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SINDA-NASTRAN Interfacing Program Theoretical Description and User's Manual

Steven R. Winegar
Lewis Research Center
Cleveland, Ohio

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Steven R. Winegar
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

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SUMMARY

Standard practice in analyzing thermal deformations or stresses in a structure often entails generation of finite difference thermal models, using a program such as SINDA (Systems Improved Numerical Differencing Analyzer), to predict temperatures in the structure, and generation of finite element structural models, using a program such as MSC/NASTRAN (NAsa STRuctural ANalysis), to predict thermal deformations and stresses in the structure. The task of converting SINDA model temperature results into NASTRAN model thermal loads can be very labor intensive if there is not one node-to-one element, or systematic node-to-element, correlation between models.

This paper describes the SINDA-NASTRAN Interfacing Program (SNIP), a FORTRAN computer code that generates NASTRAN structural model thermal load cards given SINDA (or similar thermal model) temperature results and thermal model geometric data. SNIP generates thermal load cards for NASTRAN plate, shell, bar, and beam elements.

The paper describes the interfacing procedures used by SNIP. SNIP uses a geometric search routine and a numerical coding scheme to relate thermal model nodes to structural model elements. SNIP then calculates element temperatures based on the weighted average of temperatures of the thermal nodes related to each element. User controlled input parameters provide control over node-to-element correlation.

Sections on program set up and operation discuss the mechanics of setting up and running the program. Input parameters and input files are described. Interpretation of output file results is discussed.

Sample cases are included to demonstrate use of the program and show its' performance under a variety of conditions. SNIP can provide structural model thermal loads that accurately reflect thermal model results while reducing the time required to interface thermal and structural models when compared to other methods.

INTRODUCTION

Predicting thermal distortions and thermal stresses in a structure requires the generation of both thermal and structural models of the structure under consideration. Standard practice often entails generation of finite difference thermal models, using a program such as SINDA (Systems Improved Numerical Differencing Analyzer), to predict temperatures in the structure, and generation of finite element structural models, using a program such as MSC/NASTRAN (NAsa STRuctural ANalysis), to predict thermal deformations and stresses in the structure.

Difficulty may arise, however, in converting thermal model temperature results into structural model thermal loads for large models. The task of relating specific thermal nodes to specific structural elements can be very labor intensive if there is not one node-to-one element, or systematic node-to-element, correlation between models.

This paper describes the SINDA-NASTRAN Interfacing Program (SNIP). SNIP is a FORTRAN computer program that generates NASTRAN structural model thermal loads from thermal model temperature results. SNIP correlates thermal nodes to structural elements to interface SINDA (or similar) finite difference thermal models with NASTRAN finite element structural models made up of plate, shell, bar, and beam elements. Node-to-element correlation includes determining which SINDA nodes should be related to each NASTRAN element and calculating a weighting factor for temperatures associated with each element-related thermal node.

SNIP uses thermal model geometry, information that must be combined with standard thermal model temperature results, and structural model geometry, information that is available from standard NASTRAN input, to search through three-dimensional space around each structural element for the nearest thermal nodes. Thermal and structural models must both be defined in the same, single Cartesian coordinate system. The thermal nodes located nearest each element are used to determine element temperature for thermal distortion and stress analysis. Shaping and user-controlled sizing of the three-dimensional search region, along with numerical coding of thermal node and structural element numbers, provide for separation of substructures during correlation.

SNIP can provide structural model thermal loads that accurately reflect thermal model results while reducing the time required to interface thermal and structural models when compared to other methods.

DESCRIPTION

Use of SNIP requires the generation of SINDA (or similar thermal analyzer) and NASTRAN models of the hardware under study. Note that good deal of coordination is required between analysts generating the two models.

Input to the program is a file of thermal model temperature results and physical location of each thermal node in three-dimensional space, combined in a SNIP-unique format. The thermal node physical location data required by SNIP is not a standard thermal model output, and must be generated independently. If temperature gradients exist through the structural elements (determined perhaps by the use of multiple thermal nodes in the thermal model), the gradients must be calculated prior to input to SNIP as gradients at specific thermal node locations. Note that in order to determine the proper sign and orientation of temperature gradients in the structural elements the thermal analyst must be familiar with the structural model geometry.

Also input to SNIP is a standard NASTRAN input deck for a model made up of plate, shell, beam and bar elements. SNIP supports the CTRIA, CQUAD, CBAR, and CBEAM elements of NASTRAN. Input parameters, adjusted in the program source code by the user, control the node-to-element correlation.

SINDA-NASTRAN Interfacing Program (SNIP) is, to some degree, a misnomer. Though the program was originally written to use SINDA temperature results, temperature data from any source can now be used as long as it is entered in the correct, SNIP-unique format.

For NASTRAN plate and shell elements SNIP searches through three-dimensional space to find the thermal nodes nearest each element in each of four quadrants in the element plane. For NASTRAN bar and beam elements SNIP searches through three-dimensional space to find the thermal nodes nearest each element end (grid point) in each of the two directions along the element axis. The distance from an element, or element end, to each of the nearest thermal nodes is used to determine a weighting factor for temperatures at those nodes.

Output from SNIP are NASTRAN element temperature load cards for each element and NASTRAN case control cards for each temperature load set. Also output by SNIP is a list of elements with the numbers of the SINDA nodes related to each element, and the weight given each node in temperature calculations.

PROGRAM PROCEDURES

The program uses a combination of techniques to relate thermal nodes to structural elements. The primary technique is to search in space for the nodes located nearest each element. However, since closely spaced nodes are not necessarily related (they may be nodes of two closely spaced, but separate, parts of a structure), a technique to shape and reduce the three-dimensional search region is used. The reduced, shaped search regions are called "qualification" regions and have a characteristic shape for each element type. In addition to qualification regions, a numerical coding scheme provides for keeping node-to-element correlation in order.

The correlation routine logic is depicted in figure 1. Every SINDA (thermal) node is checked against each NASTRAN element for correlation. If the node and element numbers are coded to allow a correlation, then the geometric search routine is employed to determine whether a thermal node is within the element qualification region and whether the thermal node is the nearest node in the region segment. Once node-element correlation has been determined for every element a weighting scheme is used to calculate element temperatures from thermal node temperatures. Qualification regions, numerical coding of thermal node numbers and structural element numbers, and the temperature weighting scheme are described below.

Qualification Regions

Qualification regions define the shape and size of the space in which the program will search around an element for thermal nodes. Thermal nodes outside the qualification region for an element are considered too far from the element to be useful in calculating its temperature. Qualification regions differ for different element types (i.e., plate and shell element qualification regions are shaped differently than bar and beam element qualification region).

For plate and shell elements, the objective of the correlation is to determine the average temperature of, and the temperature gradient through, each element, to be output on a NASTRAN TEMPP1 load card for each element (ref. 1). Thermal nodes may carry some thermal gradient data, which must have the correct sign with respect to the plate or shell elements to which the nodes will be related.

Qualification regions for plate and shell elements (fig. 2) are disc-shaped regions centered at the element centroid. The central plane of the disc-shaped region is the plane defined by the element centroid and the first two corners (structural nodes) listed on the NASTRAN element connectivity card for the element. The disc is separated into four quadrants (qualification region segments) using the element coordinate system. The nearest thermal node in each region quadrant is determined during the search operation and any empty region quadrant is noted.

The radius and thickness of the qualification regions are the same for all plate and shell elements, and are set up by user adjustable program input parameters. Parameter ALWDR in the program sets the radius and parameter ALWDTH sets the half-thickness of the search region.

For bar and beam elements the objective of the correlation is to determine the average temperature of, and temperature gradients in the element Y and Z directions (fig. 3) of, each end of each bar and beam element, to be output on a NASTRAN TEMPRB load card for each element (ref. 1). Gradients input as thermal node data must have the correct sign with respect to the bar or beam elements to which the nodes will be related.

Qualification regions for bar and beam elements (fig. 4) are box-shaped regions, one for each end of the element, centered at the centroid of the element end. One side of the box-shaped region is parallel to the element X-axis. Each box is separated into two halves (qualification region segments) at the end of the element. The nearest node in each half is found during the search operation and any empty half is noted.

The X, Y, and Z dimensions of the box-shaped qualification regions are the same for both ends of all bar and beam elements, and are set up by program input parameters. Parameters ALWDR2, ALWDY, and ALWDZ set the half-size of the search region in the element X, Y, and Z directions respectively.

Qualification regions allow the analyst to size the search region for all elements. However, there is still potential for temperature data from a thermal node meant to be related to one part of a structure to be used to determine temperature of a different part of the structure. For example, a plate structure supported by backing rib stiffeners may lead to overlapping qualification regions (fig. 5). Should a thermal node lie in the overlapped region it may be related to both a plate element and a bar element by the program. This situation does not create a problem if no temperature gradient data is passed from SINDA and the nodal temperature data is truly meant to be used for both the surface and backing structure. However, if the node is specifically to be related only to plate or only to bar elements (carrying appropriate temperature gradient data) a potential problem exists. Numerical coding can alleviate this problem.

Numerical Coding

Numerical coding is the use of thermal node numbers and structural element numbers to separate substructures. Appropriate numbering of thermal nodes in input data and structural elements in the input NASTRAN model identifies substructures. If thermal nodes are not numbered for correlation with a particular element, SNIP will not determine the thermal nodes physical (geometric) relation to the element to consider the node for correlation.

Numerical coding of input thermal model node numbers and NASTRAN element numbers is depicted in figure 6. Four input parameters, NVAR1, NVAR2, NVAR3, and NVAR4 control the coding operation. SINDA nodes numbered above NVAR1 are related only to plate and shell elements numbered above NVAR2. Nodes numbered below NVAR1 are related only to plate and shell elements numbered below NVAR2. SINDA nodes numbered below NVAR3 are related only to bar and beam elements numbered below NVAR4. Nodes numbered above NVAR3 are related only to bar and beam elements numbered above NVAR4. The coding scheme allows the analyst to separate substructures from each other for correlation.

One potential way to separate the supporting beam structure from a plate structure is depicted in figure 7. First, number all plate elements below NVAR2 and all supporting beam structure elements above NVAR4. Second, set NVAR1 and NVAR3 equal. Third, number SINDA nodes for the plates below NVAR1 and nodes for the beams above NVAR3. This will result in complete separation of the backing and surface structures (fig. 8) during correlation.

Overall, the numerical coding scheme and the qualification region search technique combine to give the analyst good control of the node to element correlation.

Weighting Scheme

Once the appropriate thermal nodes have been found for each structural element, and the characteristic distances for each node determined, a weighting factor for each node related to each element is calculated. The characteristic distances are element centroid to thermal node location for plate and shell elements, and centroid of element end to thermal node location for each end of bar and beam elements.

The formula used to calculate weighting factors is:

$$\text{weighting factor}_{\text{Node } x} = \frac{\frac{1}{R_x}}{\sum_{i=1}^{N} \frac{1}{R_i}}$$

where

R_x is the characteristic distance for node x, one of the nodes related to the element under consideration

R_i is the characteristic distance for node i, each of the nodes related to the element under consideration

N is the number of nodes related to an element or element end (= number of qualification region segments)

N = 4 for plates and shells; N = 2 for ends of bars and beams. The sum of the nodal weights for each element or element end is 1.0. For qualification region segments in which no correlating thermal node is found, the distance R_i to an imaginary node 0 is set very large so that the weighting factor for the node is approximately 0.0. The default characteristic distance if no thermal node is found is set by parameter XLARGE, which must be three orders of magnitude larger than the largest characteristic distance. This is variable in order to avoid machine memory problems that may be encountered when working with a variety of machines.

The NASTRAN input file must contain a standard NASTRAN input deck in the single field format. All grid point definition and element connectivity must be done with separate, explicit cards (i.e., column duplication and generation commands cannot be used). Only plate, shell, beam, and bar elements (CTRIA3, CTRIA6, CQUADA4, CQUAD8, CBEAM, and CBAR) can have temperature load cards generated by SNIP. Also, columns one and ten of the cards must have their character fields left justified.

SNIP places some further requirements on the thermal and NASTRAN models. The NASTRAN model must be defined in a single Cartesian coordinate system. In addition, the thermal model results must be described in the same single Cartesian coordinate system.

Input and output data device numbers are defined in the data section of the program code, and can be changed there by the analyst. NASTDECK is the device number for the NASTRAN input deck, INSINDA is the device number of for the SINDA input file, and ISCRTCH1, ISCRTCH2, ISCRTCH3, and IGRDHLD are scratch files for intermediate data storage.

Output Files

Outputs include a file of NASTRAN case control cards, a file of NASTRAN temperature load cards, and a file of node-element correlation information. Reference 1 describes use of the NASTRAN case control and temperature load cards. The case control file holds a subcase card, a label card, and a temperature load set number card for each thermal load subcase. Up to 10 thermal load subcases can be processed by the program in a single run. The temperature load card file holds temperature load cards for each element for each case. TEMPP1 cards are for plate or shell elements and TEMPRB cards are for bar or beam elements. The correlation information file (fig. 9) lists each structural element by element type. It lists the thermal nodes related to each element, and the weight given temperature and temperature gradients at each node for each element.

IOCHECK is the device number of the output file of node-element correlation and weighting factors to be checked by the analyst. INASSUB is the device number of the output file of NASTRAN case control cards, and INASTEMP is the device number of the output file of NASTRAN temperature load cards.

Results of the weighting factor calculations are used to weight temperatures calculated for an element or element end as:

$$\text{Temperature}_{\text{element or end of element}} = \sum_{i=1}^{N} (\text{W.F.})_{\text{Node } i} * (\text{temperature})_{\text{Node } i}$$

where

Node i are the nodes related to the element under consideration

W.F. is the weighting factor

N is the number of nodes related to an element or element end (= number of qualification region segments)

N = 4 for plate or shell elements; N = 2 for bar or beam element ends. The same equation is used to calculate element temperature gradients, with temperature gradient substituted for temperature in the equation.

A table of the NASTRAN elements with the related SINDA nodes and the weighting factors for those SINDA nodes is output for the analyst to check (fig. 9). A warning message is included for any element for which no thermal nodes were found in the correlation routine. This file shows explicitly the node-element relationships used by SNIP to generate NASTRAN thermal load cards.

PROGRAM OPERATION

Use of SNIP requires the generation of SINDA, or similar thermal, and NASTRAN models of the hardware under study. Coordination is required between the analysts generating the two models. Adjustment of input parameters in the SNIP source code allows the SNIP analyst to control the node-to-element correlation performed by the program. The output of SNIP are set of temperature load cards of each thermal load case, case control cards for each case, and a table of node-element correlation and associated weighting factors.

Input Parameters

Input parameters are used to control node-to-element correlation as described in PROGRAM PROCEDURES. Two additional parameters, IDIMI and IDIM2, dimension the arrays used in SNIP. These allow for changing memory requirements depending on problem size (problem size is limited on the PC). IDIMI sets the dimensions on most NASTRAN-related arrays, and should be set equal to the larger of the number of NASTRAN grid points and the number of NASTRAN elements in the input NASTRAN file. IDIM2 sets the dimensions on most thermal model-related arrays, and should be set equal to the number of thermal nodes in the input thermal model results file.

To change the parameters one must change the parameter settings in the PARAMETER statements of the SNIP source code and recompile the source code. Program comments in the code describe each parameter. Appendix A shows the variables and parameters lists in the comments section of the SNIP source file and shows the first 35 lines of the SNIP program. The first 35 lines contain all program PARAMETER and DATA statements.

Input Files

Inputs to the program include a file of thermal model temperature results in a SNIP-unique format, and a standard NASTRAN input deck in the single field format.

The thermal model results input file must contain, for each case, the run title, a time associated with the results, the number of node data cards for the case, and the node data cards. The run title and time are used only to generate NASTRAN subcase labels. Node data cards must contain, in order, the thermal node number, average node temperature, temperature gradient in the <u>element</u> Z direction at the node, X, Y, Z coordinates of the center of the node in space, and temperature gradient in the <u>element</u> Y direction at the node. For nodes with no associated temperature gradients a 0.0 gradient must be entered. At present no standard SINDA subroutine exists that produces temperature results in the SNIP-unique input format. Note that in order to determine temperature gradients in the element Y and Z directions the thermal analyst must be familiar with the structural model geometry. Figure 10 shows the SINDA results input file and formats required by SNIP.

SAMPLE CASES

Four sample cases show various features of SNIP and its operation. Case 1 shows the basic operation of the program for a simple temperature pattern in a structure. Case 2 shows the results of program operation for a fairly complex temperature pattern. Cases 3 demonstrates use of coding to separate substructures. Case 4 demonstrates us of qualification regions to separate substructures.

Case 1. - Basic Performance for a Simple Temperature Pattern

Case 1 shows SNIP performance for a simple temperature pattern in a structure. Case 1 consists of a square plate under a uniform temperature gradient across the plate, from corner to corner. Figure 11 shows the NASTRAN grid, a simple 10 by 10 grid of square 1 by 1 in. elements. Figure 12 shows the SINDA node layout on the plate. The locations of the SINDA nodes are their physical centers (i.e., node 1 is located at x = 1.67 in., y = 1.67 in., z = 0.0 in.).

Table I is the thermal model results input file for the temperature pattern of figure 13. There are no temperature gradients through the plate for Case 1. The relevant input parameters for Case 1 are: ALWDR = 10 in., ALWDTH = 0.01 in., XLARGE = 1×10^5 in., NVAR1 = 500, NVAR2 = 500, NVAR3 = 500, NVAR4 = 500. Figure 14 shows the temperatures of the structural elements, as calculated by SNIP. One would expect elements along lines parallel to a line from the upper left-hand corner at element 91 to the lower right-hand corner at element 10 to have approximately equal temperatures calculated by SNIP. SNIP calculates 75° temperatures for elements 10, 19, 28, 37, 46, 55, 64, 73, 82, and 91, as expected. A line from element 61 to element 7 should show a nearly constant temperature sightly greater than 50°and does. SNIP generates a gradient along a line from element 2 to 100, as expected. SNIP produces a good temperature pattern in the structural model, representative of the temperature pattern from the thermal model results for Case 1.

Figure 15 depicts the physical node-element relationships for element number 21 in Case 1. Qualification region segment 1 contains nodes 4 to 9. Node 4 is the closest of those in segment 1 and, therefore, is the node used for element temperature calculation. Similarly, only node 1, of nodes 1 to 3, which all lie in segment 4, is used for element temperature calculation. R_1 and R_4 are the characteristic distances from element 21 to the nodes in segments 1 and 4 respectively. No nodes are found in segments 2 and 3, and so R_2 and R_3 to an imaginary node 0 are set equal to parameter XLARGE. Note that node 1 is closer to element 21 than node 4, and is, therefore, given more weight in element temperature calculation (table II).

Note that ALWDR is set large in Case 1 so all thermal nodes will be considered in the search routine performed for each element. If ALWDR had been set smaller, 2.2 in. for example, only closely located nodes would have been used for temperature calculation at each element. Table II shows the node-element correlation and weighting factors for some elements with ALWDR = 10 in. for Case 1. Table III shows the node-element correlation and weighting factors for the same elements with ALWDR = 2.2 in. for Case 1. Figure 16 shows the temperatures of the structural elements calculated by SNIP for Case 1 with ALWDR = 2.2 in. The result for a small ALWDR is that temperature calculations are dominated by the nodes near each element.

Case 2. - Performance for a Complex Temperature Pattern

Case 2 demonstrates SNIP performance for a complex temperature pattern in a structure. Case 2 consists of the same structure and thermal nodes as Case 1 under a unique temperature pattern. Figure 17 shows the temperature pattern of the thermal model for Case 2. The pattern represents a case with a heat source at node 6 and a heat sink at node 4. Input parameters for Case 2 are the same as for Case 1, with ALWDR = 10 in.

Figure 18 shows the temperatures of the structural elements as calculated by SNIP for Case 2. One would expect a constant temperature line at x = 5 in., and nearly constant temperatures slightly greater than 50° from element 6 to element 96. SNIP generates expected results. Figure 19 shows what could be considered isothermal lines based on the thermal model input. Figures 18 and 19 are consistent. The Case 2 results show that SNIP can generate reasonable temperature patterns in a structural model for complex input temperature patterns.

Case 3. - Use of Coding to Separate Substructures

Case 3 shows how coding can be used to separate substructure. Case 3 adds to the structure of Case 1 and 2 a line of bar elements along y = 5 in., offset from the plate 0.5 in. in the +Z direction (fig. 20). SNIP input thermal nodes 1001, 1002, and 1003 represent the bar structure and are centered 0.5 in. above nodes 4, 5, and 6, respectively. Figure 21 shows the thermal model temperature pattern. Input parameters for Case 3 are the same as those for Casel and 2 with the addition that ALWDR2 = 10 in., ALWDY = 0.5 in., and ALWDZ = 1 in. ALWDZ is purposely set large enough to emcompass some plate thermal nodes.

Parameters NVAR1, NVAR2, NVAR3, and NVAR4 are all set equal to 500, which allows the numbering of the bar elements and the bar thermal nodes to completely separate the bar and plate structures during node-to-element correlation. As a result thermal nodes 1001 to 1003 are related only to element 501 to 510, and thermal nodes 1 to 9 are only related to elements 1 to 100 in the correlation scheme, though some nodes lie in overlapping qualification regions for Case 3. The temperatures along the bar structure, as calculated by SNIP, are: element 501 (x = 0 in. end) = -20°, element 503 (x = 2 in. end) = -15°, element 505 (x = 4 in. end) = 15°, element 507 (x = 6 in. end) = 45°, element 509 (x = 8 in. end) = 75°, and element 510 (x = 10 in. end) = 80°. The output temperature pattern of the plate is identical to that of Case 2, as expected.

The temperature cards generated by SNIP for Case 3 accurately reflect the thermal model results fed to the program.

Case 4. - Use of Qualification Regions to Separate Substructures

Case 4 demonstrates how qualification regions can be used to separate substructures. Case 4 adds to the structure of Case 3 a second line of bar elements along y = 4 in., offset from the plate 0.5 in. in the +Z direction (fig. 22). SNIP input thermal nodes 1011 to 1013 represent this additional backing structure. Locations of the nodes are 1011-(0, 4, and 0.5 in.), 1012-(5, 4, 0.5 in.), and 1013-(10, 4, 0.5 in.). Temperature input data are the same as Case 3 with the addition of temperatures for nodes 1011, 1012, and 1013 which are -15, 35, 85° respectively. Input parameters for Case 4 are the same as those for Case 3. Note that ALWDY = 0.5 in.

Figure 23 depicts the qualification region of the x = 2 in. end of element 512. Note that, because of the size and shape the region, the potential problem of using temperature data from node 1001 for calculation of the temperature of the x = 2 in. end of element 512 is precluded. Temperature data from thermal node 1011 is used at the x = 2 in. end of element 512 even though thermal node 1001 is physically closer. Table 4 shows that thermal nodes 1001, to 1003 are related only to elements 501 to 510, and thermal nodes 1011 to 1013 are related only to elements 511 to 520 by the correlation routine. Table 5 shows the resulting temperatures in the beam structures for Case 4.

One note of caution: The bar element X, Y, and Z directions happen to correspond to the global X, Y, and Z directions in this example. ALWDR2, ALWDY, and ALWDZ are the half-sizes of the box-shaped qualification region in the <u>element</u> coordinate system (figs. 2 and 3).

PROBLEM SETUP / RESULTS INTERPRETATION / OPERATING PROCEDURES

The analyst faces determination of qualification region sizes and choice of a substructure separation method (qualification regions with or without numerical coding) when setting up a SNIP run.

The spacing between thermal nodes must be considered in sizing the qualification regions. Case 1 results above show that sizing qualification regions large enough to envelope nodes in most or all of the region segments leads to smooth gradients in the temperature pattern across the structural model. Sizing qualification regions small, such that they envelope only the nodes nearest an element, leads to a structural model temperature pattern that clearly matches the layout of thermal nodes on the structure, without smooth gradients across the entire structure. The SNIP analyst must keep these results in mind when sizing qualification regions.

The choice of a substructure separation method depends primarily on model geometry. In the case where model geometry is simple enough for qualification regions alone to keep substructures separate (i.e., there is little intertwining or closely spaced substructure) coding should not be used. This allows complete freedom in node and element numbering for SINDA and NASTRAN modelers. In the case where the structure is complex (i.e., there is a significant amount of intertwining or closely spaced substructure) coding should be used, in addition to qualification regions, to separate substructures.

Potential problems the SNIP analyst faces include inappropriate qualification region sizing, inconsistency between model geometries, and incompatibility in node and element numbering (coding). The SNIP node-element correlation file provides a warning message if any element is without any correlatable nodes. This file holds the key to assuring that SNIP is performing well. Note that it is important to carefully review this file as it is the primary indicator of how SNIP has performed.

If many elements have few or no related thermal nodes, there is a possibility of: (1) undersized qualification regions, (2) inconsistency between SINDA and NASTRAN model geometries, or (3) node and element number coding incompatibility. The key to good SNIP performance is good coordination between SINDA and NASTRAN modelers to assure geometric consistency and coding compatibility. The SNIP analyst must understand both models, and understand completely the operation of SNIP, in order to set up and control operation of SNIP and to provide appropriate guidance to thermal and structural modelers.

In order to completely understand SNIP operation of the SNIP analyst should become familiar with the source code. The source code contains extensive comments in order to guide the user through its' operation.

SNIP is written in ANSI standard FORTRAN. Two versions of the program currently exist. One version runs on a IBM 3270 PC-AT and the other runs on a CRAY X-MP. The only difference in the two programs is that OPEN statements in the source code of the PC version perform the function of ASSIGN statements that must be present in the CRAY job Control Statement File when running the Cray version (ref. 2). Assign statements must be included in the user-supplied CRAY Control Statements File for each SNIP input and output file when the CRAY version is run.

For running the PC version the NASTRAN input deck must be in a file named NASTRAN.CDS, and the thermal model results must be in a file named SINDA.CDS. The PC version will write temperature load cards into a file named TMPTR.CDS, will write subcase control cards into a file named SUBCASE.CDS, will write the node-element correlation and weighting factors list into a file named SNIPIO.CHK. Appendix B is a SNIP operation checklist for running the PC version of the program.

For running the CRAY version of SNIP, CRAY Job Control Language (JCL) statements must be included in the Control Statements File to put NASTRAN and thermal model input files into CRAY files and assign the files the appropriate

FORTRAN unit number so SNIP can access the files. NASTRAN input cards must be in unit NASTDECK, and thermal model input cards must be in unit INSINDA.

CRAY JCL must also name, and assign appropriate FORTRAN unit numbers to, output files and intermediate data storage files. FORTRAN units ISCRTCH1, ISCRTCH2, ISCRTCH3, and IGRDHLD must be available for intermediate data storage. NASTRAN temperature load cards will be written into unit INASTEMP, NASTRAN subcase cards will be written into unit INASSUB, and the node-element correlation and weighting factors list will be written into unit IOCHECK by SNIP. The FORTRAN unit numbers are defined in source code data statements, and can be changed there by the analyst (see appendix A). Appendix C is a sample run file, including CRAY JCL, for running the CRAY version of SNIP.

Appendix D is a SNIP operation checklist for running the CRAY version of the program.

APPLICATIONS

SNIP can be applied to large thermal and structural models (hundreds or thousands of thermal nodes and structural elements) made up of plate, shell, bars, and beam structures. Program operation presumes a NASTRAN element mesh equal to or finer than the thermal model node mesh. This presumption is based on thermal modeling limitations when considering radiative heat transfer, as one must when analyzing structures in the space environment. A situation with a thermal node mesh equal to or greater than the finite element mesh is assumed to be one in which one node-to-one element or systematic node-to-element correlation can be exercised.

SNIP has been applied to thermal deformation analysis in satellite antenna reflectors with good results (ref. 3). The time required to feed thermal analysis results to structural analysis models using SNIP is small when compared to other methods. One indirect advantage of using SNIP is the high degree of coordination and communication that takes place between thermal and structural modelers using this approach. This can lead to early detection of errors in either or both models.

SNIP is currently in use for analysis of solar concentrators for space solar dynamic electric power generation systems. Large thermal and structural models are required to accurately predict thermally distorted surface shapes. SNIP is expected to save a significant amount of time and effort in combining concentrator thermal and structural models.

CONCLUDING REMARKS

Potential future enhancements to SNIP include the addition of more diagnostic messages, change in the method of parameter control, automation of qualification region sizing, addition of different weighting schemes, addition of the capability to use standard SINDA output, and addition of other element capability.

More diagnostic message capability could be added to the program to indicate potential problems and solutions. Control of SNIP parameters may be changed from PARAMETER statements in the source code to an input file, so the program need not be recompiled each time parameters are changed.

Qualification region sizing could be automated using a combination of SINDA node number coding information and the average SINDA node spacing. This could reduce the amount of work required of the SNIP analyst.

Additional user-controlled, and perhaps even user-written, weighting schemes could be added. This would allow more user control of the node-element relationships.

Addition of the capability to use standard SINDA output could be added. This would eliminate the need for reformatting SINDA output temperature results, though thermal model geometric data would still be added separately.

Finally, the capability to handle additional NASTRAN elements, such as solid elements, could be added. This would make SNIP applicable to a larger number of thermal-structural problems.

SNIP is, however, a very powerful analytical tool as it stands today. SNIP is useful for combining thermal and structural analysis for which there is not one node-to-one element, or systematic node-to-element correlation between models. SNIP can provide structural model thermal loads that accurately reflect thermal model results through the use of a geometric search routine and a numerical coding scheme.

SNIP requires the addition of geometric data to standard thermal model results in order to relate thermal and structural models. Though the addition of geometric data requires additional effort on the part of the thermal analyst, the overall effort required to use SNIP is, for most large models, significantly smaller than that required to interface the models manually.

SNIP Source Code Variable and Parameter Lists, and PARAMETER and DATA Statements

```
C
C       ****************** VARIABLE LIST ***************************
C       CARDS -ARRAY CONTAINING THE INPUT NASTRAN CARDS
C       IQUADS -ARRAY CONTAINING FIELDS 2 THROUGH 7 OF CQUAD4
C                    AND CQUAD8 CARDS FROM NASTRAN
C       ITRIAS -ARRAY CONTAINING FIELDS 2 THROUGH 6 OF CTRIA3
C                    AND CTRIA6 CARDS FROM NASTRAN
C       BARS -ARRAY CONTAINING FIELDS 2 THROUGH 10 OF CBAR AND CBEAM
C             CARDS FROM NASTRAN
C       IDS -ARRAY CONTAINING THE BEAM AND BAR ELEMENT NUMBERS
C       PLUS -ARRAY CONTAINING FIELDS 1 AND 4 THROUGH 9 OF CONTINUATION
C             CARDS FROM NASTRAN
C       IGRIDS,GRIDS -ARRAY CONTAINING FIELDS 2 THROUGH 6 OF GRID
C                    CARDS FROM NASTRAN
C       IPTRQ,ITPTRT,IPTRA,IPTRB -POINTER ARRAYS CONTAINING NODE NUMBER
C                                OF SINDA NODES ASSOCIATED WITH EACH
C                                QUAD, TRIA, A END, AND B END OF NASTRAN
C                                ELEMENTS
C       QFACTOR,TFACTOR,AFACTOR,BFACTOR -ARRAYS CONTAINING WEIGHTING
C                                       FACTORS ASSOCIATED WITH SINDA
C                                       NODES IN POINTER FILES ABOVE
C       CNTROID -X,Y,Z POSITION OF PLATE AND SHELL ELEMENT CENTROIDS
C       T,DELT -TEMPERATURE AND TEMPERATURE GRADIENT FILES FOR PLATE
C               AND SHELL ELEMENT TEMPERATURE CALCULATION
C       VECT1,VECT2,VECT3 -VECTORS USED FOR CHECKING SINDA NODE
C                         QUALIFICATION
C       ************************************************************
C
C
C
C        **********************PARAMETER LIST************************
C        NVAR1 - CODING PARAMETER FOR SINDA NODES TO BE RELATED TO
C                PLATE AND SHELL ELEMENTS
C        NVAR2 - CODING PARAMETER FOR NASTRAN PLATE AND SHELL ELEMENTS
C        NVAR3 - CODING PARAMETER FOR SINDA NODES TO BE RELATED TO
C                BAR AND BEAM ELEMENTS
C        NVAR4 - CODING PARAMETER FOR NASTRAN BAR AND BEAM ELEMENTS
C        ALWDR - PLATE AND SHELL ELEMENT QUALIFICATION REGION RADIUS
C                (OF DISC-SHAPED REGION)
C        ALWDTH - PLATE AND SHELL ELEMENT QUALIFICATION REGION
C                 HALF-THICKNESS (OF DISC-SHAPED REGION)
C        ALWDR2, ALWDY, ALWDZ - BAR AND BEAM ELEMENT QUALIFICATION
C                               REGION HALF-SIZES IN THE X, Y, AND Z
C                               DIRECTIONS RESPECTIVELY
C        XLARGE - DEFAULT RADIUS TO IMAGINARY NODE NUMBER "0" WHEN NO
C                 NODE IS FOUND IN A PARTICULAR QUALIFICATION REGION
C                 SEGMENT (THIS IS VARIABLE FOR MACHINE ADAPTATION
C                 PURPOSES)
C        IDIM1, IDIM2 - ARRAY DIMENSIONING PARAMETERS.  THESE ALLOW FOR
C                       CHANGING MEMORY REQUIRMENTS DEPENDING ON
C                       PROBLEM SIZE.  IDIM1 SETS DIMENSION ON MOST
C                       NASTRAN-RELATED ARRAYS.  IDIM2 SETS DIMENSION
C                       ON SINDA-RELATED ARRAYS.
C        ****************************************************************
C
C
C
C
C
C
        PROGRAM INTRFACE
        PARAMETER (NVAR1=200,NVAR2=200,ALWDR=10.,ALWDTH=.001)
        PARAMETER (ALWDZ=.5,ALWDY=.5,NVAR3=500,NVAR4=500,IDIM1=300)
        PARAMETER (ALWDR2=10.,IDIM2=300,XLARGE=1.E+5)
        DIMENSION CARDS(3*IDIM1,10)
        DIMENSION SINCD(IDIM2,7),IPTRQ(IDIM1,4),IPTRT(IDIM1,4),NUMBER(4)
        DIMENSION GRIDS(IDIM1,5),IQUADS(IDIM1,6),ITRIAS(IDIM1,5)
        DIMENSION IGRIDS(IDIM1,2),CNTROID(3),VECT1(3),VECT2(3),UNORM(3)
        DIMENSION ARE(4),QFACTOR(IDIM1,4),TFACTOR(IDIM1,4)
        DIMENSION T(4),PLUS(IDIM1,7),BARS(IDIM1,9),ZAX(3),YAX(3),DELT(4)
        DIMENSION IPTRA(IDIM1,2),IPTRB(IDIM1,2),AFACTOR(IDIM1,2)
        DIMENSION BFACTOR(IDIM1,2),IDS(IDIM1),XAX(3),VECT3(3)
        DIMENSION ISINCD(IDIM2)
        INTEGER O
        CHARACTER BAR*8,BEAM*8,QUAD4*8,QUAD8*8,TRIA3*8,TRIA6*8,GRID*8
        CHARACTER ASC*8,CARDS*8,BARS*8,PLUS*8,SINNAME*8,TIME*8
        EQUIVALENCE(SINCD(1,1),ISINCD(1))
        DATA BAR/'CBAR    '/
        DATA BEAM/'CBEAM   '/
        DATA QUAD4/'CQUAD4  '/
        DATA QUAD8/'CQUAD8  '/
        DATA TRIA3/'CTRIA3  '/
        DATA TRIA6/'CTRIA6  '/
        DATA GRID/'GRID    '/
        DATA NASTDECK/ 30 /
        DATA INSINDA/ 25 /
        DATA ISCRTCH1/ 50 /
        DATA ISCRTCH2/ 60 /
        DATA ISCRTCH3/ 90 /
        DATA IGRDHLD/ 80 /
        DATA IOCHECK/ 19 /
        DATA INASSUB/ 45 /
        DATA INASTEMP/ 46 /
        I=1
        M=1
        N=1
        O=1
```

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APPENDIX B

SNIP Operations Checklist - PC Version

1 - Place input NASTRAN Bulk Data Deck in a file named NASTRAN.CDS

2 - Place input thermal model results in a file named SINDA.CDS

3 - Adjust input parameters in SNIP source code PARAMETER statements (see appendix A)

4 - Compile source code

5 - Link and run SNIP code

6 - Review resultant node-element relationships in SNIP output file named SNIPIO.CHK (if relationships are not acceptable, review and revise inputs to 1, 2, and 3 above as appropriate and run SNIP again)

7 - NASTRAN temperature load cards are in the SNIP output file named TMPTR.CDS and NASTRAN case control cards are in the SNIP output file named SUBCASE.CDS

APPENDIX C

SNIP Sample Run File - CRAY Version

```
JOB,JN=SNIPRUN,T=15,MFL=400000.
ACCOUNT,AC=[redacted],APW=[redacted].
ASSIGN,DN=NASFILE,DC=SC,A=FT30.
ASSIGN,DN=SINFILE,DC=SC,A=FT25.
ASSIGN,DN=SCRTCH1,DC=SC,A=FT50.
ASSIGN,DN=SCRTCH2,DC=SC,A=FT60.
ASSIGN,DN=SCRTCH3,DC=SC,A=FT90.
ASSIGN,DN=GRDHLD,DC=SC,A=FT80.
ASSIGN,DN=IOCHK,DC=SC,A=FT19.
ASSIGN,DN=SUBCASE,DC=SC,A=FT45.
ASSIGN,DN=TMPTR,DC=SC,A=FT46.
COPYF,I=$IN,O=SOURCE,NF=1.
COPYF,I=$IN,O=NASFILE,NF=1.
COPYF,I=$IN,O=SINFILE,NF=1.
REWIND,DN=SOURCE.
CFT,I=SOURCE.
LDR.
DISPOSE,DN=IOCHK,DC=ST.
DISPOSE,DN=SUBCASE,DC=ST.
DISPOSE,DN=TMPTR,DC=ST.
EXIT.
/EOF
```

CRAY Control Statements File

SNIP Source Code File goes here

/EOF

Input NASTRAN Bulk Data deck goes here

/EOF

Input Thermal Model results file goes here

/EOF

APPENDIX D

SNIP Operations Checklist - CRAY Version

1 - Adjust input parameters in SNIP source code PARAMETER statements (see appendix A)

2 - Create CRAY job Control Statements File that:

    (1) ASSIGNs appropriate FORTRAN logical unit numbers to the following files:
        (1) input NASTRAN Bulk Data file (unit = NASTDECK)
        (2) input thermal model results file (unit = INSINDA)
        (3-6) four intermediate data storage files (unit = ISCRTCH1, ISCRTCH2, ISCRTCH3, and IGRDHLD)
        (7) output node-element relationships file (unit = IOCHECK)
        (8) output NASTRAN temperature load cards (unit = INASTEMP)
        (9) output NASTRAN case control cards (unit = INASSUB)
    (2) COPYs input files (NASTRAN model and thermal model results) into appropriate CRAY files
    (3) Compiles and runs the SNIP source code
    (4) DISPOSEs the output files from the CRAY to the user (see apendix C)

3 - Combine CRAY job Control Statements file, SNIP source code file, input NASTRAN Buld Data file, and input thermal model results file into a CRAY file

4 - Submit CRAY run file to CRAY for batch processing

5 - Review resulting node-element relationships in the appropriate output file (if relationships are not acceptable, review and revise input parameters and/or input data as appropriate and run SNIP again)

REFERENCES

1. McCormick, C.W., ed.: MSC/NASTRAN User's Manual, Version 63, MacNeal-Schwendler Corp., 1983.

2. CRAY-OS Version 1 Reference Manual SR-0011, Revision L, CRAY Research Inc., Minneapolis, MN, July 1983.

3. Steinbach, R.E.; and Winegar, S.R.: Interdisciplinary Design Analysis of Precision Spacecraft Antenna. 26th Structures, Structural Dynamics, and Materials Conference, Part 1, 1985, pp. 704-712.

TABLE I. - CASE 1 THERMAL MODEL RESULT
INPUT FILE

```
CASE 1
8:00
9
1,25.,0.0,1.67,1.67,0.0,0.0
2,50.,0.0,5.0,1.67,0.0,0.0
3,75.,0.0,8.33,1.67,0.0,0.0
4,50.,0.0,1.67,5.0,0.0,0.0
5,75.,0.0,5.0,5.0,0.0,0.0
6,100.,0.0,8.33,5.0,0.0,0.0
7,75.,0.0,1.67,8.33,0.0,0.0
8,100.,0.0,5.0,8.33,0.0,0.0
9,125.,0.0,8.33,8.33,0.0,0.0
```

TABLE II. - CASE 1 NODE-ELEMENT RELATIONSHIPS (ALWDR = 10.0 in.)

QUAD ELEMENT	SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2	SINDA NODE3	W.F. 3	SINDA NODE4	W.F. 4
21	4	0.342	0	0.000	0	0.000	1	0.658
22	4	0.253	0	0.000	0	0.000	1	0.747
23	5	0.149	4	0.200	1	0.450	2	0.200
24	5	0.196	4	0.185	1	0.285	2	0.334
25	5	0.193	4	0.131	1	0.167	2	0.509
26	6	0.131	5	0.193	2	0.509	3	0.167
27	6	0.185	5	0.196	2	0.334	3	0.285
28	6	0.200	5	0.149	2	0.200	3	0.450
29	0	0.000	6	0.253	3	0.747	0	0.000
30	0	0.000	6	0.342	3	0.658	0	0.000
31	4	0.533	0	0.000	0	0.000	1	0.467
32	4	0.549	0	0.000	0	0.000	1	0.451
33	5	0.196	4	0.334	1	0.285	2	0.185
34	5	0.277	4	0.248	1	0.227	2	0.248
35	5	0.358	4	0.177	1	0.168	2	0.298
36	6	0.177	5	0.358	2	0.298	3	0.168
37	6	0.248	5	0.277	2	0.248	3	0.227
38	6	0.334	5	0.196	2	0.185	3	0.285
39	0	0.000	6	0.549	3	0.451	0	0.000
40	0	0.000	6	0.533	3	0.467	0	0.000
41	4	0.706	0	0.000	0	0.000	1	0.294
42	4	0.843	0	0.000	0	0.000	1	0.157
43	5	0.193	4	0.509	1	0.167	2	0.131
44	5	0.358	4	0.298	1	0.168	2	0.177
45	5	0.599	4	0.147	1	0.106	2	0.147
46	6	0.147	5	0.599	2	0.147	3	0.106
47	6	0.298	5	0.358	2	0.177	3	0.168
48	6	0.509	5	0.193	2	0.131	3	0.167
49	0	0.000	6	0.843	3	0.157	0	0.000
50	0	0.000	6	0.706	3	0.294	0	0.000

TABLE III. - CASE 1 NODE-ELEMENT RELATIONSHIPS (ALWDR = 2.2 in.)

QUAD ELEMENT	SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2	SINDA NODE3	W.F. 3	SINDA NODE4	W.F. 4
21	0	0.000	0	0.000	0	0.000	1	1.000
22	0	0.000	0	0.000	0	0.000	1	1.000
23	0	0.000	0	0.000	1	1.000	0	0.000
24	0	0.000	0	0.000	1	0.460	2	0.540
25	0	0.000	0	0.000	0	0.000	2	1.000
26	0	0.000	0	0.000	2	1.000	0	0.000
27	0	0.000	0	0.000	2	0.540	3	0.460
28	0	0.000	0	0.000	0	0.000	3	1.000
29	0	0.000	0	0.000	3	1.000	0	0.000
30	0	0.000	0	0.000	3	1.000	0	0.000
31	4	0.533	0	0.000	0	0.000	1	0.467
32	4	0.549	0	0.000	0	0.000	1	0.451
33	0	0.000	4	0.540	1	0.460	0	0.000
34	5	1.000	0	0.000	0	0.000	0	0.000
35	5	0.545	0	0.000	0	0.000	2	0.455
36	0	0.000	5	0.545	2	0.455	0	0.000
37	0	0.000	5	1.000	0	0.000	0	0.000
38	6	0.540	0	0.000	0	0.000	3	0.460
39	0	0.000	6	0.549	3	0.451	0	0.000
40	0	0.000	6	0.533	3	0.467	0	0.000
41	4	1.000	0	0.000	0	0.000	0	0.000
42	4	1.000	0	0.000	0	0.000	0	0.000
43	0	0.000	4	1.000	0	0.000	0	0.000
44	5	0.545	4	0.455	0	0.000	0	0.000
45	5	1.000	0	0.000	0	0.000	0	0.000
46	0	0.000	5	1.000	0	0.000	0	0.000
47	6	0.455	5	0.545	0	0.000	0	0.000
48	6	1.000	0	0.000	0	0.000	0	0.000
49	0	0.000	6	1.000	0	0.000	0	0.000
50	0	0.000	6	1.000	0	0.000	0	0.000

TABLE IV. - CASE 4 BAR ELEMENT NODE-ELEMENT RELATIONSHIPS

BEAM ELEMENT	END: A	SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2	END: B	SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2
501		0	0.000	1001	1.000		0	0.000	1001	1.000
502		0	0.000	1001	1.000		1001	0.901	1002	0.099
503		1001	0.901	1002	0.099		1001	0.601	1002	0.399
504		1001	0.601	1002	0.399		1001	0.300	1002	0.700
505		1001	0.300	1002	0.700		1002	1.000	1003	0.000
506		1002	1.000	1003	0.000		1002	0.700	1003	0.300
507		1002	0.700	1003	0.300		1002	0.399	1003	0.601
508		1002	0.399	1003	0.601		1002	0.099	1003	0.901
509		1002	0.099	1003	0.901		1003	1.000	0	0.000
510		1003	1.000	0	0.000		1003	1.000	0	0.000
511		1011	1.000	1012	0.000		1011	0.800	1012	0.200
512		1011	0.800	1012	0.200		1011	0.600	1012	0.400
513		1011	0.600	1012	0.400		1011	0.400	1012	0.600
514		1011	0.400	1012	0.600		1011	0.200	1012	0.800
515		1011	0.200	1012	0.800		1012	1.000	1013	0.000
516		1012	1.000	1013	0.000		1012	0.800	1013	0.200
517		1012	0.800	1013	0.200		1012	0.600	1013	0.400
518		1012	0.600	1013	0.400		1012	0.400	1013	0.600
519		1012	0.400	1013	0.600		1012	0.200	1013	0.800
520		1012	0.200	1013	0.800		1013	1.000	0	0.000

TABLE V. - CASE 4 BAR ELEMENT TEMPERATURES

ELEMENT	TEMPERATURE, END A (X_{min})	TEMPERATURE, END B (X_{max})
501	-20.	-20.
502	-20.	-15.
503	-15.	0.
504	0.	15.
505	15.	30.
506	30.	45.
507	45.	60.
508	60.	75.
509	75.	80.
510	80.	80.
511	-15.	-5.
512	-5.	5.
513	5.	15.
514	15.	25.
515	25.	35.
516	35.	45.
517	45.	55.
518	55.	65.
519	65.	75.
520	75.	85.

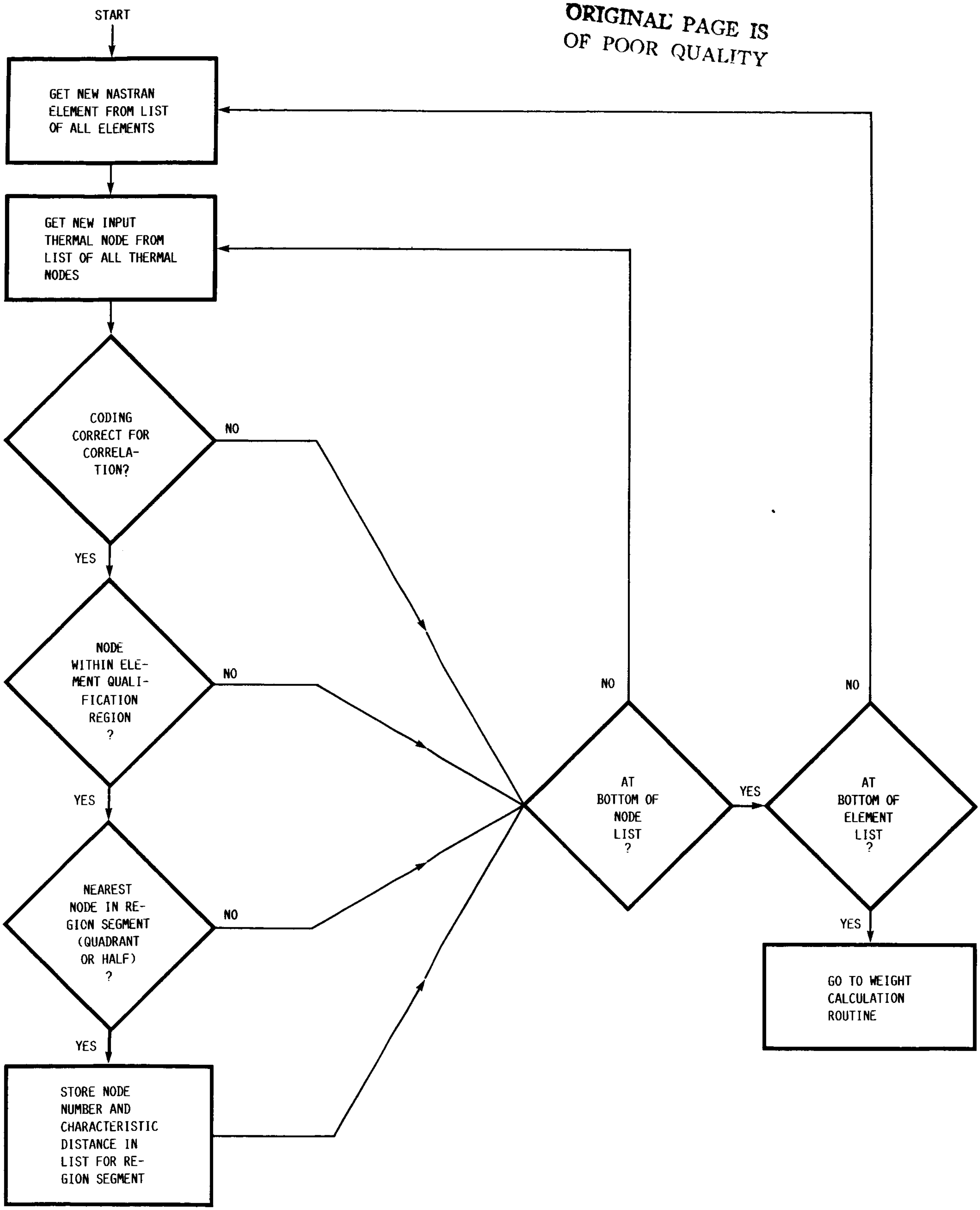

FIGURE 1. - CORRELATION ROUTINE LOGIC.

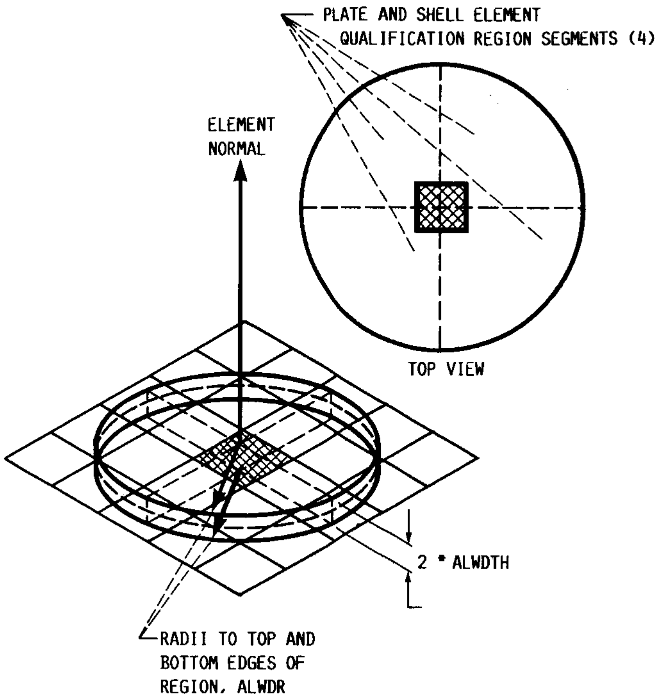

FIGURE 2. - QUALIFICATION REGION FOR THE SHADED ELEMENT OF THE PLATE ELEMENTS SHOWN.

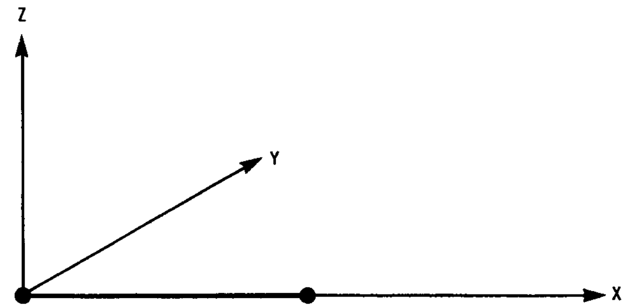

FIGURE 3. - BAR ELEMENT COORDINATE SYSTEM (X ALONG ELEMENT AXIS).

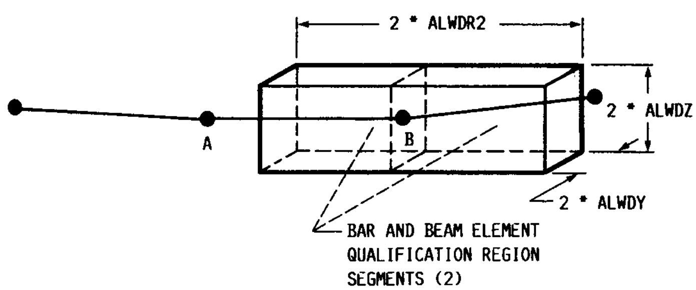

FIGURE 4. - QUALIFICATION REGION FOR END B OF THE CENTER BAR ELEMENT SHOWN.

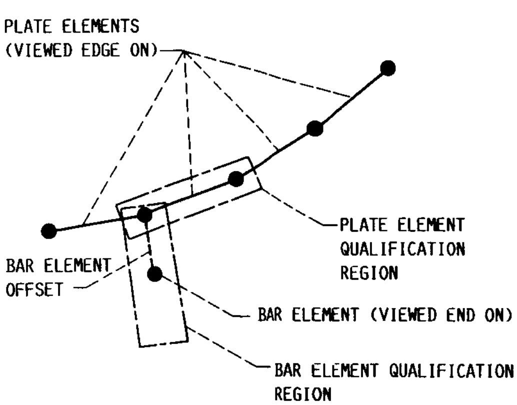

FIGURE 5. - OVERLAPPING QUALIFICATION REGIONS.

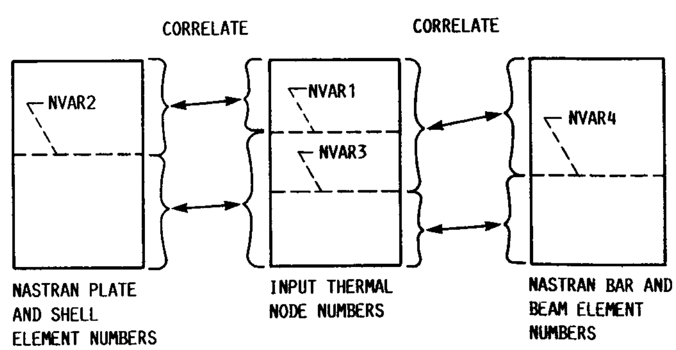

FIGURE 6. - NUMERICAL CODING SCHEME.

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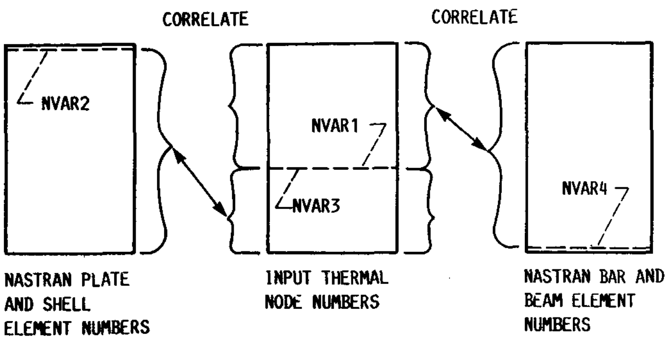


FIGURE 7. - POTENTIAL SETUP OF NUMERICAL CODING SCHEME.

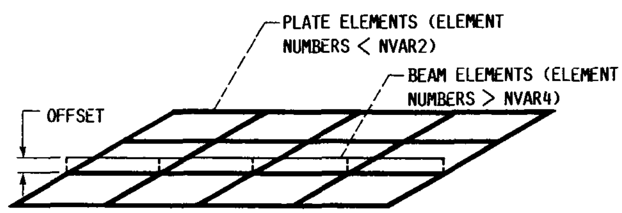


FIGURE 8. - BEAM ELEMENTS SUPPORTING PLATE ELEMENT STRUCTURE.

QUAD ELEMENT	SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2	SINDA NODE3	W.F. 3	SINDA NODE4	W.F. 4
1	1	1.000	0	0.000	0	0.000	0	0.000
2	1	1.000	0	0.000	0	0.000	0	0.000
3	2	0.342	1	0.658	0	0.000	0	0.000
4	2	0.533	1	0.467	0	0.000	0	0.000
5	2	0.706	1	0.294	0	0.000	0	0.000
6	3	0.294	2	0.706	0	0.000	0	0.000
7	3	0.467	2	0.533	0	0.000	0	0.000
8	3	0.658	2	0.342	0	0.000	0	0.000
9	0	0.000	3	1.000	0	0.000	0	0.000
10	0	0.000	3	1.000	0	0.000	0	0.000
11	1	1.000	0	0.000	0	0.000	0	0.000
12	1	1.000	0	0.000	0	0.000	0	0.000
13	2	0.253	1	0.747	0	0.000	0	0.000
14	2	0.549	1	0.451	0	0.000	0	0.000
15	2	0.843	1	0.157	0	0.000	0	0.000

BEAM ELEMENT	END: A SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2	END: B SINDA NODE1	W.F. 1	SINDA NODE2	W.F. 2
501	0	0.000	1001	1.000	0	0.000	1001	1.000
502	0	0.000	1001	1.000	1001	0.901	1002	0.099
503	1001	0.901	1002	0.099	1001	0.601	1002	0.399
504	1001	0.601	1002	0.399	1001	0.300	1002	0.700
505	1001	0.300	1002	0.700	1002	1.000	1003	0.000
506	1002	1.000	1003	0.000	1002	0.700	1003	0.300
507	1002	0.700	1003	0.300	1002	0.399	1003	0.601
508	1002	0.399	1003	0.601	1002	0.099	1003	0.901
509	1002	0.099	1003	0.901	1003	1.000	0	0.000
510	1003	1.000	0	0.000	1003	1.000	0	0.000
511	1011	1.000	1012	0.000	1011	0.800	1012	0.200
512	1011	0.800	1012	0.200	1011	0.600	1012	0.400
513	1011	0.600	1012	0.400	1011	0.400	1012	0.600
514	1011	0.400	1012	0.600	1011	0.200	1012	0.800
515	1011	0.200	1012	0.800	1012	1.000	1013	0.000
516	1012	1.000	1013	0.000	1012	0.800	1013	0.200
517	1012	0.800	1013	0.200	1012	0.600	1013	0.400
518	1012	0.600	1013	0.400	1012	0.400	1013	0.600
519	1012	0.400	1013	0.600	1012	0.200	1013	0.800
520	1012	0.200	1013	0.800	1013	1.000	0	0.000

FIGURE 9. - NODE-ELEMENT CORRELATION AND WEIGHTING FACTOR FILE LISTING.

RECORD	DATA DESCRIPTION	(FORTRAN FORMAT)
1	MODEL OR RUN NAME	(A8)
2	TIME (OF DAY) ASSOCIATED WITH RUN	(A8)
3	NUMBER OF NODES IN MODEL - N	(A18)
4	NODE #, AVERAGE TEMPERATURE AT NODE, TEMPERATURE GRADIENT IN ELEMENT Z DIRECTION AT NODE, NODE X COORDINATE, NODE Y COORDINATE, NODE Z COORDINATE, TEMPERATURE GRADIENT IN ELEMENT Y DIRECTION AT NODE	FREE
5	" "	"
•	" "	"
•	" "	"
•	" "	"
N+3		

REPEAT FOR EACH THERMAL LOAD CASE.

FIGURE 10. - SINDA (THERMAL MODEL RESULT) INPUT FILE AND FORMAT.

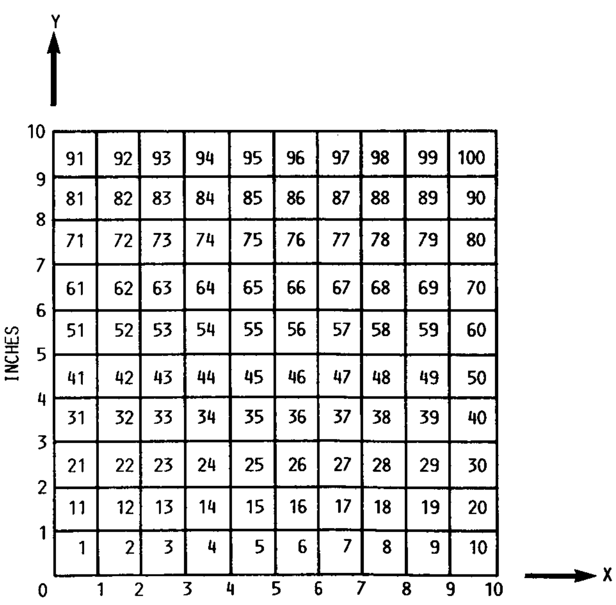


FIGURE 11. - CASE 1, 2 NASTRAN ELEMENT GRID.

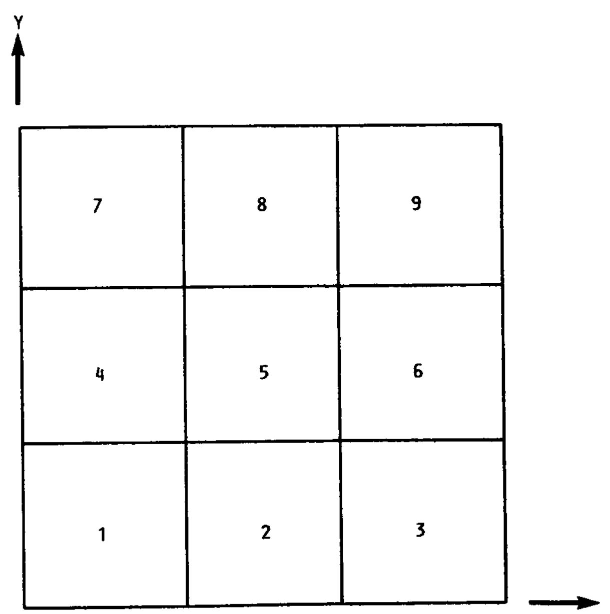


FIGURE 12. - CASE 1, 2 SINDA NODE GRID.

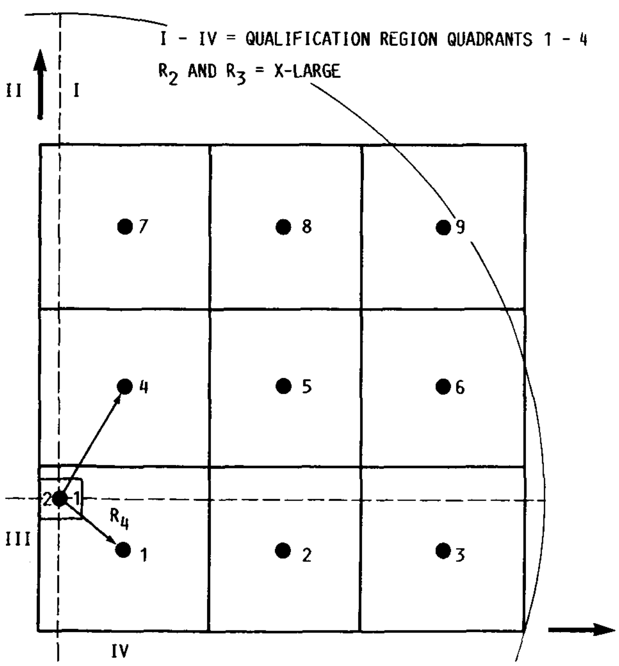
ORIGINAL PAGE IS
OF POOR QUALITY

75^0	100^0	125^0
50^0	75^0	100^0
25^0	50^0	75^0

FIGURE 13. - CASE 1 SINDA INPUT TEMPERATURE PATTERN.

75	75	84	88	93	107	112	116	125	125
75	75	81	89	96	104	111	119	125	125
66	69	75	79	84	99	102	108	119	116
62	61	71	75	78	95	99	102	111	112
57	54	66	72	75	88	95	99	104	107
43	46	51	55	62	75	78	84	96	93
38	39	48	51	55	72	75	79	89	88
34	31	42	48	51	66	71	75	81	84
25	25	31	39	46	54	61	69	75	75
25	25	34	38	43	57	62	66	75	75

FIGURE 14. - CASE 1 RESULTING NASTRAN TEMPERATURE PATTERN, DEGREES (ALWDR = 10.0").



FIGRUE 15. - NODE-ELEMENT PHYSICAL RELATIONSHIPS FOR ELEMENT 21.

75	75	75	88	100	100	112	125	125	125
75	75	75	89	100	100	111	125	125	125
75	75	75	88	100	100	112	125	125	125
62	61	62	75	86	86	75	112	111	112
50	50	50	64	75	75	86	100	100	100
50	50	50	64	75	75	86	100	100	100
38	39	38	75	64	64	75	88	89	88
25	25	25	38	50	50	62	75	75	75
25	25	25	39	50	50	61	75	75	75
25	25	25	38	50	50	62	75	75	75

FIGURE 16. - CASE 1 RESULTING NASTRAN TEMPERATURE PATTERN, DEGREES (ALWDR = 2.2").

25^0	50^0	75^0
0^0	50^0	100^0
25^0	50^0	75^0

FIGURE 17. - CASE 2 SINDA INPUT TEMPERATURE PATTERN.

25	25	34	38	43	57	62	66	75	75
25	25	31	39	46	54	61	69	75	75
16	19	29	34	39	61	66	71	81	84
12	11	26	32	37	63	68	74	89	88
7	4	20	31	40	60	69	80	96	93
7	4	20	31	40	60	69	80	96	93
12	11	26	32	37	63	68	74	89	88
16	19	29	34	39	61	66	71	81	84
25	25	31	39	46	54	61	69	75	75
25	25	34	38	43	57	62	66	75	75

FIGURE 18. - CASE 2 RESULTING NASTRAN TEMPERATURE PATTERN, DEGREES.

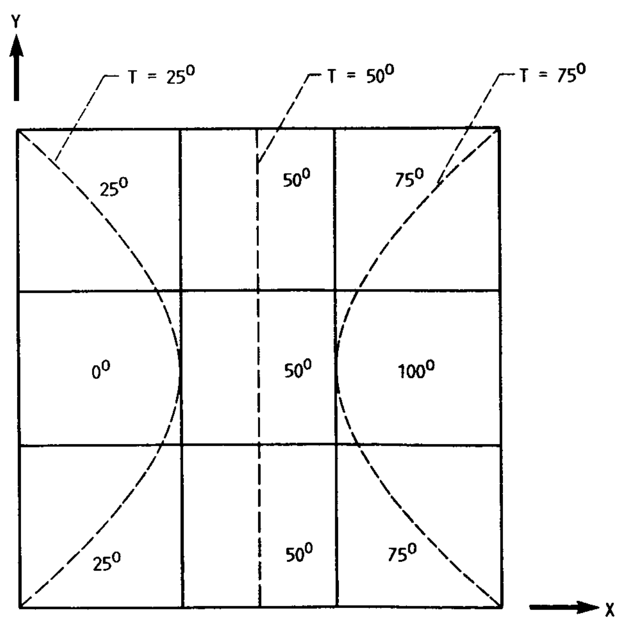


FIGURE 19. - CASE 2 ISOTHERMAL LINES OVERLAYED ON SINDA GRID.

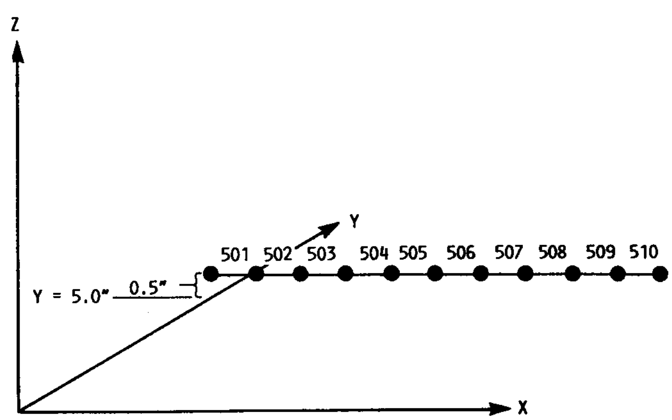


FIGURE 20. - CASE 3 BAR ELEMENTS (NUMBERED).

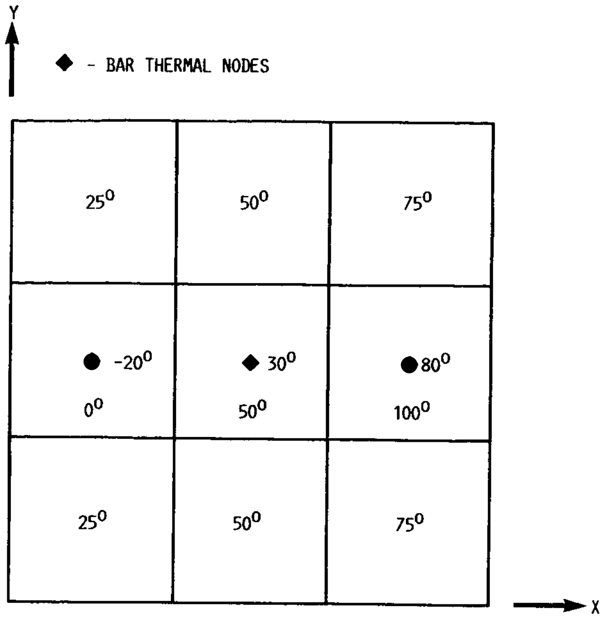


FIGURE 21. - CASE 3 SINDA INPUT TEMPERATURE PATTERN.

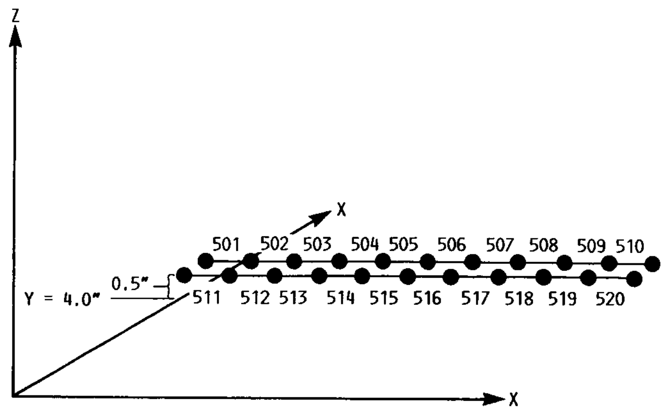


FIGURE 22. - CASE 4 BAR ELEMENTS (NUMBERED).

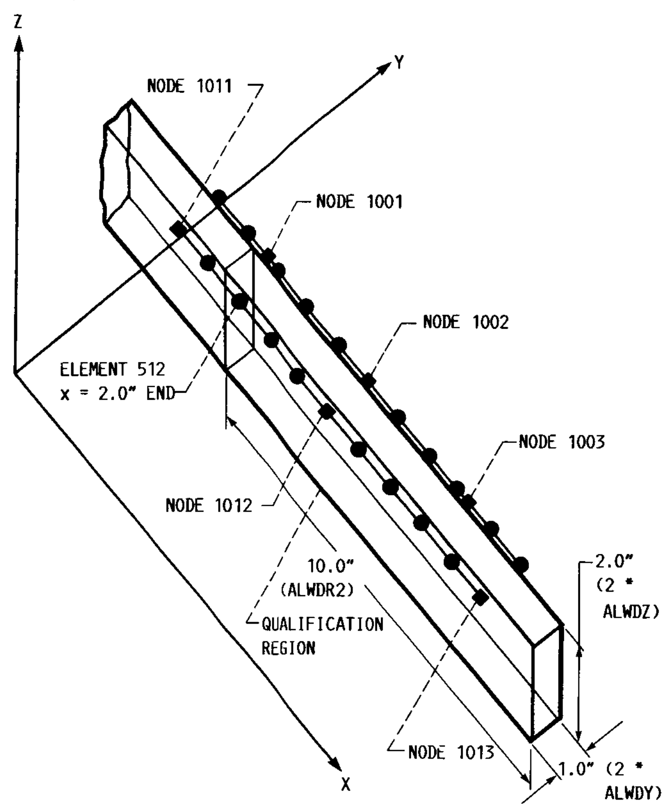


FIGURE 23. - QUALIFICATION REGION FOR x = 2.0" END OF ELEMENT 512 (CASE 4).

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15. Supplementary Notes

16. Abstract

The task of converting SINDA finite difference thermal model temperature results into NASTRAN finite element model thermal loads can be very labor intensive if there is not one node-to-one element, or systematic node-to-element, correlation between models. This paper describes the SINDA-NASTRAN Interfacing Program (SNIP), a FORTRAN computer code that generates NASTRAN structural model thermal load cards given SINDA (or similar thermal model) temperature results and thermal model geometric data. SNIP generates NASTRAN thermal load cards for NASTRAN plate, shell, bar, and beam elements. The paper describes the interfacing procedures used by SNIP, and discusses set-up and operation of the program. Sample cases are included to demonstrate use of the program and show its' performance under a variety of conditions. SNIP can provide structural model thermal loads that accurately reflect thermal model results while reducing the time required to interface thermal and structural models when compared to other methods.

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