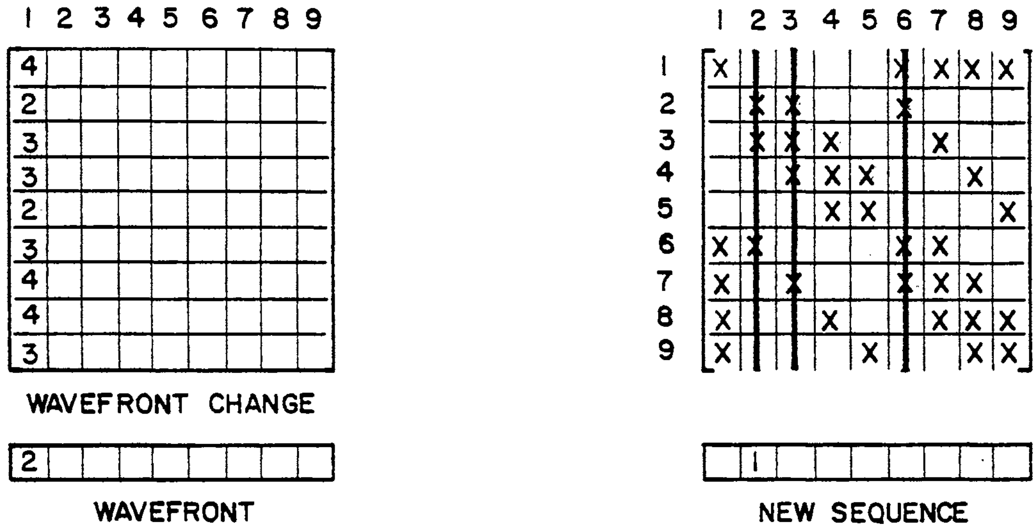
Stage 1 . . . The procedure is begun by tabulating the connectivity of each row and recording the maximum value as shown in stage 1. In this example the first node is selected with the objective of minimum wavefront in the first row of the new sequence. Original node 2 is the first node encountered with a minimum connectivity of two. Therefore, node 2 will be the first node in the new sequence. The wavefront corresponding to row 2 is 2. The columns creating the wavefront will be emphasized by a vertical line through the column. Record node number 2 as new node number 1 in the new sequence list.

Stage 2 . . . Review the matrix recording the change in wavefront that each row would produce. The smallest number, first encountered, in the wavefront change column is 1, corresponding to node 3. The new columns which are activated are columns 4 and 7. However, column 3 will diminish into the diagonal and the net resulting wavefront will be 3.

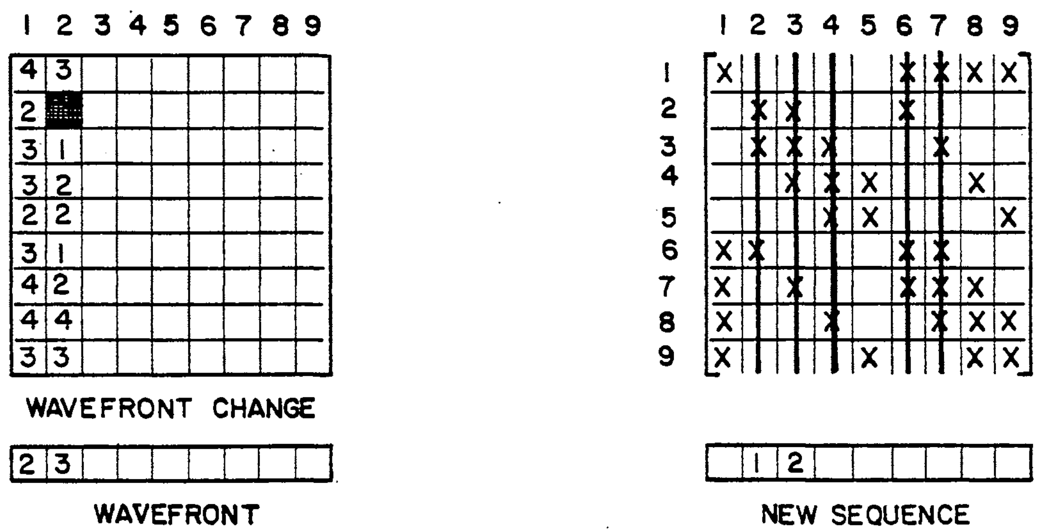
Stage 3 . . . Again review the matrix recording the change in wavefront that each row would produce. Selecting the smallest change will result in node 6 becoming new node 3. The columns activated by row 6 are 1, 2 and 7. However, columns 2 and 7 were previously activated and column 6 will leave the wavefront. The resulting wavefront remains at 3.

Stage 4 . . . Record the change in wavefront selecting the smallest

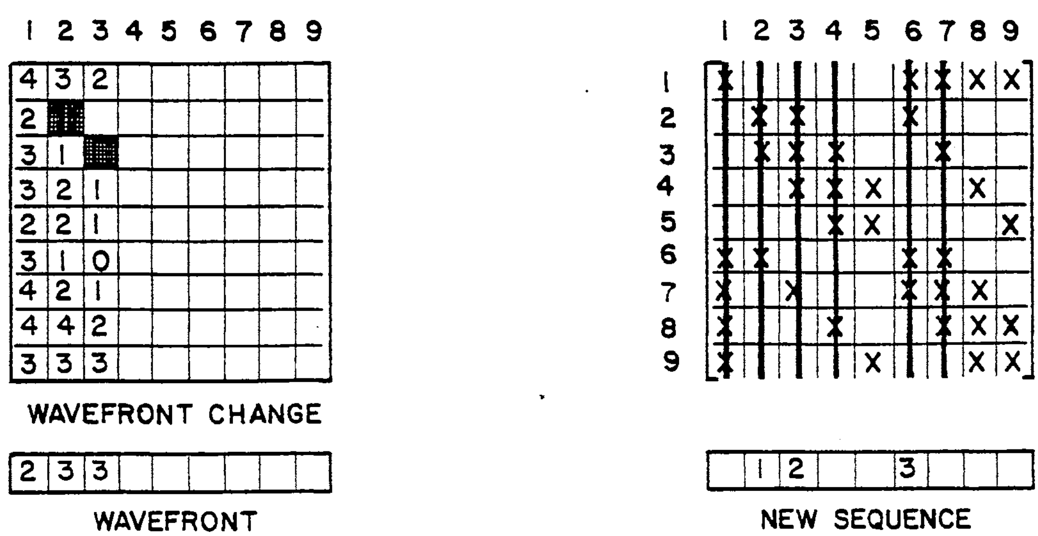
STAGE 1



STAGE 2



STAGE 3



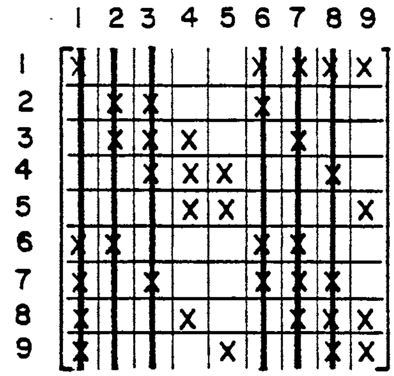
STAGE 4

1	2	3	4	5	6	7	8	9
4	3	2	1					
2	■							
3	1							
3	2	1	1					
2	2	1	1					
3	1	0	■					
4	2	1	0					
4	4	2	1					
3	3	3	2					

WAVEFRONT CHANGE

2	3	3	3					

WAVEFRONT



	1	2			3	4		

NEW SEQUENCE

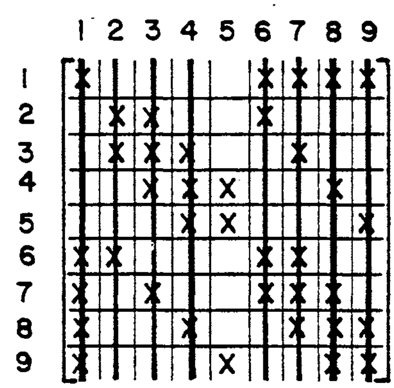
STAGE 5

1	2	3	4	5	6	7	8	9
4	3	2	1	0				
2	■							
3	1	■						
3	2	1	1	0				
2	2	1	1	1				
3	1	0	■					
4	2	1	0	■				
4	4	2	1	0				
3	3	3	2	1				

WAVEFRONT CHANGE

2	3	3	3	3				

WAVEFRONT



5	1	2			3	4		

NEW SEQUENCE

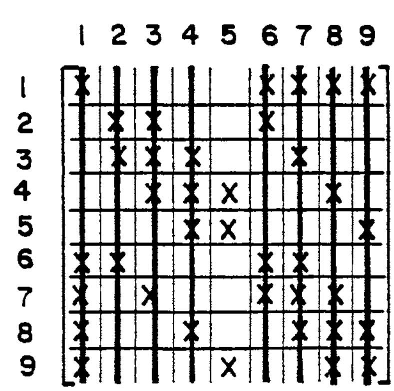
STAGE 6

1	2	3	4	5	6	7	8	9
4	3	2	1	0	■			
2	■							
3	1	■						
3	2	1	1	0	0			
2	2	1	1	1	0			
3	1	0	■					
4	2	1	0	■				
4	4	2	1	0	-1			
3	3	3	2	1	0			

WAVEFRONT CHANGE

2	3	3	3	3	2			

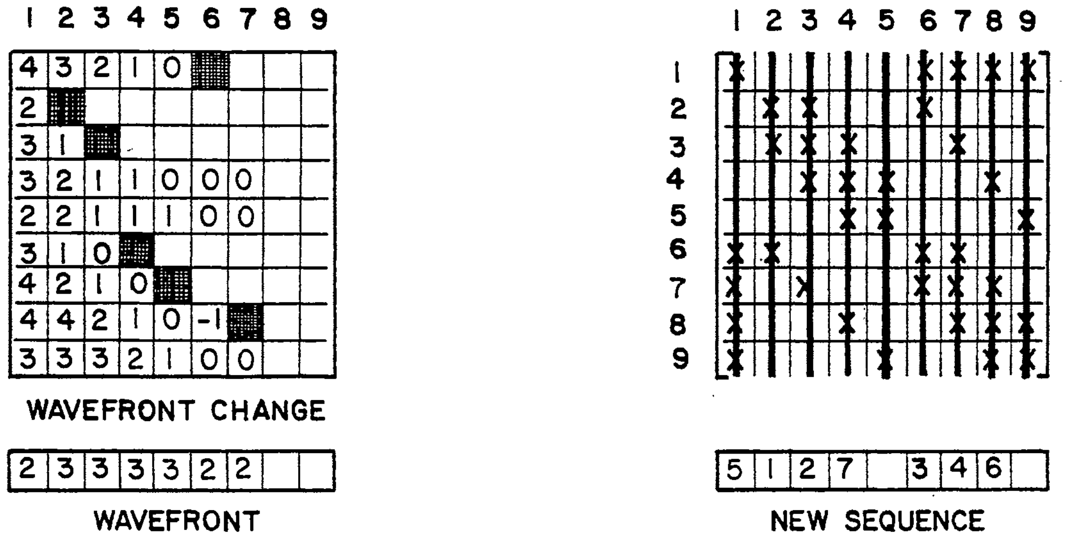
WAVEFRONT



5	1	2			3	4	6	

NEW SEQUENCE

STAGE 7



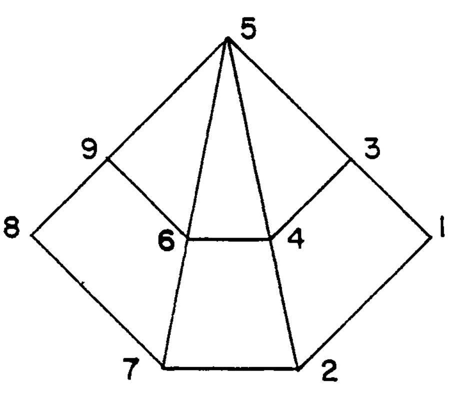


FIG. 2a.

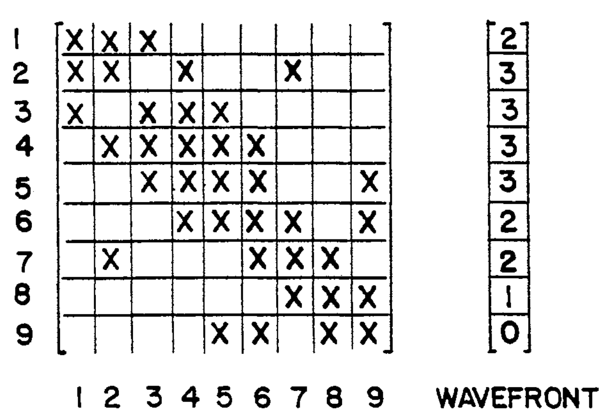


FIG. 2b.

change, which will be 0. Thus, node 7 will become new node 4. Row 7 activates columns 1, 3, 6 and 8, all of which were previously activated except column 8. However, column 7 will leave the wavefront resulting in a net increase in wavefront of zero. The wavefront is 3.

Stage 5 . . . The wavefront change is recorded and the smallest value chosen. Thus, node 1, is chosen as new node 5. Original node 1 activates columns 6, 7, 8 and 9. Columns 6, 7 and 8 were previously activated and column 1 will leave the wavefront. The net wavefront is equal to 3.

Stage 6 . . . After recording and reviewing the wavefront change table node 8 is chosen as new node 6. The wavefront change corresponding to original node 8 is -1. This is so because all columns which are activated by row 8 have previously been activated. Also column 8 will leave the wavefront resulting in a net of -1 in the wavefront change table. Thus the resulting wavefront is 2.

Stage 7 . . . Record and review the wavefront change table. The next node chosen will be node 4, which will activate columns 3, 5 and 8. Columns 3 and 8 were previously activated and column 5 will leave the wavefront. The net resulting wavefront will be 2.

At the end of stage 7 there are no remaining columns to be activated, and the wavefront has filled the connectivity matrix. The remaining nodes can be added to the new sequence in arbitrary order or on the basis of increasing connectivity. The renumbered structure and the corresponding connectivity matrix are shown in fig. 2a and 2b respectively.

Apparently the number of iterations needed to reorder the original connectivity matrix, C(n,n) is dependent upon the order of the matrix, n, and the maximum wavefront, Wfm. The reason for the relation is that the wavefront will begin to decrease beginning with row (N -(N-Wfm)) and decrease one wavefront per row, since one column will leave the wavefront by reaching the diagonal, and terminating with a wavefront value of zero at the nth row. Therefore, the number of iterations is N-Wfm. Thus, the number of required iterations cannot be determined until the resequencing is performed.

REVERSE CUTHILL-MCKEE The bandwidth and profile reduction algorithm most widely used today is the Reverse Cuthill-McKee Algorithm. The basic concepts behind the algorithm are based on graph theory and level strucutre. Therefore, before a detailed description of the algorithm can be presented the basic concepts behind graphy theory and level structure must be presented.

On the basis of graph theory a great amount of information can be gained by use of a graph representation of sparse matrices. The importance of graph theory to this paper is the fact that permuting the rows and columns of a matrix corresponds to renumbering the vertices of a graph.

Given a matrix A, where $A = (a_{i,j})$, a graph $G = \langle U,E \rangle$ can be defined such that, U is a nonempty set containing n vertices,

$$\{U_1, U_2, \ldots U_N\} \in E \quad \text{if} \quad a_{i,j} \neq 0 \quad \text{and} \quad i \neq j$$

and E is a set of unordered pairs of elements of U ,

$$E \subseteq \{\{a,b\} : a \neq b \text{ and } a,b \in U\}$$

The elements of $U=U(G)$ are defined as vertices and the elements of $E=E(G)$ are defined as edges. If $\{U_1,U_2\} \in E$ then U_1 and U_2 are said to be adjacent. The number of vertices adjacent to a vertex is defined as the degree of the vertex.

If we define a path of length t as a sequence of edges,

$$\{U_0,U_1\},\{U_1,U_2\} \ldots \{U_{t-1},U_t\}$$

then we can say that the graph G is connected if and only if there exists a path connecting each pair of vertices. If a path does not exist then the graph G consists of two or more connected components. The term diameter is defined by the shortest path connecting two vertices of maximal distance. If G has n vertices and the vertices are numbered along the diameter such that there is one and only one member $V(G)$ corresponding to a member of the set of integers I, I = $(1,2,3 \ldots n)$, then we can define the number as $f(G)$, the numbering of G . For each numbering of G we define $\beta_f(G)$, the bandwidth of G relative to f , by

$$\beta_f(G) = \text{MAX}\{|f(U_1)-f(U_2)| : \{U_1, U_2\} \in E(G)\}$$

We then define the minimum bandwidth of $\beta_f(G)$ as the bandwidth of G, $\beta(G)$.

Another important concept involved in the Cuthill-McKee Algorithm is the concept of level structures. A level structure, $L(G)$, of a graph G is a partition of the set $U(G)$ into levels $L_1 \ldots L_n$ such that

1. All vertices contained in Level 1, L_1, are in either Level L_1 or L_2.
2. All vertices contained in Level N, L_N, are in either Level L_N, or L_{N-1}.
3. All vertices contained in Level i, L_i, are contained in either level L_{i+1}, L_i or L_{i-1} ; for $1 < i > n$

For each vertex $U \in U(G)$ there exists a level structure $L_U(G)$. The level structure $L_U(G)$ is said to be rooted at U. The level structures are determined by

1. $L_1 = \{U\}$
2. L_i is comprised of all vertices adjacent to vertices of level L_{i-1} which have not been assigned a level; where $i > 1$

The width of level i in any structure $L(G)$ is defined as $w_i(L) = |L_i|$ and the width of the level structure $L(G)$ is defined as $w(L) = MAX(w_i)$. It can be easily seen that for any level structure L_i, a numbering, f_L, of G that assigns consecutive integers level by level, beginning with level one and continuing in increasing order to the last level, will form a bandwidth that will satisfy the equation

$$\beta_{f_L} \leq 2w(L)$$ [5,8,12,13]

The bandwidth of the individual level structures and the labeling of the vertices of the graph is directly related to the bandwidth and resequencing of nodes in a particular matrix. This relationship is the basis for the Cuthill-Mckee Bandwidth and Profile reduction Algorithm. The relationship can best be described by the generation of the spanning tree for the graph of $G(A)$ in a level by level fashion. This will be explained by use of an example.

The example is one that arises from the aplication of the finite element method. Consider a mesh that is obtained by subdividing a unit square into smaller square elements of side $^1/n$. The squares are further subdivided into right regular traingulars. The triangulars have degree of freedom equal to four. The mesh and associated graph $G(A)$ is presented in figures 3 and 4 respectively.

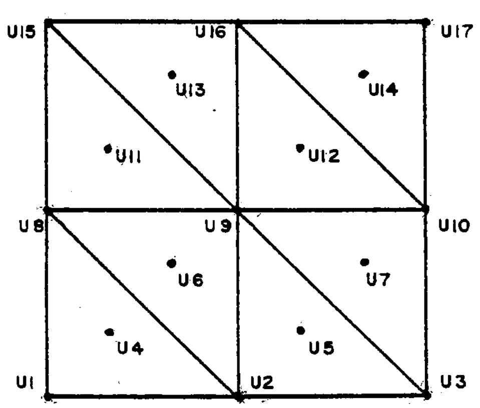


FIG. 3.

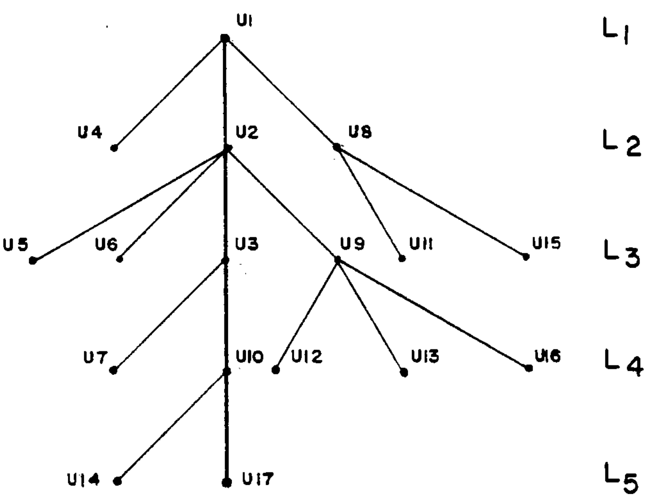


FIG 4

The starting vertex for the graph is assumed to be the first vertex U_1. The procedure used to generate the graph is as follows:

Level 1 . . . Choose a starting vertex. In this example the starting vertex is chosen as one of the nodes of least connectivity, either U1 or U 17. Choose U1.

Level 2 . . . Determine the nodes that are directly connected to U1. These nodes include U2, U4 and U8.. Arrange the nodes of level 2 in order of connectivity with ties broken aribitrarily. Therefore U4 will be first with a connectivity of 3. Nodes U2 and U8 have a connectivity of 7. U2 will be chosen before U8. Place the nodes on the graph from left to right as determined above.

Level 3 . . . Determine, in order of Level 2, the nodes contained on third level. Therefore consider node U4. Node U4 is connected to nodes U1, U2 and U8. All of which are already contained in the graph. Now consider U2 which is connected to U3, U5, U9, U6, U1, U8 and U4. Of these nodes U1, U4, and U8 have been added to the graph, so consider only the remaining nodes. Nodes U5 and U6 have a connectivity of 3 so they will be added to Level 3 first, as shown. Consider now nodes U3 and U9. Node U3 has a connectivity of 5, compared to U9, which has a connectivity of 12. Therfore U3 will be added next followed by U9. U8 will now be considered. U8 is connected to nodes U1, U4, U2, U6, U9, U11 and U15. Of these nodes U1, U4, U2 U6 and U9 have already been added to the graph. Since node U11 has a smaller connectivity than does U15, node U11 will be added to the graph before U15.

Level 4 . . . Again determine the nodes of level 4 by considering the nodes of level 3, from left to right on the graph. Therefore node U5 and then U6 will be considered. However all of the nodes connected to U5 and U6 are already contained in the graph. The next node in level 3 is U3, which is connected to nodes U2, U5, U9, U7, and U10. All of which have been previously added to the graph, with the exception of U7 and U10. Since U7 has a connectivity of 3 and U10 has a connectivity of 7, node U7 will be added before U10. The next node to be examined is U9, which has a connectivity of 12. The only nodes that are connected to U9 which have not been previously added to the graph are U12, 13 and U16. U12 and U13, both have a connectivity of 3 and can be added to Level 4, in arbitrary order. The only remaining node of Level 4 is U16.

Level 5 . . . Examining the nodes of Level 4, the only node that has connectivity, which is not already contained in the graph is node U10, which is connected to nodes U14 and U17. Since U14 has a smaller connectivity than U17, it will be added to Level 5 before U17. These are the only two nodes of Level 5.

Using the Cuthill-McKee Algorithm which takes advantage of the correlation between graph theory and nodal renumbering the vertices would be reordered and renumbered from top to bottom and left to right. The renumbered graph which would be generated and the corresponding renumbered mesh are shown in figure 5 and 6, respectively.

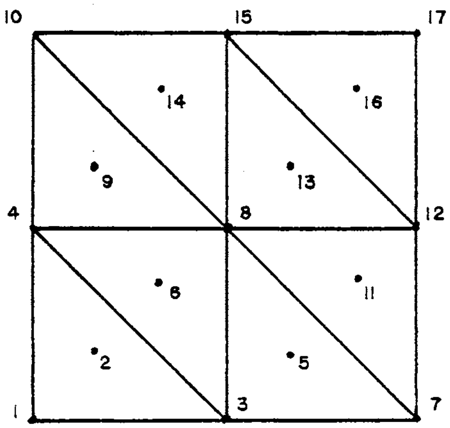


FIG. 5.

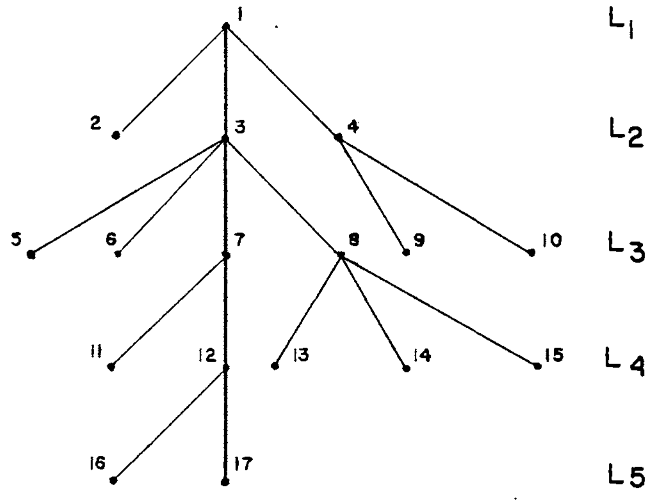


FIG. 6.

A detailed flow chart of the Cuthill-McKee Algorithm is a follows.

1. Generate the level structure rooted at each vertex of G(A) and compute their corresponding bandwidths.

2. Assign to each level structure generated in step 1 a positive consecutive integer in the following manner:

   2a. The root vertex which is the vertex of minimum degree is assigned to the lowest level structure, L_1 .

   2b. The vertex which is adjacent to the lowest numbered vertex of the preceding level is assigned to the smallest unassigned positive integer. The remaining vertices of that level are numbered depending upon their degree of freedom; with ties broken arbitrarily. This procedure is carried from level to level and terminates when the vertices of all the levels have been numbered.

3. The numbering is reversed by setting i to $N-i+1$ for $i = 1,2,\ldots N$.

Step 3 obviously will not reduce the bandwidth of the matrix, however, it will frequently reduce the profile of the matrix. It can be proven that this modification will never increase the profile of the matrix. Example problems of the Reverse Cuthill-McKee Algorithm can be found in Appendix C.

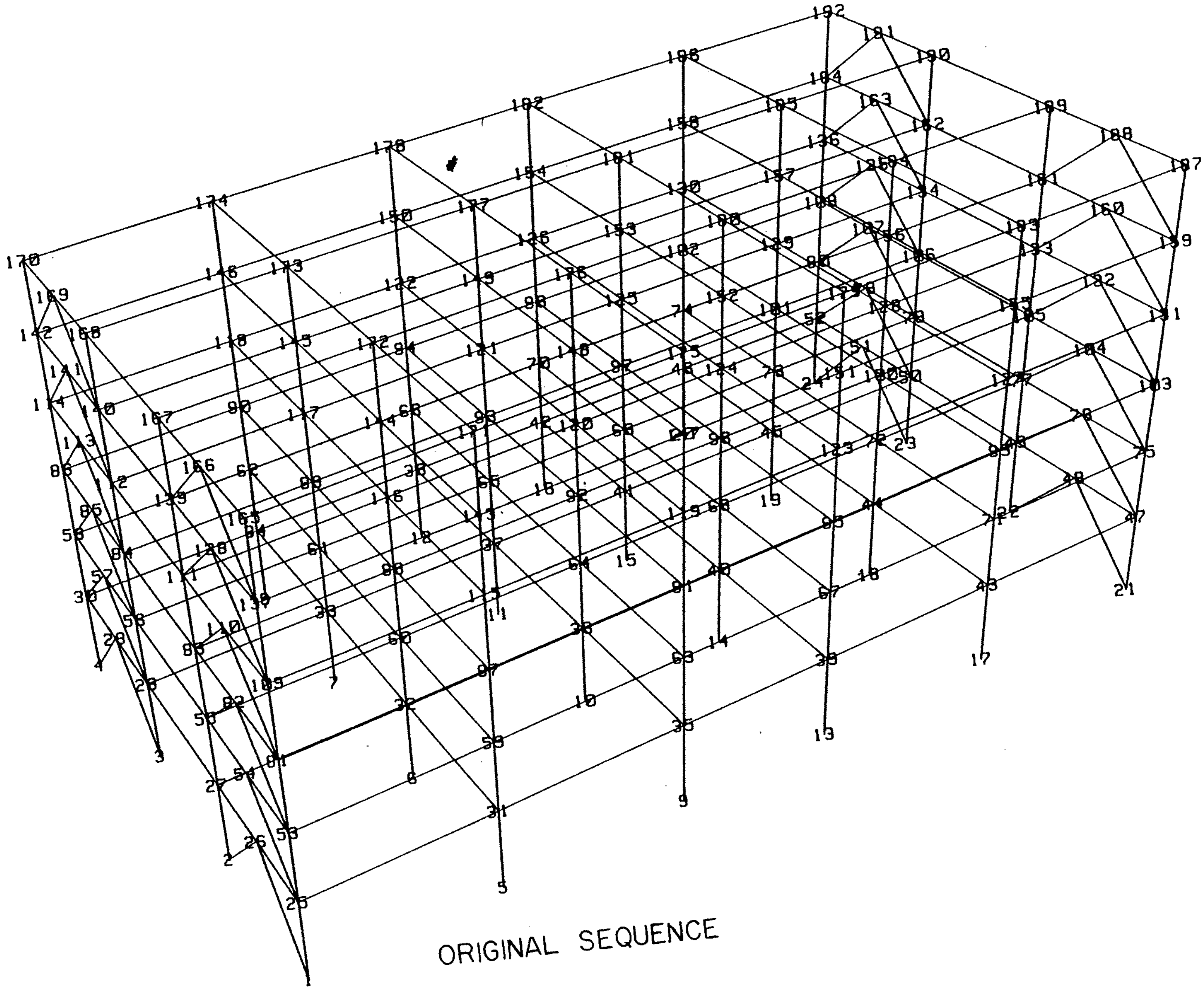
All of the techniques reviewed in this paper have proven to reduce the bandwidth of many different types of structures. It was found that reducing the bandwidth does not always reduce computational operations. An example of this is a dome that was renumbered using the Cuthill-McKee Procedure.

The dome contained 2327 nodes and had an original bandwidth of 2195. The original example was solved and found that the number of computational operations required to reduce the stiffness matrix was 20,148,407. After renumbering the dome a bandwidth of 117 was accomplished. However solving the problem required 22,578,530 operations. Thus the renumbered structure required 12% longer to solve than did the original structure. The differences is accounted for mainly because of the profile of the connectivity matrix. However, further examination of the three techniques showed that many types of structures did decrease in computational operations due to a reduction in bandwidth.

It was proven that for linear structures, bandwidth reduction, which was accomplished by one of the techniques presented here, does reduce computational operations. Of the methods presented the most efficient seem to be the Reverse Cuthill-McKee. Therefore, the author has chosen to develop and discuss an algorithm for this procedure.

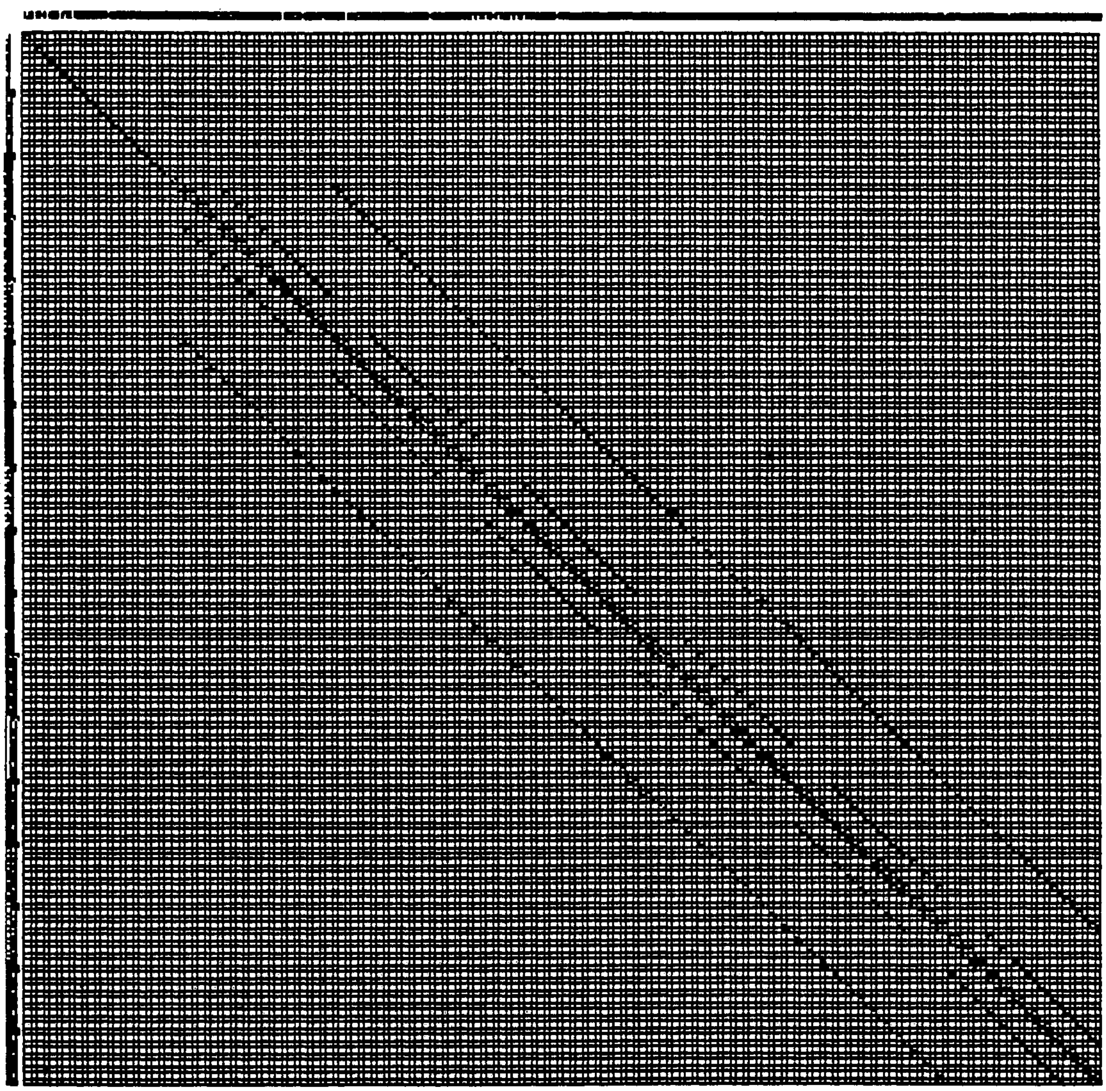
While writing the program it was found that the major problem of developing the Cuthill-McKee Algorithm was transposing the graph theory, used in the procedure to mathematical functions. This problem was solved with the use of matrix manipulations and integer sorting routines. A flow diagram of the Algorithm along with the program are shown in Appendix A.

The Algorithm was tested on a three dimensional structure containing 192 nodes. The original bandwidth was 30 and the number of computational operations required to solve the original problem was 215,115. After renumbering the structure with the Cuthill-McKee Algorithm a bandwidth of 26 was accomplished. The reduction in bandwidth from the original bandwidth is only 13%. However, the number of computational operations was reduced from 215,115 to 110,180 which was a reduction of 49%. The storage requirements were also reduced by 30%. The structure along with a graphical representation of the original and the renumbered connectivity matrices are shown on pages 25-30. Several other examples tested, as shown in Appendix C, determined that, on the average the Reverse-Cuthill McKee Algorithm developed for this paper reduced computational operations and storage requirements by about 53%. It should be noted that the original numbering of both the 2327 node dome and the 192 node 3-dimensional structure was not at all a random numbering, but to the contrary. The original numbering of both structures was generated with a great amount of experience and time. As shown, the developed algorithm still reduced computational operations by one-half. Therefore, concluding, that if the Reverse Cuthill-McKee program, developed for this paper, can reduce computational operations by 50% for the experienced user, then an even greater savings will be achieved by the program for the inexperienced users. A users' guide for the program is given in Appendix B.



ORIGINAL SEQUENCE

ANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



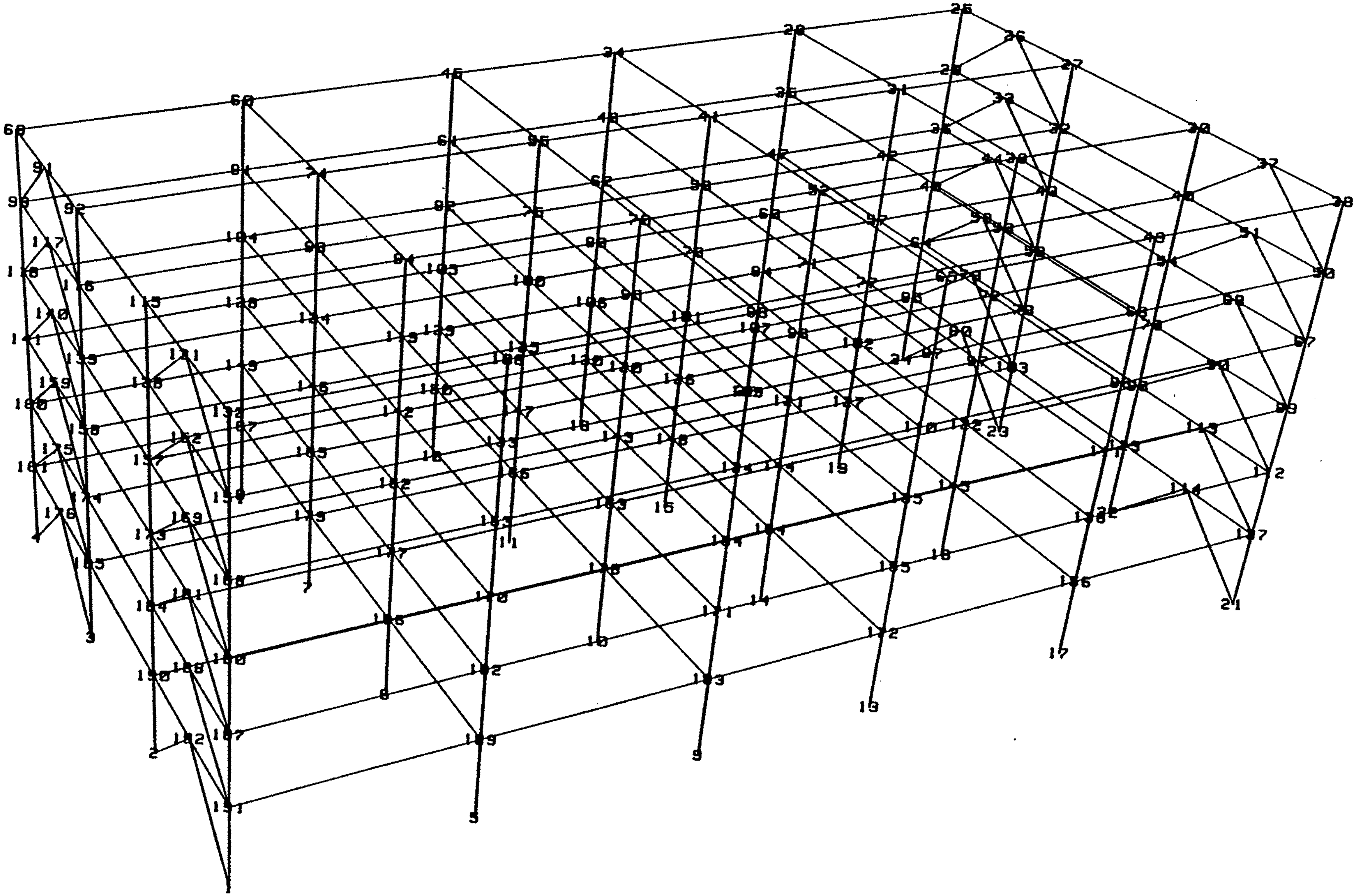
RIGINAL CONNECTIVITY MATRIX

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 26 OCCURS @ OLD Jt 70 FINAL WIDTH= 26 @ NEW JT 108

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	1	2	2	3	3	4	4	5	5	6	6
7	7	8	8	9	9	10	10	11	11	12	12
13	13	14	14	15	15	16	16	17	17	18	18
19	19	20	20	21	21	22	22	23	23	24	24
25	132	26	131	27	115	28	108	29	151	30	97
31	91	32	138	33	152	34	86	35	133	36	168
37	96	38	81	39	73	40	121	41	69	42	116
43	157	44	169	45	65	46	109	47	153	48	180
49	62	50	104	51	122	52	55	53	98	54	143
55	52	56	92	57	139	58	173	59	181	60	49
61	87	62	134	63	170	64	187	65	48	66	84
67	128	68	144	69	38	70	41	71	74	72	123
73	161	74	39	75	70	76	117	77	158	78	184
79	188	80	192	81	66	82	110	83	154	84	182
85	191	86	36	87	64	88	107	89	149	90	162
91	37	92	30	93	50	94	31	95	56	96	99
97	145	98	176	99	53	100	93	101	140	102	174
103	190	104	88	105	135	106	171	107	189	108	29
109	47	110	85	111	130	112	166	113	178	114	179
115	27	116	40	117	51	118	67	119	42	120	75
121	124	122	163	123	186	124	71	125	118	126	159
127	185	128	111	129	155	130	183	131	26	132	25
133	35	134	63	135	106	136	150	137	167	138	32
139	54	140	68	141	89	142	57	143	100	144	146
145	177	146	94	147	141	148	175	149	136	150	172
151	28	152	33	153	46	154	83	155	129	156	165
157	43	158	72	159	90	160	112	161	137	162	76
163	125	164	164	165	119	166	160	167	156	168	34
169	44	170	61	171	105	172	148	173	58	174	95
175	113	176	114	177	101	178	147	179	142	180	45
181	59	182	82	183	127	184	77	185	120	186	126
187	60	188	78	189	103	190	102	191	80	192	79

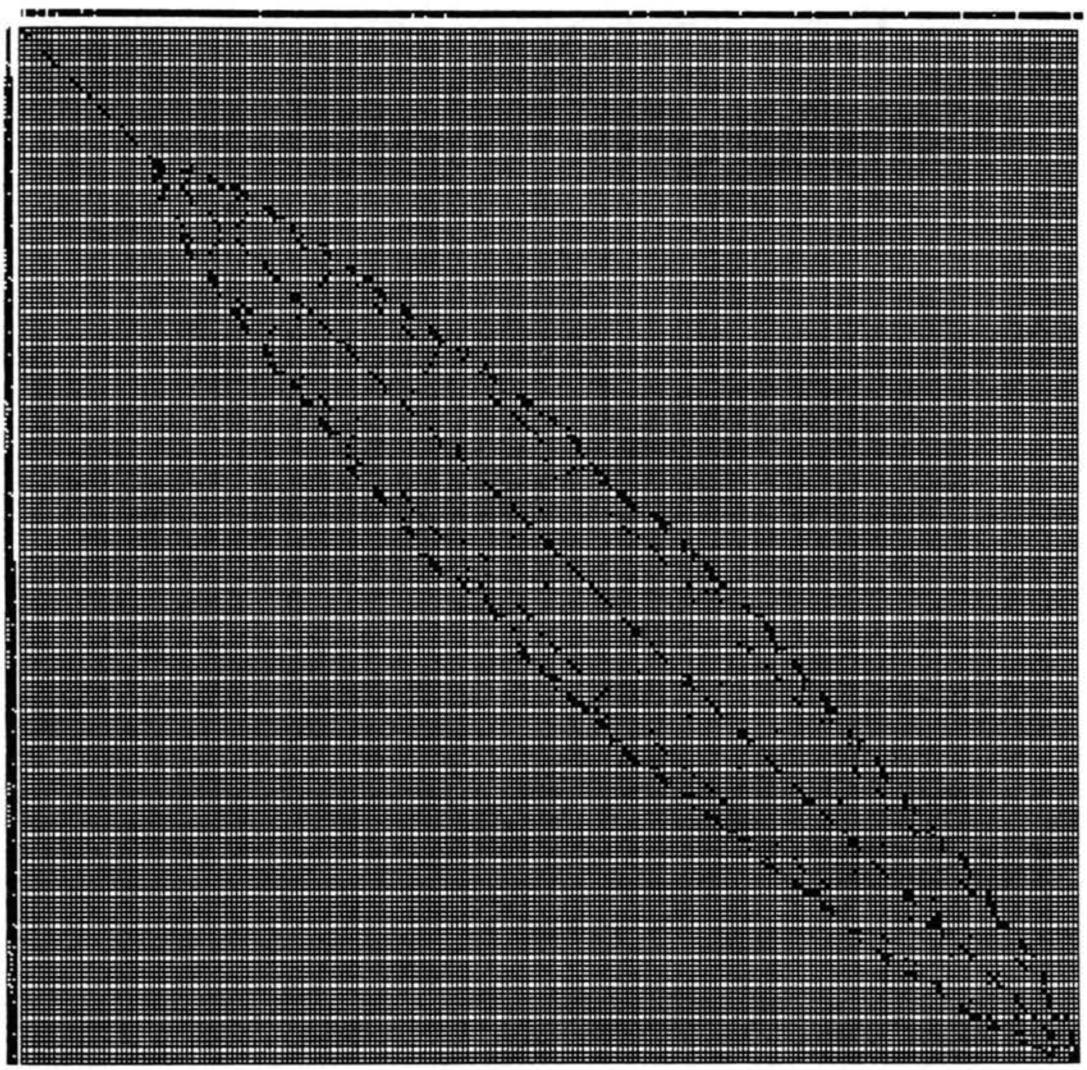
BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 2
ORIG. BANDWIDTH: 26 OCCURS @ OLD Jt 70 FINAL WIDTH= 26 @ NEW JT 108

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	1	2	2	3	3	4	4	5	5	6	6
7	7	8	8	9	9	10	10	11	11	12	12
13	13	14	14	15	15	16	16	17	17	18	18
19	19	20	20	21	21	22	22	23	23	24	24
25	132	26	131	27	115	28	108	29	151	30	97
31	91	32	138	33	152	34	86	35	133	36	168
37	96	38	81	39	73	40	121	41	69	42	116
43	157	44	169	45	65	46	109	47	153	48	180
49	62	50	104	51	122	52	55	53	98	54	143
55	52	56	92	57	139	58	173	59	181	60	49
61	87	62	134	63	170	64	187	65	48	66	84
67	128	68	144	69	38	70	41	71	74	72	123
73	161	74	39	75	70	76	117	77	158	78	184
79	188	80	192	81	66	82	110	83	154	84	182
85	191	86	36	87	64	88	107	89	149	90	162
91	37	92	30	93	50	94	31	95	56	96	99
97	145	98	176	99	53	100	93	101	140	102	174
103	190	104	88	105	135	106	171	107	189	108	29
109	47	110	85	111	130	112	166	113	178	114	179
115	27	116	40	117	51	118	67	119	42	120	75
121	124	122	163	123	186	124	71	125	118	126	159
127	185	128	111	129	155	130	183	131	26	132	25
133	35	134	63	135	106	136	150	137	167	138	32
139	54	140	68	141	89	142	57	143	100	144	146
145	177	146	94	147	141	148	175	149	136	150	172
151	28	152	33	153	46	154	83	155	129	156	165
157	43	158	72	159	90	160	112	161	137	162	76
163	125	164	164	165	119	166	160	167	156	168	34
169	44	170	61	171	105	172	148	173	58	174	95
175	113	176	114	177	101	178	147	179	142	180	45
181	59	182	82	183	127	184	77	185	120	186	126
187	60	188	78	189	103	190	102	191	80	192	79



RENUMBERED SEQUENCE

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



REBANDED CONNECTIVITY MATRIX

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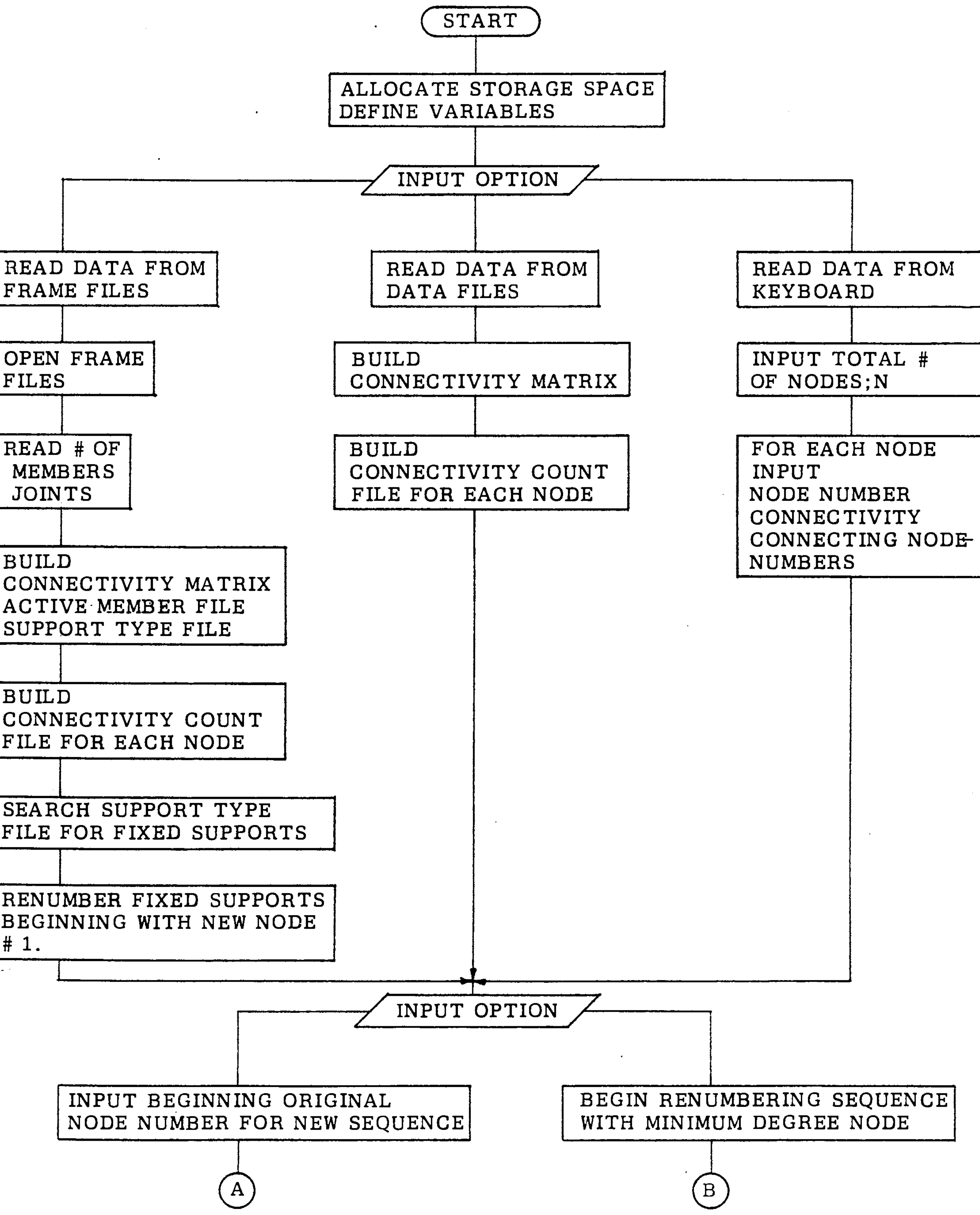
APPENDIX A

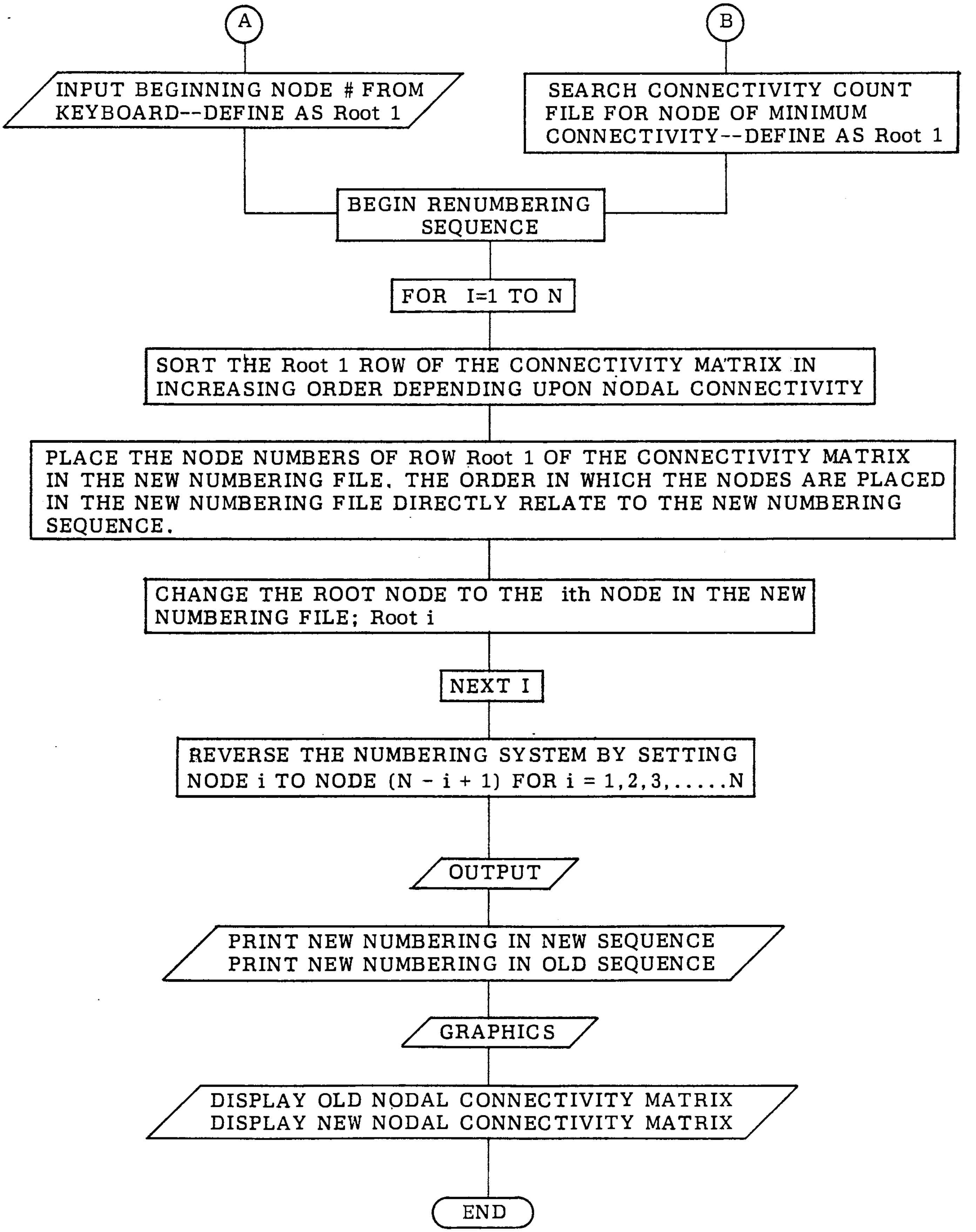
GENERAL FLOW CHART....................................33

PROGRAM LISTING......................................35

GENERAL FLOW CHART



GENERAL FLOW CHART



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```
  10  LEXICAL ORDER IS ASCII!==>9000
  20  !              PROGRAM BANDADE     BANDWIDTH REDUCTION
  30  !              REVERSE CUTHILL-McKEE
  40  !                 A. D. PHILLIPS
  50  !                    Fall 1984
  60  !  RE-STORE"BANDADE"
  70  OPTION BASE 1
  80  DIM A$[69]
  90  SHORT M(50)
 100  ALLOCATE INTEGER Num(1),Conn(1,1,1),Conplt(1,1,1),Act(1)
 110  ALLOCATE INTEGER Plot(1),Print(1),Jot(1),Newnum(1),Dum(1)
 120  Colct=Cn=50
 130  !  Rowct=2400
 140  Maxbdo=Maxbdn=Memct=0
 150  PRINTER IS CRT
 160  PRINT PAGE
 170  PRINT LIN(25),SPA(5),"INPUT OPTION NUMBER"
 180  PRINT LIN(2),SPA(7),"1. INPUT NODES AND CONNECTIVITY FROM KEYBOARD"
 190  PRINT SPA(7),"2. USE EXISTING FILE"
 200  PRINT SPA(7),"3. USE EXISTING FRAME FILE"
 210  INPUT Optnum
 220  Date1=TIMEDATE
 230  IF Optnum=1 THEN Keyb
 240  IF Optnum=2 THEN File
 250  LINPUT "TWO CHARACTER CODE OF FILES AND LOCATION....ie 06:INTERNAL",Mas$
 260  LINPUT "TWO CHARACTER CODE AND LOCATION TO STORE REBANDED DATA...ie 06:I
NTERNAL",Masst$
 270  ASSIGN #1 TO "INCID"&Mas$
 280  ASSIGN #2 TO "ACTIVE"&Mas$
 290  ASSIGN #3 TO "SUP2"&Mas$
 300  ASSIGN #4 TO "COM"&Mas$
 310  ASSIGN #5 TO "BAND"&Masst$;RETURN X
 320  IF X<>0 THEN 350
 330  ASSIGN #5 TO *
 340  PURGE "BAND"&Masst$
 350  INTEGER A,B,C,D,E
 360  SHORT Count,Member
 370  Memct=0
 380  PRINT PAGE
 390  PRINT LIN(25),"BUILDING CONNECTIVITY MATRIX"
 400  READ #4;M(*),A$
 410  Count=Rowct=M(1)
 420  Member=M(2)
 430  DEALLOCATE Num(*),Conn(*),Conplt(*),Act(*),Plot(*),Print(*),Jot(*)
 440  DEALLOCATE Newnum(*),Dum(*)
 450  ALLOCATE INTEGER Num(M(1)),Conn(M(1),Cn,2),Conplt(M(1),Cn,2),Act(M(2))
 460  ALLOCATE INTEGER Plot(M(1)),Print(M(1)),Jot(M(1)),Newnum(M(1))
 470  ALLOCATE INTEGER Dum(M(1))
 480  MAT Conn=(9999)
 490  MAT Conplt=(9999)
 500  MAT Newnum=(9999)
 510  ON END #1 GOTO Numpl
 520  ON END #2 GOTO 540
 530  READ #2;Dum(*)
 540  FOR I=1 TO -INT(-Member/5)
 550    Memn=Dum(I)
 560    Pct=0
```

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```
 570     FOR J=(5*(I-1))+1 TO (5*I)
 580       IF J>Member THEN 610
 590       Pct=Pct+1
 600       Act(J)=INT(Memn/(10^(5-Pct)))-10*INT(Memn/10^(6-Pct))
 610     NEXT J
 620   NEXT I
 630   ON END #3 GOTO 650
 640   READ #3;Dum(*)
 650   FOR I=1 TO Count
 660     Jact=INT(Dum(I)/10000)
 670     Jot(I)=(Jact=2)
 680   NEXT I
 690   Kk=0
 700   FOR I=1 TO Count
 710     IF Jot(I)=0 THEN 740
 720     Kk=Kk+1
 730     Newnum(Kk)=I
 740   NEXT I
 750   Kk=Kk+1
 760   Pnp=Kk-1
 770   Revc=Kk
 780  Nexrd:Memct=Memct+1
 790   READ #1;A,B,C,D,E
 800   IF Act(Memct)=1 THEN Nexrd
 810   IF C>=9000 THEN Four
 820  Two:P1=A
 830   Inpt=B
 840   IF Jot(B)=1 OR Jot(P1)=1 THEN Nexrd
 850   GOSUB Place
 860   P1=B
 870   Inpt=A
 880   GOSUB Place
 890   GOTO Nexrd
 900  Four:P1=A
 910   IF Jot(P1)=1 THEN 960
 920   Inpt1=B
 930   Inpt2=D
 940   Inpt3=E
 950   GOSUB Plafor
 960   P1=B
 970   IF Jot(P1)=1 THEN 1020
 980   Inpt1=A
 990   Inpt2=D
1000   Inpt3=E
1010   GOSUB Plafor
1020   P1=D
1030   IF Jot(P1)=1 THEN 1080
1040   Inpt1=A
1050   Inpt2=B
1060   Inpt3=E
1070   GOSUB Plafor
1080   P1=E
1090   IF Jot(P1)=1 THEN Nexrd
1100   Inpt1=A
1110   Inpt2=B
1120   Inpt3=D
```

```
7 Dec 1984         20:17:39

 1130  GOSUB Plafor
 1140  GOTO Nexrd
 1150 Place:FOR J=1 TO Colct
 1160    IF Inpt=Conn(Pl,J,1) THEN 1220
 1170    IF Conn(Pl,J,1)>=9999 THEN 1190
 1180    GOTO 1210
 1190    Conn(Pl,J,1)=Inpt
 1200    GOTO 1220
 1210  NEXT J
 1220  RETURN
 1230  PRINT "PROGRAM TERMINATED ERROR ENCOUNTED IN DIMENSION OF Conn"
 1240  PRINT "      1. INCREASE THE Y DEMENSION OF Conn"
 1250  PRINT "      2. SET THE PARAMETER Colct = TO THE Y DIMENSION OF Conn"
 1260  GOTO Strtpg
 1270 Plafor:Inck1=Inck2=Inck3=0
 1280  FOR J=1 TO Colct
 1290    IF Conn(Pl,J,1)>=9999 THEN 1340
 1300    IF Conn(Pl,J,1)=Inpt1 THEN Inck1=1
 1310    IF Conn(Pl,J,1)=Inpt2 THEN Inck2=1
 1320    IF Conn(Pl,J,1)=Inpt3 THEN Inck3=1
 1330    GOTO 1440
 1340    Qct=J
 1350    IF Jot(Inpt1)=1 OR Inck1=1 THEN 1380
 1360    Conn(Pl,Qct,1)=Inpt1
 1370    Qct=Qct+1
 1380    IF Jot(Inpt2)=1 OR Inck2=1 THEN 1410
 1390    Conn(Pl,Qct,1)=Inpt2
 1400    Qct=Qct+1
 1410    IF Jot(Inpt3)=1 OR Inck3=1 THEN 1430
 1420    Conn(Pl,Qct,1)=Inpt3
 1430    RETURN
 1440  NEXT J
 1450  PRINT "PROGRAM TERMINATED ERROR ENCOUNTED IN DIMENSION OF Conn"
 1460  PRINT "      1. INCREASE THE Y DEMENSION OF Conn"
 1470  PRINT "      2. SET THE PARAMETER Colct = TO THE Y DIMENSION OF Conn"
 1480  GOTO Strtpg
 1490 Numpl:MAT Num=(9999)
 1500  FOR I=1 TO Rowct
 1510    IF Conn(I,1,1)>=9999 THEN 1580
 1520    Numct=0
 1530    FOR J=1 TO Colct
 1540      IF Conn(I,J,1)>=9999 THEN Asign
 1550      Numct=Numct+1
 1560    NEXT J
 1570 Asign:Num(I)=Numct
 1580  NEXT I
 1590 Fdrot:MAT SORT Num(*) TO Print
 1600  Root=Print(1)
 1610  FOR I=1 TO Rowct
 1620    IF Conn(I,1,1)>=9999 THEN 1680
 1630    FOR J=1 TO Num(I)
 1640      IF ABS(I-Conn(I,J,1))+1<=Maxbdo THEN 1670
 1650      Maxbdo=ABS(I-Conn(I,J,1))+1
 1660      Numbdx=I
 1670    NEXT J
 1680  NEXT I
```

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```
 1690  GOTO Begin
 1700 Keyb:INPUT "INPUT THE TOTAL NUMBER OF NODES AND THE MAXIMUM NODE CONNECTI
VITY",Count,Comax
 1710  Numn=9999
 1720  Revc=1
 1730  Kk=1
 1740  DEALLOCATE Num(*),Conn(*),Conplt(*),Plot(*),Print(*),Newnum(*),Dum(*)
 1750  ALLOCATE INTEGER Num(Count),Conn(Count,Comax,2),Plot(Count),Print(Count)
 1760  ALLOCATE INTEGER Conplt(Count,Comax,2),Newnum(Count),Dum(Count)
 1770  MAT Conn=(9999)
 1780  MAT Conplt=(9999)
 1790  MAT Newnum=(9999)
 1800  FOR I=1 TO Count
 1810    PRINT LIN(25),SPA(2);"INPUT NODE AND THE DEGREE OF CONNECTIVITY"
 1820    INPUT A,Num(A)
 1830    PRINT PAGE
 1840    PRINT LIN(5),SPA(5);"NODE #";A
 1850    IF Num(A)>=Numn THEN 1880
 1860    Root=A
 1870    Numn=Num(A)
 1880    FOR J=1 TO Num(A)
 1890      INPUT "INPUT CONNECTING NODE ",Conn(A,J,1)
 1900      IF ABS(A-Conn(A,J,1))+1<=Maxbdo THEN 1930
 1910      Maxbdo=ABS(A-Conn(A,J,1))+1
 1920      Numbdx=A
 1930    NEXT J
 1940  NEXT I
 1950  GOTO Begin
 1960 File:PRINT PAGE
 1970  PRINT LIN(25),"FILE NAME OF EXISTING FILE..........ie    Conn:INTERNAL"
 1980  DEALLOCATE Num(*),Conn(*),Conplt(*),Act(*),Plot(*),Print(*),Jot(*)
 1990  DEALLOCATE Newnum(*),Dum(*)
 2000  ALLOCATE INTEGER Num(250),Conn(250,13,2),Conplt(250,13,2),Act(200)
 2010  ALLOCATE INTEGER Plot(250),Print(250),Jot(250),Newnum(250)
 2020  ALLOCATE INTEGER Dum(250)
 2030  LINPUT File$
 2040  ASSIGN #1 TO File$
 2050  MAT Conn=(9999)
 2060  MAT Newnum=(9999)
 2070  Revc=1
 2080  Count=0
 2090  Kk=1
 2100  Check=0
 2110  Pnp=0
 2120  READ #1;Root,Num(Root)
 2130  Numn=Num(Root)
 2140  A=Root
 2150  GOTO Build
 2160 Read:READ #1;A
 2170  IF A=0 THEN Begin
 2180  READ #1;Num(A)
 2190  IF Num(A)>=Numn THEN Build
 2200  Root=A
 2210  Numn=Num(A)
 2220 Build:FOR I=1 TO Num(A)
 2230    READ #1;Conn(A,I,1)
 2240    IF ABS(A-Conn(A,I,1))+1<=Maxbdo THEN 2270
```

```
7 Dec 1984           20:18:30

 2250      Maxbdo=ABS(A-Conn(A,I,1))+1
 2260      Numbdx=A
 2270    NEXT I
 2280    Count=Count+1
 2290    GOTO Read
 2300  Begin:!
 2310    PRINT "BEGIN BANDWIDTH REDUCTION"
 2320    FOR I=1 TO Count
 2330      IF Conn(I,1,1)>=9999 THEN 2370
 2340      FOR J=1 TO Num(I)
 2350        Conn(I,J,2)=Num(Conn(I,J,1))
 2360      NEXT J
 2370    NEXT I
 2380    Newnum(Kk)=Root
 2390    Kk=Kk+1
 2400    MAT Conplt=Conn
 2410  Sort:MAT SORT Conn(Root,*,2)
 2420    FOR I=1 TO Num(Root)
 2430      FOR J=1 TO Kk-1
 2440        IF Conn(Root,I,1)<>Newnum(J) THEN 2470
 2450        Check=1
 2460        GOTO 2480      !J=Kk-1
 2470      NEXT J
 2480      IF Check=1 THEN 2510
 2490      Newnum(Kk)=Conn(Root,I,1)
 2500      Kk=Kk+1
 2510      Check=0
 2520    NEXT I
 2530    Pnp=Pnp+1
 2540    Root=Newnum(Pnp)
 2550    IF Pnp=Count THEN 2570           ! Detem....2331
 2560    GOTO Sort
 2570    MAT Print=Newnum
 2580    Joct=Revc
 2590    FOR I=Revc TO Count
 2600      Newnum(I)=Print(Count-Joct+Revc)
 2610      Joct=Joct+1
 2620    NEXT I
 2630    MAT Print=Newnum
 2640  Detem:MAT SORT Newnum(*) TO Plot
 2650    FOR I=1 TO Count
 2660      IF Conplt(I,1,1)>=9999 THEN 2700   !Conn
 2670      FOR J=1 TO Num(I)
 2680        Conplt(I,J,2)=Plot(Conplt(I,J,1))    !Conn
 2690      NEXT J
 2700    NEXT I
 2710    FOR I=1 TO Count
 2720      IF Conplt(I,1,1)>=9999 THEN 2780    !Conn
 2730      FOR J=1 TO Num(I)
 2740        IF ABS(Plot(I)-Conplt(I,J,2))+1<=Maxbdn THEN 2770    !Conn
 2750        Maxbdn=ABS(Plot(I)-Conplt(I,J,2))+1        !Conn
 2760        Numbdxn=Plot(I)
 2770      NEXT J
 2780    NEXT I
 2790    Date2=TIMEDATE
 2800    INPUT "DO YOU WANT TO CREATE A FILE FOR RENUMBERED DATA ",Answer
```

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```
 2810  IF Answer=0 THEN 2890
 2820  PRINT "CREATING FILE FOR RENUMBERED NODES"
 2830  Recs=Count*2
 2840  CREATE BDAT "BAND"&Masst$,1,Recs
 2850  ASSIGN #5 TO "BAND"&Masst$
 2860  READ #5,1
 2870  PRINT #5;Newnum(*)
 2880  PRINT "RESEQUENCED NODES ARE LOCATED IN BAND";Masst$
 2890  MAT Print=Newnum
 2900  IF Maxbdn<Maxbdo THEN Print
 2910  BEEP
 2920  BEEP
 2930  PRINT PAGE
 2940  PRINT "MATRIX BANDWIDTH CANNOT BE REDUCED...DO YOU WANT TO SEE RESULTS"
 2950  INPUT Resul
 2960  IF Resul=1 THEN Print
 2970  PAUSE
 2980  GOTO Itried
 2990 Print:! ...........................................................
 3000  Page=1
 3010  Ck=0
 3020  PRINT LIN(7),"DO YOU WANT A HARD COPY OF RENUMBERED NODES"
 3030  INPUT Prt
 3040  IF Prt=1 THEN PRINTER IS 201;DRIVER "CIPERLP",WIDTH 130
 3050  IF Prt=0 THEN PRINTER IS CRT
 3060  OUTPUT PRT;"SOLUTION FOR APPENDAGE  ";Mas$;"    ";A$
 3070  OUTPUT PRT;"ELAPSED TIME FOR SOLUTION WAS ";TIME$(Date2-Date1)
 3080  OUTPUT PRT;"STARTING TIME:    ";TIME$(Date1),DATE$(Date1)
 3090  OUTPUT PRT;"TIME @ SOLUTION: ";TIME$(Date2),DATE$(Date2)
 3100 Ppp:GOSUB Pp
 3110  GOTO 3270
 3120 Pp: !TITLES
 3130  IF Ck=1 THEN 3160
 3140  PRINT A$;"...NEW vs OLD...PAGE #";Page
 3150  GOTO 3170
 3160  PRINT A$;"...OLD vs NEW...PAGE #";Page
 3170  Page=Page+1
 3180  PRINT "ORIG. BANDWIDTH:";Maxbdo;"OCCURS @ OLD Jt";Numbdx;" FINAL WIDTH="
;Maxbdn;" @ NEW JT";Numbdxn
 3190  ! PRINT CHR$(128);"RENUMBERED BANDWIDTH:";Maxbdn;"OCCURS AT NODE :";Numb
dxn
 3200  IMAGE 10("  NEW  OLD  ")
 3210  IMAGE 10("  OLD  NEW  ")
 3220  IF Ck=1 THEN 3250
 3230  PRINT USING 3200
 3240  GOTO 3260
 3250  PRINT USING 3210
 3260  RETURN
 3270  Liner=3
 3280  FOR Q=1 TO Count
 3290    PRINT USING 3300;Q;Print(Q)
 3300    IMAGE #,2(M4D),XX
 3310    IF Q/10<>INT(Q/10) THEN 3380
 3320    PRINT
 3330    Liner=Liner+1
 3340    IF Liner<>63 THEN 3380
 3350    IF Prt=1 THEN PRINT CHR$(27)&"&a0R";
 3360    GOSUB Pp
```

```
3370     Liner=3
3380   NEXT Q
3390   PRINT
3400   IF Prt=1 THEN PRINT CHR$(27)&"&a0R";
3410 Check:IF Ck=1 THEN 3460
3420   MAT Print=Plot
3430   Ck=1
3440   Check=0
3450   GOTO Ppp
3460 Pregraf:IF Count<=200 THEN 3510
3470   PRINTER IS CRT
3480   PRINT PAGE
3490   PRINT "GRAPHICS DISPLAY IS NOT POSSIBLE FOR THIS SIZE JOB"
3500   PAUSE
3510   N=Count
3520   IF N>92 THEN 3550
3530   Tick=INT(92/N)
3540   GOTO 3570
3550   Tick=1
3560   GINIT
3570 Graphics:! ............................................................
3580   GCLEAR
3590   GRAPHICS ON
3600   LINE TYPE 1
3610   CSIZE .85*Tick,.5,0
3620   VIEWPORT 17,110,0,92
3630   WINDOW 0,N*Tick,0,N*Tick
3640   FRAME
3650   GRID Tick,Tick,0,0
3660   LORG .5,8/15
3670   FOR I=0 TO N-1
3680     MOVE Tick*I+Tick/2,N*Tick-Tick*I-Tick/2
3690     LABEL "X"
3700   NEXT I
3710   IF Draw=1 THEN Newbd
3720   FOR Q=0 TO Count-1
3730     IF Conplt(Q+1,1,1)>=9999 THEN 3780
3740     FOR I=1 TO Num(Q+1)
3750       MOVE Tick*Conplt(Q+1,I,1)-Tick/2,N*Tick-Tick*Q-Tick/2
3760       LABEL "X"
3770     NEXT I
3780   NEXT Q
3790   GOTO Bord
3800 Newbd:FOR Q=1 TO Count
3810     IF Conplt(Q,1,2)>=9999 THEN 3870      !Conn
3820     FOR I=1 TO Num(Q)
3830       Y=Plot(Q)
3840       MOVE Tick*Conplt(Q,I,2)-Tick/2,N*Tick-Tick*Y+Tick/2    !Conn
3850       LABEL "X"
3860     NEXT I
3870   NEXT Q
3880   IF Draw=1 THEN End
3890 Bord:FOR I=0 TO N-1
3900     MOVE Tick*I+Tick/2,N*Tick+3
3910     LABEL I+1
3920   NEXT I
```

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```
 3930  FOR I=0 TO N-1
 3940    MOVE -2,Tick*N-Tick*I-Tick/2
 3950    LABEL I+1
 3960  NEXT I
 3970 End:ALPHA ON
 3980  PRINTER IS CRT
 3990  PRINT "DUMP GRAPHICS.?"
 4000  INPUT Answ
 4010  IF Answ=0 THEN Decid
 4020  DUMP GRAPHICS
 4030 Decid:IF Draw=0 THEN 4050
 4040  PAUSE
 4050  Draw=1
 4060  GOTO Graphics
 4070 Itried:END
```

APPENDIX B

USER'S GUIDE....................................44

The input data required to renumber a structure, involves node numbers and, their respective nodal connectivity and connecting nodes. The Algorithm was developed so that the data could be input using one of three different procedures. One procedure is set up to directly interact with an existing frame analysis program. In using this input procedure, the user needs to first execute the input portion of the frame analysis program and then execute the reband program. Using this procedure, there is no input form the keyboard required by the reband algorithm. The program will gather the required data from the frame files, which were created by the frame analysis program.

A second procedure is to build, prior to execution of the reband program, a file that contains the node numbers, nodal connectivity and connecting nodes for each joint in the strucutre,for an example use figure 7.

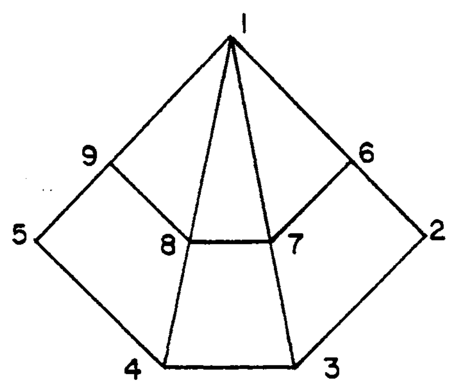


FIG. 7

The file to be built can contain the nodes in any order. For this example, the nodes will be put in numerical order. The file that is built contains only integers and would be generated as in figure 8.

In the file of fig. 8, the first 1 represents node number one. The following 4, is the nodal connectivity of node 1 and the four following numbers, 6,7,8, and 9 represent the nodes connected to node 1. The next 2 represents node 2. The following two is the nodal connectivity of node 2. The next two numbers are the node numbers connected to node 2. This procedure is continued for nodes 3 through 9. A zero is placed at the end of the file to tell the program that all the data has been read. After the file has been built and stored, the

1,4,6,7,8,9,2,2,3,6,3,3,2,4,7,4,3,3,5,8,5,2,4,9,6

3,1,2,7,7,4,1,3,6,8,8,4,1,4,7,9,9,3,1,5,8,0

FIG. 8

user needs to execute the reband program. The Algorithm will ask the user for the name of the file where the data is stored. This is the only required data input, form the keyboard, for this procedure.

The third and final input procedure is interactive with the user. The required information is the same as for procedure #2, except the information is input from the keyboard by the user. The program will ask the user for the required information. After the Cuthill-McKee Algorithm has renumbered the structure, the program will print out two lists of node numbers. The first list will contain the old joint numbers in the new sequence. The second list will contain the new joint numbers in the old sequence. This makes it easier for the user to locate nodes. The program will also give a graphical representation of the original connectivity matrix. Example problems can be found in Appendix C.

APPENDIX C

TEST EXAMPLES

EXAMPLE #1....................................47

EXAMPLE #2....................................53

EXAMPLE #3....................................59

EXAMPLE #4....................................66

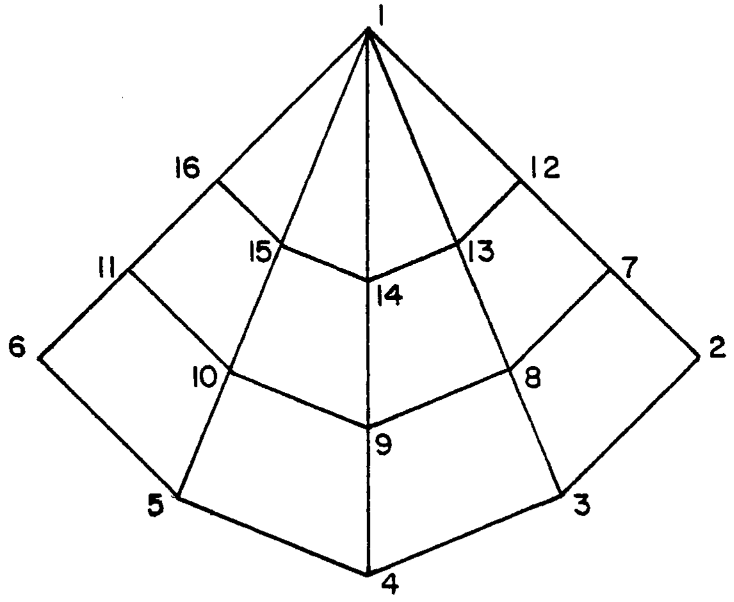
EXAMPLE #5....................................72

EXAMPLE #6....................................78

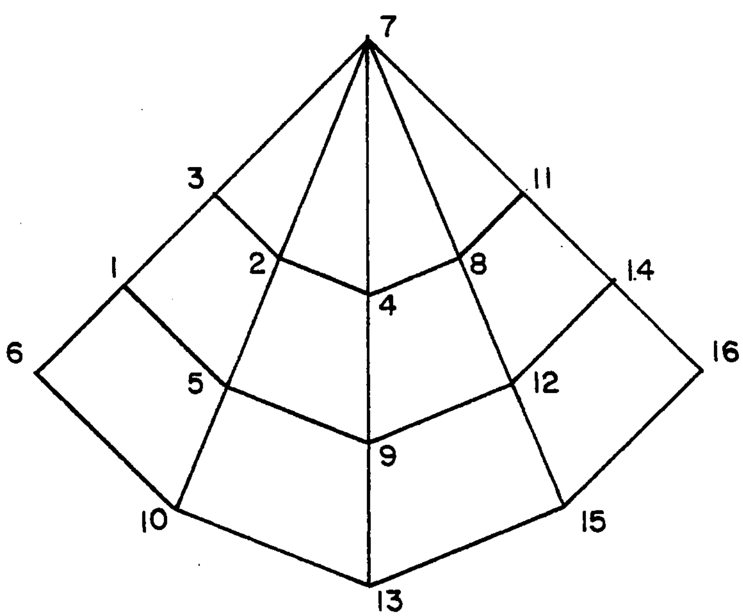
EXAMPLE #1

16 NODE FAN TRUSS

EXAMPLE #1



ORIGINAL SEQUENCE



RENUMBERED SEQUENCE

EXAMPLE #1

8 Dec 1984   19:21:59

```
 10  !       EXAMPLE INPUT PROGRAM
 20  !       MASTER'S PROJECT    Fall 1984
 30  LEXICAL ORDER IS ASCII
 40  OPTION BASE 1
 50  PRINTER IS CRT
 60  ALLOCATE INTEGER Data(100)
 70  ASSIGN #1 TO "BDATA:CS80,7";RETURN X
 80  IF NOT X THEN Purge
 90  GOTO Create
100 Purge:  ASSIGN #1 TO *
110  PURGE "BDATA:CS80,7"
120 Create: CREATE BCD "BDATA:CS80,7",1
130  ASSIGN #1 TO "BDATA:CS80,7"
140  DATA 1,5,12,13,14,15,16,2,2,3,7,3,3,2,4,8,4,3,3,5,9,5,3,4,6,10
150  DATA 6,2,5,11,7,3,2,12,8,8,4,3,13,7,9,9,4,4,14,8,10,10,4,5,15,9,11
160  DATA 11,3,6,16,10,12,3,1,7,13,13,4,1,8,12,14,14,4,1,9,13,15,15,4
170  DATA 1,10,14,16,16,3,1,15,11,0
180         FOR I=1 TO 100
190           READ A
200           PRINT #1;A
210           IF NOT A THEN End
220         NEXT I
230  PRINT "NOT ALL DATA STORED IN FILE....... INCREASE VALUE OF I"
240 End: ASSIGN #1 TO *
250  END
```

EXAMPLE #1

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

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

ORIGINAL CONNECTIVITY MATRIX

EXAMPLE #1

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 16 OCCURS @ OLD Jt 1 FINAL WIDTH= 6 @ NEW JT 7

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	11	2	15	3	16	4	14	5	10	6	6
7	1	8	13	9	9	10	5	11	12	12	8
13	4	14	7	15	3	16	2				

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	7	2	16	3	15	4	13	5	10	6	6
7	14	8	12	9	9	10	5	11	1	12	11
13	8	14	4	15	2	16	3				

EXAMPLE #1

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

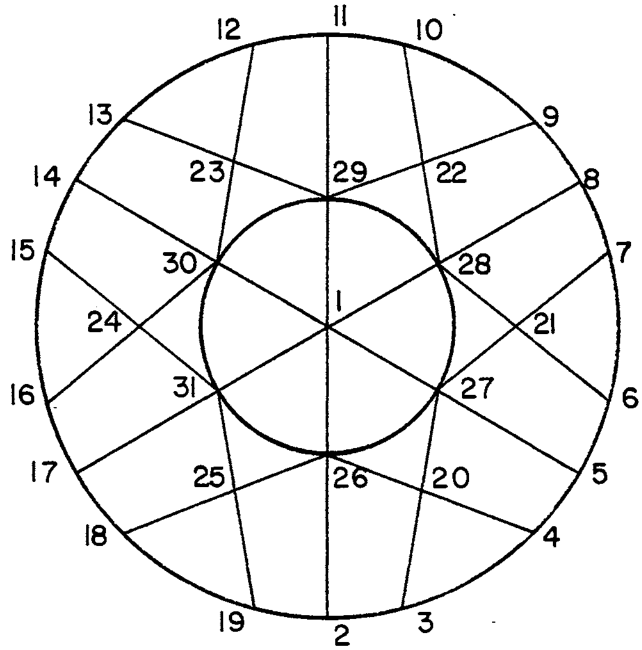
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	X		X		X	X										
2		X	X	X	X		X									
3	X	X	X				X									
4		X		X			X	X	X							
5	X	X			X				X	X						
6	X					X				X						
7		X	X	X			X	X			X					
8				X			X	X			X	X				
9				X	X				X			X	X			
10					X	X				X			X			
11							X	X			X			X		
12								X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

PREBANDED CONNECTIVITY MATRIX

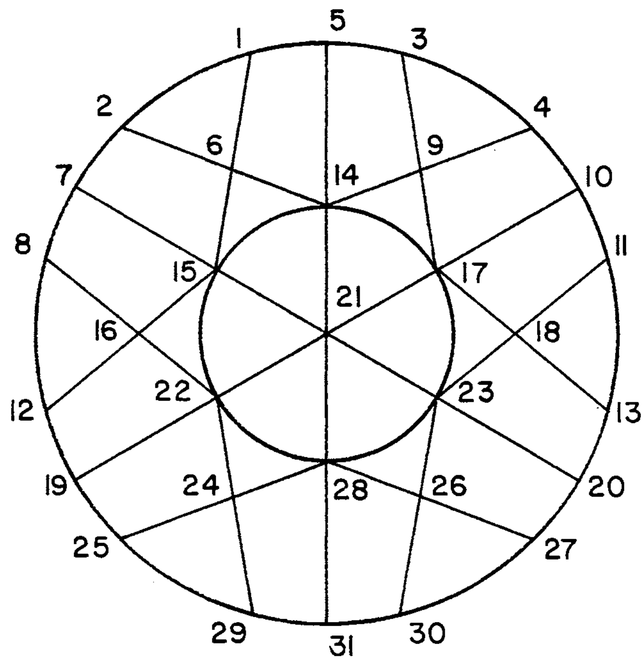
EXAMPLE #2

31 NODE RING TRUSS

EXAMPLE #2



ORIGINAL SEQUENCE



RENUMBERED SEQUENCE

EXAMPLE #2

```
8 Dec 1984          02:28:11

  10  !       EXAMPLE INPUT PROGRAM
  20  !       MASTER'S PROJECT    Fall 1984
  30  LEXICAL ORDER IS ASCII
  40  OPTION BASE 1
  50  PRINTER IS CRT
  60  ALLOCATE INTEGER Data(500)
  70  ASSIGN #1 TO "BDATA:CS80,7";RETURN X
  80  IF NOT X THEN Purge
  90  GOTO Create
 100 Purge:  ASSIGN #1 TO *
 110  PURGE "BDATA:CS80,7"
 120 Create: CREATE BCD "BDATA:CS80,7",1
 130  ASSIGN #1 TO "BDATA:CS80,7"
 140  DATA 1,6,26,27,28,29,30,31,2,3,3,19,26,3,3,2,4,20,4,3,3,5,20,5
 150  DATA 3,4,6,27,6,3,5,7,21,7,3,6,8,21,8,3,7,9,28,9,3,8,10,22,10,3
 160  DATA 9,11,22,11,3,10,12,29,12,3,11,13,23,13,3,12,14,23,14,3,13
 170  DATA 15,30,15,3,14,16,24,16,3,15,17,24,17,3,16,18,31,18,3,17,19
 180  DATA 25,19,3,2,18,25,20,4,26,27,3,4,21,4,6,7,27,28,22,4,28,29,9
 190  DATA 10,23,4,12,13,29,30,24,4,15,16,30,31,25,4,18,19,26,31,26,6
 200  DATA 2,20,25,27,31,1,27,6,1,5,20,21,26,28,28,6,1,8,21,22,27,29
 210  DATA 29,6,1,11,22,23,28,30,30,6,1,14,23,24,29,31,31,6,1,17,24,25
 220  DATA 30,26,0
 230         FOR I=1 TO 500
 240           READ A
 250           PRINT #1;A
 260           IF NOT A THEN End
 270         NEXT I
 280  PRINT "NOT ALL DATA STORED IN FILE....... INCREASE VALUE OF I"
 290 End: ASSIGN #1 TO *
 300  END
```

EXAMPLE #2

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	X																									X	X	X	X	X	X
2		X	X																X							X					
3		X	X	X																X											
4			X	X	X															X											
5				X	X	X																					X				
6					X	X	X														X										
7						X	X	X													X										
8							X	X	X																			X			
9								X	X	X												X									
10									X	X	X											X									
11										X	X	X																	X		
12											X	X	X										X								
13												X	X	X									X								
14													X	X	X															X	
15														X	X	X								X							
16															X	X	X							X							
17																X	X	X													X
18																	X	X	X						X						
19		X																X	X						X						
20			X	X																X						X	X				
21						X	X														X						X	X			
22									X	X												X						X	X		
23												X	X										X						X	X	
24															X	X								X						X	X
25																		X	X						X	X					X
26	X	X																		X					X	X	X				X
27	X				X															X	X					X	X	X			
28	X							X													X	X					X	X	X		
29	X										X											X	X					X	X	X	
30	X													X									X	X					X	X	X
31	X																X							X	X	X				X	X

ORIGINAL CONNECTIVITY MATRIX

EXAMPLE #2

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 31 OCCURS @ OLD Jt 1 FINAL WIDTH= 10 @ NEW JT 5

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	12	2	13	3	10	4	9	5	11	6	23
7	14	8	15	9	22	10	8	11	7	12	16
13	6	14	29	15	30	16	24	17	28	18	21
19	17	20	5	21	1	22	31	23	27	24	25
25	18	26	20	27	4	28	26	29	19	30	3
31	2										

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	21	2	31	3	30	4	27	5	20	6	13
7	11	8	10	9	4	10	3	11	5	12	1
13	2	14	7	15	8	16	12	17	19	18	25
19	29	20	26	21	18	22	9	23	6	24	16
25	24	26	28	27	23	28	17	29	14	30	15
31	22										

EXAMPLE #2

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

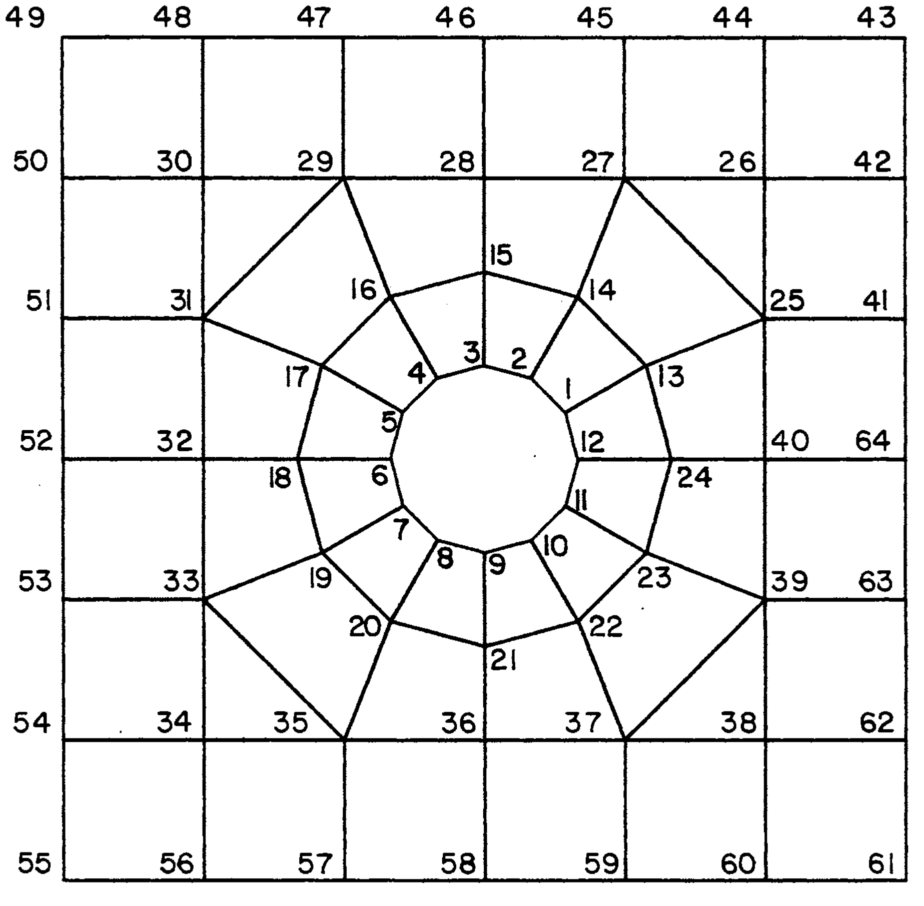
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	X	X			X	X																									
2	X	X				X	X																								
3			X	X	X				X																						
4			X	X					X	X																					
5	X		X		X									X																	
6	X	X				X								X	X																
7		X					X	X							X																
8							X	X				X				X															
9			X	X					X					X			X														
10				X						X	X						X														
11										X	X		X					X													
12								X				X				X			X												
13											X		X					X		X											
14					X	X			X					X	X		X				X										
15						X	X							X	X	X					X	X									
16								X				X			X	X						X									
17									X	X				X			X	X			X		X								
18											X		X				X	X					X								
19												X							X			X			X						
20													X							X			X				X				
21														X	X		X				X	X	X					X			
22															X	X			X		X	X		X				X			
23																	X	X		X	X		X			X		X			
24																						X		X	X			X	X		
25																			X					X	X				X		
26																							X			X	X	X		X	
27																				X						X	X			X	
28																					X	X	X	X		X		X			X
29																								X	X				X		X
30																										X	X			X	X
31																												X	X	X	X

REBANDED CONNECTIVITY MATRIX

EXAMPLE #3

48 ELEMENT, 64 NODE FINITE ELEMENT MESH FOR A SQUARE PLATE WITH CONCENTRIC HOLE

EXAMPLE #3



ORIGINAL SEQUENCE

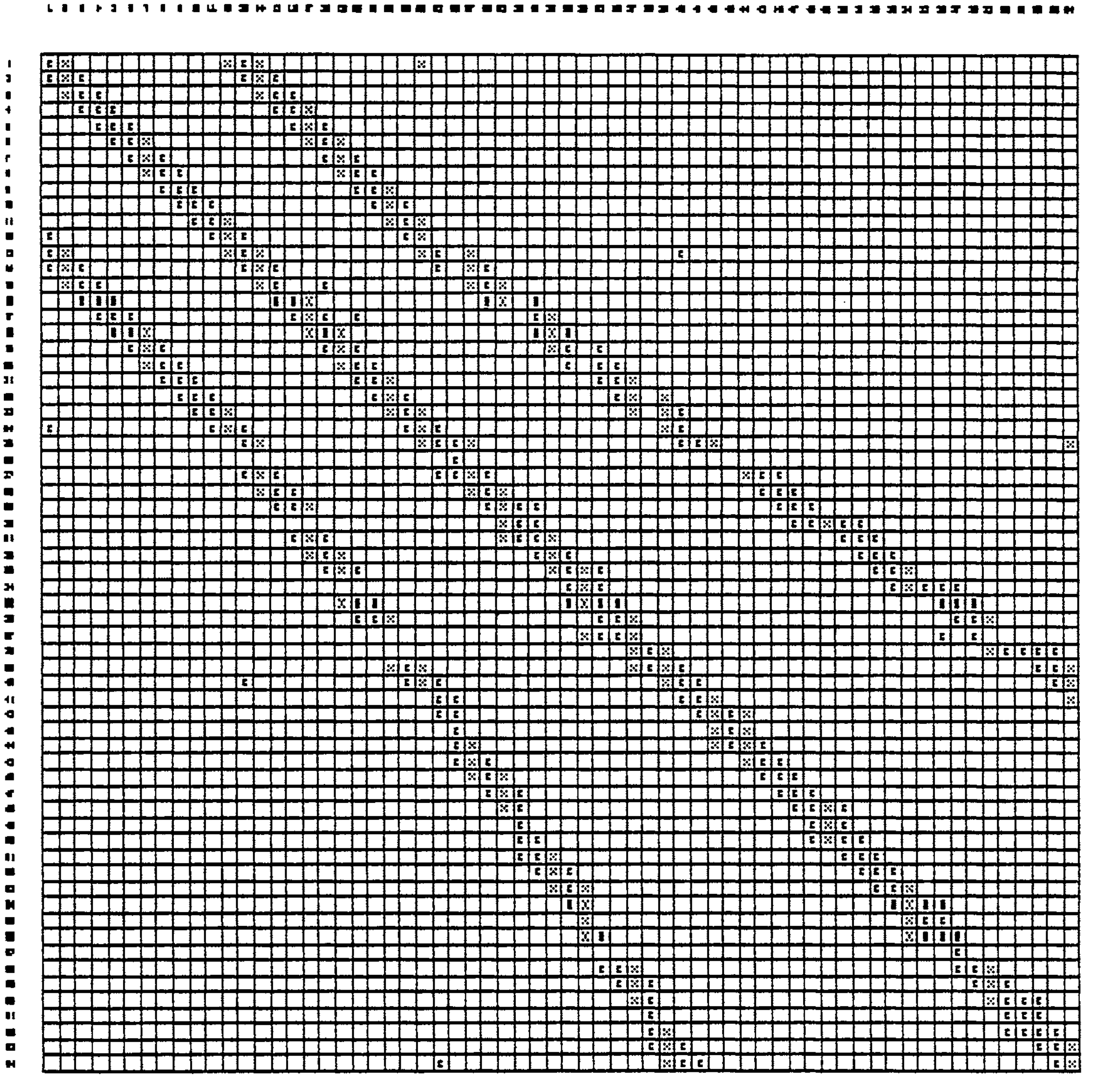
EXAMPLE #3

8 Dec 1984   16:50:18

```
  10  !       EXAMPLE INPUT PROGRAM
  20  !       MASTER'S PROJECT    Fall 1984
  30  LEXICAL ORDER IS ASCII
  40  OPTION BASE 1
  50  PRINTER IS CRT
  60  ALLOCATE INTEGER Data(800)
  70  ASSIGN #1 TO "BDATA:CS80,7";RETURN X
  80  IF NOT X THEN Purge
  90  GOTO Create
 100 Purge:  ASSIGN #1 TO *
 110  PURGE "BDATA:CS80,7"
 120 Create: CREATE BCD "BDATA:CS80,7",1
 130  ASSIGN #1 TO "BDATA:CS80,7"
 140  DATA 1,5,2,14,13,12,24,2,5,3,14,15,1,13,3,5,4,16,15,2,14,4,5,5
 150  DATA 17,16,3,15,5,5,18,17,4,16,6,6,5,7,19,18,5,17,7,5,8,20,19,6,18
 160  DATA 8,5,20,19,7,21,9,9,5,8,20,21,22,10,10,5,9,21,22,23,11,11,5
 170  DATA 10,22,23,12,24,12,5,11,23,24,1,13,13,8,25,27,14,2,1,12,24,40
 180  DATA 14,8,27,28,15,3,2,1,13,25,15,8,28,29,18,4,3,2,14,27,16,8,29,31
 190  DATA 17,5,4,3,15,28,17,8,31,32,18,6,5,4,16,20,18,8,32,33,19,7,6,5
 200  DATA 17,31,19,8,33,35,20,8,7,6,18,32,20,8,35,36,21,9,8,7,19,33,21,8
 210  DATA 36,37,22,10,9,8,20,35,22,8,37,39,36,11,10,9,21,23,23,8,39,40
 220  DATA 24,12,11,10,22,37,24,8,40,25,13,1,12,11,23,39,36,7,44,45,27,25
 230  DATA 41,42,43,25,9,41,42,26,27,14,13,24,40,64,27,9,45,46,28,15,14,13
 240  DATA 25,26,44,28,8,46,47,29,16,15,14,27,45,29,9,47,48,30,31,17,16,15
 250  DATA 28,46,30,7,48,49,50,51,31,29,47,31,9,30,50,51,52,32,18,17,16,29
 260  DATA 32,8,31,51,52,53,33,19,18,17,33,9,32,52,53,54,34,35,20,19,18,34
 270  DATA 7,33,53,54,55,56,57,35,35,9,21,20,19,33,34,56,57,58,36,36,8,22
 280  DATA 21,20,35,57,58,59,37,37,9,23,22,21,36,58,59,60,38,39,38,7,39,37
 290  DATA 59,60,61,62,63,39,9,24,23,22,37,38,62,63,64,40,40,8,13,24,23,39,63
 300  DATA 64,41,25,41,5,42,26,25,40,64,42,5,43,44,26,25,41,43,3,44,26,42
 310  DATA 44,5,45,27,26,42,43,45,5,46,28,27,26,44,46,5,47,29,28,27,45,47
 320  DATA 5,48,30,29,28,46,48,5,49,50,30,29,47,49,3,50,30,48,50,5,51,31
 330  DATA 30,48,49,51,5,50,52,30,31,32,52,5,51,53,31,32,33,53,5,52,54,32
 340  DATA 33,34,54,5,53,55,33,34,56,55,3,54,56,34,56,5,55,57,54,34,35,37
 350  DATA 5,56,58,34,35,36,58,5,57,59,35,36,37,59,5,58,60,36,37,38,60,5
 360  DATA 59,61,37,38,62,61,3,60,62,38,62,5,60,61,63,38,39,63,5,62,64,38
 370  DATA 39,40,64,5,63,41,39,40,25,0
 380         FOR I=1 TO 800
 390           READ A
 400           PRINT #1;A
 410           IF NOT A THEN End
 420         NEXT I
 430  PRINT "NOT ALL DATA STORED IN FILE....... INCREASE VALUE OF I"
 440 End: ASSIGN #1 TO *
 450  END
```

EXAMPLE #3

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



ORIGINAL CONNECTIVITY MATRIX

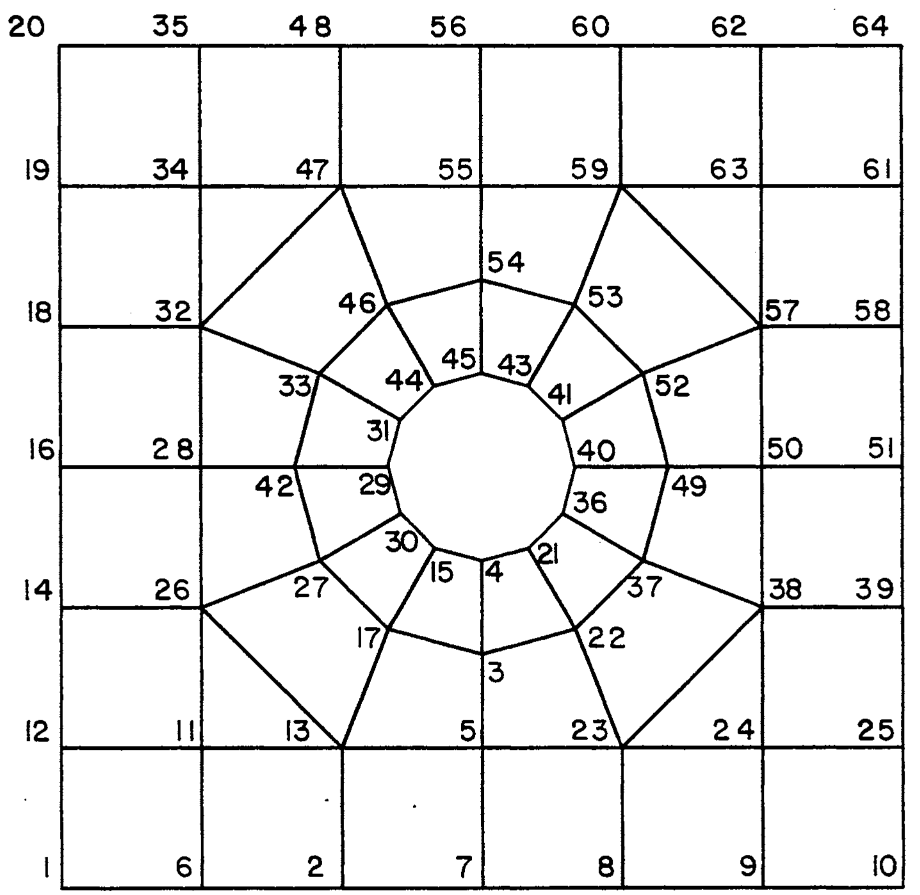
EXAMPLE #3

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 40 OCCURS @ OLD Jt 25 FINAL WIDTH= 21 @ NEW JT 3

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	55	2	57	3	21	4	9	5	36	6	56
7	58	8	59	9	60	10	61	11	34	12	54
13	35	14	53	15	8	16	52	17	20	18	51
19	50	20	49	21	10	22	22	23	37	24	38
25	62	26	33	27	19	28	32	29	6	30	7
31	5	32	31	33	17	34	30	35	48	36	11
37	23	38	39	39	63	40	12	41	1	42	18
43	2	44	4	45	3	46	16	47	29	48	47
49	24	50	40	51	64	52	13	53	14	54	15
55	28	56	46	57	25	58	41	59	27	60	45
61	42	62	44	63	26	64	43				

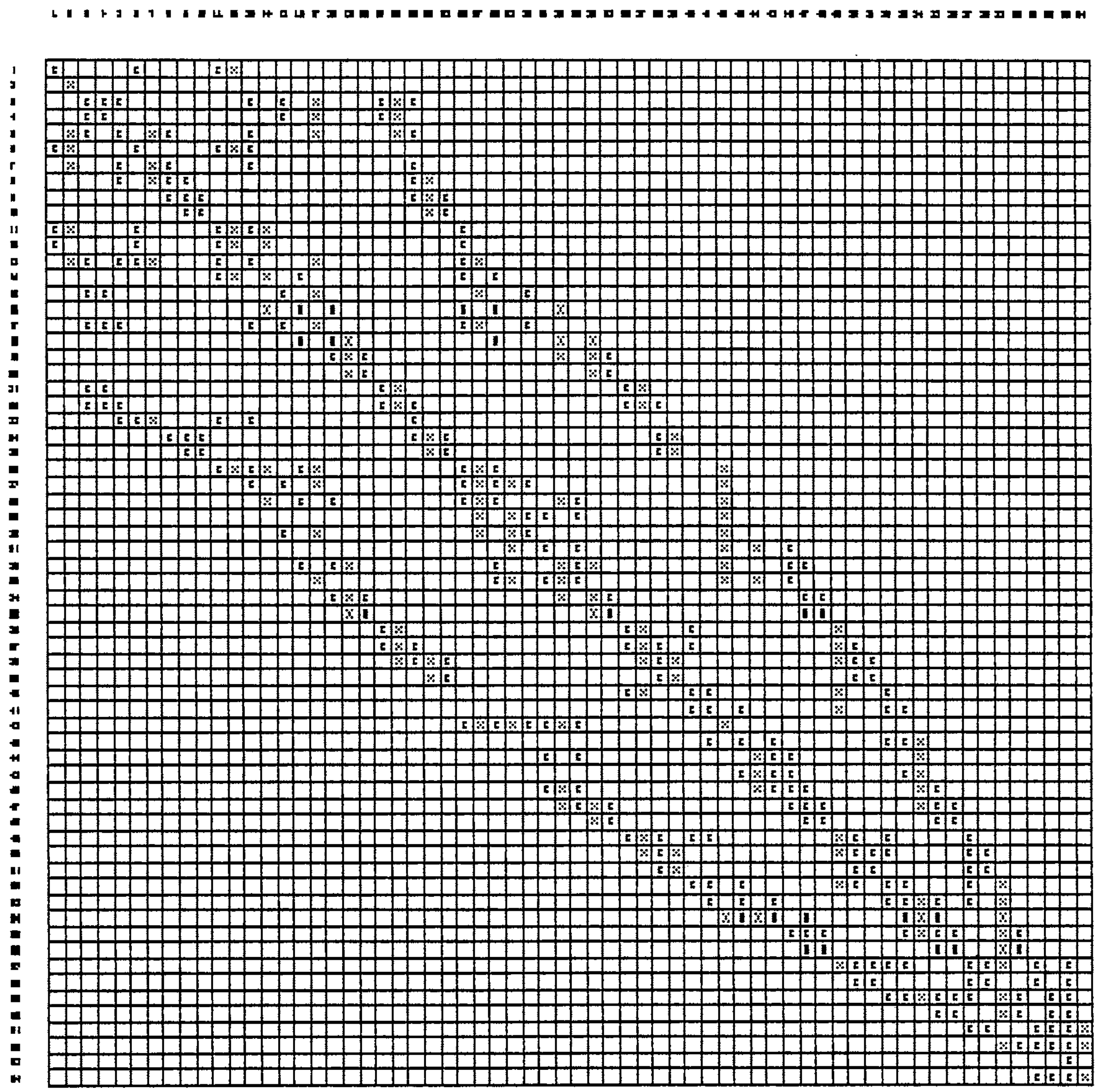
OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	41	2	43	3	45	4	44	5	31	6	29
7	30	8	15	9	4	10	21	11	36	12	40
13	52	14	53	15	54	16	46	17	33	18	42
19	27	20	17	21	3	22	22	23	37	24	49
25	57	26	63	27	59	28	55	29	47	30	34
31	32	32	28	33	26	34	11	35	13	36	5
37	23	38	24	39	38	40	50	41	58	42	61
43	64	44	62	45	60	46	56	47	48	48	35
49	20	50	19	51	18	52	16	53	14	54	12
55	1	56	6	57	2	58	7	59	8	60	9
61	10	62	25	63	39	64	51				

EXAMPLE #3



RENUMBERED SEQUENCE

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

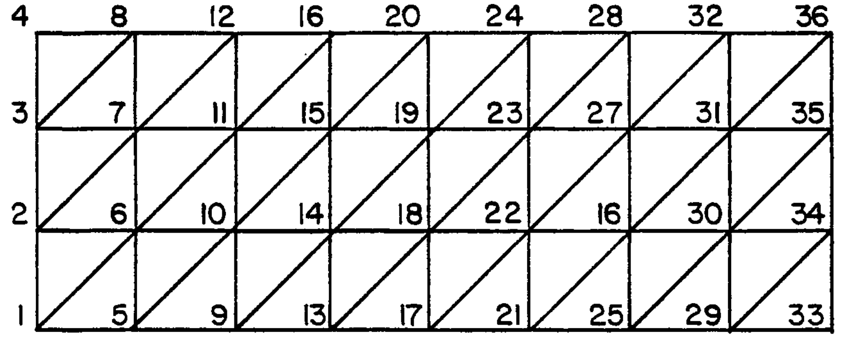


REBANDED CONNECTIVITY MATRIX

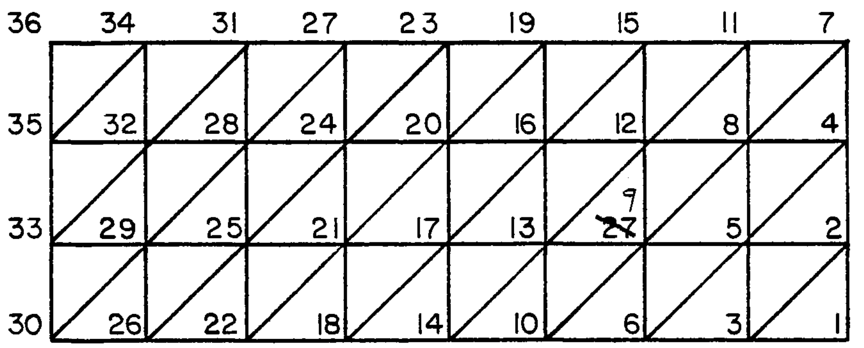
EXAMPLE #4

48 ELEMENT, 36 NODE FINITE ELEMENT
MESH FOR A RECTANGULAR PLATE

EXAMPLE #4



ORIGINAL SEQUENCE



RENUMBERED SEQUENCE

EXAMPLE #4

```
8 Dec 1984          02:00:22

  10  !       EXAMPLE INPUT PROGRAM
  20  !       MASTER'S PROJECT    Fall 1984
  30  LEXICAL ORDER IS ASCII
  40  OPTION BASE 1
  50  PRINTER IS CRT
  60  ALLOCATE INTEGER Data(500)
  70  ASSIGN #1 TO "BDATA:CS80,7";RETURN X
  80  IF NOT X THEN Purge
  90  GOTO Create
 100 Purge:  ASSIGN #1 TO *
 110  PURGE "BDATA:CS80,7"
 120 Create: CREATE BCD "BDATA:CS80,7",1
 130  ASSIGN #1 TO "BDATA:CS80,7"
 140  DATA 1,3,2,5,6,2,4,1,6,7,3,3,4,2,7,8,4,4,2,3,8,5,4,1,9,6,10
 150  DATA 6,6,5,10,11,7,2,1,7,6,6,11,12,8,3,2,8,4,7,3,4,12,9,4,5
 160  DATA 13,10,14,10,6,9,14,15,11,5,6,11,6,10,15,16,12,7,6,12,4
 170  DATA 11,16,8,7,13,4,9,17,14,18,14,6,13,18,19,15,10,9,15,6
 180  DATA 14,19,20,16,10,11,16,4,15,20,12,11,17,4,13,21,18,22,18
 190  DATA 6,17,22,23,19,14,13,19,6,18,23,24,20,15,14,20,4,19,24
 200  DATA 16,15,21,4,25,26,22,17,22,6,21,26,27,23,18,17,23,6,22,27
 210  DATA 28,24,19,18,24,4,23,28,19,20,25,4,29,30,26,21,26,6,25,30
 220  DATA 31,27,22,21,27,6,26,31,32,28,23,22,28,4,27,32,23,24,29,4
 230  DATA 25,33,34,30,30,6,29,34,35,31,26,25,31,6,35,36,32,27,26,30
 240  DATA 32,4,31,36,28,27,33,2,29,34,34,4,33,29,30,35,35,4,34,30
 250  DATA 31,36,36,3,31,32,35,0
 260         FOR I=1 TO 500
 270           READ A
 280           PRINT #1;A
 290           IF NOT A THEN End
 300         NEXT I
 310  PRINT "NOT ALL DATA STORED IN FILE....... INCREASE VALUE OF I"
 320 End: ASSIGN #1 TO *
 330  END
```

EXAMPLE #4

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	X	X			X	X																														
2	X	X	X			X	X																													
3		X	X	X			X	X																												
4			X	X				X																												
5	X				X	X			X	X																										
6	X	X			X	X	X			X	X																									
7		X	X			X	X	X			X	X																								
8			X	X			X	X				X																								
9					X				X	X			X	X																						
10					X	X			X	X	X			X	X																					
11						X	X			X	X	X			X	X																				
12							X	X			X	X				X																				
13									X				X	X			X	X																		
14									X	X			X	X	X			X	X																	
15										X	X			X	X	X			X	X																
16											X	X			X	X				X																
17													X				X	X			X	X														
18													X	X			X	X	X			X	X													
19														X	X			X	X	X			X	X												
20															X	X			X	X				X												
21																	X				X	X			X	X										
22																	X	X			X	X	X			X	X									
23																		X	X			X	X	X			X	X								
24																			X	X			X	X				X								
25																					X				X	X			X	X						
26																					X	X			X	X	X			X	X					
27																						X	X			X	X	X			X	X				
28																							X	X			X	X				X				
29																									X				X	X			X	X		
30																									X	X			X	X	X			X	X	
31																										X	X			X	X	X			X	X
32																											X	X			X	X				X
33																													X				X	X		
34																													X	X			X	X	X	
35																														X	X			X	X	X
36																															X	X			X	X

ORIGINAL CONNECTIVITY MATRIX

EXAMPLE #4

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 6 OCCURS @ OLD Jt 1 FINAL WIDTH= 5 @ NEW JT 30

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	30	2	33	3	35	4	36	5	26	6	29
7	32	8	34	9	22	10	25	11	28	12	31
13	18	14	21	15	24	16	27	17	14	18	17
19	20	20	23	21	10	22	13	23	16	24	19
25	6	26	9	27	12	28	15	29	3	30	5
31	8	32	11	33	1	34	2	35	4	36	7

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	30	2	33	3	35	4	36	5	26	6	29
7	32	8	34	9	22	10	25	11	28	12	31
13	18	14	21	15	24	16	27	17	14	18	17
19	20	20	23	21	10	22	13	23	16	24	19
25	6	26	9	27	12	28	15	29	3	30	5
31	8	32	11	33	1	34	2	35	4	36	7

EXAMPLE #4

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	X	X	X																																	
2	X	X	X	X	X																															
3	X	X	X		X	X																														
4		X		X	X		X	X																												
5		X	X	X	X	X		X	X																											
6			X		X	X			X	X																										
7				X			X	X			X																									
8				X	X		X	X	X		X	X																								
9					X	X		X	X	X		X	X																							
10						X			X	X			X	X																						
11							X	X			X	X			X																					
12								X	X		X	X	X		X	X																				
13									X	X		X	X	X		X	X																			
14										X			X	X			X	X																		
15											X	X			X	X			X																	
16												X	X		X	X	X		X	X																
17													X	X		X	X	X		X	X															
18														X			X	X			X	X														
19															X	X			X	X			X													
20																X	X		X	X	X		X	X												
21																	X	X		X	X	X		X	X											
22																		X			X	X			X	X										
23																			X	X			X	X			X									
24																				X	X		X	X	X		X	X								
25																					X	X		X	X	X		X	X							
26																						X			X	X			X	X						
27																							X	X			X	X			X					
28																								X	X		X	X	X		X	X				
29																									X	X		X	X	X		X	X			
30																										X			X	X			X			
31																											X	X			X	X		X		
32																												X	X		X	X	X	X	X	
33																													X	X		X	X		X	
34																															X	X		X	X	X
35																																X	X	X	X	X
36																																		X	X	X

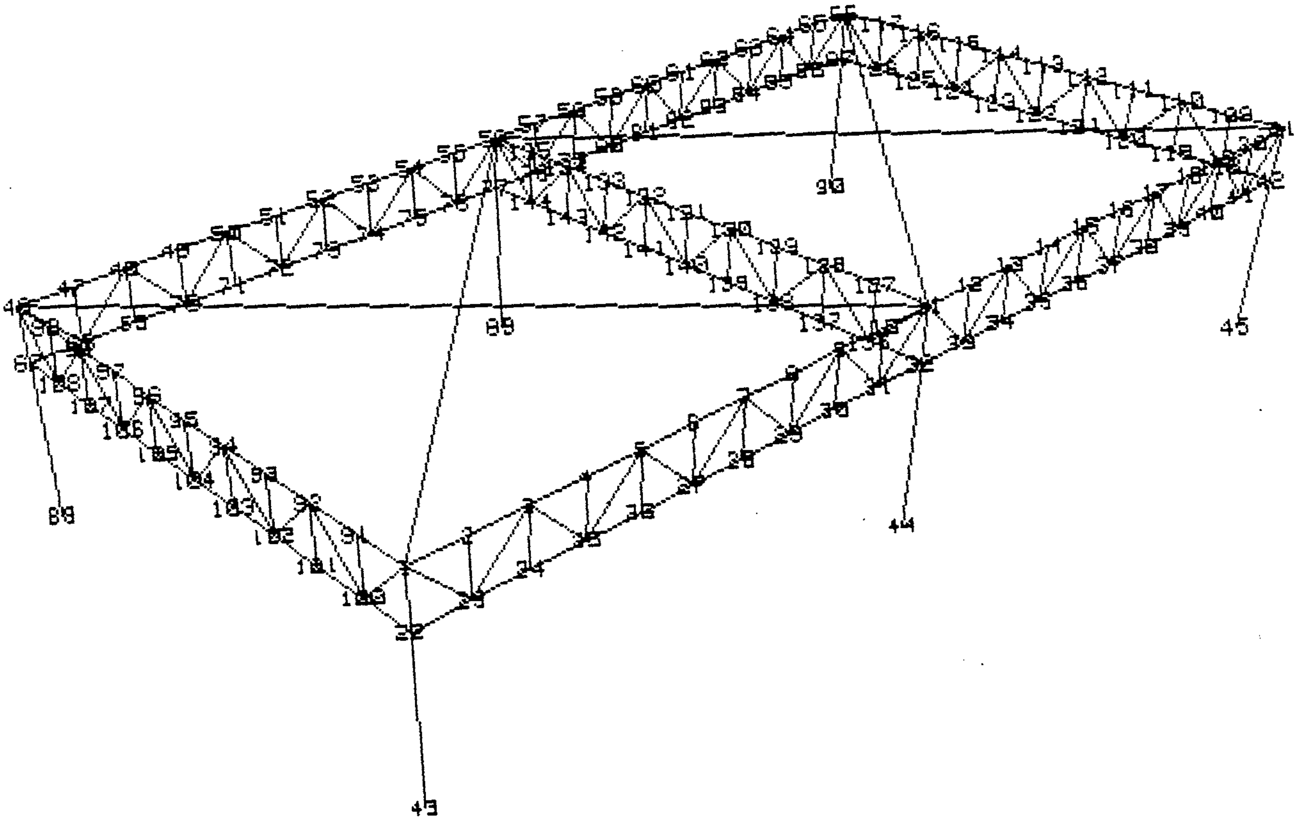
REBANDED CONNECTIVITY MATRIX

EXAMPLE #5

144 NODE 3-DIMENSIONAL TRUSS STRUCTURE

AMPLE #5

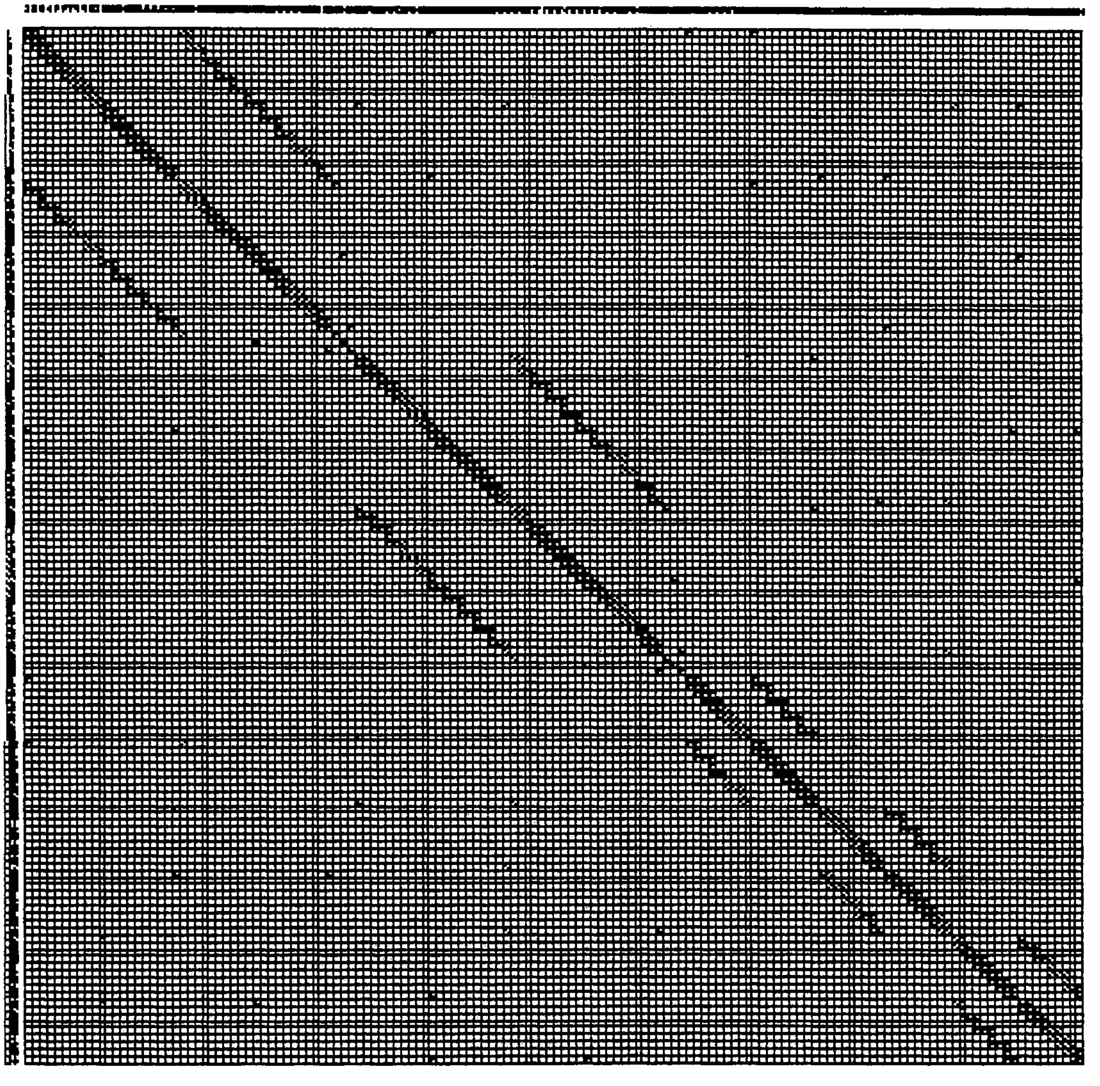
NDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



ORIGINAL SEQUENCE

EXAMPLE #5

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



ORIGINAL CONNECTIVITY MATRIX

EXAMPLE #5

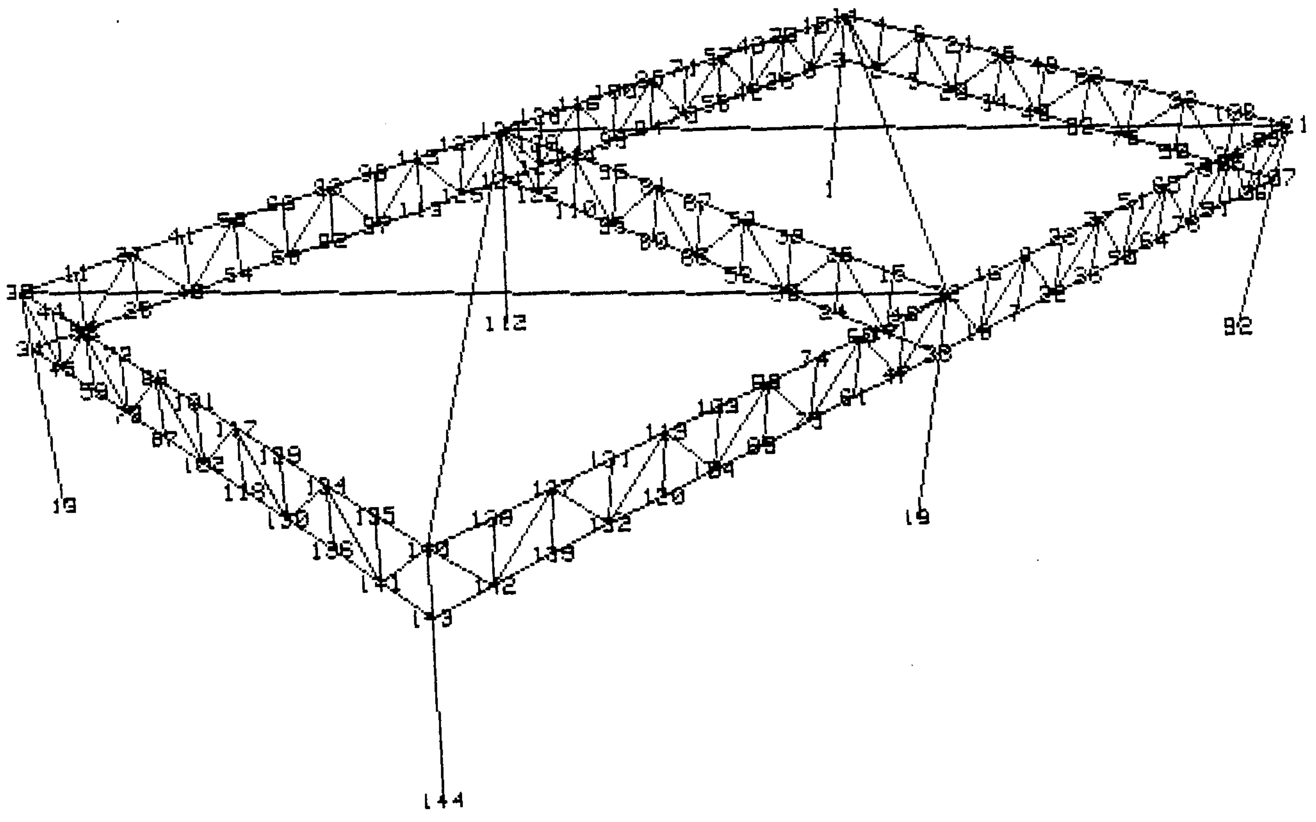
BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 126 OCCURS @ OLD Jt 11 FINAL WIDTH= 21 @ NEW JT 29

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	90	2	126	3	87	4	117	5	125	6	116
7	34	8	13	9	86	10	65	11	47	12	68
13	88	14	66	15	127	16	12	17	136	18	33
19	44	20	124	21	115	22	35	23	14	24	137
25	128	26	69	27	48	28	85	29	64	30	46
31	67	32	11	33	32	34	123	35	114	36	36
37	15	38	138	39	129	40	70	41	49	42	84
43	63	44	99	45	108	46	10	47	31	48	122
49	113	50	37	51	16	52	139	53	130	54	71
55	50	56	83	57	62	58	98	59	107	60	9
61	30	62	121	63	112	64	38	65	17	66	140
67	131	68	72	69	51	70	82	71	61	72	97
73	106	74	8	75	29	76	120	77	111	78	39
79	18	80	141	81	132	82	73	83	52	84	81
85	60	86	96	87	105	88	7	89	28	90	119
91	40	92	45	93	110	94	19	95	142	96	133
97	74	98	53	99	80	100	59	101	95	102	104
103	6	104	27	105	118	106	41	107	42	108	109
109	20	110	143	111	79	112	89	113	75	114	134
115	54	116	58	117	94	118	103	119	5	120	26
121	21	122	144	123	78	124	77	125	76	126	135
127	55	128	57	129	93	130	102	131	4	132	25
133	56	134	92	135	91	136	101	137	3	138	2
139	24	140	1	141	100	142	23	143	22	144	43

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	140	2	138	3	137	4	131	5	119	6	103
7	88	8	74	9	60	10	46	11	32	12	16
13	8	14	23	15	37	16	51	17	65	18	79
19	94	20	109	21	121	22	143	23	142	24	139
25	132	26	120	27	104	28	89	29	75	30	61
31	47	32	33	33	18	34	7	35	22	36	36
37	50	38	64	39	78	40	91	41	106	42	107
43	144	44	19	45	92	46	30	47	11	48	27
49	41	50	55	51	69	52	83	53	98	54	115
55	127	56	133	57	128	58	116	59	100	60	85
61	71	62	57	63	43	64	29	65	10	66	14
67	31	68	12	69	26	70	40	71	54	72	68
73	82	74	97	75	113	76	125	77	124	78	123
79	111	80	99	81	84	82	70	83	56	84	42
85	28	86	9	87	3	88	13	89	112	90	1
91	135	92	134	93	129	94	117	95	101	96	86
97	72	98	58	99	44	100	141	101	136	102	130
103	118	104	102	105	87	106	73	107	59	108	45
109	108	110	93	111	77	112	63	113	49	114	35
115	21	116	6	117	4	118	105	119	90	120	76
121	62	122	48	123	34	124	20	125	5	126	2
127	15	128	25	129	39	130	53	131	67	132	81
133	96	134	114	135	126	136	17	137	24	138	38
139	52	140	66	141	80	142	95	143	110	144	122

XAMPLE #5

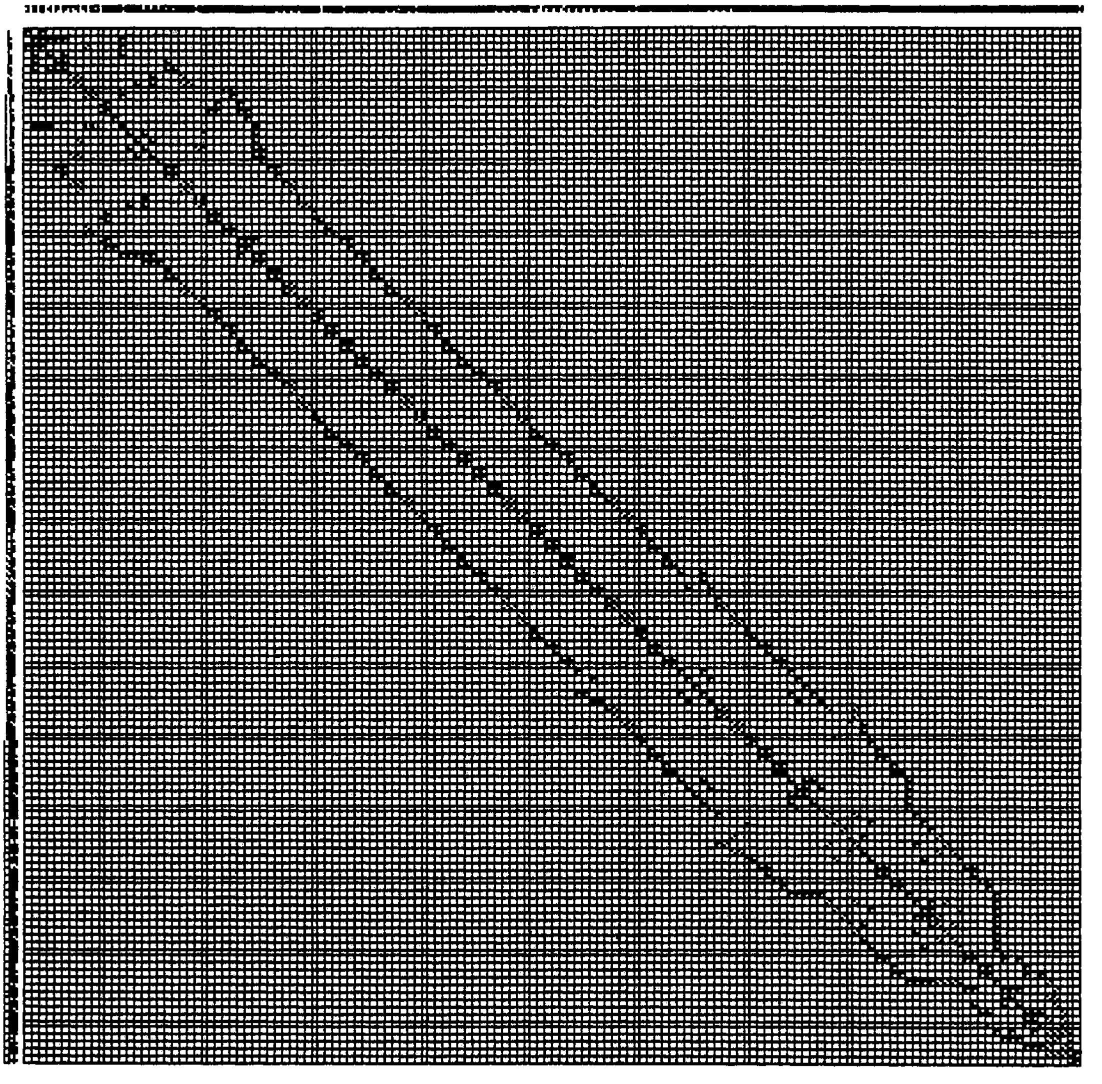
ANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



RENUMBERED SEQUENCE

EXAMPLE #5

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



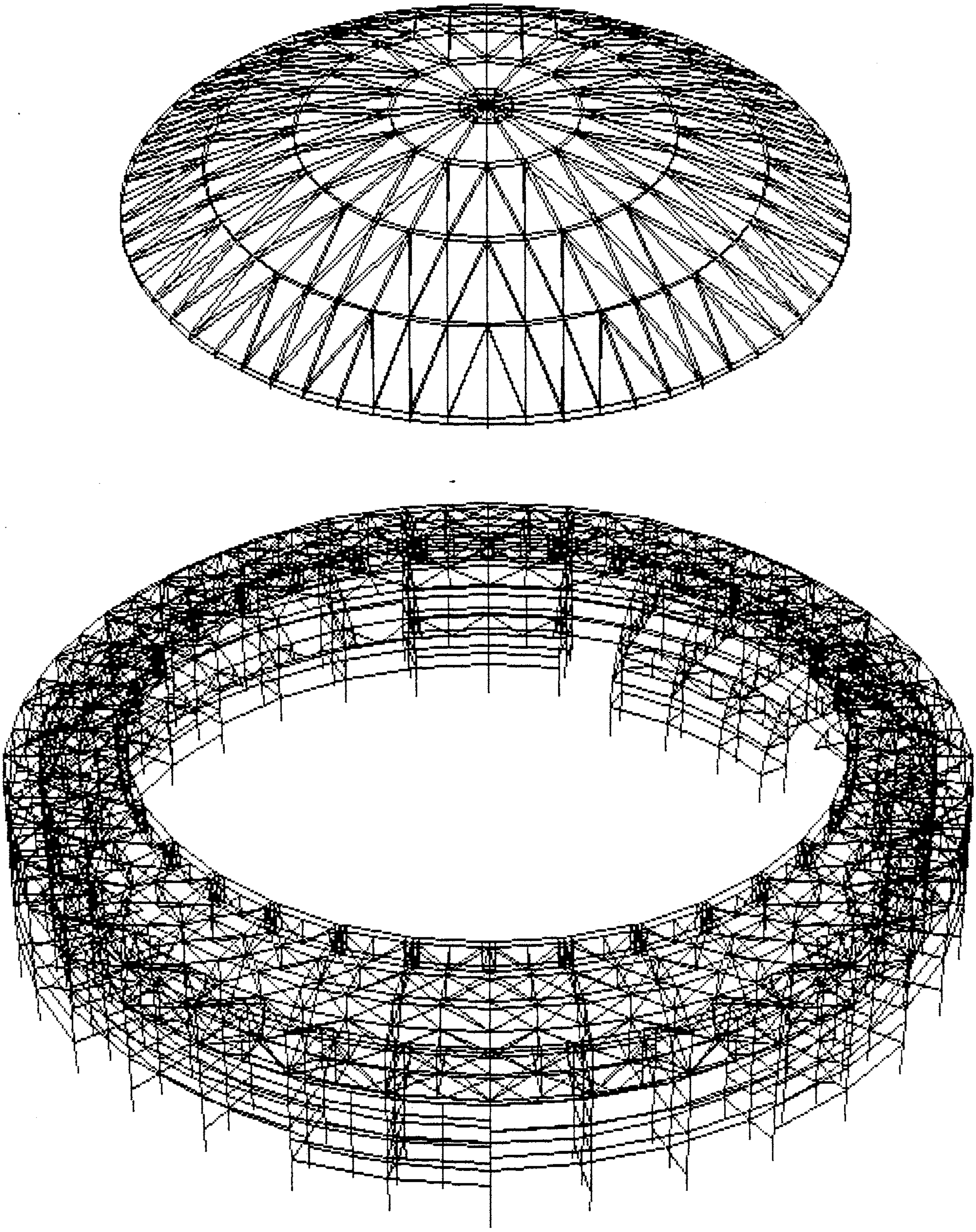
REBANDED CONNECTIVITY MATRIX

EXAMPLE #6

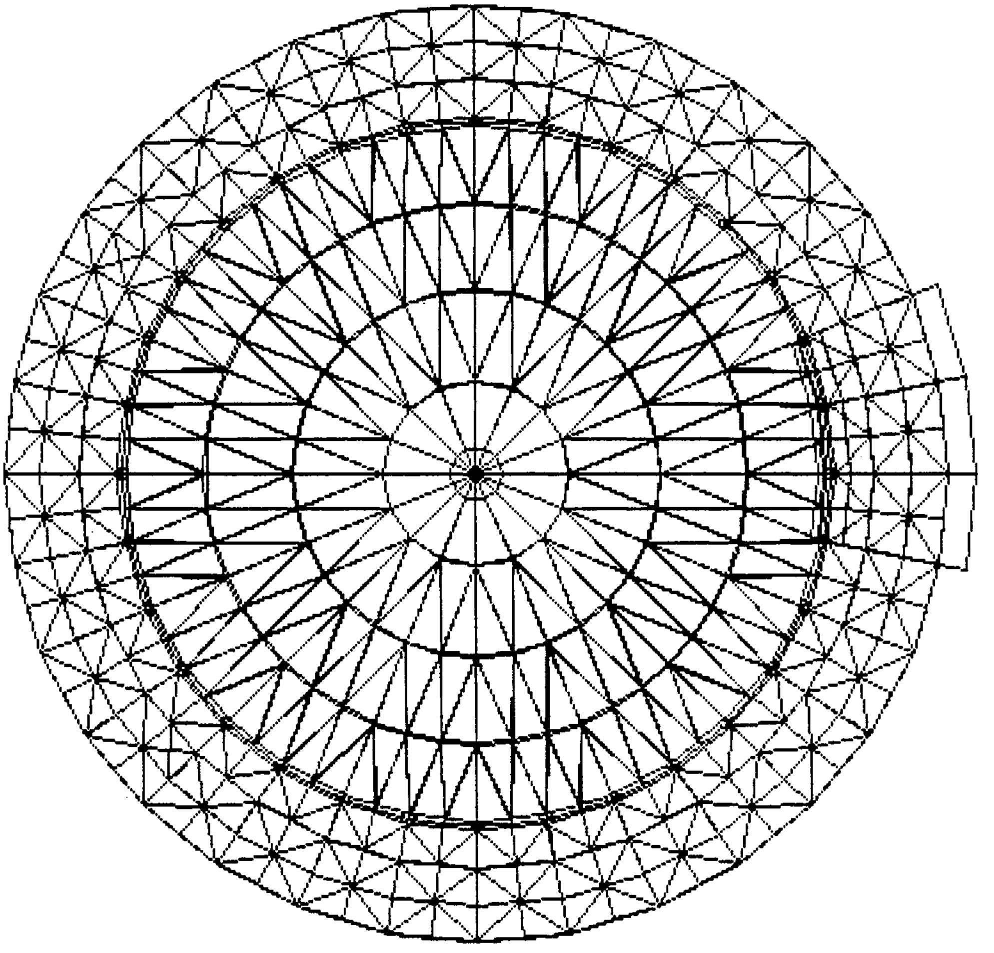
2327 NODE LAMELLA DOME

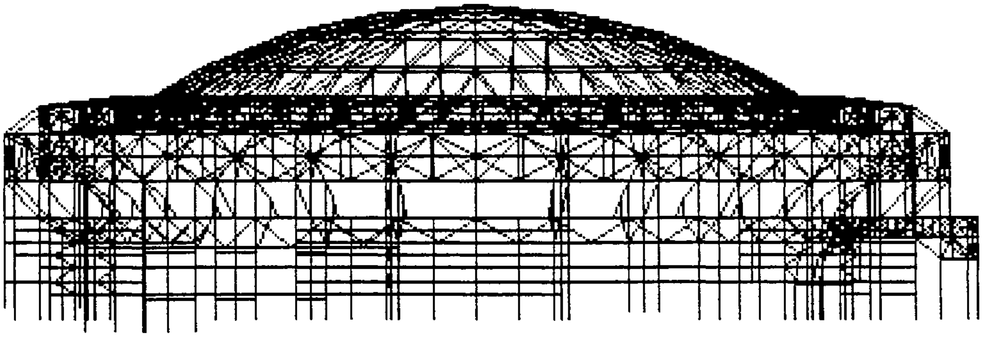
XAMPLE #6

ANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984



3ANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984





EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 1
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1	1	2	2	3	3	4	4	5	5	6	6
7	7	8	8	9	9	10	10	11	11	12	12
13	13	14	14	15	15	16	16	17	17	18	18
19	19	20	20	21	21	22	22	23	23	24	24
25	25	26	26	27	27	28	28	29	29	30	30
31	31	32	32	33	33	34	34	35	35	36	36
37	37	38	38	39	39	40	40	41	41	42	42
43	43	44	44	45	45	46	46	47	47	48	48
49	49	50	50	51	51	52	52	53	53	54	54
55	55	56	56	57	57	58	58	59	59	60	60
61	61	62	62	63	63	64	64	65	65	66	66
67	67	68	68	69	69	70	70	71	71	72	72
73	73	74	74	75	75	76	76	77	77	78	78
79	79	80	80	81	81	82	82	83	83	84	84
85	85	86	86	87	87	88	88	89	89	90	90
91	91	92	92	93	93	94	94	95	95	96	96
97	97	98	98	99	99	100	100	101	101	102	102
103	103	104	104	105	140	106	203	107	267	108	275
109	276	110	277	111	278	112	279	113	280	114	281
115	282	116	283	117	284	118	285	119	286	120	287
121	288	122	289	123	290	124	291	125	292	126	293
127	294	128	295	129	296	130	297	131	298	132	299
133	350	134	408	135	416	136	417	137	418	138	419
139	420	140	421	141	422	142	423	143	424	144	425
145	426	146	427	147	428	148	429	149	430	150	431
151	432	152	433	153	434	154	435	155	436	156	437
157	438	158	439	159	440	160	492	161	543	162	551
163	552	164	553	165	554	166	555	167	556	168	557
169	558	170	559	171	560	172	561	173	562	174	563
175	564	176	565	177	566	178	567	179	568	180	569
181	570	182	571	183	572	184	573	185	574	186	575
187	619	188	674	189	682	190	683	191	684	192	685
193	686	194	687	195	688	196	689	197	690	198	691
199	692	200	693	201	694	202	695	203	696	204	697
205	698	206	699	207	700	208	701	209	702	210	703
211	704	212	705	213	706	214	757	215	818	216	826
217	827	218	828	219	829	220	830	221	831	222	832
223	833	224	834	225	835	226	836	227	837	228	838
229	839	230	840	231	841	232	842	233	843	234	844
235	845	236	846	237	847	238	848	239	849	240	850
241	898	242	953	243	961	244	962	245	963	246	964
247	965	248	966	249	967	250	968	251	969	252	970
253	971	254	972	255	973	256	974	257	975	258	976
259	977	260	978	261	979	262	980	263	981	264	982
265	983	266	984	267	985	268	1035	269	1093	270	1101
271	1102	272	1103	273	1104	274	1105	275	1106	276	1107
277	1108	278	1109	279	1110	280	1111	281	1112	282	1113
283	1114	284	1115	285	1116	286	1117	287	1118	288	1119
289	1120	290	1121	291	1122	292	1123	293	1124	294	1125
295	1177	296	1228	297	1236	298	1237	299	1238	300	1239
301	1240	302	1241	303	1242	304	1243	305	1244	306	1245
307	1246	308	1247	309	1248	310	1249	311	1250	312	1251

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 2
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
313	1252	314	1253	315	1254	316	1255	317	1256	318	1257
319	1258	320	1259	321	1260	322	1261	323	1262	324	1306
325	1361	326	1369	327	1370	328	1371	329	1372	330	1373
331	1374	332	1375	333	1376	334	1377	335	1378	336	1379
337	1380	338	1381	339	1382	340	1383	341	1384	342	1385
343	1386	344	1387	345	1388	346	1389	347	1390	348	1391
349	1392	350	1393	351	1444	352	1505	353	1513	354	1514
355	1515	356	1516	357	1517	358	1518	359	1519	360	1520
361	1521	362	1522	363	1523	364	1524	365	1525	366	1526
367	1527	368	1528	369	1529	370	1530	371	1531	372	1532
373	1533	374	1534	375	1535	376	1536	377	1537	378	1584
379	1638	380	1646	381	1647	382	1648	383	1649	384	1650
385	1651	386	1652	387	1653	388	1654	389	1655	390	1656
391	1657	392	1658	393	1659	394	1660	395	1661	396	1662
397	1663	398	1664	399	1665	400	1666	401	1667	402	1668
403	1669	404	1670	405	1720	406	1778	407	1786	408	1787
409	1788	410	1789	411	1790	412	1791	413	1792	414	1793
415	1794	416	1795	417	1796	418	1797	419	1798	420	1799
421	1800	422	1801	423	1802	424	1803	425	1804	426	1805
427	1806	428	1807	429	1808	430	1809	431	1810	432	1862
433	1913	434	1921	435	1922	436	1923	437	1924	438	1925
439	1926	440	1927	441	1928	442	1929	443	1930	444	1931
445	1932	446	1933	447	1934	448	1935	449	1936	450	1937
451	1938	452	1939	453	1940	454	1941	455	1942	456	1943
457	1944	458	1945	459	1989	460	2044	461	2052	462	2053
463	2054	464	2055	465	2056	466	2057	467	2058	468	2059
469	2060	470	2061	471	2062	472	2063	473	2064	474	2065
475	2066	476	2067	477	2068	478	2069	479	2070	480	2071
481	2072	482	2073	483	2074	484	2075	485	2076	486	2127
487	2190	488	2198	489	2199	490	2200	491	2201	492	2202
493	2203	494	2204	495	2205	496	2206	497	2207	498	2208
499	2209	500	2210	501	2211	502	2212	503	2213	504	2214
505	2215	506	2216	507	2217	508	2218	509	2219	510	2220
511	2221	512	2222	513	2273	514	2303	515	2304	516	2305
517	2306	518	2307	519	2308	520	2309	521	2310	522	2311
523	2312	524	2313	525	2314	526	2315	527	2316	528	2317
529	2318	530	2319	531	2320	532	2321	533	2322	534	2323
535	2324	536	2325	537	2326	538	2327	539	1512	540	1585
541	1589	542	1510	543	1506	544	1451	545	1509	546	1590
547	1586	548	1587	549	1591	550	1639	551	1643	552	1508
553	1448	554	1507	555	1548	556	1511	557	1449	558	1445
559	1368	560	1542	561	1583	562	1592	563	1597	564	1547
565	1588	566	1602	567	1640	568	1644	569	1641	570	1645
571	1721	572	1725	573	1539	574	1447	575	1538	576	1504
577	1456	578	1461	579	1543	580	1462	581	1450	582	1446
583	1365	584	1366	585	1362	586	1313	587	1582	588	1593
589	1579	590	1581	591	1580	592	1596	593	1637	594	1671
595	1601	596	1676	597	1642	598	1726	599	1681	600	1722
601	1723	602	1727	603	1779	604	1783	605	1608	606	1541
607	1540	608	1544	609	1452	610	1398	611	1443	612	1503
613	1453	614	1500	615	1457	616	1403	617	1502	618	1364
619	1404	620	1367	621	1363	622	1310	623	1311	624	1235

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 3
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
625	1307	626	1578	627	1576	628	1577	629	1613	630	1594
631	1598	632	1595	633	1636	634	1672	635	1633	636	1635
637	1634	638	1675	639	1719	640	1728	641	1733	642	1680
643	1724	644	1784	645	1738	646	1780	647	1781	648	1785
649	1863	650	1867	651	1687	652	1562	653	1501	654	1559
655	1609	656	1554	657	1395	658	1545	659	1498	660	1546
661	1552	662	1549	663	1499	664	1442	665	1454	666	1458
667	1439	668	1455	669	1441	670	1394	671	1360	672	1318
673	1399	674	1323	675	1309	676	1232	677	1233	678	1229
679	1324	680	1312	681	1308	682	1184	683	1575	684	1574
685	1570	686	1569	687	1571	688	1572	689	1565	690	1616
691	1600	692	1606	693	1599	694	1603	695	1614	696	1632
697	1630	698	1631	699	1673	700	1677	701	1674	702	1718
703	1729	704	1715	705	1717	706	1716	707	1747	708	1688
709	1732	710	1777	711	1811	712	1816	713	1737	714	1782
715	1868	716	1821	717	1864	718	1865	719	1869	720	1914
721	1918	722	1694	723	1690	724	1479	725	1440	726	1497
727	1482	728	1611	729	1560	730	1610	731	1555	732	1485
733	1459	734	1396	735	1400	736	1496	737	1463	738	1492
739	1486	740	1551	741	1493	742	1495	743	1550	744	1491
745	1490	746	1438	747	1437	748	1397	749	1359	750	1315
751	1356	752	1358	753	1231	754	1314	755	1305	756	1267
757	1230	758	1273	759	1234	760	1319	761	1272	762	1181
763	1182	764	1178	765	1100	766	1605	767	1628	768	1604
769	1573	770	1568	771	1566	772	1619	773	1617	774	1624
775	1623	776	1625	777	1629	778	1626	779	1615	780	1679
781	1685	782	1678	783	1682	784	1697	785	1695	786	1714
787	1712	788	1713	789	1730	790	1734	791	1731	792	1746
793	1751	794	1691	795	1748	796	1689	797	1776	798	1812
799	1773	800	1775	801	1774	802	1815	803	1861	804	1870
805	1875	806	1820	807	1866	808	1919	809	1880	810	1915
811	1830	812	1916	813	1994	814	1920	815	1990	816	1693
817	1750	818	1831	819	1700	820	1357	821	1478	822	1436
823	1460	824	1466	825	1563	826	1483	827	1564	828	1557
829	1472	830	1561	831	1612	832	1556	833	1424	834	1475
835	1435	836	1355	837	1465	838	1464	839	1434	840	1487
841	1494	842	1489	843	1401	844	1354	845	1405	846	1316
847	1320	848	1317	849	1263	850	1189	851	1227	852	1304
853	1264	854	1194	855	1268	856	1301	857	1303	858	1180
859	1195	860	1183	861	1179	862	1097	863	1098	864	1094
865	1042	866	1701	867	1627	868	1567	869	1620	870	1607
871	1622	872	1684	873	1710	874	1683	875	1618	876	1706
877	1705	878	1707	879	1711	880	1708	881	1698	882	1696
883	1736	884	1742	885	1735	886	1739	887	1744	888	1755
889	1772	890	1770	891	1771	892	1752	893	1692	894	1749
895	1813	896	1817	897	1814	898	1860	899	1871	900	1857
901	1859	902	1858	903	1874	904	1912	905	1946	906	1951
907	1879	908	1829	909	1832	910	1917	911	1992	912	1996
913	2049	914	2045	915	1995	916	1956	917	1991	918	1754
919	1833	920	1834	921	1758	922	1302	923	1353	924	1402
925	1408	926	1420	927	1431	928	1432	929	1469	930	1468
931	1425	932	1430	933	1429	934	1480	935	1484	936	1553

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 4
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
937	1471	938	1473	939	1558	940	1341	941	1416	942	1337
943	1321	944	1407	945	1351	946	1406	947	1433	948	1488
949	1352	950	1325	951	1300	952	1299	953	1186	954	1226
955	1265	956	1223	957	1269	958	1266	959	1225	960	1185
961	1176	962	1130	963	1190	964	1135	965	1096	966	1095
967	1136	968	1099	969	1039	970	1040	971	1036	972	1745
973	1759	974	1702	975	1621	976	1709	977	1686	978	1704
979	1741	980	1768	981	1740	982	1699	983	1764	984	1763
985	1765	986	1769	987	1766	988	1756	989	1819	990	1825
991	1818	992	1822	993	1827	994	1753	995	1856	996	1854
997	1855	998	1872	999	1876	1000	1873	1001	1911	1002	1947
1003	1908	1004	1910	1005	1909	1006	1836	1007	1835	1008	2051
1009	2132	1010	2128	1011	2047	1012	1993	1013	1950	1014	1988
1015	1997	1016	2007	1017	2046	1018	2050	1019	2002	1020	1955
1021	1838	1022	1887	1023	1842	1024	960	1025	1224	1026	1298
1027	1322	1028	1328	1029	1348	1030	1349	1031	1342	1032	1411
1033	1347	1034	1346	1035	1470	1036	1417	1037	1421	1038	1426
1039	1422	1040	1467	1041	1428	1042	1476	1043	1481	1044	1414
1045	1474	1046	1338	1047	1410	1048	1413	1049	1332	1050	1330
1051	1297	1052	1350	1053	1427	1054	1327	1055	1296	1056	1326
1057	1270	1058	1274	1059	1187	1060	1191	1061	1222	1062	1221
1063	1188	1064	1175	1065	1127	1066	1172	1067	1174	1068	1126
1069	1092	1070	1047	1071	1052	1072	1131	1073	1038	1074	1053
1075	1041	1076	1037	1077	1828	1078	1760	1079	1703	1080	1767
1081	1743	1082	1762	1083	1824	1084	1852	1085	1823	1086	1757
1087	1848	1088	1847	1089	1849	1090	1853	1091	1850	1092	1840
1093	1837	1094	1878	1095	1884	1096	1877	1097	1881	1098	1907
1099	1905	1100	1906	1101	1948	1102	1952	1103	1949	1104	1889
1105	1888	1106	2134	1107	2195	1108	2191	1109	2048	1110	2130
1111	2087	1112	2129	1113	2133	1114	2077	1115	2001	1116	2043
1117	1987	1118	1998	1119	2006	1120	2082	1121	1984	1122	1986
1123	1985	1124	2013	1125	1839	1126	1886	1127	1963	1128	1843
1129	957	1130	958	1131	954	1132	1173	1133	1220	1134	1271
1135	1277	1136	1293	1137	1294	1138	1287	1139	1292	1140	1291
1141	1343	1142	1409	1143	1345	1144	1418	1145	1423	1146	1477
1147	1415	1148	1284	1149	1339	1150	1412	1151	1279	1152	1333
1153	1331	1154	905	1155	1276	1156	1218	1157	1275	1158	1344
1159	1295	1160	1219	1161	1171	1162	1192	1163	1170	1164	1196
1165	1128	1166	1132	1167	1129	1168	1091	1169	1044	1170	1090
1171	1088	1172	1043	1173	1034	1174	990	1175	1048	1176	995
1177	1844	1178	1761	1179	1851	1180	1826	1181	1846	1182	1883
1183	1903	1184	1882	1185	1841	1186	1899	1187	1898	1188	1900
1189	1904	1190	1901	1191	1892	1192	1890	1193	1954	1194	1960
1195	1953	1196	1957	1197	1983	1198	1981	1199	1982	1200	1965
1201	1964	1202	2014	1203	2096	1204	2197	1205	2278	1206	2274
1207	2131	1208	2193	1209	2145	1210	2192	1211	2196	1212	2135
1213	2081	1214	2126	1215	2078	1216	2086	1217	2140	1218	2042
1219	1999	1220	2039	1221	2003	1222	2000	1223	2041	1224	2040
1225	2016	1226	1891	1227	1962	1228	1894	1229	956	1230	996
1231	959	1232	955	1233	1089	1234	1133	1235	1169	1236	1193
1237	1199	1238	1215	1239	1216	1240	1209	1241	1214	1242	1213
1243	1288	1244	1329	1245	1290	1246	1340	1247	1419	1248	1206

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 5
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1249	1285	1250	1335	1251	1201	1252	1280	1253	1334	1254	902
1255	903	1256	899	1257	825	1258	1217	1259	1289	1260	1198
1261	1167	1262	1197	1263	1168	1264	1137	1265	1087	1266	1086
1267	1045	1268	1046	1269	1049	1270	1033	1271	987	1272	1030
1273	1032	1274	1895	1275	1845	1276	1902	1277	1885	1278	1897
1279	1959	1280	1979	1281	1958	1282	1893	1283	1975	1284	1974
1285	1976	1286	1980	1287	1977	1288	1968	1289	1966	1290	2005
1291	2011	1292	2004	1293	2008	1294	2095	1295	2018	1296	2017
1297	2099	1298	2280	1299	141	1300	2194	1301	2276	1302	2233
1303	2275	1304	2279	1305	2223	1306	2139	1307	2189	1308	2136
1309	2144	1310	2228	1311	2125	1312	2079	1313	2122	1314	2083
1315	2038	1316	2037	1317	2080	1318	2124	1319	2155	1320	2036
1321	2098	1322	2015	1323	1967	1324	1970	1325	2156	1326	986
1327	952	1328	910	1329	991	1330	915	1331	1031	1332	1157
1333	1085	1334	1134	1335	1140	1336	1084	1337	1164	1338	1165
1339	1158	1340	1163	1341	1162	1342	1210	1343	1278	1344	1212
1345	1286	1346	1336	1347	1154	1348	1207	1349	1282	1350	1148
1351	1202	1352	1281	1353	901	1354	916	1355	904	1356	900
1357	822	1358	823	1359	819	1360	764	1361	1211	1362	1166
1363	1139	1364	1083	1365	1138	1366	1050	1367	1054	1368	1029
1369	1028	1370	988	1371	992	1372	989	1373	1971	1374	1896
1375	1978	1376	1961	1377	1973	1378	2010	1379	2034	1380	2009
1381	1969	1382	2030	1383	2029	1384	2031	1385	2035	1386	2032
1387	2022	1388	2093	1389	2154	1390	2101	1391	2019	1392	2100
1393	144	1394	2277	1395	2292	1396	2281	1397	145	1398	2282
1399	2227	1400	2272	1401	2224	1402	2232	1403	2287	1404	2188
1405	2137	1406	2185	1407	2141	1408	2088	1409	2187	1410	2121
1411	2138	1412	2084	1413	2120	1414	2123	1415	2157	1416	2085
1417	2091	1418	2097	1419	2104	1420	2020	1421	2021	1422	2025
1423	2158	1424	1153	1425	951	1426	907	1427	948	1428	950
1429	949	1430	1056	1431	1027	1432	1051	1433	1057	1434	1073
1435	1146	1436	1080	1437	1081	1438	1143	1439	1079	1440	1078
1441	1074	1442	1142	1443	1065	1444	1159	1445	1161	1446	1200
1447	1208	1448	1283	1449	1155	1450	1204	1451	1149	1452	1203
1453	906	1454	897	1455	855	1456	911	1457	860	1458	821
1459	861	1460	824	1461	820	1462	761	1463	762	1464	758
1465	681	1466	1160	1467	1082	1468	1025	1469	1055	1470	1021
1471	1020	1472	1026	1473	993	1474	997	1475	1023	1476	1060
1477	947	1478	946	1479	2026	1480	1972	1481	2033	1482	2012
1483	2028	1484	2090	1485	2117	1486	2089	1487	2113	1488	2112
1489	2023	1490	2094	1491	2105	1492	2153	1493	2102	1494	2159
1495	2239	1496	142	1497	208	1498	146	1499	204	1500	147
1501	2286	1502	139	1503	2283	1504	2291	1505	152	1506	2271
1507	2225	1508	2268	1509	2229	1510	2270	1511	2184	1512	2226
1513	2118	1514	2115	1515	2146	1516	2183	1517	2186	1518	2142
1519	2119	1520	2160	1521	2114	1522	2103	1523	2024	1524	2108
1525	2161	1526	1069	1527	908	1528	912	1529	909	1530	945
1531	994	1532	1000	1533	1022	1534	1015	1535	1005	1536	1145
1537	1075	1538	1141	1539	1077	1540	1071	1541	1144	1542	1070
1543	1066	1544	1156	1545	1205	1546	1151	1547	1150	1548	1059
1549	1013	1550	896	1551	852	1552	893	1553	895	1554	894
1555	851	1556	817	1557	769	1558	856	1559	774	1560	760

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 6
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1561	775	1562	763	1563	759	1564	678	1565	679	1566	675
1567	626	1568	1076	1569	1024	1570	1058	1571	1019	1572	999
1573	943	1574	998	1575	944	1576	1017	1577	941	1578	913
1579	917	1580	2147	1581	2027	1582	2116	1583	2111	1584	2092
1585	2176	1586	2175	1587	2106	1588	2180	1589	2109	1590	2151
1591	2162	1592	2242	1593	2238	1594	106	1595	143	1596	206
1597	210	1598	272	1599	268	1600	209	1601	157	1602	205
1603	148	1604	138	1605	2284	1606	135	1607	2288	1608	137
1609	2267	1610	2285	1611	2234	1612	2266	1613	2269	1614	2230
1615	2148	1616	2181	1617	2182	1618	2143	1619	2149	1620	2163
1621	2107	1622	2165	1623	1012	1624	1008	1625	892	1626	891
1627	890	1628	914	1629	920	1630	940	1631	1016	1632	1062
1633	1002	1634	1063	1635	1147	1636	922	1637	1072	1638	1067
1639	1152	1640	1061	1641	1010	1642	1014	1643	939	1644	938
1645	853	1646	857	1647	854	1648	816	1649	766	1650	813
1651	815	1652	765	1653	756	1654	711	1655	770	1656	716
1657	677	1658	717	1659	680	1660	676	1661	623	1662	624
1663	620	1664	550	1665	1018	1666	942	1667	1001	1668	919
1669	888	1670	918	1671	935	1672	889	1673	886	1674	2235
1675	2179	1676	2110	1677	2174	1678	2150	1679	2258	1680	2259
1681	2178	1682	2152	1683	2263	1684	2250	1685	2241	1686	2166
1687	2301	1688	2302	1689	109	1690	105	1691	169	1692	274
1693	355	1694	351	1695	270	1696	207	1697	151	1698	202
1699	211	1700	221	1701	269	1702	273	1703	216	1704	156
1705	149	1706	153	1707	134	1708	150	1709	2293	1710	133
1711	136	1712	2289	1713	2264	1714	2236	1715	2265	1716	2231
1717	2237	1718	2177	1719	2164	1720	2170	1721	2168	1722	1009
1723	928	1724	862	1725	858	1726	814	1727	859	1728	865
1729	885	1730	934	1731	1003	1732	1064	1733	923	1734	867
1735	932	1736	1068	1737	1006	1738	1011	1739	933	1740	937
1741	929	1742	884	1743	883	1744	812	1745	811	1746	767
1747	771	1748	768	1749	755	1750	708	1751	752	1752	754
1753	707	1754	673	1755	631	1756	712	1757	636	1758	622
1759	637	1760	625	1761	621	1762	547	1763	548	1764	499
1765	544	1766	413	1767	357	1768	409	1769	936	1770	887
1771	880	1772	921	1773	864	1774	808	1775	863	1776	804
1777	803	1778	2262	1779	2173	1780	2257	1781	2294	1782	2300
1783	125	1784	126	1785	2172	1786	2261	1787	2253	1788	130
1789	166	1790	167	1791	2249	1792	2247	1793	2169	1794	117
1795	108	1796	172	1797	168	1798	233	1799	271	1800	353
1801	310	1802	352	1803	356	1804	300	1805	215	1806	266
1807	201	1808	212	1809	220	1810	305	1811	198	1812	200
1813	197	1814	158	1815	196	1816	199	1817	154	1818	131
1819	2295	1820	132	1821	2290	1822	2296	1823	2260	1824	2171
1825	2252	1826	2243	1827	2245	1828	2240	1829	2251	1830	2167
1831	2298	1832	2299	1833	2297	1834	2246	1835	931	1836	873
1837	809	1838	806	1839	810	1840	805	1841	879	1842	925
1843	1004	1844	924	1845	868	1846	877	1847	1007	1848	930
1849	874	1850	882	1851	878	1852	753	1853	772	1854	776
1855	751	1856	750	1857	709	1858	713	1859	710	1860	672
1861	628	1862	669	1863	671	1864	627	1865	618	1866	580
1867	632	1868	585	1869	546	1870	496	1871	354	1872	411

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 7
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
1873	415	1874	497	1875	493	1876	586	1877	549	1878	545
1879	414	1880	368	1881	410	1882	747	1883	777	1884	800
1885	881	1886	807	1887	802	1888	159	1889	2256	1890	129
1891	124	1892	165	1893	188	1894	189	1895	2255	1896	128
1897	120	1898	193	1899	180	1900	171	1901	114	1902	2248
1903	116	1904	230	1905	236	1906	232	1907	231	1908	358
1909	304	1910	349	1911	301	1912	309	1913	363	1914	265
1915	213	1916	262	1917	217	1918	214	1919	264	1920	222
1921	263	1922	218	1923	194	1924	160	1925	195	1926	155
1927	161	1928	127	1929	2254	1930	119	1931	110	1932	2244
1933	107	1934	112	1935	118	1936	163	1937	164	1938	162
1939	113	1940	876	1941	778	1942	773	1943	779	1944	799
1945	795	1946	870	1947	926	1948	869	1949	796	1950	743
1951	742	1952	793	1953	927	1954	875	1955	797	1956	866
1957	670	1958	749	1959	748	1960	745	1961	782	1962	714
1963	718	1964	668	1965	667	1966	629	1967	633	1968	630
1969	617	1970	577	1971	614	1972	616	1973	359	1974	495
1975	412	1976	576	1977	542	1978	504	1979	362	1980	407
1981	441	1982	451	1983	494	1984	510	1985	498	1986	581
1987	509	1988	446	1989	367	1990	719	1991	746	1992	801
1993	192	1994	123	1995	187	1996	223	1997	229	1998	252
1999	253	2000	122	2001	191	2002	183	2003	257	2004	177
2005	179	2006	115	2007	244	2008	235	2009	348	2010	302
2011	345	2012	306	2013	261	2014	260	2015	303	2016	347
2017	258	2018	224	2019	259	2020	219	2021	225	2022	190
2023	121	2024	182	2025	111	2026	173	2027	170	2028	175
2029	181	2030	226	2031	227	2032	228	2033	176	2034	792
2035	744	2036	798	2037	786	2038	871	2039	781	2040	738
2041	660	2042	659	2043	780	2044	741	2045	789	2046	872
2047	794	2048	615	2049	666	2050	715	2051	721	2052	720
2053	664	2054	739	2055	665	2056	634	2057	638	2058	613
2059	612	2060	578	2061	582	2062	579	2063	360	2064	364
2065	500	2066	445	2067	491	2068	541	2069	540	2070	501
2071	406	2072	442	2073	450	2074	505	2075	538	2076	403
2077	639	2078	663	2079	740	2080	186	2081	256	2082	251
2083	185	2084	255	2085	247	2086	178	2087	243	2088	241
2089	311	2090	312	2091	340	2092	405	2093	344	2094	361
2095	307	2096	343	2097	346	2098	313	2099	308	2100	314
2101	254	2102	184	2103	246	2104	174	2105	239	2106	237
2107	245	2108	234	2109	240	2110	785	2111	791	2112	784
2113	737	2114	787	2115	783	2116	734	2117	735	2118	722
2119	658	2120	736	2121	790	2122	605	2123	604	2124	539
2125	611	2126	635	2127	641	2128	661	2129	662	2130	724
2131	640	2132	609	2133	610	2134	583	2135	587	2136	537
2137	536	2138	402	2139	503	2140	444	2141	490	2142	502
2143	443	2144	489	2145	487	2146	506	2147	447	2148	608
2149	657	2150	588	2151	250	2152	249	2153	336	2154	335
2155	242	2156	341	2157	339	2158	338	2159	369	2160	370
2161	401	2162	404	2163	365	2164	342	2165	337	2166	248
2167	238	2168	328	2169	398	2170	788	2171	730	2172	733
2173	727	2174	654	2175	655	2176	728	2177	731	2178	723
2179	653	2180	732	2181	642	2182	603	2183	529	2184	528

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...NEW vs OLD...PAGE # 8
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD
2185	488	2186	535	2187	584	2188	590	2189	606	2190	656
2191	607	2192	589	2193	533	2194	534	2195	507	2196	448
2197	485	2198	511	2199	452	2200	486	2201	512	2202	453
2203	602	2204	532	2205	397	2206	394	2207	393	2208	333
2209	332	2210	334	2211	329	2212	399	2213	371	2214	400
2215	366	2216	372	2217	331	2218	327	2219	325	2220	396
2221	375	2222	729	2223	650	2224	726	2225	651	2226	600
2227	644	2228	652	2229	725	2230	649	2231	599	2232	527
2233	591	2234	484	2235	508	2236	449	2237	514	2238	455
2239	530	2240	601	2241	531	2242	513	2243	483	2244	454
2245	482	2246	481	2247	526	2248	478	2249	477	2250	391
2251	392	2252	373	2253	326	2254	395	2255	330	2256	324
2257	316	2258	321	2259	374	2260	389	2261	390	2262	645
2263	643	2264	597	2265	524	2266	647	2267	648	2268	598
2269	596	2270	523	2271	479	2272	525	2273	480	2274	473
2275	475	2276	515	2277	476	2278	456	2279	387	2280	322
2281	320	2282	315	2283	388	2284	323	2285	472	2286	318
2287	376	2288	385	2289	386	2290	458	2291	646	2292	592
2293	521	2294	594	2295	319	2296	595	2297	522	2298	520
2299	474	2300	471	2301	383	2302	317	2303	384	2304	469
2305	377	2306	379	2307	382	2308	457	2309	593	2310	516
2311	518	2312	381	2313	462	2314	519	2315	470	2316	467
2317	378	2318	468	2319	380	2320	459	2321	517	2322	465
2323	466	2324	463	2325	460	2326	464	2327	461		

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 9
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1	1	2	2	3	3	4	4	5	5	6	6
7	7	8	8	9	9	10	10	11	11	12	12
13	13	14	14	15	15	16	16	17	17	18	18
19	19	20	20	21	21	22	22	23	23	24	24
25	25	26	26	27	27	28	28	29	29	30	30
31	31	32	32	33	33	34	34	35	35	36	36
37	37	38	38	39	39	40	40	41	41	42	42
43	43	44	44	45	45	46	46	47	47	48	48
49	49	50	50	51	51	52	52	53	53	54	54
55	55	56	56	57	57	58	58	59	59	60	60
61	61	62	62	63	63	64	64	65	65	66	66
67	67	68	68	69	69	70	70	71	71	72	72
73	73	74	74	75	75	76	76	77	77	78	78
79	79	80	80	81	81	82	82	83	83	84	84
85	85	86	86	87	87	88	88	89	89	90	90
91	91	92	92	93	93	94	94	95	95	96	96
97	97	98	98	99	99	100	100	101	101	102	102
103	103	104	104	105	1690	106	1594	107	1933	108	1795
109	1689	110	1931	111	2025	112	1934	113	1939	114	1901
115	2006	116	1903	117	1794	118	1935	119	1930	120	1897
121	2023	122	2000	123	1994	124	1891	125	1783	126	1784
127	1928	128	1896	129	1890	130	1788	131	1818	132	1820
133	1710	134	1707	135	1606	136	1711	137	1608	138	1604
139	1502	140	105	141	1299	142	1496	143	1595	144	1393
145	1397	146	1498	147	1500	148	1603	149	1705	150	1708
151	1697	152	1505	153	1706	154	1817	155	1926	156	1704
157	1601	158	1814	159	1888	160	1924	161	1927	162	1938
163	1936	164	1937	165	1892	166	1789	167	1790	168	1797
169	1691	170	2027	171	1900	172	1796	173	2026	174	2104
175	2028	176	2033	177	2004	178	2086	179	2005	180	1899
181	2029	182	2024	183	2002	184	2102	185	2083	186	2080
187	1995	188	1893	189	1894	190	2022	191	2001	192	1993
193	1898	194	1923	195	1925	196	1815	197	1813	198	1811
199	1816	200	1812	201	1807	202	1698	203	106	204	1499
205	1602	206	1596	207	1696	208	1497	209	1600	210	1597
211	1699	212	1808	213	1915	214	1918	215	1805	216	1703
217	1917	218	1922	219	2020	220	1809	221	1700	222	1920
223	1996	224	2018	225	2021	226	2030	227	2031	228	2032
229	1997	230	1904	231	1907	232	1906	233	1798	234	2108
235	2008	236	1905	237	2106	238	2167	239	2105	240	2109
241	2088	242	2155	243	2087	244	2007	245	2107	246	2103
247	2085	248	2166	249	2152	250	2151	251	2082	252	1998
253	1999	254	2101	255	2084	256	2081	257	2003	258	2017
259	2019	260	2014	261	2013	262	1916	263	1921	264	1919
265	1914	266	1806	267	107	268	1599	269	1701	270	1695
271	1799	272	1598	273	1702	274	1692	275	108	276	109
277	110	278	111	279	112	280	113	281	114	282	115
283	116	284	117	285	118	286	119	287	120	288	121
289	122	290	123	291	124	292	125	293	126	294	127
295	128	296	129	297	130	298	131	299	132	300	1804
301	1911	302	2010	303	2015	304	1909	305	1810	306	2012
307	2095	308	2099	309	1912	310	1801	311	2089	312	2090

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 10
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
313	2098	314	2100	315	2282	316	2257	317	2302	318	2286
319	2295	320	2281	321	2258	322	2280	323	2284	324	2256
325	2219	326	2253	327	2218	328	2168	329	2211	330	2255
331	2217	332	2209	333	2208	334	2210	335	2154	336	2153
337	2165	338	2158	339	2157	340	2091	341	2156	342	2164
343	2096	344	2093	345	2011	346	2097	347	2016	348	2009
349	1910	350	133	351	1694	352	1802	353	1800	354	1871
355	1693	356	1803	357	1767	358	1908	359	1973	360	2063
361	2094	362	1979	363	1913	364	2064	365	2163	366	2215
367	1989	368	1880	369	2159	370	2160	371	2213	372	2216
373	2252	374	2259	375	2221	376	2287	377	2305	378	2317
379	2306	380	2319	381	2312	382	2307	383	2301	384	2303
385	2288	386	2289	387	2279	388	2283	389	2260	390	2261
391	2250	392	2251	393	2207	394	2206	395	2254	396	2220
397	2205	398	2169	399	2212	400	2214	401	2161	402	2138
403	2076	404	2162	405	2092	406	2071	407	1980	408	134
409	1768	410	1881	411	1872	412	1975	413	1766	414	1879
415	1873	416	135	417	136	418	137	419	138	420	139
421	140	422	141	423	142	424	143	425	144	426	145
427	146	428	147	429	148	430	149	431	150	432	151
433	152	434	153	435	154	436	155	437	156	438	157
439	158	440	159	441	1981	442	2072	443	2143	444	2140
445	2066	446	1988	447	2147	448	2196	449	2236	450	2073
451	1982	452	2199	453	2202	454	2244	455	2238	456	2278
457	2308	458	2290	459	2320	460	2325	461	2327	462	2313
463	2324	464	2326	465	2322	466	2323	467	2316	468	2318
469	2304	470	2315	471	2300	472	2285	473	2274	474	2299
475	2275	476	2277	477	2249	478	2248	479	2271	480	2273
481	2246	482	2245	483	2243	484	2234	485	2197	486	2200
487	2145	488	2185	489	2144	490	2141	491	2067	492	160
493	1875	494	1983	495	1974	496	1870	497	1874	498	1985
499	1764	500	2065	501	2070	502	2142	503	2139	504	1978
505	2074	506	2146	507	2195	508	2235	509	1987	510	1984
511	2198	512	2201	513	2242	514	2237	515	2276	516	2310
517	2321	518	2311	519	2314	520	2298	521	2293	522	2297
523	2270	524	2265	525	2272	526	2247	527	2232	528	2184
529	2183	530	2239	531	2241	532	2204	533	2193	534	2194
535	2186	536	2137	537	2136	538	2075	539	2124	540	2069
541	2068	542	1977	543	161	544	1765	545	1878	546	1869
547	1762	548	1763	549	1877	550	1664	551	162	552	163
553	164	554	165	555	166	556	167	557	168	558	169
559	170	560	171	561	172	562	173	563	174	564	175
565	176	566	177	567	178	568	179	569	180	570	181
571	182	572	183	573	184	574	185	575	186	576	1976
577	1970	578	2060	579	2062	580	1866	581	1986	582	2061
583	2134	584	2187	585	1868	586	1876	587	2135	588	2150
589	2192	590	2188	591	2233	592	2292	593	2309	594	2294
595	2296	596	2269	597	2264	598	2268	599	2231	600	2226
601	2240	602	2203	603	2182	604	2123	605	2122	606	2189
607	2191	608	2148	609	2132	610	2133	611	2125	612	2059
613	2058	614	1971	615	2048	616	1972	617	1969	618	1865
619	187	620	1663	621	1761	622	1758	623	1661	624	1662

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 11
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
625	1760	626	1567	627	1864	628	1861	629	1966	630	1968
631	1755	632	1867	633	1967	634	2056	635	2126	636	1757
637	1759	638	2057	639	2077	640	2131	641	2127	642	2181
643	2263	644	2227	645	2262	646	2291	647	2266	648	2267
649	2230	650	2223	651	2225	652	2228	653	2179	654	2174
655	2175	656	2190	657	2149	658	2119	659	2042	660	2041
661	2128	662	2129	663	2078	664	2053	665	2055	666	2049
667	1965	668	1964	669	1862	670	1957	671	1863	672	1860
673	1754	674	188	675	1566	676	1660	677	1657	678	1564
679	1565	680	1659	681	1465	682	189	683	190	684	191
685	192	686	193	687	194	688	195	689	196	690	197
691	198	692	199	693	200	694	201	695	202	696	203
697	204	698	205	699	206	700	207	701	208	702	209
703	210	704	211	705	212	706	213	707	1753	708	1750
709	1857	710	1859	711	1654	712	1756	713	1858	714	1962
715	2050	716	1656	717	1658	718	1963	719	1990	720	2052
721	2051	722	2118	723	2178	724	2130	725	2229	726	2224
727	2173	728	2176	729	2222	730	2171	731	2177	732	2180
733	2172	734	2116	735	2117	736	2120	737	2113	738	2040
739	2054	740	2079	741	2044	742	1951	743	1950	744	2035
745	1960	746	1991	747	1882	748	1959	749	1958	750	1856
751	1855	752	1751	753	1852	754	1752	755	1749	756	1653
757	214	758	1464	759	1563	760	1560	761	1462	762	1463
763	1562	764	1360	765	1652	766	1649	767	1746	768	1748
769	1557	770	1655	771	1747	772	1853	773	1942	774	1559
775	1561	776	1854	777	1883	778	1941	779	1943	780	2043
781	2039	782	1961	783	2115	784	2112	785	2110	786	2037
787	2114	788	2170	789	2045	790	2121	791	2111	792	2034
793	1952	794	2047	795	1945	796	1949	797	1955	798	2036
799	1944	800	1884	801	1992	802	1887	803	1777	804	1776
805	1840	806	1838	807	1886	808	1774	809	1837	810	1839
811	1745	812	1744	813	1650	814	1726	815	1651	816	1648
817	1556	818	215	819	1359	820	1461	821	1458	822	1357
823	1358	824	1460	825	1257	826	216	827	217	828	218
829	219	830	220	831	221	832	222	833	223	834	224
835	225	836	226	837	227	838	228	839	229	840	230
841	231	842	232	843	233	844	234	845	235	846	236
847	237	848	238	849	239	850	240	851	1555	852	1551
853	1645	854	1647	855	1455	856	1558	857	1646	858	1725
859	1727	860	1457	861	1459	862	1724	863	1775	864	1773
865	1728	866	1956	867	1734	868	1845	869	1948	870	1946
871	2038	872	2046	873	1836	874	1849	875	1954	876	1940
877	1846	878	1851	879	1841	880	1771	881	1885	882	1850
883	1743	884	1742	885	1729	886	1673	887	1770	888	1669
889	1672	890	1627	891	1626	892	1625	893	1552	894	1554
895	1553	896	1550	897	1454	898	241	899	1256	900	1356
901	1353	902	1254	903	1255	904	1355	905	1154	906	1453
907	1426	908	1527	909	1529	910	1328	911	1456	912	1528
913	1578	914	1628	915	1330	916	1354	917	1579	918	1670
919	1668	920	1629	921	1772	922	1636	923	1733	924	1844
925	1842	926	1947	927	1953	928	1723	929	1741	930	1848
931	1835	932	1735	933	1739	934	1730	935	1671	936	1769

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 12
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
937	1740	938	1644	939	1643	940	1630	941	1577	942	1666
943	1573	944	1575	945	1530	946	1478	947	1477	948	1427
949	1429	950	1428	951	1425	952	1327	953	242	954	1131
955	1232	956	1229	957	1129	958	1130	959	1231	960	1024
961	243	962	244	963	245	964	246	965	247	966	248
967	249	968	250	969	251	970	252	971	253	972	254
973	255	974	256	975	257	976	258	977	259	978	260
979	261	980	262	981	263	982	264	983	265	984	266
985	267	986	1326	987	1271	988	1370	989	1372	990	1174
991	1329	992	1371	993	1473	994	1531	995	1176	996	1230
997	1474	998	1574	999	1572	1000	1532	1001	1667	1002	1633
1003	1731	1004	1843	1005	1535	1006	1737	1007	1847	1008	1624
1009	1722	1010	1641	1011	1738	1012	1623	1013	1549	1014	1642
1015	1534	1016	1631	1017	1576	1018	1665	1019	1571	1020	1471
1021	1470	1022	1533	1023	1475	1024	1569	1025	1468	1026	1472
1027	1431	1028	1369	1029	1368	1030	1272	1031	1331	1032	1273
1033	1270	1034	1173	1035	268	1036	971	1037	1076	1038	1073
1039	969	1040	970	1041	1075	1042	865	1043	1172	1044	1169
1045	1267	1046	1268	1047	1070	1048	1175	1049	1269	1050	1366
1051	1432	1052	1071	1053	1074	1054	1367	1055	1469	1056	1430
1057	1433	1058	1570	1059	1548	1060	1476	1061	1640	1062	1632
1063	1634	1064	1732	1065	1443	1066	1543	1067	1638	1068	1736
1069	1526	1070	1542	1071	1540	1072	1637	1073	1434	1074	1441
1075	1537	1076	1568	1077	1539	1078	1440	1079	1439	1080	1436
1081	1437	1082	1467	1083	1364	1084	1336	1085	1333	1086	1266
1087	1265	1088	1171	1089	1233	1090	1170	1091	1168	1092	1069
1093	269	1094	864	1095	966	1096	965	1097	862	1098	863
1099	968	1100	765	1101	270	1102	271	1103	272	1104	273
1105	274	1106	275	1107	276	1108	277	1109	278	1110	279
1111	280	1112	281	1113	282	1114	283	1115	284	1116	285
1117	286	1118	287	1119	288	1120	289	1121	290	1122	291
1123	292	1124	293	1125	294	1126	1068	1127	1065	1128	1165
1129	1167	1130	962	1131	1072	1132	1166	1133	1234	1134	1334
1135	964	1136	967	1137	1264	1138	1365	1139	1363	1140	1335
1141	1538	1142	1442	1143	1438	1144	1541	1145	1536	1146	1435
1147	1635	1148	1350	1149	1451	1150	1547	1151	1546	1152	1639
1153	1424	1154	1347	1155	1449	1156	1544	1157	1332	1158	1339
1159	1444	1160	1466	1161	1445	1162	1341	1163	1340	1164	1337
1165	1338	1166	1362	1167	1261	1168	1263	1169	1235	1170	1163
1171	1161	1172	1066	1173	1132	1174	1067	1175	1064	1176	961
1177	295	1178	764	1179	861	1180	858	1181	762	1182	763
1183	860	1184	682	1185	960	1186	953	1187	1059	1188	1063
1189	850	1190	963	1191	1060	1192	1162	1193	1236	1194	854
1195	859	1196	1164	1197	1262	1198	1260	1199	1237	1200	1446
1201	1251	1202	1351	1203	1452	1204	1450	1205	1545	1206	1248
1207	1348	1208	1447	1209	1240	1210	1342	1211	1361	1212	1344
1213	1242	1214	1241	1215	1238	1216	1239	1217	1258	1218	1156
1219	1160	1220	1133	1221	1062	1222	1061	1223	956	1224	1025
1225	959	1226	954	1227	851	1228	296	1229	678	1230	757
1231	753	1232	676	1233	677	1234	759	1235	624	1236	297
1237	298	1238	299	1239	300	1240	301	1241	302	1242	303
1243	304	1244	305	1245	306	1246	307	1247	308	1248	309

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 13
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1249	310	1250	311	1251	312	1252	313	1253	314	1254	315
1255	316	1256	317	1257	318	1258	319	1259	320	1260	321
1261	322	1262	323	1263	849	1264	853	1265	955	1266	958
1267	756	1268	855	1269	957	1270	1057	1271	1134	1272	761
1273	758	1274	1058	1275	1157	1276	1155	1277	1135	1278	1343
1279	1151	1280	1252	1281	1352	1282	1349	1283	1448	1284	1148
1285	1249	1286	1345	1287	1138	1288	1243	1289	1259	1290	1245
1291	1140	1292	1139	1293	1136	1294	1137	1295	1159	1296	1055
1297	1051	1298	1026	1299	952	1300	951	1301	856	1302	922
1303	857	1304	852	1305	755	1306	324	1307	625	1308	681
1309	675	1310	622	1311	623	1312	680	1313	586	1314	754
1315	750	1316	846	1317	848	1318	672	1319	760	1320	847
1321	943	1322	1027	1323	674	1324	679	1325	950	1326	1056
1327	1054	1328	1028	1329	1244	1330	1050	1331	1153	1332	1049
1333	1152	1334	1253	1335	1250	1336	1346	1337	942	1338	1046
1339	1149	1340	1246	1341	940	1342	1031	1343	1141	1344	1158
1345	1143	1346	1034	1347	1033	1348	1029	1349	1030	1350	1052
1351	945	1352	949	1353	923	1354	844	1355	836	1356	751
1357	820	1358	752	1359	749	1360	671	1361	325	1362	585
1363	621	1364	618	1365	583	1366	584	1367	620	1368	559
1369	326	1370	327	1371	328	1372	329	1373	330	1374	331
1375	332	1376	333	1377	334	1378	335	1379	336	1380	337
1381	338	1382	339	1383	340	1384	341	1385	342	1386	343
1387	344	1388	345	1389	346	1390	347	1391	348	1392	349
1393	350	1394	670	1395	657	1396	734	1397	748	1398	610
1399	673	1400	735	1401	843	1402	924	1403	616	1404	619
1405	845	1406	946	1407	944	1408	925	1409	1142	1410	1047
1411	1032	1412	1150	1413	1048	1414	1044	1415	1147	1416	941
1417	1036	1418	1144	1419	1247	1420	926	1421	1037	1422	1039
1423	1145	1424	833	1425	931	1426	1038	1427	1053	1428	1041
1429	933	1430	932	1431	927	1432	928	1433	947	1434	839
1435	835	1436	822	1437	747	1438	746	1439	667	1440	725
1441	669	1442	664	1443	611	1444	351	1445	558	1446	582
1447	574	1448	553	1449	557	1450	581	1451	544	1452	609
1453	613	1454	665	1455	668	1456	577	1457	615	1458	666
1459	733	1460	823	1461	578	1462	580	1463	737	1464	838
1465	837	1466	824	1467	1040	1468	930	1469	929	1470	1035
1471	937	1472	829	1473	938	1474	1045	1475	834	1476	1042
1477	1146	1478	821	1479	724	1480	934	1481	1043	1482	727
1483	826	1484	935	1485	732	1486	739	1487	840	1488	948
1489	842	1490	745	1491	744	1492	738	1493	741	1494	841
1495	742	1496	736	1497	726	1498	659	1499	663	1500	614
1501	653	1502	617	1503	612	1504	576	1505	352	1506	543
1507	554	1508	552	1509	545	1510	542	1511	556	1512	539
1513	353	1514	354	1515	355	1516	356	1517	357	1518	358
1519	359	1520	360	1521	361	1522	362	1523	363	1524	364
1525	365	1526	366	1527	367	1528	368	1529	369	1530	370
1531	371	1532	372	1533	373	1534	374	1535	375	1536	376
1537	377	1538	575	1539	573	1540	607	1541	606	1542	560
1543	579	1544	608	1545	658	1546	660	1547	564	1548	555
1549	662	1550	743	1551	740	1552	661	1553	936	1554	656
1555	731	1556	832	1557	828	1558	939	1559	654	1560	729

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 14
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1561	830	1562	652	1563	825	1564	827	1565	689	1566	771
1567	868	1568	770	1569	686	1570	685	1571	687	1572	688
1573	769	1574	684	1575	683	1576	627	1577	628	1578	626
1579	589	1580	591	1581	590	1582	587	1583	561	1584	378
1585	540	1586	547	1587	548	1588	565	1589	541	1590	546
1591	549	1592	562	1593	588	1594	630	1595	632	1596	592
1597	563	1598	631	1599	693	1600	691	1601	595	1602	566
1603	694	1604	768	1605	766	1606	692	1607	870	1608	605
1609	655	1610	730	1611	728	1612	831	1613	629	1614	695
1615	779	1616	690	1617	773	1618	875	1619	772	1620	869
1621	975	1622	871	1623	775	1624	774	1625	776	1626	778
1627	867	1628	767	1629	777	1630	697	1631	698	1632	696
1633	635	1634	637	1635	636	1636	633	1637	593	1638	379
1639	550	1640	567	1641	569	1642	597	1643	551	1644	568
1645	570	1646	380	1647	381	1648	382	1649	383	1650	384
1651	385	1652	386	1653	387	1654	388	1655	389	1656	390
1657	391	1658	392	1659	393	1660	394	1661	395	1662	396
1663	397	1664	398	1665	399	1666	400	1667	401	1668	402
1669	403	1670	404	1671	594	1672	634	1673	699	1674	701
1675	638	1676	596	1677	700	1678	782	1679	780	1680	642
1681	599	1682	783	1683	874	1684	872	1685	781	1686	977
1687	651	1688	708	1689	796	1690	723	1691	794	1692	893
1693	816	1694	722	1695	785	1696	882	1697	784	1698	881
1699	982	1700	819	1701	866	1702	974	1703	1079	1704	978
1705	877	1706	876	1707	878	1708	880	1709	976	1710	873
1711	879	1712	787	1713	788	1714	786	1715	704	1716	706
1717	705	1718	702	1719	639	1720	405	1721	571	1722	600
1723	601	1724	643	1725	572	1726	598	1727	602	1728	640
1729	703	1730	789	1731	791	1732	709	1733	641	1734	790
1735	885	1736	883	1737	713	1738	645	1739	886	1740	981
1741	979	1742	884	1743	1081	1744	887	1745	972	1746	792
1747	707	1748	795	1749	894	1750	817	1751	793	1752	892
1753	994	1754	918	1755	888	1756	988	1757	1086	1758	921
1759	973	1760	1078	1761	1178	1762	1082	1763	984	1764	983
1765	985	1766	987	1767	1080	1768	980	1769	986	1770	890
1771	891	1772	889	1773	799	1774	801	1775	800	1776	797
1777	710	1778	406	1779	603	1780	646	1781	647	1782	714
1783	604	1784	644	1785	648	1786	407	1787	408	1788	409
1789	410	1790	411	1791	412	1792	413	1793	414	1794	415
1795	416	1796	417	1797	418	1798	419	1799	420	1800	421
1801	422	1802	423	1803	424	1804	425	1805	426	1806	427
1807	428	1808	429	1809	430	1810	431	1811	711	1812	798
1813	895	1814	897	1815	802	1816	712	1817	896	1818	991
1819	989	1820	806	1821	716	1822	992	1823	1085	1824	1083
1825	990	1826	1180	1827	993	1828	1077	1829	908	1830	811
1831	818	1832	909	1833	919	1834	920	1835	1007	1836	1006
1837	1093	1838	1021	1839	1125	1840	1092	1841	1185	1842	1023
1843	1128	1844	1177	1845	1275	1846	1181	1847	1088	1848	1087
1849	1089	1850	1091	1851	1179	1852	1084	1853	1090	1854	996
1855	997	1856	995	1857	900	1858	902	1859	901	1860	898
1861	803	1862	432	1863	649	1864	717	1865	718	1866	807
1867	650	1868	715	1869	719	1870	804	1871	899	1872	998

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BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 15
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
1873	1000	1874	903	1875	805	1876	999	1877	1096	1878	1094
1879	907	1880	809	1881	1097	1882	1184	1883	1182	1884	1095
1885	1277	1886	1126	1887	1022	1888	1105	1889	1104	1890	1192
1891	1226	1892	1191	1893	1282	1894	1228	1895	1274	1896	1374
1897	1278	1898	1187	1899	1186	1900	1188	1901	1190	1902	1276
1903	1183	1904	1189	1905	1099	1906	1100	1907	1098	1908	1003
1909	1005	1910	1004	1911	1001	1912	904	1913	433	1914	720
1915	810	1916	812	1917	910	1918	721	1919	808	1920	814
1921	434	1922	435	1923	436	1924	437	1925	438	1926	439
1927	440	1928	441	1929	442	1930	443	1931	444	1932	445
1933	446	1934	447	1935	448	1936	449	1937	450	1938	451
1939	452	1940	453	1941	454	1942	455	1943	456	1944	457
1945	458	1946	905	1947	1002	1948	1101	1949	1103	1950	1013
1951	906	1952	1102	1953	1195	1954	1193	1955	1020	1956	916
1957	1196	1958	1281	1959	1279	1960	1194	1961	1376	1962	1227
1963	1127	1964	1201	1965	1200	1966	1289	1967	1323	1968	1288
1969	1381	1970	1324	1971	1373	1972	1480	1973	1377	1974	1284
1975	1283	1976	1285	1977	1287	1978	1375	1979	1280	1980	1286
1981	1198	1982	1199	1983	1197	1984	1121	1985	1123	1986	1122
1987	1117	1988	1014	1989	459	1990	815	1991	917	1992	911
1993	1012	1994	813	1995	915	1996	912	1997	1015	1998	1118
1999	1219	2000	1222	2001	1115	2002	1019	2003	1221	2004	1292
2005	1290	2006	1119	2007	1016	2008	1293	2009	1380	2010	1378
2011	1291	2012	1482	2013	1124	2014	1202	2015	1322	2016	1225
2017	1296	2018	1295	2019	1391	2020	1420	2021	1421	2022	1387
2023	1489	2024	1523	2025	1422	2026	1479	2027	1581	2028	1483
2029	1383	2030	1382	2031	1384	2032	1386	2033	1481	2034	1379
2035	1385	2036	1320	2037	1316	2038	1315	2039	1220	2040	1224
2041	1223	2042	1218	2043	1116	2044	460	2045	914	2046	1017
2047	1011	2048	1109	2049	913	2050	1018	2051	1008	2052	461
2053	462	2054	463	2055	464	2056	465	2057	466	2058	467
2059	468	2060	469	2061	470	2062	471	2063	472	2064	473
2065	474	2066	475	2067	476	2068	477	2069	478	2070	479
2071	480	2072	481	2073	482	2074	483	2075	484	2076	485
2077	1114	2078	1215	2079	1312	2080	1317	2081	1213	2082	1120
2083	1314	2084	1412	2085	1416	2086	1216	2087	1111	2088	1408
2089	1486	2090	1484	2091	1417	2092	1584	2093	1388	2094	1490
2095	1294	2096	1203	2097	1418	2098	1321	2099	1297	2100	1392
2101	1390	2102	1493	2103	1522	2104	1419	2105	1491	2106	1587
2107	1621	2108	1524	2109	1589	2110	1676	2111	1583	2112	1488
2113	1487	2114	1521	2115	1514	2116	1582	2117	1485	2118	1513
2119	1519	2120	1413	2121	1410	2122	1313	2123	1414	2124	1318
2125	1311	2126	1214	2127	486	2128	1010	2129	1112	2130	1110
2131	1207	2132	1009	2133	1113	2134	1106	2135	1212	2136	1308
2137	1405	2138	1411	2139	1306	2140	1217	2141	1407	2142	1518
2143	1618	2144	1309	2145	1209	2146	1515	2147	1580	2148	1615
2149	1619	2150	1678	2151	1590	2152	1682	2153	1492	2154	1389
2155	1319	2156	1325	2157	1415	2158	1423	2159	1494	2160	1520
2161	1525	2162	1591	2163	1620	2164	1719	2165	1622	2166	1686
2167	1830	2168	1721	2169	1793	2170	1720	2171	1824	2172	1785
2173	1779	2174	1677	2175	1586	2176	1585	2177	1718	2178	1681
2179	1675	2180	1588	2181	1616	2182	1617	2183	1516	2184	1511

EXAMPLE #6

BANDER TEST EXAMPLE--MASTER'S PROJECT--FALL 1984...OLD vs NEW...PAGE # 16
ORIG. BANDWIDTH: 2195 OCCURS @ OLD Jt 108 FINAL WIDTH= 117 @ NEW JT 1885

OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
2185	1406	2186	1517	2187	1409	2188	1404	2189	1307	2190	487
2191	1108	2192	1210	2193	1208	2194	1300	2195	1107	2196	1211
2197	1204	2198	488	2199	489	2200	490	2201	491	2202	492
2203	493	2204	494	2205	495	2206	496	2207	497	2208	498
2209	499	2210	500	2211	501	2212	502	2213	503	2214	504
2215	505	2216	506	2217	507	2218	508	2219	509	2220	510
2221	511	2222	512	2223	1305	2224	1401	2225	1507	2226	1512
2227	1399	2228	1310	2229	1509	2230	1614	2231	1716	2232	1402
2233	1302	2234	1611	2235	1674	2236	1714	2237	1717	2238	1593
2239	1495	2240	1828	2241	1685	2242	1592	2243	1826	2244	1932
2245	1827	2246	1834	2247	1792	2248	1902	2249	1791	2250	1684
2251	1829	2252	1825	2253	1787	2254	1929	2255	1895	2256	1889
2257	1780	2258	1679	2259	1680	2260	1823	2261	1786	2262	1778
2263	1683	2264	1713	2265	1715	2266	1612	2267	1609	2268	1508
2269	1613	2270	1510	2271	1506	2272	1400	2273	513	2274	1206
2275	1303	2276	1301	2277	1394	2278	1205	2279	1304	2280	1298
2281	1396	2282	1398	2283	1503	2284	1605	2285	1610	2286	1501
2287	1403	2288	1607	2289	1712	2290	1821	2291	1504	2292	1395
2293	1709	2294	1781	2295	1819	2296	1822	2297	1833	2298	1831
2299	1832	2300	1782	2301	1687	2302	1688	2303	514	2304	515
2305	516	2306	517	2307	518	2308	519	2309	520	2310	521
2311	522	2312	523	2313	524	2314	525	2315	526	2316	527
2317	528	2318	529	2319	530	2320	531	2321	532	2322	533
2323	534	2324	535	2325	536	2326	537	2327	538		