
AREVA

TNI Transportability Tool

A Software to Calculate the Transport Feasibility of Used Fuel Casks

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LOGISTICS

AREVA

Context – Set of Problems – Stakes

- **Transportation of nuclear materials: a risky activity**
  - **Radioactive materials are close to the environment**
  - **Many risks : accidents, terrorism, loss…**

- **Ways to prevent risks:**

  ⇒ **The cask itself**
  - **shielding**
  - **confinement**
  - **sub-criticality**

  ⇒ **Reduce transport frequency**
  - **optimise loadings in casks**

Calculation Methods and Codes

- Use of three-dimensional Monte-Carlo codes coupled with evolution codes for all radioprotection calculations
- Shielding calculations are composed of two evaluation steps
  - radioactive sources
  - dose rates
- Codes used at TNI for the evaluation of radioactive sources
  - ORIGEN-2
  - ORIGEN-S
  - DARWIN-2

  } for the irradiated fuel
  - APOLLO-2 for the activation products on the fuel assembly ends

Calculation Methods and Codes

- **Evaluation of dose rates around the cask are made with the three-dimensional Monte-Carlo code TRIPOLI-4**
  - **Calculation method without approximations**
  - **Three-dimensional geometry description**
    - **Eliminates approximation due to the modeling of the cask and content**
    - **Calculation in precise places such as trunnions**
  - **Detailed description of the sources (geometry and spectra)**
  - **Point wise cross section representation**
- **Calculation improvements are made without significant increase of computing time**
- **Using this method, the calculated dose equivalent rate values are very close to actual measurements around a package**

Validation Process – Benchmarking

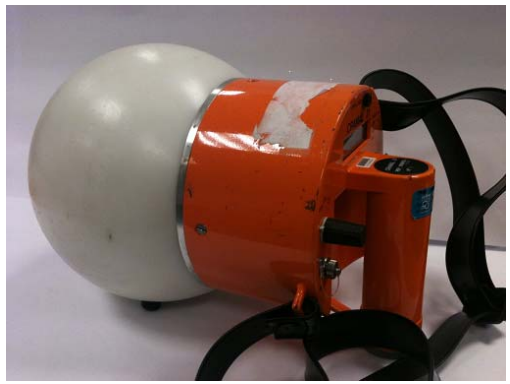
- **The TNI shielding calculation method is validated by comparisons between the calculated and measured dose rates on casks**
  - **Several measurement experiments carried out on various casks**
  - **Full dose rate cartography around the cask when possible**
  - **Use of precise and well-calibrated instruments**

Gamma-rays:

- Babyline

Neutrons:

- Cramal
- Berthold



Validation Process – Benchmarking

- **Summary of differences between measured and computed dose rates in the middle of the TN®112 cask in radial position**

	Contact			2 metres		
Position	Measurements (10^{-2} mSv/h)	Calculations (10^{-2} mSv/h)	Differences* (%)	Measurements (10^{-2} mSv/h)	Calculations (10^{-2} mSv/h)	Differences* (%)
0°	8.97	9.52	+6.2%	2.44	2.60	+6.6%
45°	8.69	9.74	+12.0%	2.22	2.53	+14.1%
90°	9.23	9.62	+4.3%	2.83	2.54	-10.2%
135°	9.43	9.58	+1.6%	2.70	2.56	-5.2%
180°	9.13	9.51	+4.1%	-	2.57	-
225°	8.80	9.82	+11.7%	2.73	2.53	-7.5%
270°	9.23	9.50	+2.9%	2.88	2.54	-11.7%
315°	8.01	9.72	+21.4%	2.38	2.55	+7.1%
Average	**8.94**	**9.63**	**+7.7%**	**2.60**	**2.55**	**-1.7%**
Max	**9.43**	**9.82**	**+4.2%**	**2.88**	**2.60**	**-9.7%**
Min	**8.01**	**9.50**	**+18.6%**	**2.22**	**2.53**	**+14.1%**

* (calculated/measured -1) × 100%

Transportability
A Software Tool

LOGISTICS

Transportability – Overview

- **Transportability is an internal software developed by TNI to manage: spent fuel assemblies, optimisation of loading plans, feasibility of transport**
- **Software functionalities**
  - **Inventory of the fuel assemblies per nuclear plant unit**
  - **Creation of loading plans in real time (fuel batch, position in basket)**
  - **Check of transport feasibility for a given date**
  - **Schedule earliest transport date for a given fuel batch**
- **Use**
  - **Transportability falls under the responsibility of the Calculation Department**
  - **Transportability is used by the shipping agents and sometimes by the customers**
  - **All transport scenarios are validated before expedition**

Transportability – Principles

- **Transportability includes four steps:**
  - Input of data: the utility fuel assembly database
  - Creation of a loading plan with the chosen fuel assemblies
  - Choice of cask model, internal arrangements and transport date
  - Calculation in two steps

Transportability – Addition of a Model

- **The TN®112 can contain 12 MOX spent fuel assemblies per shipment**

- **The TN®112 will be input into Transportability following a three-step method**
  - **Modelling**
  - **Measurements**
  - **Model fitting**

Transportability – Model Adjustment

- **Methodology**
  - **Determine the average ratio Measurements/Calculations**
  - **Apply this ratio as a factor for each point**
  - **Apply an additional margin to the gamma-ray and neutron dose rates to cover measurement uncertainties**
- **Example: Comparison between measured and computed dose rates at 2 metres from the TN®112 cask**

	TRI3.79			TRI3.84		
Position	Measurements (10^{-2} mSv/h)	Calculations (10^{-2} mSv/h)	Ratio M/C	Measurements (10^{-2} mSv/h)	Calculations (10^{-2} mSv/h)	Ratio M/C
0°	1.92	2.03	0.948	2.44	2.73	0.893
45°	2.44	2.20	1.108	2.22	2.68	0.826
90°	2.46	2.27	1.083	2.83	2.73	1.037
135°	2.10	2.13	0.988	2.70	2.69	1.004
180°	-	2.13	-	-	2.73	-
225°	1.92	2.05	0.936	2.73	2.70	1.011
270°	2.10	1.93	1.088	2.88	2.74	1.051
315°	2.36	2.02	1.169	2.38	2.69	0.885

Transportability – Model Adjustment

- **Example of model adjusting for the TN®112 cask based on two measurement experiments**
  - **Calculation of the average ratio Measurements/Calculations to determine the adjustment factor for each point**
  - **Application of an additional 20% margin to the gamma-ray and neutron dose rates to cover measurement uncertainties**

- **Results at 2 metres from the TN®112 cask in radial position**

Position	Fitting Factor (ff)	Neutron Dose Rates (10^{-2} mSv/h)	Gamma Dose Rates (10^{-2} mSv/h)	Neutron × ff + 20%	Gamma × ff + 20%	Final tuned Dose Rates (10^{-2} mSv/h)	Measure-ments (10^{-2} mSv/h)	Diffe-rences (%)
0°	0.920	0.78	1.95	0.87	2.15	**3.01**	2.44	+23.7%
45°	0.967	0.79	1.90	0.91	2.20	**3.11**	2.22	+40.5%
90°	1.060	0.79	1.94	1.01	2.47	**3.47**	2.83	+22.7%
135°	0.996	0.79	1.90	0.94	2.27	**3.22**	2.70	+19.1%
180°	-	0.79	1.94	-	-	-	-	-
225°	0.974	0.79	1.91	0.92	2.23	**3.16**	2.73	+15.5%
270°	1.069	0.79	1.95	1.01	2.50	**3.52**	2.88	+22.1%
315°	1.027	0.78	1.91	0.97	2.35	**3.32**	2.38	+39.3%

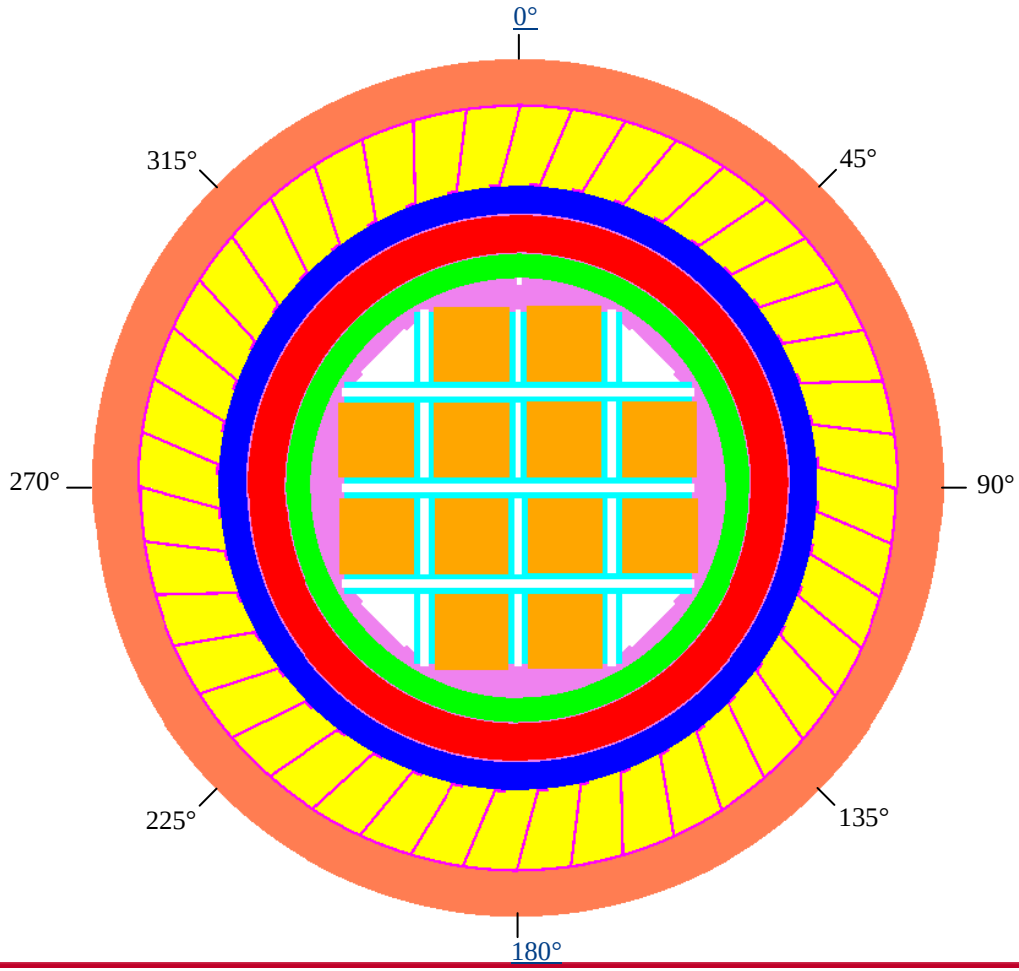
Conclusion

Transportability is an innovative calculation tool

- Casks can be loaded with used fuel assemblies reaching 80% of the radioprotection criteria
- Radiological performance of the TNI transport casks is improved
- Increasing source intensities can be anticipated and compensated for
- General safety of the transport of radioactive materials is significantly enhanced

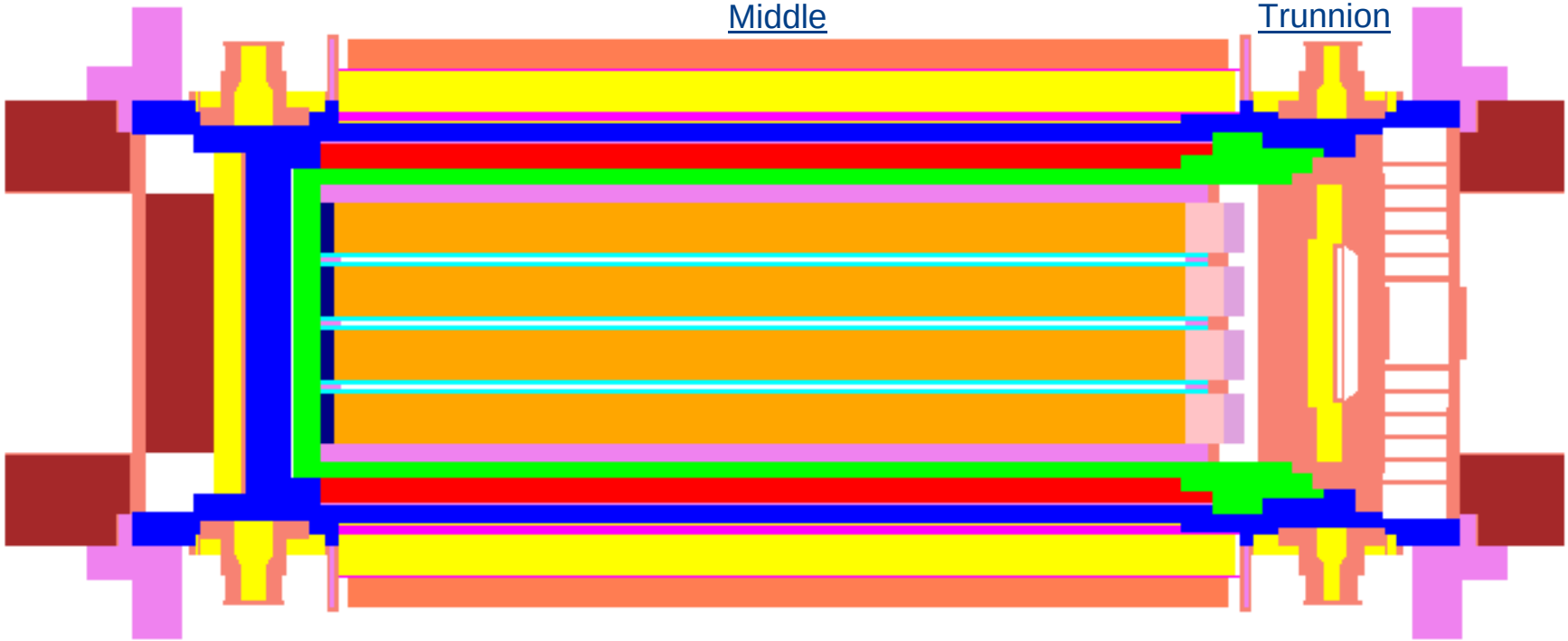
Calculation Methods and Codes

- **TN®112 TRIPOLI 4.3 model: radial cross section**



Calculation Methods and Codes

- **TN®112 TRIPOLI 4.3 model: axial cross section**



Transportability – Principles

Transportability – Principles

Consultation d'un Lot Service Calcul

Lot

Référence ACL : **Example_PATRAM** Date du document : 27/09/2010
Référence Client :
Tranche : TRI3
Statut : Créé
Créateur : Mikael DE BIASI Date de création : 27/09/2010

Liste des éléments combustibles : [12]

Supprimer | Modifier

EC	Combustible	U235 (%)	PU Métal (%)	Combustion (MW.j/t)	Activité (PBq)	Puissance Thermique (kW)	Intégrité	B3S	Transporté
FXP3MA	MOX	0,25	6,46	39261	51,83	7,67	Sain	Accepté	Non
FXP3MC	MOX	0,25	6,47	38750	51,43	7,58	Sain	Accepté	Non
FXP3MD	MOX	0,25	6,46	39346	51,76	7,64	Sain	Accepté	Non
FXP3MK	MOX	0,25	6,47	38761	51,19	7,56	Sain	Accepté	Non
FX1JRW	UOX	3,70	0	42225	18,70	1,97	Sain	Accepté	Oui
FX1JRZ	UOX	3,70	0	44603	11,88	1,06	Sain	Accepté	Oui
FX1JTC	UOX	3,70	0	44751	19,62	2,12	Sain	Accepté	Oui
FX1JTE	UOX	3,70	0	43021	11,43	1	Sain	Accepté	Oui
FX139E	UOX	3,71	0	46819	9,67	0,83	Sain	Accepté	Oui
FX139F	UOX	3,71	0	47432	9,79	0,85	Sain	Accepté	Oui
FX139G	UOX	3,71	0	47648	9,82	0,85	Sain	Accepté	Oui
FX139L	UOX	3,71	0	44049	9,85	0,83	Sain	Accepté	Oui

Plans de chargement : [0]

Nouveau

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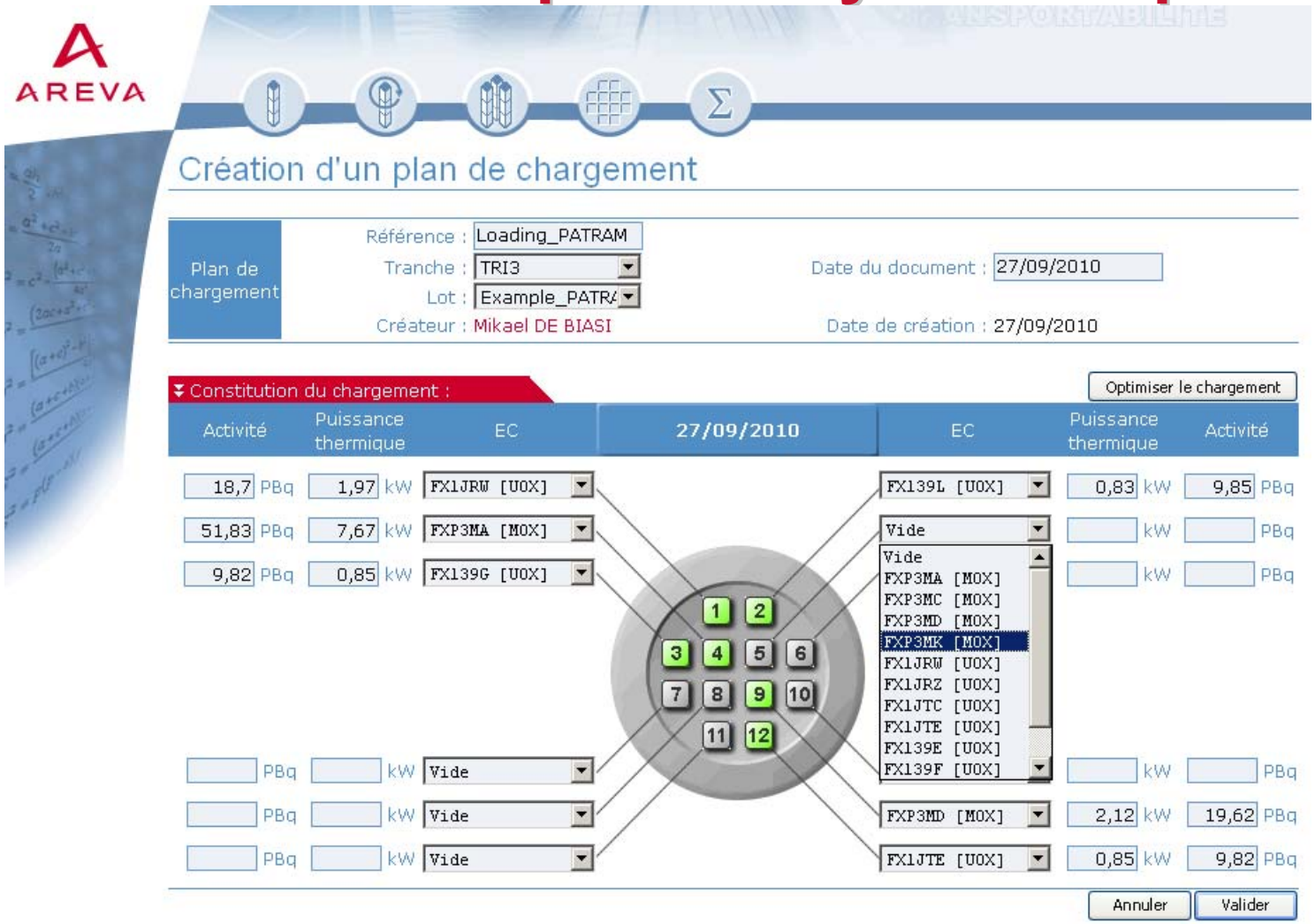
Transportability – Principles



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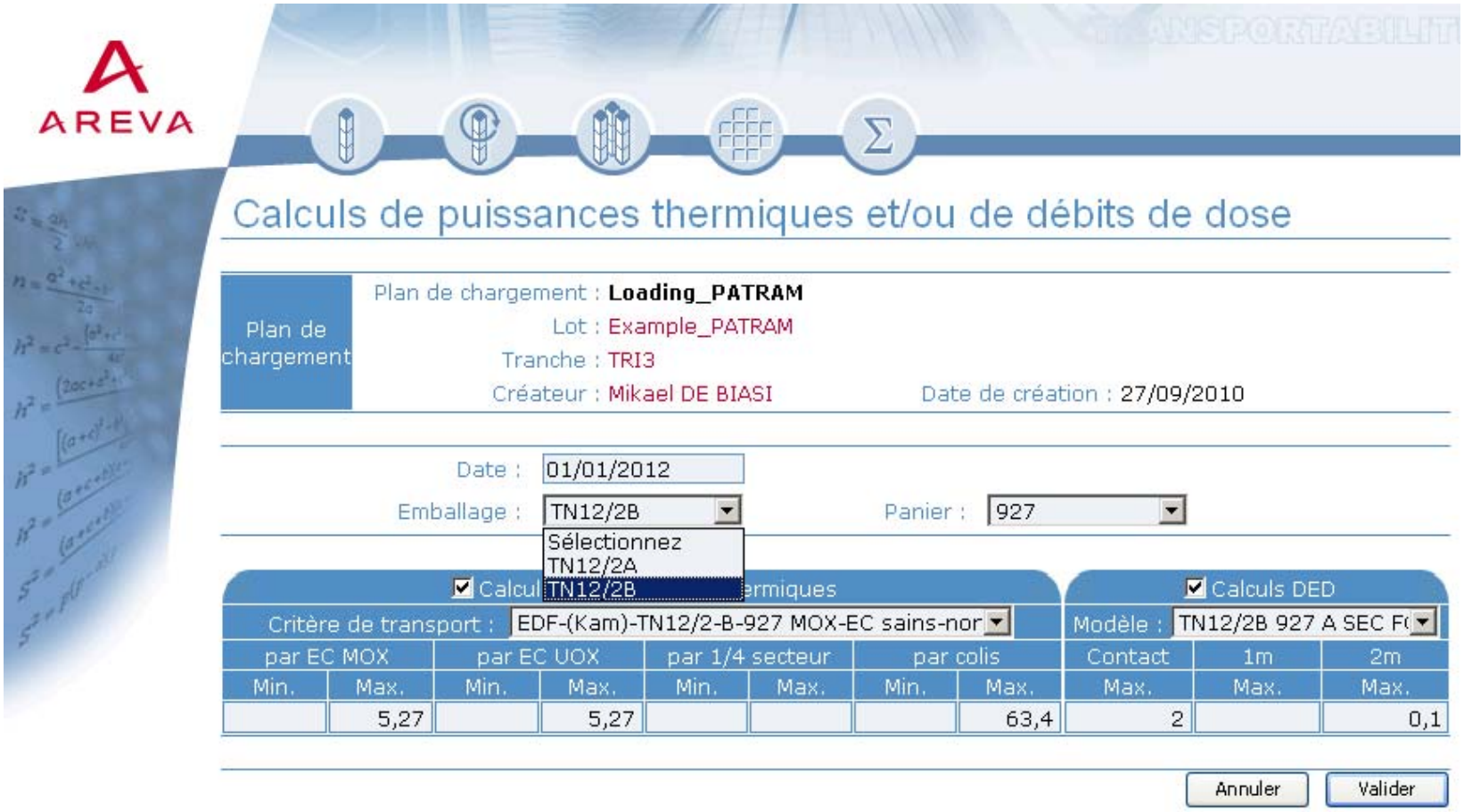
Transportability – Principles



Transportability – Principles

Image des plans de coupe :

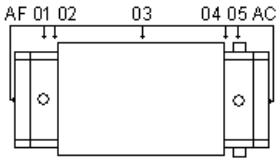
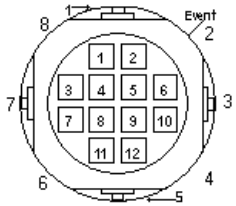


Image d'une coupe radiale :



Réponses unitaires gamma :

Réponses unitaires neutron et gamma de capture :

	A	B	C	D	E	F	G	H
1	N° EC	N° Plan	N° Point	Distance	Fission spontanée Neutron	Fission spontanée Gamma de capture	Alpha N neutron	Alpha N gamma de capture
2	1	AC	1	0	1,17665E-03	8,99975E-04	1,46731E-03	1,01690E-03
3	1	AC	1	1	3,36705E-04	2,77061E-04	4,21675E-04	3,12541E-04
4	1	AC	1	2	1,33421E-04	1,57610E-04	1,67484E-04	1,77885E-04
5	1	AF	1	0	1,17966E-02	4,06852E-03	1,40296E-02	4,30457E-03
6	1	AF	1	1	3,58696E-03	1,13816E-03	4,27392E-03	1,20137E-03
7	1	AF	1	2	9,96090E-04	5,26197E-04	1,18771E-03	5,55095E-04
8	1	1	1	0	1,53880E-02	8,91777E-04	2,07976E-02	9,47331E-04
9	1	1	1	1	2,01069E-03	3,58514E-04	2,71879E-03	3,80549E-04
10	1	1	1	2	8,68474E-04	3,17546E-04	1,17584E-03	3,37042E-04
11	1	1	2	0	1,53880E-02	8,91777E-04	2,07976E-02	9,47331E-04
12	1	1	2	1	2,01069E-03	3,58514E-04	2,71879E-03	3,80549E-04
13	1	1	2	2	8,68474E-04	3,17546E-04	1,17584E-03	3,37042E-04
14	1	1	3	0	1,53880E-02	8,91777E-04	2,07976E-02	9,47331E-04
15	1	1	3	1	2,01069E-03	3,58514E-04	2,71879E-03	3,80549E-04
16	1	1	3	2	8,68474E-04	3,17546E-04	1,17584E-03	3,37042E-04

Feuille1

Supprimer | Modifier | Rendre applicable | Fermer

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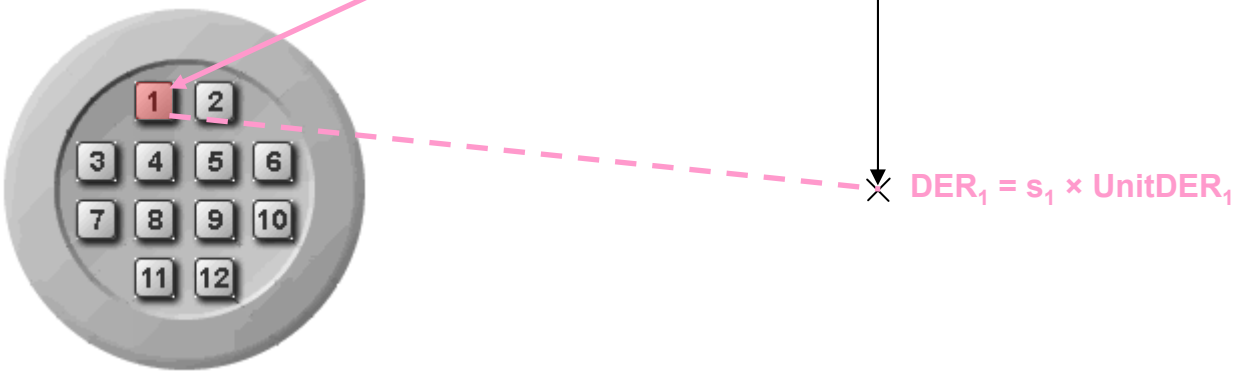
Transportability – Principles

- 1st assembly:

Data base → ORIGEN2 → Thermal power : P_{th1}

ORIGEN2 → Source: s_1

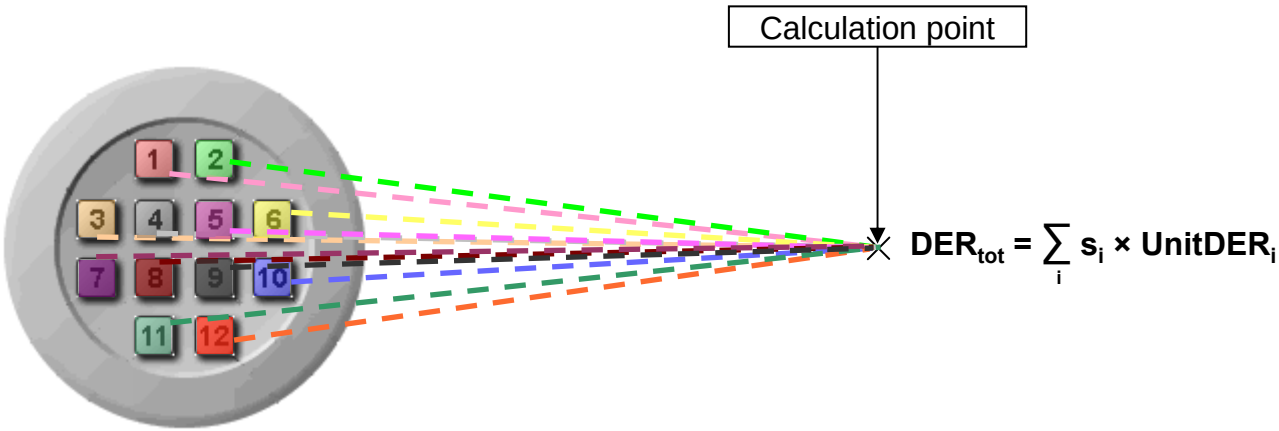


Transportability – Principles

- **For the 12 assemblies:**

Data base → **ORIGEN2** → **Thermal power of the loading** $P_{th\ tot} = \sum_i P_{th\ i}$

Sources: s_1, s_2, s_3,… s_{12}



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