DESIGN DATA SHEET
DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

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1 July 1980

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MAST DESIGN

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PART I. INTRODUCTION

170-0-a. References

(1) DOD-STD-1399, Section 301
Military Standard - Interface Standard for Shipboard Systems - Ship Motion and Attitude

(2) A Simplified Method of Designing Ship Structure for Air Blast by L.C. Dye and B.W. Lankford, Jr., Naval Engineers Journal, August 1966

(3) DOD-STD-1399, Section 072, Part 3 Military Standard - Interface Standard for Shipboard Systems - Blast Environment, Nuclear Weapons

(4) DDS-072-1 Shock Design Values

(5) NAVSHIPS 250-423-30 Shock Design of Shipboard Equipment - Dynamic Design-Analysis Method

(6) Report No. SUPSHIP 280-6, November 1972 Mathematical Modeling and Dynamic Shock Analysis Guide for Masts, by Supervisor of Shipbuilding, Conversion, and Repair USN, Third Naval District, New York

(7) Publication, NAVSEA 0908-LP-000-3010 Shock Design Criteria for Surface Ships

(8) Structural Design for Dynamic Loads by Norris, Hansen, Holley, Biggs, Namyet, and Minami McGraw-Hill, 1959

(9) Structural Mechanics Computer Programs by Pilkey, Saczalski and Schaffer University Press of Virginia, 1974

(10) Principles of Naval Architecture Edited by Comstock, The Society of Naval Architects and Marine Engineers, New York, 1967

(11) Ships Vibration by McGoldrick, David Taylor Model Basin Report 1451, 1960

(12) DDS-100-4, Strength of Structural Members, 1 February 1979

(13) NASA SP-222(03) NASTRAN Users Manual

(14) MIL-STD-1690, Maritime Metric Practice Guide

170-0-b. Purpose and Scope

This Design Data Sheet provides uniform standards and simplified methods for the design of ship's masts. Included in this discussion are procedures for designing polemasts, stayed polemasts, tripod masts, and four-legged masts. The Design Data Sheet incorporates basic design guidelines from three superseded Design Data Sheets on mast design (DDS-170-1, 170-2, and 170-3) into a single document. In addition, this Design Data Sheet contains discussions of vibration, nuclear blast, and the use and application of the NASTRAN computer program as an aid to mast design and analysis.

170-0-c. Symbols, Abbreviations, and Definitions

A_s	Stay area
C.G.	Center of gravity
D	Outside diameter of structural tubing
E_s	Modulus of elasticity of stay
f_B	Actual bending stress
f_c	Actual column stress
F_c	Column buckling stress
F_y	Yield stress
L	Distance from stay point to lower end of stay
p	Given Peak Overpressure - dynamic pressure associated with nuclear air blast
P_a	Axial load
P_o	Ambient pressure ahead of the shock front
q	Peak Dynamic Pressure - wind pressure associated with nuclear air blast
S	Actual length of stay between points of attachment
t	Wall thickness of the structural tubing
X,Y,Z	Variable distances in the fore and aft, athwartship, and vertical directions describing stay locations (See figure 7)
θ	Angle of stay with mast

170-0-d. Units of Measurements

In design and analysis, measurements and properties may be expressed in either inch-pound or SI (metric) units, unless a specific unit system is specified in the ordering document. The example problems in Appendices C, D, and E have been completed using inch-pound units. Appendix A has been provided for convenient conversion.

PART II. DESIGN CRITERIA

Applicable specifications (Ship Specifications, General Specifications, SHIPALT Descriptions, Scopes, etc.) should always be consulted in regard to loadings and associated factors of safety. The following criteria, however, may be considered typical and may be used in the absence of more explicit requirements.

170-0-e. Loadings

Wind load.- Wind load is based on a 90-knot wind. The following loads may be applied to the structure as an approximation. For essentially vertical structure, use 30 lb/ft^2 applied to the maximum projected area, including both the windward and leeward structure where appropriate. For platforms, use 30 lb/ft^2 of area projected to a vertical plane at maximum ship's roll. For radar antennas, wind loadings specified on the detailed equipment drawings, corresponding to a 90-knot wind, may be used. For cases other than 90 knots, the wind pressure load can be proportioned on the ratio of velocity squared.

Snow and ice.- This load may be neglected. The factor of safety (Section 170-0-f) provides adequate margin for ice loadings, and other miscellaneous loadings.

Catenary antennas.- Use the breaking strength of the weak links provided in the wire rope antenna, as the design load. This load will only be considered if mast stresses are increased by its application, and will not be considered if it reduces the stresses from other loads.

Live load.- Platforms or portions of masts should be checked to ensure adequate strength to support personnel required for equipment installation and maintenance. These live loads shall be 75 lb/ft^2, and should not be combined with wind and dynamic loads in the analysis.

Dynamic loads.- Roll, Pitch, Heave, and Slam. The dynamic loads are generated by the ship's motion as it traverses the ocean environment. These dynamic loads, expressed in "g's" will vary from one class of ship to another. The applicable Ship Specifications shall be consulted for appropriate load factors. For cases where Ship Specifications are unavailable, or ship motion factors are not given, the general formulation expressed in reference 1 shall be used.

For high speed ships with tall masts, such as destroyers, the slam induced load may be expected to be the governing dynamic load.

Gravity.- The force normal to the base plane of the ship may be assumed equal to the weight. As the ship heels, the gravity component (in the Z direction, see figure 7) is reduced, but this effect may be offset by heaving and pitching accelerations. Gravity loads are generally included with the dynamic loads to produce a single factor. For design the maximum load (that is, $F_{vert} = F_{grav} + F_{heave} + F_{pitch} + F_{roll}$) applied at the member of equipment centroid, shall be used (vector sum).

Nuclear air blast.- Reference 2 describes the procedure for calculating loadings on structure due to nuclear air blast. Dynamic pressure rather than direct overpressure (see Section 170-0-c for definitions) is more important for mast structures. Direct overpressure on mast structures is not critical because the elements are quickly engulfed by the blast wave providing equalized pressures on all surfaces. The dynamic pressure may be related theoretically to the overpressure.

The dynamic pressure for a given overpressure is given by:

$$q = \frac{5}{2} \frac{p^2}{7p_o + p}$$

(Reference 3)

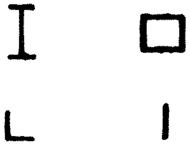
in which "q" is the peak dynamic pressure, (lb/in^2 or KN/M^2), above ambient
p is the peak overpressure, above ambient (from Ship Specifications)
po is the ambient pressure ahead of the shock front. (14.7 lb/in^2 typically)

The effective dynamic pressure is obtained by multiplying the dynamic pressure by an appropriate drag coefficient for the shape being loaded. Drag coefficients and dynamic pressure for various overpressures and associated structural shapes are provided in Table 1.

High shock loads.- Shipbuilding or procurement specifications may include high shock mounting requirements for equipment. This requirement necessitates a dynamic shock analysis of that mast. References 4, 5, 6, and 7 provide information on procedures and factors to be used in this analysis.

A Dynamic Design Analysis Method (DDAM) has been developed which requires the vibrational response of a structure to determine the deflections and stresses due to shock. The vibrational response inputs required for DDAM may be developed using a number of computer programs. Appendix D provides an example of the NASTRAN computer program used for vibration analysis. Section 170-0-n discusses modeling for DDAM.

TABLE 1

CROSS-SECTIONAL STRUCTURAL SHAPE (DIRECTION OF BLAST ➞)	DRAG * COEFFICIENT	DIRECT OVERPRESSURE P	DYNAMIC PRESSURE q	EFFECTIVE ** DYNAMIC PRESSURE
		Lb/in^2	Lb/in^2	Lb/in^2
	1.0	3	0.21	0.21
		7	1.11	1.11
		10	2.21	2.21
	1.8	3	0.21	0.38
		7	1.11	2.00
		10	2.21	3.98
	2.0	3	0.21	0.42
		7	1.11	2.22
		10	2.21	4.42

* FROM REFERENCE NO. 8

** (DRAG COEFFICIENT x DYNAMIC PRESSURE)

Combined loading.- Wind, dynamic, and gravity loads shall be combined to determine the worst loading condition that produces the maximum stresses.

For symmetrical masts (such as a polemast), the worst condition can be determined by developing the resultant of the pitch and roll and adding the wind in the same direction (see Figure 1).

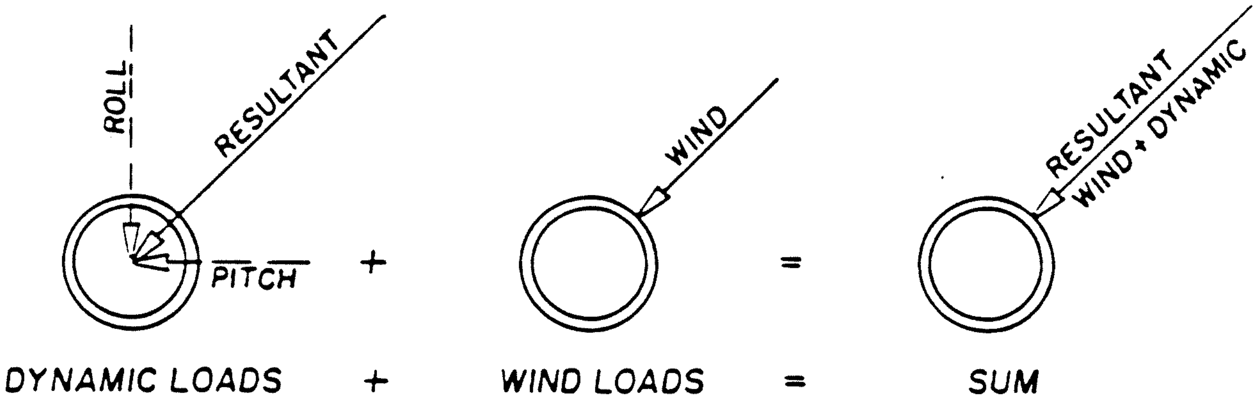


FIGURE 1

For non-symmetrical masts, the worst condition may not be readily predictable, and several loading conditions shall be tried. Three recommended combinations are shown in Figure 2.

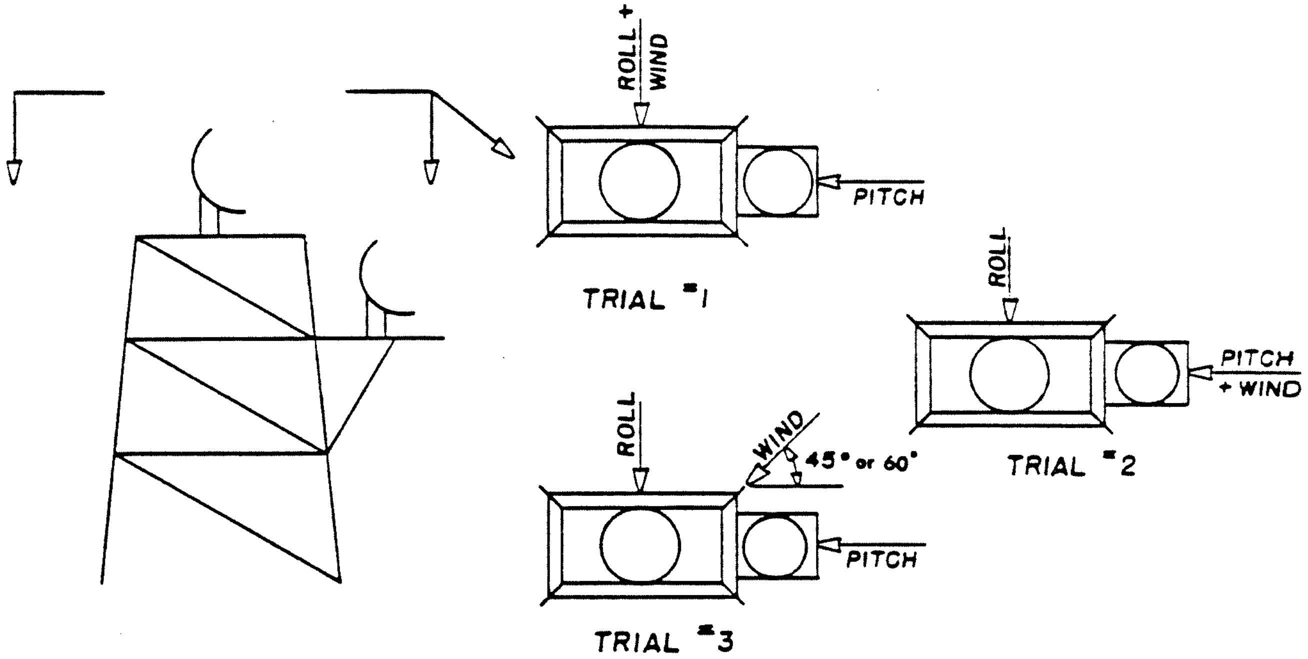


FIGURE 2

The nuclear air blast load shall be applied separately from dynamic and wind loads, but in combination with gravity. For symmetrical sections, the load may be applied in any direction. For non-symmetrical sections, drag load shall be applied in the direction which maximizes the loaded surface area while minimizing the mast section resisting the load. The worst condition may not be obvious and several loading conditions may be required. Three recommended trials are as shown in Figure 3.

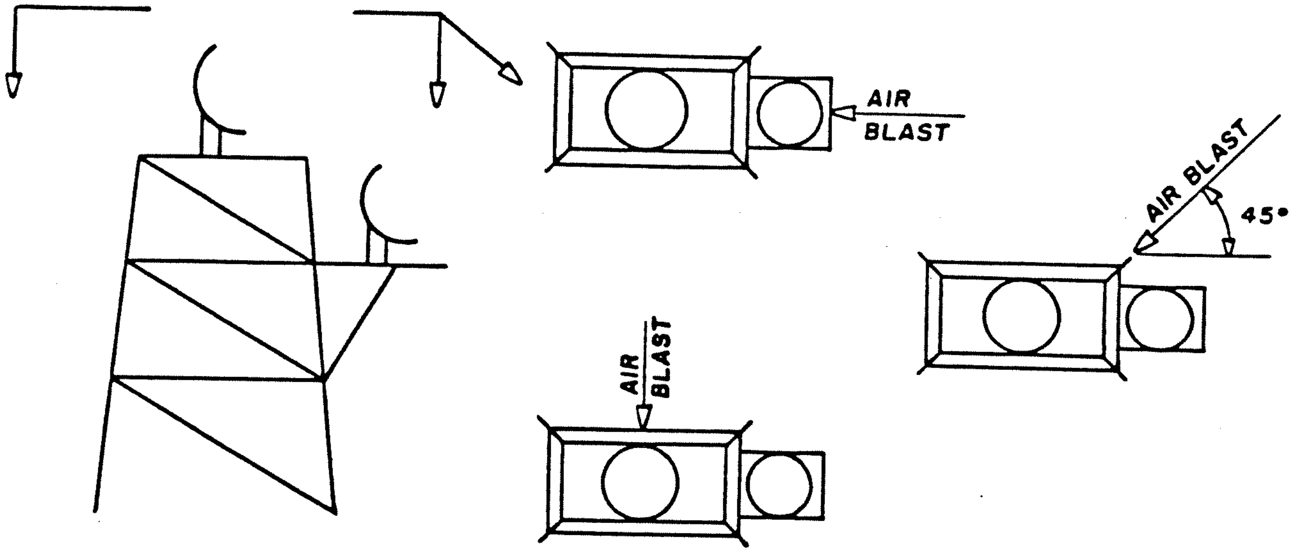


FIGURE 3

High shock loads shall be applied separately from dynamic and wind loads, but in combination with gravity. Load factors for high shock are calculated for the fore-and-aft, athwartship, and vertical directions only. Each direction shall be analyzed separately, with no combination of stresses from the various directions.

170-0-f. Factor of Safety

Unless otherwise stated in the Ship Specifications for new design, a factor of safety of 2.5 on the yield strength (welded yield strength, if applicable) of the material is required for loadings other than nuclear blast and high shock. For existing structure, a factor of safety of 2.0 is acceptable. The difference between the two factors of safety constitutes an allowance for possible increases in mass of supported equipment after the mast has been built. The factor of safety also provides a margin for ice loadings and secondary stresses. For nuclear air blast and high shock, a factor of safety of 1.0 on welded yield strength of material is required. (Material strength properties can be obtained from Ship Specifications and material Military, Federal, or Industry Specifications.)

170-0-g. Vibration

If the natural frequency of a mast structure coincides with an excitation frequency during some operating condition of the ship, resonance may occur which forces the mast to sway with progressively greater displacement amplitudes. These displacements can hinder the operation of equipment supported by the mast and will produce progressively greater stress in the mast, eventually leading to failure of the structure.

Natural frequencies of mast structures can be determined with the use of computer programs such as NASTRAN and STRUDL. An example using NASTRAN is shown in Appendix D. For a more complete list of programs useful in mast vibration analysis, see reference (9).

Vibration excitation in frequencies which may affect mast structures can come from several sources. The frequencies of rotating antennas, propellers, hull motion in a seaway, and large reciprocating machinery, should be considered and compared to the natural frequency of the mast structure to assure non-resonance.

One of the more important sources of vibratory excitation of masts are propeller forces. These forcing frequencies can be a direct result of propeller rotation (driving frequencies equals shaft rotation rate) or a result of action from the propeller blades (driving frequency equals shaft rotation rate times number of blades). Shaft rates at higher speeds should especially be considered due to the higher energy input as compared to lower speeds. In general, mast fundamental frequencies should be kept approximately 25 percent above the highest shaft rotation rate. If this is not practical, a detailed vibration analysis should be performed to determine that the mast frequency does not, in fact, match any of the ships standard shaft rotation rates used for high-speed operations. Information on these shaft rotation rates can, in most cases, be found in the Ship Specifications.

The second most important source of excitation is the structure of the ship, usually the hull. In a seaway the ship receives impacts from waves and swells. The hull reacts to these loads by vibrating in one or more of its natural modes (see Figure 4). The effect of this vibratory motion is most drastic when the mast is located near one of the nodes of the mode in which the hull is vibrating, and diminishes the closer the mast is to the antinodes (see Figure 5) in vertical and athwartship vibration. The oposite would apply for torsional vibration. Typical values of hull frequencies range from less than 1 Hz to over 4 Hz. This range coincides with the frequency range of most masts; therefore, it is important to determine the hull frequencies of the particular ship for which the mast is designed so they can be avoided.

It is desirable to design the mast so that its natural fundamental frequency is at least 25 percent above the frequency of the 3-noded vertical mode of the hull to insure against resonance or the high amplitude motions associated with a near-resonance condition. In any case, the frequency of the mast should not directly match either the two-noded or three-noded vertical modes or the fundamental longitudinal torsional mode.

Independent superstructures, such as aircraft carrier islands, can vibrate at their own natural frequencies. Masts connected to them are more directly affected by these deckhouse frequencies than by hull frequencies. Therefore, it is important to consider also the frequencies of large superstructures.

In some ships a condition may exist where one of the higher propeller blade rates matches one of the hull natural frequencies. This amplifies the driving motion that the mast would feel under propeller or hull excitation acting alone. It is extremely important, therefore, for the mast frequency to clear this frequency in cases where it exists.

One possible source of information on hull or superstructure natural frequencies for many of the ships of the U. S. Navy is the David Taylor Naval Ship Research and Development Center, Code 1962. Methods for determining approximate hull natural frequencies are shown in references (10) and (11).

Most radar antennas operate at 6 to 12 r/min, much lower than the natural frequencies of mast structures and generally do not cause a problem. E.C.M. antennas, on the other hand, operate at higher rates of rotation; therefore, the mast should be checked for resonance.

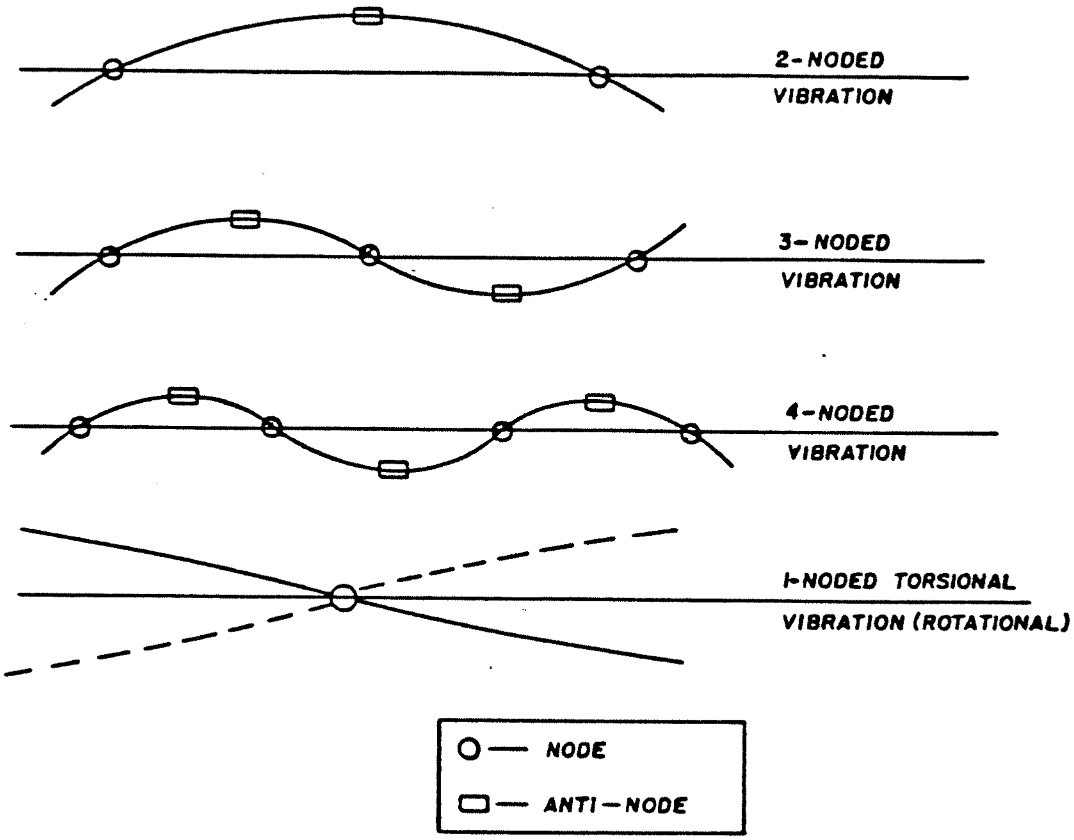


FIGURE 4

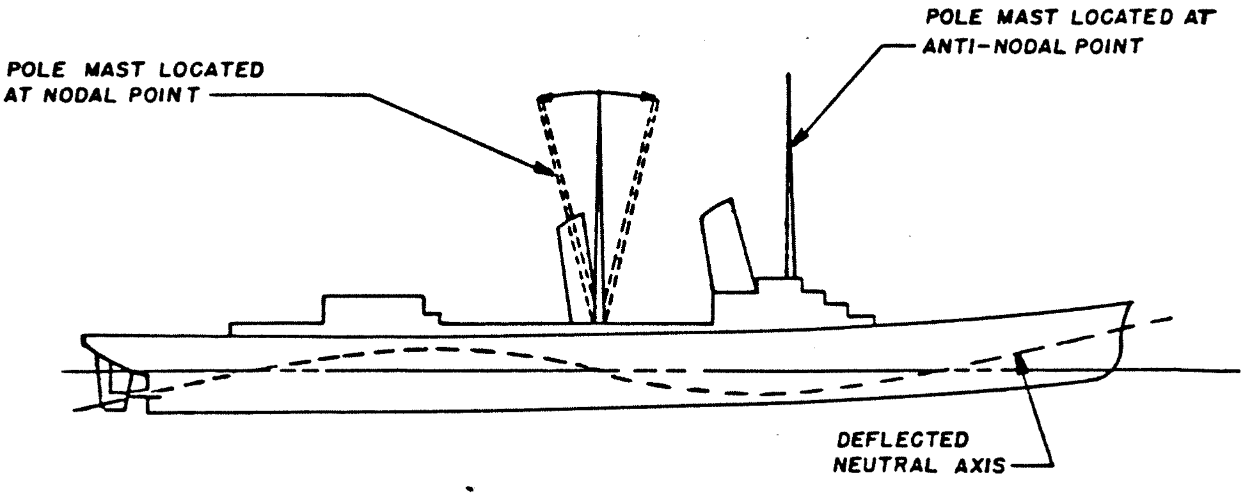


FIGURE 5

Reciprocating type of propulsion engines can pose a vibration problem to mast structures on ships so equipped. Steam or gas turbines, on the other hand, operate at speeds much higher than the natural frequencies of mast structures and therefore are not considered as having an effect on them.

For complex structures, isolated portions may vibrate independently of the entire structure, and may require local stiffening (see Figure 6).

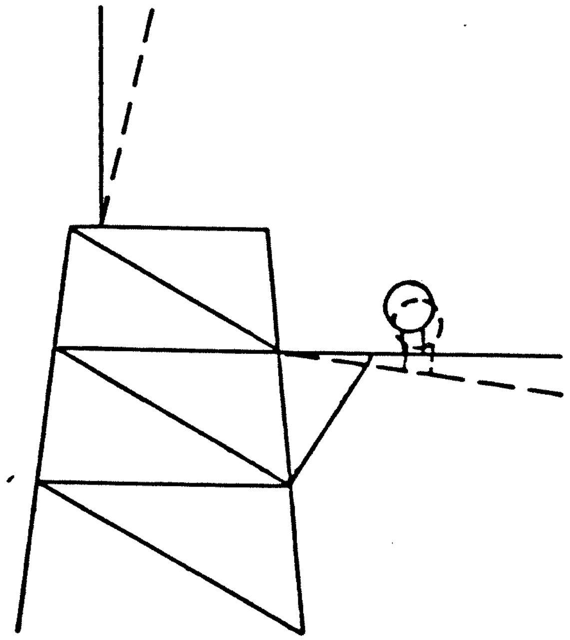


FIGURE 6

PART III. DESIGN PROCEDURE FOR MAST STRUCTURE

170-0-h. General Discussion

This section includes design procedures for polemasts, stayed polemasts, tripod masts, and four-legged masts.

Local buckling of cylindrical, and similiar compressive members should, in general, meet the following:

$$\frac{D}{t} < .128 \frac{Es}{Fy}$$

where D = outside diameter of the structural tubing

t = wall thickness of the tubing

E_s = modulus of elasticity of member

F_y = yield stress

For the simplest of the mast types, the polemast, the discussion will center on calculating stresses using standard hand methods.

For the more complex mast types (tripod, stayed polemasts, and four-legged), a computer analysis will assist in the design. The basic design procedure outlined in the example problem, Appendix D, will be applicable to all three of the more complex mast types, with minor variations.

170-0-i. Polemast

Description of structure.- The polemast is the simplest of the mast types, consisting of a vertical cantilever beam. The structure may be complicated with attached yardarms or platforms which can normally be analyzed separately.

Design procedure.- Generally, a simple polemast does not require computer analysis and may be done by hand calculation.

The polemast is divided into stations (normally at changes in section, at points of attachment for platforms or equipment, or at intermediate points if lengths of segments are in excess of one-fourth of the height of the polemast). Bending moments are calculated at each station using the loads as discussed in Section 170-0-e. Proceeding from top to base, axial forces, shear forces, and moments are computed. Bending moments are computed by adding:

1. Moment at station above.
2. Shear at station above times distance between stations.
3. Moments of intervening loads.

For circular sections, the maximum bending stress is obtained by dividing the section modulus into the sum of the wind moment and the resultant of the rolling and pitching moments. Compressive stresses from axial loads are determined, combined with the bending stresses, and checked against the allowable stresses.

Care must be taken that the existing ship structure provides adequate support at the base of the polemast. Location of the mast above a transverse bulkhead or deep frame is preferred to provide athwartship support. Ideally, the polemast should extend down through several levels of ship structure to distribute the load and thereby provide adequate structural support. The member of levels depends upon the height of the pole and equipment on it.

Appendix C is an example of a polemast analysis. This nomograph provided in Appendix B provides guidance in initial selection of circular sections for analysis.

170-0-j. Stayed Polemast

Description of structure.- A stayed polemast is the basic polemast of Section 170-0-i, with stays in the form of cables or rods to provide restraint (see Figure 7).

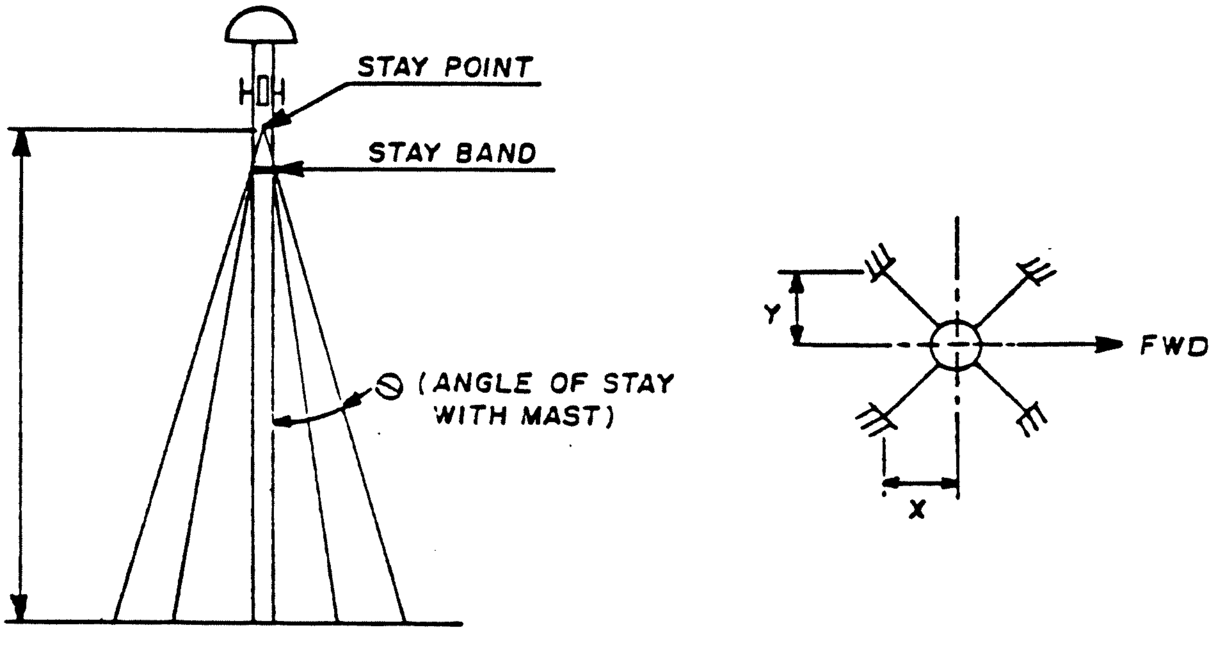


FIGURE 7

Design criteria.- In addition to the design criteria of Part II Sections 170-0-e through g, the following design criteria are normally required (check applicable specifications).

Where there is a design requirement for the mast to stand without stays (unstayed), generally for combatant ships but not auxiliaries, the mast shall be designed to stand unstayed with a factor of safety of 1.25 on the welded yield strength of the material and column strength. With stays in place, the factor of safety for the mast shall be 2.5. Stresses shall be calculated with initial pretension in the stays equal to 20 percent of breaking strength. Maximum calculated tension in the stays shall not exceed 40 percent of the specified breaking strength of the stay material.

A mast with stays at two levels is not normally required to stand unstayed. Allowable stay tension for this configuration is 35 percent of breaking strength.

Design procedure and theory.- The stayed polemast is a statically indeterminate structure. The design approach to such a structure is basically trial and error, assuming an arrangement of structural elements, performing an analysis, and adjusting the sizes of structural elements to suit the stresses. This process is repeated until a suitable design is developed.

For the stayed polemast that has the design requirement to stand unstayed, initial sizing of the polemast is completed without stays following the procedure outlined in Section 170-0-i. Following this initial sizing, stays are added and stresses again checked. Because of the complexity of the structure, use of a computer analysis is recommended. Stay size and locations may be adjusted based on the results of the computer analysis. Problem formulation and solution would be similar to the example in Appendix D.

Design of stays.- The purpose of the stays is to provide adequate horizontal restraint to the mast to reduce mast stresses to an allowable level. Effectiveness of the stays is dependent on the location of the stay attachment to both the mast and ship structure.

By relocating the stay attachments, stresses in the mast and forces in the stays may be adjusted. Stay geometry should be such that the "stay point" represents the intersection of the stays (extended) with the centerline of the mast. Generally, it will be advantageous to locate the stay-point as high as practicable. This gives the stay reaction the maximum lever arm. The effectiveness of the stay is somewhat reduced (reducing the horizontal force component of the stay), however, by increasing Z without changing X and Y (see Figure 7). If all stays make a very small angle with the mast, mast stresses will be the limiting factor in design of the stays. If the angle is uniformly large, stay stresses will probably control. The objective of the designer is to select the stay arrangement that provides a balanced design. That is, stresses in the mast should approach maximum allowable at the same time that forces in the stays approach maximum allowable. This may be accomplished by use of the following design procedure.

The reaction of the stays on the mast must be sufficient to reduce stress in the mast to that allowed for the stayed conditions. As a first approximation, select stay sizes so that the horizontal stiffness of the stays on one side is about three-fourths that of the unstayed mast. That is:

$$K_{yy} = \Sigma\,[(Y/L)^2(A_sE_s/S)] = .75K_y$$

where: K_y = Athwartship force on mast in unstayed condition, required at staypoint to develop a unit displacement

K_{yy} = Total athwartship component of stay reaction due to unit athwartship displacement

L = Distance from stay point to lower end of stay

S = Actual length of stay between points of attachment

A_s = Area of stay

E_s = Modulus of elasticity of stay

Check to see whether bending moments in the athwartship plane seem to be reduced by a suitable proportion. Somewhat less restraint is needed in the fore-and-aft direction, and stays can usually be arranged to give ample restraint longitudinally.

After checking forces from the computer analysis, stay locations or sizes may be adjusted. If the forces in a few stays are too high, but quite moderate in the others, it may be advisable to relocate the lower end of the highly stressed stays nearer the base of the mast. If forces are generally excessive, an increase in sectional area of some or all the stays is indicated. It should be remembered that increasing the size of one stay automatically increases its share of the total load. Stay forces can be reduced by increasing the stiffness of the mast, but this will not usually be advantageous, assuming the mast is economically designed to carry the specified loads in the unstayed condition.

Stresses in stayed mast.- When compressive stresses are quite small, compared to bending stresses, it is necessary only that the sum of the two be within the allowable limit. This is generally the case for a mast designed to stand unstayed. Where a slender mast is subjected to compressive loads from stay tension, however, the possibility of instability as a column must be considered. The procedure for checking the mast for this instability is described in reference 12.

Suitable precautions should be taken against the danger of local buckling. A diameter-to-thickness ratio of 150 should not be exceeded on a steel mast unless stiffening is provided. For aluminum, the ratio should be 75 or less.

Special design considerations.- Some difficulty may be experienced with computer programs in attempting to model stayed masts. Most programs do not make allowance for members that exhibit different stiffness properties in tension and compression. Also, many programs do not allow for applying a pretension, as required in the design criteria for stayed masts.

This problem can be alleviated by proper modeling technique and by adjusting the results of the computer analysis. Since stays cannot carry compressive loads, it is assumed that pretensioning in the stays is such that no stays become slack under loading. In the computer analysis, replace the existing pretensioned stays with slender rods with no pretension. Model the vertical load on the mast from the pretensioned stays as an appropriate vertical force applied at the stay point. If the stays are not symmetric the appropriate horizontal forces must also be applied. Following the computer analysis, determine the actual loads or stresses in the stays as follows:

1. For those rods in the computer model that exhibit tension, add this tension to the pretension to determine total load in the stay.

2. For those rods in the computer model that exhibit compression, subtract this compression from the pretension to determine the actual load in the stay. If the compression load exceeds the pretension load, the cable has gone slack and the model should be adjusted.

As with the polemast previously discussed, care must be taken that the existing ship structure provides the required support. In addition to insuring that the base of the mast is adequately supported, ship structure at points of stay attachment must be checked.

170-0-k. Tripod Masts

Description of structure.- The tripod mast is structurally very similar to the stayed polemast, the design of which is discussed in Section 170-0-j. Often the differences may be described as more quantitative than qualitative. Lateral support for the "mast proper" (see Figure 8) is provided by two struts, which support compressive loads as well as tensile forces instead of a number of wire rope stays. These struts must be adequately braced to prevent buckling under compressive and bending loads. Struts which are slender in comparison with the mast provide primarily lateral support for the mast with little resistance to bending and torsion. If the struts are larger, they will carry more of the moment acting at the stay point. However, additional material offers more effective resistance to these moments if it is applied to the mast proper. If the struts are required to be larger to support local loads applied directly to the struts, a truss arrangement of a four-legged mast should be considered.

Arrangement of tripod legs.- For resisting a single, concentrated load, a tripod would be most effective if the centerlines of the three legs intersected at the point of application of the load. The members would then be subjected only to axial stresses. Because this ideal loading condition is not realized in most installations, eccentric loads result, requiring the mast to be designed for adequate strength in torsion and bending. The arrangement should be such that these stresses are minimized to be consistent with the requirements for practical structural details.

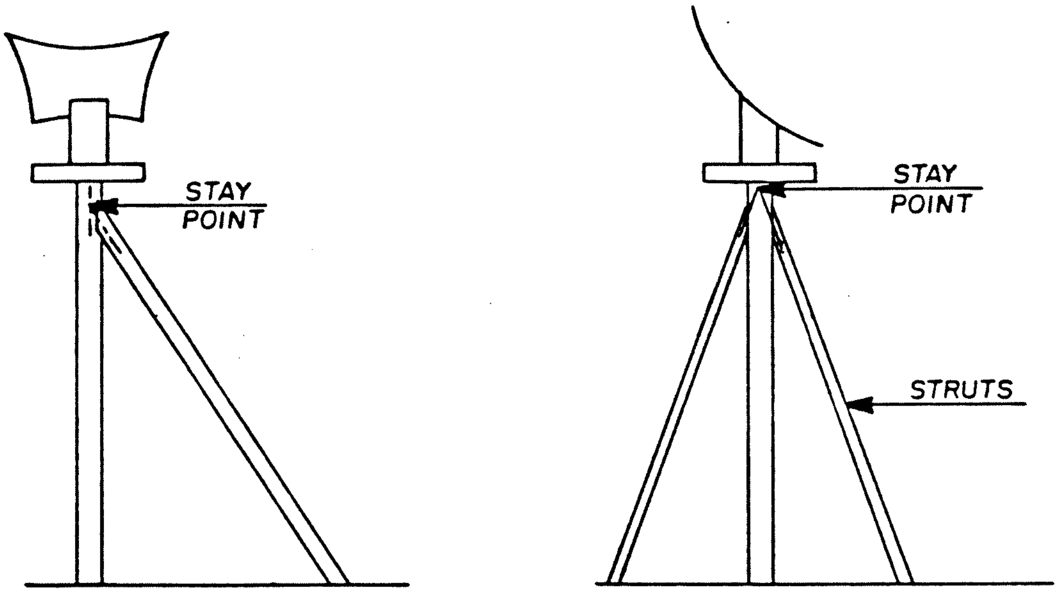


FIGURE 8

Often a tripod mast must be designed to support a large radar antenna together with its working platform and a number of comparatively small items, some of which may be carried by a topmast extending some distance above the platform. With struts symmetrical about a fore-and-aft centerline, the athwartship forces acting on the platform, and above it, are resisted almost entirely by the two struts. In addition, part of the load on the mast below the platform produces a reaction in the struts. If the resultant of these forces and associated moments acts at the point of intersection of the strut centerlines, there will be no tendency for the platform to rotate, and bending moments will be a minimum.

The stay-point for loads in the athwartship (Y) direction should be located so as to minimize the torsional moments. This may require two separate stay-points, as in Figure 9. This may be accomplished by attaching the struts at an intermediate point to a platform or spar arrangement, in addition to the uppermost attachment point.

It is essential that the three legs be held together rigidly by the connecting structure. Difficulties in accomplishing this rigidity and properly supporting the platform must be considered, as well as the effects of external moments on the mast and secondary moments generated by eccentricities.

Ample spread for the legs of the mast, especially port to starboard, has the greatest effect of any single factor in reducing the stress level. This is due to the fact that the dynamic load due to roll which acts in the athwartship direction is larger than other loads and spreading the legs, in general, stabilizes the total mast.

As in the previously discussed mast types, the supporting ship structure must be checked to ensure adequate strength to support the loads applied by the mast.

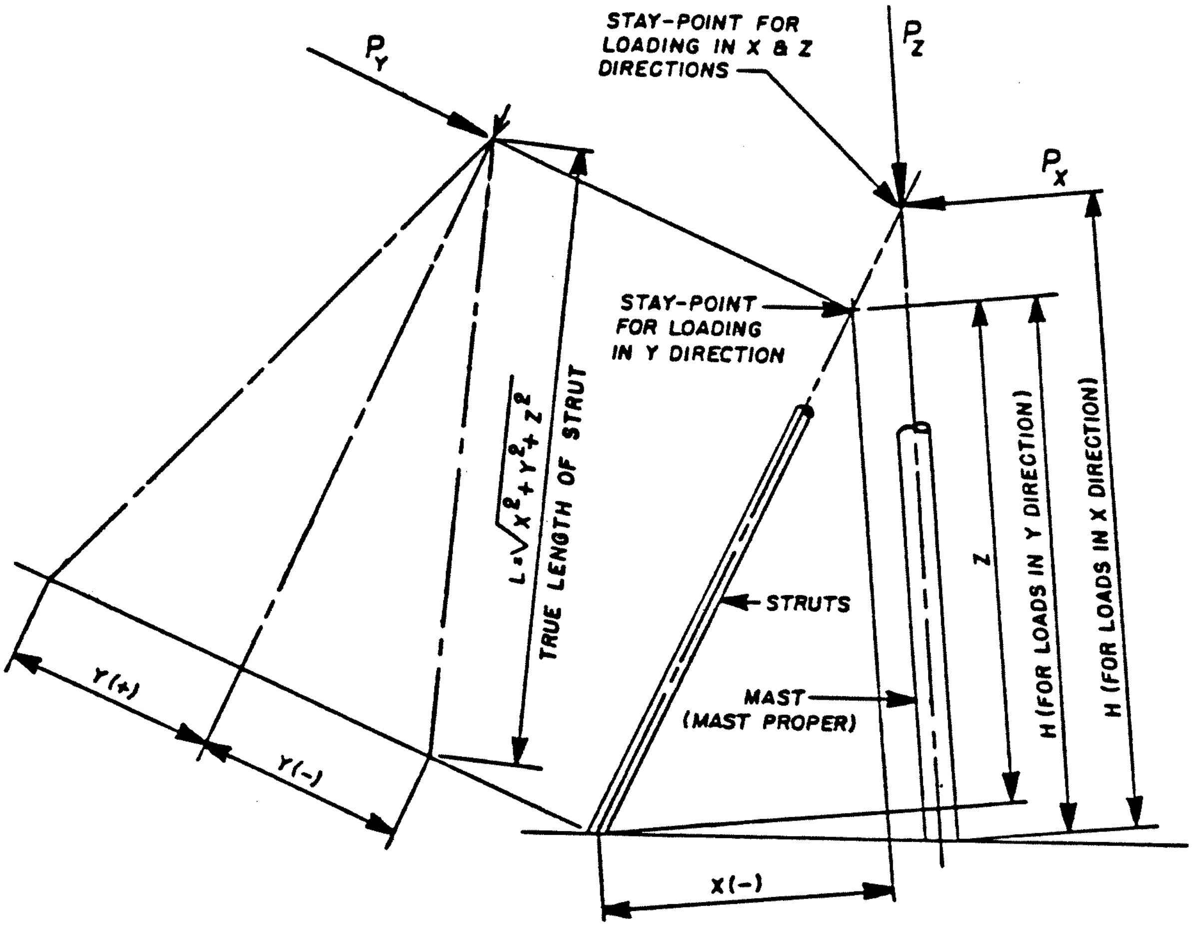


FIGURE 9

Design procedure.- The design procedure to be followed for tripod masts is very similar to that for stayed polemasts and four-legged masts.

The complexity of the structure suggests the use of a computer program for the stress analysis. The initial member sizes are selected and their configuration is modeled and analyzed using the design criteria of section 170-0-e. Member size is then adjusted to meet the stress requirements. The design procedure for the tripod mast is similiar to the procedure outlined in the Appendix D example.

170-0-1. Four-Legged Masts

Description of structure.- A four-legged mast consists of four nearly vertical members joined together by horizontal and diagonal bracing. The four trusses formed by the members provide fairly rigid support. Such a structure is suitable for carrying radar antennas and other equipment which cannot be concentrated within a small area. The advantage of a four-legged mast over a polemast or tripod is that the principal forces and moments, including torsional effects, are resisted by axial reactions in the members. Bending moments are substantially reduced.

Arrangement of members.- Figure 10 shows four arrangements of bracing.

Figure 10(A), with diagonals only, is the simplest and probably the most efficient in resisting the loads on the mast as a whole. Where horizontals are needed for support of platforms and equipment, or to reduce the slenderness ratio of the legs, they can be incorporated in the trusses as in Figure 10(B). The only axial stresses in the horizontal members come from the point loads at their ends.

In Figure 10(C), the horizontal members are more heavily loaded, while stresses in the legs and diagonals are unchanged. A possible advantage of this arrangement is the smaller number of members connected at a single joint.

With the K-bracing of Figure 10(D), the lengths of the diagonal members are reduced, but their number is increased, and the joint at the middle of the horizontal member is undesirable.

In all cases, a joint must be supported in both the athwartship and fore-and-aft planes to be considered an effective panel point.

Design procedure.- The analysis procedure for a four-legged mast is similar to the previously discussed structures; see four-legged mast example in Appendix D.

The following is a brief outline of the steps to use in designing the four-legged mast using a computer analysis:

STEP 1: Develop a mast configuration compatible with the equipment to be mounted, including the first estimate of the member size.

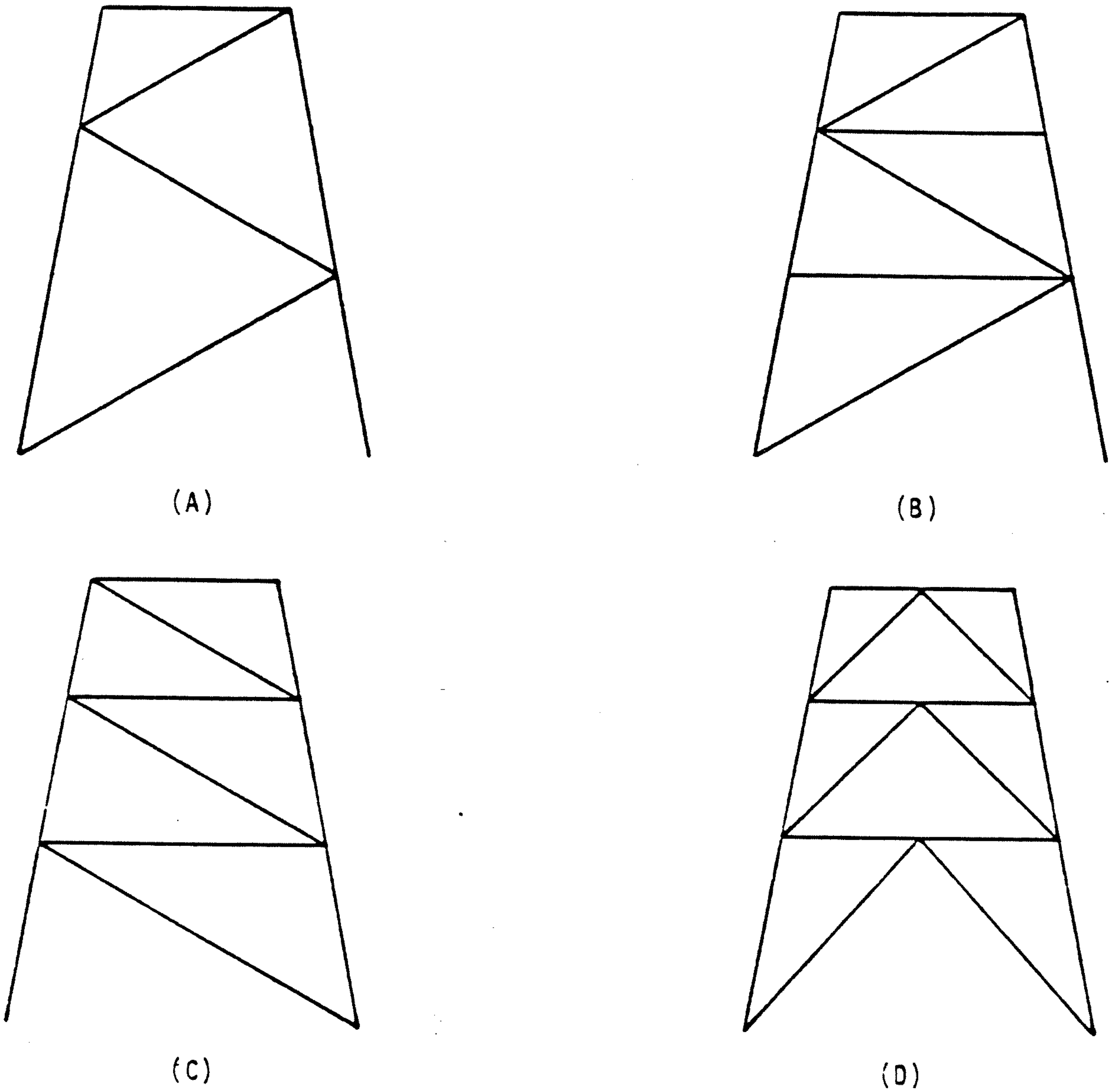
STEP 2: Model the structure using the procedure outlined in Section 170-4-n.

STEP 3: Apply the loads to the structure and check the stress levels in the members, and determine its natural frequency.

STEP 4: Resize the member to balance and reduce the stresses to the desired levels, and change the mast's natural frequency.

STEP 5: Repeat steps 2 through 4 until the desired stress level and natural frequency is reached.

STEP 6: Check the restraint points to ensure that the joints and supports are adequate.



(A) (B) (C) (D)

FIGURE 10

PART IV. USE OF THE COMPUTER IN MAST ANALYSIS AND DESIGN

170-0-m. Introduction to NASTRAN

A large number of computer programs have been developed to aid the engineer in design and analysis of structures. The selection of the proper program for a particular application is dependent on a number of factors, including size and complexity of structure, output data required, and availability of programs. This document does not recommend one program over another, but presents NASTRAN as one example of the typical programs available. The selection of the proper program for each design situation is left to the individual engineer. See reference 9 for a more complete list of available programs.

NASTRAN uses a lumped element approach. The distributed physical properties of a structure are represented by a model consisting of a finite number of idealized substructures or elements that are connected at a finite number of grid points, to which loads are applied. The grid points form the basic framework for the structural model. All other parts of the structural model are referenced either directly or indirectly to grid points.

Various kinds of restraints can be applied to the grid points. Singlepoint constraints are used to specify boundary conditions, including enforced displacements of grid points.

Static loads may be applied directly to the structural model as concentrated loads at grid points, pressure loads on surfaces, or indirectly, by means of mass and thermal expansion properties of structural elements.

NASTRAN has various structural elements in its library to model the structure. These include BAR elements (resists axial, bending, shear, and torsion), ROD elements (resists axial and torsion), and various plate elements. Connectivity and orientation is specified by data cards prefixed by C (CBAR, CROD). Element properties (cross-section area, moment of inertia, etc.) are specified by data cards prefixed by P (PBAR, PROD, etc.). The property card in turn refers to a material card which gives the material properties. See reference 13 for more detailed information for using NASTRAN.

170-0-n. Modeling

Modeling procedures vary greatly depending on the use for which the model is intended. For traditional stress analysis, a complex model using the available computer program elements to represent the actual structure is used to obtain a good correlation between the computer model and structure. The physical properties of the mast (including material properties, member properties, member and mass locations, and degrees of freedom) are represented in the model. End restraints (supports) and loads are applied to the mast model and the computer develops forces, deflections, and stresses in the model elements. This same model may be used in the vibration analysis to check the acceptability of the structure's natural frequency. Note: Not all finite element analysis programs have Dynamics options which calculate natural frequency. An example of this modeling technique is provided in Appendix D.

Special modeling techniques are required for structures of a very complex nature, or when the result of the vibration analysis are to be used in a high shock design utilizing the Dynamic Design Analysis Method (DDAM). Care must be taken that the number of masses involved in the dynamic analysis be reduced to a minimum consistent with maintaining the accuracy in representing the significant dynamic characteristics of the mast. For vibration analysis, care must be taken that the torsional characteristics of the mast are maintained.

The reduction in model complexity is accomplished by combining model masses. These lumped masses are applied to the model structure at discrete points such that the distributed mass and inertia characteristics of the physical system are adequately represented. This modeling technique is reviewed in more detail in reference 8.

APPENDIX A

SELECTED MEASUREMENT UNITS AND CONVERSION FACTORS

TABLE A: SELECTED SI CONVERSION FACTORS

Category	To Convert From Inch-Pound Units	To SI Units	Multiply By
LENGTH:	foot (ft)	meter (m)	0.3048
	inch (in)	meter (m)	2.540×10^{-2}
	inch (in)	millimeter (mm)	25.4
AREA:	foot^2 (ft^2)	meter^2 (m^2)	9.290×10^{-2}
	inch^2 (in^2)	millimeter^2 (mm^2)	6.452×10^{2}
FORCE:	kip	newton (N)	4.448×10^{3}
	pound-force (lbf)	newton (N)	4.448
MASS:	pound (lb)	kilogram (Kg)	0.454
	ton (long, 2240 lb)	metric ton	1.016
STRESS:	kip/inch^2 (ksi)	pascal (Pa)	6.895×10^{6}
(FORCE/AREA)	poundforce/inch^2 (psi)	pascal (Pa)	6.895×10^{3}

SI makes extensive use of prefixes to form decimal multiples; it officially establishes 16 prefixes. Those 5 prefixes* most frequently used are as follows:

giga	G	$1,000,000,000 = 10^9$
mega	M	$1,000,000 = 10^6$
kilo	k	$1,000 = 10^3$
milli	m	$0.001 = 10^{-3}$
micro	μ	$0.000\ 001 = 10^{-6}$

*See MIL-STD-1690, "Maritime Metric Practice Guide," reference 14.

APPENDIX B

PROPERTIES OF CIRCULAR PIPE SECTIONS

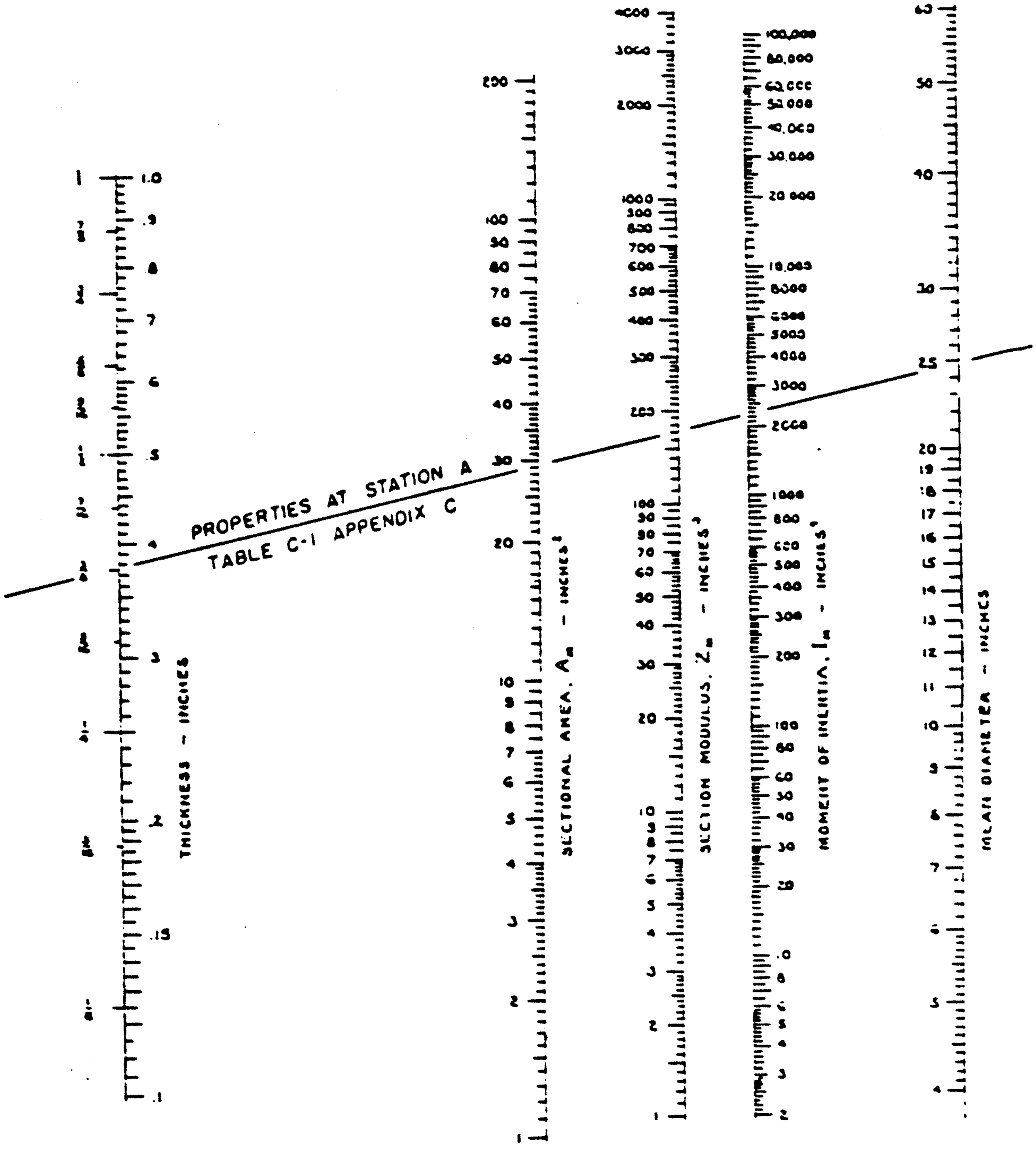


FIGURE B-1

APPENDIX C

EXAMPLE CALCULATION (UNSTAYED POLEMAST)

Introduction

This example calculation is provided to illustrate a typical approach to the design of an unstayed polemast. This approach is also applicable to the initial stages for design of a stayed polemast.

Task Description

Develop new structure to support the following equipment:

1. ABC/94 antenna at the 117 foot level, about frame 120, forty feet, zero inch forward of amidships.
2. ABC/95 antenna at the 105 foot level, about frame 116.

Use the design criteria based on the Ship Specifications for the USS NEVERSAIL.

Equipment Specifications and Design Criteria

1. ABC/94 antenna
   WEIGHT: 1,200 pounds applied at the C.G.
   WIND LOAD: 200 pounds at 90 knots applied at the C.P.
2. ABC/95 antenna
   WEIGHT: 1,600 pounds applied at the C.G.
   WIND LOAD: 1,000 pounds at 90 knots applied at the C.P.
3. LOADINGS (from Ship Specifications)
   a. WIND LOAD: 30 lb/ft^2 of projected area
   b. SNOW AND ICE: Ignored for mast analysis
   c. DYNAMIC FACTORS: (Will differ from ship to ship; see Ship Specifications.)

      LONGITUDINAL: 0.25 +0.035 for each 10 feet above 20-foot waterline
      TRANSVERSE: 0.50 +0.07 for each 10 feet above 20-foot waterline
      +0.02 for each 10 feet forward or aft of amidships
      DOWN: 1.2 +0.035 for every 10 feet forward or aft of amidships

   d. NUCLEAR AIR BLAST: Design to overpressure of 10 PSI (lb/in^2)
4. FACTOR OF SAFETY
   a. 2.5 on yield strength of material for wind and dynamic loads
   b. 1.0 on yield strength of material for nuclear air blast

5. MATERIAL PROPERTIES

Use Mild Steel
For Dynamic and Wind Loads:

$F_y = 32$ KSI (MIL-S-22698)

$$\text{allowable } f_B = \frac{F_y}{F.S.} = 32\ \frac{KSI}{2.5} = 12.8 \text{ KSI}$$

For Air Blast:

allowable $f_B = F_y = 32$ KSI

Analysis

STEP 1: Develop a mast compatible with the equipment to be mounted. Include the first estimate of the member size (see Figure C-1).

STEP 2: Develop a model dividing the structure into stations at changes in section, or at the quarter points, as a minimum (see Figure C-2).

STEP 3: Obtain the properties of the member from Appendix B, by direct calculations, or from a handbook; see Table C-1.

STEP 4: Develop Table C-2 (Summary of forces and physical data) with the data developed from the design criteria loadings and mast arrangements.

a. Indicate item designation (letter or number) in "Item" column.
b. Indicate item or mast section weights in "Weight" column.
*c. Compute longitudinal and transverse factor at mid span of each section (at C.G. for equipment).
*d. Multiply factors by weight to obtain longitudinal and transverse forces.
e. Multiply the projected area by wind and air blast effective dynamic pressure to obtain the wind and air blast forces.

* Asterisked items are applicable to equipment

Equipment Only: Multiply the blast pressure by the projected area to obtain the air blast force. (An approximate projected area may be obtained by dividing the wind force, at 90 knots, by 30 lb/ft^2.) The center of pressure for wind loads of most radar antennae differs from its center of gravity.

REPEAT STEPS a. THROUGH e. FOR EACH SECTION

STEP 5: Tabulate the moments as in Table C-3 and C-4. *Asterisked items are applicable to equipment.

*a. Indicate item designation (letter or number) at mid span of section in "Item" column.

*b. Sum previous items weights in "Force" column.

c. Indicate distance to centroid of section or equipment, above nearest station, in "Lever" column. Indicate distance between end points, in "Lever" column, for "Force" above section.

d. Multiply section lever by vertical, longitudinal, transverse, wind, and air blast force sums. Indicate those values in the appropriate moment column.

e. Sum previous vertical, longitudinal, transverse, wind, and blast forces and moments.

REPEAT STEPS a. THROUGH e. FOR EACH SECTION

(Add platform moments, if any, at mast juncture level.)

<u>STEP 6</u>: Combine the bending moments and determine the maximum stresses as in Table C-5.

<u>STEP 7</u>: Resize the members to suit the stress levels, and repeat steps 3 through 6 until suitable stress levels are reached.

<u>STEP 8</u>: Check vibration (natural frequency), and adjust structure accordingly.

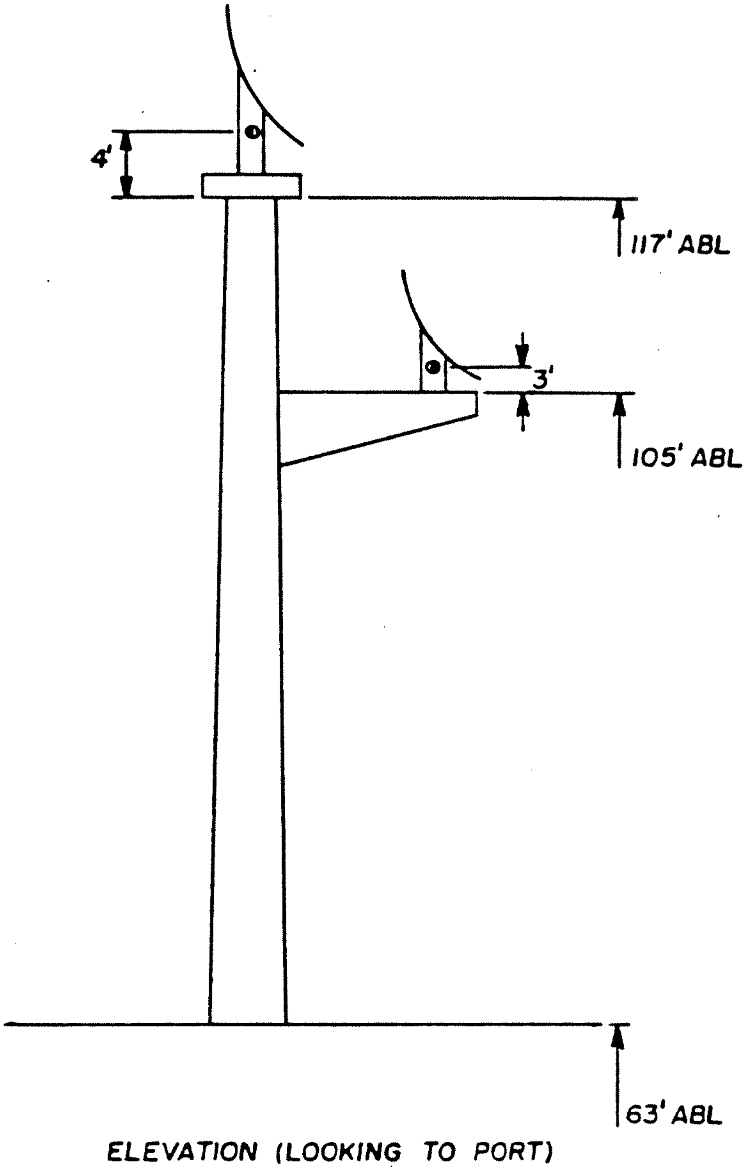
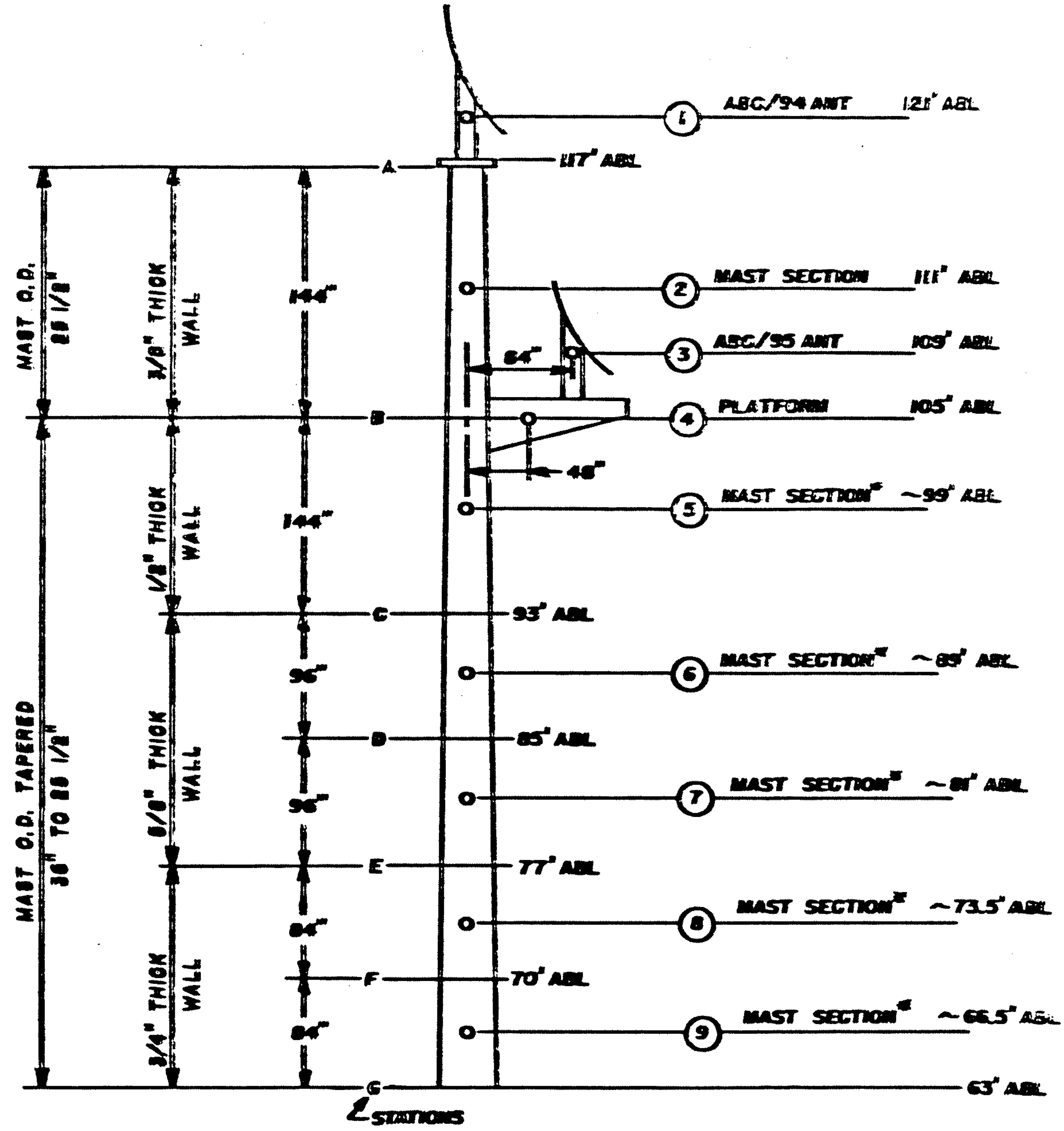


FIGURE C-1



*C.G. of tapered sections assumed at midheight

ELEVATION (LOOKING TO PORT)
MAST MODEL

FIGURE C-2

TABLE C-1: CHARACTERISTICS OF MAST

STATION		THICKNESS INCHES	OUTSIDE DIA. INCHES	MATERIAL	SECTION AREA Am (IN^2)	SECTION MODULUS Zm (IN^3)	MOM. OF INERTIA Im (IN^4)	UNIT WEIGHT* (LBS/FT)
A								
	BELOW	$\frac{3}{8}$	$25\frac{1}{2}$	MS	$29\frac{1}{2}$	175	2,300	125
B	ABOVE	$\frac{3}{8}$	$25\frac{1}{2}$		$29\frac{1}{2}$	175	2,300	125
	BELOW	$\frac{1}{2}$	$25\frac{1}{2}$		39	240	3,100	160
C	ABOVE	$\frac{1}{2}$	$28\frac{1}{2}$		44	300	4,400	170
	BELOW	$\frac{5}{8}$	$28\frac{1}{2}$		55	370	5,300	210
D	ABOVE	$\frac{5}{8}$	$30\frac{1}{2}$		59	430	6,500	230
	BELOW	$\frac{5}{8}$	$30\frac{1}{2}$		59	430	6,500	230
E	ABOVE	$\frac{5}{8}$	$32\frac{1}{2}$		63	490	8,000	240
	BELOW	$\frac{3}{4}$	$32\frac{1}{2}$		75	580	9,400	280
F	ABOVE	$\frac{3}{4}$	$34\frac{1}{4}$		79	650	11,000	290
	BELOW	$\frac{3}{4}$	$34\frac{1}{4}$		79	650	11,000	290
G	ABOVE	$\frac{3}{4}$	36		83	720	13,000	310
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							

*UNIT WEIGHT = Am X 3.4 (FOR STEEL) PLUS ALLOWANCES FOR FITTINGS ETC. @25 LB/FT.

TABLE C-2: SUMMARY OF FORCES AND PHYSICAL DATA

ITEM	PHYSICAL DATA				DYNAMIC LOADS						PRESSURE LOADS		
					VERTICAL		LONGITUDINAL		TRANSVERSE		WIND	BLAST	
	WEIGHT	MAXIMUM PROJECTED AREA	CENTER OF GRAVITY ABV BL	CENTER OF AREA ABV BL	FACTOR	FORCE	FACTOR	FORCE	FACTOR	FORCE	DRAG FORCE	EFFECTIVE DYNAMIC PRESSURE	DRAG FORCE
	LBS	SQ. FT	FT	FT		LBS		LBS		LBS	LBS	Lb/in^2	LBS
--ABV A--													
ABC/94 ANT	1200	—	121.0	123.2	1.34	1608	0.61	724	1.29	1,544	200	2.21	2,120
--A-B--												↓	
MAST SECTION	1500	25.5	111.0	111.0	1.34	2010	0.57	853	1.22	1,826	765	↓	8,100
ABC/95 ANT	1600	—	109.0	110.7	1.36	2183	0.56	898	1.22	1,947	1000	↓	10,600
PLATFORM	980	22.5	105.0	105.3	1.35	1327	0.55	537	1.18	1,159	330	4.42	7,000
--B-C--													
MAST SECTION	1980	27.0	~99.0	99.0	1.34	2653	0.53	1042	1.13	2,243	810	2.21	8,600
--C-D--												↓	
MAST SECTION	1760	19.7	~89.0	89.0	1.34	2358	0.49	865	1.06	1,871	590	↓	6,260
--D-E--												↓	
MAST SECTION	1880	21.0	~81.0	81.0	1.34	2519	0.46	871	1.01	1,893	630	↓	6,680
--E-F--												↓	
MAST SECTION	1995	19.5	~73.5	73.5	1.34	2673	0.44	872	0.95	1,904	584	↓	6,200
--F-G--												↓	
MAST SECTION	2100	20.5	~66.5	66.5	1.34	2814	0.41	861	0.90	1890	615	↓	6,500

TABLE C-3: MOMENT TABULATION OF DYNAMIC LOADS

ITEM	MOMENTS DUE TO DYNAMIC LOADING										
	VERTICAL					LONGITUDINAL			TRANSVERSE		
	FORCE	ECCENTRICITY PORT (-) STBD (+)	MOMENT (X 10³)	ECCENTRICITY FWD (-) AFT (+)	MOMENT (X 10³)	FORCE	LEVER ABV STA	MOMENT	FORCE	LEVER ABV STA	MOMENT
	LBS	IN.	IN. – LBS	IN.	IN. – LBS	LBS	IN.	IN.-LBS(X10³)	LBS	IN.	IN.-LBS(X10³)
—·ABOVE A·—											
ABC/94 ANT	1,608					724	48	34.75	1,544	48	74.11
A- TOTAL	1,608		0		0	724 ↘	Σ→	34.75	1,544 ↘	Σ→	74.11
—A-B—							144 →	104.26		144 →	222.34
MAST SECTION	2,010					853 →	72 →	61.42	1,826 →	72 →	131.47
ABC/95 ANT	2,183			-84	-183.4	898 →	48 →	43.10	1,947 →	48 →	93.46
PLATFORM	1,327			-48	-63.7	537 →	0 →	0	1,159 →	0 →	0
B- TOTAL	7,128		0		-247.1	3,012 ↘	Σ→	243.53	6,476 ↘	Σ→	521.38
—B-C—							144	433.73		144 →	933.54
MAST SECTION	2,653					1,042 →	72 →	75.02	2,243 →	72 →	161.50
C- TOTAL	9,781		0		-247.1	4,054	Σ→	752.28	8,719	Σ→	1615.42
—C-D—							96	389.18		96	837.02
MAST SECTION	2,358					865	48	41.52	1,871	48	89.81
D- TOTAL	12,139		0		-247.1	4,919		1,182.98	10,590		2,542.25
—D-E—							96	472.22		96	1016.64
MAST SECTION	2,519					871	48	41.81	1,893	48	90.86
E- TOTAL	14,658		0		-247.1	5790		1,697.01	12,483		3,649.75
—E-F—							84	486.36		84	1048.57
MAST SECTION	2673					872	42	36.62	1904	42	79.97
F- TOTAL	17,331		0		-247.1	6662		2219.99	14,387		4778.29
—F-G—							84	559.61		84	1208.51
MAST SECTION	2814					861	42	36.16	1890	42	79.38
G- TOTAL	20,145		0		-247.1	7523		2815.76	16,277		6,066.18
TOTAL	20,145	0	0	-12.56	-247.1	7523		2815.76	16,277		6,066.18

TABLE C-4: MOMENT TABULATION OF PRESSURE LOADS

ITEM	MOMENTS DUE TO PRESSURE LOADING					
	WIND LOADING			BLAST LOADING		
	FORCE	LEVER ABV STA	MOMENT	FORCE	LEVER ABV STA	MOMENT
	LBS	IN.	X10^3 IN.-LBS	LBS	IN.	X 10^3 IN.-LBS
ABOVE A						
ABC/94 ANT	200	48	9.60	2,120	48	101.8
A-TOTAL	200		9.60	2,120		101.8
—A-B—		144	28.80		144	305.28
MAST SECTION	765	72	55.1	8,100	72	583.2
ABC/95 ANT	1000	48	48.0	10,600	48	508.8
PLATFORM	300	0	0	14,320.	0	0
B-TOTAL	2265		141.50	35,140		1499.1
—B-C—		144	326.16		144	5060.16
MAST SECTION	810	72	58.3	8,600	72	619.2
C-TOTAL	3,075		525.96	43,740		7178.44
—C-D—		96	295.20		96	4,199.04
MAST SECTION	590	48	28.3	6,260	48	3,00.5
D-TOTAL	3665		849.46	50,000		11,677.98
—D-E—		96	351.84		96	4,800.
MAST SECTION	630	48	30.2	6,680	48	320.6
E-TOTAL	4,295		1231.50	56,680		16,798.6
—E-F—		84	360.78		84	4,761.1
MAST SECTION	584	42	24.5	6,200	42	260.4
F-TOTAL	4,879		1616.78	62,880		21,820.08
—F-G—		84	409.84		84	5,281.9
MAST SECTION	615	42	25.8	6,500	42	273.0
G-TOTAL	5,494		2,052.42	69,380		27,374.98
TOTAL	5,494		2,052.42	69,380		27,374.98

TABLE C-5: STRESSES IN MAST

STA	BENDING MOMENTS: INCH-KIPS						AXIAL LOADS P_A (KIPS)
	LONG. * M_L	TRANSV. * M_T	RESULTANT M_R $(M_L^2+M_T^2)^{1/2}$	WIND M_W	TOTAL M (M_R+M_W)	AIR BLAST M_B	
A	34.75	74.11	81.85	9.6	91.45	101.8	1.608
B	490.63	521.38	715.93	141.5	857.43	1499.1	7.128
C	999.38	1615.42	1899.56	525.96	2425.52	7178.44	9.781
D	1430.08	2542.25	2916.88	849.46	3766.34	11677.98	12.139
E	1944.11	3649.75	4135.24	1231.5	5366.74	16798.55	14.653
F	2467.09	4778.29	5377.60	1616.78	6994.38	21820.08	17.331
G	3062.86	6066.18	6795.56	2052.42	8847.98	27374.98	20.145

STA	SECTION AREA A_M	SECTION MODULUS Z_M	STRESS: KIPS/INCH^2					
			BENDING M/Z_M	DIRECT P_A/A_M	TOTAL $M/Z_M + P_A/A_M$	ALLOW	BENDING (BLAST) M_S/Z_M	ALLOW
A	29.5	175	.52	.05	.57	12.8	.59	32.
B	29.5	175	4.90	.24	5.14	↓	8.57	↓
C	44	300	8.09	.22	8.31	↓	23.93	↓
D	59	430	8.76	.21	8.97	↓	27.16	↓
E	63	490	10.95	.23	11.18	↓	34.28	↓
F	79	650	10.76	.22	10.98	↓	33.57	↓
G	83	720	12.29	.24	12.53	↓	38.02	↓

Note: The stresses at stations E, F, G, (Bending, Blast), exceed the allowable, 32. The analysis could be completed again to reduce this stress by either increasing the section at E, F, G or reducing the size of the upper mast sections to reduce the Blast reaction at E, F, G.

APPENDIX D

EXAMPLE CALCULATION (FOUR-LEGGED MAST)

Introduction

This example calculation is provided to illustrate a typical approach to the design of a four-legged mast. The approach is also applicable to the design of a polemast, stayed polemast, or tripod mast, with variations in the model.

Task Description

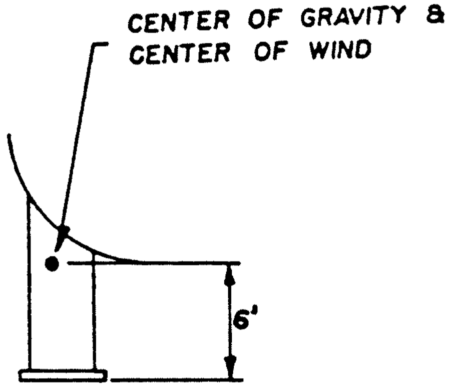
Develop new structure to support the following equipment:

1. ABC/99 Ant at the 100 foot level, about FR 125.
2. ABC/98 Ant at the 124 foot level, about FR 129.

Use design criteria based on the Ship Specifications for the USS NEVERSAIL.

Equipment Specifications and Design Criteria

1. ABC/99 Ant

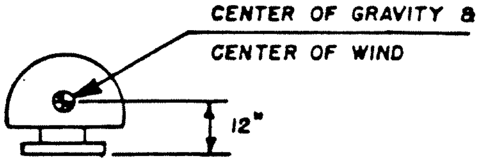


WEIGHT: 6,000 pounds

WIND LOAD: 3,000 pounds at 90 knots

MOUNTING EQUIPMENT: Base stiffness of 75,000 lb/in horizontal

2. ABC/98 Ant



WEIGHT: 400 pounds

WIND LOAD: 110 pounds at 90 knots

MOUNTING REQUIREMENTS: No special requirements

3. LOADING: (From Ship Specifications)

   a. WIND LOAD: 30 lb/ft^2 of projected area
   b. SNOW AND ICE: Ignored for mast analysis
   c. DYNAMIC FACTORS: (Will vary from ship to ship; see Ship Specifications)

LONGITUDINAL: 0.25 +0.035 for each 10 feet above 20-foot waterline

TRANSVERSE: 0.50 +0.07 for each 10 feet above 20-foot waterline
+0.02 for each 10 feet forward or aft of amidships

DOWN: 1.3 +0.035 for each 10 feet forward or aft of amidships

d. GRAVITY: Included with dynamic factor
e. NUCLEAR AIR BLAST: Design to overpressure of 10 PSI (lb/in^2)

4. FACTOR OF SAFETY

a. 2.5 for wind and dynamic loads
b. 1.0 for nuclear air blast

5. MATERIAL PROPERTIES

Use 5086-H32 aluminum tubing or 5086-H116 aluminum plate

F_y = 22 KSI (Welded Condition)

Analysis

This analysis pre-supposes the analyst is familiar with NASTRAN as previously discussed in Part IV and reference I3. Definitions of data cards mentioned below are contained in reference I3.

STEP 1: Develop a mast configuration compatible with the equipment to be mounted. Include the first estimate of member size (see Figure D-1) for gravity loadings.

STEP 2: Model the structure using the procedure outlined in Section 170-I-m. Prepare the data cards. (Data cards required include GRID, CBAR, PBAR, MAT1.) (See Figures D-2 and D-3.)

STEP 3: Tabulate the design criteria loads to be applied to the structure and convert these loads to forces at grid points, see Tables D-1 and D-2 (similar to the analysis method in Table C-2). Prepare the data cards for this information. (Requires the control cards, "FORCE" and "GRAV".)

NOTE 1: This analysis assumes that the vertical dynamic load is constant throughout the structure. This load is applied using a modified "GRAV" input with an appropriate increase for dynamic acceleration.

NOTE 2: These loads will be combined by the computer to check the various loading combinations.

STEP 4: Determine the load combinations to be checked and the desired output. (Requires the case control cards "SUBCOM" and "SUBSEQ".)

STEP 5: Submit the data to the computer terminal for analysis.

STEP 6: Obtain the computer analysis of the data.

STEP 7: Check the stress levels in the members, including a check for buckling. Check the stiffness properties of the antenna base if it is required. (See sheets D-23 and D-24 for stiffness check and sheet D-11 for buckling check.)

STEP 8: Resize the members to balance and reduce the stresses to the desired levels.

STEP 9: Repeat steps 3 through 8 until the desired stress levels are reached.

STEP 10: Check the restraint points to determine that the joints and supports are adequate.

STEP 11: Continue with the vibration analysis and check the results, as discussed in Section 170-1-g. (See Figure D-4 for typical primary mode shapes.)

MEMBER	SECTION*	$A(in^2)$	l_1 in4**	l_2 in4**
1.	6" OD X 1/2" WALL TUBE	8.64	33.	33.
2.	7" OD X 3/8" WALL TUBE	7.8	43.	43.
3.	12" OD X 7/8" WALL TUBE	30.58	476.	476.
4.	10 1/2" OD X 1/2" WALL TUBE	15.71	197.	197.
5.	24" OD X 3/4" WALL TUBE	54.78	3700.	3700.
6.	14" X 12" X 1/2" WALL BOX BEAM	25.0	730.	574.

* ALUMINUM

** HERE, l_1 is l_{vert}, l_2 is l_{horiz}

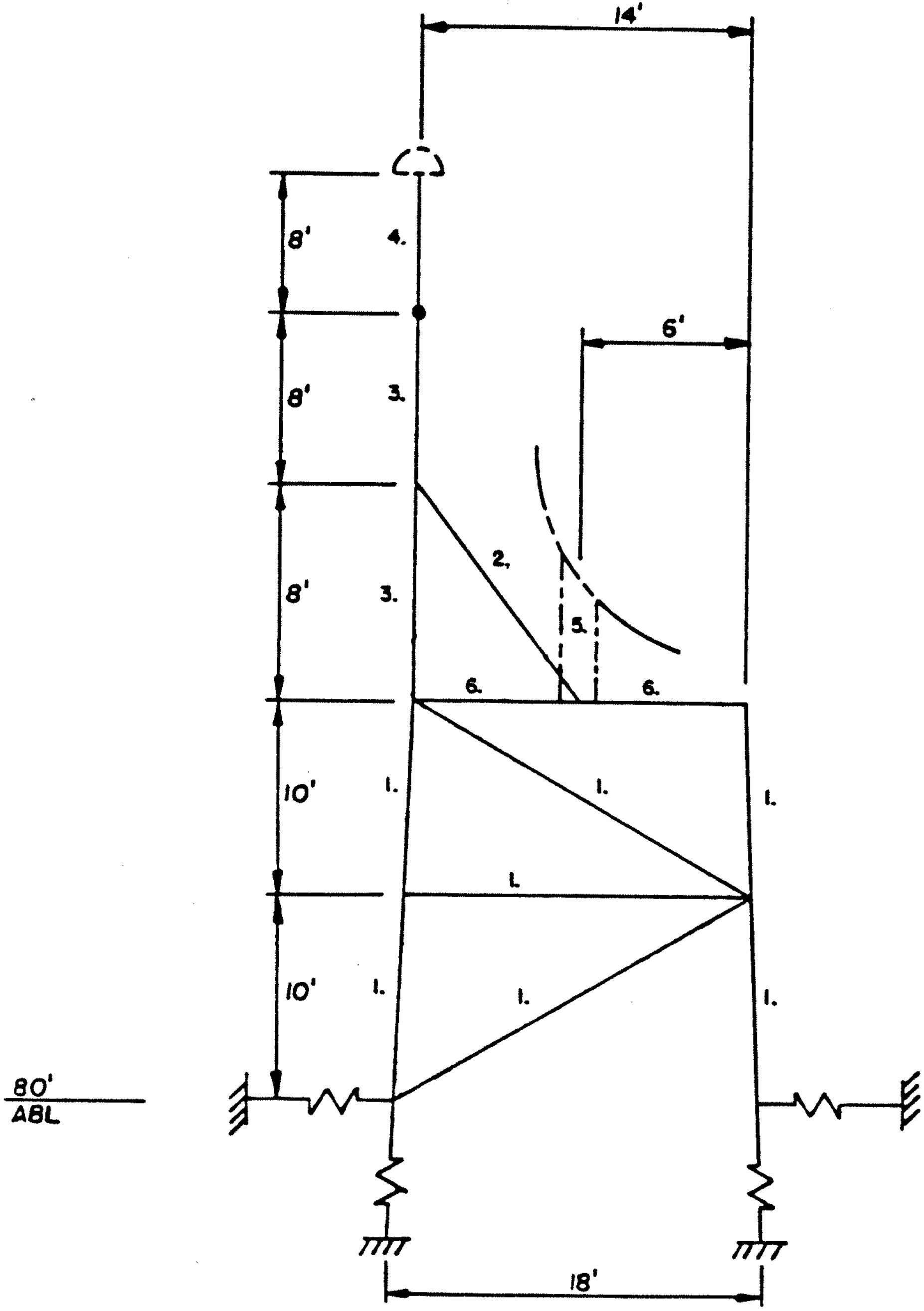


FIGURE D-1

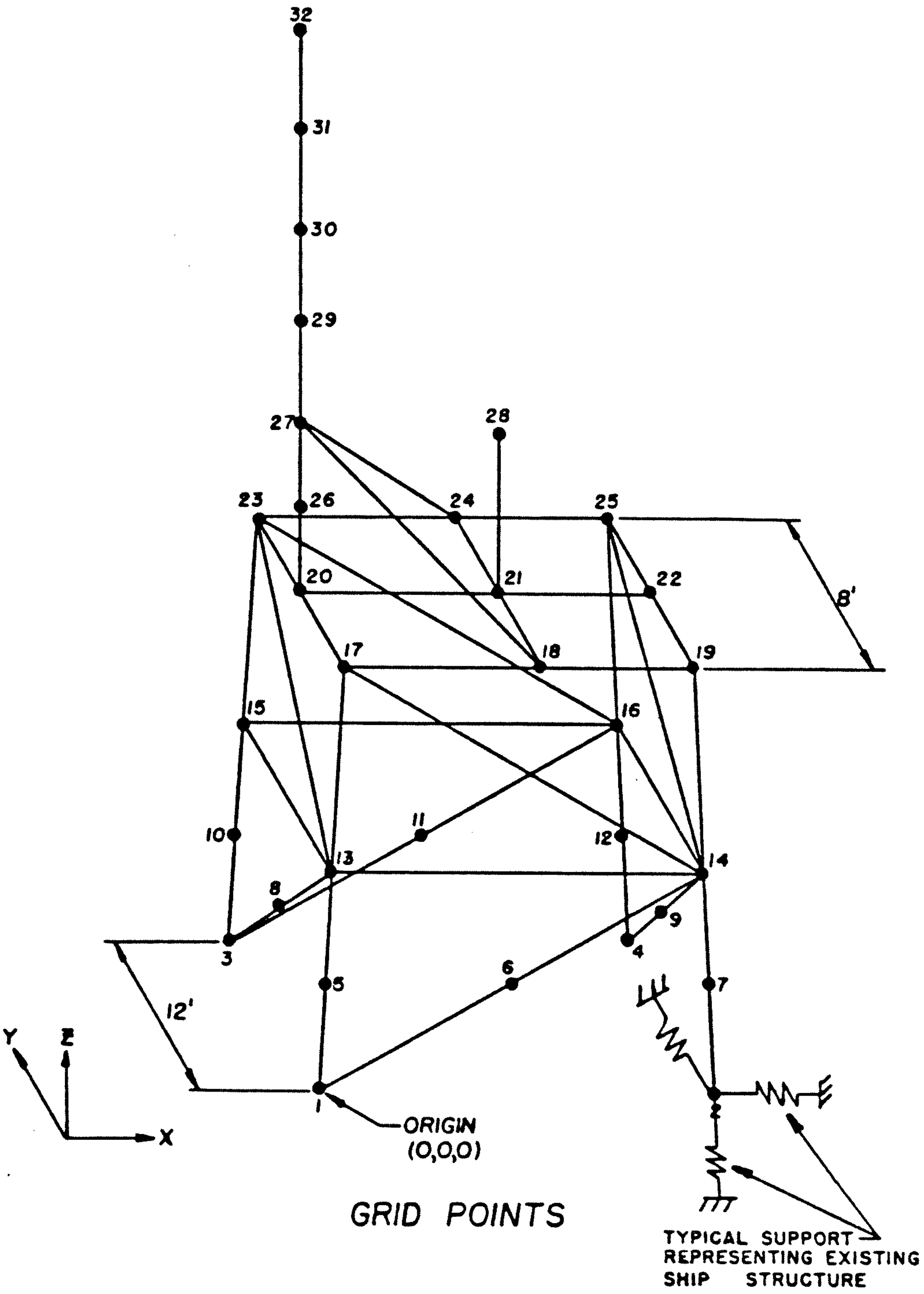
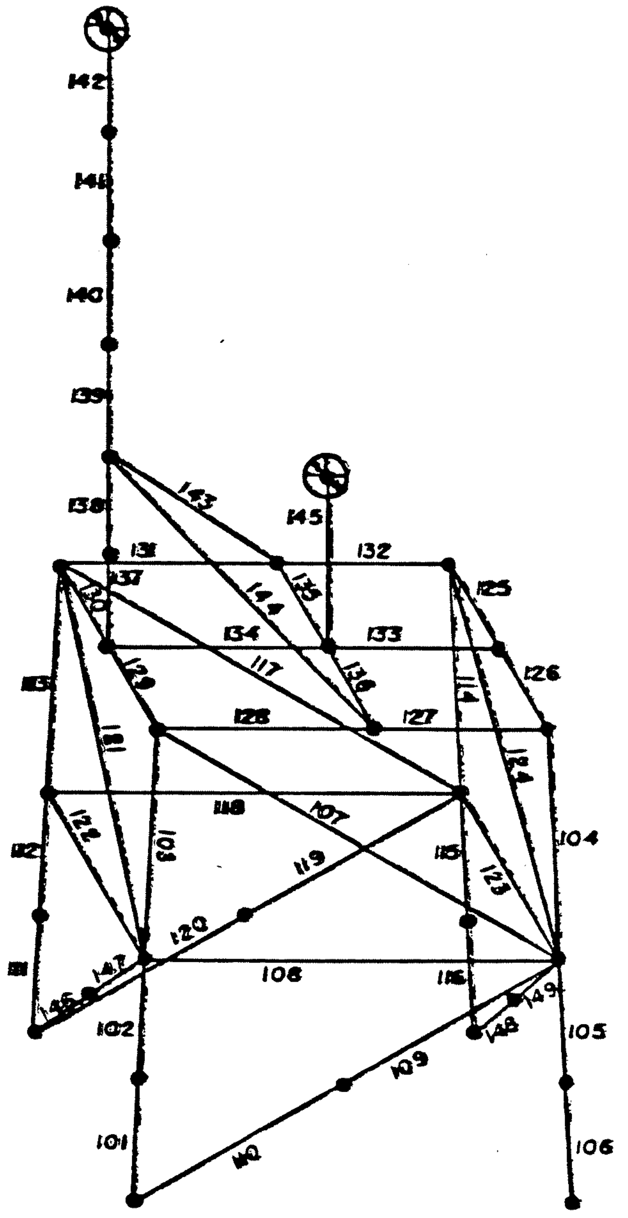

32
31
30
29
27
28
23
26
24
25
20
21
22
8'
17
18
19
15
16
10
11
12
13
14
8
3
9
4
5
6
7
12'
Y
Z
X
1
ORIGIN (0,0,0)
GRID POINTS
TYPICAL SUPPORT REPRESENTING EXISTING SHIP STRUCTURE

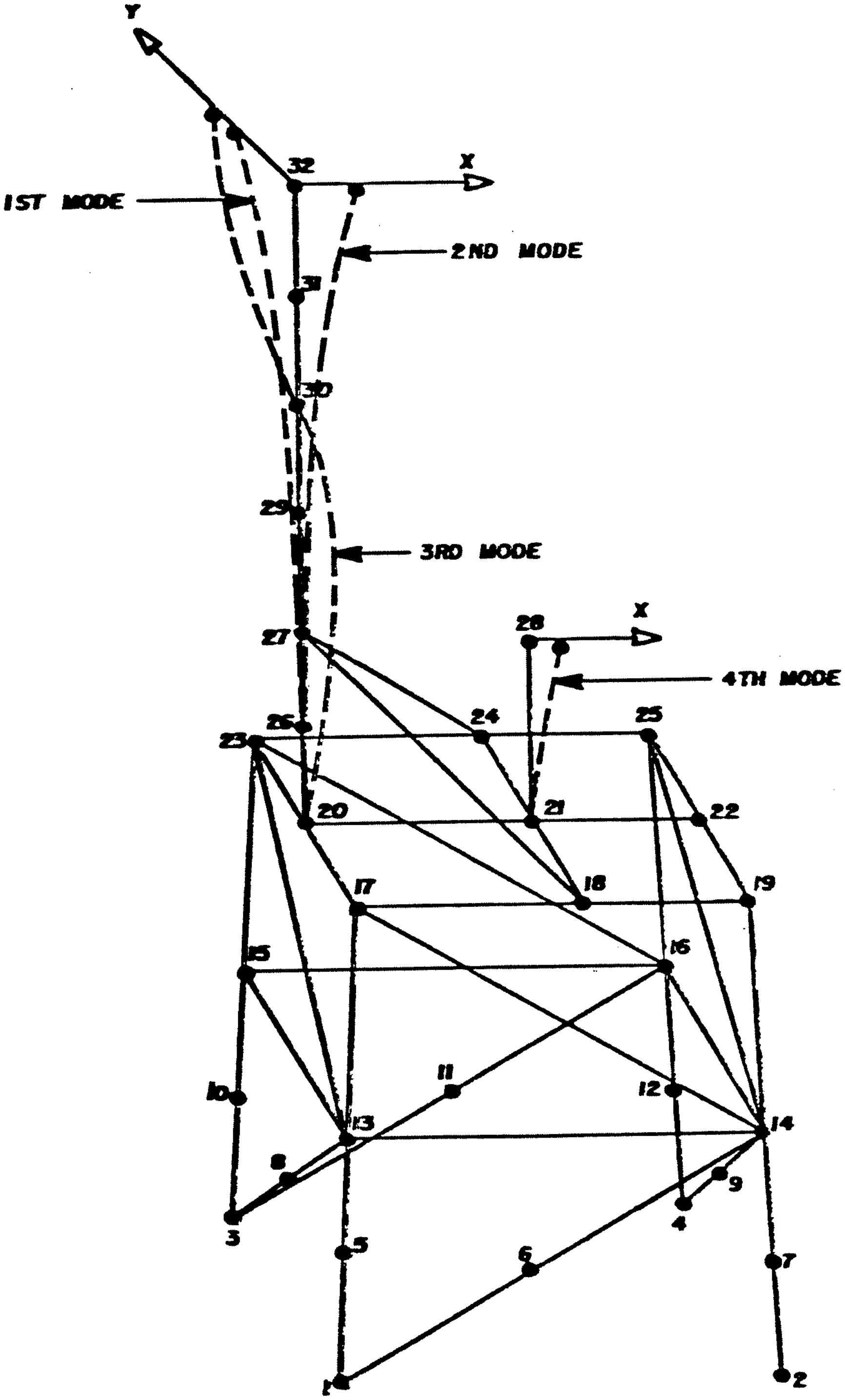
FIGURE D-2



BAR ELEMENTS

FIGURE D-3

NOTE: Relative displacements of truss structure are very small and are not shown on this Figure. See sheets D-42 thru D-45 for relative displacement.



PRIMARY MODE SHAPES

FIGURE D-4

TABLE D-1: SUMMARY OF LOADS

ITEM OR BAR ELEMENT	PHYSICAL DATA				DYNAMIC LOADS*				PRESSURE LOADS						
	WEIGHT	END POINTS		CENTER OF GRAVITY ABV. REF.	LONG		TRANSV		PROJECTED AREA		WIND LOAD		AIR BLAST LOAD §		
		FROM	TO		FACTOR	FORCE	FACTOR	FORCE	LONG	TRANSV	LONG	TRANSV	DRAG COEF	LOAD LONG	LOAD TRANSV
	POUNDS	—	—	FEET	—	LBS	—	LBS	FT²	FT²	LBS	LBS	—	LBS	LBS
BAR 101	51.31	1	5	82.5	.54	27.64	1.12	57.36	2.51	2.51	75.37	75.37	1.0	796	796
102	51.31	5	13	87.5	.56	28.54	1.15	59.21	2.51	2.51	75.37	75.37	↓	796	796
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
110	100.32	1	6	82.5	.54	54.05	1.13	112.96	2.51	4.93	75.37	147.92	1.0	796	1562
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
138	124.68	26	27	106.0	.62	77.43	1.29	160.34	4.00	4.00	120.0	120.0	1.0	1267	1267
139	124.68	27	29	110.0	.64	79.17	1.31	163.83	4.00	4.00	120.0	120.0		1267	1267
140	124.68	29	30	114.0	.65	80.92	1.34	167.32	4.00	4.00	120.0	120.0		1267	1267
141	73.88	30	31	118.0	.66	48.98	1.37	101.22	3.50	3.50	105.0	105.0		1109	1109
142	73.88	31	32	122.0	.68	50.02	1.40	103.28	3.50	3.50	105.0	105.0		1109	1109
143	110.15	24	27	104.0	.61	67.63	1.28	140.99	5.22	6.60	156.5	199.0		1653	2091
144	110.15	18	27	104.0	.61	67.63	1.28	140.99	5.22	6.60	156.5	198.0	↓	1653	2091
145	—	21	28	—	—	—	—	—	—	—	—	—	—	—	—
ABC/98 ANT	400.	32	–	124.0	.71	284	1.45	581.6	–	–	110	110	–	1162	1162
ABC/99 ANT	6000.	21	–	106.0	.62	3220	1.31	7860	–	–	3000	3000	–	31680	31680

* VERTICAL DYNAMIC LOADING IS PROVIDED BY A GRAVITY INPUT ADJUSTED FOR THE DYNAMIC LOAD.

§ BLAST LOAD = PROJECTED AREA X DYNAMIC PRESSURE X DRAG COEFFICIENT (SEE TABLE 1).

TABLE D-2: SUMMARY OF FORCES AT GRID POINTS

GRID POINT	ITEMS OR CONNECTING BARS	SUM OF DYNAMIC LOADS (POUNDS)*		SUM OF WIND LOADS (POUNDS)*		SUM OF BLAST LOADS (POUNDS)*	
		LONG	TRANSV	LONG	TRANSV	LONG	TRANSV
1	101, 110	40.85	85.16	75.37	111.65	796.	1179.
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
27	138, 139, 143, 144	145.93	303.08	276.52	317.99	2920.	3358.
28	145, ABC/99 ANT	3720.0	7860.0	3000.	3000.	31680.	31680.
29	139, 140	80.05	165.58	120.0	120.0	1267.	1267.
30	140, 141	64.95	134.27	112.5	112.5	1188.	1188.
31	141, 142	49.50	102.25	105.0	105.0	1109.	1109.
32	142, ABC/98 ANT	309.01	633.24	162.5	162.5	1716.	1716.

* NOTE: $\frac{1}{2}$ THE LOAD ON ANY BAR ELEMENT IS TRANSFERRED TO EACH END OF THE ELEMENT.

TABLE D 3

BUCKLING CHECK

DYNAMIC LOADING (REQ'D FS ≥ 2.5)

BAR ELEMENT	MEMBER SIZE & PROPERTIES	$r = \sqrt{\frac{I}{A}}$	L IN	C(1)	Fa/Fy (2)	Fy KSI	Fa KSI	fa (3) KSI	fc (3) KSI	$F.S. = \frac{1}{fa/Fa + fb/Fy}$ (4)
124 (SHT D-26)	6" O.D. × ½ THK TUBE $I = 32.94\ IN^4$, $A = 8.64\ IN^2$	1.95 in	237	5.69	0.31	22	6.82	0.90	1.19	4.64 > 2.5
116 (SHT D-28)	SAME AS ABOVE	1.95 in	121.2	2.92	0.74	22	16.3	0.28	2.91	5.29 > 2.5

AIR BLAST (REQ'D FS ≥ 1)

BAR ELEMENT	MEMBER SIZE & PROPERTIES	$r = \sqrt{\frac{I}{A}}$	L IN	C(1)	Fa/Fy (2)	Fy KSI	Fa KSI	fa (3) KSI	fc (3) KSI	$F.S. = \frac{1}{fa/Fa + fb/Fy}$ (4)
121 (SHT D-30)	SAME AS ABOVE	1.95	237	5.69	0.31	22	6.82	1.20	6.13	1.05 > 1.0
101 (SHT D-29)	SAME AS ABOVE	1.95	121.2	2.92	0.74	22	16.3	1.87	10.38	1.89 > 1.0

(1) $C = \frac{KL}{r}\sqrt{\frac{Fy}{E}}$ (FROM DDS 100-4 STRENGTH OF STRUCTURAL MEMBERS SHT 4)

(2) FROM FIG 1 DDS 100-4

(3) FROM COMPUTER OUTPUT SHEETS, NOTE: TENSILE AXIAL LOADS ARE CHECKED AGAINST COMPRESSIVE DESIGN CRITERIA BECAUSE REVERSAL OF APPLIED LOADS WOULD RESULT IN COMPARABLE COMPRESSIVE LOADS.

(4) FROM DDS 1100-3 STRENGTH OF STRUCTURAL MEMBERS, 7 MAR 1956

CDC 6000 SERIES
6400 / 6500

RIGID FORMAT SERIES P

LEVEL 17.5.1

SYSTEM GENERATION DATE -

APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS

```
                                                           OCTOBER  11, 1979   NASTRAN  8/15/79

    N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O


  ID GRUNENFELDER, CODE 250.5
  $PUNCH NONE
  $SEQUENCE YES
  $GRID 32
  APP DISP
  SOL 1,0
  TIME 10
  CEND
```

APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

```
                                                      OCTOBER  11, 1979   NASTRAN  8/15/79


                          C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      TITLE=APPENDIX D-EXAMPLE PROBLEM-STRESS ANALYSIS(MAST)
  2      $   SUBCASES 1 THRU 7 IDENTIFY LOADS TO BE APPLIED TO THE MAST
  3      SUBCASE 1
  4      LABEL=DYNAMIC LOADS LONGITUDINAL
  5      LOAD=1000
  6      $     SEE THE APPROPRIATE  FORCE  CARDS IN BULK DATA FOR LOADINGS
  7      SUBCASE 2
  8      LABEL=DYNAMIC LOADS TRANSVERSE
  9      LOAD=2000
 10      SUBCASE 3
 11      LABEL=DYNAMIC LOADS VERTICAL (INCLUDE GRAVITY)
 12      LOAD=3000
 13      SUBCASE 4
 14      LABEL=WIND LOAD LONGITUDINAL
 15      LOAD=4000
 16      SUBCASE 5
 17      LABEL=WIND LOAD TRANSVERSE
 18      LOAD=5000
 19      SUBCASE 6
 20      LABEL=AIR BLAST LONGITUDINAL
 21      LOAD=6000
 22      SUBCASE 7
 23      LABEL=AIR BLAST TRANSVERSE
 24      LOAD=7000
 25      $   SUBCASE 8 AND 9 ARE USED TO CHECK ANTENNA BASE STIFFNESS
 26      SUBCASE 8
 27      LABEL=UNIT LOAD AT ABC/99 ANTENNA BASE (LONGITUDINAL)
 28      LOAD=8000
 29      DISP=ALL
 30      SUBCASE 9
 31      LABEL=UNIT LOAD AT ABC/99 ANT (TRANSVERSE)
 32      LOAD=9000
 33      DISP=ALL
 34      $   SUBCOM 10 THRU 15 COMBINE THE PREVIOUS SUBCASES FOR COMBINED LOADINGS
 35      SUBCOM 10
 36      LABEL=DYNAMIC LOADS WITH WIND (LONGITUDINAL)
 37      SUBSEQ=1.0,1.0,1.0,1.0,0.,0.,0.,0.,0.
 38      $   THE SUBSEQ CARD INDICATES WHAT PORTION OF THE PREVIOUS SUBCASES IS INCLUDED
 39      $             IN THE SUBCOM
 40      $   THE FOLLOWING CARDS INDICATE WHAT PRINTED OUTPUT IS DESIRED
 41      SPCFORCE=ALL
 42      STRESS=ALL
 43      OLOAD=ALL
 44      FORCE=ALL
 45      SUBCOM 11
 46      LABEL=DYNAMIC LOADS WITH WIND (TRANSVERSE)
 47      SUBSEQ=1.0,1.0,1.0,0.,1.0,0.,0.,0.,0.
 48      SPCFORCE=ALL
 49      STRESS=ALL
 50      OLOAD=ALL
```

```
APPENDIX D=EXAMPLE PROBLEM=STRESS ANALYSIS(MAST)                    OCTOBER  11, 1979   NASTRAN  8/15/79


                                  C A S E   C O N T R O L   D E C K   E C H O
   CARD
   COUNT
    51        SUBCOM 12
    52        LABEL=DYNAMIC LOADS WITH WIND AT 45 DEGREES
    53        SUBSEQ=1.0,1.0,1.0,.707,.707,0.,0.,0.,0.
    54        SPCFORCF=ALL
    55        STRESS=ALL
    56        OLOAD=ALL
    57        FORCE=ALL
    58        SUHCOM 13
    59        LABEL=AIR BLAST LONG
    60        SUHSEQ=0.0,0.,.75,0.,0.,1.0,0.,0.,0.
    61        SPCFORCE=ALL
    62        STRESS=ALL
    63        OLOAD=ALL
    64        FORCE=ALL
    65        SURCOM 14
    66        LAREL=AIR RLAST TRANSVERSE
    67        SURSEQ=0.,0.,.75,0.,0.,0.,1.0,0.,0.
    68        SPCFORCE=ALL
    69        STRESS=ALL
    70        OLOAD=ALL
    71        FORCE=ALL
    72        SUHCOM 15
    73        LABEL=AIR BLAST AT 45 DEGREES
    74        SUHSEQ=0.,0.,.75,0.,0.,.707,.707,0.,0.
    75        SPCFORCE=ALL
    76        STRESS=ALL
    77        OLOAD=ALL
    78        FORCF=ALL
    79        BEGIN BULK


*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.
```

```
                                S O R T E D   B U L K   D A T A   E C H O
 CARD
 COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
    1-        CBAR    101     200     1       5       .0      1.0     .0      1
    2-        CBAR    102     200     5       13      .0      1.0     .0      1
    3-        CBAR    103     200     13      17      .0      1.0     .0      1
    4-        CBAR    104     200     19      14      .0      1.0     .0      1
    5-        CBAR    105     200     14      7       .0      1.0     .0      1
    6-        CBAR    106     200     7       2       .0      1.0     .0      1
    7-        CBAR    107     200     14      17      .0      .0      1.0     1
    8-        CBAR    108     200     13      14      .0      .0      1.0     1
    9-        CBAR    109     200     14      6       .0      .0      1.0     1
   10-        CBAR    110     200     6       1       .0      .0      1.0     1
   11-        CBAR    111     200     3       10      .0      1.0     .0      1
   12-        CBAR    112     200     10      15      .0      1.0     .0      1
   13-        CBAR    113     200     15      23      .0      1.0     .0      1
   14-        CBAR    114     200     25      16      .0      1.0     .0      1
   15-        CBAR    115     200     16      12      .0      1.0     .0      1
   16-        CBAR    116     200     12      4       .0      1.0     .0      1
   17-        CBAR    117     200     16      23      .0      .0      1.0     1
   18-        CBAR    118     200     15      16      .0      .0      1.0     1
   19-        CBAR    119     200     16      11      .0      .0      1.0     1
   20-        CBAR    120     200     11      3       .0      .0      1.0     1
   21-        CBAR    121     200     13      23      .0      .0      1.0     1
   22-        CBAR    122     200     13      15      .0      .0      1.0     1
   23-        CBAR    123     200     14      16      .0      .0      1.0     1
   24-        CBAR    124     200     25      16      .0      .0      1.0     1
   25-        CBAR    125     203     25      22      .0      .0      1.0     1
   26-        CBAR    126     203     22      19      .0      .0      1.0     1
   27-        CBAR    127     203     19      18      .0      .0      1.0     1
   28-        CBAR    128     203     18      17      .0      .0      1.0     1
   29-        CBAR    129     203     17      28      .0      .0      1.0     1
   30-        CBAR    130     203     20      23      .0      .0      1.0     1
   31-        CBAR    131     203     23      24      .0      .0      1.0     1
   32-        CBAR    132     203     24      25      .0      .0      1.0     1
   33-        CBAR    133     203     22      21      .0      .0      1.0     1
   34-        CBAR    134     203     21      20      .0      .0      1.0     1
   35-        CBAR    135     203     24      21      .0      .0      1.0     1
   36-        CBAR    136     203     21      18      .0      .0      1.0     1
   37-        CBAR    137     201     20      26      .0      1.0     .0      1
   38-        CBAR    138     201     26      27      .0      1.0     .0      1
   39-        CBAR    139     201     27      29      .0      1.0     .0      1
   40-        CBAR    140     201     29      30      .0      1.0     .0      1
   41-        CBAR    141     205     30      31      .0      1.0     .0      1
   42-        CBAR    142     205     31      32      .0      1.0     .0      1
   43-        CBAR    143     202     27      24      .0      .0      1.0     1
   44-        CBAR    144     202     27      18      .0      .0      1.0     1
   45-        CBAR    145     204     21      28      .0      1.0     .0      1
   46-        CBAR    146     200     3       8       .0      .0      1.0     1
   47-        CBAR    147     200     8       13      .0      .0      1.0     1
   48-        CBAR    148     200     4       9       .0      .0      1.0     1
   49-        CBAR    149     200     9       14      .0      .0      1.0     1
   50-        CELAS2  981     10.+5                   1       1
```

```
                 APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

                              S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT       .   1   ..  2   ..  3   ..  4   ..  5   ..  6   ..  7   ..  8   ..  9   ..  10  .
   51-       CELAS2  982     10.+5                   1       2
   52-       CELAS2  983     10.+5                   1       3
   53-       CELAS2  984     10.+5                   2       1
   54-       CELAS2  985     10.+5                   2       2
   55-       CELAS2  986     10.+5                   2       3
   56-       CELAS2  987     10.+5                   3       1
   57-       CELAS2  988     10.+5                   3       2
   58-       CELAS2  989     10.+5                   3       3
   59-       CELAS2  990     10.+5                   4       1
   60-       CELAS2  991     10.+5                   4       2
   61-       CELAS2  992     10.+5                   4       3
   62-       CONM2   500     32              1.035                                   123
   63-       +23     1.04            1.04                    1.04
   64-       CONM2   501     28              15.528                                  234
   65-       +34     2.0             2.0                     2.0
   66-       EIGR    41      INV     .0      10.0    20      20              1.-3    AX1
   67-       +X1     MAX
   68-       FORCE   1000    1               40.84   1.0     .0      .0
   69-       FORCE   1000    2               13.82   1.0     .0      .0
   70-       FORCE   1000    3               61.23   1.0     .0      .0
   71-       FORCE   1000    4               34.21   1.0     .0      .0
   72-       FORCE   1000    5               28.09   1.0     .0      .0
   73-       FORCE   1000    6               54.93   1.0     .0      .0
   74-       FORCE   1000    7               28.09   1.0     .0      .0
   75-       FORCE   1000    8               41.44   1.0     .0      .0
   76-       FORCE   1000    9               41.44   1.0     .0      .0
   77-       FORCE   1000    10              28.09   1.0     .0      .0
   78-       FORCE   1000    11              54.93   1.0     .0      .0
   79-       FORCE   1000    12              28.09   1.0     .0      .0
   80-       FORCE   1000    13              179.75  1.0     .0      .0
   81-       FORCE   1000    14              261.08  1.0     .0      .0
   82-       FORCE   1000    15              118.78  1.0     .0      .0
   83-       FORCE   1000    16              200.11  1.0     .0      .0
   84-       FORCE   1000    17              189.15  1.0     .0      .0
   85-       FORCE   1000    18              192.58  1.0     .0      .0
   86-       FORCE   1000    19              118.09  1.0     .0      .0
   87-       FORCE   1000    20              178.96  1.0     .0      .0
   88-       FORCE   1000    21              194.04  1.0     .0      .0
   89-       FORCE   1000    22              123.48  1.0     .0      .0
   90-       FORCE   1000    23              229.07  1.0     .0      .0
   91-       FORCE   1000    24              192.58  1.0     .0      .0
   92-       FORCE   1000    25              158.01  1.0     .0      .0
   93-       FORCE   1000    26              76.55   1.0     .0      .0
   94-       FORCE   1000    27              145.94  1.0     .0      .0
   95-       FORCE   1000    28              3720.   1.0     .0      .0
   96-       FORCE   1000    29              80.04   1.0     .0      .0
   97-       FORCE   1000    30              64.95   1.0     .0      .0
   98-       FORCE   1000    31              49.50   1.0     .0      .0
   99-       FORCE   1000    32              309.    1.0     .0      .0
  100-       FORCE   2000    1               85.16   .0      1.0     .0
```

NOTE: ROUND OFF DISCREPANCIES BETWEEN FORCE CARDS AND HAND CALCULATIONS (TABLE D-2) ARE DUE TO THE USE OF A COMPUTER SUB-ROUTINE TO GENERATE FORCE CARDS.

```
                  APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

                             S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
 101-        FORCE   2000    2               29.58   .0      1.0     .0
 102-        FORCE   2000    3               127.47  .0      1.0     .0
 103-        FORCE   2000    4               73.21   .0      1.0     .0
 104-        FORCE   2000    5               58.28   .0      1.0     .0
 105-        FORCE   2000    6               115.57  .0      1.0     .0
 106-        FORCE   2000    7               60.03   .0      1.0     .0
 107-        FORCE   2000    8               85.98   .0      1.0     .0
 108-        FORCE   2000    9               88.56   .0      1.0     .0
 109-        FORCE   2000    10              58.28   .0      1.0     .0
 110-        FORCE   2000    11              115.57  .0      1.0     .0
 111-        FORCE   2000    12              60.03   .0      1.0     .0
 112-        FORCE   2000    13              374.14  .0      1.0     .0
 113-        FORCE   2000    14              552.81  .0      1.0     .0
 114-        FORCE   2000    15              247.68  .0      1.0     .0
 115-        FORCE   2000    16              423.05  .0      1.0     .0
 116-        FORCE   2000    17              394.63  .0      1.0     .0
 117-        FORCE   2000    18              403.49  .0      1.0     .0
 118-        FORCE   2000    19              249.97  .0      1.0     .0
 119-        FORCE   2000    20              371.95  .0      1.0     .0
 120-        FORCE   2000    21              407.07  .0      1.0     .0
 121-        FORCE   2000    22              261.25  .0      1.0     .0
 122-        FORCE   2000    23              477.41  .0      1.0     .0
 123-        FORCE   2000    24              403.49  .0      1.0     .0
 124-        FORCE   2000    25              334.81  .0      1.0     .0
 125-        FORCE   2000    26              158.59  .0      1.0     .0
 126-        FORCE   2000    27              303.09  .0      1.0     .0
 127-        FORCE   2000    28              720.    .0      1.0     .0
 128-        FORCE   2000    29              165.57  .0      1.0     .0
 129-        FORCE   2000    30              134.27  .0      1.0     .0
 130-        FORCE   2000    31              102.25  .0      1.0     .0
 131-        FORCE   2000    32              633.2   .0      1.0     .0
 132-        FORCE   4000    1               75.37   1.0     .0      .0
 133-        FORCE   4000    2               37.69   1.0     .0      .0
 134-        FORCE   4000    3               131.12  1.0     .0      .0
 135-        FORCE   4000    4               93.43   1.0     .0      .0
 136-        FORCE   4000    5               75.37   1.0     .0      .0
 137-        FORCE   4000    6               75.37   1.0     .0      .0
 138-        FORCE   4000    7               75.37   1.0     .0      .0
 139-        FORCE   4000    8               111.50  1.0     .0      .0
 140-        FORCE   4000    9               111.50  1.0     .0      .0
 141-        FORCE   4000    10              75.37   1.0     .0      .0
 142-        FORCE   4000    11              75.37   1.0     .0      .0
 143-        FORCE   4000    12              75.37   1.0     .0      .0
 144-        FORCE   4000    13              344.71  1.0     .0      .0
 145-        FORCE   4000    14              457.77  1.0     .0      .0
 146-        FORCE   4000    15              188.06  1.0     .0      .0
 147-        FORCE   4000    16              301.12  1.0     .0      .0
 148-        FORCE   4000    17              220.75  1.0     .0      .0
 149-        FORCE   4000    18              148.26  1.0     .0      .0
 150-        FORCE   4000    19              145.37  1.0     .0      .0
```

APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

```
                                 S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
  151-       FORCE   4000    20                 200.00  1.0     .0      .0
  152-       FORCE   4000    21                 140.00  1.0     .0      .0
  153-       FORCE   4000    22                 140.00  1.0     .0      .0
  154-       FORCE   4000    23                 321.65  1.0     .0      .0
  155-       FORCE   4000    24                 148.26  1.0     .0      .0
  156-       FORCE   4000    25                 246.28  1.0     .0      .0
  157-       FORCE   4000    26                 120.00  1.0     .0      .0
  158-       FORCE   4000    27                 276.52  1.0     .0      .0
  159-       FORCE   4000    28                 3000.   1.0     .0      .0
  160-       FORCE   4000    29                 120.00  1.0     .0      .0
  161-       FORCE   4000    30                 112.50  1.0     .0      .0
  162-       FORCE   4000    31                 105.00  1.0     .0      .0
  163-       FORCE   4000    32                 162.5   1.0     .0      .0
  164-       FORCE   5000    1                  111.65  .0      1.0     .0
  165-       FORCE   5000    2                  37.69   .0      1.0     .0
  166-       FORCE   5000    3                  149.34  .0      1.0     .0
  167-       FORCE   5000    4                  75.37   .0      1.0     .0
  168-       FORCE   5000    5                  75.37   .0      1.0     .0
  169-       FORCE   5000    6                  147.92  .0      1.0     .0
  170-       FORCE   5000    7                  75.37   .0      1.0     .0
  171-       FORCE   5000    8                  75.37   .0      1.0     .0
  172-       FORCE   5000    9                  75.37   .0      1.0     .0
  173-       FORCE   5000    10                 75.37   .0      1.0     .0
  174-       FORCE   5000    11                 147.92  .0      1.0     .0
  175-       FORCE   5000    12                 75.37   .0      1.0     .0
  176-       FORCE   5000    13                 346.18  .0      1.0     .0
  177-       FORCE   5000    14                 555.29  .0      1.0     .0
  178-       FORCE   5000    15                 233.06  .0      1.0     .0
  179-       FORCE   5000    16                 442.23  .0      1.0     .0
  180-       FORCE   5000    17                 350.98  .0      1.0     .0
  181-       FORCE   5000    18                 343.99  .0      1.0     .0
  182-       FORCE   5000    19                 180.37  .0      1.0     .0
  183-       FORCE   5000    20                 200.00  .0      1.0     .0
  184-       FORCE   5000    21                 245.00  .0      1.0     .0
  185-       FORCE   5000    22                 105.00  .0      1.0     .0
  186-       FORCE   5000    23                 425.96  .0      1.0     .0
  187-       FORCE   5000    24                 343.99  .0      1.0     .0
  188-       FORCE   5000    25                 259.75  .0      1.0     .0
  189-       FORCE   5000    26                 120.00  .0      1.0     .0
  190-       FORCE   5000    27                 317.99  .0      1.0     .0
  191-       FORCE   5000    28                 3000.   .0      1.0     .0
  192-       FORCE   5000    29                 120.00  .0      1.0     .0
  193-       FORCE   5000    30                 112.50  .0      1.0     .0
  194-       FORCE   5000    31                 105.00  .0      1.0     .0
  195-       FORCE   5000    32                 162.5   .0      1.0     .0
  196-       FORCE   6000    1                  795.95  1.0     .0      .0
  197-       FORCE   6000    2                  397.97  1.0     .0      .0
  198-       FORCE   6000    3                  1384.64 1.0     .0      .0
  199-       FORCE   6000    4                  986.67  1.0     .0      .0
  200-       FORCE   6000    5                  795.95  1.0     .0      .0
```

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                                APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
                                          S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT      .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
  201-     FORCE   6000    6                     795.95  1.0     .0      .0
  202-     FORCE   6000    7                     795.95  1.0     .0      .0
  203-     FORCE   6000    8                     1177.39 1.0     .0      .0
  204-     FORCE   6000    9                     1177.39 1.0     .0      .0
  205-     FORCE   6000    10                    795.95  1.0     .0      .0
  206-     FORCE   6000    11                    795.95  1.0     .0      .0
  207-     FORCE   6000    12                    795.95  1.0     .0      .0
  208-     FORCE   6000    13                    3640.14 1.0     .0      .0
  209-     FORCE   6000    14                    4834.07 1.0     .0      .0
  210-     FORCE   6000    15                    1985.92 1.0     .0      .0
  211-     FORCE   6000    16                    3179.85 1.0     .0      .0
  212-     FORCE   6000    17                    3070.30 1.0     .0      .0
  213-     FORCE   6000    18                    2304.85 1.0     .0      .0
  214-     FORCE   6000    19                    2274.35 1.0     .0      .0
  215-     FORCE   6000    20                    3590.40 1.0     .0      .0
  216-     FORCE   6000    21                    2956.80 1.0     .0      .0
  217-     FORCE   6000    22                    2956.80 1.0     .0      .0
  218-     FORCE   6000    23                    4135.82 1.0     .0      .0
  219-     FORCE   6000    24                    2304.85 1.0     .0      .0
  220-     FORCE   6000    25                    3339.87 1.0     .0      .0
  221-     FORCE   6000    26                    1267.20 1.0     .0      .0
  222-     FORCE   6000    27                    2920.10 1.0     .0      .0
  223-     FORCE   6000    28                    31680.  1.0     .0      .0
  224-     FORCE   6000    29                    1267.20 1.0     .0      .0
  225-     FORCE   6000    30                    1188.00 1.0     .0      .0
  226-     FORCE   6000    31                    1188.00 1.0     .0      .0
  227-     FORCE   6000    32                    1716.4  1.0     .0      .0
  228-     FORCE   7000    1                     1179.01 .0      1.0     .0
  229-     FORCE   7000    2                     397.97  .0      1.0     .0
  230-     FORCE   7000    3                     1576.98 .0      1.0     .0
  231-     FORCE   7000    4                     795.95  .0      1.0     .0
  232-     FORCE   7000    5                     795.95  .0      1.0     .0
  233-     FORCE   7000    6                     1562.07 .0      1.0     .0
  234-     FORCE   7000    7                     795.95  .0      1.0     .0
  235-     FORCE   7000    8                     795.95  .0      1.0     .0
  236-     FORCE   7000    9                     795.95  .0      1.0     .0
  237-     FORCE   7000    10                    795.95  .0      1.0     .0
  238-     FORCE   7000    11                    1562.07 .0      1.0     .0
  239-     FORCE   7000    12                    795.95  .0      1.0     .0
  240-     FORCE   7000    13                    3655.05 .0      1.0     .0
  241-     FORCE   7000    14                    6863.87 .0      1.0     .0
  242-     FORCE   7000    15                    2461.12 .0      1.0     .0
  243-     FORCE   7000    16                    4669.95 .0      1.0     .0
  244-     FORCE   7000    17                    5180.54 .0      1.0     .0
  245-     FORCE   7000    18                    6219.78 .0      1.0     .0
  246-     FORCE   7000    19                    3013.55 .0      1.0     .0
  247-     FORCE   7000    20                    3590.40 .0      1.0     .0
  248-     FORCE   7000    21                    5174.39 .0      1.0     .0
  249-     FORCE   7000    22                    2217.60 .0      1.0     .0
  250-     FORCE   7000    23                    5976.49 .0      1.0     .0
```

APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

```
                              S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT     .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
251-      FORCE      7000       24                    6219.78    .0         1.0        .0
252-      FORCE      7000       25                    3809.50    .0         1.0        .0
253-      FORCE      7000       26                    1267.20    .0         1.0        .0
254-      FORCE      7000       27                    3357.97    .0         1.0        .0
255-      FORCE      7000       28                    31680.     .0         1.0        .0
256-      FORCE      7000       29                    1267.20    .0         1.0        .0
257-      FORCE      7000       30                    1188.00    .0         1.0        .0
258-      FORCE      7000       31                    1108.80    .0         1.0        .0
259-      FORCE      7000       32                    1716.4     .0         1.0        .0
260-      FORCE      8000       21                    1000.      1.         0.0        0.0
261-      FORCE      9000       21                    1000.      0.0        1.         0.0
262-      GRAV       3000                  515.       0.0        0.0        -1.0
263-      GRID       1                     .0         .0         .0
264-      GRID       2                     216.0      .0         .0
265-      GRID       3                     .0         144.0      .0
266-      GRID       4                     216.0      144.0      .0
267-      GRID       5                     6.0        6.0        60.0
268-      GRID       6                     102.0      6.0        60.0
269-      GRID       7                     210.0      6.0        60.0
270-      GRID       8                     6.0        78.0       60.0
271-      GRID       9                     210.0      78.0       60.0
272-      GRID       10                    6.0        138.0      60.0
273-      GRID       11                    102.0      138.0      60.0
274-      GRID       12                    210.0      138.0      60.0
275-      GRID       13                    12.0       12.0       120.0
276-      GRID       14                    204.0      12.0       120.0
277-      GRID       15                    12.0       132.0      120.0
278-      GRID       16                    204.0      132.0      120.0
279-      GRID       17                    24.0       24.0       240.0
280-      GRID       18                    120.0      24.0       240.0
281-      GRID       19                    192.0      24.0       240.0
282-      GRID       20                    24.0       72.0       240.0
283-      GRID       21                    120.0      72.0       240.0
284-      GRID       22                    192.0      72.0       240.0
285-      GRID       23                    24.0       120.0      240.0
286-      GRID       24                    120.0      120.0      240.0
287-      GRID       25                    192.0      120.0      240.0
288-      GRID       26                    24.0       72.0       288.0
289-      GRID       27                    24.0       72.0       336.0
290-      GRID       28                    120.0      72.0       312.0
291-      GRID       29                    24.0       72.0       384.0
292-      GRID       30                    24.0       72.0       432.0
293-      GRID       31                    24.0       72.0       480.0
294-      GRID       32                    24.        72.        528.0
295-      MAT1       400        10.+6      3.8+6                 2.45-4                                      149
296-      +49        22.+3      22.+3      13.2+3
297-      PBAR       200        400        8.64       32.94      32.94      49.                              345
298-      +45        3.0        0.0        -3.0       0.0        0.         3.0        0.0        -3.0
299-      PBAR       201        400        30.58      476.       476.       681.                             456
300-      +56        6.0        0.0        -6.0       0.0        0.         6.0        0.0        -6.0
```

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                                                                         OCTOBER  11, 1979   NASTRAN  8/15/79

                        APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

                                           S O R T E D   B U L K   D A T A   E C H O
           CARD
           COUNT        .   1   ..   2   ..   3   ..   4   ..   5   ..   6   ..   7   ..   8   ..   9   ..  10   .
            301-        PBAR     202     400     7.8     43.     43.     72.                             567
            302-        +67      3.5     0.      -3.5    0.      0.      3.5     0.      -3.5
            303-        PBAR     203     400     25.00   730.    574.    964.                            678
            304-        +78      7.      6.      -7.     6.      -7.     -6.     7.      -6.
            305-        PBAR     204     400     54.78   3700.0  3700.0  7410.91                         789
            306-        +89      12.0    12.0    -12.0   12.0    -12.0   -12.0   12.0    -12.0
            307-        PBAR     205     400     15.71   197.    197.    337.                            890
            308-        +90      5.25    0.      -5.25   0.      0.      5.25    0.      -5.25
            309-        SEQGP    1       2       5       6       13      14      17      20                 9    6
            310-        SEQGP    4       3       11      11      22      18      18      25
            311-        SEQGP    6       7       3       4       10      10      15      16
            312-        SEQGP    19      19      14      13      7       5       2       1
            313-        SEQGP    20      24      24      26      21      23      26      27
            314-        SEQGP    23      22      25      21      16      15      12      8
            315-        SEQGP    27      28      29      29      30      30      31      31
            316-        SEQGP    32      32      28      17      8       12      9       9
                        ENDDATA


     **NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**



*** SYSTEM INFORMATION MESSAGE 3113, EMGPRO PROCESSING SINGLE PRECISION ELEMENTS OF TYPE       34 STARTING WITH ID     101

*** SYSTEM INFORMATION MESSAGE 3113, EMGPRO PROCESSING SINGLE PRECISION ELEMENTS OF TYPE       12 STARTING WITH ID     981

*** SYSTEM INFORMATION MESSAGE 3113, EMGPRO PROCESSING SINGLE PRECISION ELEMENTS OF TYPE       30 STARTING WITH ID     500


***USER INFORMATION MESSAGE 3023--PARAMETERS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK KLL       ( N =  192 )
               TIME ESTIMATE=      2            C AVG =     28          PC AVG =     0   SPILL GROUPS =     0            S AVG =
           ADDITIONAL CORE= -27024              C MAX =     53           PCMAX =     0      PC GROUPS =     0  PREFACE LOOPS =

                                                     METHOD 2 NT,NBR PASSES =   1,EST. TIME =       .2
                                                     METHOD 1 NT,NBR PASSES =   1,EST. TIME =      1.5
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APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

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UNIT LOAD AT ABC/99 ANTENNA BASE (LONGITUDINAL)                                                                SUBCASE 8

                                         D I S P L A C E M E N T   V E C T O R

              POINT ID.   TYPE          T1              T2              T3              R1              R2              R3
                     1      0     4.403590E-04    5.516877E-05    5.487221E-04   -3.487480E-06    1.397773E-05   -4.762687E-06
                     2      0     5.499431E-05   -5.507943E-05   -5.487221E-04    5.641436E-06    2.363845E-05   -3.404233E-06
                     3      0     4.480314E-04   -5.826658E-05    5.623890E-04   -4.922138E-06    1.719984E-05   -5.500351E-07
                     4      0     5.661529E-05    5.817724E-05   -5.623890E-04    8.446415E-06    2.537424E-05    1.146003E-06
                     5      0     1.543683E-03    2.537104E-04    6.385361E-04   -2.739122E-06    2.042680E-05   -4.701122E-06
                     6      0     1.568840E-03   -2.261716E-04   -5.296787E-04   -7.749039E-07    7.405987E-06   -3.911922E-06
                     7      0     1.518831E-03   -3.886619E-04   -7.615491E-04    4.497860E-06    2.296459E-05   -3.451205E-06
                     8      0     1.662165E-03    2.248315E-04    7.580817E-04   -3.826854E-06    2.211019E-05    5.904974E-08
                     9      0     1.624139E-03   -3.809336E-04   -8.943984E-04    5.762849E-06    2.439614E-05    2.387919E-07
                    10      0     1.637092E-03    2.117595E-04    6.955938E-04   -4.078373E-06    2.116034E-05    7.723709E-08
                    11      0     1.662055E-03   -2.187263E-04   -2.087573E-04   -1.249879E-06    8.279663E-06   -4.272189E-06
                    12      0     1.591507E-03   -3.941864E-04   -8.546138E-04    6.896920E-06    2.392688E-05    1.261256E-07
                    13      0     2.906448E-03    2.963188E-04    7.179875E-04    1.727714E-06    2.264715E-05   -4.588532E-06
                    14      0     2.902368E-03   -5.844516E-04   -9.961852E-04    1.067135E-06    2.094304E-05   -3.592123E-06
                    15      0     2.961921E-03    2.939317E-04    7.964363E-04    1.384519E-06    2.168062E-05   -1.014247E-07
                    16      0     2.956762E-03   -5.824050E-04   -1.137387E-03   -7.544397E-08    2.000246E-05   -1.683725E-06
                    17      0     5.869079E-03   -2.147726E-04    9.135143E-04    2.005634E-08    9.720924E-06   -1.003035E-05
                    18      0     5.998679E-03   -3.465569E-04    7.043541E-06   -4.159046E-07    9.498373E-06   -5.976833E-06
                    19      0     6.034940E-03   -4.527246E-04   -7.009438E-04   -1.024359E-06    1.046153E-05   -6.805675E-06
                    20      0     6.384763E-03   -2.244552E-04    9.057642E-04   -3.451267E-07    8.781609E-06   -1.116114E-06
   GRID PT AT       21      0     6.506436E-03   -3.496860E-04   -1.833492E-05   -7.112159E-07    9.997436E-06   -1.205705E-06
   ANT BASE         22      0     6.432032E-03   -4.402013E-04   -7.530396E-04   -1.112091E-06    1.045532E-05   -1.145542E-06
                    23      0     5.977835E-03   -2.339848E-04    8.907414E-04   -1.559792E-07    1.042046E-05    7.456152E-06
                    24      0     6.109117E-03   -3.524130E-04   -6.028771E-05   -9.685624E-07    9.862208E-06    3.561276E-06
                    25      0     6.145736E-03   -4.278861E-04   -8.088039E-04   -1.187730E-06    1.123393E-05    4.273733E-06
                    26      0     6.724212E-03   -2.025409E-04    9.063766E-04   -5.456613E-07    5.967147E-06   -1.132134E-06
                    27      0     6.995692E-03   -1.742132E-04    9.069891E-04   -6.123562E-07    5.532875E-06   -1.148154E-06
                    28      0     7.226752E-03   -2.984784E-04   -1.833492E-05   -7.112159E-07    9.997436E-06   -1.205705E-06
                    29      0     7.261270E-03   -1.448201E-04    9.069891E-04   -6.123562E-07    5.532875E-06   -1.148154E-06
                    30      0     7.526848E-03   -1.184270E-04    9.069891E-04   -6.123562E-07    5.532875E-06   -1.148154E-06
                    31      0     7.792426E-03   -8.603384E-05    9.069891E-04   -6.123562E-07    5.532875E-06   -1.148154E-06
                    32      0     8.058004E-03   -5.664079E-05    9.069891E-04   -6.123562E-07    5.532875E-06   -1.148154E-06
```

CHECK LONGL DIRECTION BASE STIFFNESS

$$\text{BASE STIFFNESS} = \frac{P}{\Delta} = \frac{1000\ \text{Lb}}{6.51(10)^{-3}\ \text{IN}} = 153610\ \text{Lb}/_{\text{IN}} > 75000\ \text{Lb}/_{\text{IN}}$$

APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

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UNIT LOAD AT ABC/99 ANT (TRANSVERSE)                                                              SUBCASE 9

                                        D I S P L A C E M E N T   V E C T O R

     POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
            1     G       1.150915E-04   8.126563E-05   8.143581E-04  -3.005707E-05  -8.049149E-06   2.441388E-06
            2     G      -8.527376E-05   8.510783E-05   8.823085E-04  -3.260989E-05  -2.878607E-06  -3.565100E-06
            3     G      -1.152516E-04   3.830573E-04  -8.143581E-04  -2.438552E-05   4.060909E-06  -1.739662E-07
            4     G       8.543382E-05   4.505692E-04  -8.823085E-04  -2.482456E-05   1.261610E-06  -4.648205E-06
            5     G      -2.967656E-04   1.924920E-03   1.238432E-03  -2.977968E-05  -6.465680E-06   5.030818E-07
            6     G      -2.778423E-04   2.259472E-03   1.378534E-03  -3.397658E-05  -5.921438E-06   1.533021E-06
            7     G      -2.914571E-04   2.138830E-03   1.236258E-03  -3.328882E-05  -2.641816E-06  -3.656672E-06
            8     G      -2.010847E-04   1.986820E-03   2.648409E-04  -2.071065E-05   4.213457E-08  -3.704293E-06
            9     G      -1.552781E-04   2.204205E-03   2.128191E-04  -2.169173E-05  -8.810085E-07  -4.052160E-06
           10     G       1.092937E-04   1.992906E-03  -1.026708E-03  -2.820058E-05   3.800814E-06  -8.706380E-08
           11     G       1.283444E-04   2.279200E-03  -1.152899E-03  -3.211480E-05   4.302472E-06   2.108465E-06
           12     G       1.799863E-04   2.210112E-03  -1.014749E-03  -3.130677E-05   1.176281E-06  -4.551904E-06
           13     G      -4.628334E-04   3.835660E-03   1.831218E-03  -3.269524E-05  -2.581447E-07  -1.578329E-06
           14     G      -4.681267E-04   4.270723E-03   1.614902E-03  -3.532561E-05  -1.931444E-06  -3.931388E-06
           15     G       1.754948E-04   3.840287E-03  -1.199470E-03  -3.233006E-05  -1.190442E-06  -4.418346E-07
           16     G       1.805181E-04   4.274611E-03  -1.186096E-03  -3.500702E-05  -1.889682E-06  -4.475470E-06
           17     G      -3.136973E-04   8.893999E-03   1.177570E-03  -2.536067E-05   2.650671E-06   1.059086E-05
           18     G      -3.712412E-04   1.105185E-02   9.627278E-04  -2.319201E-05   3.720974E-07   6.164788E-08
           19     G      -4.234858E-04   9.802776E-03   1.054167E-03  -2.593940E-05  -1.654698E-06  -1.039594E-05
           20     G      -3.472926E-04   8.870588E-03  -8.054017E-05  -2.854134E-05   6.492107E-07   3.893683E-06
GRID PT AT 21     G      -3.496860E-04   1.111037E-02  -1.416984E-04  -2.320586E-05   5.716639E-07  -6.126373E-07
ANT BASE   22     G      -3.813993E-04   9.772293E-03  -1.762739E-04  -2.542820E-05   4.115776E-07  -4.461728E-06
           23     G      -3.805675E-04   8.810190E-03  -1.345547E-03  -2.566340E-05  -1.467177E-06   1.099295E-05
           24     G      -3.201444E-04   1.104884E-02  -1.250428E-03  -2.334787E-05   8.383689E-07  -2.880970E-07
           25     G      -2.658155E-04   9.701126E-03  -1.414793E-03  -2.628613E-05   2.356089E-06  -1.135630E-05
           26     G      -3.156084E-04   1.072704E-02  -8.054638E-05  -4.642672E-05   6.691426E-07   6.220556E-06
           27     G      -2.832300E-04   1.309856E-02  -8.055259E-05  -5.000139E-05   6.781335E-07   8.747430E-06
           28     G      -3.085262E-04   1.278119E-02  -1.416984E-04  -2.320586E-05   5.716639E-07  -6.126373E-07
           29     G      -2.506796E-04   1.549863E-02  -8.055259E-05  -5.000139E-05   6.781335E-07   8.747430E-06
           30     G      -2.181292E-04   1.789870E-02  -8.055259E-05  -5.000139E-05   6.781335E-07   8.747430E-06
           31     G      -1.855788E-04   2.029876E-02  -8.055259E-05  -5.000139E-05   6.781335E-07   8.747430E-06
           32     G      -1.530284E-04   2.269883E-02  -8.055259E-05  -5.000139E-05   6.781335E-07   8.747430E-06
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CHECK TRANSV DIRECTION BASE STIFFNESS

$$\text{BASE STIFFNESS} = \frac{P}{\Delta} = \frac{1000\ \text{Lb}}{1.11(10)^{-2}\ \text{IN}} = 90090\ \text{Lb}/_{\text{IN}} > 75000\ \text{Lb}/_{\text{IN}}$$

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                                                                          OCTOBER  11, 1979   NASTRAN  8/15/79
                                 APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
          DYNAMIC LOADS WITH WIND (TRANSVERSE)                                                             SURCOM 11

                                    S T R E S S E S   I N   B A R   E L E M E N T S          ( C B A R )
 ELEMENT        SA1            SA2            SA3            SA4           AXIAL          SA-MAX          SA-MIN       M.S.-
   ID.          SB1            SB2            SB3            SB4           STRESS         SB-MAX          SB-MIN       M.S.-

   101      1.751351E+02  -1.751351E+02  -1.629517E+02   1.629517E+02   2.405453E+03   2.580588E+03   2.230318E+03   7.1E+
            3.083690E+02  -3.083690E+02  -1.003855E+02   1.003855E+02                  2.713822E+03   2.097084E+03

   102      3.083690E+02  -3.083690E+02  -1.003855E+02   1.003855E+02   2.411170E+03   2.719539E+03   2.102801E+03   7.0E+
           -3.267594E+02   3.267594E+02   1.527127E+02  -1.527127E+02                  2.737929E+03   2.084410E+03

   103     -4.440389E+02   4.440389E+02   3.273214E+02  -3.273214E+02   6.482964E+02   1.092335E+03   2.042575E+02   1.9E+
            3.413733E+02  -3.413733E+02  -3.898982E+02   3.898982E+02                  1.038195E+03   2.583982E+02

   104      1.356874E+02  -1.356874E+02  -9.999784E+01   9.999784E+01   2.500572E+02   3.857446E+02   1.143698E+02   3.2E+
           -4.193751E+02   4.193751E+02  -3.007496E+01   3.007496E+01                  6.694323E+02  -1.693179E+02   1.3E+

   105     -2.240932E+02   2.240932E+02  -3.646811E+01   3.646811E+01   1.592363E+03   1.816456E+03   1.368270E+03   1.1E+
            2.784672E+02  -2.784672E+02   4.075528E+01  -4.075528E+01                  1.870831E+03   1.313896E+03

   106      2.784672E+02  -2.784672E+02   4.075528E+01  -4.075528E+01   1.586023E+03   1.864490E+03   1.307555E+03   1.1E+
           -7.951866E-12   7.951866E-12   6.295227E-12  -6.295227E-12                  1.586023E+03   1.586023E+03

   107     -1.266529E+02   1.266529E+02   5.043881E+01  -5.043881E+01  -2.761387E+02  -1.494858E+02  -4.027917E+02
            1.710322E+02  -1.710322E+02   3.820614E+01  -3.820614E+01                 -1.051066E+02  -4.471709E+02   4.8E+

   108      8.016084E+01  -8.016084E+01   1.618146E+02  -1.618146E+02  -4.647289E+01   1.153418E+02  -2.082875E+02   7.6E+
           -7.549675E+01   7.549675E+01  -3.316165E+02   3.316165E+02                  2.851437E+02  -3.788894E+02   5.7E+

   109      5.164984E+02  -5.164984E+02  -7.238722E+02   7.238722E+02   3.203285E+02   1.044201E+03  -4.835437E+02   1.7E+
           -4.405967E+02   4.405967E+02   9.269500E+02  -9.269500E+02                  1.247279E+03  -6.066215E+02   3.5E+

   110     -4.405967E+02   4.405967E+02   9.269500E+02  -9.269500E+02   3.197751E+02   1.246725E+03  -6.071749E+02   1.7E+
            1.885430E+02  -1.885430E+02  -2.259604E+02   2.259604E+02                  5.457355E+02   9.381472E+01   3.5E+

   111      8.044271E+01  -8.044271E+01   6.363584E+00  -6.363584E+00  -1.801570E+03  -1.721127E+03  -1.882012E+03
            2.298234E+02  -2.298234E+02  -2.389309E+02   2.389309E+02                 -1.562639E+03  -2.040501E+03   9.8E+

   112      2.298234E+02  -2.298234E+02  -2.389309E+02   2.389309E+02  -1.792790E+03  -1.553859E+03  -2.031720E+03
           -3.203746E+02   3.203746E+02  -2.936935E+02   2.936935E+02                 -1.472415E+03  -2.113164E+03   9.4E+

   113     -4.439975E+02   4.439975E+02  -4.496011E+02   4.496011E+02  -1.762054E+03  -1.312453E+03  -2.211655E+03
            4.561211E+02  -4.561211E+02   1.267078E+03  -1.267078E+03                 -4.949765E+02  -3.029132E+03   6.3E+

   114      6.164134E+02  -6.164134E+02   1.660959E+03  -1.660959E+03  -2.177267E+03  -5.163080E+02  -3.838226E+03
           -5.773564E+02   5.773564E+02  -8.046217E+02   8.046217E+02                 -1.372846E+03  -2.981889E+03   4.7E

   115     -2.556004E+02   2.556004E+02   4.809574E+01  -4.809574E+01  -2.695368E+03  -2.439767E+03  -2.950968E+03
            1.808874E+02  -1.808874E+02   1.058212E+02  -1.058212E+02                 -2.514680E+03  -2.876055E+03   6.5E

   116      1.808874E+02  -1.808874E+02   1.058212E+02  -1.058212E+02  -2.704812E+03  -2.524124E+03  -2.885499E+03
           -8.915921E+01   8.915921E+01   4.556801E+01  -4.556801E+01                 -2.615652E+03  -2.793971E+03   6.6E
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                                                                                  OCTOBER  11, 1979   NASTRAN  8/15/79
                                 APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
       DYNAMIC LOADS WITH WIND (TRANSVERSE)                                                                   SUBCOM 11

                                      S T R E S S E S   I N   B A R   E L E M E N T S          ( C B A R )
   ELEMENT        SA1            SA2            SA3            SA4           AXIAL         SA-MAX         SA-MIN       M.S.-
     ID.          SB1            SB2            SB3            SB4           STRESS        SB-MAX         SB-MIN       M.S.-

       117   4.651184E+02  -4.651184E+02  -5.407875E+01   5.407875E+01  -4.356966E+02   2.942181E+01  -9.008151E+02  5.4E+
            -8.365653E+02   8.365653E+02   1.676699E+02  -1.676699E+02                 4.008687E+02  -1.272262E+03  1.6E+

       118   1.402882E+02  -1.402882E+02   1.542628E+02  -1.542628E+02   7.640767E+00   1.619036E+02  -1.466221E+02  8.9E+
            -4.705461E+01   4.705461E+01  -2.381342E+02   2.381342E+02                 2.457749E+02  -2.304934E+02  9.4E+

       119   3.842328E+02  -3.842328E+02  -7.142625E+02   7.142625E+02   4.192329E+02   1.133495E+03  -2.950296E+02  1.6E+
            -4.040738E+02   4.040738E+02   8.435366E+02  -8.435366E+02                 1.262769E+03  -4.243037E+02  5.1E+

       120  -4.040738E+02   4.040738E+02   8.435366E+02  -8.435366E+02   4.155910E+02   1.259128E+03  -4.279457E+02  1.6E+
             2.247545E+02  -2.247545E+02  -4.720150E+02   4.720150E+02                 8.876059E+02  -5.642400E-01  5.0E+

       121   2.370815E+02  -2.370815E+02   1.843470E+02  -1.843470E+02   1.319778E+03   1.556860E+03   1.082697E+03  1.1E+
            -1.735879E+02   1.735879E+02  -5.581702E+02   5.581702E+02                 1.877948E+03   7.616081E+02

       122  -8.186634E+01   8.186634E+01  -2.836845E+02   2.836845E+02   7.606938E+01   3.597539E+02  -2.076152E+02  6.0E+
             1.081822E+02  -1.081822E+02   2.435871E+02  -2.435871E+02                 3.196565E+02  -1.675177E+02  1.0E+

       123   4.402906E+01  -4.402906E+01   3.808883E+02  -3.808883E+02   1.306160E+02   5.115044E+02  -2.502723E+02  4.2E+
            -1.023714E+00   1.023714E+00  -2.834968E+02   2.834968E+02                 4.141129E+02  -1.528808E+02  8.7E+

CHECK           24  -2.764675E+02   2.764675E+02  -8.965419E+02   8.965419E+02   1.187288E+03   2.083830E+03   2.907463E+02  9.6E+
BUCKLING             3.482091E+02  -3.482091E+02   3.862120E+02  -3.862120E+02                 1.573500E+03   8.010763E+02
SEE SHT D-11
                25   1.372113E+03   4.182756E+02  -1.372113E+03  -4.182756E+02  -2.233418E+02   1.148772E+03  -1.595455E+03  1.1E+
            -2.049223E+03   7.277567E+02   2.049223E+03  -7.277567E+02                 1.825881E+03  -2.272565E+03  8.7E+

       126  -4.929757E+01   8.131596E+02   4.929757E+01  -8.131596E+02  -9.221933E+01   7.209403E+02  -9.053790E+02  2.3E+
            -1.021075E+03  -2.810852E+02   1.021075E+03   2.810852E+02                 9.288556E+02  -1.113244E+03  1.9E+

       127  -1.455959E+03   1.652868E+02   1.455959E+03  -1.652868E+02  -6.884118E+01   1.387117E+03  -1.524800E+03  1.1E+
             1.895165E+03   3.400065E+01  -1.895165E+03  -3.400065E+01                 1.826324E+03  -1.964006E+03  1.0E+

       128   2.452553E+03   2.397406E+02  -2.452553E+03  -2.397406E+02  -6.783677E+01   2.384716E+03  -2.520390E+03  8.2E+
            -1.723289E+03  -5.964421E+02   1.723289E+03   5.964421E+02                 1.655452E+03  -1.791126E+03  7.7E+

       129  -1.556452E+03  -7.487461E+02   1.556452E+03   7.487461E+02  -1.100167E+02   1.446436E+03  -1.666469E+03  1.2E+
             1.807061E+03   1.780183E+01  -1.807061E+03  -1.780183E+01                 1.697044E+03  -1.917077E+03  1.0E+

       130  -2.027998E+03   7.206222E+02   2.027998E+03  -7.206222E+02  -2.485950E+02   1.779403E+03  -2.276593E+03  1.1E+
             1.367935E+03   7.369080E+02  -1.367935E+03  -7.369080E+02                 1.119340E+03  -1.616530E+03  8.7E+

       131   1.977661E+03   1.134029E+02  -1.977661E+03  -1.134029E+02   2.159030E+02   2.193563E+03  -1.761758E+03  3.6E+
            -4.572823E+03   2.006080E+03   4.572823E+03  -2.006080E+03                 4.788726E+03  -4.356920E+03  4.0E+

       132  -4.889821E+03   2.539399E+03   4.889821E+03  -2.539399E+03   7.410465E+01   4.963925E+03  -4.815716E+03  3.4E+
             1.699109E+03  -1.486183E+01  -1.699109E+03   1.486183E+01                 1.773214E+03  -1.625004E+03  3.6E+
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                    APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)  OCTOBER 11, 1979   NASTRAN  8/15/79

   DYNAMIC LOADS WITH WIND (TRANSVERSE)
                                                                                                              SUBCOM 11
                                 S T R E S S E S   I N   B A R   E L E M E N T S          ( C B A R )
 ELEMENT       SA1            SA2            SA3            SA4            AXIAL          SA-MAX         SA-MIN        M.S.-
   ID.         SB1            SB2            SB3            SB4            STRESS         SB-MAX         SB-MIN        M.S.-

   133     -8.527301E+02  -1.232590E+03   8.527301E+02   1.232590E+03  -3.674087E+01   1.195849E+03  -1.269331E+03   5.1E+
           -1.368298E+03   3.665896E+03   1.368298E+03  -3.665896E+03                  3.629155E+03  -3.702637E+03   4.9E+

   134      1.080456E+03   2.040861E+03  -1.080456E+03  -2.040861E+03   6.896213E+01   2.109823E+03  -1.971899E+03   8.4E+
           -1.210068E+03  -1.728341E+03   1.210068E+03   1.728341E+03                  1.797304E+03  -1.659379E+03   1.0E+

   135     -7.150850E+02   4.374544E+02   7.150850E+02  -4.374544E+02  -9.904102E+01   6.160440E+02  -8.141260E+02   4.9E+
           -3.791979E+03   3.857187E+03   3.791979E+03  -3.857187E+03                  3.758146E+03  -3.956228E+03   4.6E+

   136      1.677399E+03  -2.435902E+03  -1.677399E+03   2.435902E+03   1.241956E+02   2.560098E+03  -2.311706E+03   7.6E+
            1.165476E+03  -3.059471E+02  -1.165476E+03   3.059471E+02                  1.289672E+03  -1.041281E+03   8.5E+

   137     -2.115823E+03   2.115823E+03  -5.472265E+02   5.472265E+02   1.139105E+01   2.127214E+03  -2.104432E+03   9.0E+
           -2.192564E+03   2.192564E+03   1.713600E+02  -1.713600E+02                  2.203955E+03  -2.181173E+03   9.1E+

   138     -2.192564E+03   2.192564E+03   1.713600E+02  -1.713600E+02   1.744745E+01   2.210011E+03  -2.175116E+03   8.0E+
           -2.437863E+03   2.437863E+03   9.362626E+02  -9.362626E+02                  2.455311E+03  -2.420416E+03   8.1E+

   139     -2.773307E+03   2.773307E+03   9.647032E+02  -9.647032E+02  -3.273787E+01   2.740569E+03  -2.806045E+03   7.0E+
           -1.844392E+03   1.844392E+03   6.600706E+02  -6.600706E+02                  1.811654E+03  -1.877130E+03   6.8E+

   140     -1.844392E+03   1.844392E+03   6.600706E+02  -6.600706E+02  -2.668147E+01   1.817710E+03  -1.871073E+03   1.1E+
           -1.888259E+03   1.888259E+03   4.038655E+02  -4.038655E+02                  1.861577E+03  -1.914940E+03   1.1E+

   141     -2.300811E+03   2.300811E+03   8.538579E+02  -8.538579E+02  -4.301363E+01   2.257798E+03  -2.343825E+03   8.7E+
           -1.017850E+03   1.017850E+03   3.952690E+02  -3.952690E+02                  9.748361E+02  -1.060863E+03   8.4E+

   142     -1.017850E+03   1.017850E+03   3.952690E+02  -3.952690E+02  -3.695723E+01   9.808925E+02  -1.054807E+03   2.1E+
           -2.463336E-09   2.463336E-09  -5.646439E-10   5.646439E-10                 -3.695723E+01  -3.695723E+01   2.0E+

   143     -8.951284E+02   8.951284E+02   6.967825E+02  -6.967825E+02  -7.112450E+02   1.838834E+02  -1.606373E+03   1.2E+
           -2.552837E+02   2.552837E+02  -2.671347E+01   2.671347E+01                 -4.559613E+02  -9.665286E+02   1.3E+

   144      7.759471E+02  -7.759471E+02   9.231814E+02  -9.231814E+02   3.461092E+02   1.269291E+03  -5.770722E+02   1.6E+
           -4.475323E+02   4.475323E+02  -1.869968E+02   1.869968E+02                  7.936415E+02  -1.014231E+02   3.7E+

   145     -1.667286E+03   3.404627E+03   1.667286E+03  -3.404627E+03  -1.505248E+02   3.254102E+03  -3.555152E+03   5.8E+
            5.920191E-10  -7.128393E-10  -5.920191E-10   7.128393E-10                 -1.505248E+02  -1.505248E+02   5.2E+

   146      1.479797E+02  -1.479797E+02  -4.037469E+02   4.037469E+02  -1.235939E+03  -8.321921E+02  -1.639686E+03
            9.307747E+01  -9.307747E+01  -2.565781E+02   2.565781E+02                 -9.793609E+02  -1.492517E+03   1.2E+

   147      9.307747E+01  -9.307747E+01  -2.565781E+02   2.565781E+02  -1.214903E+03  -9.583253E+02  -1.471482E+03
           -2.311710E+02   2.311710E+02   3.455414E+02  -3.455414E+02                 -8.693620E+02  -1.560445E+03   1.3E+

   148      8.057501E+01  -8.057501E+01   6.938566E+01  -6.938566E+01  -1.274721E+03  -1.194146E+03  -1.355296E+03
            1.090116E+02  -1.090116E+02  -1.561431E+02   1.561431E+02                 -1.118578E+03  -1.430864E+03   1.4E+
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                                                                                   OCTOBER  11, 1979   NASTRAN  8/15/79
                                    APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
          DYNAMIC LOADS WITH WIND AT 45 DEGREES                                                                  SUBCOM 12

                                              S T R E S S E S   I N   B A R   E L E M E N T S           ( C B A R )
     ELEMENT          SA1              SA2              SA3              SA4           AXIAL          SA-MAX           SA-MIN        M.S.
       ID.            SB1              SB2              SB3              SB4           STRESS         SB-MAX           SB-MIN        M.S.

       101      1.542956E+02    -1.542956E+02    -1.644459E+02     1.644459E+02    2.365145E+03    2.529591E+03     2.200699E+03   7.4E
                2.639249E+02    -2.639249E+02    -2.310872E+02     2.310872E+02                    2.629070E+03     2.101220E+03

       102      2.639249E+02    -2.639249E+02    -2.310872E+02     2.310872E+02    2.370504E+03    2.634429E+03     2.106579E+03   7.3F
               -2.706345E+02     2.706345E+02     1.854249E+02    -1.854249E+02                    2.641139E+03     2.099870E+03

       103     -4.032339E+02     4.032339E+02     3.741807E+02    -3.741807E+02    8.010681E+02    1.204302E+03     3.978343E+02   1.7F
                3.561205E+02    -3.561205E+02    -3.747563E+02     3.747563E+02                    1.175824E+03     4.263119E+02

       104      6.043342E+01    -6.043342E+01     1.369921E+02    -1.369921E+02    9.397966E+01    2.309718E+02    -4.301249E+01   4.8F
               -3.514286E+02     3.514286E+02    -2.116142E+02     2.116142E+02                    4.454083E+02    -2.574490E+02   8.4F

       105     -2.249302E+02     2.249302E+02    -6.750422E+01     6.750422E+01    9.743486E+02    1.199279E+03     7.494185E+02   1.7F
                2.188592E+02    -2.188592E+02     1.715480E+02    -1.715480E+02                    1.193208E+03     7.554894E+02

       106      2.188592E+02    -2.188592E+02     1.715480E+02    -1.715480E+02    9.671442E+02    1.186003E+03     7.482849F+02   1.8F
                1.590373E-11    -1.590373E-11     1.325311E-11    -1.325311E-11                    9.671442E+02     9.671442E+02

       107     -1.304938E+02     1.304938E+02     5.918614E+01    -5.918614E+01   -5.091807E+02   -3.786869E+02    -6.396745E+02
                1.380126E+02    -1.380126E+02     4.583185E+01    -4.583185E+01                   -3.711681E+02    -6.471933E+02   3.3F

       108      1.038411E+02    -1.038411E+02     1.785401E+02    -1.785401E+02   -8.170961E+01    9.683053E+01    -2.602498E+02   8.7F
               -9.716781E+01     9.716781E+01    -3.321899E+02     3.321899E+02                    2.504803E+02    -4.138995E+02   5.2F

       109      6.043528E+02    -6.043528E+02    -5.617595E+02     5.617595E+02    6.147440E+02    1.219097E+03     1.039115F+01   1.5F
               -5.359100E+02     5.359100E+02     7.723873E+02    -7.723073E+02                    1.387131E+03    -1.576434E+02   1.4F

       110     -5.359100E+02     5.359100E+02     7.723873E+02    -7.723873E+02    6.192456E+02    1.391633E+03    -1.531417E+02   1.5F
                1.868359F+02    -1.868359E+02    -1.965290E+02     1.965290E+02                    8.157746E+02     4.227166E+02   1.4F

       111      4.004246E+01    -4.004246E+01    -5.634847E+01     5.634847E+01   -1.414600E+03   -1.358252E+03    -1.470949E+03
                1.946803E+02    -1.946803E+02    -3.590637E+02     3.590637E+02                   -1.055537E+03    -1.773664E+03   1.1E

       112      1.946803E+02    -1.946803E+02    -3.590637E+02     3.590637E+02   -1.406684E+03   -1.047620E+03    -1.765747E+03
               -2.318816E+02     2.318816E+02    -1.786255E+02     1.786255E+02                   -1.174802E+03    -1.638565E+03   1.1F

       113     -3.345430E+02     3.345430E+02    -3.386870E+02     3.386870E+02   -1.374666E+03   -1.035979E+03    -1.713353E+03
                2.927855E+02    -2.927855E+02     1.134852E+03    -1.134852E+03                   -2.398143E+02    -2.509518E+03   7.8F

       114      6.504813E+02    -6.504813E+02     1.745507E+03    -1.745507E+03   -2.116126E+03   -3.706189E+02    -3.861633E+03
               -5.653067E+02     5.653067E+02    -9.171467E+02     9.171467E+02                   -1.198979E+03    -3.033272E+03   4.7F

       115     -2.601167E+02     2.601167E+02    -1.905173E+01     1.905173E+01   -2.898159E+03   -2.638042E+03    -3.158276E+03
                1.158039E+02    -1.158039E+02     2.315621E+02    -2.315621E+02                   -2.666597E+03    -3.129721E+03   6.0F

       116      1.158039E+02    -1.158039E+02     2.315621E+02    -2.315621E+02   -2.907961E+03   -2.676399E+03    -3.139523E+03
               -9.023632E+01     9.023632E+01     7.157568E+01    -7.157568E+01                   -2.817724E+03    -2.998197E+03   6.0F
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CHECK
BUCKLING
SEE SH D-11

CHECK BUCKLING SEE SH D-11

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                                                                                      OCTOBER  11, 1979   NASTRAN  8/15/79
                                          APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
                 AIR BLAST TRANSVERSE
                                                                                                                   SUBCOM 14

                                             S T R E S S E S   I N   B A R   E L E M E N T S            ( C B A R )
        ELEMENT          SA1              SA2              SA3              SA4            AXIAL           SA-MAX           SA-MIN        M.S.-
          ID.            SB1              SB2              SB3              SB4            STRESS          SB-MAX           SB-MIN        M.S.-
            101     9.130998E+02    -9.130998E+02     9.565129E+00    -9.565129E+00    1.038411E+04    1.129721E+04     9.471008E+03     7.9E-
                    1.873915E+03    -1.873915E+03     2.395687E+02    -2.395687E+02                    1.225802E+04     8.510193E+03
            102     1.873915E+03    -1.873915E+03     2.395687E+02    -2.395687E+02    1.038066E+04    1.225458E+04     8.506749E+03     8.0E-
                   -1.563355E+03     1.563355E+03     4.967797E+02    -4.967797E+02                    1.194402E+04     8.817309E+03
            103    -2.381288E+03     2.381288E+03     1.240963E+03    -1.240963E+03    1.904395E+03    4.285683E+03    -4.768930E+02     4.1E+
                    2.011127E+03    -2.011127E+03    -2.212034E+03     2.212034E+03                    4.116429E+03    -3.076390E+02     4.5E+
            104     1.651003E+03    -1.651003E+03    -2.485150E+03     2.485150E+03    2.109844E+03    4.594995E+03    -3.753059E+02     3.0E+
                   -2.372195E+03     2.372195E+03     1.136627E+03    -1.136627E+03                    4.482040E+03    -2.623509E+02     5.0E+
            105    -7.431537E+02     7.431537E+02    -2.502819E+02     2.502819E+02    1.035697E+04    1.110013E+04     9.613818E+03     8.1E-
                    1.827466E+03    -1.827466E+03    -1.387447E+02     1.387447E+02                    1.218444E+04     8.529505E+03
            106     1.827466E+03    -1.827466E+03    -1.387447E+02     1.387447E+02    1.036042E+04    1.218788E+04     8.532949E+03     8.1E-
                    1.060249E-11    -1.060249E-11    -1.192780E-11     1.192780E-11                    1.036042E+04     1.036042E+04
            107    -7.675978E+02     7.675978E+02     3.733940E+01    -3.733940E+01    3.618690E+02    1.129467E+03    -4.057288E+02     1.2E+
                    1.273827E+03    -1.273827E+03     2.998255E+02    -2.998255E+02                    1.635696E+03    -9.119578E+02     2.3E+
            108     2.196078E+02    -2.196078E+02     7.770251E+02    -7.770251E+02   -8.682405E+01    6.902011E+02    -8.638492E+02     1.5E+
                   -2.089660E+02     2.089660E+02    -1.444440E+03     1.444440E+03                    1.357616E+03    -1.531264E+03     1.3E+
            109     5.384026E+02    -5.384026E+02    -4.616349E+03     4.616349E+03   -2.882403E+02    4.328109E+03    -4.904590E+03     3.3E+
                   -3.645042E+02     3.645042E+02     5.442567E+03    -5.442567E+03                    5.154326E+03    -5.730807E+03     2.8E+
            110    -3.645042E+02     3.645042E+02     5.442567E+03    -5.442567E+03   -2.847633E+02    5.157803E+03    -5.727330E+03     3.3E+
                    1.353635E+02    -1.353635E+02    -1.326484E+03     1.326484E+03                    1.041720E+03    -1.611247E+03     2.8E+
            111     7.939602E+02    -7.939602E+02     6.994222E+02    -6.994222E+02   -7.114636E+03   -6.320676E+03    -7.908596E+03
                    1.658228E+03    -1.658228E+03    -2.349707E+02     2.349707E+02                   -5.456407E+03    -8.772864E+03     1.5E+
            112     1.658228E+03    -1.658228E+03    -2.349707E+02     2.349707E+02   -7.099836E+03   -5.441608E+03    -8.758065E+03
                   -1.821711E+03     1.821711E+03    -1.142156E+03     1.142156E+03                   -5.278125E+03    -8.921547E+03     1.5E+
            113    -2.087987E+03     2.087987E+03    -1.386808E+03     1.386808E+03   -7.091013E+03   -5.003026E+03    -9.179000E+03
                    2.007731E+03    -2.007731E+03     3.074825E+03    -3.074825E+03                   -4.016188E+03    -1.016584E+04     1.2E+
            114     1.609545E+03    -1.609545E+03     2.971548E+03    -2.971548E+03   -6.607196E+03   -3.635648E+03    -9.578744E+03
                   -2.130155E+03     2.130155E+03    -1.193071E+03     1.193071E+03                   -4.477042E+03    -8.737351E+03     1.3E+
            115    -8.526456E+02     8.526456E+02     1.222638E+02    -1.222638E+02   -6.994023E+03   -6.141377E+03    -7.846668E+03
                    1.636838E+03    -1.636838E+03     1.480050E+02    -1.480050E+02                   -5.357184E+03    -8.630861E+03     1.5E+
            116     1.636838E+03    -1.636838E+03     1.480050E+02    -1.480050E+02   -7.008822E+03   -5.371984E+03    -8.645661E+03
                   -2.178850E+02     2.178850E+02     2.009538E+02    -2.009538E+02                   -6.790937E+03    -7.226707E+03     1.5E+
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CHECK BUCKLING SEE SH D-11

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                                                                               OCTOBER  11, 1979   NASTRAN  8/15/79
                                      APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
    AIR BLAST TRANSVERSE                                                                                    SUBCOM 14

                                     S T R E S S E S   I N   B A R   E L E M E N T S           ( C B A R )
  ELEMENT          SA1              SA2              SA3              SA4             AXIAL           SA-MAX           SA-MIN      M.S.-
    ID.            SB1              SB2              SB3              SB4             STRESS          SB-MAX           SB-MIN      M.S.-

    117      1.188596E+03    -1.188596E+03    -6.222520E+00     6.222520E+00    -3.752321E+02    8.133638E+02    -1.563828E+03   1.3E+
            -1.941303E+03     1.941303E+03     4.040356E+02    -4.040356E+02                     1.566071E+03    -2.316535E+03   8.5E+

    118      2.301706E+02    -2.301706E+02     7.751768E+02    -7.751768E+02     9.108952E+01    8.662463E+02    -6.840873E+02   1.4E+
             2.757881E-01    -2.757881E-01    -1.381308E+03     1.381308E+03                     1.472397E+03    -1.290218E+03   1.6E+

    119     -1.125025E+02     1.125025E+02    -4.044225E+03     4.044225E+03     2.982551E+02    4.342480E+03    -3.745970E+03   3.1E+
            -5.524253E+01     5.524253E+01     5.035916E+03    -5.035916E+03                     5.334171E+03    -4.737661E+03   3.6E+

    120     -5.524253E+01     5.524253E+01     5.035916E+03    -5.035916E+03     2.834223E+02    5.319338E+03    -4.752494E+03   3.1E+
             4.023012E+02    -4.023012E+02    -2.711909E+03     2.711909E+03                     2.995131E+03    -2.428487E+03   3.6E+

    121      1.203288E+03    -1.203288E+03     4.281350E+02    -4.281350E+02     6.132189E+03    7.335477E+03     4.928901E+03   2.0E+
            -9.430998E+02     9.430998E+02    -1.162547E+03     1.162547E+03                     7.294736E+03     4.969642E+03

    122     -2.493978E+01     2.493978E+01    -1.315287E+03     1.315287E+03     4.136104E+02    1.728897E+03    -9.016764E+02   1.2E+
             1.469728E+02    -1.469728E+02     1.292967E+03    -1.292967E+03                     1.706578E+03    -8.793567E+02   2.3E+

    123      7.389432E+02    -7.389432E+02     1.747551E+03    -1.747551E+03     7.137485E+02    2.461300E+03    -1.033803E+03   7.9E+
            -6.664842E+02     6.664842E+02    -1.671817E+03     1.671817E+03                     2.385565E+03    -9.580680E+02   2.0E+

    124     -6.701923E+02     6.701923E+02    -1.461355E+03     1.461355E+03     5.277068E+03    6.738424E+03     3.815713E+03   2.3E+
             1.272456E+03    -1.272456E+03     3.954548E+02    -3.954548E+02                     6.549524E+03     4.004613E+03

    125      4.444159E+03     1.680486E+03    -4.444159E+03    -1.680486E+03    -9.274831E+02    3.516676E+03    -5.371643E+03   5.3E+
            -3.890001E+03    -1.457039E+02     3.890001E+03     1.457039E+02                     2.962518E+03    -4.817484E+03   3.1E+

    126      3.028505E+03     9.122777E+02    -3.028505E+03    -9.122777E+02    -3.936055E+02    2.634899E+03    -3.422110E+03   4.8E+
            -4.217718E+03    -1.428663E+03     4.217718E+03     1.428663E+03                     3.824113E+03    -4.611324E+03   3.8E+

    127     -5.328111E+03    -2.911122E+02     5.328111E+03     2.911122E+02    -2.970409E+02    5.031070E+03    -5.625152E+03   1.2E+
             1.030857E+04    -2.389323E+03    -1.030857E+04     2.389323E+03                     1.001153E+04    -1.060561E+04   1.1E+

    128      1.072446E+04    -1.228890E+03    -1.072446E+04     1.228890E+03    -5.584080E+02    1.016605E+04    -1.128286E+04   1.2E+
            -6.120736E+03    -1.810574E+03     6.120736E+03     1.810574E+03                     5.562328E+03    -6.679144E+03   9.5E-

    129     -5.100346E+03    -2.748614E+03     5.100346E+03     2.748614E+03    -4.682369E+02    4.634109E+03    -5.566582E+03   3.0E+
             5.980716E+03    -4.257826E+02    -5.980716E+03     4.257826E+02                     5.514479E+03    -6.446953E+03   2.4E+

    130     -7.225109E+03     1.385345E+03     7.225109E+03    -1.385345E+03    -1.078828E+03    6.146281E+03    -8.303938E+03   2.6E+
             5.421983E+03     2.926595E+03    -5.421983E+03    -2.926595E+03                     4.343154E+03    -6.500811E+03   1.6E+

    131      6.581289E+03     1.742422E+03    -6.581289E+03    -1.742422E+03     5.644227E+02    7.145712E+03    -6.016867E+03   6.7E-
            -1.263154E+04     2.596312E+03     1.263154E+04    -2.596312E+03                     1.319597E+04    -1.206712E+04   8.2E-

    132     -1.225243E+04     3.835810E+03     1.225243E+04    -3.835810E+03     2.946345E+02    1.254706E+04    -1.195780E+04   7.5E-
             5.557376E+03     3.568165E+02    -5.557376E+03    -3.568165E+02                     5.852011E+03    -5.262742E+03   8.4E-
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                                                                                        OCTOBER  11, 1979   NASTRAN  8/15/79
                                        APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)
     AIR BLAST TRANSVERSE
                                                                                                                SUBCOM 14
                                   S T R E S S E S   I N   B A R   E L E M E N T S          ( C B A R )
  ELEMENT        SA1             SA2             SA3             SA4           AXIAL          SA-MAX          SA-MIN        M.S.-T
    ID.          SB1             SB2             SB3             SB4           STRESS         SB-MAX          SB-MIN        M.S.-C

    133    -3.903851E+03   -4.072637E+03    3.903851E+03    4.072637E+03   -2.284787E+01    4.049789E+03   -4.095484E+03   3.1E+00
            3.407424E+03    5.368267E+03   -3.407424E+03   -5.368267E+03                    5.345419E+03   -5.391115E+03   3.1E+00

    134     4.770144E+03    6.696685E+03   -4.770144E+03   -6.696685E+03   -1.715489E+01    6.679531E+03   -6.713840E+03   2.3E+00
           -5.120186E+03   -5.656581E+03    5.120186E+03    5.656581E+03                    5.639426E+03   -5.673735E+03   2.3E+00

    135    -2.921675E+03    1.054568E+03    2.921675E+03   -1.054568E+03   -3.089442E+02    2.612731E+03   -3.230620E+03   1.3E+00
           -8.575444E+03    9.976653E+03    8.575444E+03   -9.976653E+03                    9.667709E+03   -1.028560E+04   1.1E+00

    136     7.064877E+03   -8.354807E+03   -7.064877E+03    8.354807E+03    2.767305E+02    8.631538E+03   -8.078076E+03   1.5E+00
            3.090198E+03   -1.254631E+03   -3.090198E+03    1.254631E+03                    3.366928E+03   -2.813467E+03   1.7E+00

    137    -7.298786E+03    7.298786E+03   -3.637216E+02    3.637216E+02   -2.995132E+01    7.268835E+03   -7.328738E+03   2.0E+00
           -6.910830E+03    6.910830E+03   -1.502314E+02    1.502314E+02                    6.880878E+03   -6.940781E+03   2.0E+00

    138    -6.910830E+03    6.910830E+03   -1.502314E+02    1.502314E+02   -2.540902E+01    6.885421E+03   -6.936239E+03   2.0E+00
           -7.289582E+03    7.289582E+03    6.325882E+01   -6.325882E+01                    7.264173E+03   -7.314991E+03   2.0E+00

    139    -8.370877E+03    8.370877E+03   -3.228324E-11    3.228324E-11   -2.455340E+01    8.346324E+03   -8.395431E+03   1.6E+0
           -5.176013E+03    5.176013E+03   -2.347872E-11    2.347872E-11                    5.151460E+03   -5.200567E+03   1.6E+0

    140    -5.176013E+03    5.176013E+03   -8.804520E-12    8.804520E-12   -2.001110E+01    5.156802E+03   -5.196025E+03   3.3E+01
           -2.747859E+03    2.747859E+03   -8.804520E-12    8.804520E-12                    2.727848E+03   -2.767870E+03   3.2E+01

    141    -5.809559E+03    5.809559E+03    3.722927E-11   -3.722927E-11   -3.226022E+01    5.777299E+03   -5.841820E+03   2.8E+0
           -2.195598E+03    2.195598E+03    2.792195E-11   -2.792195E-11                    2.163338E+03   -2.227858E+03   2.8E+0

    142    -2.195598E+03    2.195598E+03    3.722927E-11   -3.722927E-11   -2.771792E+01    2.167880E+03   -2.223316E+03   9.1E+0
           -2.558892E-08    2.558892E-08    5.584390E-11   -5.584390E-11                   -2.771792E+01   -2.771792E+01   8.9E+0

    143    -2.498054E+03    2.498054E+03    2.583804E+03   -2.583804E+03   -1.926360E+03    6.574437E+02   -4.510164E+03   3.2E+0
           -2.589302E+01    2.589302E+01   -3.088338E+02    3.088338E+02                   -1.617526E+03   -2.235194E+03   3.9E+0

    144     2.949280E+03   -2.949280E+03    2.597950E+03   -2.597950E+03    1.869556E+03    4.818836E+03   -1.079724E+03   3.6E+0
           -7.235846E+02    7.235846E+02   -3.894541E+02    3.894541E+02                    2.593140E+03    1.145971E+03   1.9E+0

    145    -7.397708E+03    7.397708E+03    7.397708E+03   -7.397708E+03   -1.128936E+02    7.284815E+03   -7.510602E+03   2.0E+0
            1.123628E-09   -1.196120E-09   -1.123628E-09    1.196120E-09                   -1.128936E+02   -1.128936E+02   1.9E+0

    146     5.341340E+02   -5.341340E+02   -2.180087E+03    2.180087E+03   -5.852639E+03   -3.672552E+03   -8.032726E+03
            1.332114E+03   -1.332114E+03   -6.800230E+02    6.800230E+02                   -4.520525E+03   -7.184754E+03   1.7E+

    147     1.332114E+03   -1.332114E+03   -6.800230E+02    6.800230E+02   -5.778949E+03   -4.446835E+03   -7.111084E+03
           -1.760327E+03    1.760327E+03    1.406761E+03   -1.406761E+03                   -4.018622E+03   -7.539277E+03   1.9E+

    148     1.816013E+02   -1.816013E+02    2.825614E+02   -2.825614E+02   -5.979912E+03   -5.697350E+03   -6.262473E+03
            1.401945E+03   -1.401945E+03   -8.014878E+01    8.014878E+01                   -4.577966E+03   -7.381857E+03   2.0E+
```

APPENDIX D - EXAMPLE PROBLEM - STRESS ANALYSIS (MAST)

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APPENDIX D-EXAMPLE PROBLEM-STRESS ANALYSIS(MAST)                        OCTOBER  11, 1979   NASTRAN  8/15/79

AIR BLAST TRANSVERSE                                                                                        SUBCOM 14

                                  S T R E S S E S   I N   B A R   E L E M E N T S       ( C B A R )
ELEMENT          SA1             SA2            SA3             SA4           AXIAL          SA-MAX         SA-MIN      M.S.-T
  ID.            SB1             SB2            SB3             SB4           STRESS         SB-MAX         SB-MIN      M.S.-C

  149       1.401945E+03  -1.401945E+03  -8.014878E+01   8.014878E+01  -5.906221E+03  -4.504276E+03  -7.308167E+03
           -1.268133E+03   1.268133E+03  -1.029580E+03   1.029580E+03                 -4.638088E+03  -7.174355E+03  2.0E+00
```

*** END OF JOB ***

CDC 6000 SERIES
6400 / 6500

RIGID FORMAT SERIES P

LEVEL 17.5.1

SYSTEM GENERATION DATE -

APPENDIX "D" EXAMPLE PROBLEM - VIBRATION ANALYSIS

```
                                                        OCTOBER  19, 1979   NASTRAN  8/15/79

     N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O


ID GRUNENFELDER, CODE 250.5
$PUNCH NONE
$SEQUENCE YES
$GRID 32
APP DISP
SOL 3,0
TIME 10
CEND
```

```
                    APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)   OCTOBER  19, 1979   NASTRAN  8/15/79
VIBRATION ANALYSIS

                                     C A S E   C O N T R O L   D E C K   E C H O
               CARD
               COUNT
                1       TITLE=APPENDIX D-EXAMPLE PROBLEM-VIBRATION ANALYSIS (MAST)
                2       LABEL=VIBRATION ANALYSIS
                3       METHOD=41
                4       DISP=ALL
                5       BEGIN BULK

*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED,XSORT WILL RE-ORDER DECK.
```

APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)

```
                                                                          OCTOBER  19, 1979   NASTRAN  8/15/79
VIBRATION ANALYSIS

                                          S O R T E D   B U L K   D A T A   E C H O
          CARD
          COUNT      .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
             1-      CBAR    101     200     1       5       .0      1.0     .0      1
             2-      CBAR    102     200     5       13      .0      1.0     .0      1
             3-      CBAR    103     200     13      17      .0      1.0     .0      1
             4-      CBAR    104     200     19      14      .0      1.0     .0      1
             5-      CBAR    105     200     14      7       .0      1.0     .0      1
             6-      CBAR    106     200     7       2       .0      1.0     .0      1
             7-      CBAR    107     200     14      17      .0      .0      1.0     1
             8-      CBAR    108     200     13      14      .0      .0      1.0     1
             9-      CBAR    109     200     14      6       .0      .0      1.0     1
            10-      CBAR    110     200     6       1       .0      .0      1.0     1
            11-      CBAR    111     200     3       10      .0      1.0     .0      1
            12-      CBAR    112     200     10      15      .0      1.0     .0      1
            13-      CBAR    113     200     15      23      .0      1.0     .0      1
            14-      CBAR    114     200     25      16      .0      1.0     .0      1
            15-      CBAR    115     200     16      12      .0      1.0     .0      1
            16-      CBAR    116     200     12      4       .0      1.0     .0      1
            17-      CBAR    117     200     16      23      .0      .0      1.0     1
            18-      CBAR    118     200     15      16      .0      .0      1.0     1
            19-      CBAR    119     200     16      11      .0      .0      1.0     1
            20-      CBAR    120     200     11      3       .0      .0      1.0     1
            21-      CBAR    121     200     13      23      .0      .0      1.0     1
            22-      CBAR    122     200     13      15      .0      .0      1.0     1
            23-      CBAR    123     200     14      16      .0      .0      1.0     1
            24-      CBAR    124     200     25      14      .0      .0      1.0     1
            25-      CBAR    125     203     25      22      .0      .0      1.0     1
            26-      CBAR    126     203     22      19      .0      .0      1.0     1
            27-      CBAR    127     203     19      18      .0      .0      1.0     1
            28-      CBAR    128     203     18      17      .0      .0      1.0     1
            29-      CBAR    129     203     17      20      .0      .0      1.0     1
            30-      CBAR    130     203     20      23      .0      .0      1.0     1
            31-      CBAR    131     203     23      24      .0      .0      1.0     1
            32-      CBAR    132     203     24      25      .0      .0      1.0     1
            33-      CBAR    133     203     22      21      .0      .0      1.0     1
            34-      CBAR    134     203     21      20      .0      .0      1.0     1
            35-      CBAR    135     203     24      21      .0      .0      1.0     1
            36-      CBAR    136     203     21      18      .0      .0      1.0     1
            37-      CBAR    137     201     20      26      .0      1.0     .0      1
            38-      CBAR    138     201     26      27      .0      1.0     .0      1
            39-      CBAR    139     201     27      29      .0      1.0     .0      1
            40-      CBAR    140     201     29      30      .0      1.0     .0      1
            41-      CBAR    141     205     30      31      .0      1.0     .0      1
            42-      CBAR    142     205     31      32      .0      1.0     .0      1
            43-      CBAR    143     202     27      24      .0      .0      1.0     1
            44-      CBAR    144     202     27      18      .0      .0      1.0     1
            45-      CBAR    145     204     21      28      .0      1.0     .0      1
            46-      CBAR    146     200     3       8       .0      .0      1.0     1
            47-      CBAR    147     200     8       13      .0      .0      1.0     1
            48-      CBAR    148     200     4       9       .0      .0      1.0     1
            49-      CBAR    149     200     9       14      .0      .0      1.0     1
            50-      CELAS2  981     10.+5                           1       1
```

```
                                    SORTED BULK DATA ECHO
CARD
COUNT       .   1   ..  2   ..  3   ..  4   ..  5   ..  6   ..  7   ..  8   ..  9   ..  10  .
   51-      CELAS2  982     10.+5                   1       2
   52-      CELAS2  983     10.+5                   1       3
   53-      CELAS2  984     10.+5                   1       3
   54-      CELAS2  985     10.+5                   2       1
   55-      CELAS2  986     10.+5                   2       2
   56-      CELAS2  987     10.+5                   2       3
   57-      CELAS2  988     10.+5                   3       1
   58-      CELAS2  989     10.+5                   3       2
   59-      CELAS2  990     10.+5                   3       3
   60-      CELAS2  991     10.+5                   4       1
   61-      CELAS2  992     10.+5                   4       2
   62-      CONM2   500     32              1.035   4       3
   63-      +23     1.04            1.04                    1.04                    123
   64-      CONM2   501     28              15.528
   65-      +34     2.0             2.0                     2.0                     234
   66-      EIGR    41      INV     .0      10.0    20      20
   67-      +X1     MAX                                                     1.-3    AX1
   68-      GRID    1               .0      .0      .0
   69-      GRID    2               216.0   .0      .0
   70-      GRID    3               .0      144.0   .0
   71-      GRID    4               216.0   144.0   .0
   72-      GRID    5               6.0     6.0     60.0
   73-      GRID    6               102.0   6.0     60.0
   74-      GRID    7               210.0   6.0     60.0
   75-      GRID    8               6.0     78.0    60.0
   76-      GRID    9               210.0   78.0    60.0
   77-      GRID    10              6.0     138.0   60.0
   78-      GRID    11              102.0   138.0   60.0
   79-      GRID    12              210.0   138.0   60.0
   80-      GRID    13              12.0    12.0    120.0
   81-      GRID    14              204.0   12.0    120.0
   82-      GRID    15              12.0    132.0   120.0
   83-      GRID    16              204.0   132.0   120.0
   84-      GRID    17              24.0    24.0    240.0
   85-      GRID    18              120.0   24.0    240.0
   86-      GRID    19              192.0   24.0    240.0
   87-      GRID    20              24.0    72.0    240.0
   88-      GRID    21              120.0   72.0    240.0
   89-      GRID    22              192.0   72.0    240.0
   90-      GRID    23              24.0    120.0   240.0
   91-      GRID    24              120.0   120.0   240.0
   92-      GRID    25              192.0   120.0   240.0
   93-      GRID    26              24.0    72.0    288.0
   94-      GRID    27              24.0    72.0    336.0
   95-      GRID    28              120.0   72.0    312.0
   96-      GRID    29              24.0    72.0    384.0
   97-      GRID    30              24.0    72.0    432.0
   98-      GRID    31              24.0    72.0    480.0
   99-      GRID    32              24.     72.     528.0
  100-      MAT1    400     10.+6   3.8+6           2.45-4
```

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                                                                              OCTOBER  19, 1979   NASTRAN  8/15/79
                                     APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)
VIBRATION ANALYSIS
                                                 S O R T E D   B U L K   D A T A   E C H O
                CARD
                COUNT         .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
                 101-         PBAR    200     400     8.64    32.94   32.94   49.                     345
                 102-         +45     3.0     0.0     -3.0    0.0      0.     3.0     0.0     -3.0
                 103-         PBAR    201     400     30.58   476.    476.    681.                    456
                 104-         +56     6.0     0.0     -6.0    0.0     0.      6.0     0.0     -6.0
                 105-         PRAR    202     400     7.8     43.     43.     72.                     567
                 106-         +67     3.5     0.      -3.5    0.      0.      3.5     0.      -3.5
                 107-         PBAR    203     400     25.00   730.    574.    964.                    678
                 108-         +78     7.      6.      -7.     6.      -7.     -6.     7.      -6.
                 109-         PBAR    204     400     54.78   3700.0  3700.0  7410.91                 789
                 110-         +89     12.0    12.0    -12.0   12.0    -12.0   -12.0   12.0    -12.0
                 111-         PRAR    205     400     15.71   197.    197.    337.                    890
                 112-         +90     5.25    0.      -5.25   0.      0.      5.25    0.      -5.25
                 113-         SEOGP   1       2       5       6       13      14      17      20          9  6
                 114-         SEOGP   4       3       11      11      22      18      18      25
                 115-         SEOGP   6       7       3       4       10      10      15      16
                 116-         SEOGP   19      19      14      13      7       5       2       1
                 117-         SEOGP   20      24      24      26      21      23      26      27
                 118-         SEOGP   23      22      25      21      16      15      12      8
                 119-         SEOGP   27      28      29      29      30      30      31      31
                 120-         SEOGP   32      32      28      17      8       12      9       9
                              ENDDATA


          **NO ERRORS FOUND - EXECUTE NASTRAN PROGRAM**



*** SYSTEM INFORMATION MESSAGE 3113, EMGPRO PROCESSING SINGLE PRECISION ELEMENTS OF TYPE       34 STARTING WITH ID      101

*** SYSTEM INFORMATION MESSAGE 3113, EMGPRO PROCESSING SINGLE PRECISION ELEMENTS OF TYPE       12 STARTING WITH ID      981

*** SYSTEM INFORMATION MESSAGE 3113, EMGPRO PROCESSING SINGLE PRECISION ELEMENTS OF TYPE       30 STARTING WITH ID      500



***USER INFORMATION MESSAGE 3023--PARAMETERS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK LAMA      ( N =   192 )
            TIME ESTIMATE=       2             C AVG =     28           PC AVG =     0   SPILL GROUPS =     0            S AVG =
          ADDITIONAL CORE= -22258              C MAX =     53            PCMAX =     0      PC GROUPS =     0   PREFACE LOOPS =

***USER INFORMATION MESSAGE 3023--PARAMETERS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK LAMA      ( N =   192 )
            TIME ESTIMATE=       2             C AVG =     28           PC AVG =     0   SPILL GROUPS =     0            S AVG =
          ADDITIONAL CORE= -22258              C MAX =     53            PCMAX =     0      PC GROUPS =     0   PREFACE LOOPS =

***USER INFORMATION MESSAGE 3023--PARAMETERS FOR SYMMETRIC DECOMPOSITION OF DATA BLOCK LAMA      ( N =   192 )
            TIME ESTIMATE=       2             C AVG =     28           PC AVG =     0   SPILL GROUPS =     0            S AVG =
          ADDITIONAL CORE= -22258              C MAX =     53            PCMAX =     0      PC GROUPS =     0   PREFACE LOOPS =
```

```
                                                                     OCTOBER  19, 1979   NASTRAN  8/15/79
VIBRATION ANALYSIS

                    E I G E N V A L U E   A N A L Y S I S   S U M M A R Y   (INVERSE POWER METHOD)

                         NUMBER OF EIGENVALUES EXTRACTED  . . . . . .          5

                         NUMBER OF STARTING POINTS USED . . . . . . .          2

                         NUMBER OF STARTING POINT MOVES . . . . . . .          0

                         NUMBER OF TRIANGULAR DECOMPOSITIONS  . . . .          4

                         TOTAL NUMBER OF VECTOR ITERATIONS  . . . . .         50


                         REASON FOR TERMINATION . . . . . . . . . . .          7


                         LARGEST OFF-DIAGONAL MODAL MASS TERM . . . .    .15E-13

                                   MODE PAIR . . . . . . . . . . . . .         3
                                                               . . .           1
                         NUMBER OF OFF-DIAGONAL MODAL MASS
                              TERMS FAILING CRITERION . . . . . . . .          0
```

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                                                                              OCTOBER  19, 1979   NASTRAN  8/15/79
```

APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)

```
     VIBRATION ANALYSIS

                                                 R E A L   E I G E N V A L U E S

   MODE      EXTRACTION         EIGENVALUE              RADIAN               CYCLIC              GENERALIZED          GENERALIZED
    NO.         ORDER                                   FREQUENCY            FREQUENCY              MASS               STIFFNESS

       1            1           6.821724E+02         2.611843E+01         4.156877E+00         1.414825E+00         9.651548E+02
       2            2           9.079820E+02         3.013274E+01         4.795775E+00         1.273472E+00         1.156290E+03
       3            3           2.185727E+03         4.675176E+01         7.440773E+00         1.211588E+01         2.648201E+04
       4            4           2.939423E+03         5.421644E+01         8.628815E+00         1.777540E+01         5.224941E+04
       5            5           8.966505E+03         9.469163E+01         1.507064E+01         1.970951E+01         1.767254E+05
```

```
                                                                                 OCTOBER  19, 1979   NASTRAN  8/15/79
VIBRATION ANALYSIS
 EIGENVALUE =   6.821724E+02
                                          R E A L   E I G E N V E C T O R   N O .         1

POINT ID.    TYPE          T1             T2             T3             R1             R2             R3
      1       G     -6.613625E-05   2.719256E-04   2.721175E-03  -8.743997E-05  -5.447637E-05   1.885449E-05
      2       G     -3.144659E-04   3.120423E-04   3.132479E-03  -6.872201E-05  -4.187416E-05  -5.538968E-05
      3       G      5.412647E-05   9.097435E-04  -2.743298E-03  -8.066789E-05   4.257584E-05  -3.228539E-05
      4       G      3.119450E-04   6.244029E-04  -3.110264E-03  -6.596437E-05   2.433757E-05  -2.966914E-05
      5       G     -3.199007E-03   5.590637E-03   4.597514E-03  -8.464404E-05  -4.521216E-05   5.646386E-07
      6       G     -2.875708E-03   7.688959E-03   5.642573E-03  -1.052235E-04  -2.101823E-05  -8.166521E-07
      7       G     -2.577161E-03   5.123129E-03   4.665921E-03  -7.537527E-05  -3.515267E-05  -5.672716E-05
      8       G     -1.821409E-03   5.755904E-03   1.313477E-03  -7.205268E-05   8.928533E-06  -5.319677E-05
      9       G     -7.540024E-04   5.222808E-03   1.117146E-03  -7.118134E-05   9.637746E-06  -3.818663E-05
     10       G      2.947183E-03   5.731059E-03  -4.200824E-03  -8.450437E-05   5.081010E-05  -3.641156E-05
     11       G      2.163908E-03   5.524001E-03  -4.788221E-03  -1.084112E-04   1.742241E-05  -3.408524E-06
     12       G      1.922749E-03   5.157253E-03  -4.494750E-03  -7.573412E-05   2.787614E-05  -2.647495E-05
     13       G     -3.966448E-03   1.132694E-02   6.195255E-03  -1.061728E-04   1.979702E-05  -2.086725E-05
     14       G     -4.037333E-03   1.079384E-02   6.193319E-03  -9.758375E-05  -1.600741E-05  -6.086253E-05
     15       G      3.586715E-03   1.134728E-02  -5.353232E-03  -1.095429E-04  -3.047812E-05  -4.736978E-05
     16       G      3.677764E-03   1.079789E-02  -5.753717E-03  -1.040830E-04   2.894923E-05  -2.538523E-05
     17       G     -4.200492E-03   2.869770E-02   6.453035E-03  -1.410905E-04  -2.449471E-04  -1.764508E-05
     18       G     -4.778490E-03   3.536139E-02   2.500098E-02  -4.494140E-04   5.815401E-05  -4.576170E-05
     19       G     -4.766870E-03   2.848221E-02   6.999709E-03  -1.682490E-04   2.851033E-04  -1.011171E-04
     20       G     -4.811088E-04   2.858228E-02  -2.471416E-04  -1.755607E-04  -3.051056E-06  -5.310340E-05
     21       G     -4.913683E-04   3.533174E-02  -1.498100E-05  -5.779802E-04  -8.035892E-07  -7.011247E-05
     22       G     -4.976875E-04   2.845972E-02  -1.473335E-04  -1.568911E-04   3.508079E-06  -8.895329E-05
     23       G      3.218500E-03   2.852412E-02  -6.897099E-03  -1.395471E-04   2.356778E-04  -1.566060E-05
     24       G      3.794692E-03   3.535849E-02  -2.497480E-02  -4.477615E-04  -5.832161E-05  -4.559200E-05
     25       G      3.786495E-03   2.839473E-02  -7.285613E-03  -1.674546E-04  -2.762328E-04  -1.031983E-04
     26       G     -5.934616E-04   4.925502E-02  -2.494925E-04  -7.906115E-04  -2.406509E-06   5.490809E-05
     27       G     -7.872116E-04   1.145893E-01  -2.518337E-04  -2.037433E-03  -6.454337E-06   1.629196E-04
     28       G     -5.701370E-04   7.988017E-02  -1.500308E-05  -6.391027E-04  -1.239222E-06  -7.011271E-05
     29       G     -1.247303E-03   2.499561E-01  -2.518861E-04  -3.522067E-03  -1.238770E-05   1.629217E-04
     30       G     -1.946078E-03   4.451903E-01  -2.519287E-04  -4.536858E-03  -1.642404E-05   1.629239E-04
     31       G     -2.883747E-03   7.005925E-01  -2.519975E-04  -5.937782E-03  -2.198121E-05   1.629282E-04
     32       G     -3.995877E-03   1.000000E+00  -2.520567E-04  -6.387620E-03  -2.376357E-05   1.629325E-04
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                                                                              OCTOBER  19, 1979   NASTRAN  8/15/79
                                       APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)
VIBRATION ANALYSIS
 EIGENVALUE =  9.079820E+02
                                       R E A L   E I G E N V E C T O R   N O .          2

 POINT ID.   TYPE          T1             T2             T3             R1             R2             R3
        1      G     7.051707E-04   1.863355E-04   1.851757E-03  -1.538825E-05   4.444245E-05  -2.201573E-07
        2      G     1.901749E-04  -1.940432E-04  -1.923921E-03   3.054250E-05   2.731941E-05  -4.025294E-05
        3      G     6.981659E-04  -1.795326E-04   1.815204E-03  -3.273958E-05   4.829289E-05  -1.263892E-05
        4      G     1.884391E-04   1.844997E-04  -1.901247E-03   3.346313E-05   4.149378E-05   1.194939E-05
        5      G     3.975644E-03   1.168800E-03   2.519347E-03  -1.131997E-05   5.313754E-05   9.244186E-06
        6      G     2.943280E-03   4.170416E-04  -2.501707E-04  -1.254924E-05   1.703870E-05  -1.610597E-05
        7      G     2.454766E-03  -1.733495E-03  -2.919735E-03   2.143075E-05   3.955519E-05  -4.238769E-05
        8      G     3.451356E-03   1.260188E-03   3.129711E-03  -1.429832E-05   3.697711E-05   1.244071E-05
        9      G     3.731881E-03  -1.704363E-03  -3.617176E-03   2.413280E-05   6.665601E-05  -9.664384E-06
       10      G     3.969054E-03   1.823984E-03   2.754581E-03  -2.925166E-05   5.230610E-05  -1.489596E-05
       11      G     3.068363E-03  -1.601403E-03  -6.437016E-04  -4.395487E-06   2.165859E-05  -2.336774E-05
       12      G     2.707715E-03  -1.529917E-03  -3.182143E-03   2.282381E-05   4.063937E-05   1.457791E-05
       13      G     6.181240E-03   1.693355E-03   3.338968E-03   1.982501E-06   1.204953E-05   2.276342E-05
       14      G     6.241136E-03  -2.172329E-03  -3.873160E-03  -4.978011E-06   7.765269E-05  -4.883832E-05
       15      G     6.129385E-03   1.647013E-03   3.586723E-03   3.796592E-05   1.359487E-05  -2.779841E-05
       16      G     6.169349E-03  -2.167900E-03  -4.260889E-03  -2.719913E-06   7.272160E-05   1.900966E-05
       17      G     1.436939E-02  -6.845860E-04   4.888368E-03   2.153622E-04   2.559712E-04   2.646248E-05
       18      G     1.481283E-02  -4.882311E-04  -1.465009E-02   9.911935E-05   2.511844E-05   1.429584E-05
       19      G     1.469412E-02  -8.274885E-05  -4.900983E-03  -2.065844E-05  -2.045453E-04   1.544097E-05
       20      G     1.298110E-02  -6.320598E-04   1.209860E-02  -2.979995E-06   1.492823E-04   2.167266E-06
       21      G     1.368442E-02  -2.932425E-04  -1.127820E-02  -8.550307E-07   1.260722E-04   2.228046E-06
       22      G     1.383760E-02  -1.284186E-04  -5.879432E-03   1.660740E-07  -1.832377E-04   2.343925E-06
       23      G     1.417156E-02  -5.788474E-04   4.683550E-03  -2.150106E-04   2.528583E-04  -2.062587E-05
       24      G     1.461893E-02  -9.561074E-05  -1.475015E-02  -1.012176E-04   2.375470E-05  -9.061265E-06
       25      G     1.449908E-02  -1.740686E-04  -4.916986E-03   1.882313E-05  -2.029938E-04  -1.265861E-05
       26      G     1.562545E-02  -5.094688E-04   1.278934E-02  -3.183716E-06   1.821722E-04   2.738165E-06
       27      G     5.173162E-02  -2.257136E-04   1.347944E-02  -9.681774E-06   1.543936E-03   3.309065E-06
       28      G     2.393153E-02  -2.434938E-04  -1.129979E-02  -6.089171E-07   1.504454E-04   2.228057E-06
       29      G     1.751194E-01   4.678763E-04   1.348317E-02  -1.874642E-05   3.493581E-03   3.309123E-06
       30      G     3.773874E-01   1.529288E-03   1.348622E-02  -2.502016E-05   4.835225E-03   3.309181E-06
       31      G     6.594397E-01   2.964567E-03   1.349113E-02  -3.374846E-05   6.695860E-03   3.309298E-06
       32      G     1.000000E+00   4.674488E-03   1.349535E-02  -3.656099E-05   7.294621E-03   3.309415E-06
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                                                                                OCTOBER  19, 1979   NASTRAN  8/15/79
VIBRATION ANALYSIS
 EIGENVALUE =  2.185727E+03
                                             R E A L   E I G E N V E C T O R   N O .         3

 POINT ID.    TYPE          T1              T2              T3              R1              R2              R3
        1      G      -3.917230E-03  -3.060462E-03  -3.049123E-02   1.052422E-03   3.965394E-04  -3.679891E-04
        2      G       3.258480E-03  -3.254530E-03  -3.252640E-02   1.132599E-03   1.659488E-04   2.190892E-04
        3      G       5.486634E-03  -1.230323E-02   3.294370E-02   9.293261E-04  -1.907161E-04  -2.965055E-05
        4      G      -3.034638E-03  -1.404276E-02   3.029819E-02   9.394139E-04   7.589893E-07   1.601780E-04
        5      G       1.546443E-02  -6.791231E-02  -4.733680E-02   1.005701E-03   2.348866E-04  -2.059566E-04
        6      G       1.836710E-02  -9.958711E-02  -6.170856E-02   1.110893E-03   2.144330E-04  -3.930973E-05
        7      G       1.353306E-02  -7.460175E-02  -4.763029E-02   1.122169E-03   1.337269E-04   2.212684E-04
        8      G       1.145536E-02  -7.109511E-02  -1.166393E-02   7.643956E-04   4.785168E-05   1.772902E-04
        9      G       6.924222E-03  -7.806879E-02  -1.385143E-02   7.870127E-04   1.803868E-05   1.620781E-04
       10      G      -4.733942E-03  -7.041484E-02   4.426476E-02   9.691560E-04  -1.366526E-04   9.423528E-06
       11      G      -5.254455E-03  -9.066107E-02   5.076436E-02   1.127591E-03  -1.314460E-04  -4.416520E-05
       12      G      -3.191051E-03  -7.727016E-02   3.774855E-02   1.073164E-03   1.680098E-05   1.541815E-04
       13      G       1.994045E-02  -1.352345E-01  -6.243443E-02   1.199135E-03  -5.818228E-05  -5.479794E-05
       14      G       2.016628E-02  -1.469026E-01  -6.299185E-02   1.198943E-03   5.063110E-05   2.372553E-04
       15      G      -2.744061E-04  -1.356439E-01   5.339606E-02   1.210497E-03   2.840750E-04   6.501291E-05
       16      G      -7.323332E-04  -1.474522E-01   4.475595E-02   1.210157E-03   8.918715E-05   1.541438E-04
       17      G       1.032930E-02  -3.263300E-01  -5.407759E-02   1.092858E-03   7.769865E-04  -3.526494E-04
       18      G       1.014215E-02  -3.663286E-01  -1.152305E-01   1.526872E-03  -1.526433E-04  -9.816132E-05
       19      G       1.155595E-02  -3.435042E-01  -5.447937E-02   1.135937E-03  -9.803625E-04   4.004017E-05
       20      G       2.217566E-02  -3.261152E-01   5.335806E-03   1.609573E-03  -4.319094E-05  -2.441431E-04
       21      G       2.237879E-02  -3.682238E-01   5.685219E-03   4.404083E-03   1.596932E-04  -1.589992E-04
       22      G       2.232731E-02  -3.427108E-01   1.838445E-03   1.338084E-03   8.549495E-06  -1.060737E-04
       23      G       3.240216E-02  -3.239845E-01   6.333528E-02   1.055371E-03  -8.253105E-04  -3.378134E-04
       24      G       3.288926E-02  -3.662827E-01   1.262307E-01   1.519142E-03   2.219695E-04  -7.300747E-05
       25      G       3.154142E-02  -3.406014E-01   6.029027E-02   1.197679E-03   1.041329E-03   9.128688E-05
       26      G       2.164429E-02  -4.397946E-01   5.305996E-03   2.509186E-03   3.226919E-06  -3.642343E-05
       27      G       2.084027E-02  -5.090187E-01   5.275532E-03  -2.148474E-04  -5.317871E-05   1.712962E-04
       28      G       3.839500E-02  -7.767224E-01   5.711490E-03   6.308360E-03   2.538250E-04  -1.590010E-04
       29      G       1.578908E-02  -3.925200E-01   5.279058E-03  -4.457763E-03  -1.534808E-04   1.713034E-04
       30      G       6.519637E-03  -9.969210E-02   5.281933E-03  -7.537011E-03  -2.279376E-04   1.713107E-04
       31      G      -7.308705E-03   3.802520E-01   5.286568E-03  -1.195041E-02  -3.358696E-04   1.713253E-04
       32      G      -2.456358E-02   1.000000E+00   5.290551E-03  -1.339211E-02  -3.712853E-04   1.713399E-04
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                                                                                   OCTOBER  19, 1979   NASTRAN  8/15/79
                             APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)

VIBRATION ANALYSIS
 EIGENVALUE =  2.939423E+03
                                            R E A L   E I G E N V E C T O R   N O .

 POINT ID.   TYPE          T1               T2               T3               R1               R2               R3
       1      G      2.512070E-02     4.277366E-03     4.253428E-02    -4.250224E-04     8.863648E-04    -4.443149E-04
       2      G      3.567755E-03    -3.569726E-03    -3.547904E-02     3.660533E-04     1.464512E-03    -2.346036E-04
       3      G      2.466970E-02    -3.044849E-03     3.774759E-02    -6.048734E-04     1.209618E-03    -1.414240E-04
       4      G      4.114153E-03     4.724648E-03    -4.063211E-02     6.497362E-04     1.559854E-03     2.299397E-04
       5      G      9.003612E-02     2.868425E-02     5.468593E-02    -3.484338E-04     1.132819E-03    -4.152266E-04
       6      G      9.961692E-02    -1.609216E-02    -1.233444E-02    -2.340430E-04     5.191477E-04    -3.236034E-04
       7      G      9.314580E-02    -2.420308E-02    -4.983709E-02     2.456434E-04     1.354981E-03    -2.356915E-04
       8      G      1.037868E-01     3.051382E-02     6.519975E-02    -3.946877E-04     1.515498E-03    -1.648753E-04
       9      G      1.072098E-01    -2.737637E-02    -6.730887E-02     3.242552E-04     1.407803E-03     1.728943E-05
      10      G      9.717725E-02     2.969245E-02     5.189593E-02    -4.712684E-04     1.195880E-03    -7.296993E-05
      11      G      1.075431E-01    -1.479745E-02    -3.460921E-02    -3.097807E-04     5.906609E-04    -4.300444E-04
      12      G      9.744512E-02    -2.823163E-02    -6.311408E-02     4.169481E-04     1.388308E-03     8.334600E-05
      13      G      1.749416E-01     3.932153E-02     6.619793E-02     1.879408E-05     1.612414E-03    -4.385162E-04
      14      G      1.732893E-01    -3.114286E-02    -6.649168E-02    -7.563840E-05     1.209839E-03    -2.533055E-04
      15      G      1.778977E-01     3.909098E-02     6.287361E-02     1.603075E-04     1.535861E-03    -1.894103E-05
      16      G      1.765456E-01    -3.096094E-02    -8.397789E-02    -2.985915E-04     1.184124E-03    -1.147866E-04
      17      G      3.653131E-01     1.129320E-02     8.904063E-02     7.890035E-04    -5.251429E-04    -5.340137E-04
      18      G      3.716697E-01     1.062492E-02     6.538025E-02    -1.177257E-04     1.789277E-03    -2.877736E-04
      19      G      3.735020E-01     4.754992E-03    -6.172166E-02    -1.211676E-03     1.580025E-03    -3.583892E-04
      20      G      3.932161E-01     1.094257E-02     1.137376E-01    -1.685926E-04    -9.255506E-04    -1.690290E-05
      21      G      3.976059E-01     1.039004E-02     5.590958E-02    -4.282579E-04     6.168536E-03    -3.019838E-05
      22      G      3.936357E-01     5.194701E-03    -1.063359E-01    -1.523883E-04     6.220906E-04    -3.263032E-05
      23      G      3.674159E-01     1.044774E-02     7.707341E-02    -9.756157E-04    -3.207817E-04     4.903221E-04
      24      G      3.738382E-01     9.834526E-03     3.963759E-02    -2.450454E-04     1.756067E-03     2.207589E-04
      25      G      3.759447E-01     5.528961E-03    -7.575646E-02     8.979103E-04     1.397855E-03     2.555684E-04
      26      G      4.000954E-01     2.266036E-02     1.130483E-01    -2.717888E-04     7.429136E-04    -3.131372E-05
      27      G      4.211232E-01     3.253250E-02     1.123404E-01    -9.362298E-05    -3.019094E-04    -4.572454E-05
      28      G      1.000000E+00     4.897525E-02     5.625795E-02    -5.897313E-04     9.465635E-03    -3.019883E-05
      29      G      3.524102E-01     2.955281E-02     1.124414E-01     2.059981E-04    -2.488861E-03    -4.572714E-05
      30      G      1.905731E-01     1.400839E-02     1.125238E-01     4.273876E-04    -4.152025E-03    -4.572973E-05
      31      G     -7.407611E-02    -1.509379E-02     1.126567E-01     7.484695E-04    -6.598076E-03    -4.573497E-05
      32      G     -4.166314E-01    -5.439492E-02     1.127709E-01     8.539415E-04    -7.405951E-03    -4.574021E-05
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                                                                                 OCTOBER  19, 1979   NASTRAN  8/15/79
                         APPENDIX D - EXAMPLE PROBLEM - VIBRATION ANALYSIS (MAST)
VIBRATION ANALYSIS
 EIGENVALUE =   8.966505E+03
                                              R E A L   E I G E N V E C T O R   N O .          5

POINT ID.    TYPE          T1               T2               T3               R1               R2               R3
        1      G      -3.311280E-03     3.421832E-03     3.358798E-02    -5.707166E-04    -2.915328E-03     1.689644E-04
        2      G      -6.105509E-03     6.184777E-03     6.109294E-02    -1.111200E-03    -4.677185E-04     9.772498E-04
        3      G      -3.665416E-03    -2.413269E-03     3.235223E-02    -1.379012E-03    -3.300445E-03     2.024422E-03
        4      G      -6.006209E-03    -4.377787E-03     5.926101E-02    -1.825457E-03    -8.264053E-04    -9.253061E-04
        5      G      -1.247555E-01     3.766895E-02     6.897995E-02    -4.070896E-04    -9.506480E-04    -3.888975E-04
        6      G      -1.504652E-01     5.043585E-02     2.577997E-01    -1.347737E-06     1.067910E-04     1.600669E-04
        7      G      -4.481985E-02     6.286176E-02     9.523846E-02    -6.948564E-04    -4.885925E-04     1.020972E-03
        8      G      -8.709898E-02     6.044618E-02     1.089305E-01    -2.407529E-04    -1.045245E-03     5.593813E-05
        9      G      -9.796429E-02     8.752843E-02     1.481773E-01    -5.776681E-04    -8.313470E-04     9.683921E-05
       10      G      -1.279399E-01     5.873605E-02     7.689306E-02    -3.187249E-04    -1.007325E-03     1.361691E-03
       11      G      -1.655486E-01     2.814704E-01     3.143957E-01     1.801949E-04     1.027584E-05     3.501616E-04
       12      G      -5.618978E-02     8.493995E-02     1.063647E-01    -8.304137E-04    -5.085438E-04    -9.079528E-04
       13      G      -8.945791E-02     4.511236E-02     9.132949E-02     1.298382E-04     1.903369E-03    -1.073023E-03
       14      G      -9.101302E-02     7.563868E-02     1.329206E-01     2.156102E-04    -7.752434E-04     1.140683E-03
       15      G      -8.942364E-02     4.499480E-02     9.761885E-02     8.515528E-04     1.964474E-03     7.558292E-04
       16      G      -9.074534E-02     7.651459E-02     1.451734E-01     1.215988E-03    -4.168319E-04    -8.080786E-04
       17      G      -1.054239E-01    -1.316305E-02     1.500381E-01     2.882093E-03    -1.045204E-02    -8.516122E-06
       18      G      -1.053163E-01    -1.052099E-02     8.065983E-01     5.146755E-03     1.459275E-03     2.247288E-05
       19      G      -1.037323E-01    -9.121758E-03     2.112065E-01     3.363087E-03     1.158942E-02     6.386411E-05
       20      G      -1.060591E-01    -1.234858E-02     2.379414E-01    -8.232960E-05    -1.046974E-02     3.012603E-05
       21      G      -1.067174E-01    -1.083123E-02     9.811306E-01    -1.689862E-04     1.383729E-03     2.723041E-05
       22      G      -1.063813E-01    -8.165480E-03     3.144111E-01    -6.595651E-05     1.272243E-02     1.687308E-05
       23      G      -1.075576E-01    -1.152346E-02     1.448998E-01    -2.908281E-03    -1.024064E-02     4.384095E-07
       24      G      -1.077309E-01    -1.124531E-02     7.932346E-01    -5.365797E-03     1.435443E-03     2.742543E-05
       25      G      -1.062277E-01    -7.163774E-03     2.072320E-01    -3.364901E-03     1.132750E-02     5.800377E-05
       26      G      -4.891533E-01    -7.154618E-03     2.381310E-01    -1.239339E-04    -5.722287E-03     2.612354E-05
       27      G      -6.835643E-01    -1.514786E-03     2.382002E-01    -9.904670E-05    -2.735185E-03     2.212105E-05
       28      G      -1.368168E-02     2.583893E-03     1.000000E+00    -1.949903E-04     1.246391E-03     2.723166E-05
       29      G      -7.266222E-01     1.759484E-03     2.388576E-01    -3.952470E-05     1.000211E-03     2.212488E-05
       30      G      -5.909429E-01     2.507338E-03     2.393942E-01     5.762738E-06     4.523178E-03     2.212871E-05
       31      G      -2.206959E-01     4.160387E-04     2.402602E-01     7.389628E-05     1.030876E-02     2.213645E-05
       32      G       3.381550E-01    -3.862329E-03     2.410046E-01     9.675635E-05     1.231041E-02     2.214419E-05


                                                  *** END OF JOB ***
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APPENDIX E
BLANK CALCULATION FORMS

CHARACTERISTICS OF MAST

STATION		THICKNESS INCHES	OUTSIDE DIA. INCHES	MATERIAL	SECTION AREA A_m (IN^2)	SECTION MODULUS Z_m (IN^3)	MOM. OF INERTIA I_m (IN^4)	UNIT WEIGHT * (LBS/FT)
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							
	ABOVE							
	BELOW							

* UNIT WEIGHT = A_m x 3.4 (FOR STEEL) PLUS ALLOWANCES FOR FITTINGS ETC. @ 25 LB/FT.

SUMMARY OF FORCES

ITEM	PHYSICAL DATA				DYNAMIC LOADS						PRESSURE LOADS		
					VERTICAL		LONGITUDINAL		TRANSVERSE		WIND	BLAST	
	WEIGHT	MAXIMUM PROJECTED AREA	CENTER OF GRAVITY ABV BL	CENTER OF AREA ABV BL	FACTOR	FORCE	FACTOR	FORCE	FACTOR	FORCE	DRAG FORCE	Effective Dynamic Pressure	DRAG FORCE
	LBS	SQ. FT	FT	FT		LBS		LBS		LBS	LBS	Lb/in^2	LBS

MOMENT TABULATION OF DYNAMIC LOADS

ITEM	MOMENTS DUE TO DYNAMIC LOADING										
	VERTICAL					LONGITUDINAL			TRANSVERSE		
	FORCE	ECCENTRICITY PORT (-) STBD (+)	MOMENT (X 10^3)	ECCENTRICITY FWD (-) AFT (+)	MOMENT (X 10^3)	FORCE	LEVER ABV STA	MOMENT	FORCE	LEVER ABV STA	MOMENT
	LBS	IN.	IN. — LBS	IN.	IN. — LBS	LBS	IN.	IN.-LBS(X10^3)	LBS	IN.	IN-LBS(X10^3)

MOMENT TABULATION OF PRESSURE LOADS

ITEM	MOMENTS DUE TO PRESSURE LOADING					
	WIND LOADING			BLAST LOADING		
	FORCE	LEVER ABV STA	MOMENT	FORCE	LEVER ABV STA	MOMENT
	LBS	IN.	X10^3 IN.-LBS	LBS	IN.	X10^3 IN.-LBS

STRESSES IN MAST

STA	BENDING MOMENTS: INCH-KIPS						AXIAL LOADS P_A (KIPS)
	LONG.* M_L	TRANSV.* M_T	RESULTANT M_R $(M_L^2 + M_T^2)^{1/2}$	WIND M_W	TOTAL M $(M_R + M_W)$	AIR BLAST M_B	

STA	SECTION AREA A_M	SECTION MODULUS Z_M	STRESS: KIPS/INCH^2					
			BENDING M/Z_M	DIRECT P/A_M	TOTAL $M/Z_M + P/A_M$	ALLOW	BENDING (BLAST) M_B / Z_M	ALLOW

* M_L & M_T INCLUDES MOMENTS DUE TO VERTICAL LOADS.

SUMMARY OF LOADS

ITEM OR BAR ELEMENT	PHYSICAL DATA				DYNAMIC LOADS *				PRESSURE LOADS						
	WEIGHT	END POINTS		CENTER OF GRAVITY ABV. REF.	LONG		TRANSV		PROJECTED AREA		WIND LOAD		AIR BLAST LOAD		
		FROM	TO		FACTOR	FORCE	FACTOR	FORCE	LONG	TRANSV	LONG	TRANSV	DRAG COEF	LOAD	
														LONG	TRANSV
	POUNDS	—	—	FEET	—	LBS	—	LBS	FT^2	FT^2	LBS	LBS	—	LBS	LBS

* VERTICAL DYNAMIC LOADING IS PROVIDED BY A GRAVITY INPUT ADJUSTED FOR THE DYNAMIC LOAD.

SUMMARY OF FORCES AT GRID POINTS

GRID POINT	ITEMS OR CONNECTING BARS	SUM OF DYNAMIC LOADS (POUNDS)*		SUM OF WIND LOADS (POUNDS)*		SUM OF BLAST LOADS (POUNDS)*	
		LONG	TRANSV	LONG	TRANSV	LONG	TRANSV

*NOTE: $\frac{1}{2}$ THE LOAD ON ANY BAR ELEMENT IS TRANSFERRED TO EACH END OF THE ELEMENT.

BUCKLING CHECK

DYNAMIC LOADING (REQ'D FS ≥ 2.5)

BAR ELEMENT	MEMBER SIZE & PROPERTIES	$r = \sqrt{\frac{I}{A}}$	L IN	$C^{(1)}$	$F_C/F_Y^{(2)}$	F_Y KSI	F_a KSI	$F_B^{(3)}$ KSI	$F_a^{(3)}$ KSI	$F.S. = \frac{1}{F_C/F_a + F_B/F_Y}$

AIR BLAST (REQ'D FS ≥ 1)

(1) $C = \frac{KL}{r}\sqrt{\frac{F_Y}{E}}$ (FROM DDS 100-4 STRENGTH OF STRUCTURAL MEMBERS SHT 4)

(2) FROM FIG 1 DDS 100-4

(3) FROM COMPUTER OUTPUT SHEETS, NOTE: TENSILE AXIAL LOADS ARE CHECKED AGAINST COMPRESSIVE DESIGN CRITERIA BECAUSE REVERSAL OF APPLIED LOADS WOULD RESULT IN COMPARABLE COMPRESSIVE LOADS.