

The logo for IRSN, consisting of the letters 'IRSN' in a bold, sans-serif font. The 'I' and 'R' are red, the 'S' is blue, and the 'N' is red.

INSTITUT  
DE RADIOPROTECTION  
ET DE SÛRETÉ NUCLÉAIRE

*Enhancing nuclear safety*

# French requirements for the design, manufacture and use of bolts and screws equipping packages for the transport and storage of radioactive material

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PATRAM 2019

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MEMBER OF

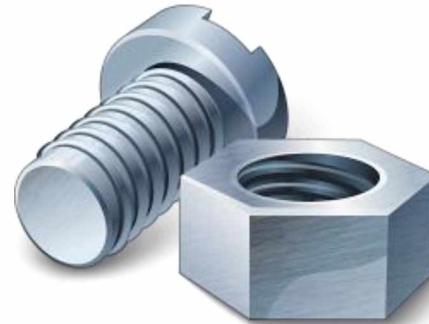
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# Summary

1. Context of the working group
2. Design criteria
3. Events declared in France
  - Self-loosening of impact limiters screws
  - Screws do not comply with the PDSR
  - Hydrogen embrittlement
  - Lubrication of the screws



# Context of the working group

## Participants

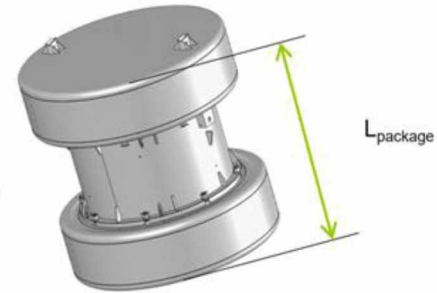
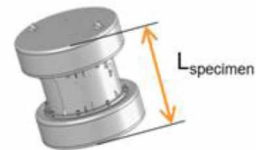
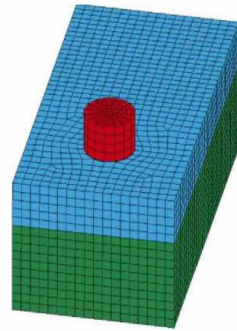


## Main objectives:

- Specify requirements in order to improve the safety level
- Provide a technical support by writing a handbook
- Better understanding of the safety issues
- Reducing the assessment duration and improving the information exchange

# Handbook is divided in 4 chapters

- 1) Design and modeling
- 2) Representativeness of screw assemblies during drop test
- 3) Manufacturing process
- 4) Exploitation



# Safety functions

## ■ Ensure the integrity of the package design safety functions

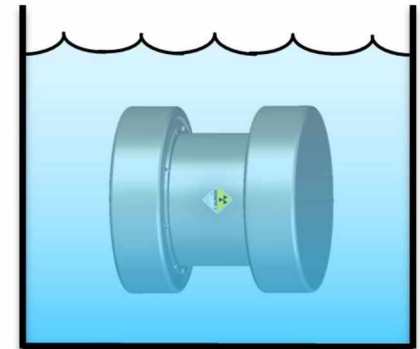
- Containment (lid closure system): gaskets must have a sufficient compression ratio in all conditions of transport



- Criticality safety: prevent the water penetration in the package cavity

- Mechanical behavior (impact limiters) :

- ✓ absorb mechanical energy in case of impact
- ✓ ensure a thermal protection of the containment system gaskets



- Thermal behavior



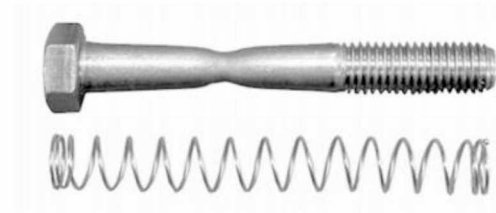
# Design Criteria

## ➤ Recommendations

- Containment screw assemblies have to stay in their elastic behaviour in all conditions of transport



Elastic behaviour



Plastic behaviour

- Pre-load can't be exceeded in routine conditions of transport
- No plastic strain allowed in normal conditions of transport

# Self-loosening of package impact limiters screws

- 25 events declared in France during the last 7 years
- Hypothesis and observations:
  - Heavy type B packages (spent fuel for most events)
  - Large impact limiters with few screws
  - Large diameter screws
  - Dynamic transverse loads are more likely to generate a screw self-loosening
- Self-loosening solutions:



2 impact limiters



Serrated washer



Grower washer



Nord-lock washer

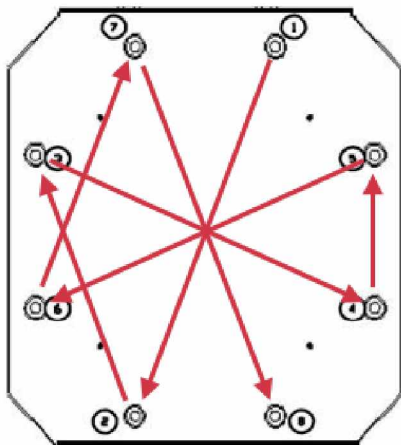


***These solutions may degrade the bearing surface !***

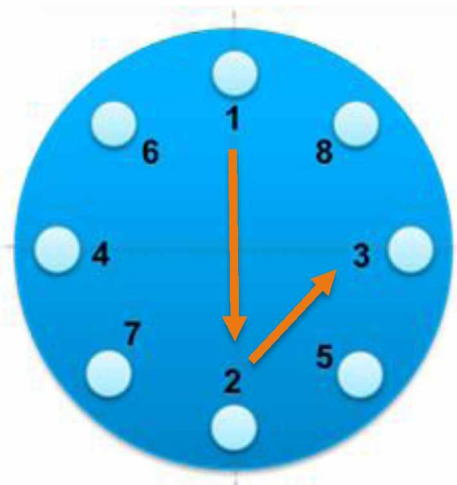
# Self-loosening of package impact limiter screws

## ➤ Recommendations

- Apply a sufficient pre-load in the screws
- Guaranty the cleanliness of screws and the threads (visual control, storage in clean spaces, anti-dust plug on the screw holes)
- Tightening operations:
  - ✓ respect the tightening order
  - ✓ respect the waiting period until the thermal steady state
  - ✓ check of the screw tightening by another operator with a different wrench



Star order



Cross order





# Recognition of the screws

- One event declared in France in 2015:
  - ✓ impact limiters screws didn't comply with the safety report
  - ✓ same diameter but the length was different
- Screws can be confused when they have similar characteristics

## ➤ Recommendations

- screw marking
- method for identifying screws:
  - ✓ color code to associate the screws to the components to fix
  - ✓ storage racks

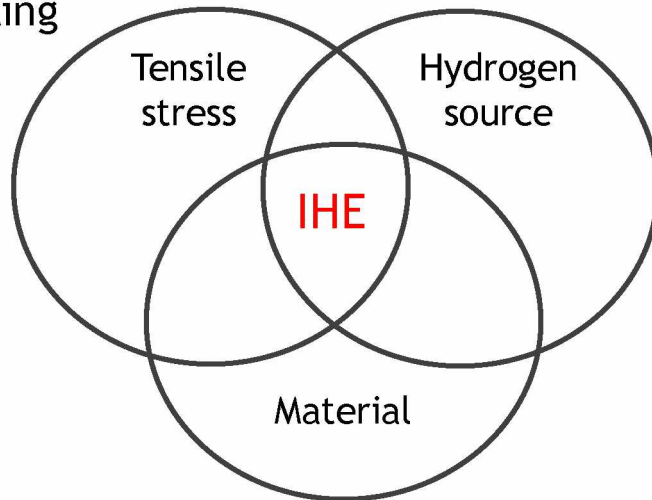


# Hydrogen Embrittlement Failure

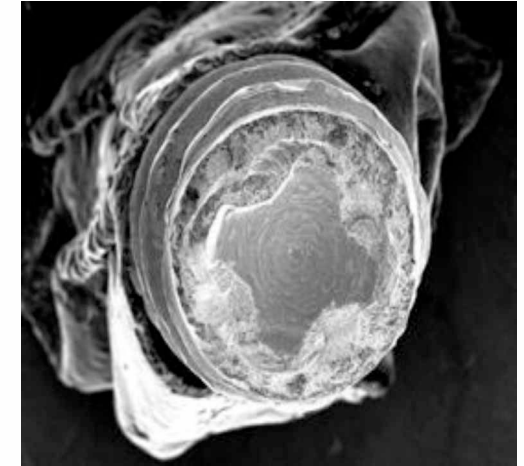
During tightening, some failure of high quality class screws occurred

## Internal Hydrogen Embrittlement (IHE):

- residual hydrogen from processing steps such as pickling and electroplating



3 conditions are necessary



Property class screws  $\geq 10.9$  are susceptible to hydrogen (Vickers hardness  $\geq 360$  HV)

# Hydrogen Embrittlement Failure

## ➤ Recommendations

- Acid pickling for property class screws > 10.9 is not recommended
- When the screw is coated by an electroplating process:

Property class	≤ 9.8	10.9	12.9
Vickers Hardness	< 360 HV	360 HV ≤ Hardness ≤ 390 HV	> 390 HV
Specifications	<p>Additional verification of the manufactural process or hydrogen embrittlement test methods</p> <p><b>AND</b></p> <p>No necessary baking</p>	<p>Additional verification of the manufactural process or hydrogen embrittlement test methods</p> <p><b>OR</b></p> <p>Baking</p>	<p>Additional verification of the manufactural process or hydrogen embrittlement test methods</p> <p><b>AND</b></p> <p>Baking</p>

- Baking is a low temperature heat treatment allowing extract hydrogen

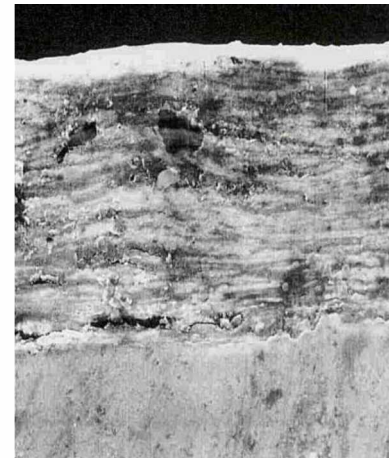
# Hydrogen Embrittlement Failure

## Zinc lamellar coatings

- Zinc lamellar coatings are :
  - not concerned by hydrogen embrittlement
  - non-electrolytically applied
- Mixture of zinc and aluminium flakes, which are bonded together



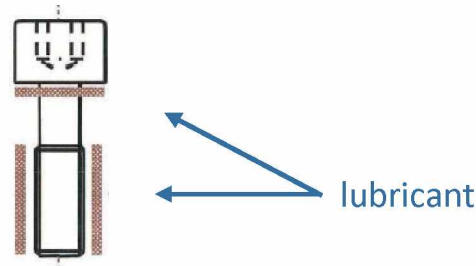
Acid pickling is still prohibited



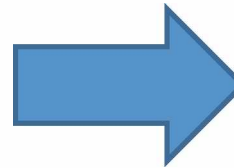
Zn  
coating

- Quality class screws  $\geq 14.9$  is not recommended

# Lubrication of the screws



- When lubricant is required only on thread, it may be applied involuntarily under head (even if it's forbidden !)



- lubrication under screw head decrease the friction coefficient
- increase the stress in the screw

$$P = \frac{T \times (1 \pm \Delta T)}{0.16 \times p + 0.58 \times \mu \times (1 + \Delta \mu) \times d_2}$$

pre-load (N) torque (N.m)  
pitch (m) friction coefficient external thread Ø (m)



# Lubrication of the screws

## ➤ Recommendations

- If lubrication is necessary, apply lubricant on the threads and under the screw head
- Lubricant must be consistent with the friction coefficients used in the design calculations
- Guarantee the friction coefficient:
  - number of tightening/untightening
  - periodicity for screws replacement



TN 24 DH Packages  
Doel (Belgium)

# Conclusion

- Recommendations included in a dedicated guidance established thanks to the French nuclear authority for defense activities
- Positive feedback from the collaboration between safety authority, TSO and applicants
- Some topics are not yet fully known:
  - self-loosening of the impact limiters screws
  - brittle fracture
- Some additional requirements may be added in a future review of the handbook

Thank you for your attention

For more information, please contact:

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