Utilisation de CASTEM pour des études de mécanique des fluides dans une enceinte de réacteur nucléaire

Application et validation sur les essais PHEBUS FPT0 et FPT1

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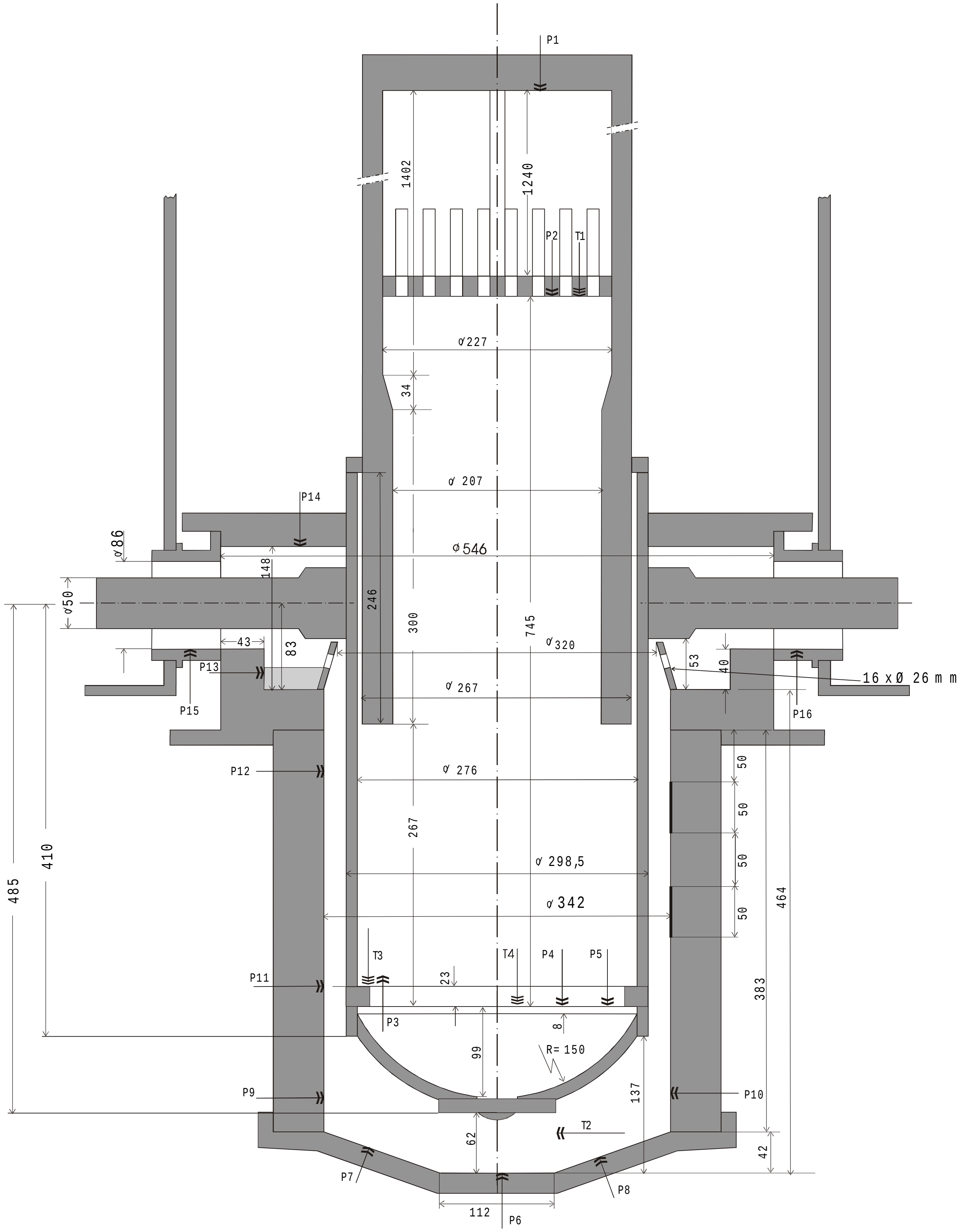
Caractérisation de l'écoulement vapeur dans la cavité du réacteur en situation accidentelle

C. Caroli, ENEA - Italy

Work carried out by ENEA in collaboration with IPSN

Liste des exposés



Vertical cut of the DISCO mock-up

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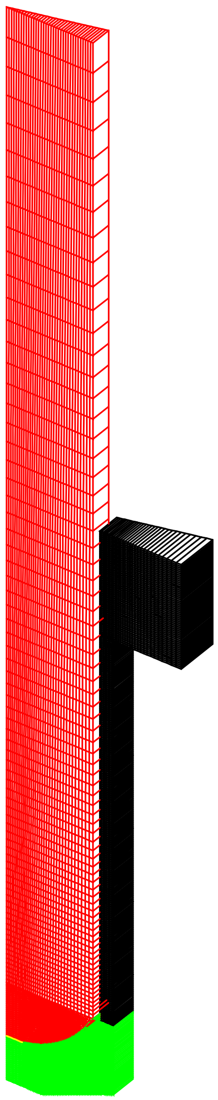

Disco 3d mesh

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Experiment	Initial RPV Pressure	Hole Diameter	Gas	Note
	MPa	mm		
B2	1.100	50	N_2	Experiment with pure gas
L05	0.600	50	N_2	Experiment with pure gas
D5	1.200	50	N_2	Gas + Water
D6	0.619	50	N_2	Gas + Water
D7	0.620	25	N_2	Gas + Water
H1	0.641	25	He	Gas + Water

Table 1: Main characteristics of the modeled Disco-C experiments

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The 3-D model

Conservation equations: $\frac{\partial \underline{u}}{\partial t} + \frac{\partial \underline{f_x}}{\partial x} + \frac{\partial \underline{f_y}}{\partial y} + \frac{\partial \underline{f_z}}{\partial z} = 0$

$$\underline{u} = \begin{pmatrix} \rho \\ \rho u \\ \rho v \\ \rho w \\ \rho e_t \end{pmatrix}, \qquad \underline{f_x} = \begin{pmatrix} \rho u \\ \rho u^2 + p \\ \rho uv \\ \rho uw \\ \rho u h_t \end{pmatrix}, \qquad \underline{f_y} = \begin{pmatrix} \rho v \\ \rho vu \\ \rho v^2 + p \\ \rho vw \\ \rho v h_t \end{pmatrix}, \qquad \underline{f_z} = \begin{pmatrix} \rho w \\ \rho wu \\ \rho wv \\ \rho w^2 + p \\ \rho w h_t \end{pmatrix}$$

Jump conditions: $[\rho \cdot u_n] = 0$, $[\rho \cdot u_n \cdot h_t] = 0$, $[p + \rho \cdot u_n^2] = 0$, $[\rho \cdot u_n \cdot u_{t1}] = 0$, $[\rho \cdot u_n \cdot u_{t2}] = 0$

Model hypotheses:

Polytropic gas

Viscous and diffusion phenomena neglected

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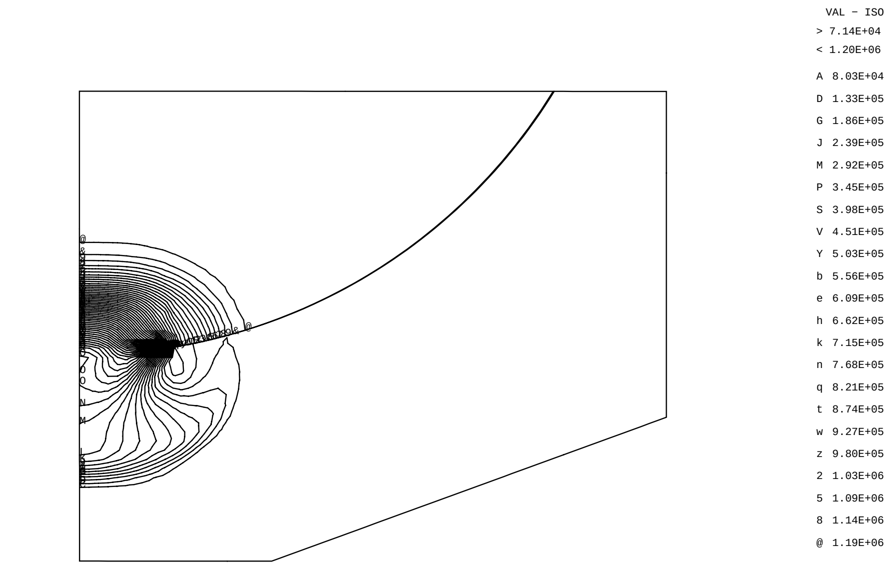
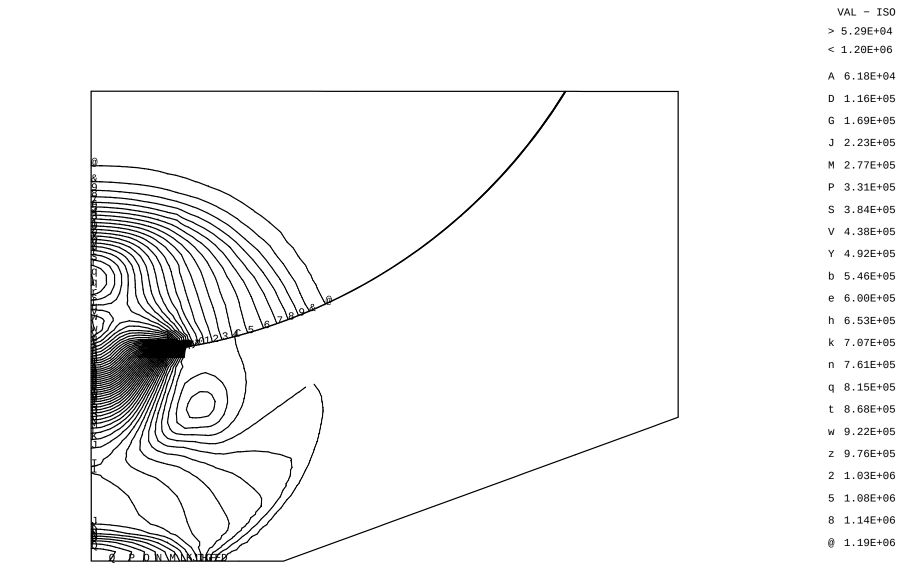
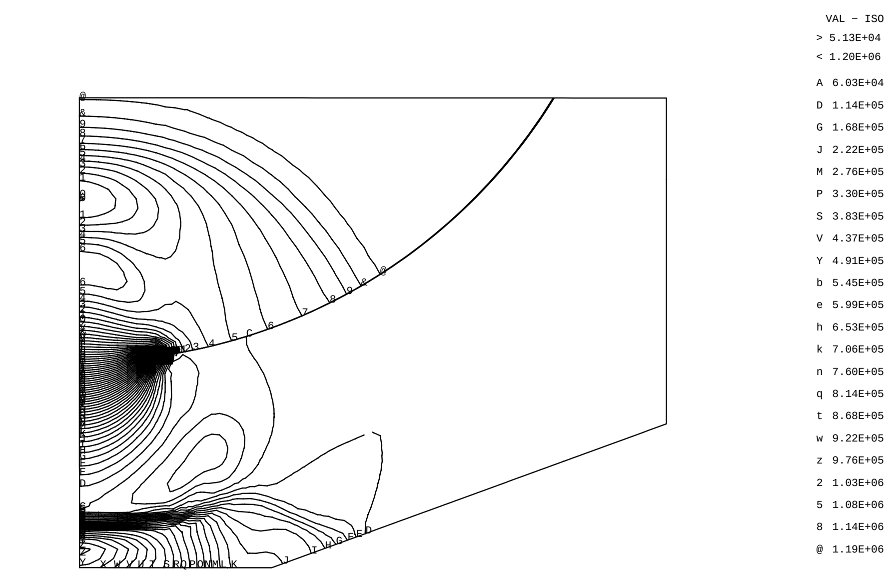


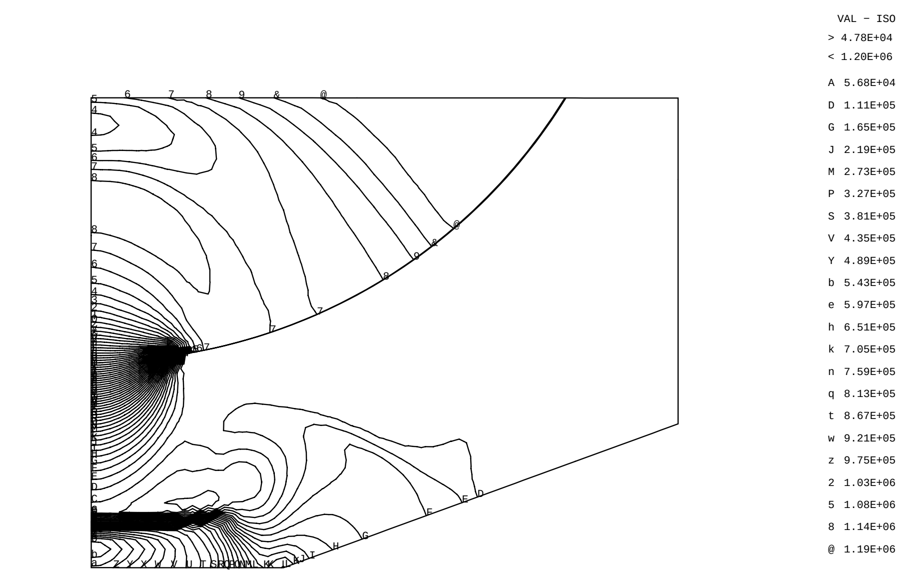
Disco D5 – P1/P2=12,d=50,N2 – t [s]= 6.14143E-05 P [Pa]



Disco D5 – P1/P2=12,d=50,N2 – t [s]= 1.22231E-04 P [Pa]



Disco D5 – P1/P2=12,d=50,N2 – t [s]= 1.85073E-04 P [Pa]



Disco D5 – P1/P2=12,d=50,N2 – t [s]= 2.44964E-04 P [Pa]

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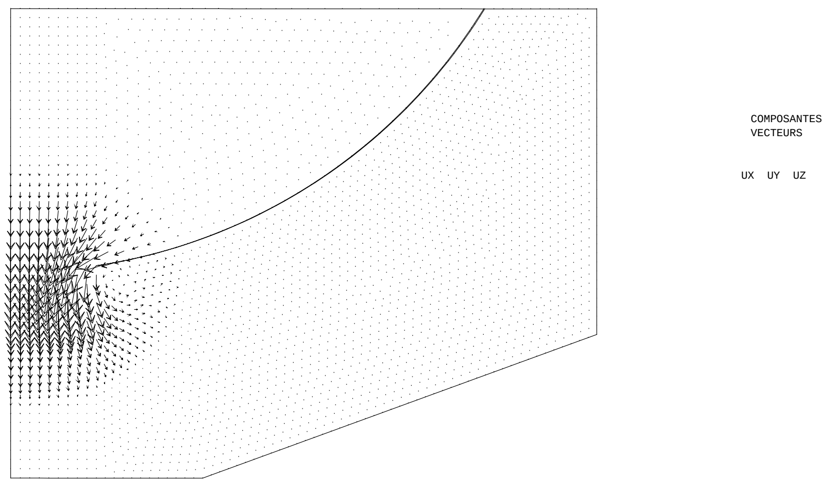
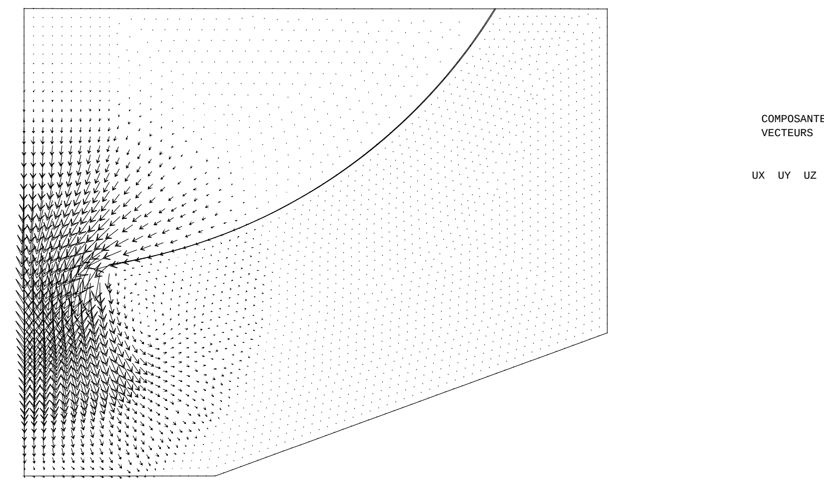


Disco D5 - P1/P2=12,d=50,N2 - t [s]= 6.14143E-05 RhoU [kg/m2/s]



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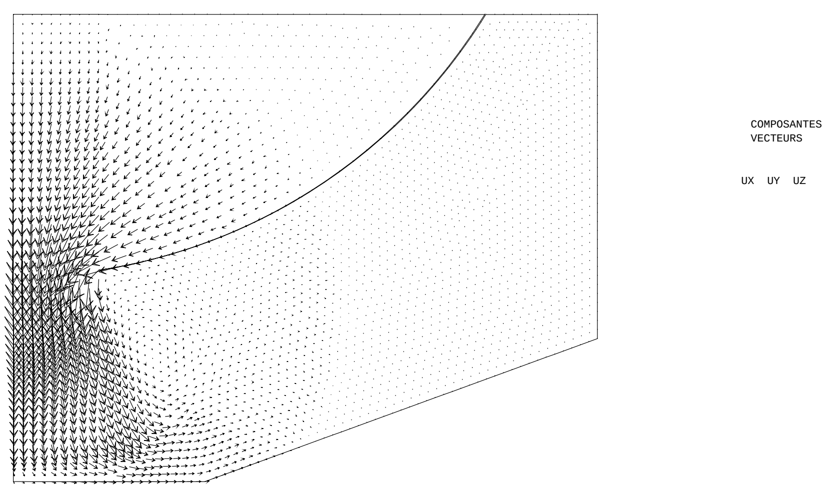

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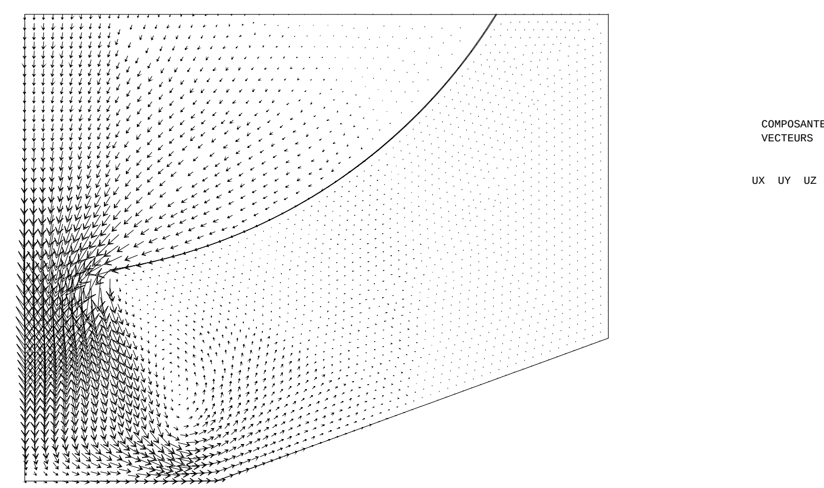

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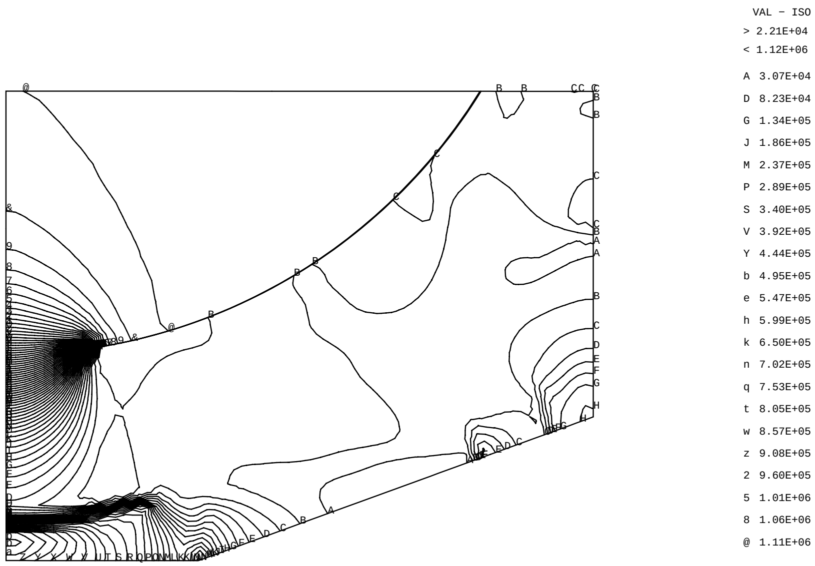
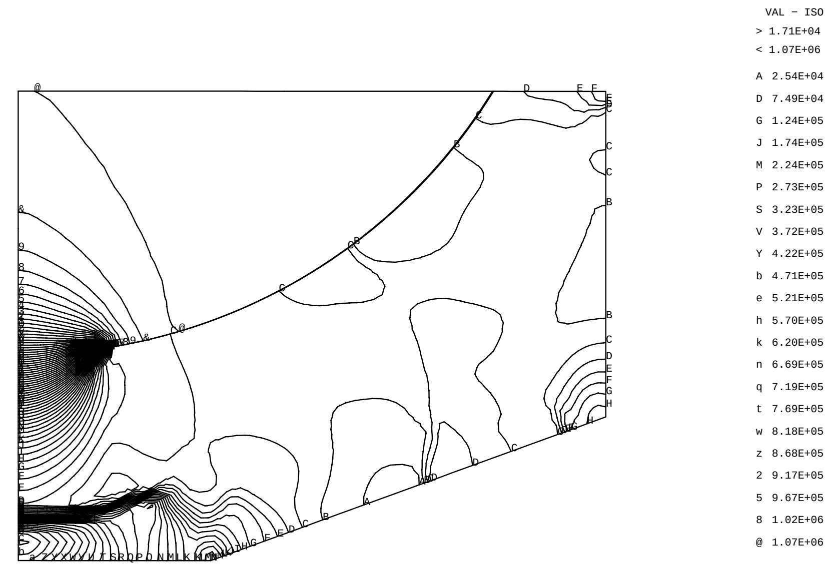


Disco D5 - P1/P2=12.d=50.N2 - t [s]= 1.00000E-02 P [Pa]



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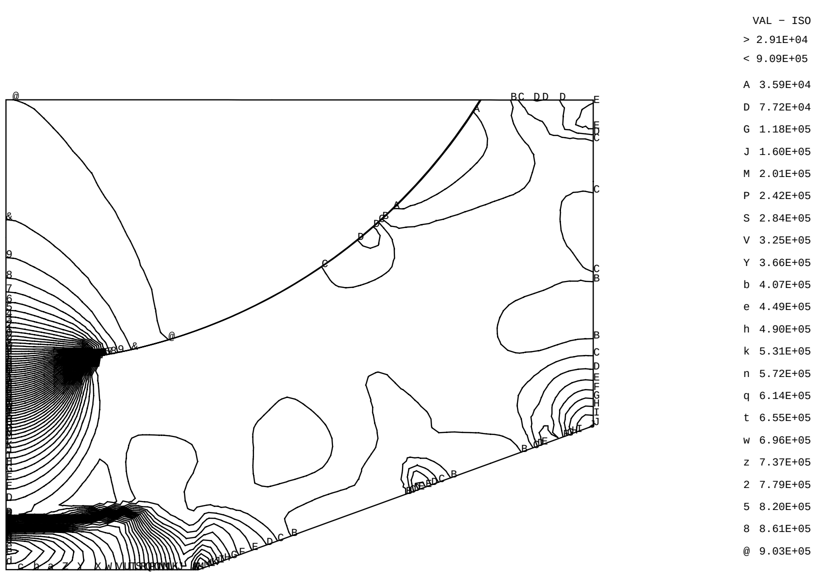
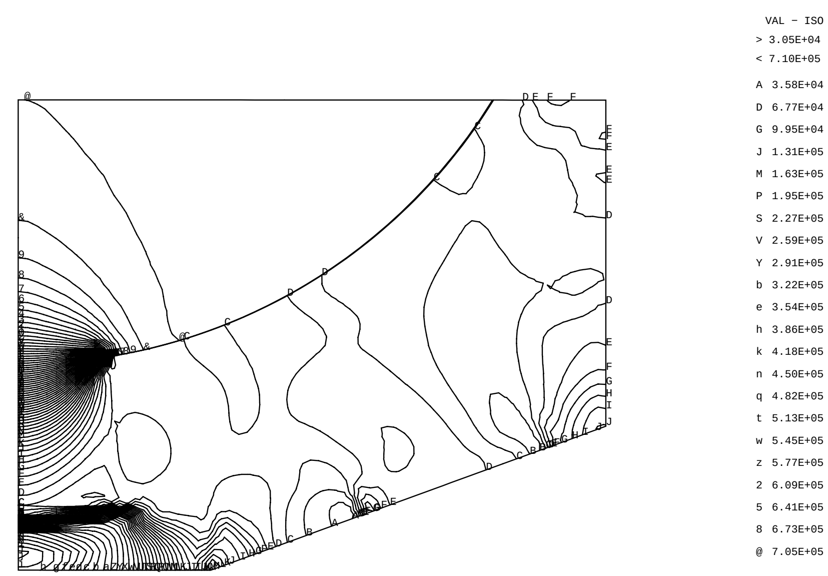


Disco D5 - P1/P2=12.d=50.N2 - t [s]= 5.00000E-02 P [Pa]



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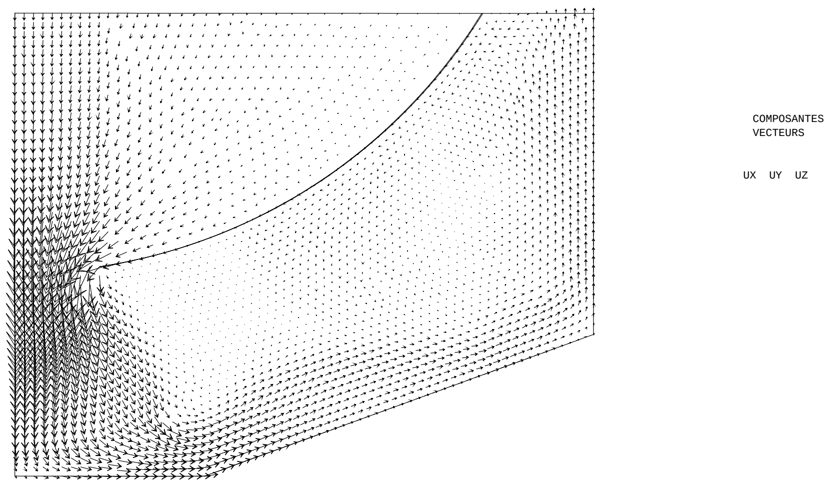

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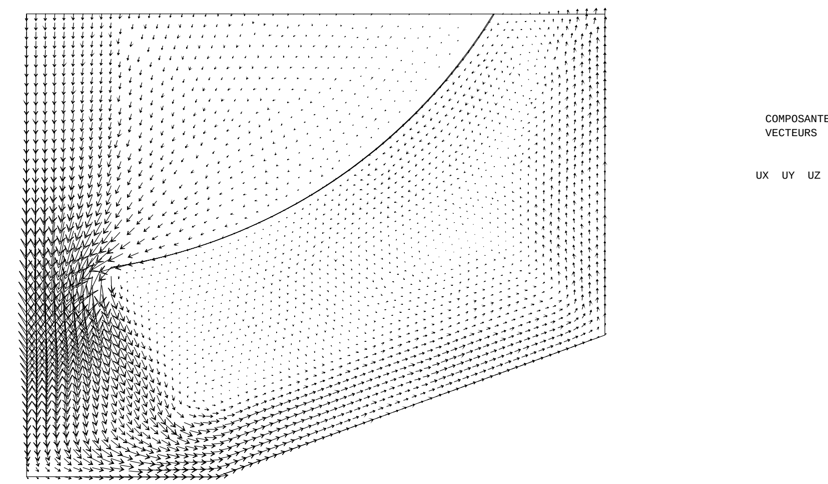

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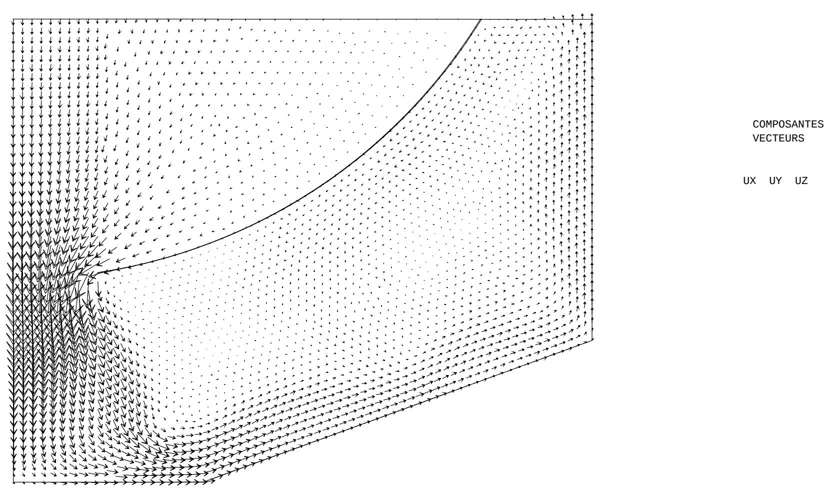

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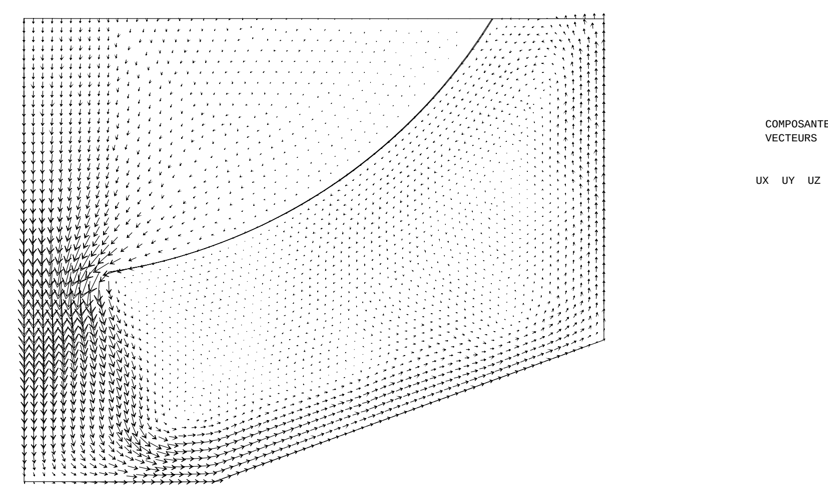

Disco D5 – P1/P2=12,d=50,N2 – t [s]= 1.00000E-01 RhoU [kg/m2/s]

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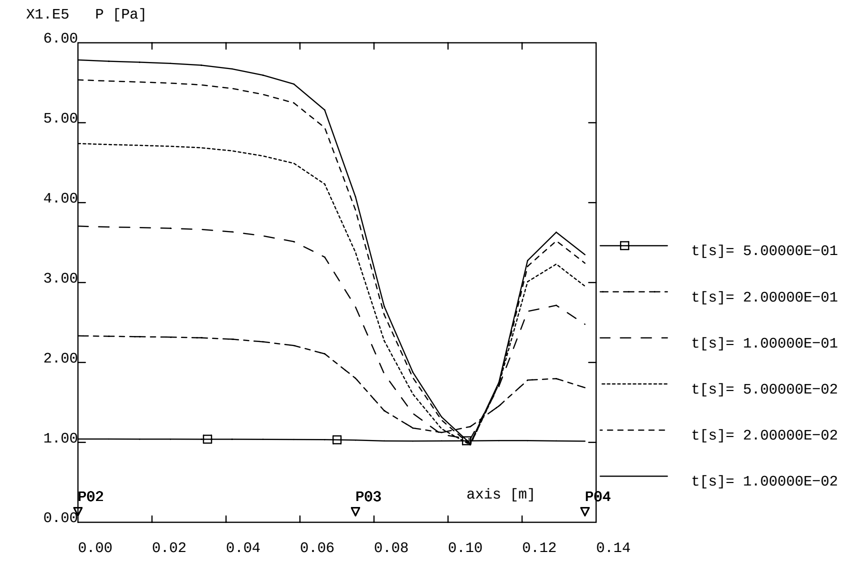
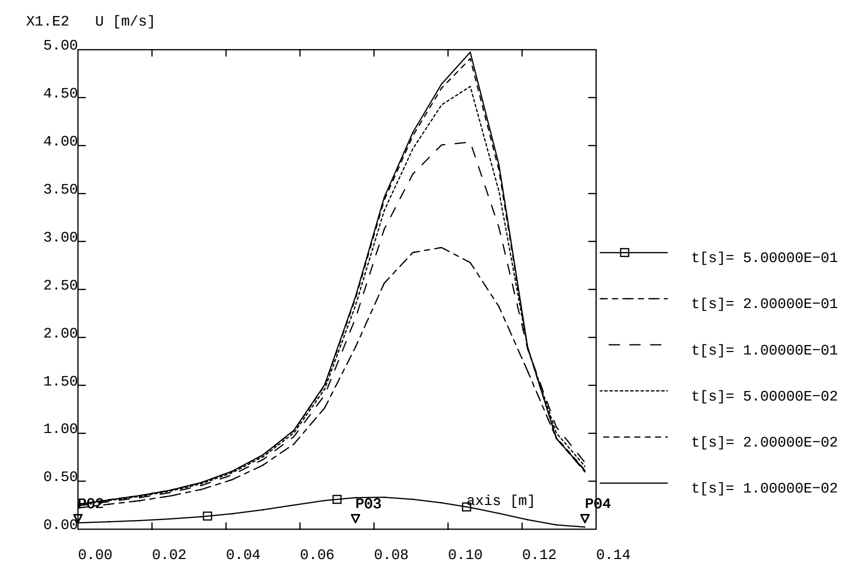
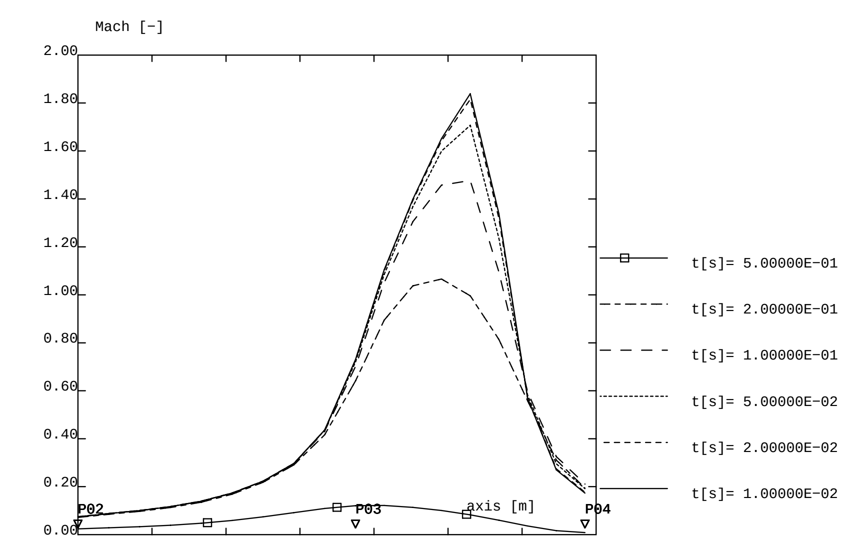


Disco D6 − Pressure along the axis



Disco D6 − Velocity along the axis



Disco D6 − Mach along the axis

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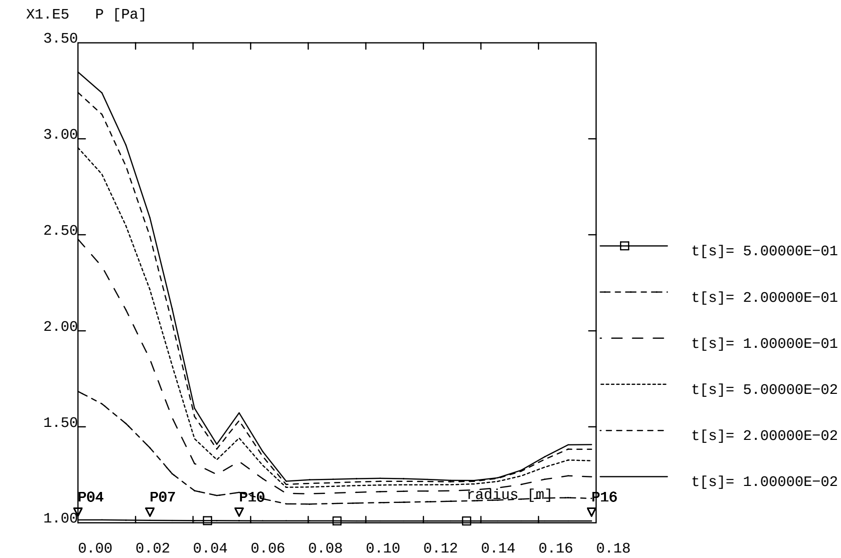
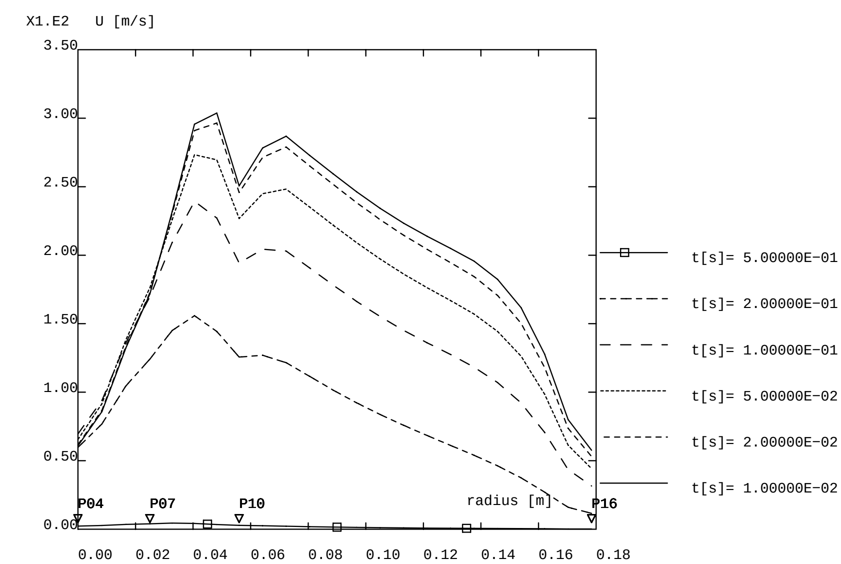
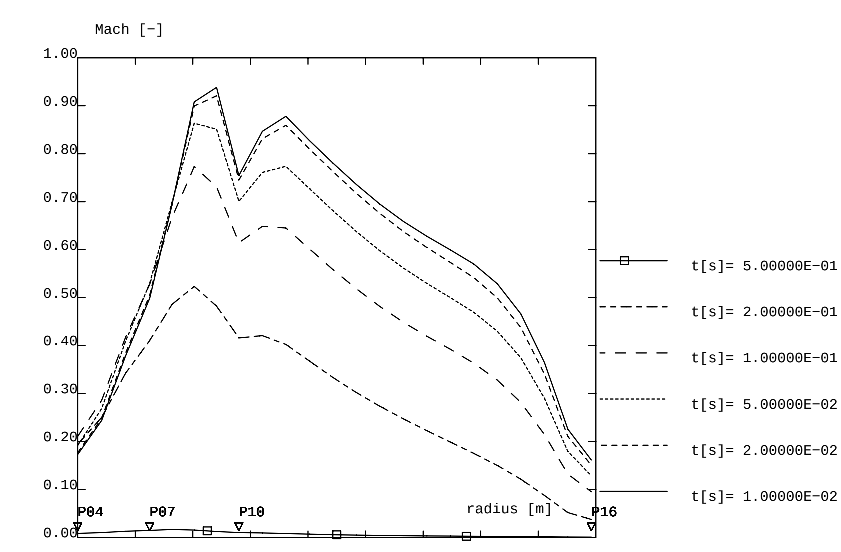


Disco D6 − Pressure in the cavity floor



Disco D6 − Velocity in the Cavity floor



Disco D6 − Mach in the cavity floor

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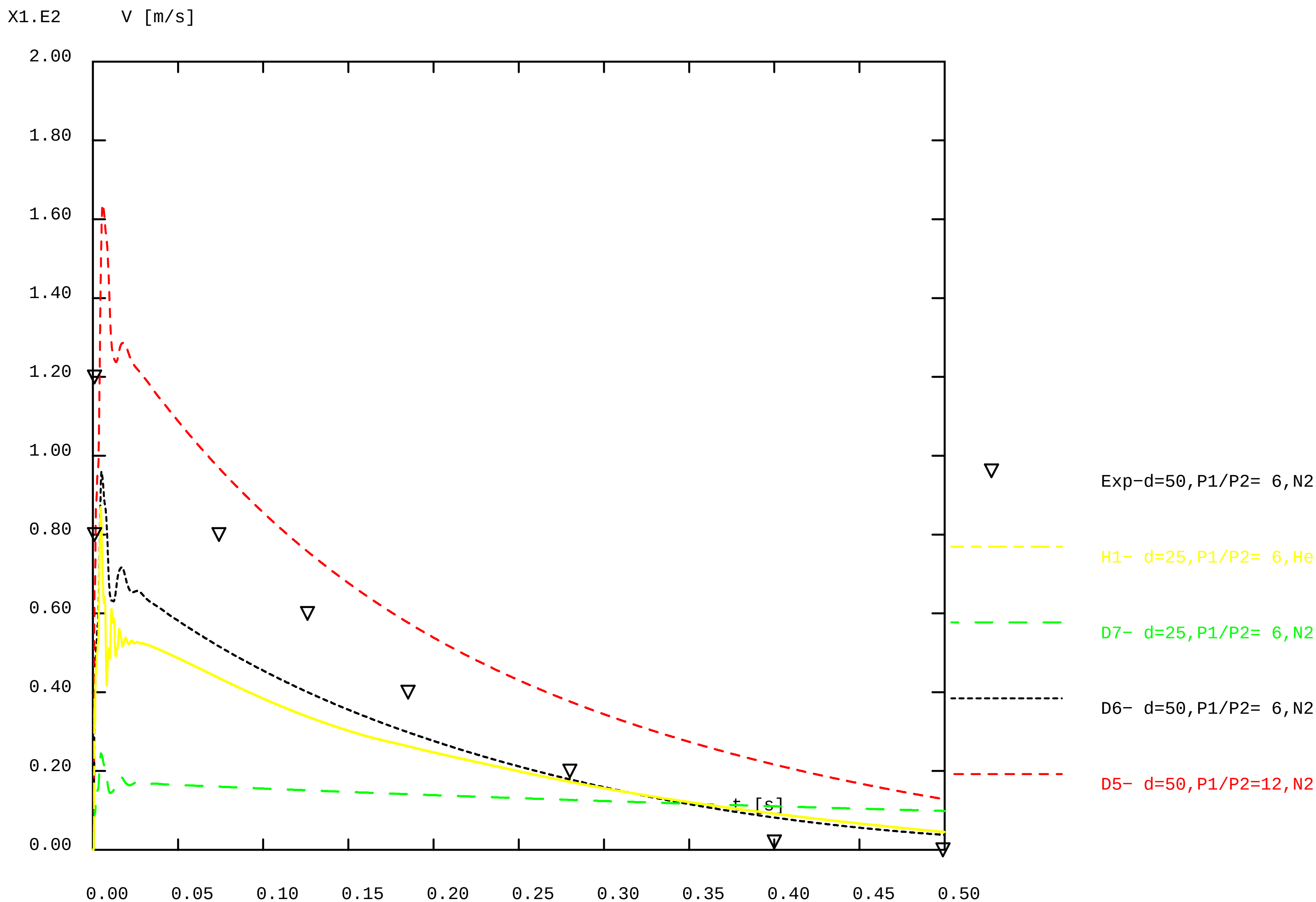

Velocity in the annular space v.s. time

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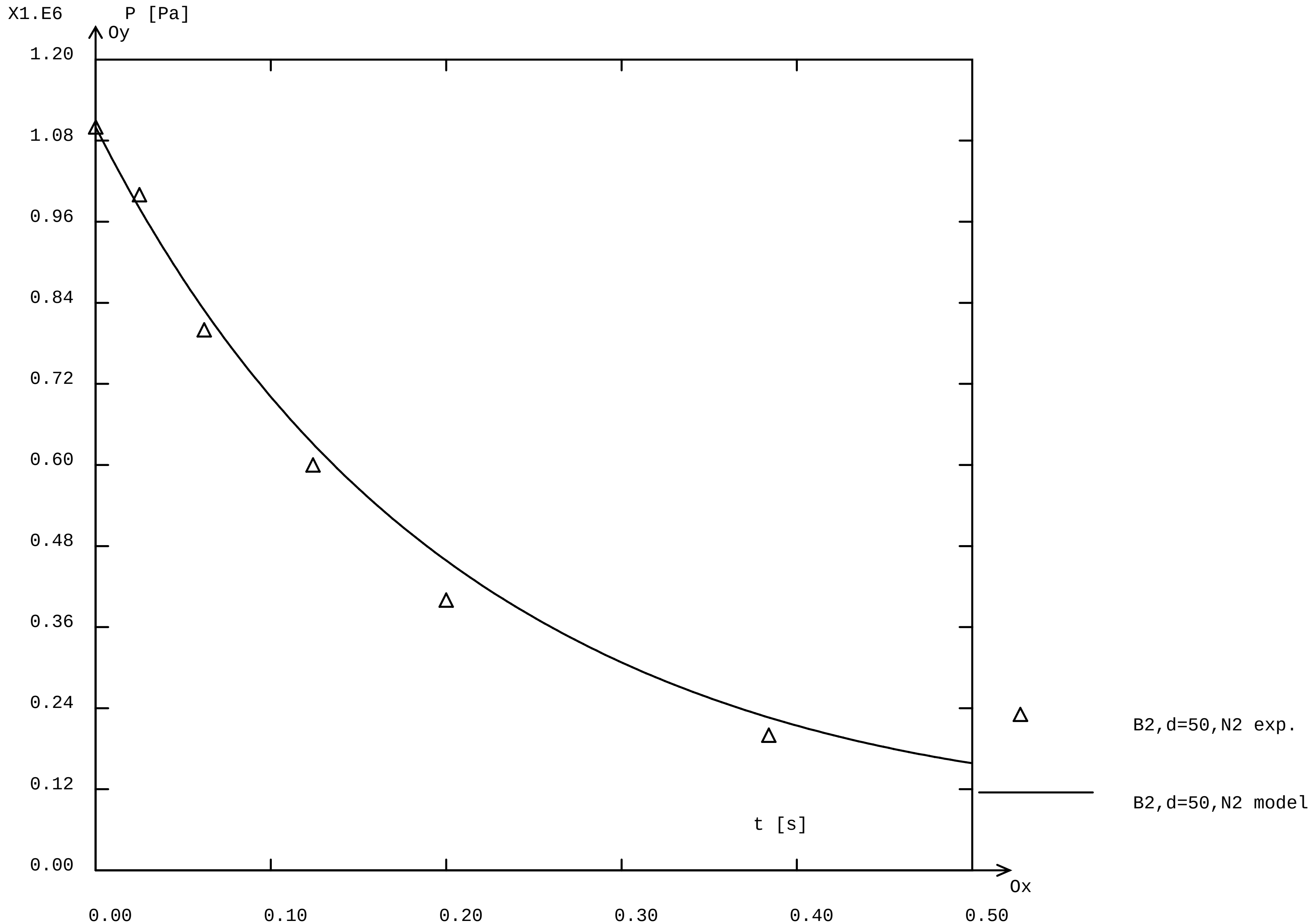

Disco experiment B2 (Pure Gas) – RPV pressure histories

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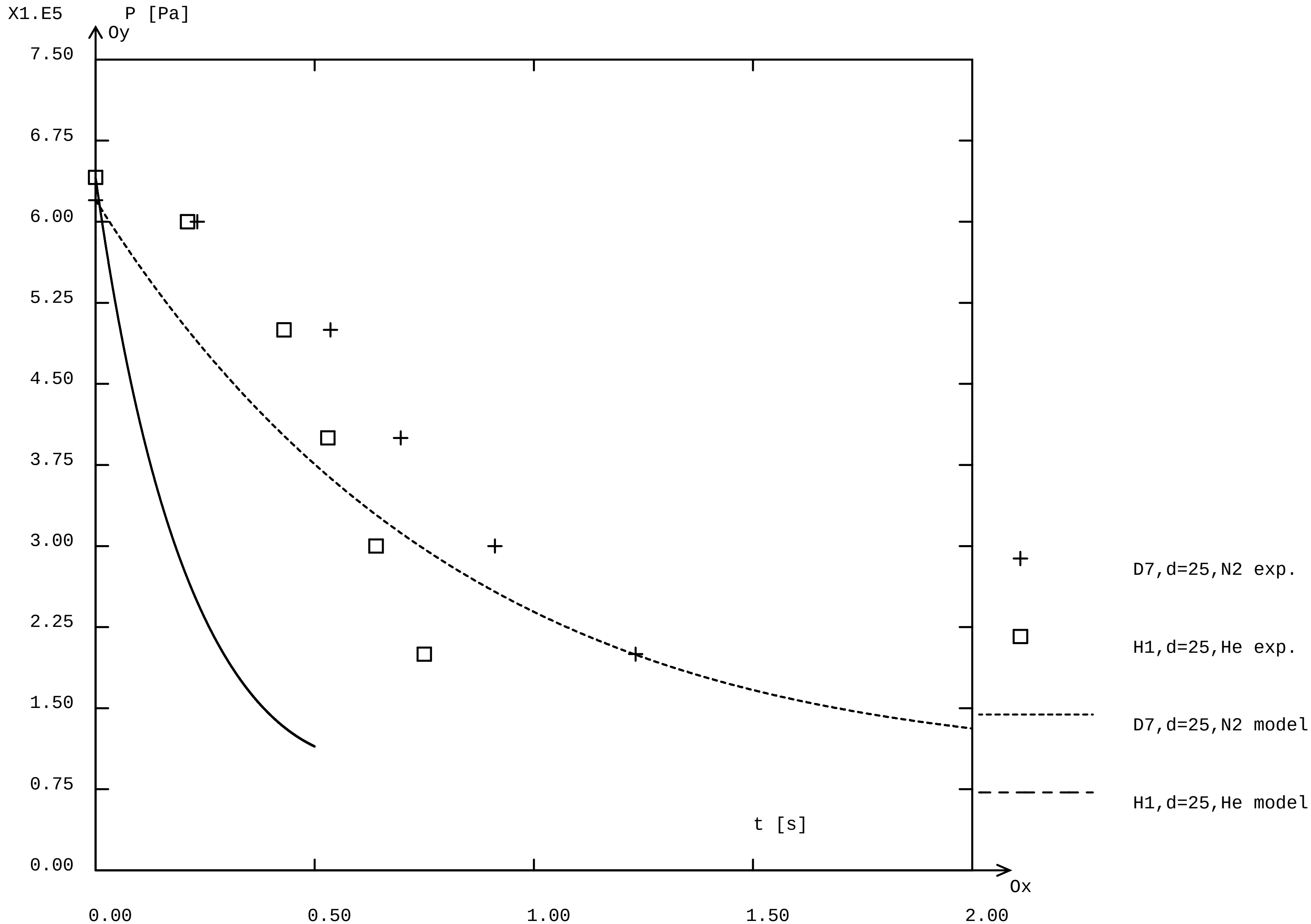

Disco experiment − RPV pressure histories for different gas

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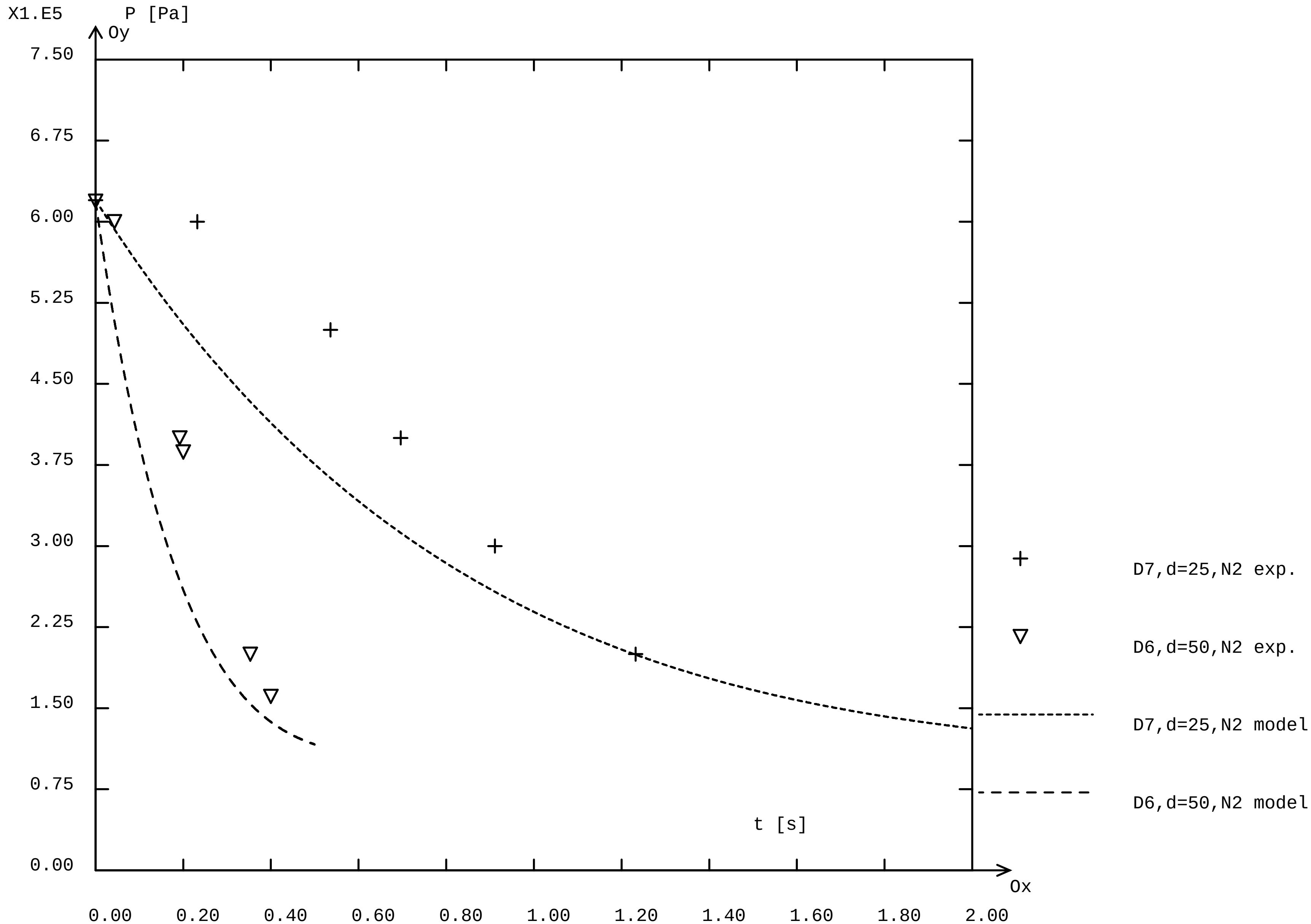

Disco experiment – RPV pressure histories for different hole sizes

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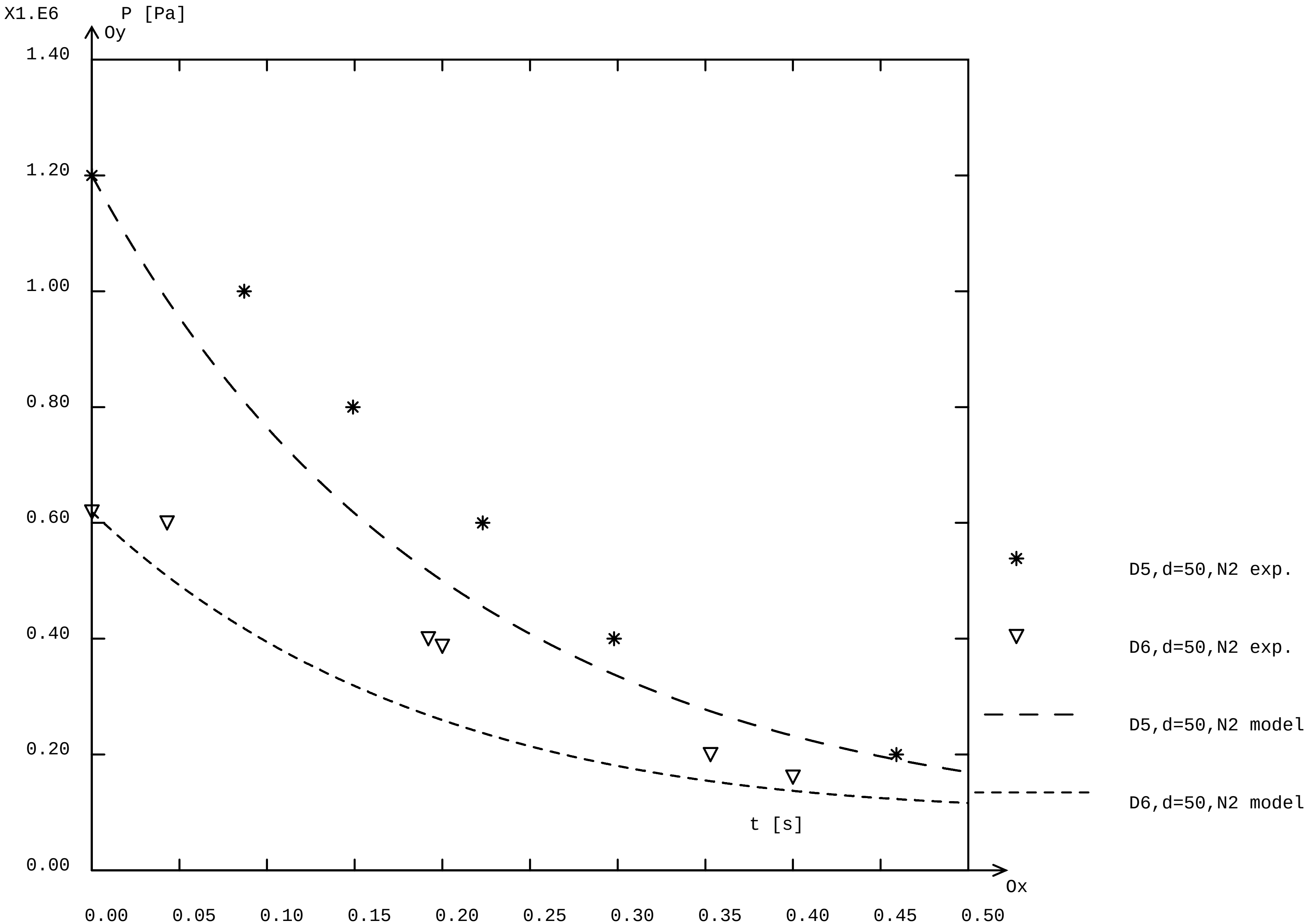

Disco experiment- RPV pressure histories for different initial pressure

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Conclusions

- Global validity of the modeling approach followed (inviscid compressible flow of perfect gases)
- Need to consider a two-phase flow model to correctly describe some aspects of the flow (blow down and annular space velocities behavior)
- Gas flow characterized by a fast transient at the beginning of the blow down followed by quasi-steady state (depressurization time constant much larger than the flow field time constant)
- Blow through time much more dependent on the failure size and on the gas specie than on the initial pressure drop.
- Gas velocities at the RPV failure supersonic over a large time interval no matter the considered case.
- Gas flow in the cavity essentially confined in a thin layer parallel to the cavity floor. A recirculation observed but with a limited velocity level.

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