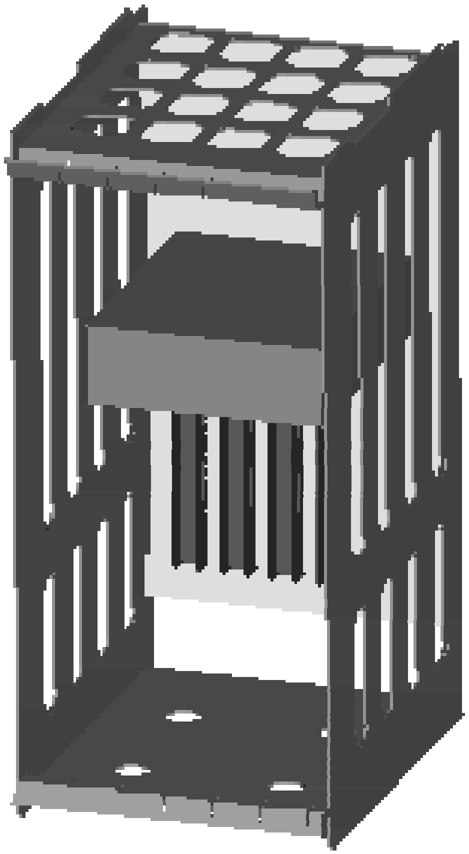
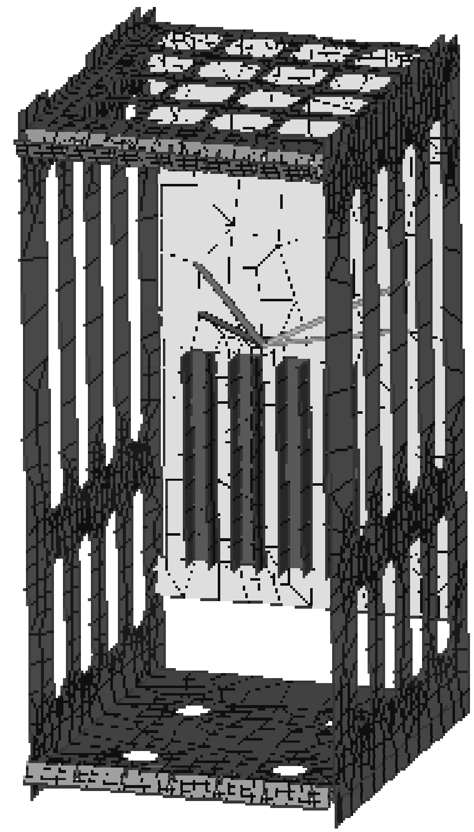
Simulation of Bellcore Testing of Electronics Cabinets for the Telecommunications Industry

Richardson, TX February 16, 2001





Simulation of Bellcore Testing of Electronics Cabinets for the Telecommunications Industry
Richardson, TX February 16, 2001

Agenda

- Summary of Bellcore Tests
- Software Tools
- Finite Element Modeling
- Review of Test Simulation Methods using Finite Element Analysis
- Brief Shell Element Meshing Demo

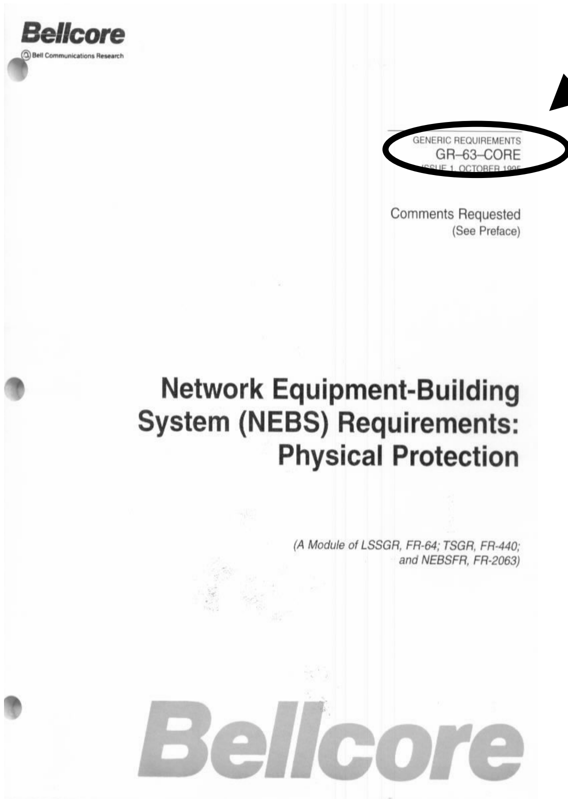
Summary of Bellcore Tests

- Static Pull Test*
- Frequency Sweep Test
- Seismic Analysis for Zones 4 Test**
- Test for Transportation Loads
- Drop Test
- Impact Test
- Thermal Analysis Test

* This test can be done entirely in the Pro/E GUI.

** This test can be done entirely in the Pro/E GUI using an additional product from DRD Technology.

Bellcore GR-63-CORE


Bellcore
Bell Communications Research

GENERIC REQUIREMENTS
GR–63–CORE
ISSUE 1, OCTOBER

Comments Requested
(See Preface)

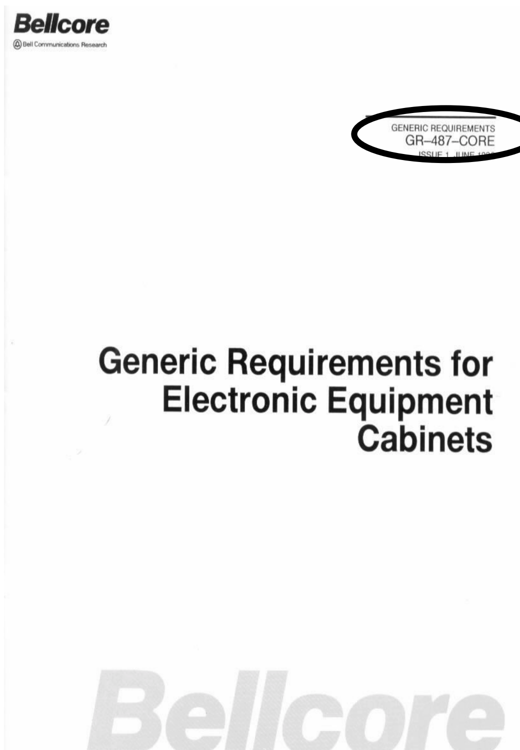
Network Equipment-Building
System (NEBS) Requirements:
Physical Protection

(A Module of LSSGR, FR-64; TSGR, FR-440;
and NEBSFR, FR-2063)

Bellcore

All of the test descriptions come from this document, except for the impact and thermal tests.

Bellcore GR-487-CORE


Bellcore

GENERIC REQUIREMENTS
GR-487-CORE

Generic Requirements for
Electronic Equipment
Cabinets

Bellcore

The impact and thermal test descriptions comes from this document.

Software Tools for Bellcore Test Simulation

- Pro/ENGINEER, including Pro/MECHANICA FEM
- ANSYS FEA Software

- ANSYS-Pro/ENGINEER Interface (Optional)
- Bellcore Response Spectrum Library (Optional)
- ANSYS/LS-DYNA Explicit Dynamics (Optional)

Finite Element Modeling

3D Shell vs. Solid Finite Elements

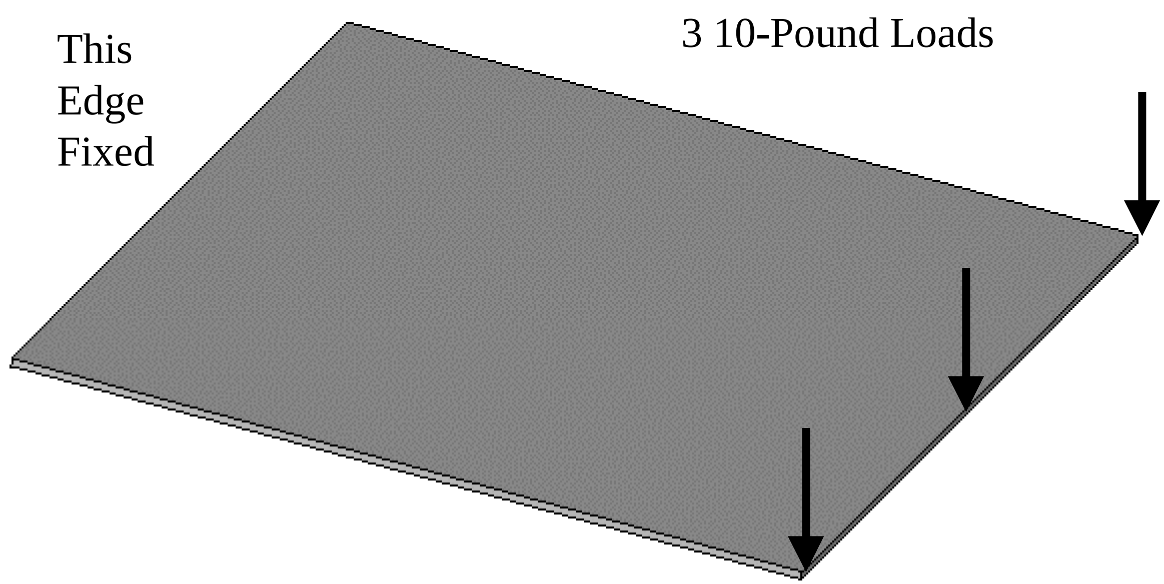
3D shell elements are used to model structures whose components are relatively thin in one direction. Structures constructed from sheetmetal or structural steel plates are good candidates for modeling with shells.

This applies especially to sheetmetal cabinets like the ones used in the telecommunications industry.

3D Shell vs. Solid Finite Elements

Consider this 10” x 10” steel plate with t = 0.1”.

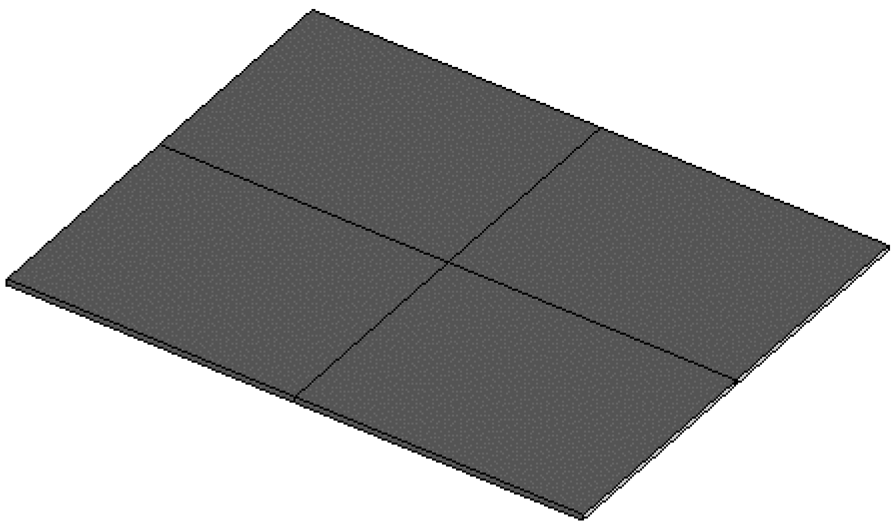
Let’s model it with 3D solid and 3D shell elements and compare the solutions.



3D Shell vs. Solid Finite Elements

The closed form solution for a plate predicts a tip deflection equal to .364”.

3D Shell vs. Solid Finite Elements



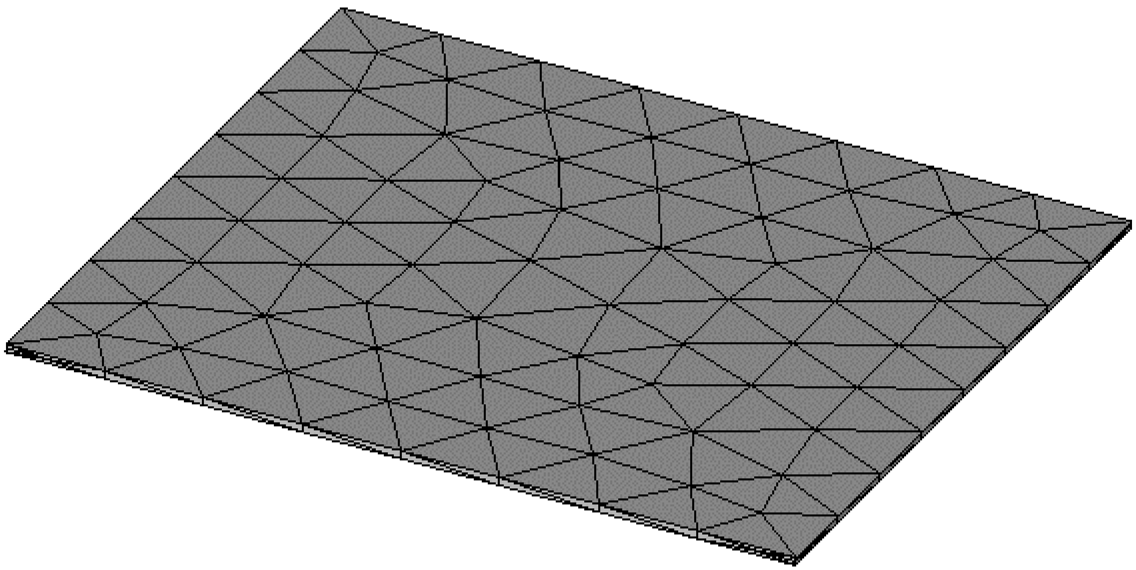
This 4-element shell model predicts a tip deflection equal to .375”.

This model has 9 nodes and 54 DOF.

When you use shell elements only the midsurface geometry is modeled.

Closed Form Solution: u = .364”

3D Shell vs. Solid Finite Elements

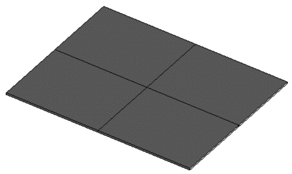
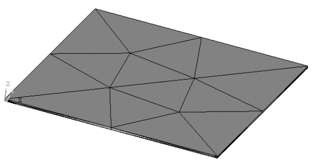
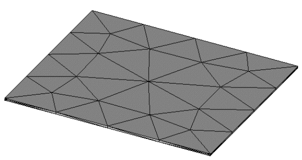
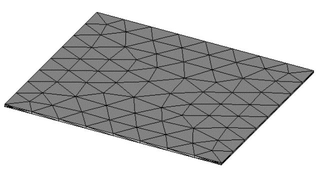


This 472-element 3D solid element model predicts a tip deflection equal to .354”.

This model has 1047 nodes and 3141 DOF.

Closed Form Solution: u = .364”

3D Shell vs. Solid Finite Elements

FEM	Type	# Elements	# Nodes	# DOF	Max Deflection
	Shell	4	9	54	0.375”
	Solid	85	196	588	0.271”
	Solid	148	355	1065	0.337”
	Solid	472	1047	3141	0.354”

Correct Answer = 0.364”

3D Shell vs. Solid Finite Elements

Summary of 3D Shell Versus Solid Element Plate Solution

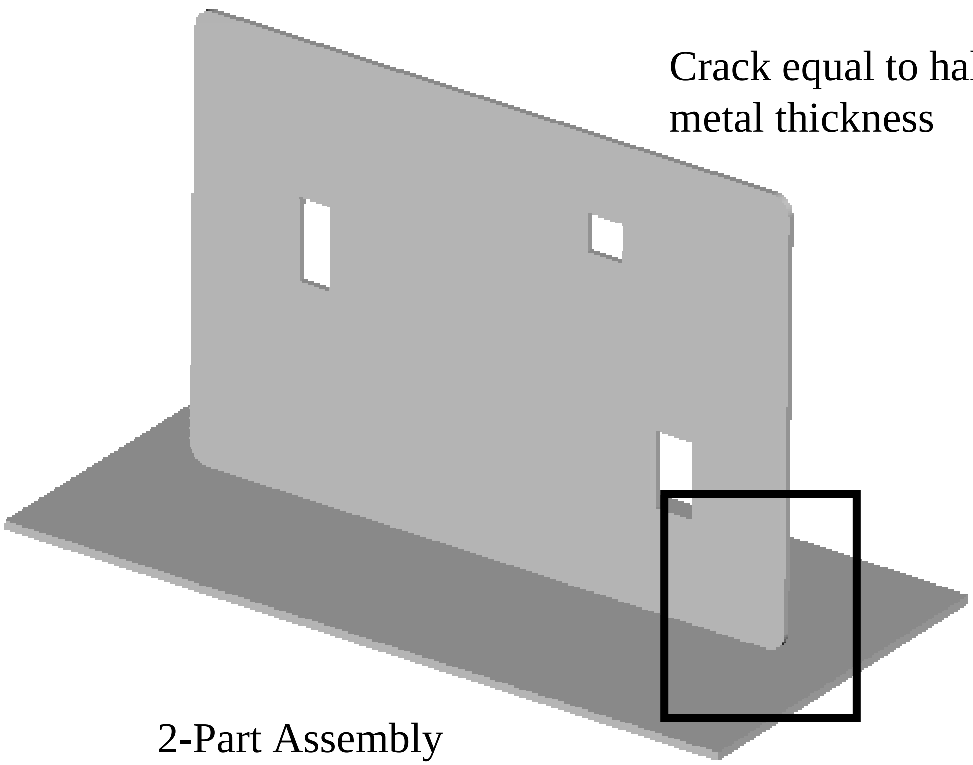
The shell model calculates the correct solution with a model that has only 54 DOF.

The 3D solid model requires a model with 3141 DOF to calculate the correct solution.

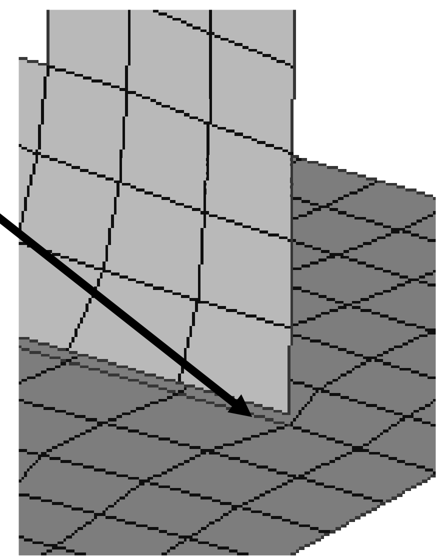
Meshing Sheetmetal Assemblies in Pro/MECHANICA FEM

Shown below are 2 sheet metal parts that are mated. Without any input from the user, a ‘crack’ between the parts will be created when meshed.

Crack equal to half of sheet metal thickness



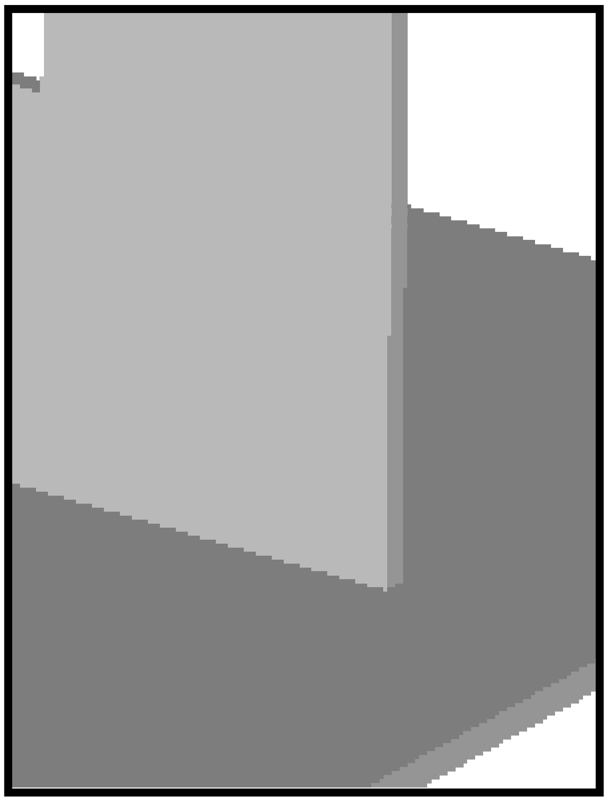
2-Part Assembly

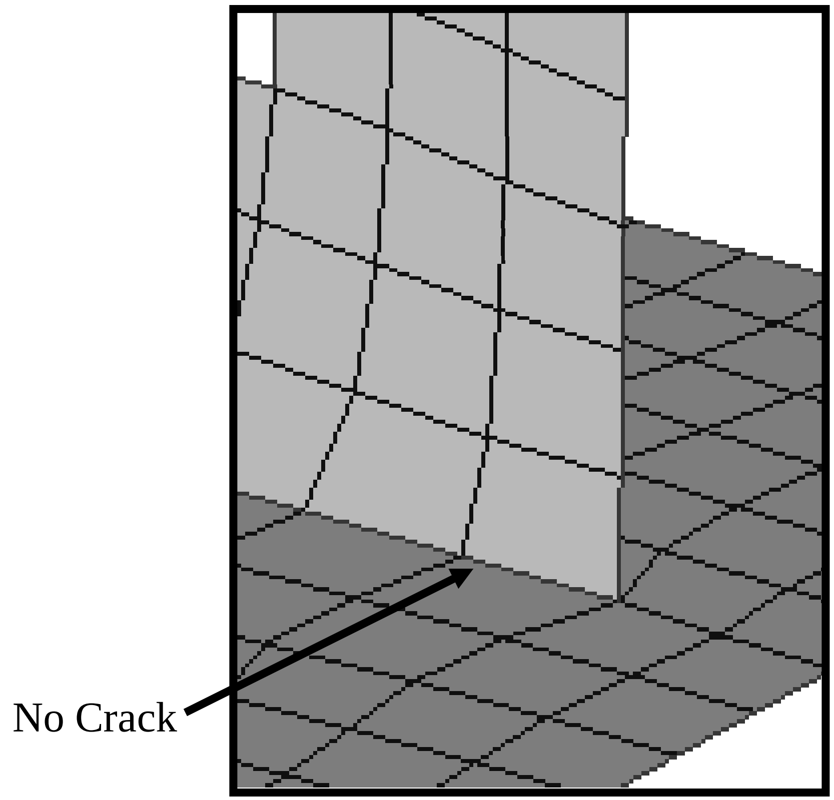


Finite Element Mesh

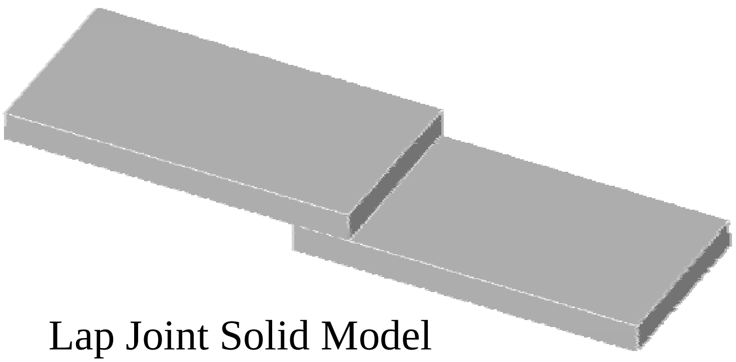
Meshing Sheetmetal Assemblies in Pro/MECHANICA FEM

To fix the ‘crack’ in the assembly, you specify an End Weld between the mated surfaces. When this is done, the two parts will be connected. This can be done as many times as need to completely tie a large welded assembly together.

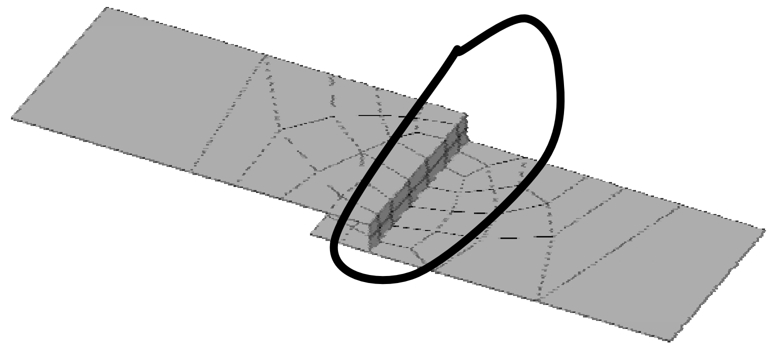




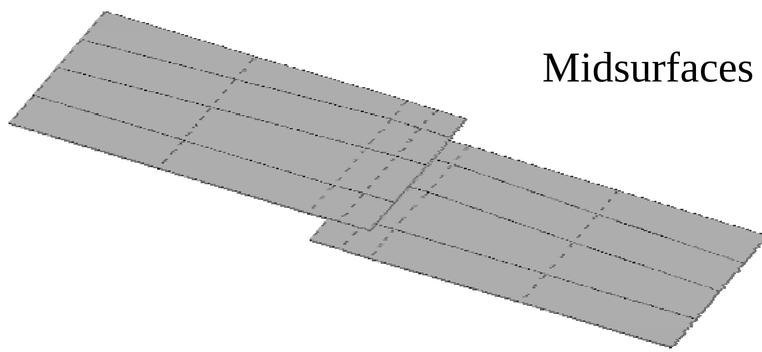
Meshing Sheetmetal Assemblies
Lap Joint with Fillet Weld Example



Lap Joint Solid Model

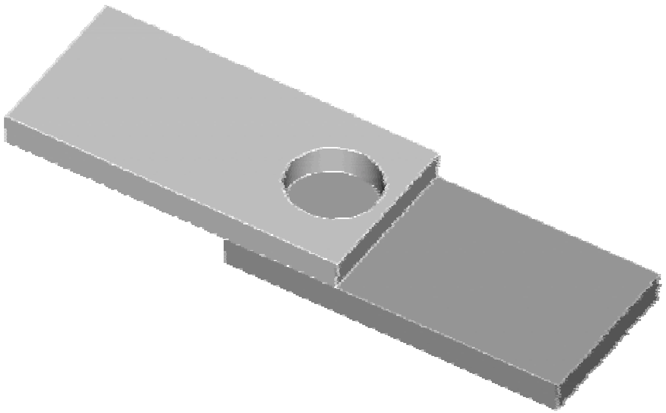


Midsurfaces Meshed with Fillet Weld

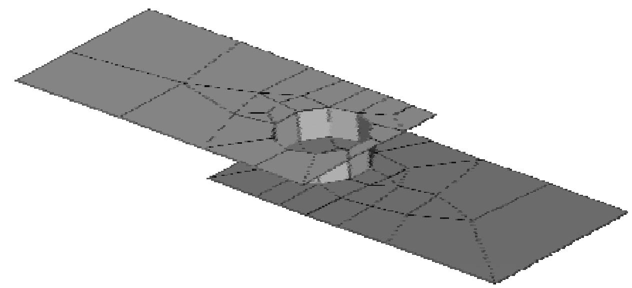


Midsurfaces Meshed without Fillet Weld

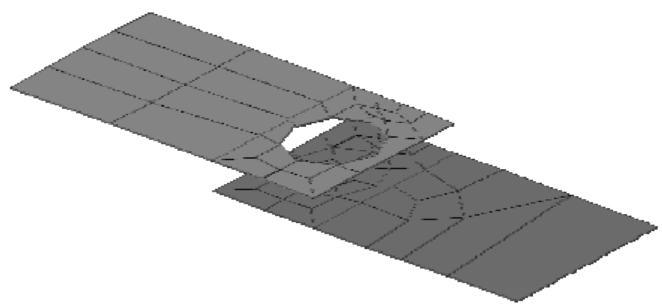
Meshing Sheetmetal Assemblies
Lap Joint with Plug Weld Example



Lap Joint Solid Model

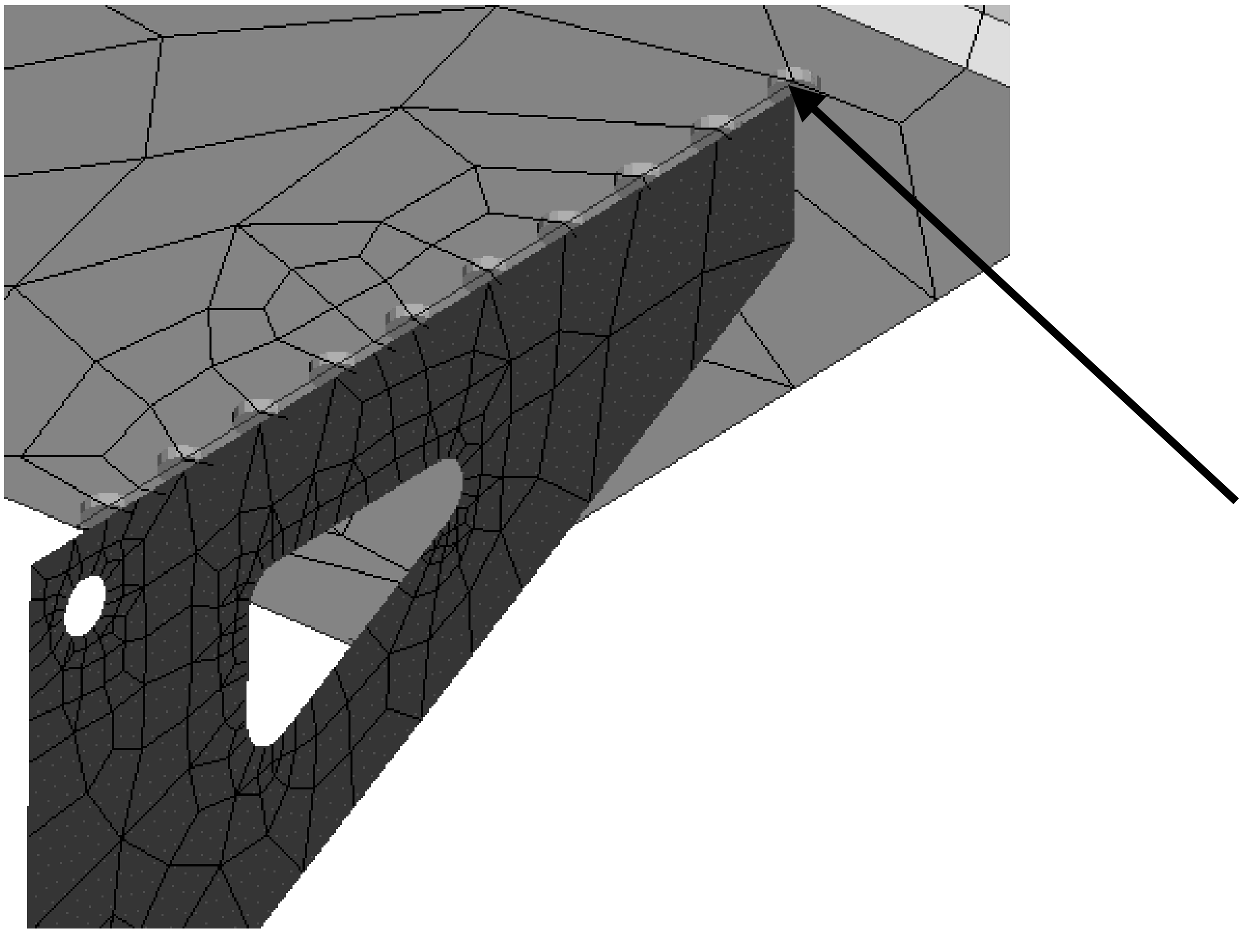


Midsurfaces Meshed with Plug Weld



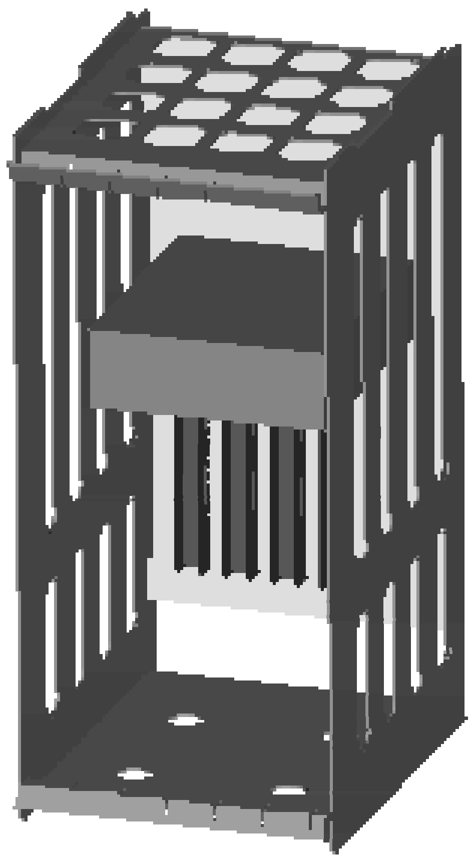
Midsurfaces Meshed without Plug Weld

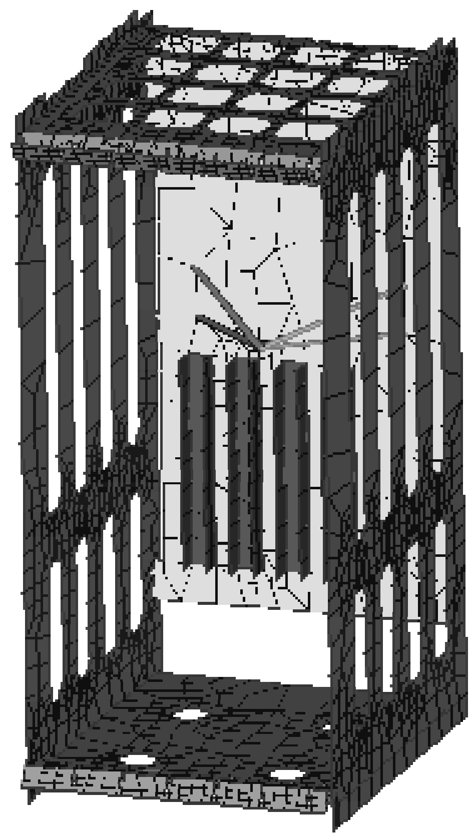
Meshing Sheetmetal Assemblies
Spot Weld Example



Short Beams Represent Spot Welds, and are also suitable for modeling screws.

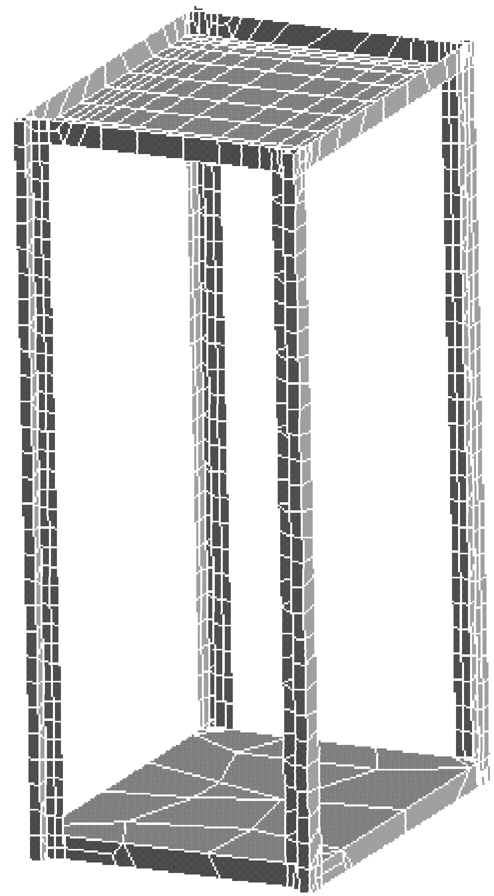
Electronic Components Replaced with Lumped Masses and Beams





Review of Test Simulation Methods using Finite Element Analysis

Generic Cabinets for Illustrating Analysis Methods



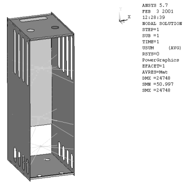
Bellcore GR-63-CORE Description of Static Test

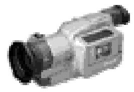
5.4.1.4 Static Test Procedure

Follow the procedure below applying a load in **both directions** of the front-to-back axis, and **both directions** of the side-to-side axis of the framework. (It is permissible to static test a different framework specimen than is used for dynamic testing.)

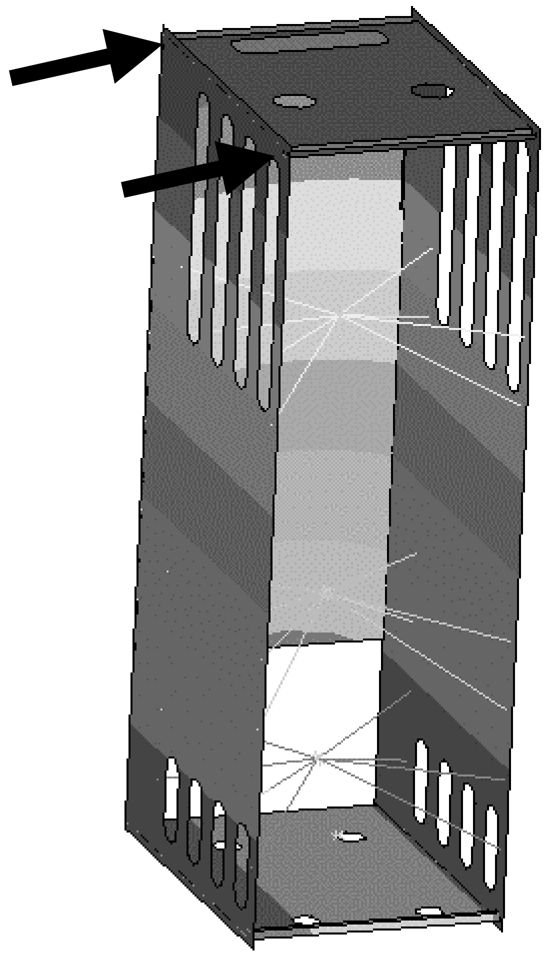
1. Photograph the framework.
2. Slowly (about 45 N/second {10 lb./sec.}) apply a horizontal load to the top of the framework.
3. Record the deflection and load as the load increases from 0 up to a load equal to or greater than the total weight of the equipped framework plus the overhead cable weight, for Zone 4 level testing. Zone 3 may use 0.6 of this load. Zones 1 and 2 may use 0.4 of this load.
4. Continue to record the deflection and load as the load is slowly removed.
5. Record observations of structural damage.
6. Photograph the unloaded framework.

Page 5-33





Static Analysis of Cabinet



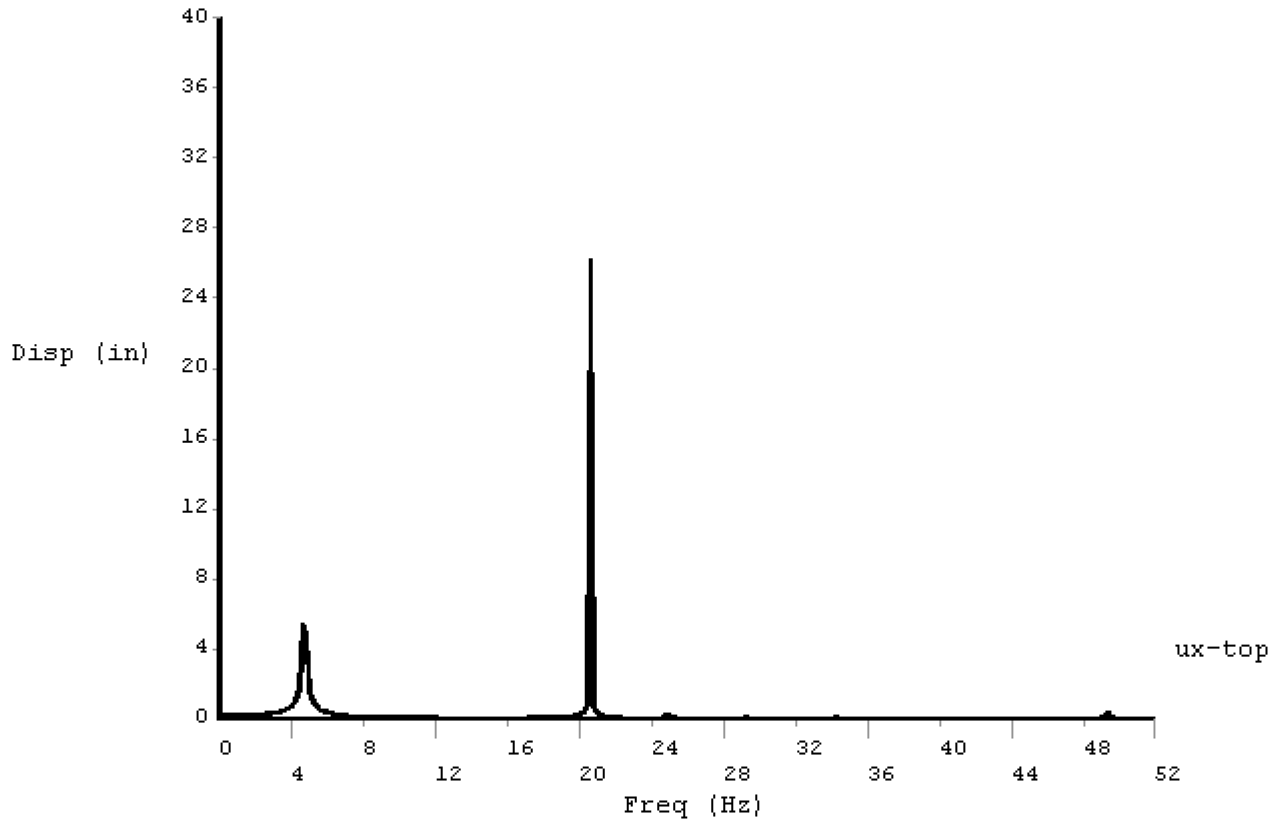
Bellcore GR-63-CORE Description of Swept Sine Survey

Follow the procedure below for vertical, front-to-back, and side-to-side framework axes:

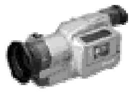
1. Perform a swept sine survey with an acceleration amplitude of 0.2 g from 1 to 50 Hz at a sweep rate of 1.0 octave per minute. (Higher sweep rates are permitted to reduce equipment stress.)

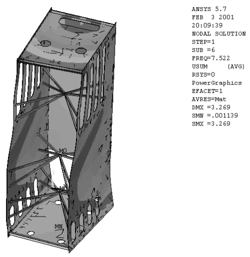
Page 5-34

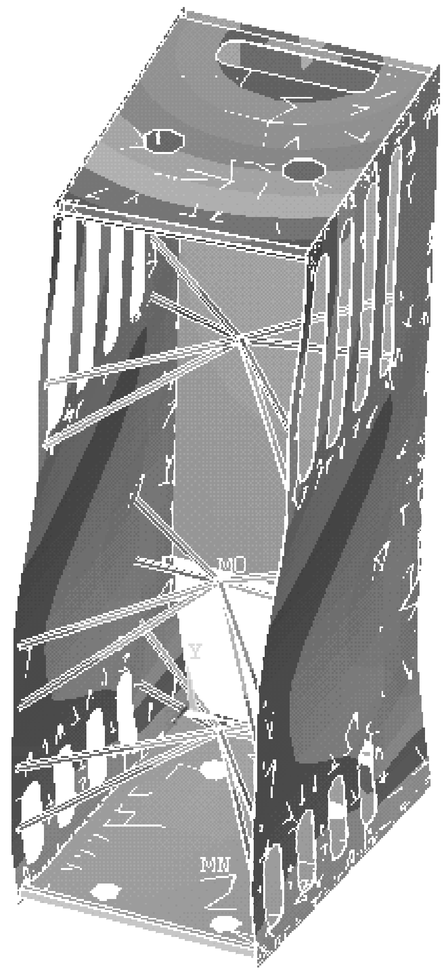
Typical Swept Sine Survey FEA Results at Top Front Corner of Cabinet



Swept Sine Survey FEA Results at Base Forcing
Frequency = 7.5 Hz







Hand Calculation to Check Harmonic Response FEA Results

$$X(\omega) = \frac{A}{[(1 - (\omega/\omega_n)^2)^2 + (2\xi\omega/\omega_n)^2]^{1/2}}$$

$X(\omega)$ = Displacement of SDOF

A = Base Displacement

ω = Forcing Frequency

ω_n = SDOF Natural Frequency

ξ = Damping Coefficient (%)

Bellcore GR-63-CORE Zone 4 Base Acceleration vs Time

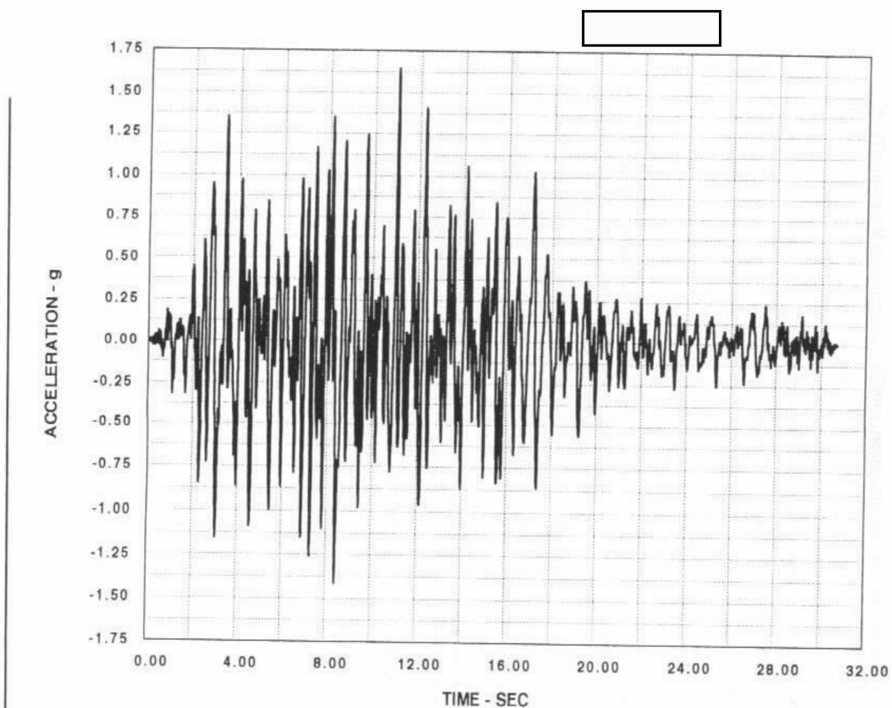
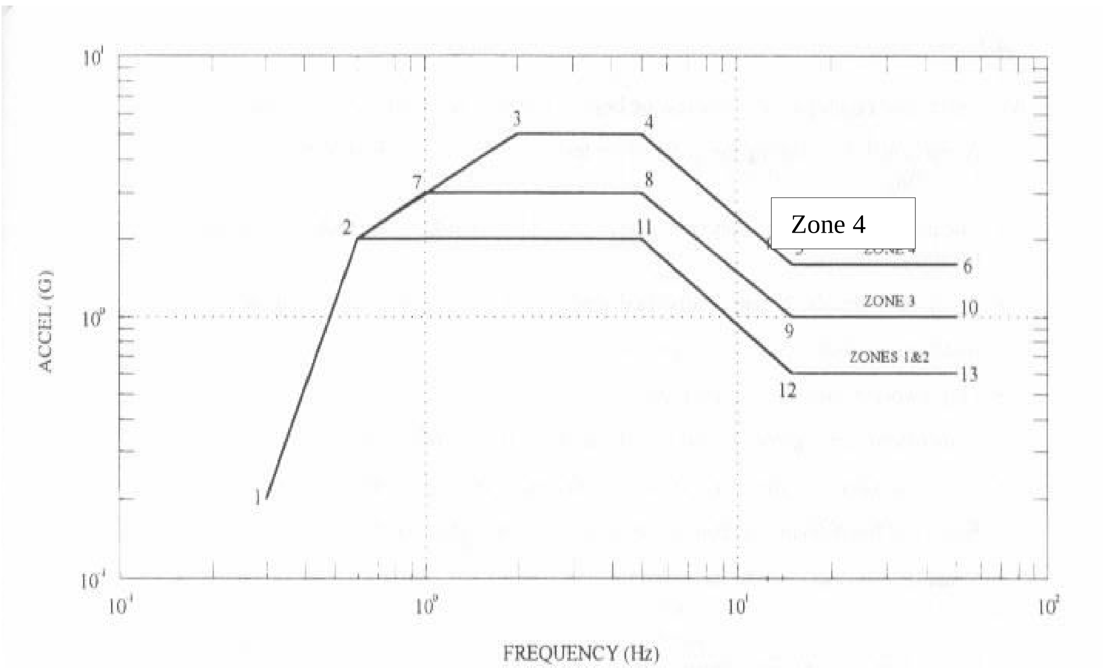


Figure 5-14. Earthquake Synthesized Waveform - VERTEQII

This time history of acceleration is converted to a response spectrum for FEA

Page 5-28

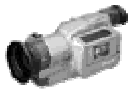
Bellcore GR-63-CORE Zone 4 Response Spectrum

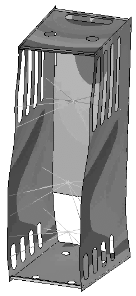


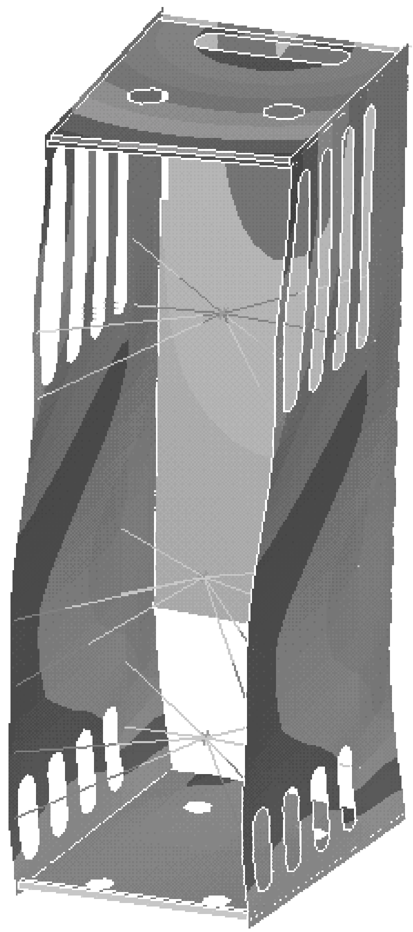
Spectral values from this curve are used to scale each of the modes from the modal analysis to find actual displacements for a Zone 4 earthquake

Page 5-29

Normal Modes Analysis
Animation of Mode 1 (f = 7.5 Hz)



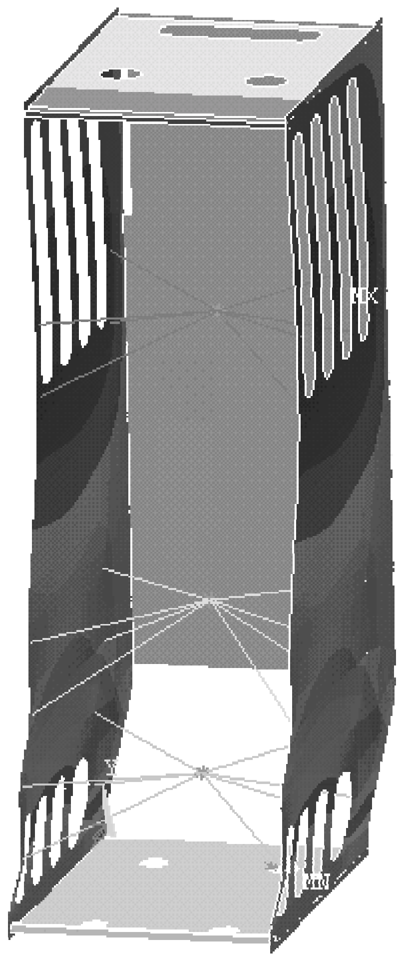




Key Results

- Natural Frequency
- Mode Shapes

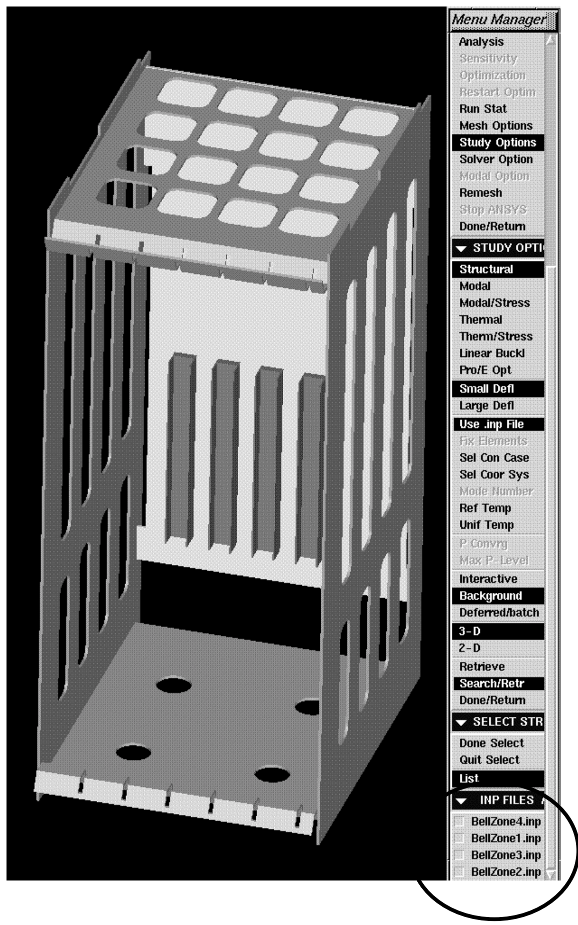
Maximum Displacements due to Zone 4 Spectrum



Key Results

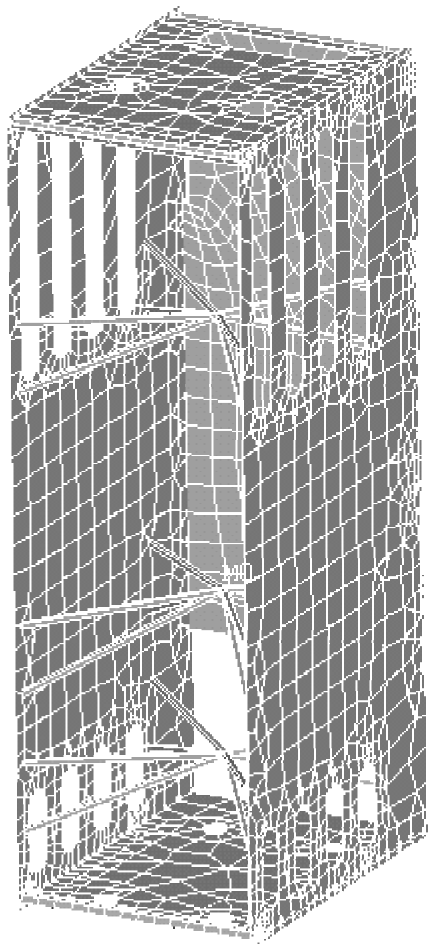
- Top Corner Deflection
- Stress Hot Spots

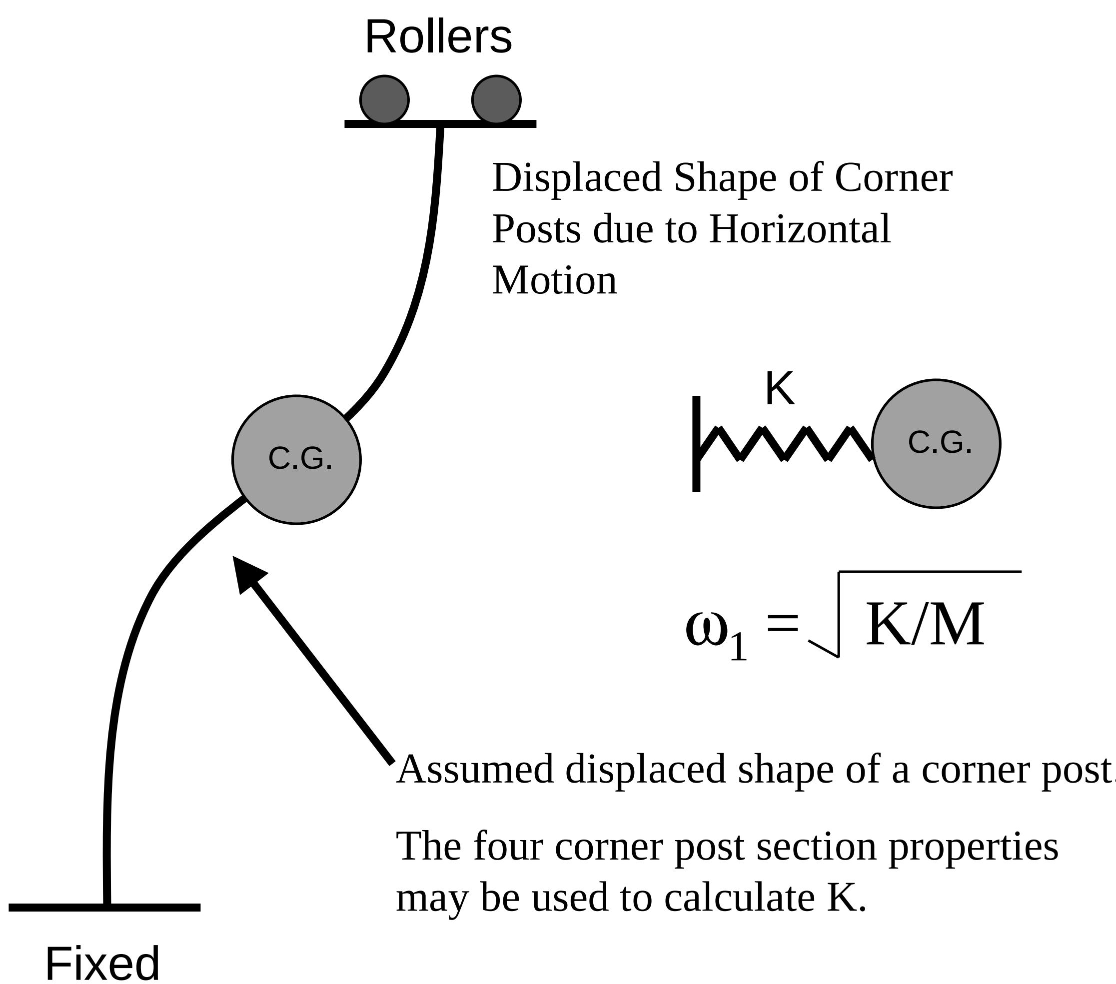
Selecting the Zone and Direction from Within Pro/E



DRD's 'Response Spectrum Library' product enables Zone 4 analysis while working in Pro/E.

Hand Calculation for Cabinet First Natural Frequency to Verify Results





$$\omega_1 = \sqrt{K/M}$$

The four corner post section properties may be used to calculate K.

Hand Calculation to Check Seismic FEA Results

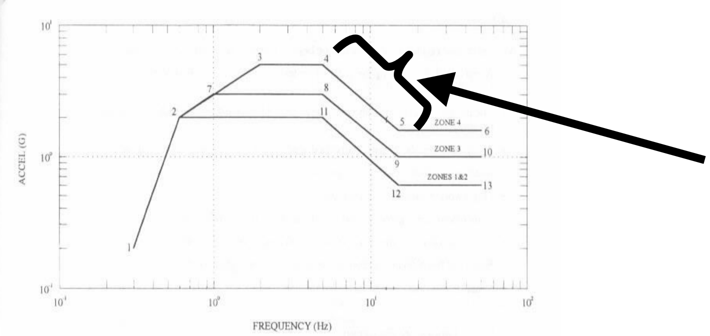
1. Read acceleration, a, from response spectrum curve based on natural frequency, $\omega_{n,}$ of the SDOF system.

2. Displacement amplitude = u = a /(ω_n 2Π)^2

This calculation approximates the displacement amplitude of the cabinet at its center of gravity.

Comparison of Zone 4 Displacement Response at Frequencies 7.7, 10, and 17 Hz Using Hand Calculations

Natural Frequency (Hz)	Zone 4 Acceleration (in/sec^2)	Displacement (in)
7.7	1275	.5
10	1005	.25
17	657	.06



In this portion of the curve between 5 and 15 Hz, the acceleration decreases rapidly with natural frequency.

Expenses to Repeat a Bellcore Zone 4 Test Per Cabinet Per Test

	Itemized Costs (US$)
Tooling/Fabrication	$3000
Engineering	$4000
Test Cost	$7500
Shipping	$2000
Prototype Cabinet	$5000
Total Cost	$21,500

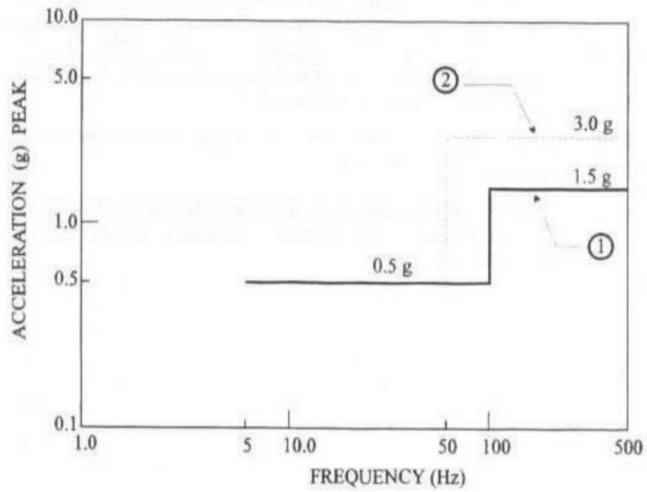
These figures are provided by Allan Daggs and Alan Herda of Motorola, Fort Worth, TX.

Testimonial from Alan Daggs and Alan Herda of Motorola

Seismic FEA in ANSYS® of the Motorola SC™4812ET cabinets allowed both cabinets to pass Bellcore seismic certification testing on the first prototype pass. Due largely to this success, initial product shipment was pulled in <u>two months</u>, allowing for <u>millions of dollars in additional sales.</u>

"SEISMIC SIMULATION OF THE MOTOROLA SC™4812ET RF AND POWER CABINETS USING PRO/ENGINEER® AND ANSYS®" by Allan Daggs and Alan Herda, presented at the 2000 ANSYS Conference and Exhibition, Pittsburgh, PA.

Bellcore GR-63-CORE Response Spectrum Analysis for Transportation Loads



Vibration Source	Curve	Freq. Range (Hz)	Sweep rate (Octaves/Min)
Commercial Transportation (Rail, Truck, Ship, Jet Aircraft)	1	5 - 100 100 - 500	0.1 0.25
Commercial Transportation (Rail, Truck, Ship, Jet, Reciprocating or Turbo-prop Aircraft)	2	5 - 50 50 - 500	0.1 0.25

Figure 4-3. Commercial Transportation Vibration Environment

Page 4-24

This is a response spectrum for transportation loads

Except for the specific response spectrum, the FEA is identical to a seismic analysis

Bellcore GR-63-CORE Drop Test Simulation Set Up for a Corner Test

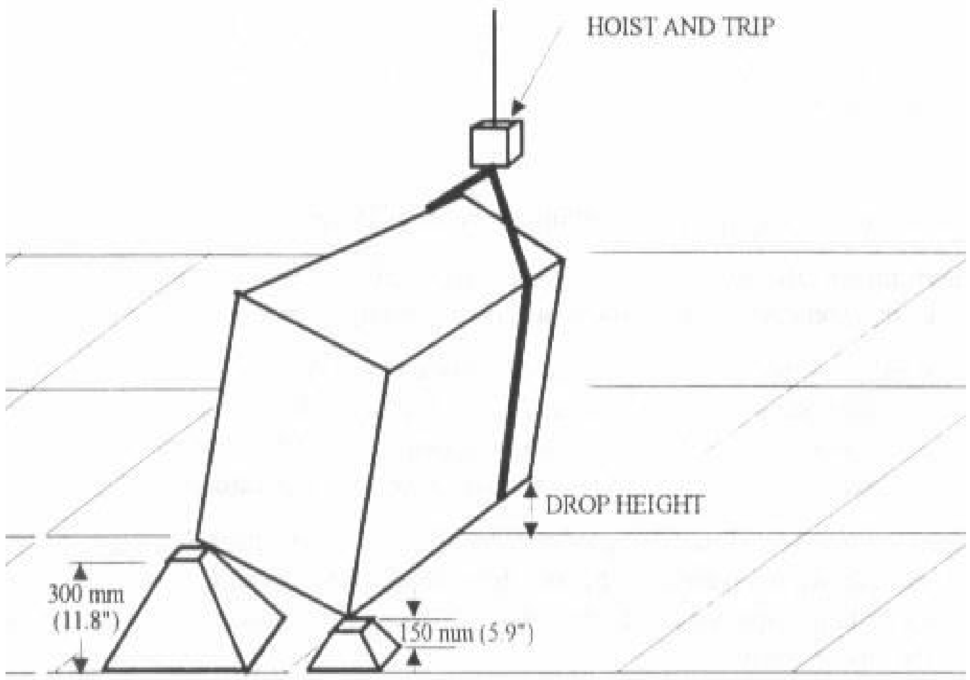
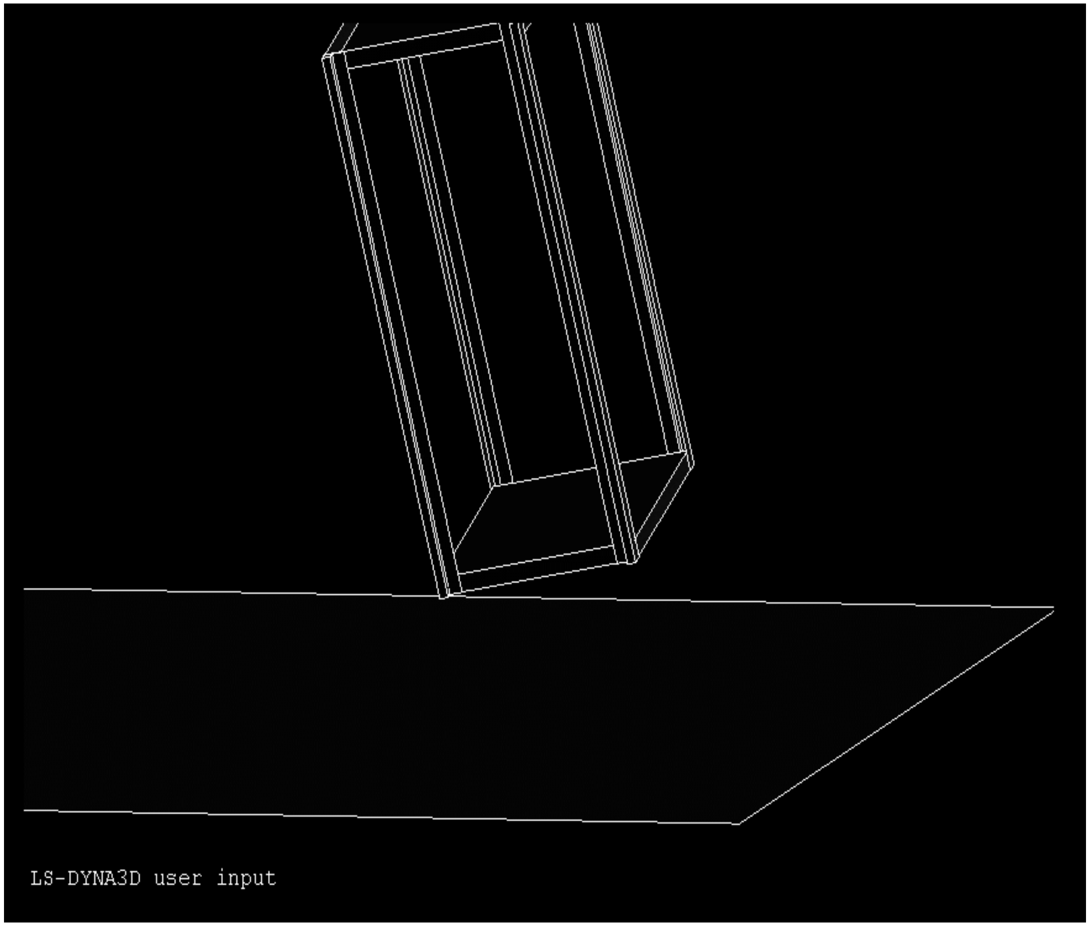


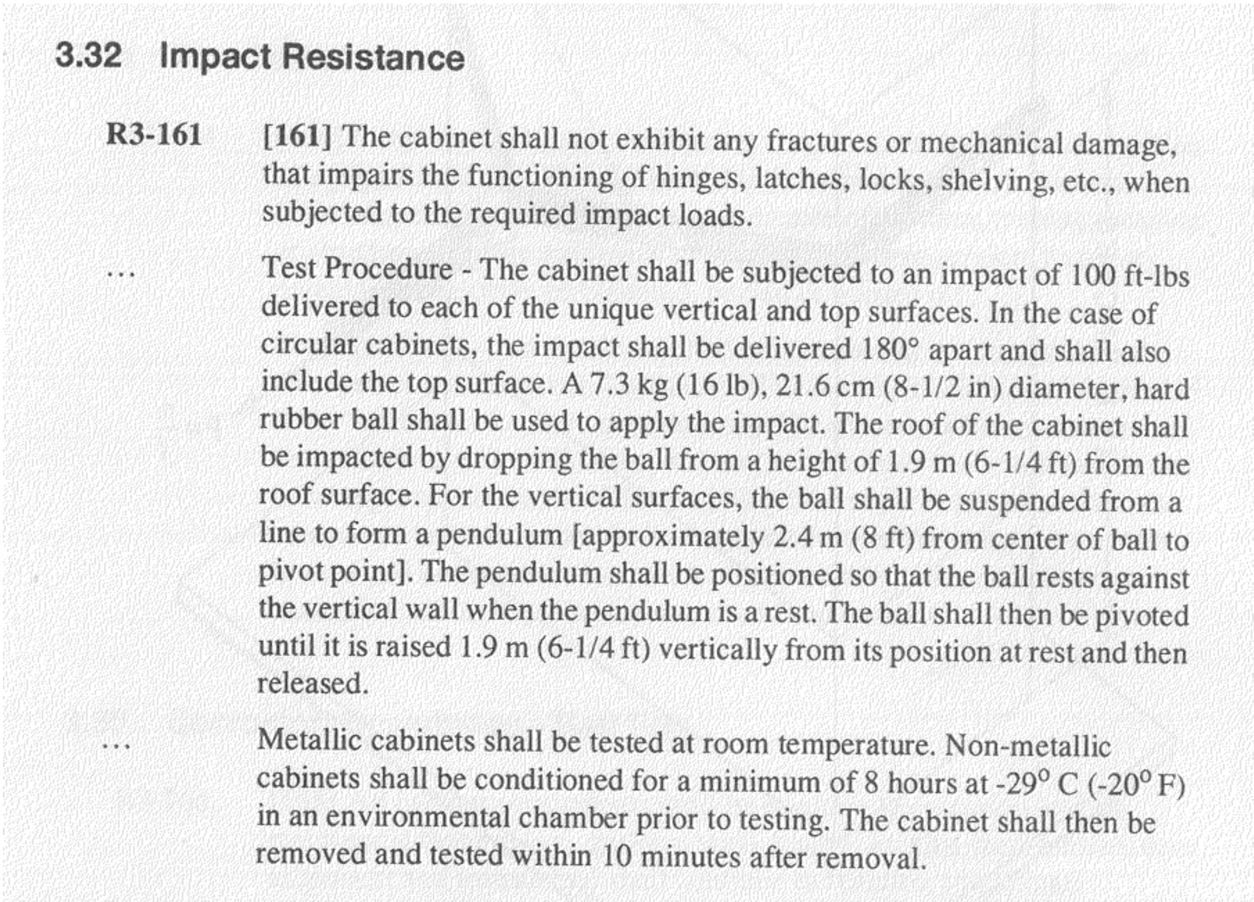
Figure 5-13. Test Setup for Category B Container, Cornerwise Drop

Page 5-25

Cabinet Drop Test Simulation using ANSYS/LS-DYNA



Bellcore GR-487-CORE Description of Impact Test


3.32 Impact Resistance

R3-161 **[161]** The cabinet shall not exhibit any fractures or mechanical damage, that impairs the functioning of hinges, latches, locks, shelving, etc., when subjected to the required impact loads.

... Test Procedure - The cabinet shall be subjected to an impact of 100 ft-lbs delivered to each of the unique vertical and top surfaces. In the case of circular cabinets, the impact shall be delivered 180° apart and shall also include the top surface. A 7.3 kg (16 lb), 21.6 cm (8-1/2 in) diameter, hard rubber ball shall be used to apply the impact. The roof of the cabinet shall be impacted by dropping the ball from a height of 1.9 m (6-1/4 ft) from the roof surface. For the vertical surfaces, the ball shall be suspended from a line to form a pendulum [approximately 2.4 m (8 ft) from center of ball to pivot point]. The pendulum shall be positioned so that the ball rests against the vertical wall when the pendulum is a rest. The ball shall then be pivoted until it is raised 1.9 m (6-1/4 ft) vertically from its position at rest and then released.

... Metallic cabinets shall be tested at room temperature. Non-metallic cabinets shall be conditioned for a minimum of 8 hours at -29° C (-20° F) in an environmental chamber prior to testing. The cabinet shall then be removed and tested within 10 minutes after removal.

Page 3-29

Cabinet Impact Test Simulation

This presentation does not include a cabinet impact test simulation example. The modeling techniques are similar to those for drop test simulation.

Bellcore GR-487-CORE Description of Thermal Test

R3-151 **[151]** The cabinet manufacturer shall determine the maximum internal steady state cabinet temperature when the cabinet is exposed to an ambient temperature of 46° C (115° F) and maximum solar load using the stated test procedure. Full details of test procedure implementation shall be provided.

Test Procedure:

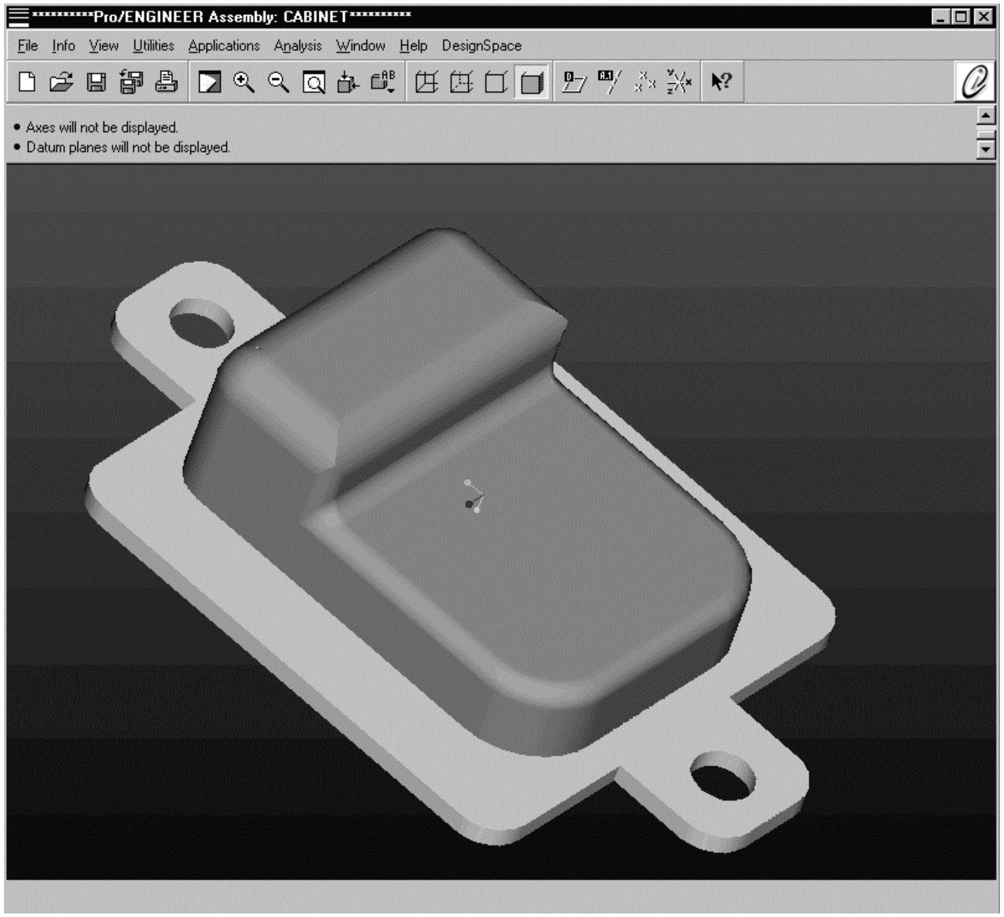
A. Calculation of Solar Load

The solar load induced by the sun (incident solar load) is partially reflected and partially absorbed by the cabinet. The amount of heat absorbed is dependent on the solar absorptance value of the cabinet surfaces. This value is related to cabinet color, gloss and texture. Typical solar absorptance values can be found in heat transfer handbooks or may be provided by the suppliers of the cabinet finish. Absorptance values will increase as the cabinet finish ages. Published values should be increased by 50% to reflect this effect. Either incident or absorbed solar loads will be utilized in this test procedure depending on the method used to apply the solar load. **Absorbed solar loads** can be determined by multiplying the incident solar load for each surface by it's solar absorptance value. **Incident solar loads** may be determined by either of the following methods:

Method 1 - The **incident solar load** may be calculated assuming a total short wave radiation intensity of 753 W/m^2 (70 W/ft^2) applied to 100% of the horizontal (top) surface area, 100% of a vertical front or rear surface area and 100% of a vertical side surface area of the cabinet. This is a simplified procedure, allowing the application of a uniform solar load to three surfaces as compared to Method 2 which uses varied loads over all

Page 3-23

Thermal Analysis



<u>ANSYS Thermal Model Attributes</u>

- Internal heat generation.
- Incident solar radiation.
- Radiation from enclosure to environment.
- Temperature dependent convection coefficients.
- Air nodes to handle convection in internal voids.

<u>Advantages Over Solutions such as Flotherm</u>

- Very fast solution times.
- Same model can be used for thermal-stress analysis.
- Same model to study creep seal integrity, and stress.

Copies of Today's Presentations and Related Papers

Today's presentations are available on DRD's web site at www.drd.com on the page that describes today's seminar.

Additional related material on our web site are:

- Seismic Simulation of the Motorola SC™4812ET RF and Power Cabinets Using Pro/ENGINEER® and ANSYS®, by Allan Daggs and Alan Herda, presented at the 2000 ANSYS Conference and Exhibition, Pittsburgh, PA.
- Bellcore Response Spectrum Analysis using ANSYS and Pro/ENGINEER, by Andy Bax and Chris Andersen DRD Technology Corporation Tulsa, OK, published in *Analysis Solutions*, Volume 2, Number 1, Spring 1998 and *Pro/E: The Magazine*, Volume 6, Number 5, July/August 1998.
- Dynamic Shock Simulation of a Computer Hard Drive Using an ANSYS/LS-DYNA Implicit-Explicit Sequential Solution, by Chris Andersen, DRD Technology Corporation and John Stricklin, Seagate Technology, presented at the 2000 ANSYS Conference and Exhibition, Pittsburgh, PA.