LEUPA

Type B(U) Package for Fissile Substances Content

ANALYSIS OF THE LEUPA PACKAGE IMPACT TEST

Prepared by:
INVAP

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CONTENTS

1 PURPOSE

1. To assess the structural integrity of the LEUPA package exposed to a drop and subsequent impact against the rigid ground, reaching a previous terminal velocity above 90 m/s.

2 SCOPE

1. This document evaluates the behavior of the LEUPA package in the event of a drop. The study is focused exclusively on accidental conditions during transport.

3 APPLICABLE DOCUMENTS

1. APL1 - 0908-LE01-3AEIN-010 "Packaging – Main Body" ("Embalaje Cuerpo Principal").
2. APL2 - 0908-LE01-3BEIN-024 LEUPA – Criticality Analysis ("LEUPA – Análisis de Criticidad").
3. APL3 - 0908-LE00-3BSIN-024 Analysis of the Orientation of the LEUPA Package Drop Test ("LEUPA – Análisis de la Orientación del Ensayo de Caída del Bulto LEUPA").

4 REFERENCE DOCUMENTS

1. REF1 - Nuclear Regulatory Authority (ARN in Spanish). *Standard for the Transport of Radioactive Material.* AR 10.16.1. Standard Rev. 2. Argentina: ARN, 2011.
2. REF2 - ASM International. *Atlas of Stress-Strain Curves*. Second Edition. Materials Park, OH.: ASM International, 2002. 816 pp. ISBN 978-0-87170-739-0.

5 ABBREVIATIONS

Abbreviation	Description
CM	Center of mass
FM	Fissile material
LEUPA	Low Enriched Uranium Package

6 INTRODUCTION

6.1 Description of the Package

1. The package is designed for the transport of FM, and should be able to protect its cargo from accidental impacts and high outdoor temperatures. Construction details can be found in REF1.
2. According to the APL2, the package has a total mass of approximately 437 kg.
3. The ANSYS 14.5 calculation program was used for the impact simulation.

6.2 Drop Test

1. One of the tests that the package is subject to is a drop from a considerable height, reaching a final velocity above 90 m/s prior to the impact. The test is specified on REF2, paragraph 737.
2. The final velocity for the test was set at 100 m/s. Afterwards, the height from which that velocity can be reach is estimated, disregarding the effects of the viscosity of air, such as:

$$H_{eq} = \frac{V^2}{2g} = \frac{(100\ [{}^{m}/_{s}])^2}{2 \times 10\ \left[{}^{m}/_{s^2}\right]} = 500\ [m]$$

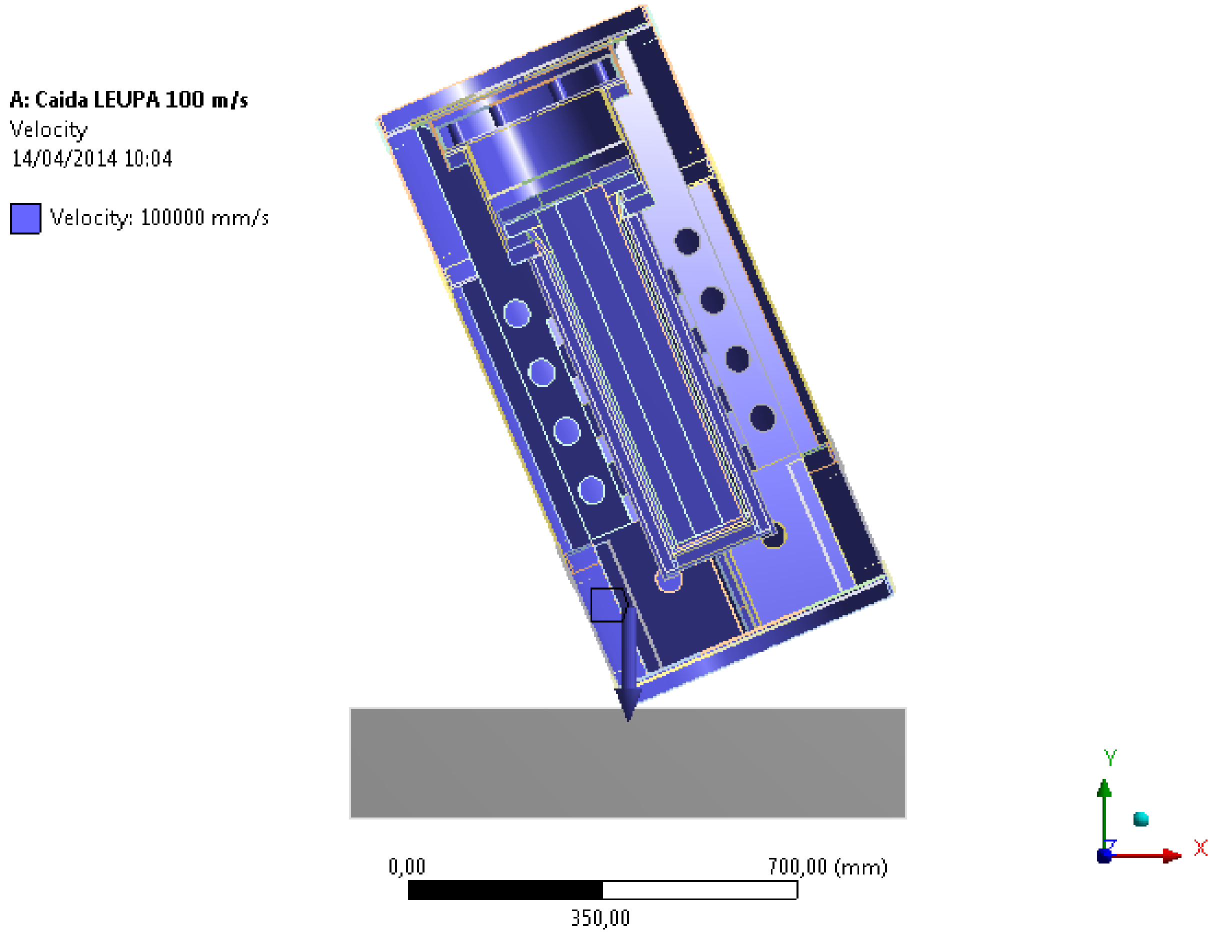
3. For the purpose of simulating the most unfavourable drop, an impact was simulated with an angle of 23º in relation with the right angle of the ground, as shown on Figure 1:. According to APL3, this is the most unfavourable impact angle.

6.3 Simplifying Hypothesis

6.3.1 Model

1. The test was modeled with the finite elements method, through a non-linear explicit method.
2. On Figure 1: there is an image of the model of the package before hitting the rigid surface at a speed of 100 m/s.

Figure 1: View of the impact model of LEUPA package

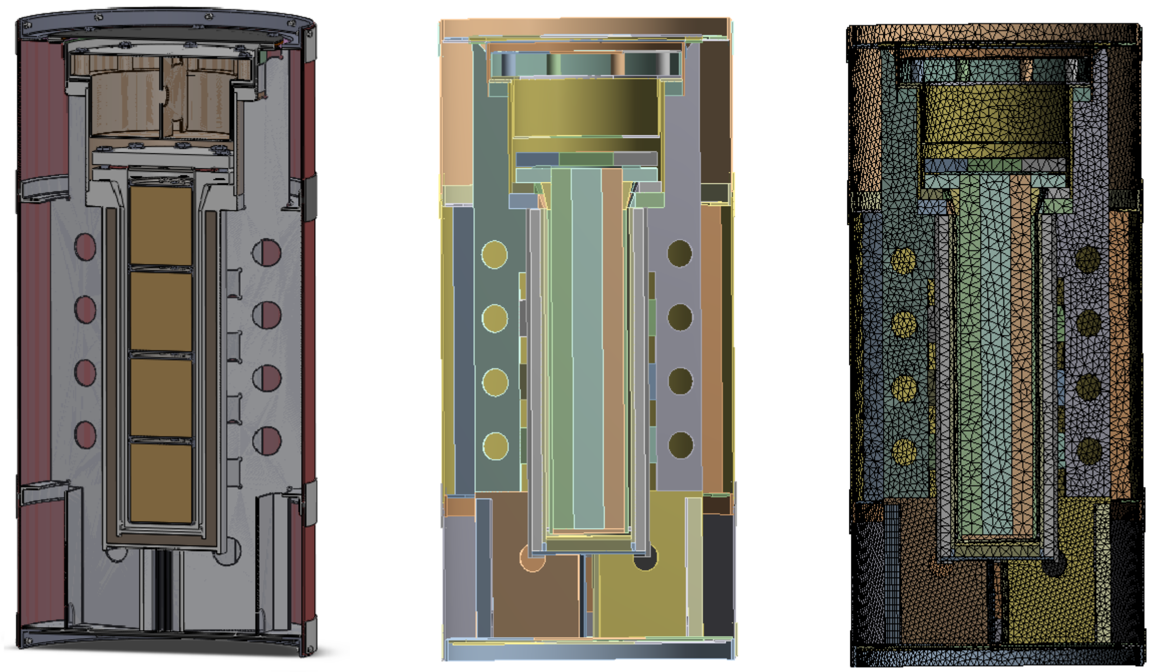


3. For the model, it was considered that the package hits a rigid surface represented by a block of steel, which is represented in grey in Figure 1:.

6.3.2 Simplification of the Package

1. To facilitate the meshing of the model, the details of some components were simplified. Bolts were removed and replaced with a fixed contact between the sides of the bolted plates.
2. The Kaolite filling was not considered in simulations due to its complex geometry and because it has no structural function in the package.
3. Due to the geometric symmetry of the package, only one half was simulated to optimize calculation resources.

Figure 2: Simplification of the model and meshing



Original model **Simplified model** **Meshed model**

6.4 Meshing

1. Hexahedral and tetrahedral elements were used, creating a mesh of 172615 solid elements with refinements in the lower parts where the impact occurs. The size of the elements varies from 30 to 12 mm (See Figure 2:).

7 MATERIALS

1. The package is made of type stainless steel 304L, and its elastic properties are listed in Table 1:, obtained from REF2.
2. It is assumed that the block where the package impact is made of the same steel 304L.

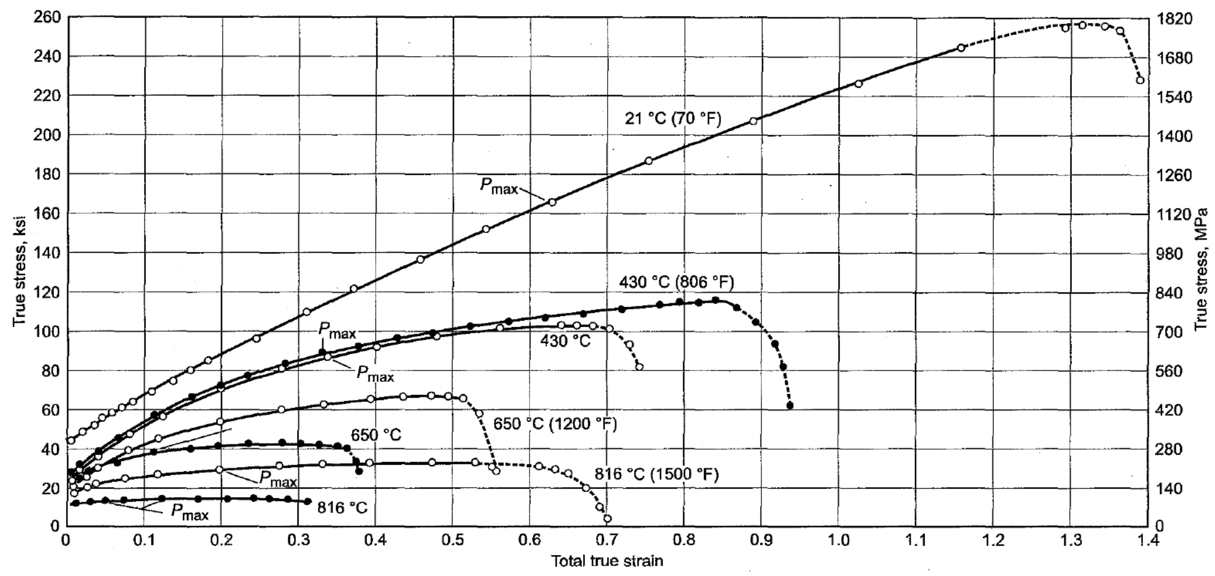
Table 1: Mechanical properties of 304L steel

Property	A312 – TP304L
Modulus of elasticity	193 [GPa]

Property	A312 – TP304L
Poisson's Ratio	0.31
Yield strength	240 [MPa]

3. Non-linear elastic behavior properties of the material, corresponding to the elastoplastic behavior, are also required for the impact simulation. The following Figure 3: and Figure 4: show graphs on the stress-strain considered in the simulation.

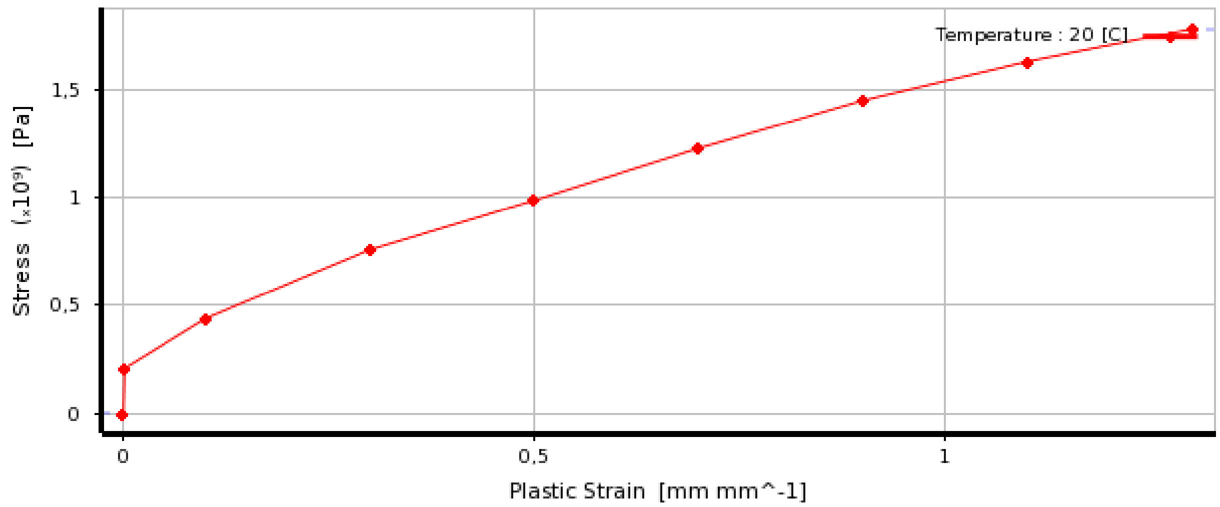
Figure 3: Stress curve - true strain of steel 304L taken from REF2



SS.044 304 annealed stainless steel bar. true stress-strain curves at room and elevated temperatures

The curve was considered at room temperature.

Figure 4: Stress curve - strain entered into the calculation program for the simulation



4. The curve of stress – strain entered into the model presents an elastoplastic behavior. Initially, the material has a linear response to stress below 240 MPa. Above this elastic

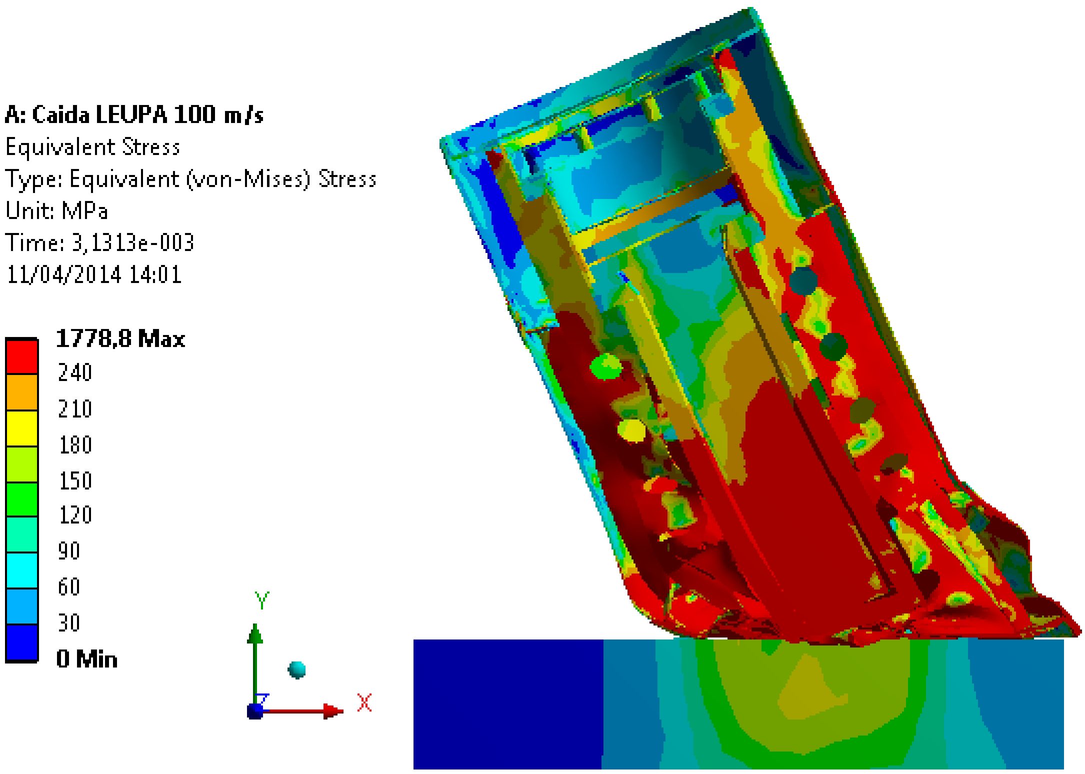
limit, steel reaches a yield state with hardening up to a 1770 MPa stress, where rupture will occur.

8 RESULTS

8.1 Drop on the Edge at 100 m/s

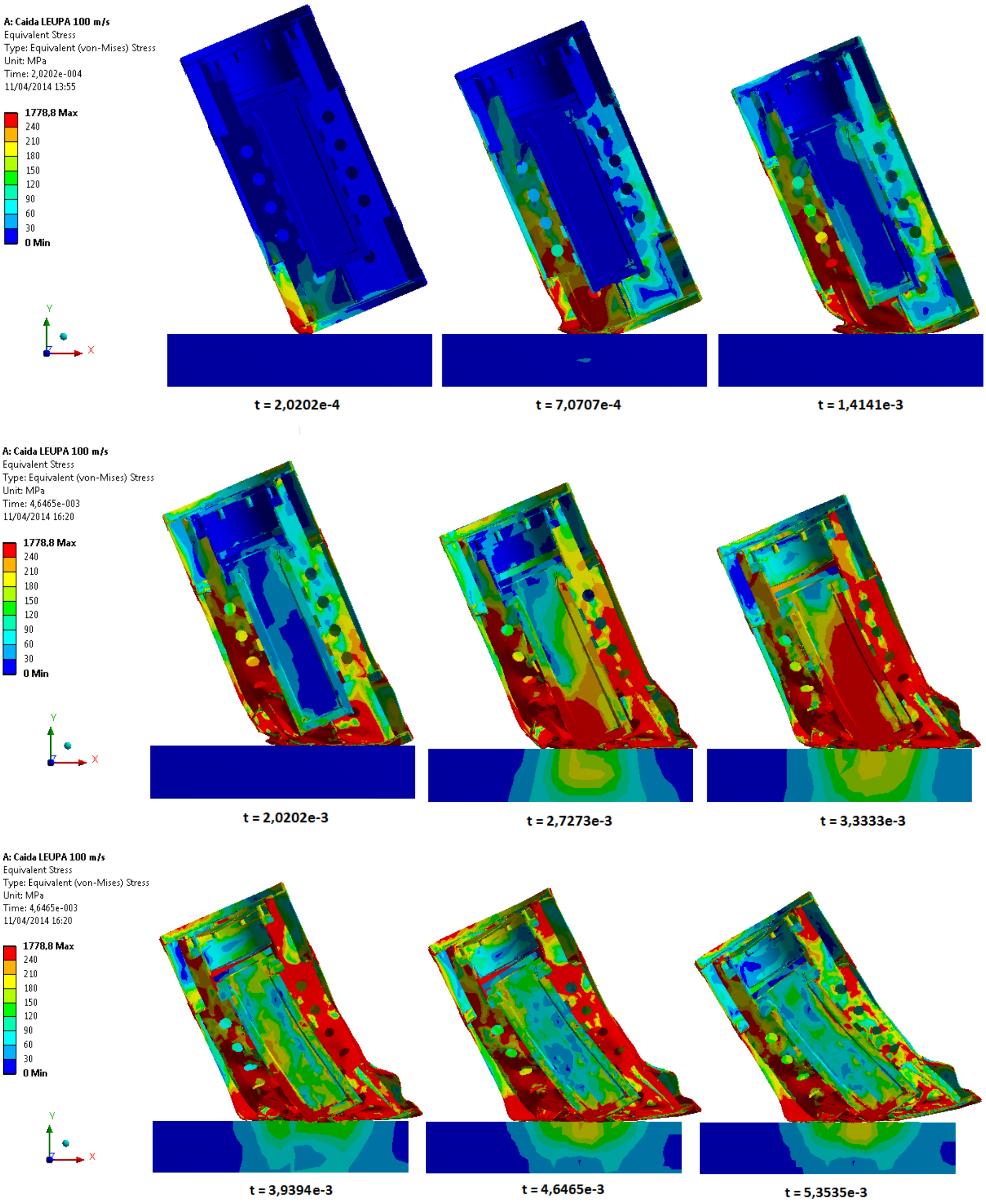
1. According to APL3 a drop on the lower edge, under the GC is the most unfavourable drop position and it was the tested position.
2. In Figure 5:, Von Mises stresses occur in the moment of the collision at 0.004 seconds after the first contact of the package with the rigid surface.

Figure 5: Von Mises stresses at impact (t = 3, 1e-3 s) when most of the damage occurs



3. The components reaching the elastic limit of steel 304L (240 MPa) are in red. The deformation is presented on real scale.
4. Below there is a sequence of images of the stress state of the package, from the instant prior to the impact until its end.

Figure 6: Von Mises stresses of the package in a sequence of images upon impact



9 CONCLUSIONS

1. Under the stated conditions, the geometric characteristics and properties of the stated materials, the conclusions are as follows:
   a. According to the results obtained, at a speed of 100 m/s prior to impact in the most unfavourable position, external sheets suffer generalized plastic deformation with macroscopic distortions.

b. Inner containers (cadmium chamber and inner container) reach high stress levels, even reaching the yield limits, but with no considerable deformations.
c. As the inner container preserves its structural integrity without releasing the FM, the result of the simulation is admissible.