Structural Drop Test Simulation of a Cask for Spent Fuel Elements from Nuclear Research Reactors

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The simulation main purpose is developing a modeling and results evaluation methods in order to apply in future prototypes design, as part of a multinational project sponsored by AIEA.

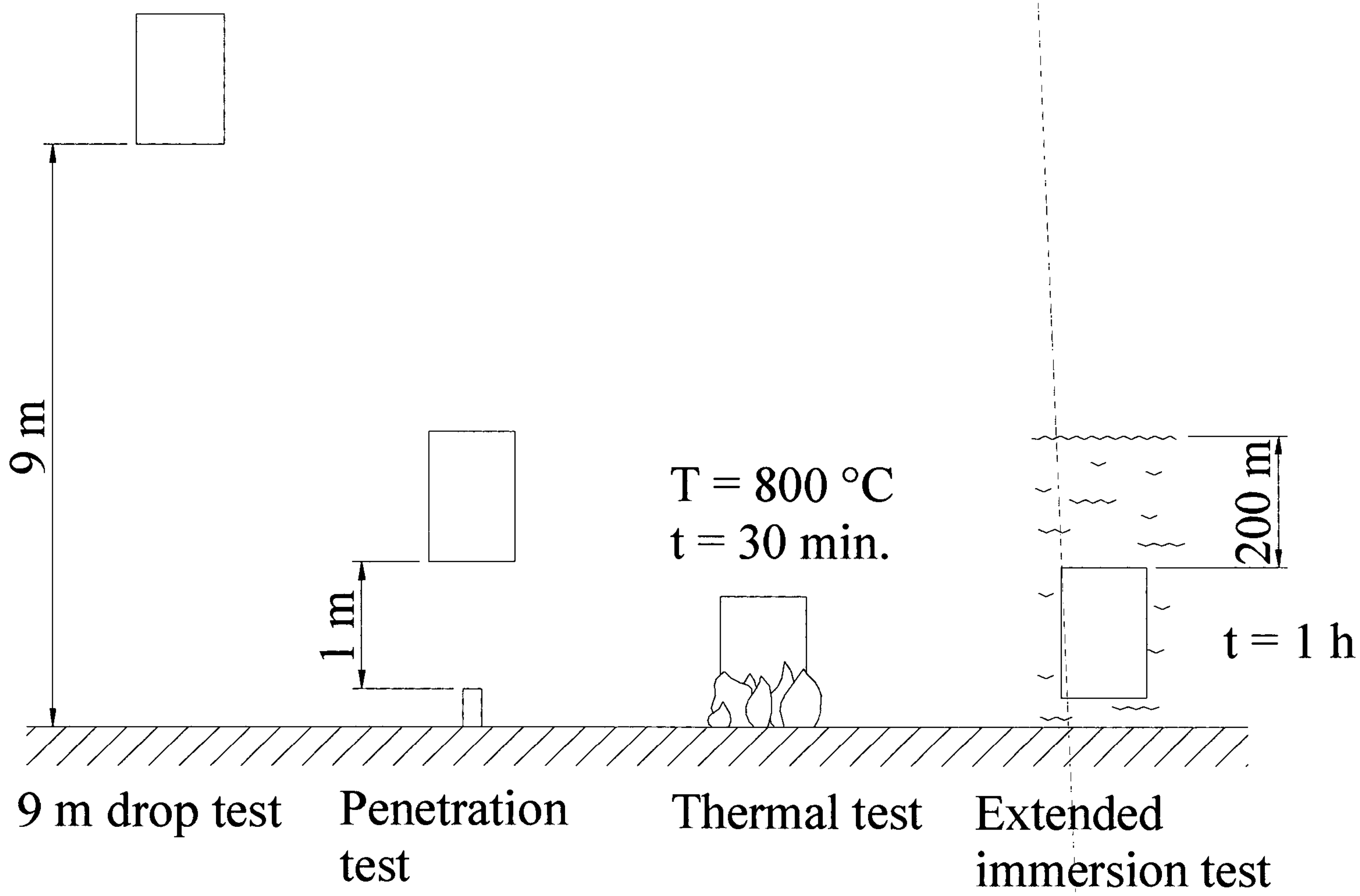
The project partners are IPEN, CDTN and South American countries with research reactors, to qualify a shipping cask for their burned fuel elements.

In the 9 m drop test simulation, the existing non-linearities related with the several contacts, material mechanical properties and geometry are considered.

Licensing

- Safety Analysis Report for the Packaging - SARP (prepared according to USNRC Regulatory Guide 7.9, rev.1)
  - General Information (packaging description, drawings, QA)
  - Structural Evaluation (materials, lifting and tiedown devices, normal and accident conditions)
  - Thermal Evaluation (thermal properties of materials, normal and accident conditions)
  - Containment (containment boundary, normal and accident conditions)
  - Shielding Evaluation (gamma and neutron sources)
  - Criticality Evaluation (criticality models for MTR and TRIGA fuels)
  - Operating Procedures (loading and unloading, dry/wet (un)loading)
  - Acceptance Tests and Maintenance Program (visual inspection; structural, thermal and leak tests; shielding integrity verification)

Prescribed tests



Physical testing and numerical simulation interaction

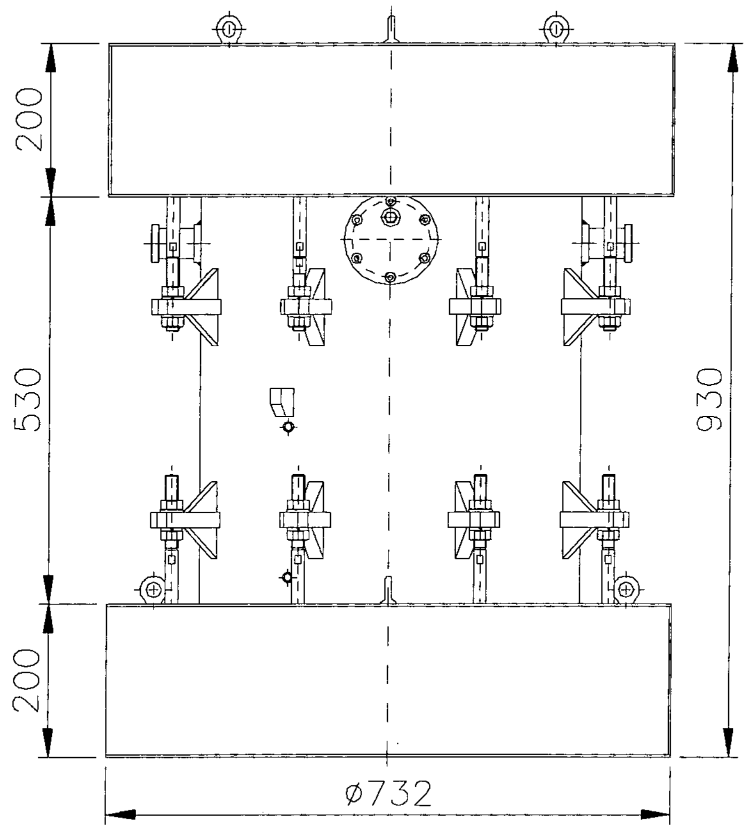
- Model (1:2)
  - 9 m drop test + penetration test + thermal test
  - Damaged model
  - Extended immersion test (p = 20 bar) numerically simulated using damaged model

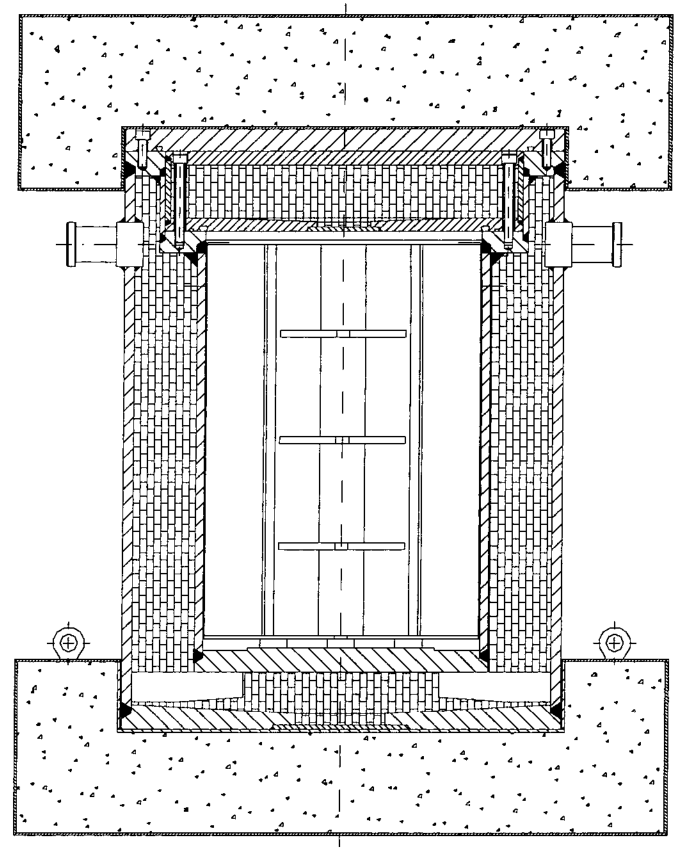
- Prototype: All tests numerically simulated

Cask structural design

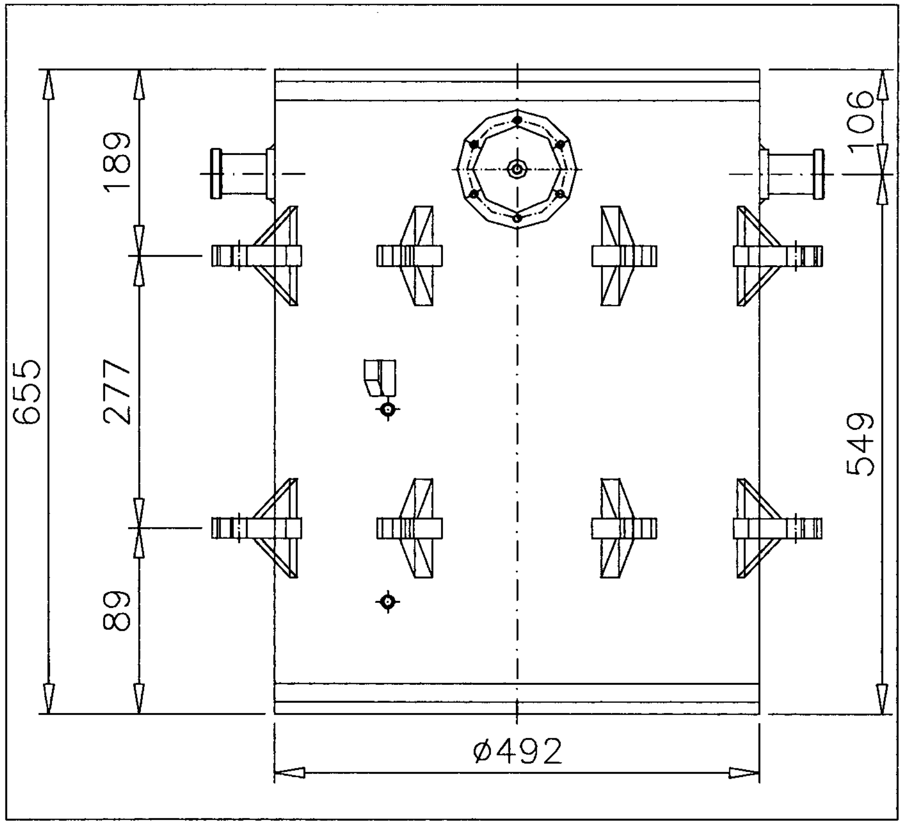
- Design criteria: 21 MTR or 78 TRIGA, max. weight 10 t, Type B fissile package
- Main parts:
  - Main body
  - Lids: internal and external
  - Basket
  - Impact limiters

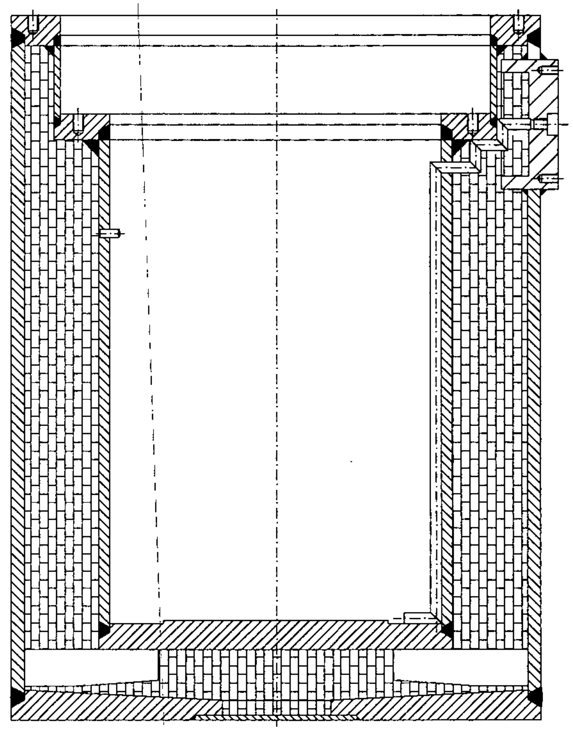
Half scale model - general view





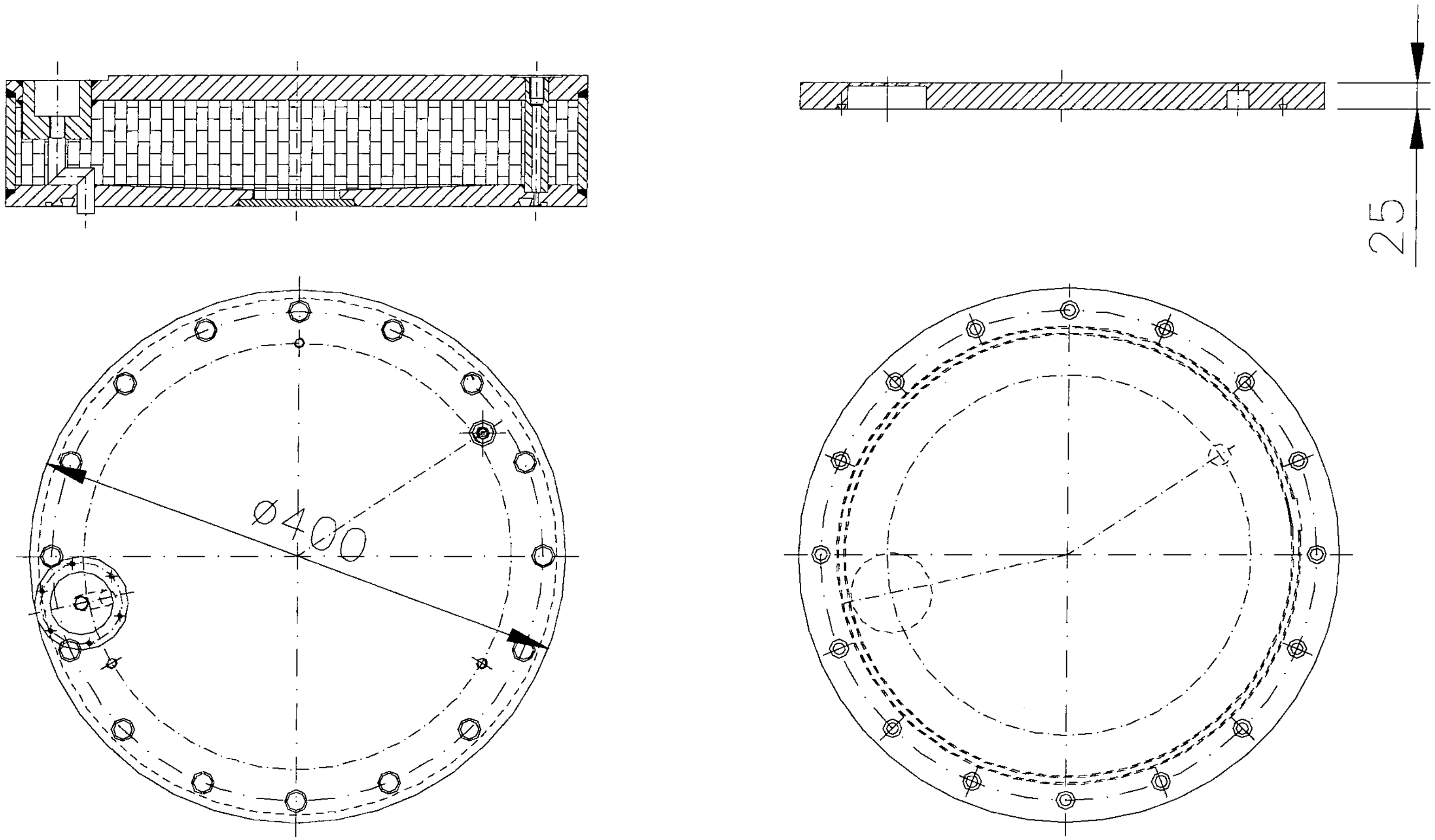
Main body



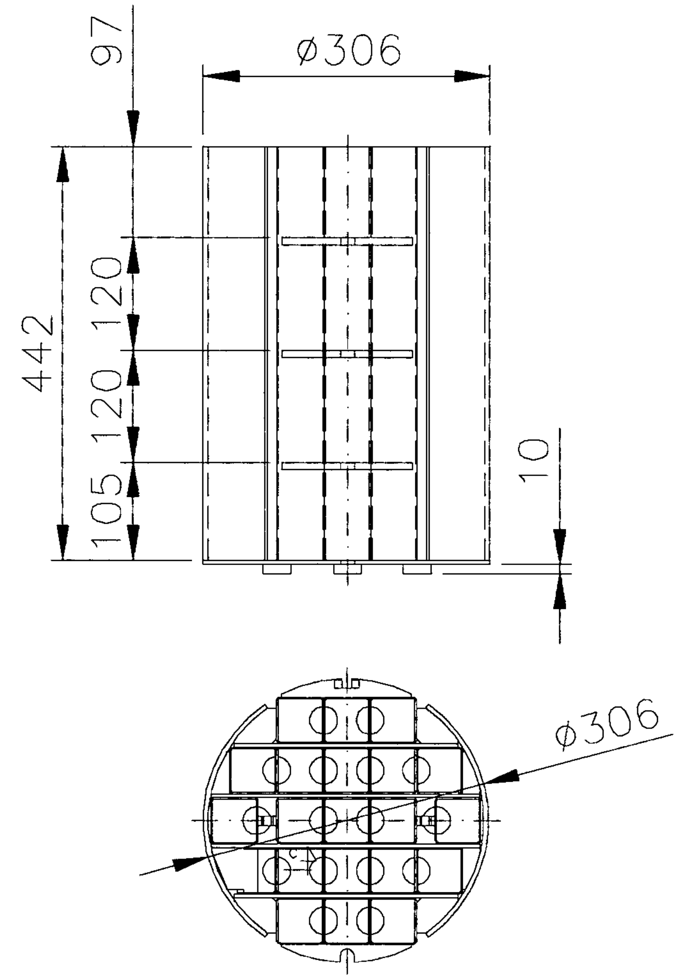


External wall: resist puncture
Cavity wall: resist lead contraction

Internal and external lids

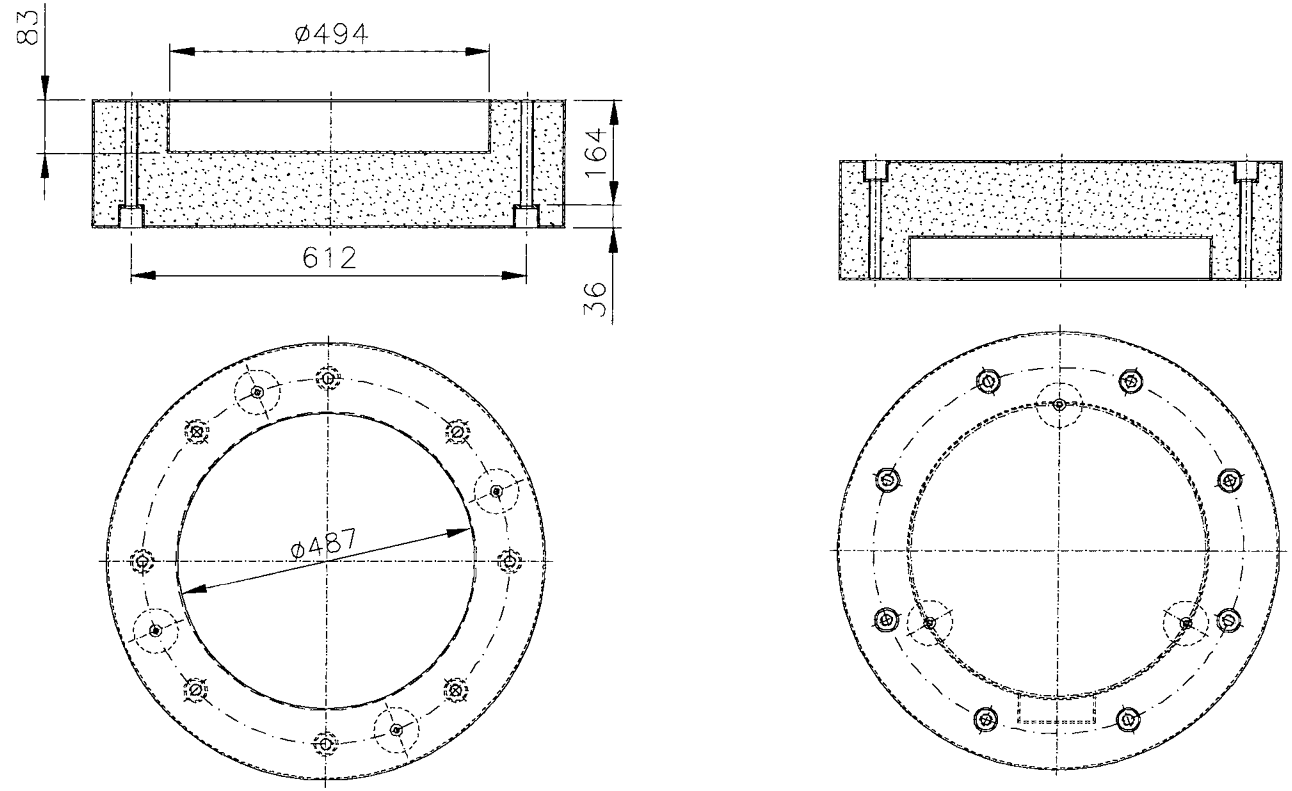


Internal basket



- Only for MTR fuel elements
- 20 positions for fuel elements, one position for accelerometer

Impact limiters



- Filling material: light mortar, wood, polyurethane foam

Impact limiters

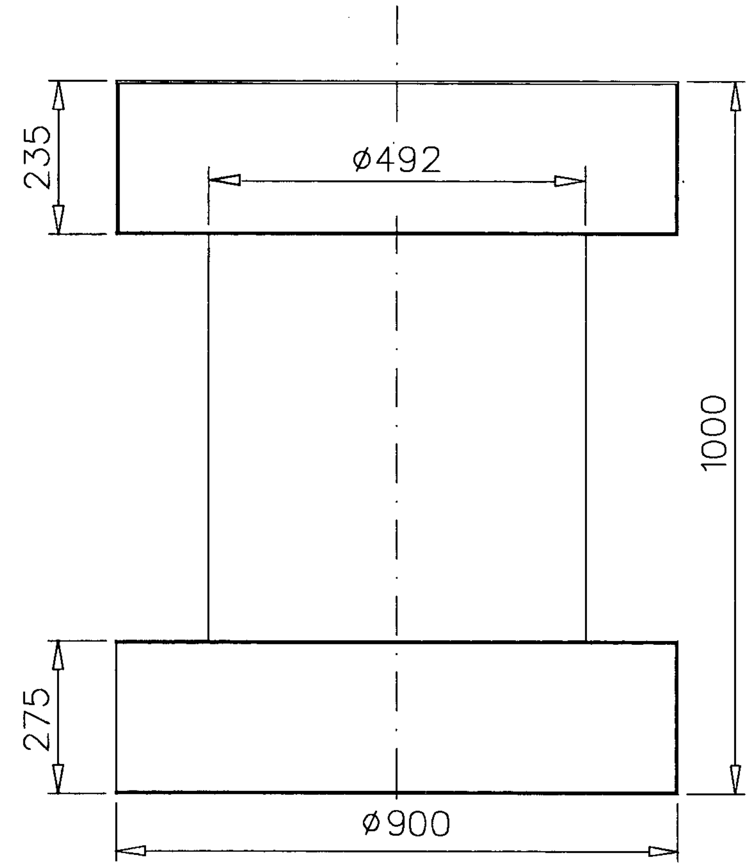
Filling material	Advantages	Disadvantages
Solid wood (Eucaliptus, Pinus)	•High energy absorption capacity (tenacity)	•Flammable •Hard to model •Anisotropic, not homogeneous
Reconstituted wood (OSB)	•Homogeneous	•Flammable •Hard to model •Anisotropic
Polyurethane foam	•Only slightly anisotropic •Easily modeled	•Challenging manufacture •Organic, flammable
Light mortar	•Homogeneous, isotropic •Good resistance to fire •Inorganic •Easily modeled	•Needs baking

Model description:

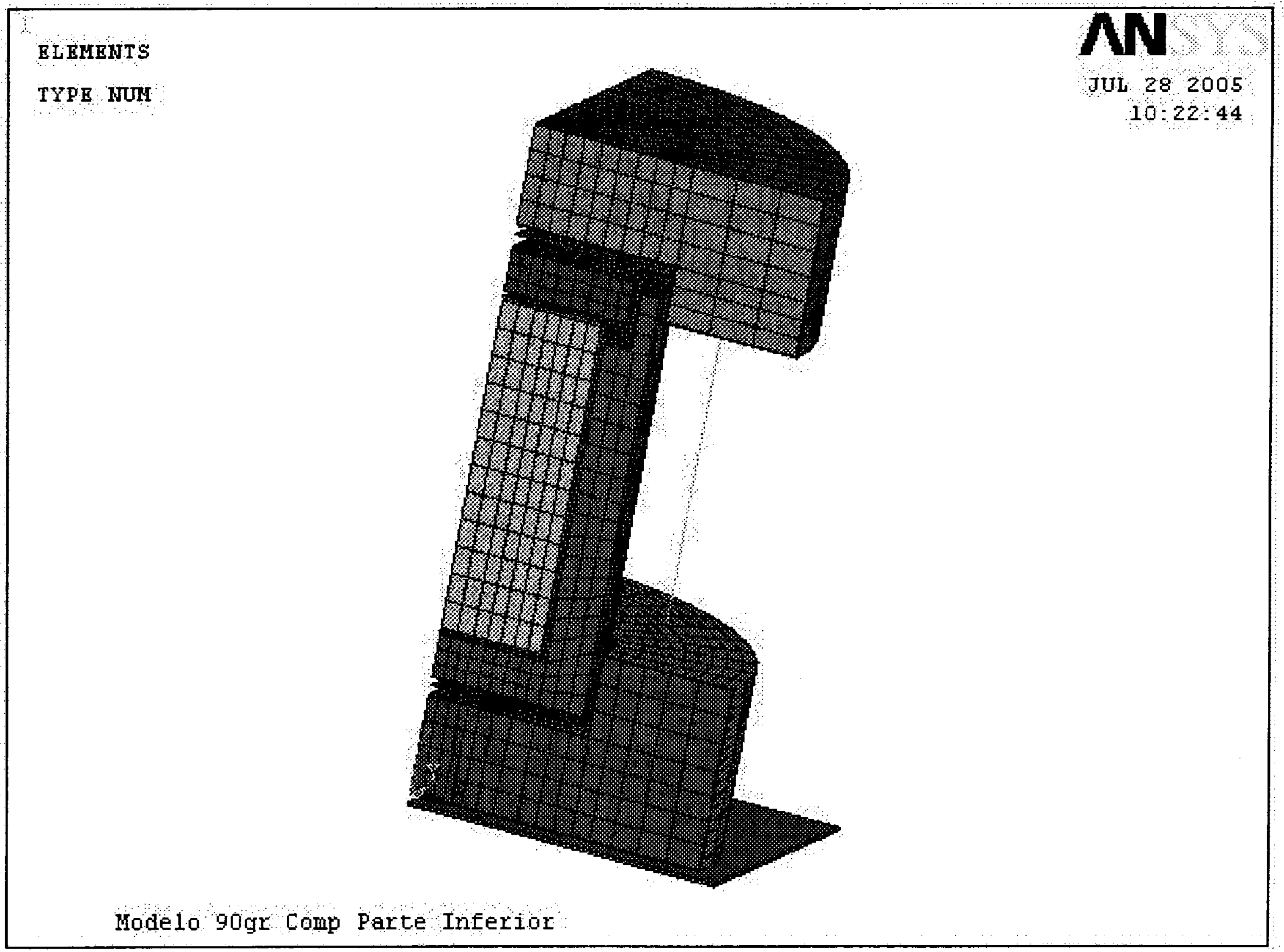
The cask itself is a stainless steel cylinder with flat heads (the bottom one is welded and the upper one has flanges with threaded connections) and internals (for the fuel elements)

It is surrounded by a biological shield of lead and it has also upper and bottom wood dampers. All contained in stainless steel shells.

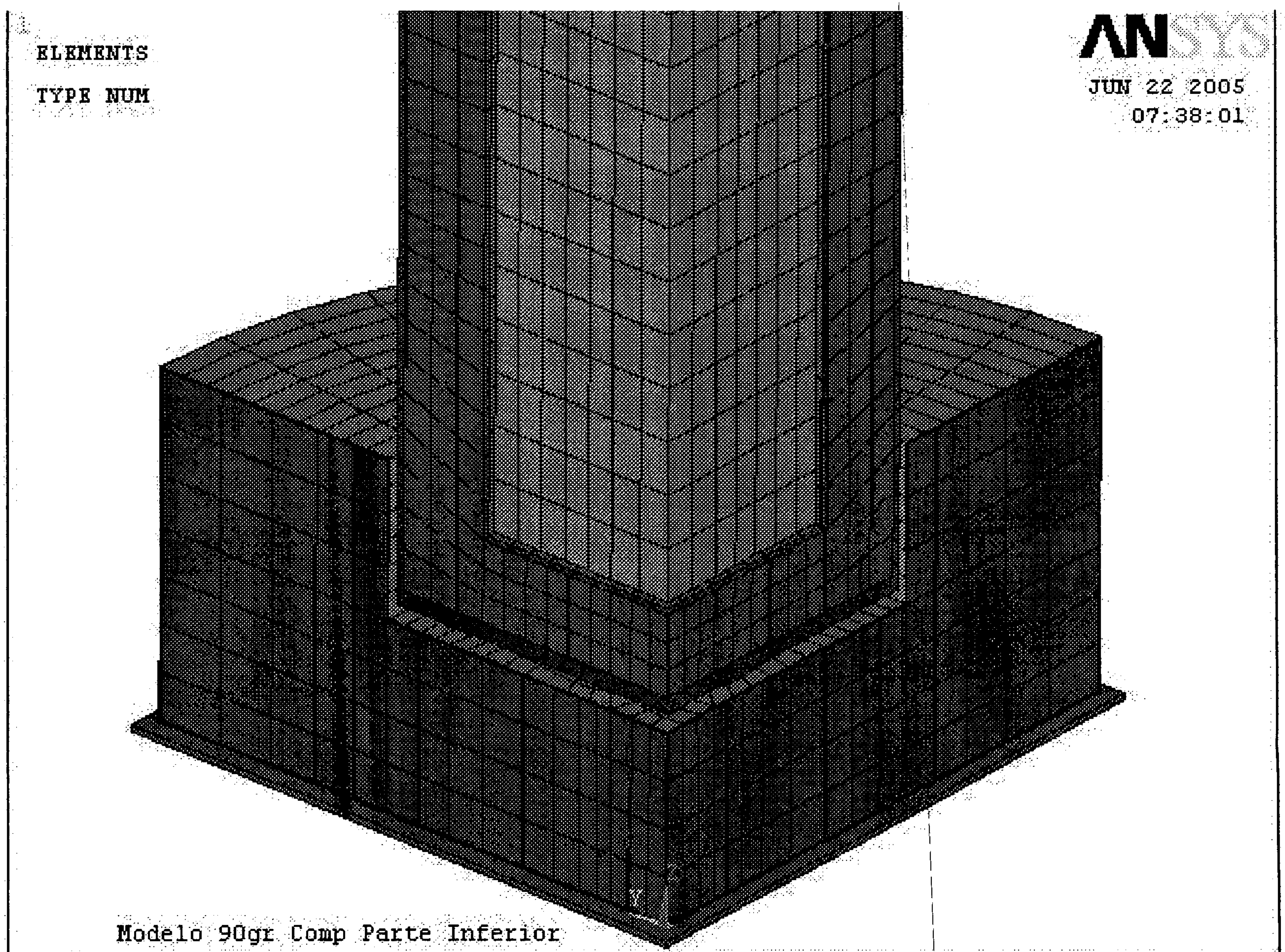
Model Description – general dimensions



Model Description – general view

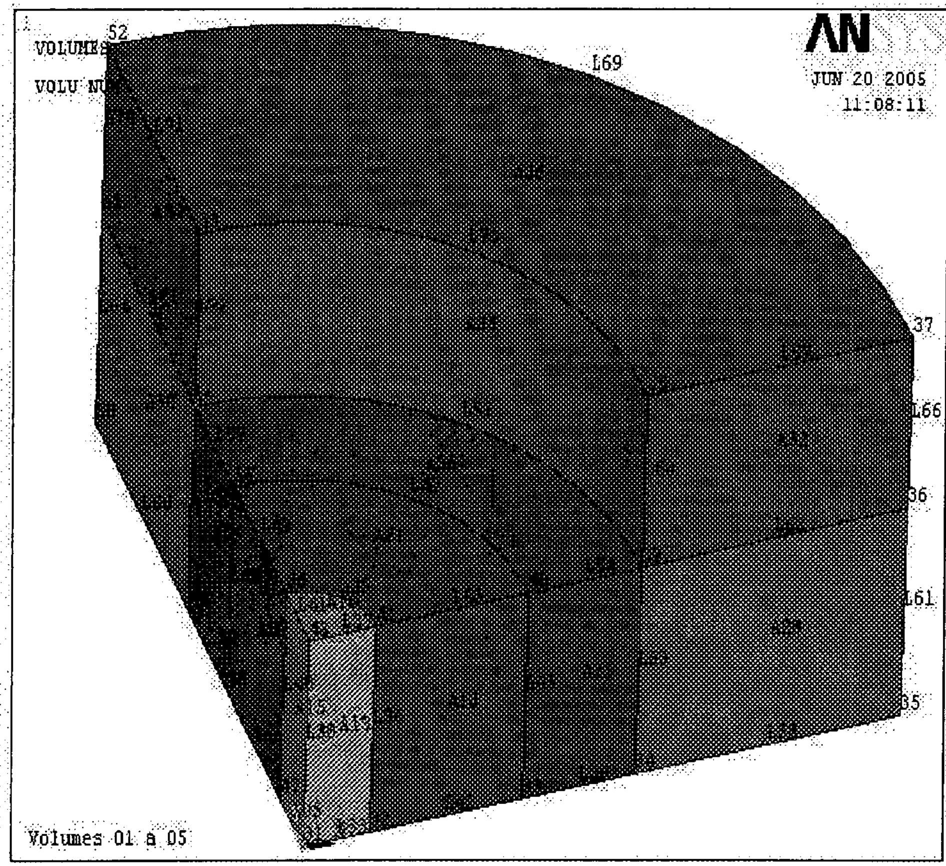


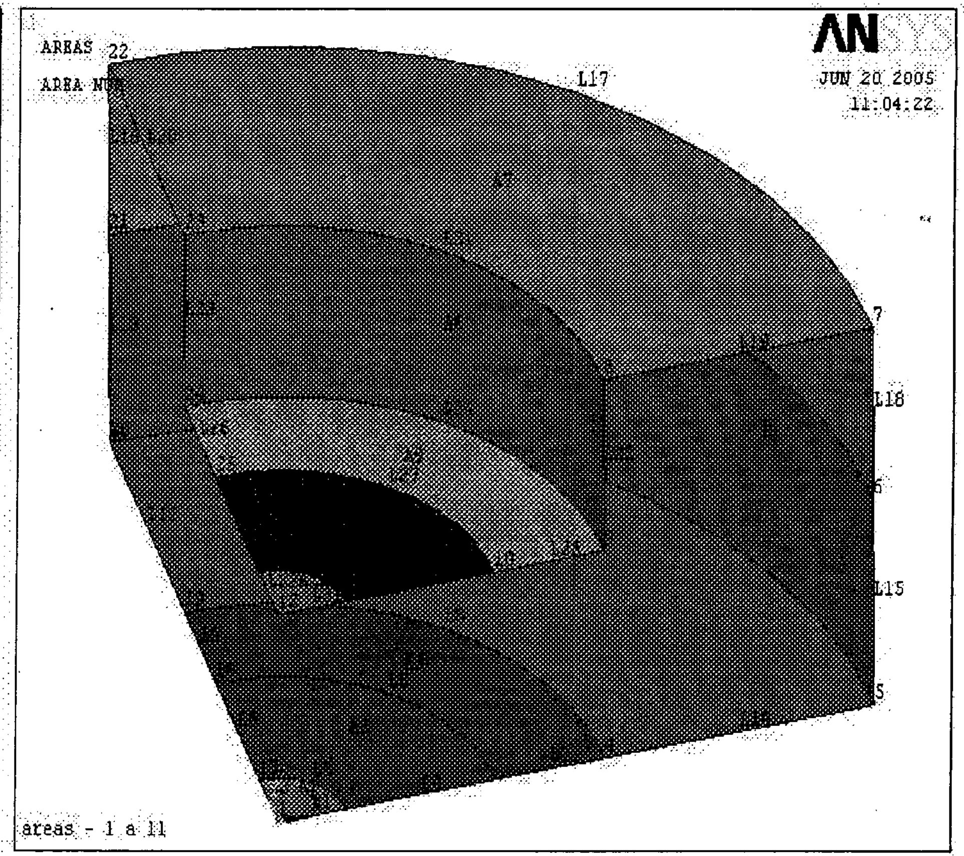
Model Description – bottom details



Model Description – bottom details

Damper & Lower Shell





Analysis Data:

	Material	Dimensions
Lower shell	stainless steel	dia = 900 mm
Lower Damper	wood	dia = 894 mm
Inner Shell	stainless steel	dia = 328 mm
Lead	..	
Outer Shell	stainless steel	dia = 492 mm
Upper Damper	wood	dia = 894 mm
Upper shell	stainless steel	dia = 900 mm

Loading:

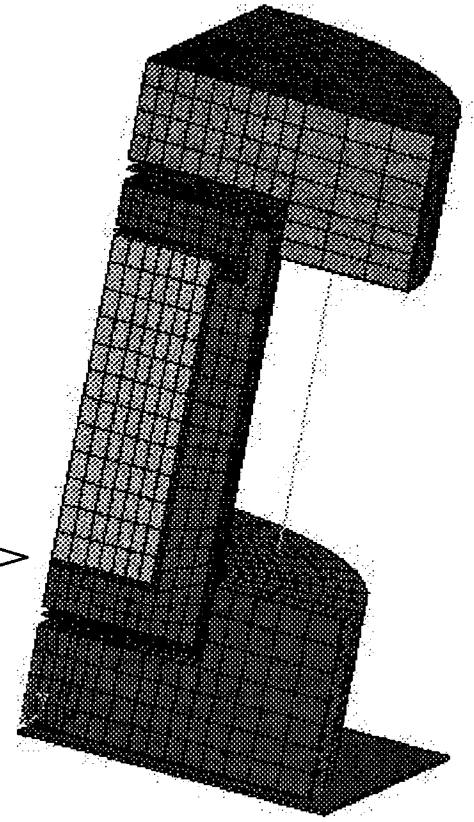
It was applied an initial velocity that corresponds to 9 m drop test plus gravity acceleration.

The analysis was performed until 10 ms.

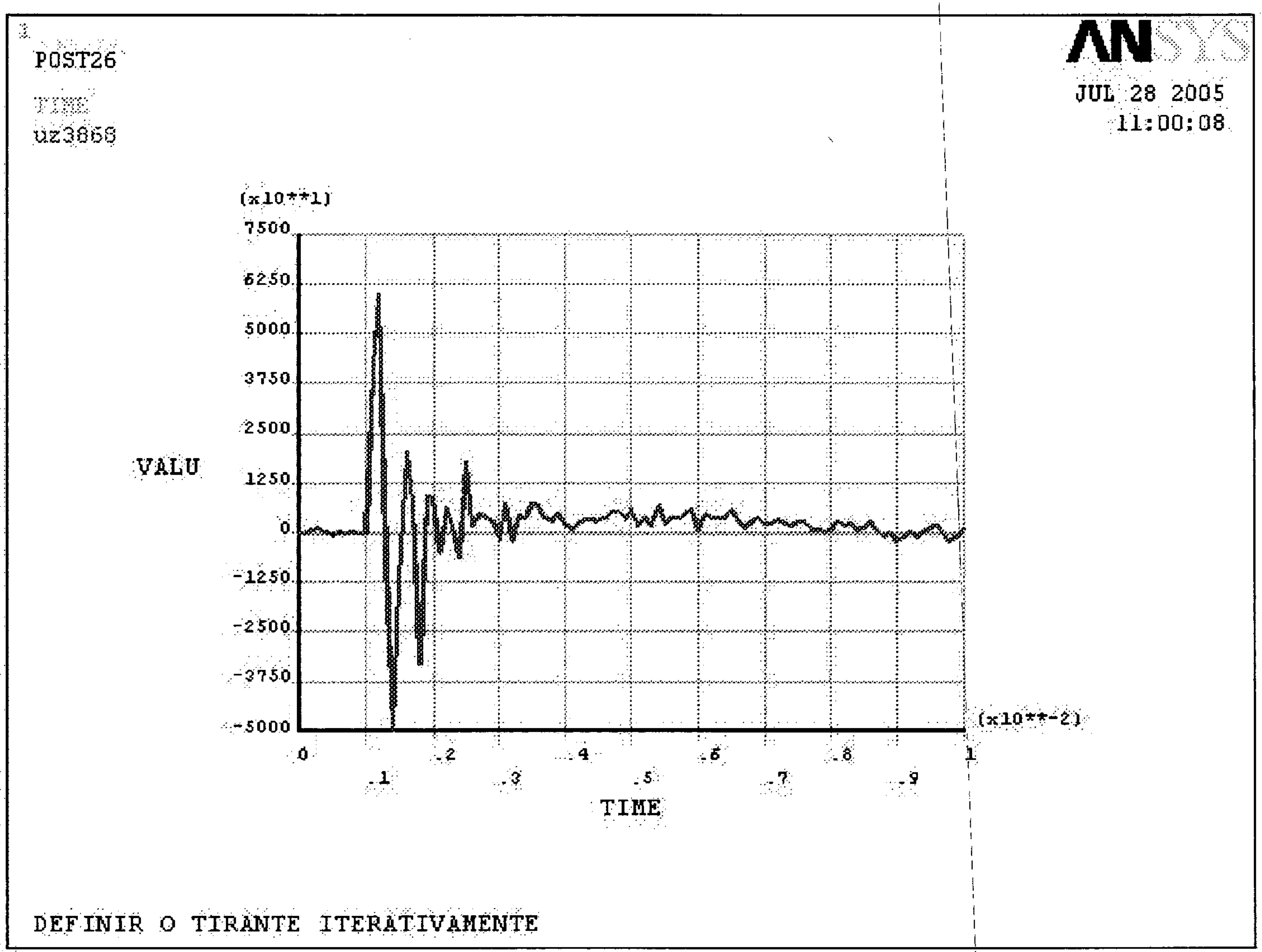
Results:

As results will be showed:

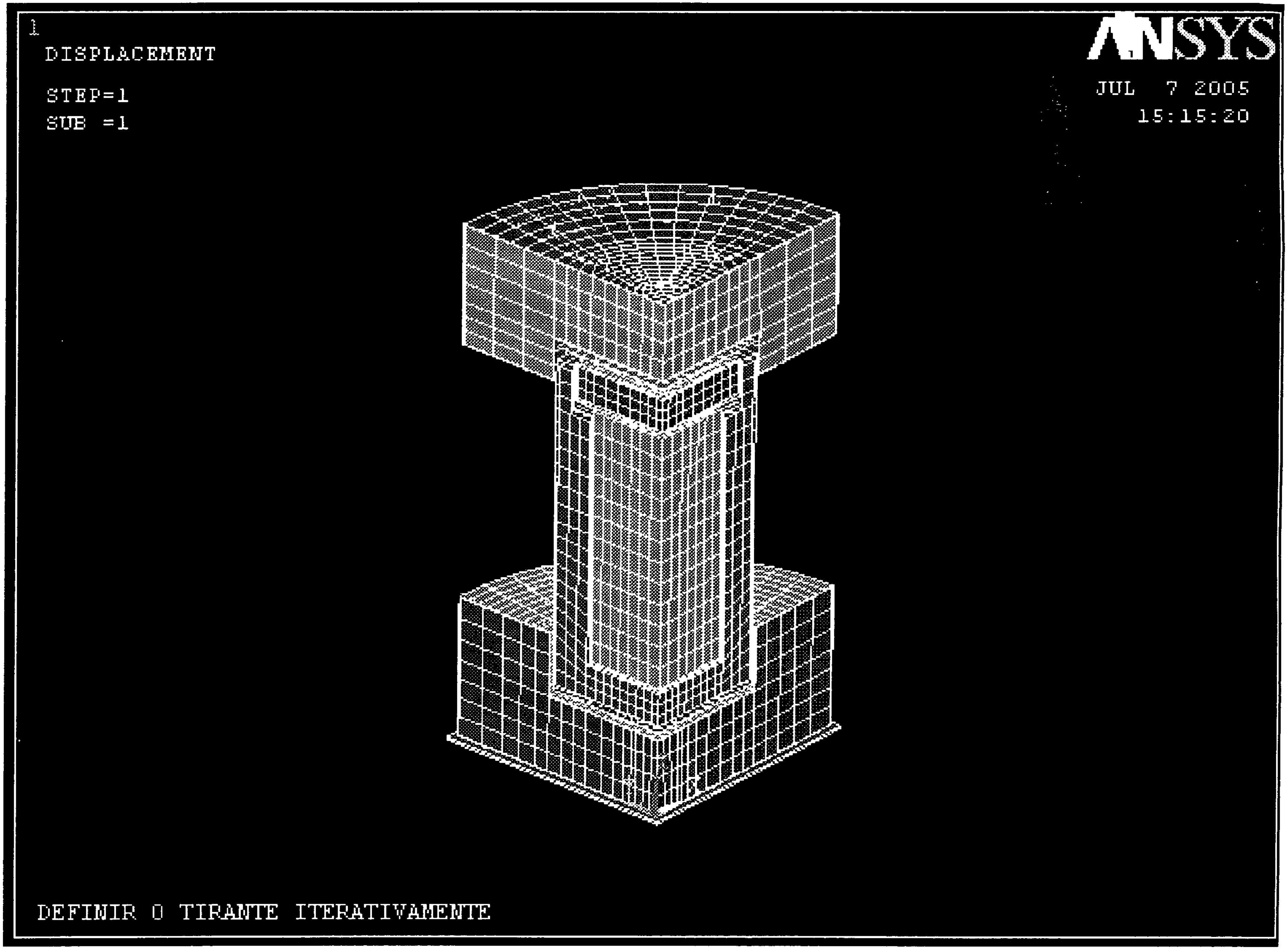
• a plot with the vertical acceleration for the indicated node (it belongs to the lower part of the internal mass);



• the display of the deformed structure during the analysis;



Vertical Acceleration at node 3868


1
DISPLACEMENT
STEP=1
SUB =1
ANSYS
JUL 7 2005
15:15:20
DEFINIR O TIRANTE ITERATIVAMENTE

Discussion and Conclusions

This is a first analysis and it was performed with preliminary data (mostly for the materials);

For future analysis, in skewed positions, the model will be duplicated (180^0);

The model for the final simulations will be calibrated with experimental data;

Once the model is calibrated, the prototype structural qualification will be done numerically;