

## TPNA300 - Generating tube of heat with variable conductivity

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### Summary:

This test is resulting from the validation independent of version 3 in nonlinear stationary thermics.

It is about an axisymmetric problem 2D represented by four modelings, two axisymmetric, plane and the voluminal last.

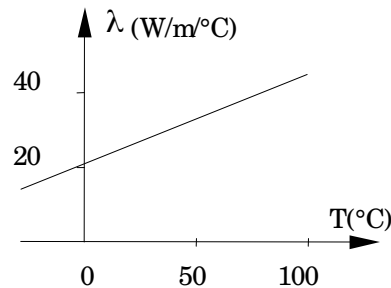
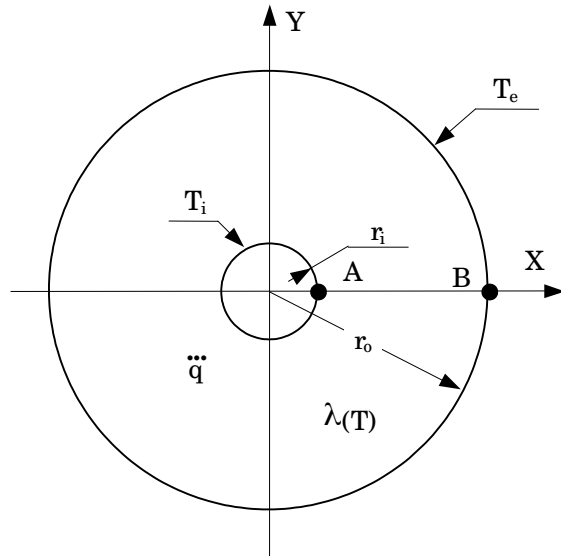
The features tested are the following ones:

- axisymmetric thermal element,
- thermal element plan,
- voluminal thermal element,
- variable properties,
- limiting conditions (source of heat, imposed temperature).

The interest of the test lies in the taking into account of variable properties and the nonlinear behavior.

## 1 Problem of reference

### 1.1 Geometry



$$r_i = 6.35 \cdot 10^{-3} \text{ m}$$

$$r_o = 25.4 \cdot 10^{-3} \text{ m}$$

### 1.2 Properties of material

$$\lambda = C_0 + C_1 T \text{ W/m}^\circ \text{C} \quad \text{Thermal conductivity}$$

with

$$C_0 = 21.461 \text{ W/m}^\circ \text{C}$$

$$C_1 = 0.234 \text{ W/m}^\circ \text{C}^2$$

### 1.3 Boundary conditions and loadings

- interior surface:  $T_i = -17.78^\circ \text{C}$
- external surface:  $T_e = -17.78^\circ \text{C}$
- source of heat:  $Q = 1.035 \cdot 10^7 \text{ W/m}^3$

### 1.4 Initial conditions

Without object.

## 2 Reference solution

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### 2.1 Method of calculating used for the reference solution

The original reference solution given in the book [bib1] is based on a graphic estimate. This reference is quoted in the handbook of checking of ANSYS [bib2].

### 2.2 Results of reference

Temperature along  $AB$  with  $\Delta r = 2.167 \text{ mm}$

### 2.3 Uncertainty on the solution

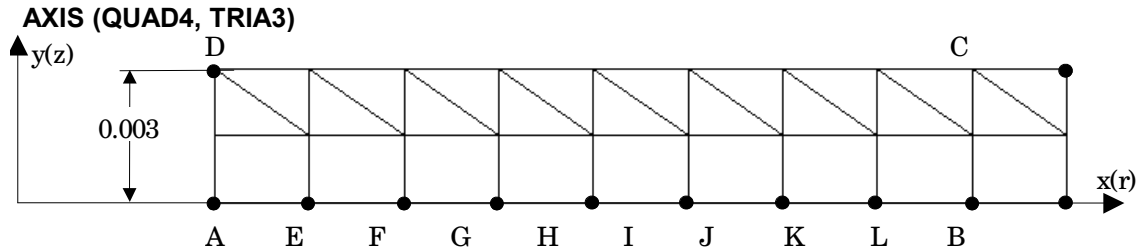
Unknown factor, it was not possible to get the original reference (delivers old, more published).

### 2.4 References bibliographical

1. Schneider, P.J., "Conduction Heat Transfer", Addison-Wesley Publishing Co., Inc. Reading, Farmhouse., 2nd Printing, 1957.
2. ANSYS, "checking manual", 1st edition, June 1.1976

## 3 Modeling A

### 3.1 Characteristics of modeling



Conditions aux limites:

- cotés AB, CD:  $\phi = 0$
- cotés AD, BC:  $T = -17.78^\circ\text{C}$

Noeud	r ( $10^{-3}\text{m}$ )	z ( $10^{-3}\text{m}$ )	Points	Noeud	r ( $10^{-3}\text{m}$ )	z ( $10^{-3}\text{m}$ )
N4	8.47	0.0	E	N6	8.47	3.0
N7	10.58	0.0	F	N9	10.58	3.0
N10	12.70	0.0	G	N12	12.70	3.0
N13	14.82	0.0	H	N15	14.82	3.0
N16	16.92	0.0	I	N18	16.92	3.0
N19	19.05	0.0	J	N21	19.05	3.0
N22	21.17	0.0	K	N24	21.17	3.0
N25	23.28	0.0	L	N27	23.28	3.0

### 3.2 Characteristics of the grid

Many nodes: 30  
Many meshes and types: 27: (9 QUAD4, 18 TRIA3)

## 4 Results of modeling A

### 4.1 Values tested

Identification	Reference	Aster	% difference	tolerance
Temperature (°C)				
N4	-5.00	-4.92	-1.70	5%
N7	2.22	2.06	<b>-7.35</b>	5%
N10	5.56	5.57	0.10	5%
N13	6.67	6.60	-1.07	5%
N16	5.56	5.60	0.76	5%
N19	2.78	2.76	-0.71	5%
N22	-1.67	-1.93	<b>15.30</b>	5%
N25	-8.89	-8.63	-2.90	5%
N6	-5.00	-4.96	-0.87	5%
N9	2.22	2.04	<b>-8.18</b>	5%
N12	5.56	5.56	0.04	5%
N15	6.67	6.60	-1.02	5%
N18	5.56	5.61	0.91	5%
N21	2.78	2.77	-0.26	5%
N24	-1.67	-1.91	<b>14.24</b>	5%
N27	-8.89	-8.61	-3.17	5%

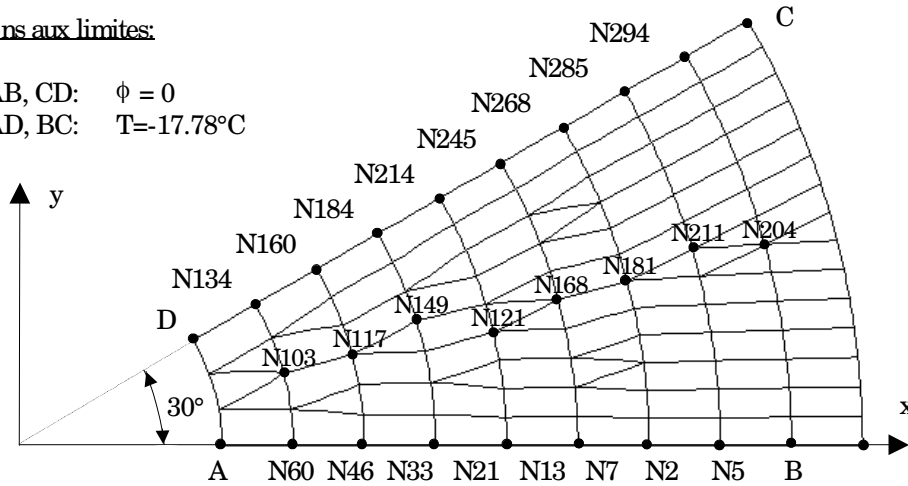
## 5 Modeling B

### 5.1 Characteristics of modeling

PLAN (QUAD8, TRIA6)

Conditions aux limites:

- cotés AB, CD:  $\phi = 0$
- cotés AD, BC:  $T = -17.78^\circ\text{C}$



### 5.2 Characteristics of the grid

Many nodes:	300
Many meshes and types:	95 (73 QUAD8, 22 TRIA6)

## 6 Results of modeling B

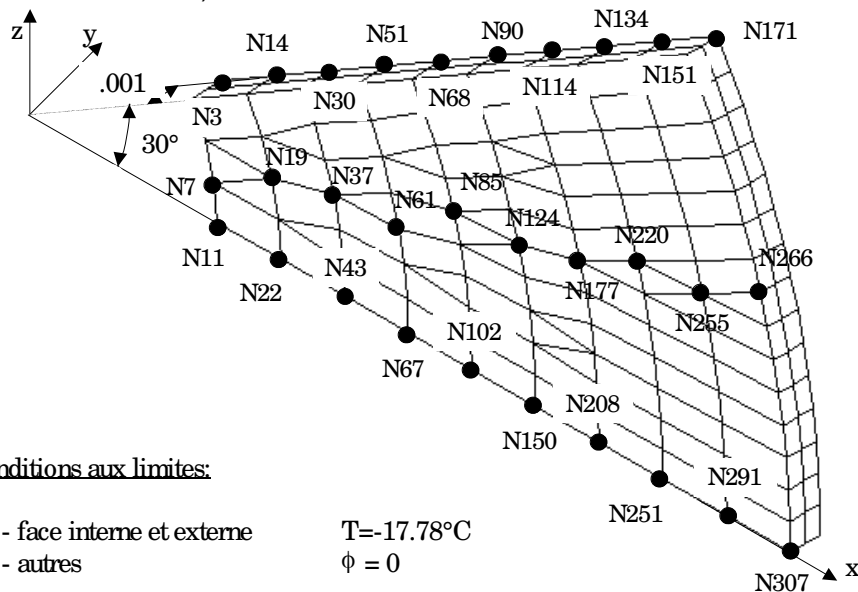
### 6.1 Values tested

Identification	Reference	Aster	% difference	tolerance
Temperature (°C)				
N60	-5.00	-4.84	-3,194	5%
N46	2.22	2.14	-3,491	5%
N33	5.56	5.65	1,544	5%
N21	6.67	6.66	-0,082	5%
N13	5.56	5.65	1,694	5%
N7	2.78	2.80	0,665	5%
N2	-1.67	-1.90	<b>13,788</b>	5%
N5	-8.89	-8.62	-3,089	5%
N134	-5.00	-4.84	-3,194	5%
N160	2.22	2.14	-3,491	5%
N184	5.56	5.65	1,543	5%
N214	6.67	6.66	-0,082	5%
N245	5.56	5.65	1,694	5%
N268	2.78	2.80	0,665	5%
N285	-1.67	-1.90	<b>13,737</b>	5%
N294	-8.89	-8.62	-3,089	5%
N103	-5.00	-4.84	-3,141	5%
N117	2.22	2.15	-3,365	5%
N149	5.56	5.65	1,557	5%
N121	6.67	6.66	-0,078	5%
N168	5.56	5.65	1,694	5%
N181	2.78	2.80	0,650	5%
N211	-1.67	-1.90	<b>13,777</b>	5%
N204	-8.89	-8.62	-3,075	5%

## 7 Modeling C

### 7.1 Characteristics of modeling

3D (HEXA8, PENTA6)



Conditions aux limites:

- face interne et externe
- autres

$T = -17.78^{\circ}\text{C}$   
 $\phi = 0$

### 7.2 Characteristics of the grid

Many nodes:	309
Many meshes and types:	190 (144 HEXA8, 46 PENTA6)



## 8 Results of modeling C

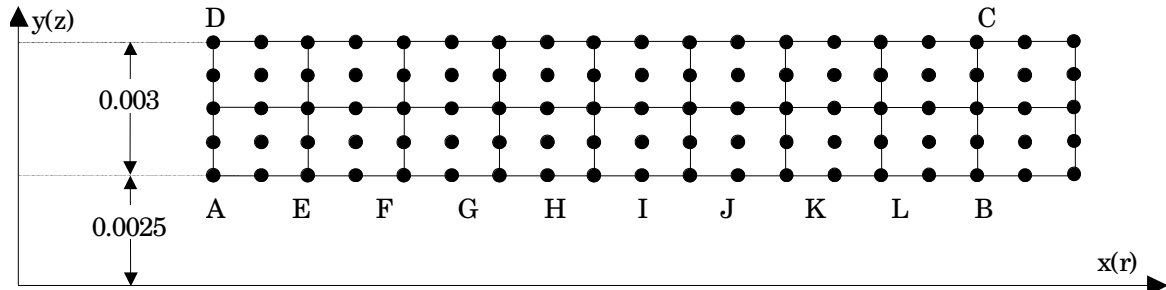
### 8.1 Values tested

Identification	Reference	Aster	% difference	tolerance
Temperature (°C)				
N22	-5.00	-4.90	-1,909	5%
N43	2.22	2.09	<b>-5,933</b>	5%
N67	5.56	5.58	0,408	5%
N102	6.67	6.63	-0,561	5%
N150	5.56	5.62	0,993	5%
N208	2.78	2.77	-0,217	5%
N251	-1.67	-1.92	<b>15,047</b>	5%
N291	-8.89	-8.63	-2,960	5%
N14	-5.00	-4.90	-1,908	5%
N30	2.22	2.09	<b>-5,933</b>	5%
N51	5.56	5.58	0,408	5%
N68	6.67	6.63	-0,561	5%
N90	5.56	5.62	0,993	5%
N114	2.78	2.77	-0,217	5%
N134	-1.67	-1.92	<b>15,047</b>	5%
N151	-8.89	-8.63	-2,960	5%
N19	-5.00	-4.93	-1,440	5%
N37	2.22	2.16	-2,596	5%
N61	5.56	5.54	-0,274	5%
N85	6.67	6.65	-0,260	5%
N124	5.56	5.60	0,705	5%
N177	2.78	2.82	1,536	5%
N220	-1.67	-1.90	<b>13,946</b>	5%
N255	-8.89	-8.58	-3,474	2%

## 9 Modeling D

### 9.1 Characteristics of modeling

AXIS (QUAD9)



Conditions aux limites:

- cotés AB, CD:  $\phi = 0$
- cotés AD, BC:  $T = -17.78^\circ\text{C}$

Noeud	r ( $10^{-3}\text{m}$ )	z ( $10^{-3}\text{m}$ )	Points	Noeud	r ( $10^{-3}\text{m}$ )	z ( $10^{-3}\text{m}$ )
N11	8.47	2.5	E	N15	8.47	5.5
N21	10.58	2.5	F	N25	10.58	5.5
N31	12.70	2.5	G	N35	12.70	5.5
N41	14.82	2.5	H	N45	14.82	5.5
N51	16.92	2.5	I	N55	16.92	5.5
N61	19.05	2.5	J	N65	19.05	5.5
N71	21.17	2.5	K	N75	21.17	5.5
N81	23.28	2.5	L	N85	23.28	5.5

### 9.2 Characteristics of the grid

Many nodes: 95  
Many meshes and types: 18 QUAD9

## 10 Results of modeling D

### 10.1 Values tested

Identification	Reference	Aster	Relative	Absolute deviation		
			variation %	tolerance	difference	tolerance
Temperature (°C)						
N11	-5.00	-4.83	-3,333	5%	0,167	0.3
N21	2.22	2.15	-3,347	5%	-0,074	0.3
N31	5.56	5.65	1,551	5%	0,086	0.3
N41	6.67	6.66	-0,078	5%	-0,005	0.3
N51	5.56	5.65	1,694	5%	0,094	0.3
N61	2.78	2.80	0,663	5%	0,018	0.3
N71	-1.67	-1.90	<b>13,741</b>	5%	-0,229	0.3
N81	-8.89	-8.62	-3,088	5%	0,275	0.3
N15	-5.00	-4.83	-3,333	5%	0,167	0.3
N25	2.22	2.15	-3,347	5%	-0,074	0.3
N35	5.56	5.65	1,551	5%	0,082	0.3
N45	6.67	6.66	-0,078	5%	-0,005	0.3
N55	5.56	5.65	1,694	5%	0,094	0.3
N65	2.78	2.80	0,663	5%	0,018	0.3
N75	-1.67	-1.90	<b>13,741</b>	5%	-0,229	0.3
N85	-8.89	-8.62	-3,088	5%	0,275	0.3

## 11 Summary of the results

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Four modelings give results whose certain values exceed the tolerance fixed initially (5%):

- for modeling A (AXIS: QUAD4, TRIA3), the maximum change is of 15.3% and 4 values out of 16 exceed the tolerance,
- for modeling B (PLAN: QUAD8, TRIA6), the maximum change is of 13.8% and 3 values out of 24 exceed the tolerance,
- for modeling C (3D: HEXA8, PENTA6), the maximum change is of 15% and 5 values out of 24 exceed the tolerance,
- for modeling D (AXIS: QUAD9), the maximum change is of 13.7% and 4 values out of 16 exceed the tolerance.

These goings beyond tolerance are observed for values close to 0.

Calculations were carried out in °C. The determination of the variation, by considering the temperatures in °F (as in the reference solution), gives a maximum change very different from that obtained in °C (3% instead of 15%).

Moreover, it was not possible to get the original reference (delivers of Kreith), quoted in the handbook of checking of ANSYS. The method of acquisition the reference solution (graphic estimate) and its uncertainty are thus not known.

The results are regarded as acceptable taking into account the points evoked above.

This test made it possible to test the taking into account a variable thermal conductivity within several modelings. The principal orders tested are the following ones:

- `DEFI_MATERIAU` associated with the keyword `THER_NL`, allowing to define the characteristics of a material whose characteristics vary according to the temperature,
- `THER_NON_LINE` order allowing the resolution of a stationary thermal nonlinear problem or not.