Enclosure 6 to TN E-33729

Supplemental Documents Referenced in Enclosure 5

AREVA

ADVANCED NUCLEAR FUELS GmbH

Work-*Report*

Titel/Title:	
Statics calculations for shipping container	
	Nummer/Number ANFG-11.118 (01E) Rev. 4

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AREVA

Arbeits-Bericht / Work-*Report*

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Numerierung (lfd. Nr./Jahr) / *Report No. (Serial No./Year)*

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P. Ladwig (BT3)
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Statics calculations for shipping container

Bezug (z.B. Projekt, F+E-Vorhaben)
Reference (e.g. Project, R+D)

RESTRICTED AREVA	signed P. Ladwig
Handhabung *Handling*	Unterschrift Klassifizierender *Signature for Classification*

Zusammenfassung *Summary* | Textseiten 15 *Pages* | Anlagen *App.* | (Bei Besprechungsberichten voransetzen: Gesprächsort, -datum, -leiter, -teilnehmer und -dauer) *(Minutes of Meeting to start with place, date and participants)*

Summary:

The ANF-50 shipping container (drawing no.: AD-003750-001) is sufficiently dimensioned for stress factors occurring under normal transport conditions. It is proven that the loads during transport do not cause the allowed stresses in the temperature range between -40°C to +70°C to be exceeded.
According to [1; Para. 8.41], the materials used are suitable for usage in low temperatures and also covered by this calculation.

signed H. Chr. Kuper

Gegenzeichnung: H. CHr. Kuper (BT 3)
Countersignature

signed P. Ladwig

Verfasser: P. Ladwig (BT 3)
Author

Verteiler (falls nur Zusammenfassung zur Kenntnisnahme "z.K." anfügen):
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Revision Index:

Rev. 4 chapter 7. → text and figures adepted
chapter 7.1 → safety factor 3 added to the documentation
chapter 7.2 → removed
chapter 8. → specification added
chapter 10. → added

Table of contents

1. Purpose

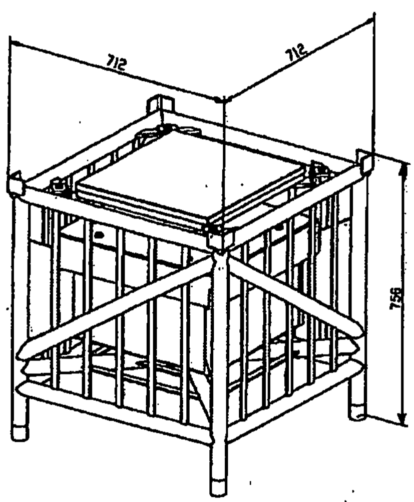
The following construction of the ANF-50 shipping container is proven. The documentation provided is in accordance with generally accepted technological codes of practice. Calculational proof of the following is provided:

- stress conditions of the shipping container ANF-50 when handling it with a fork lift truck,
- stress conditions of the shipping container ANF-50 when handling it with a crane,
- stress conditions of the shipping container ANF-50 during load securing,
- stress conditions of the pellet box when removing it from the shipping frame.

The shipping container consists of a shipping frame, receptacle box, pellet box, supporting frame, pellet trays, clamping device, container lid, box lid and protective lid (refer to Fig. 1). The ANF-50 shipping container is used for the transportation of non-irradiated UO_2 pellets and non-irradiated UO_2 pellet scrap between the individual production locations. The dimensions and design are shown in Fig. 1.

2. Scope of Applicability and Validity

This report applies to the ANF-50 shipping container.



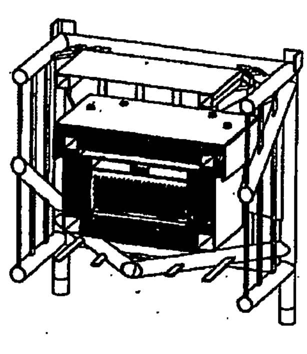


Figure 1: ANF-50 shipping container

3. Basis of the report

The report is based on the relevant standards and directives currently in force, particularly

[1]	DIN EN 10028-7	Flat products made of steels for pressure purposes...
[2]	DIN 18800	Structural steelwork
[3]	DIN 15018-1	Cranes, steel structures, verification and analyses
[4]	DIN EN ISO 3506-1	Mechanical properties of corrosion-resistant stainless-steel fasteners
[5]	DIN EN 10216-5	Stainless steel tubes...
[6]	DIN EN 10088-2	Technical delivery conditions for sheet/plate and strip of corrosion resisting steels...

Where other regulations and standards or literature are referred to, this is indicated at the relevant points in the design calculations.

4. Materials and permissible stresses

The strength-relevant parts of the shipping container are manufactured from material 1.4306, 1.4404, 1.4541, 1.4550, 1.4571. The documentation of statics properties is covered by the strength values for material 1.4306.
The bolts for the pellet box, receptacle box and protective lid are manufactured from material A4-70.

<u>Certainties:</u>
Partial safety factor for resistivity: $\gamma_M = 1.1$

Partial safety factor for permanent influences: $\gamma_F = 1.35$

Partial safety factor for varying influences: $\gamma_F = 1.50$

Characteristic material properties according to [1; 5] at room temperature:

Material number: 1.4306

$E = 197000\ N/mm^2 = 19700\ kN/cm^2$ for $t \leq 30$ mm

$f_{y,k} = R_{P0,2} = 180 N/mm^2$

Min $f_{u,k} = R_m = 460 N/mm^2$

$R_{P0,2} / R_m = 180 N/mm^2 / 460 N/mm^2 = 0.39 < 0.7$ (S355 J2 G3)

Limiting stress:

$\sigma_{R,d} = f_{y,k} / \gamma_M = 180 N/mm^2 / 1.1 = 163.63 N/mm^2 = 16.37 kN/cm^2$

$\tau_{R,d} = \sigma_{R,d} / \sqrt{3} = 163.63 N/mm^2 / \sqrt{3} = 94.47 N/mm^2 = 9.45 kN/cm^2$

Welds:

For welds in accordance with [2] Part 1 Table 21 Lines 1 and 2, $\alpha_W = 1,0$.
No documentation is required for these welds. They are normally covered by the documentation for the component stresses.

The factor $\alpha_W = 0.8$ should be used for fillet welds.

$\sigma_{W,R,d} = 0.8 \bullet \sigma_{R,d} = 0.8 \bullet 16.37 kN/cm^2 = 13.1 kN/cm^2$

Material for bolts: A4-70 [2]:

$E = 197000 N/mm^2 = 19700 kN/cm^2$ for $t \leq 30$ mm

$f_{y,k} = R_{P0,2} = 450 N/mm^2$

Min $f_{u,k} = R_m = 700 N/mm^2$

$R_{P0,2} / R_m = 450\ N/mm^2 / 700 N/mm^2 = 0.64 < 0.7$ (S355 J2 G3)

Limiting stress for A4-70 bolts:

$\sigma_{R,d} = f_{y,k} / \gamma_M = 450 N/mm^2 / 1.1 = 409 N/mm^2 = 40.9 kN/cm^2$

$\tau_{R,d} = \sigma_{R,d} / \sqrt{3} = 409 N/mm^2 / \sqrt{3} = 236 N/mm^2 = 23.6 kN/cm^2$

Characteristic material properties according to [1; 5] at ambient temperature +70 °C:

Material number: 1.4306
$E = 197000\ N/mm^2 = 19700\ kN/cm^2$ for $t \leq 30$ mm
$f_{y,k} = R_{P0,2}$ *(interpolated)* = 157 N/mm²
Min $f_{u,k} = R_m$ *(interpolated)* = 438 N/mm²
$R_{P0,2} / R_m$ 157N/mm² / 438N/mm² = 0.36 < 0.7 (S355 J2 G3)

Limiting stress:

$\sigma_{R,d} = f_{y,k} / \gamma_M = 157N/mm^2 / 1.1 = 142.73N/mm^2 = 14.27kN/cm^2$

$\tau_{R,d} = \sigma_{R,d} / \sqrt{3} = 142.73N/mm^2 / \sqrt{3} = 82.4N/mm^2 = 8.24kN/cm^2$

Welds:

For welds in accordance with [2] Part 1 Table 21 Lines 1 and 2, $\alpha_W = 1.0$. No documentation is required for these welds. They are normally covered by the documentation for the component stresses.

The factor $\alpha_W = 0.8$ should be used for fillet welds.
$\sigma_{W,R,d} = 0.8 \bullet \sigma_{R,d} = 0.8 \bullet 14.27kN/cm^2 = 11.4kN/cm^2$

Material for bolts: A4-70 [2] reduced by 5% analogous to material 1.4306:

$E = 197000\ N/mm^2 = 19700\ kN/cm^2$ for $t \leq 30$ mm
$f_{y,k} = R_{P0,2} = 427N/mm^2$
Min $f_{u,k} = R_m = 665N/mm^2$
$R_{P0,2} / R_m = 427N/mm^2 / 665N/mm^2 = 0.64 < 0.7$ (S355 J2 G3)

Limiting stress for A4-70 bolts

$\sigma_{R,d} = f_{y,k} / \gamma_M = 427N/mm^2 / 1.1 = 388N/mm^2 = 38.8kN/cm^2$

$\tau_{R,d} = \sigma_{R,d} / \sqrt{3} = 388N/mm^2 / \sqrt{3} = 224N/mm^2 = 22.4kN/cm^2$

The following calculations are carried out with the material properties at an ambient temperature of 70 °C. Further calculations at room temperature are not necessary, as these are also covered by the conservative documentation at an ambient temperature of 70 °C.

5. Load assumptions

The net weight of the ANF-50 shipping container is: $G \leq 250kg$

The net weight of the pellet box is: $G_p \leq 117kg$

Lifting load coefficient: The ANF-50 shipping container is normally moved with a fork lifting truck only. However, the possibility of using attachment devices and crane for handling cannot be ruled out. The pellet box is removed from the shipping frame with a crane. According to [3], lifting class H2 (mobile crane) should be assigned in both cases. The lifting speed is assumed at $v \leq 40$ m/min.

$$\psi = 1.2 + 0.0044 \bullet v = 1.2 + 0.0044 \bullet 40m/min = 1.376$$

6. Handling the ANF-50 shipping container with a fork lift truck

Handling: Normally, up to three stacked shipping containers are handled with the fork lifting truck. The stressed cross-section from 2 pipes 42.4x1.6 of the shipping container ANF-50 is documented. The contributory effect of the struts in this area is conservatively ignored.

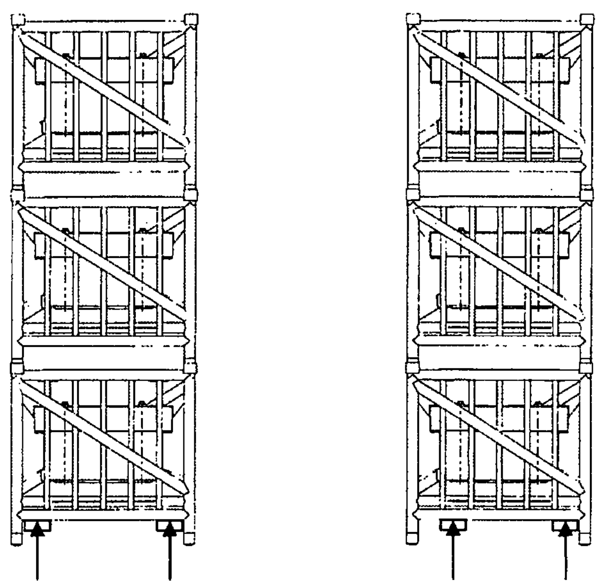


Figure 2: Lifting with the fork lift truck

Load: Taking into account the safety and live load factors, the following load results:

$F_d = G \bullet g \bullet \psi \bullet \gamma_f = 250kg \bullet 9.81m/s^2 \bullet 1.376 \bullet 1.5 = 5062N$

The total load for three stacked ANF-50 shipping containers is
$F_{st} = 3 \bullet F_d = 3 \bullet 5062N = 15186N$.

Section modulus of the stressed cross-section:

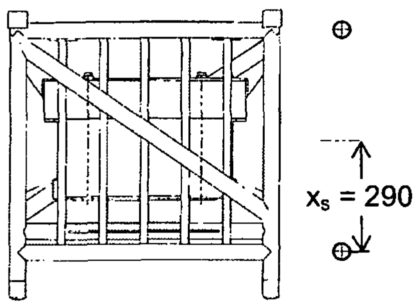


Figure 3: Cross-section under load

$I_n = \pi / 64 \bullet (D^4 - d^4) = \pi / 64 \bullet ((42.44mm)^4 - (39.2mm)^4) = 42739mm^4$
$A_n = A_{pipe} = \pi / 4 \bullet (D^2 - d^2) = \pi / 4 \bullet ((42.4mm)^2 - (39.22mm)^2) = 205mm^2$
$W_q = I_s / x_s = 2 \bullet (I_n + A_n \bullet x_s^2) / x_s = 2 \bullet (42739mm^4 + 205mm^2 \bullet (290mm)^2) / 290mm$
$W_q = 119194mm^3$

6.1 Stress application centered with maximum fork spacing

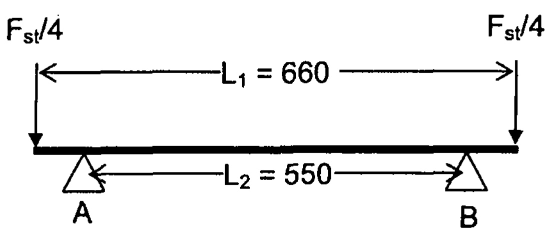


Figure 4: Stress application centered with maximum fork spacing

Determination of the maximum bending moment:

$M_{max} = F_{st} / 4 \bullet (L_1 - L_2) / 2 = 15186N / 4 \bullet (660mm - 550mm) / 2 = 208808Nmm$

Determination of the bending stress σ_{max}

$\sigma_{max} = M_{max} / W_q = 208808Nmm / 119194mm^3 = 1.8N/mm^2$

The condition "$\sigma_{max} / \sigma_{R,d} = 1.8N/mm^2 / 142N/mm^2 = 0.01 < 1$" for the structural integrity assessment has been fulfilled.

Determination of the shear stress:

$\tau_{Qy} = F_{st} / 4 / A_{pipe} = 15186N / 4 / 205mm^2 = 18.5N/mm^2$

The condition "$\tau_{Qy} / \tau_{R,d} = 18.5N/mm^2 / 82.4N/mm^2 = 0.2 < 0.5$" for the structural integrity assessment has been fulfilled.

6.2 Stress application eccentrical with reduced fork spacing

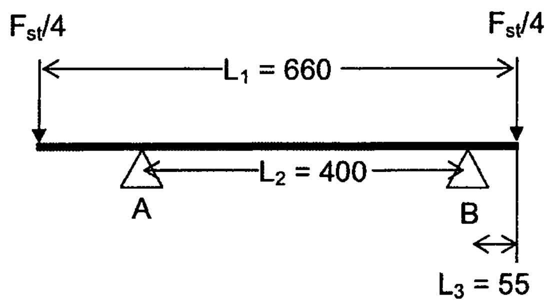


Figure 5: Stress application eccentrical with reduced fork spacing

Determination of the maximum bending moment:

$M_{max} = F_{st} / 4 \bullet (L_1 - L_2 - L_3) = 15186N / 4 \bullet (660mm - 400 - 55mm) = 778283Nmm$

Determination of the bending stress:

$\sigma_{max} = M_{max} / W_q = 778283Nmm / 119194mm^3 = 6.5N/mm^2$

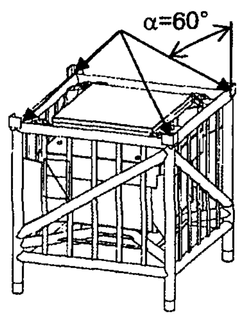
The condition "$\sigma_{max} / \sigma_{R,d} = 6.5N/mm^2 / 142N/mm^2 = 0.05 < 1$" for the structural integrity assessment has been fulfilled.

Determination of the shear stress:

Refer to Chapter 6.1

7. Handling the ANF-50 shipping container with a crane

Handling: For handling using a crane, the shipping container is attached by means of four round slings, which are attached to the four upper corners of the shipping container (Figure 6).
According to EN 1492-2 "Textile slings...", the maximum admissible vertical tilt angle $\alpha = 60°$. As at this tilt angle, the greatest stresses occur, the calculational proof is carried out conservatively with this value.



Attaching with 4 round slings

Figure 6: Attaching the shipping container

7.1 Stress application with 4 round slings

For this stress application, the upper pipes 42.4x1.6 are put under pressure stress with the force F_{x1} or F_{x2}.

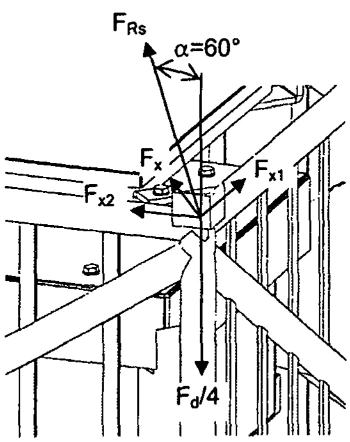


Figure 7: Forces in the stressed area

<u>Determination of the forces F_{x1} and F_{x2}</u>

$F_x = F_d / 4 \bullet \tan60° = 5062N / 4 \bullet \tan60° = 2192N$

$F_{x1} = F_{x2} = F_x \bullet \cos 45° = 2192N \bullet \cos 45° = 1550N$

Determination of the compressive stress

$\sigma_d = F_{x1} / A_{pipe} = 1550N / 205mm^2 = 7.6 \ N/mm^2$

The condition "$\sigma_d / \sigma_{R,d} = 7.6 \ N/mm^2 / 142N/mm^2 = 0.05 < 1$" for the structural integrity assessment has been fulfilled.
The stress by a safety factor of 3 does not exceed the yield strength (R_{p02}), because the condition for the safety factor $s = R_{P0,2\,(at\,70°C)} / \sigma_d = 157 \ N/mm^2 / 7,6 \ N/mm^2 = 20,6 > 3$ has been fullfilled.

8. Load securing the ANF-50 shipping container in the 20' ISO standard container

The ANF-50 shipping containers are transported exclusively in the locked and leaded 20' ISO standard container, with one container being loaded with 8 rows of 3x3 ANF-50 shipping containers each (refer to figure 9), so that the maximum load is 72 ANF-50 shipping containers. Additional a part load of the 20' ISO standard container with 7 rows (63 ANF-50) or 6 rows (54 ANF 50) is possible. The ANF-50 shipping containers are mechanically supported in the ISO container at both long sides and at the back and front (2 supports per level). Vertical fixing from the top is also achieved mechanically.

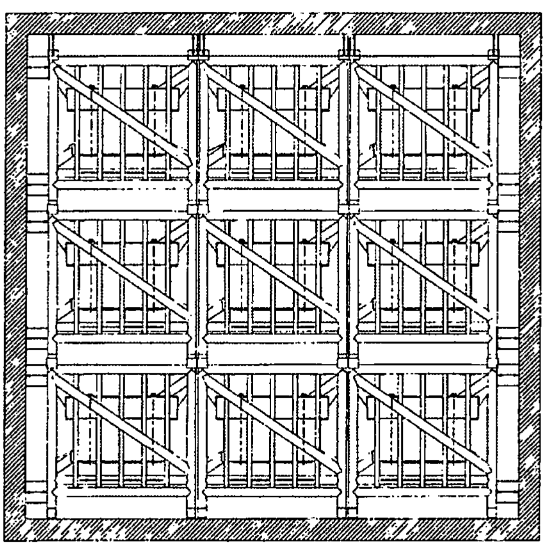


Figure 9: Shipping container with load securing

The horizontal stresses result from the design accelerations of 1.2g during transport. The vertical stresses result from net weight, load securing (F_L) and design accelerations of 1.2g during transport. Stresses from load securing (F_L) and the transport stresses are taken up by the pipes of the ANF-50 shipping container.
The pipes of the ANF-50 shipping container must be able to bear the respective stresses. Four pipes each bear pressure stress in axial direction.

Determination of horizontal stress:
$F_h = 8 \bullet G \bullet 1.2 \bullet g = 8 \bullet 250kg \bullet 9.81m/s^2 \bullet 1.2 = 23544N$

Determination of vertical stress:
$F_v = 3 \bullet G \bullet g \bullet (1 + 1{,}2) + F_L = 3 \bullet 250kg \bullet 9.81m/s^2 \bullet 2.2 + 1000N = 17187N$

Determination of the compressive stress
As horizontal stress is greater than vertical stress, the force F_h is used for stress analysis. Documentation of vertical stress is not required.
$\sigma_d = F_h / 4 / A_{pipe} = 23544N / 4 / 205mm^2 = 29\ N/mm^2$

The condition "$\sigma_d / \sigma_{R,d} = 29\ N/mm^2 / 142N/mm^2 = 0.2 < 1$" for the structural integrity assessment has been fulfilled.

9. Removing the pellet box from the shipping frame

The pellet box can be removed from the shipping frame at the four shackles by means of crane and slings.

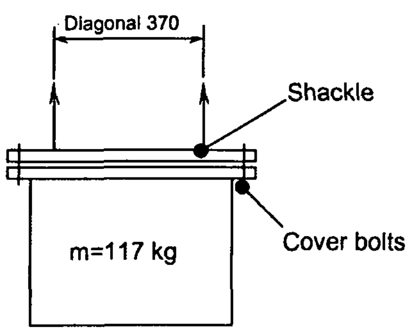


Fig. 10: Pellet box

9.1 Shackle M8 / pellet box for ANF-50 shipping container

Effect: It is conservatively assumed that only two of the four shackles bear the load.
$F_y = G_p \bullet g \bullet \psi \bullet \gamma_f / 2 = 117kg \bullet 9.81m/s2 \bullet 1.376 \bullet 1.5 / 2 = 1185N$

Cross-sectional values for the M8 bolt:
Core diameter $D_3 = 6.466$ mm
Stressed cross-section $A_s = 36.6$ mm^2

Cross-sectional variables:
$N = F_y = 1185N$

Stresses at ambient temperature +70°C:
$\sigma_{max} = N / A_s = 1185N / 36.6mm^2 = 32.4N/mm^2$

$\sigma_{R,d} = 388N/mm^2$

$\sigma_{max} / \sigma_{R,d} = 32.4N/mm^2 / 388N/mm^2 = 0.08 < 1.00$
The permissible carrying force for a shackle is 4000 N

9.2 Cover bolts M8 / pellet box for ANF-50 shipping container

Effect: The cover bolts consist of 12 M8 bolts around the cover. The arrangement of the bolts is covered by the calculation for the shackle bolts since the container weight is borne by 12 bolts.
When lifting the pellet box with the shackle, one bolt has to bear the following maximum load: $F_s = F_y / 12$ bolts = 99N.
One bolt M8 A4-70 can provide a pre-stressing force of approx. 16.5 kN [4; $R_{p0,2} = 450N/mm^2$; $A_s = 36.6$ mm^2]. If the screws are tightened properly, gaping of the pellet box flange is therefore not possible.
No further documentation is required!

9.3 Tightening torques for the bolts used

Documentation of the tightening torques:
All bolts with DIN 13-1 metric threads with shank diameters ≥ the core diameter are tightened with the following torques M_A. A comparison with the minimum breaking torque $M_{B\ min}$ (as per [4], Table 4) shows sufficient reliability against bolt break.

	M_A [Nm]	$M_{B\ min}$ [Nm]	Safety M_A / $M_{B\ min} \leq 1$
Bolt M8	18	32	0.56
Bolt M10	30	65	0.46
Bolt M12	40	110	0.36

10. Stacking Test according to IAEA Regulations

When loaded with uranium dioxide pellets the shipping container has a maximum total mass of G ≤ 250kg. The vertically projected area of the shipping container is calculated to be 0,712m • 0,712m = 0,507m^2. The stacking test is to be performed with a compressive load equal to the greater of the following:

a) The equivalent of five times the mass of the actuel package corresponds to 250kg • 9,81m/s^2 • 5 = 12262,5N.
b) The equivalent of 13kPa multiplied by the vertically projected area of the package corresponds to 13kPa • 0,507m^2 = 6591N.

In the stacking test the loads are transmitted via the four vertical tubes of the outer frame (outside diameter 42,4mm, wall thickness 1,6mm, cross section A_{rohr}=205mm^2). The relevant load determined above subjects the tubes to a stress of σ_d = 12262,5N / 4 / 205mm² = 15N/mm^2. If the load is only transmitted via two tubes, this stress increases to around 30N/mm^2.

For a stress of 30N/mm^2, neither plastic deformation nor instabilities are anticipated in the load transmitting tubes ($R_{P0,2\ (at\ 70°C)}$ = 157 N/mm^2). Thus demonstration of compliance for the stacking test has been provided analytically.