Luca Bottura
The NET Team

"Validation Results for 3-D Quench Propagation"

Validation of the 3-D quench propagation code SARUMAN

L. Bottura

&

Superconducting Magnets Group
of
ENEA C.R.E.-Frascati

Which code ?

SARUMAN has:

- 3-D winding pack description

  ➡ 1-D f.e. solution of heat conduction along the conductor

  ➡ 2-D equivalent (thermal resistances) of heat conduction across the winding

- 1-D helium flow in equivalent channel

  ➡ 1-D f.e. solution of mass, momentum, energy balances

- Circuital Solution

  ➡ Coupled analysis of external coils and power supplies

- Hydraulic network

  ➡ Coupled analysis of external piping and pumps

Introduction

Why a 3-D quench program ?

What is a 3-D program ?

large magnets

large cooling lengths

long times required for the longitudinal propagation

effect of transverse conduction becomes important

☞ 3-D code is taking into account the transverse conduction

⇨ comparable V_{long}/V_{trans} ratio

☞ 3-D code is relevant for large magnets (e.g. fusion applications)

☞ 3-D code can be necessary for safety analysis studies

Introduction

Why coupled circuit and hydraulic networks?

coil systems

inductive coupling

common manifolding

operating current and field evolution

boundary p and T evolution

☞ coupled code is modifying operating and boundary conditions according to the environment changes

⇨ coil systems

☞ 3-D code is relevant in the analysis of quench evolution and safety for large magnets and magnetic systems

Introduction

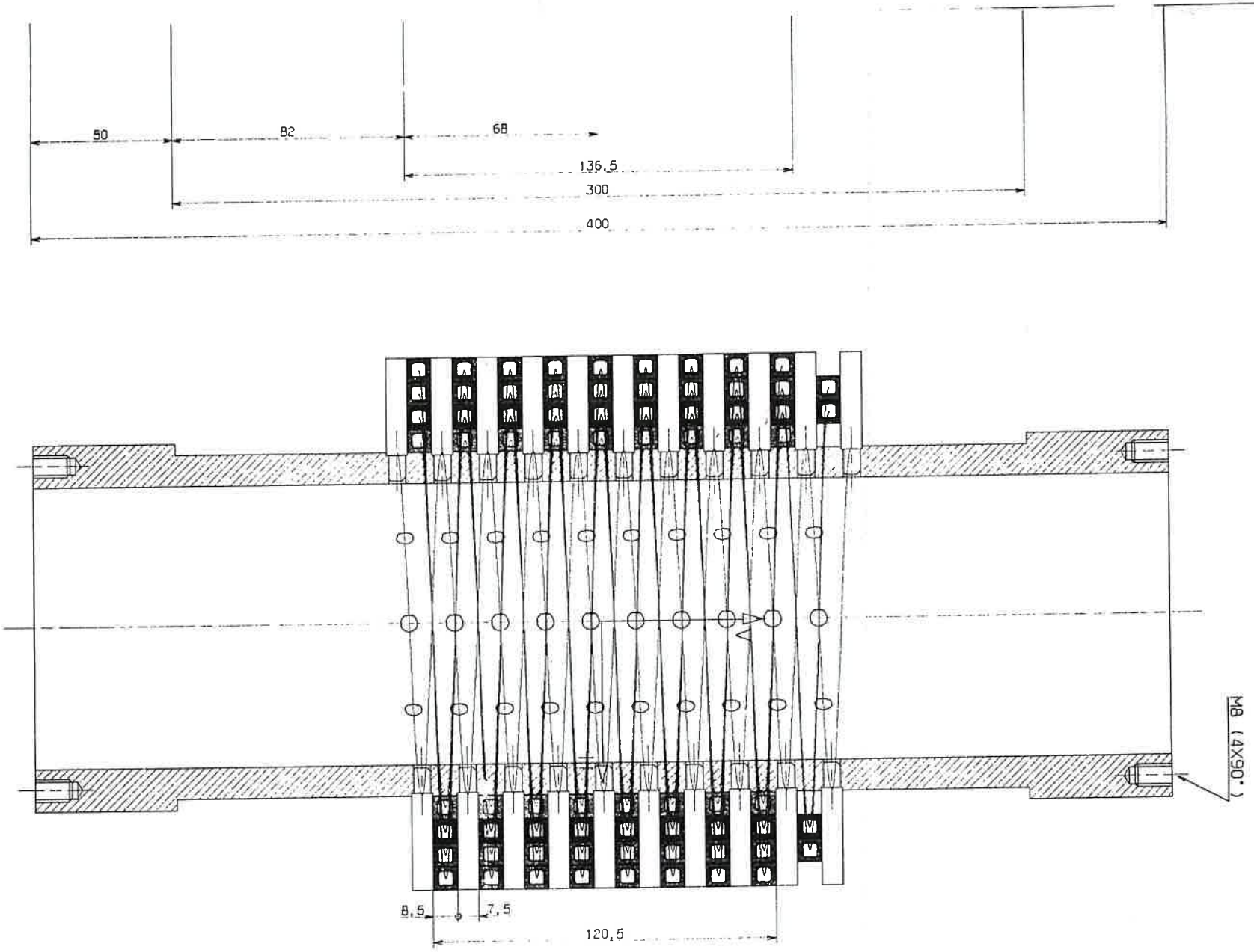
Fine, we have the 3-D code. And now ?

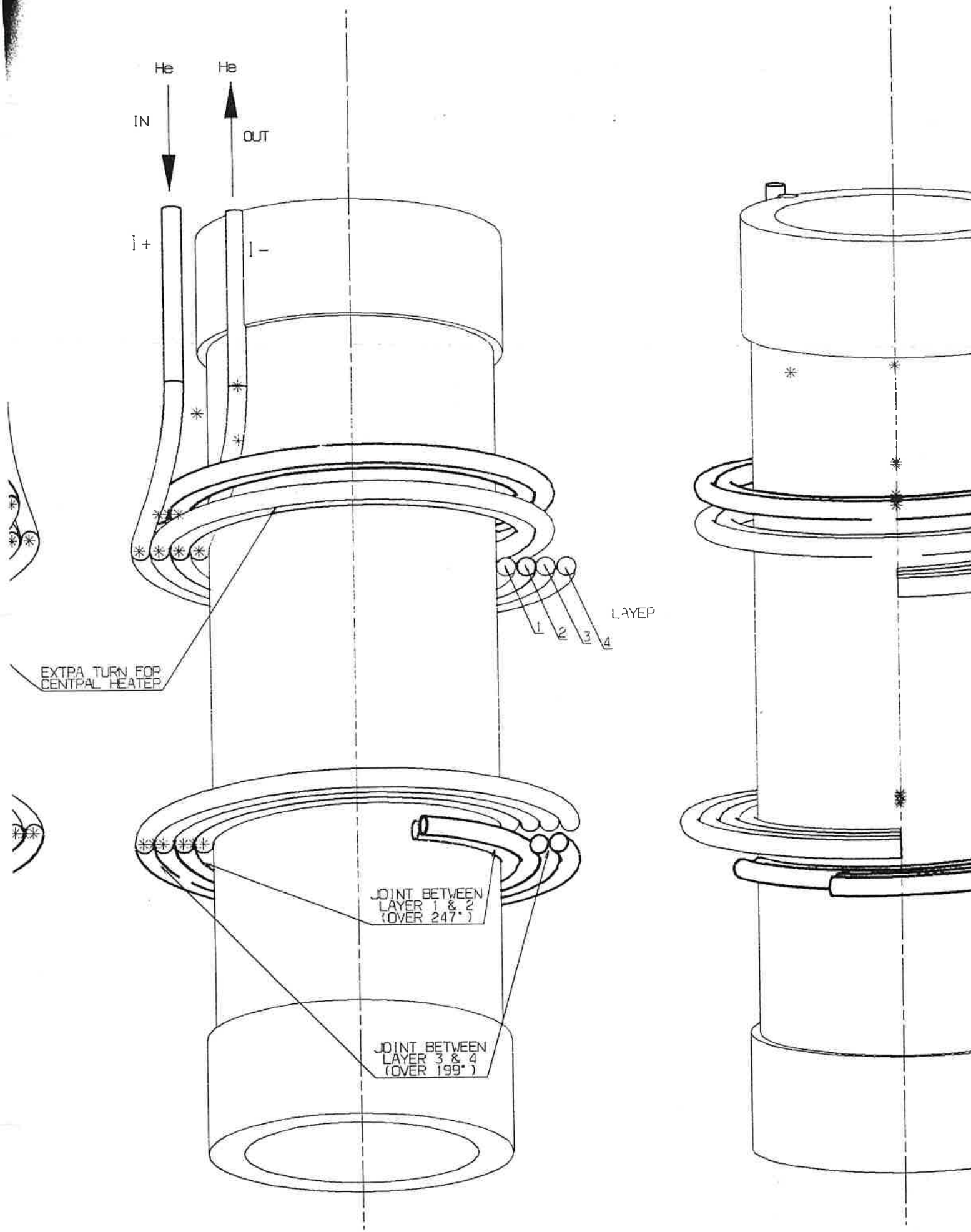
Option 1 How much do you believe it ?
issues of reliability, performance, safety factors,...

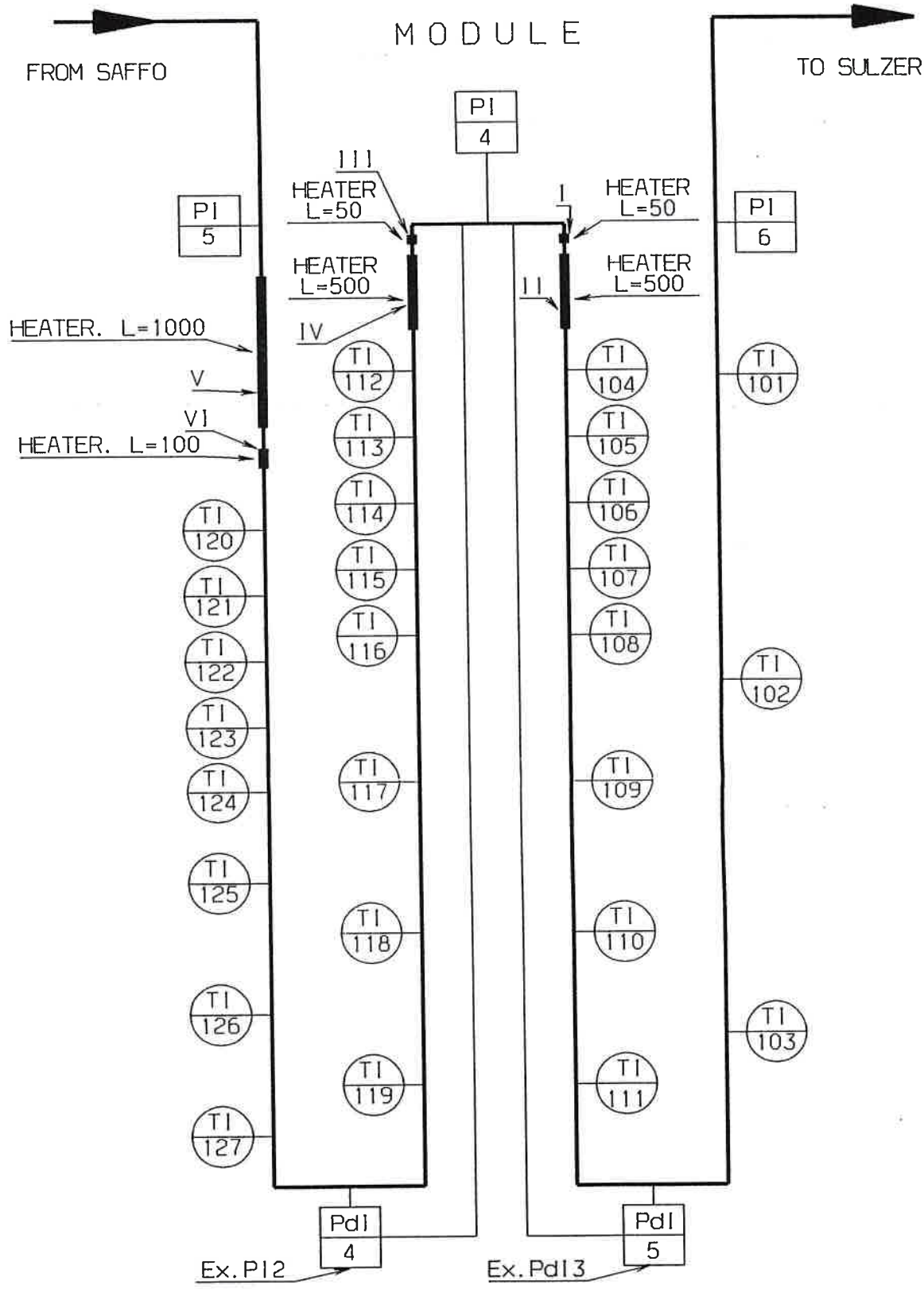
- Validation Studies
- Code Improvements

Option 2 I need something to justify my salary and invitations to workshops
fun, honor & glory

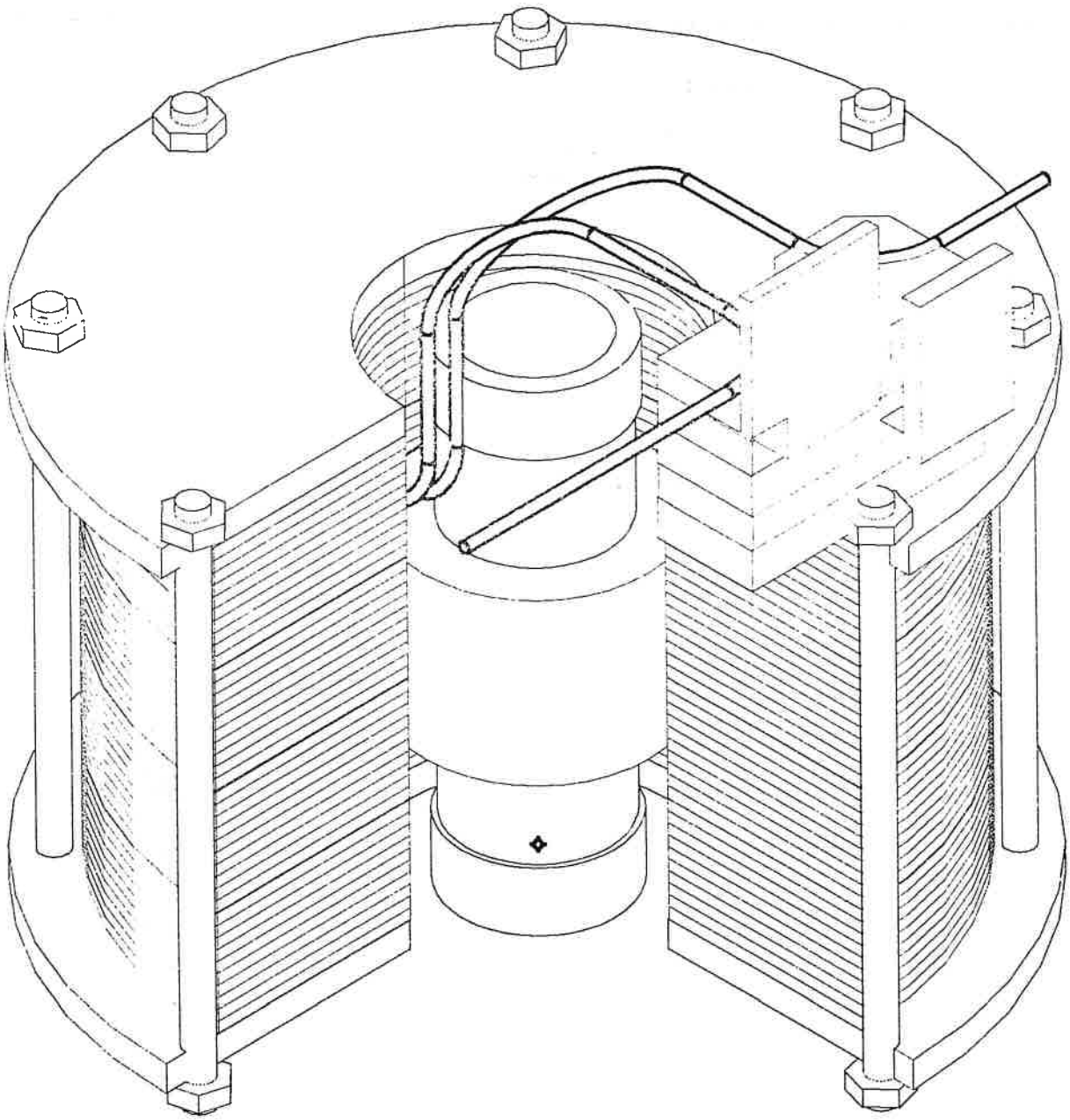
- Validation Studies
- Code Improvements

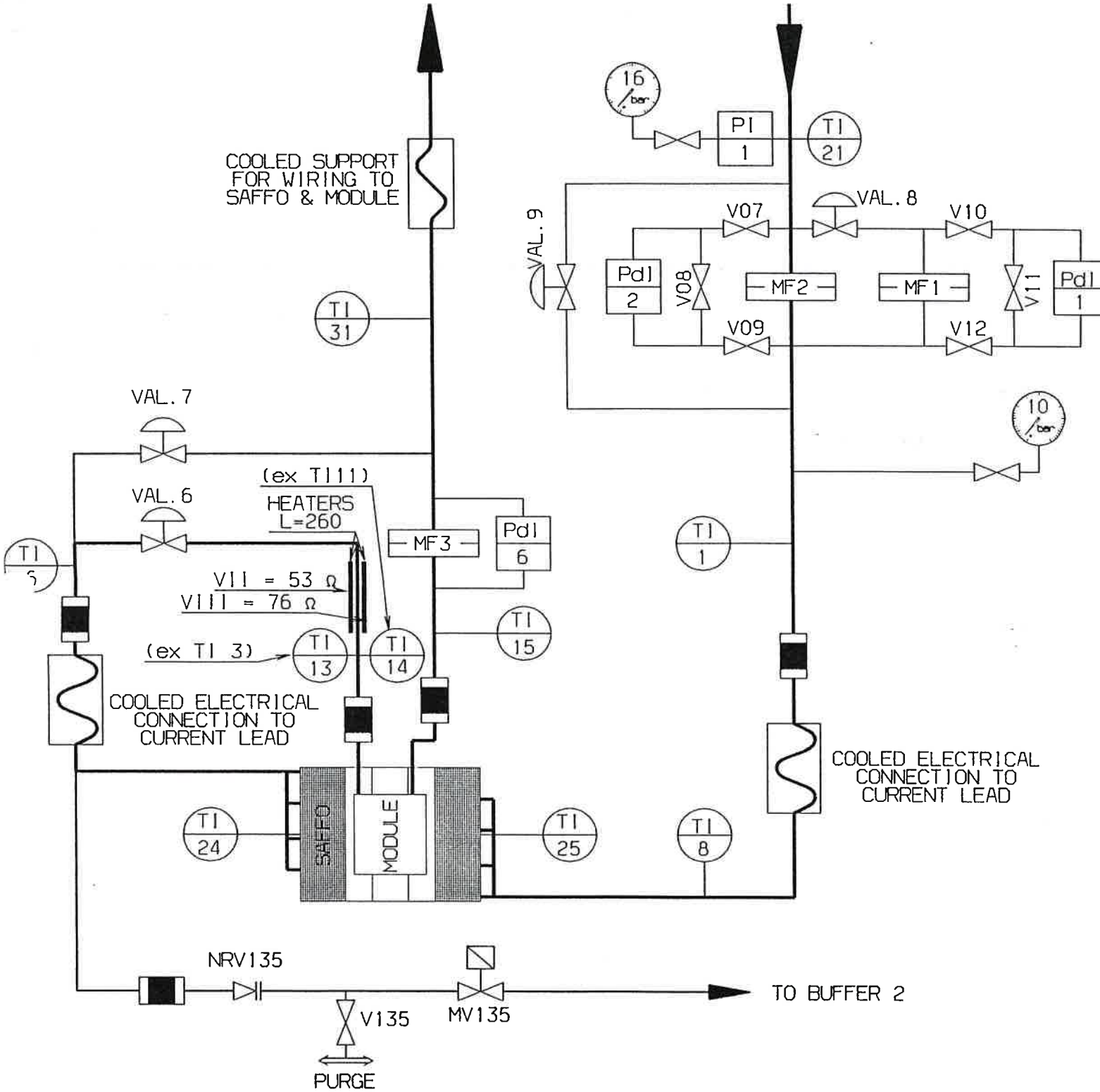

50
82
68
136,5
300
400
8,5
7,5
120,5
M8 (4X90°)

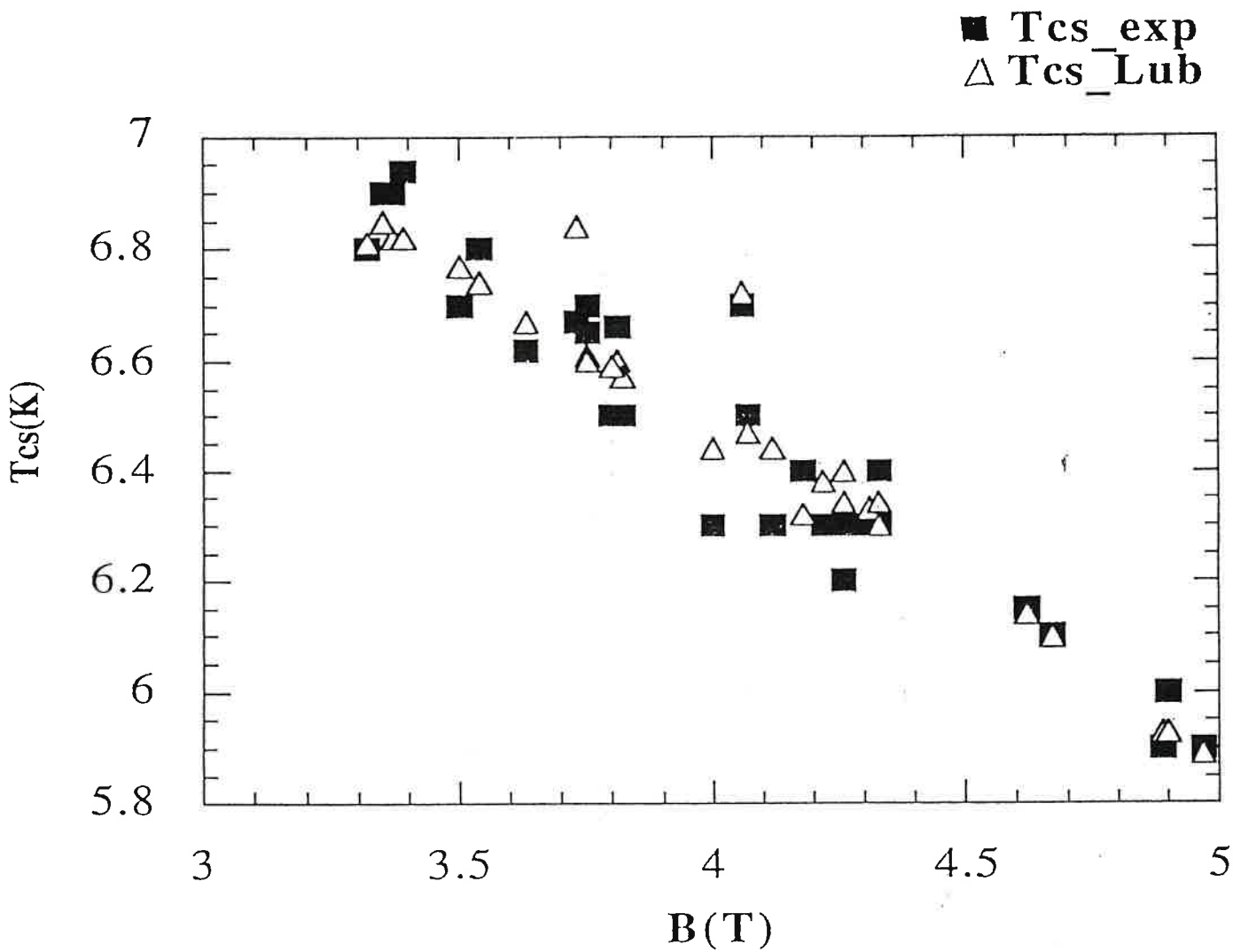

He
He
IN
OUT
I +
I −
LAYEP
1
2
3
4
EXTPA TURN FOP
CENTPAL HEATEP
JOINT BETWEEN
LAYER 1 & 2
(OVER 247°)
JOINT BETWEEN
LAYER 3 & 4
(OVER 199°)

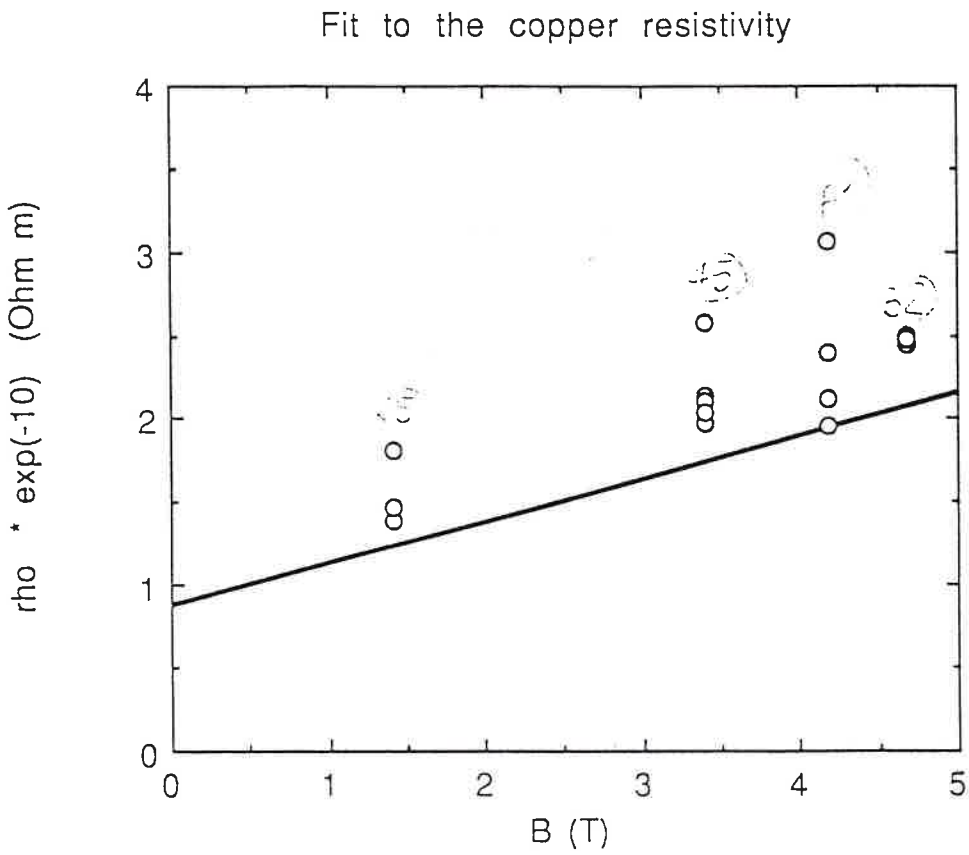


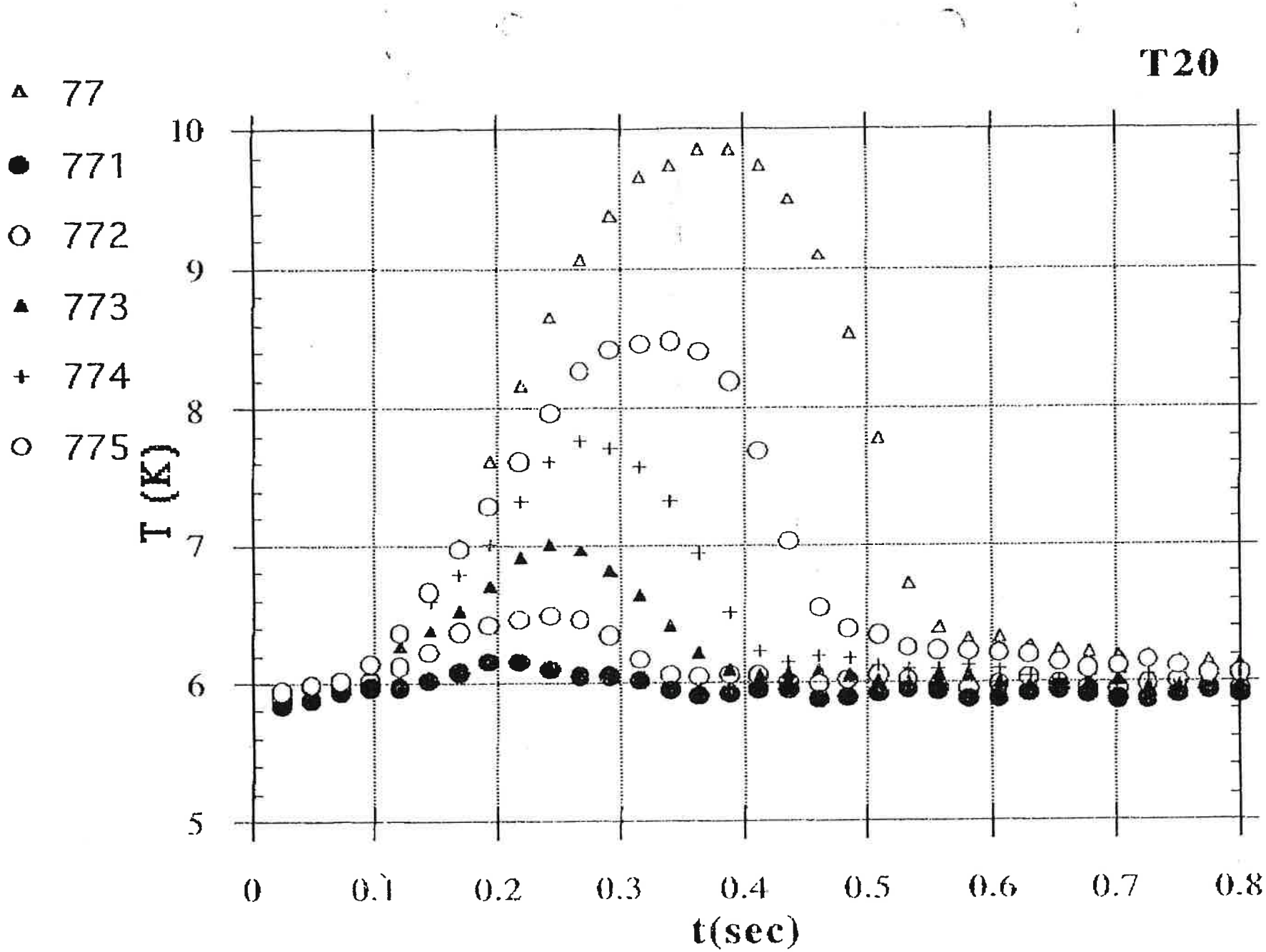
POS.	N PEZZI	DENOMINAZIONE E DIMENSIONI	MATERIALE	PIFEPIM. DISEGNO	NOTE
ENEA		LABORATORIO SUPERCONDUTTIVITA'-CRE FRASCATI		Via E.Fermi N 27	
MODIF.	INDICE / DATA / FIRMA	HYDRAULIC FLOWS SCHEME & LOCATION OF SENSORS IN SAFFO & MODULE			
TPATTAM. SUPEPFICIALI	TRATTAM. TERMICI				
	TOLL. GEN.	SCALA	DATA	SOSTITUISCE	DISEGNO N
		DIS.	PROG.	SOSTITUITO	

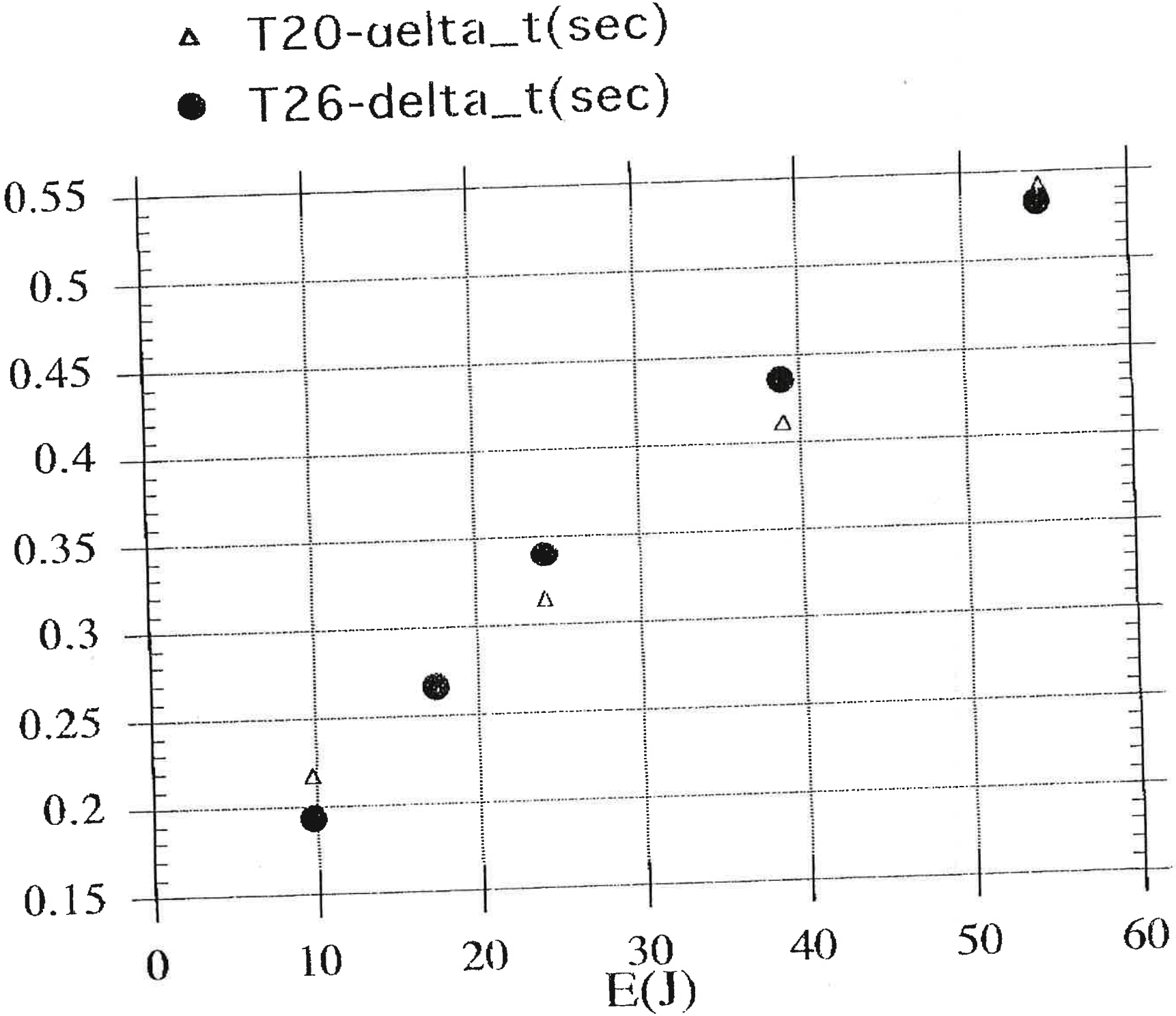



COOLED SUPPORT FOR WIRING TO SAFFO & MODULE
16 bar
PI 1
TI 21
VAL. 9
V07
VAL. 8
V10
Pdl 2
V08
MF2
MF1
V11
Pdl 1
V09
V12
TI 31
VAL. 7
10 bar
(ex TI11)
HEATERS L=260
VAL. 6
MF3
Pdl 6
TI 1
TI 5
VII = 53 Ω
VIII = 76 Ω
TI 15
(ex TI 3)
TI 13
TI 14
COOLED ELECTRICAL CONNECTION TO CURRENT LEAD
COOLED ELECTRICAL CONNECTION TO CURRENT LEAD
SAFFO
MODULE
TI 24
TI 25
TI 8
NRV135
TO BUFFER 2
V135
MV135
PURGE

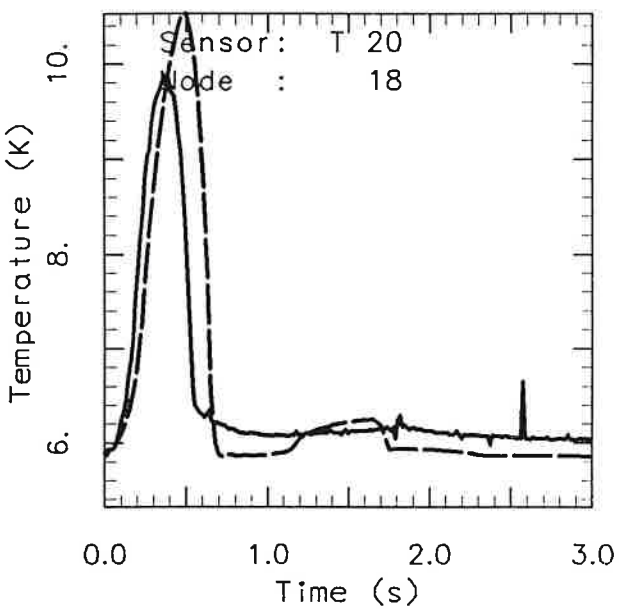

Tcs_exp
Tcs_Lub
7
6.8
6.6
6.4
6.2
6
5.8
Tcs(K)
3
3.5
4
4.5
5
B(T)

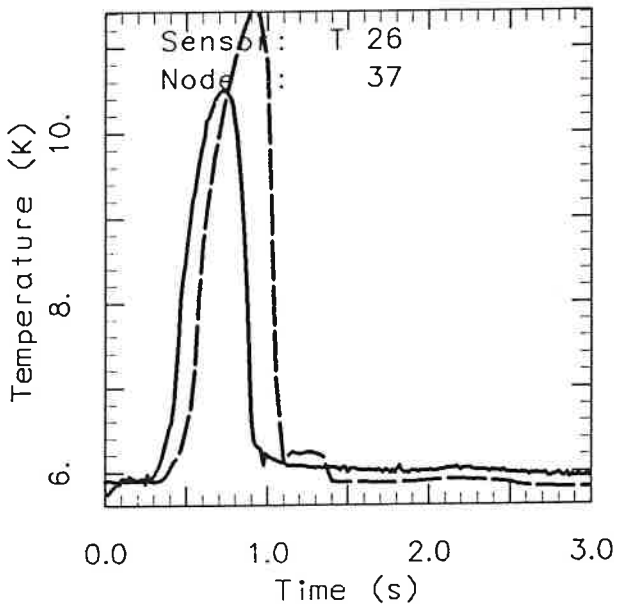

Fit to the copper resistivity
rho * exp(-10) (Ohm m)
B (T)
0
1
2
3
4
5

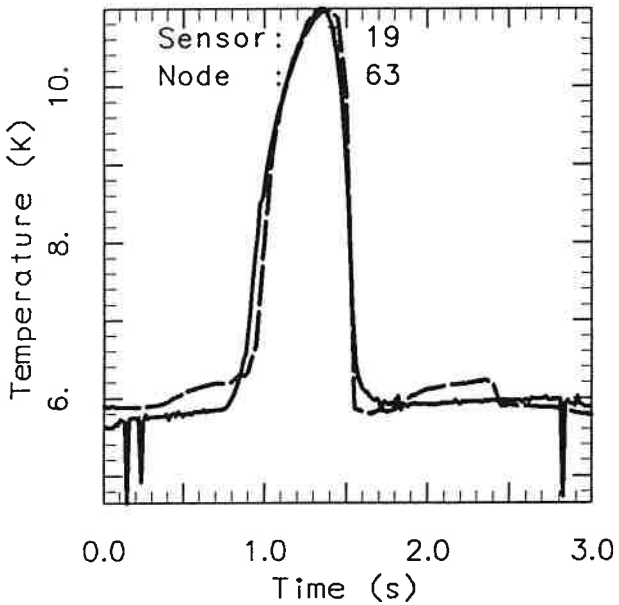

T20
77
771
772
773
774
775
10
9
8
7
6
5
T (K)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
t(sec)

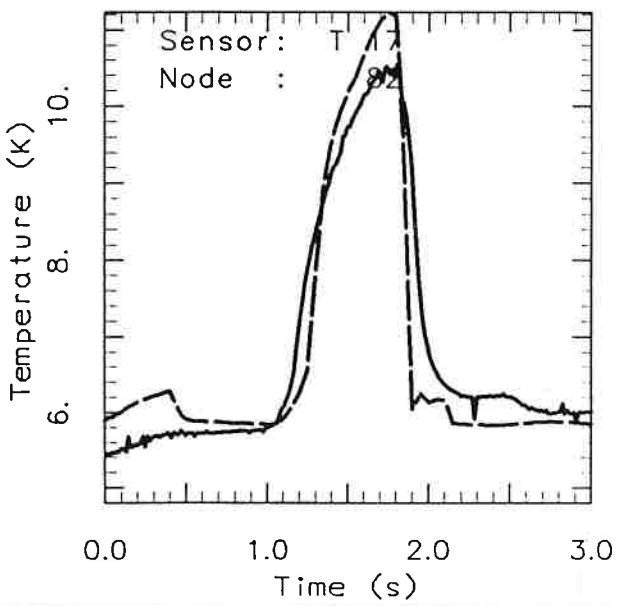


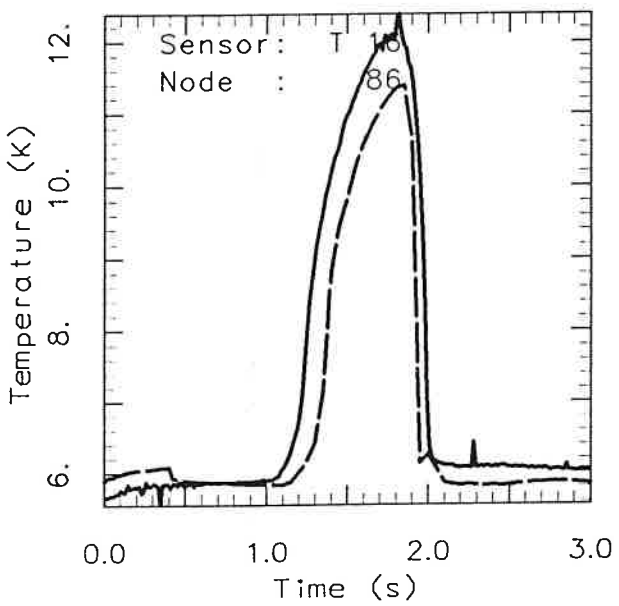
SIM # 77. t→in=0.20 mm. TSS 3 m→it. Min htc. eff pulse. rho=1.65

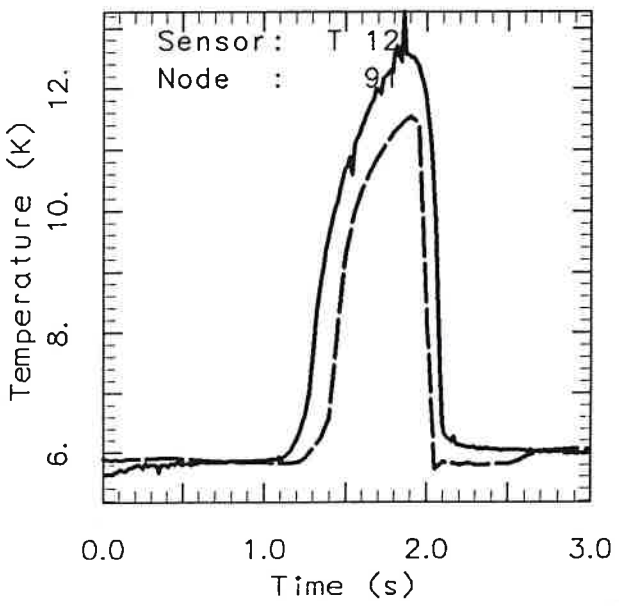












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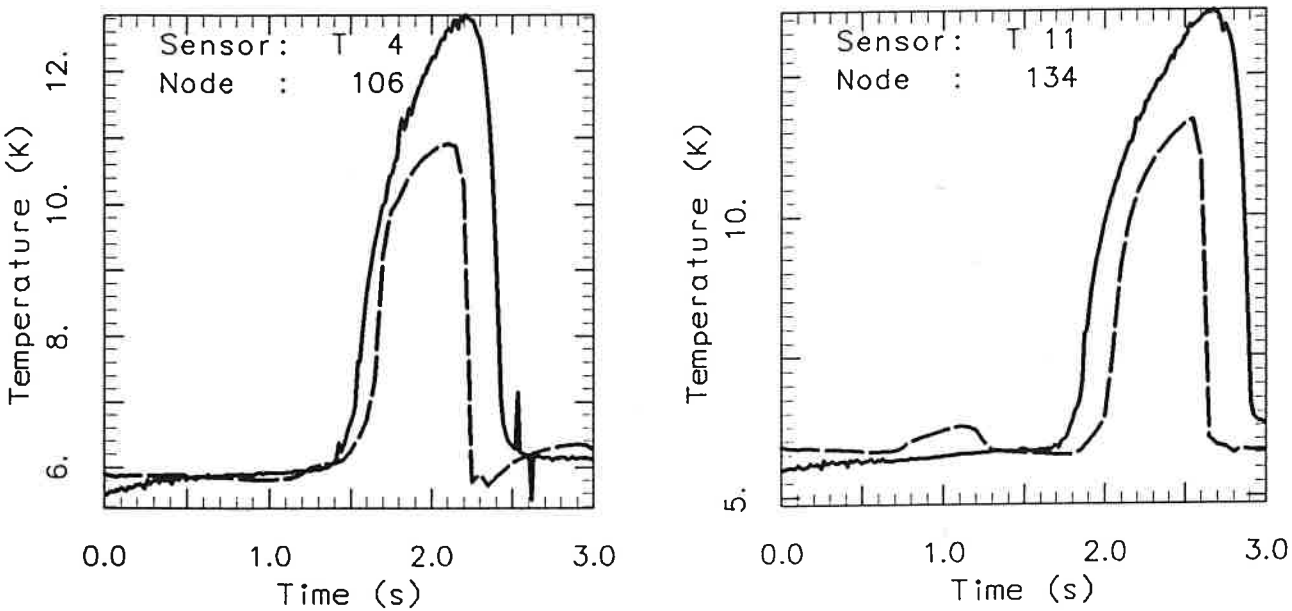

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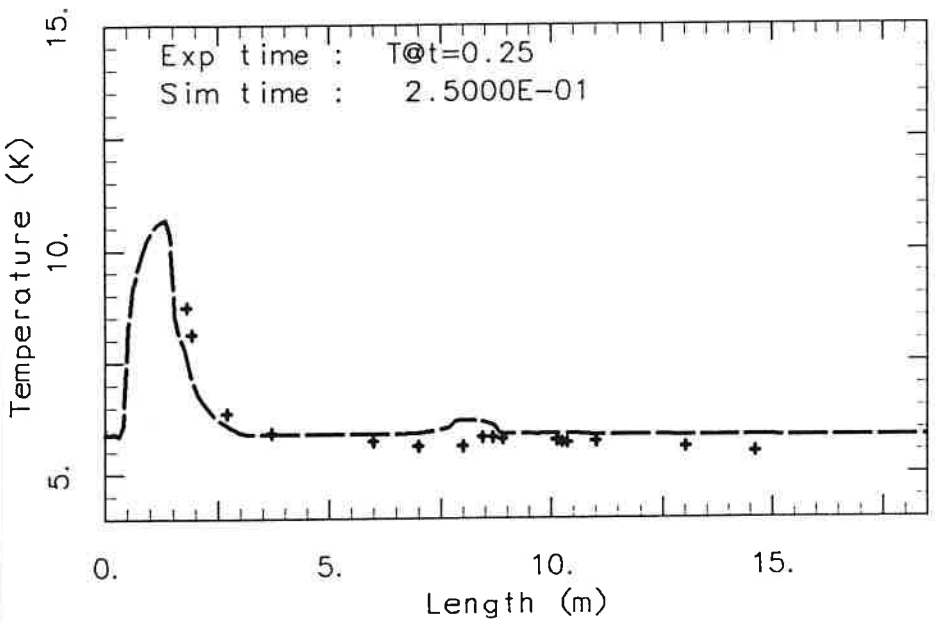

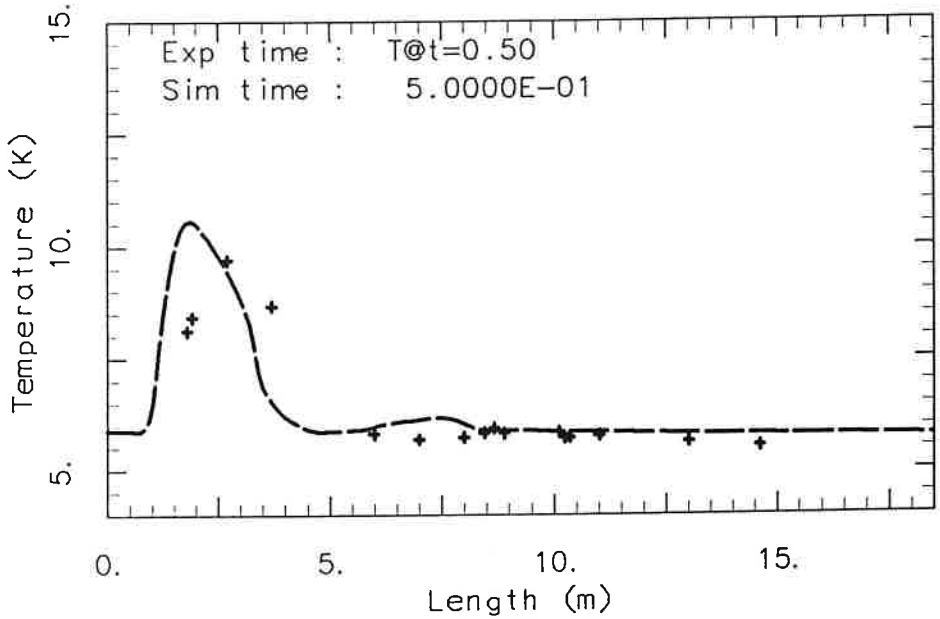

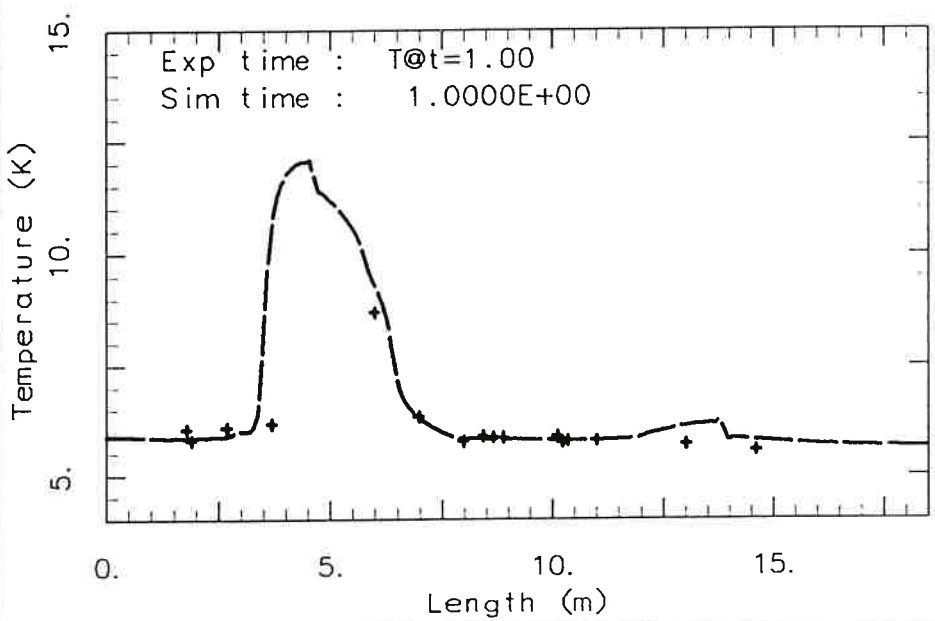

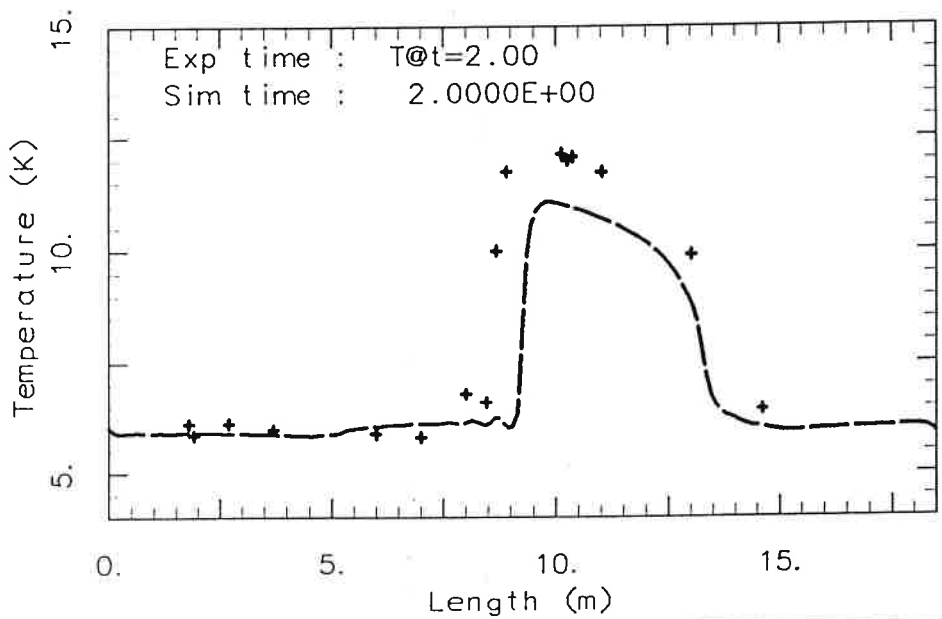

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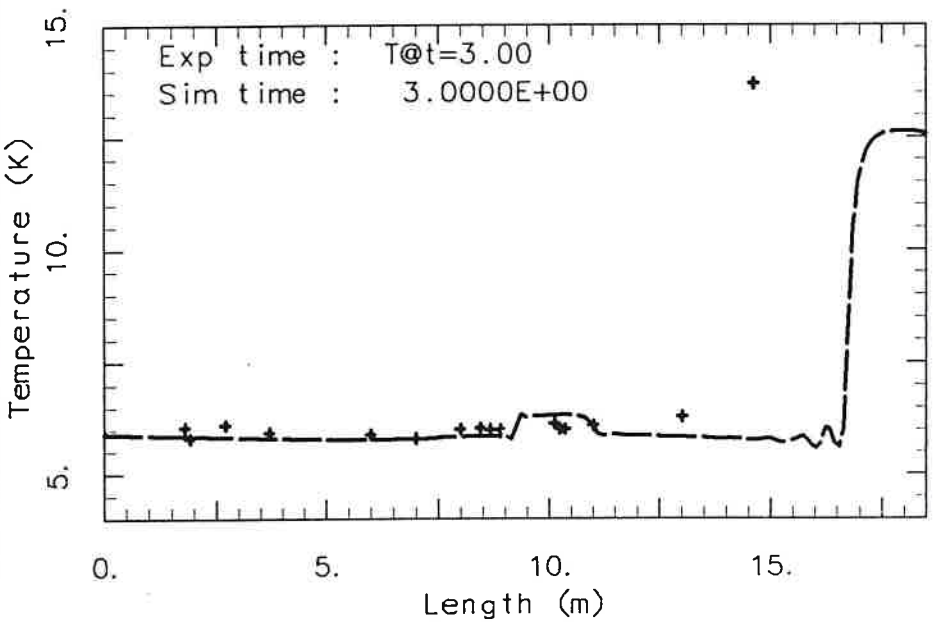

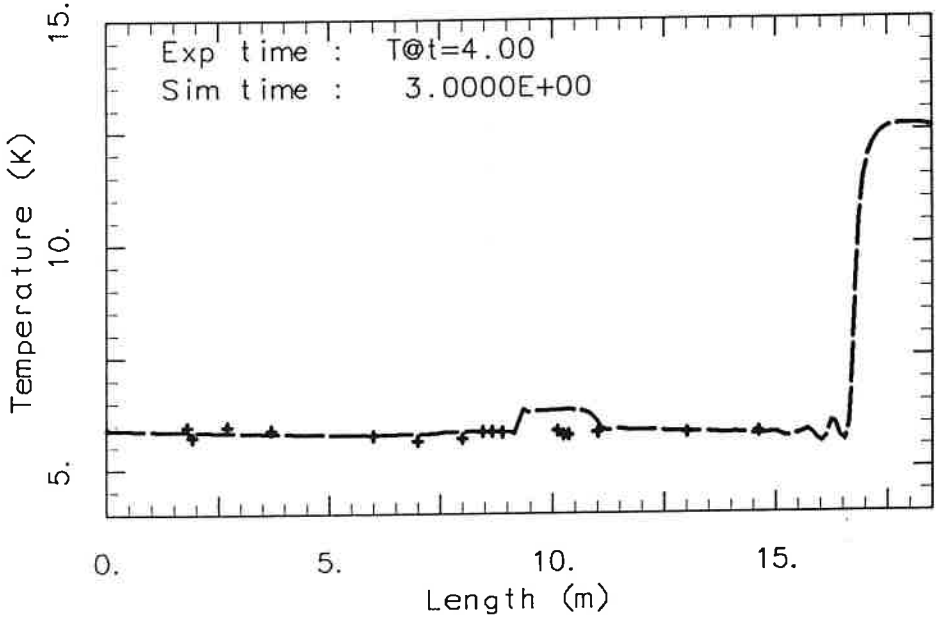

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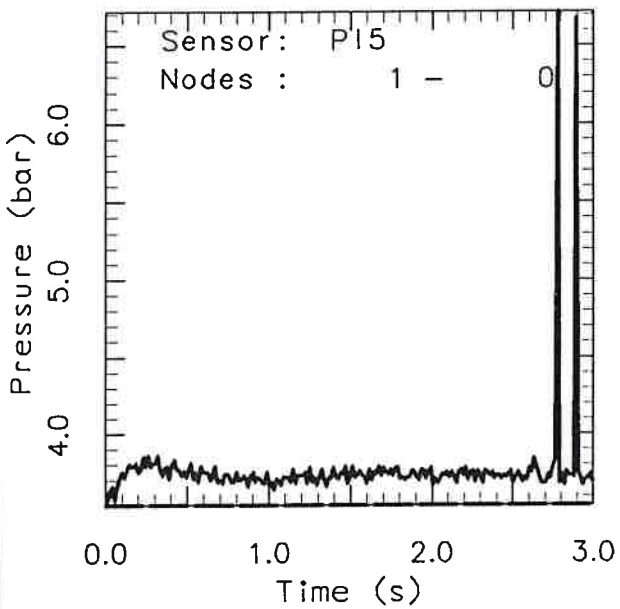

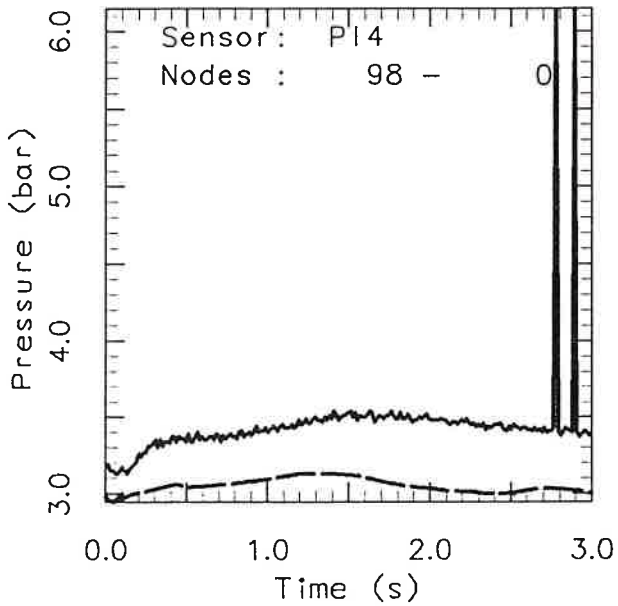

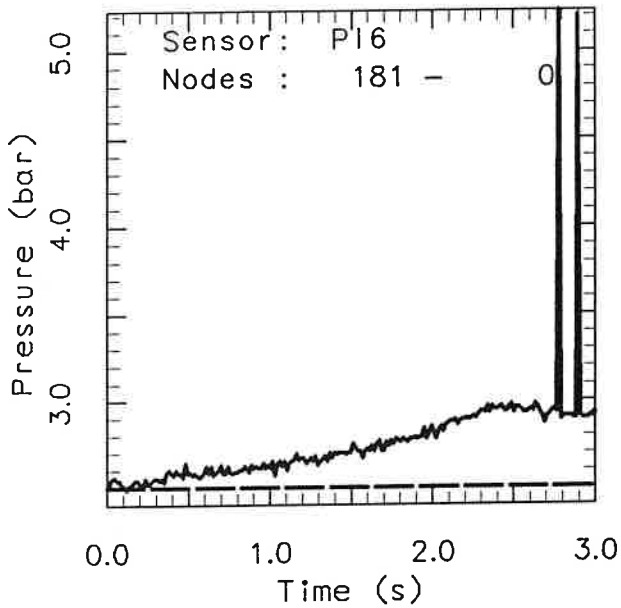

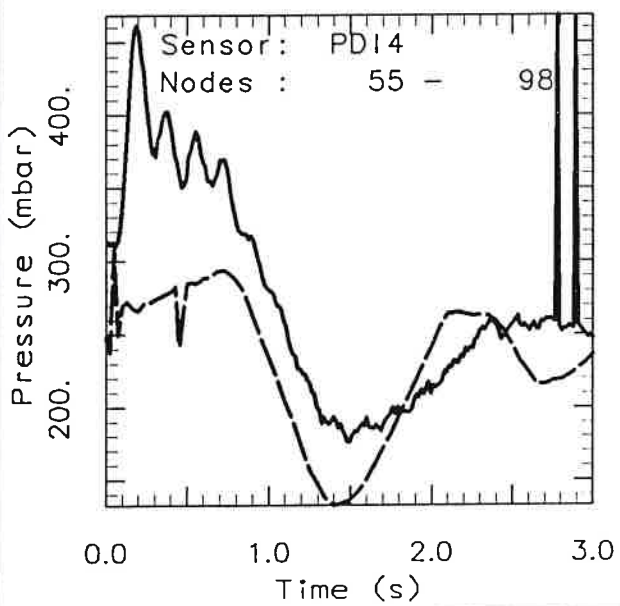

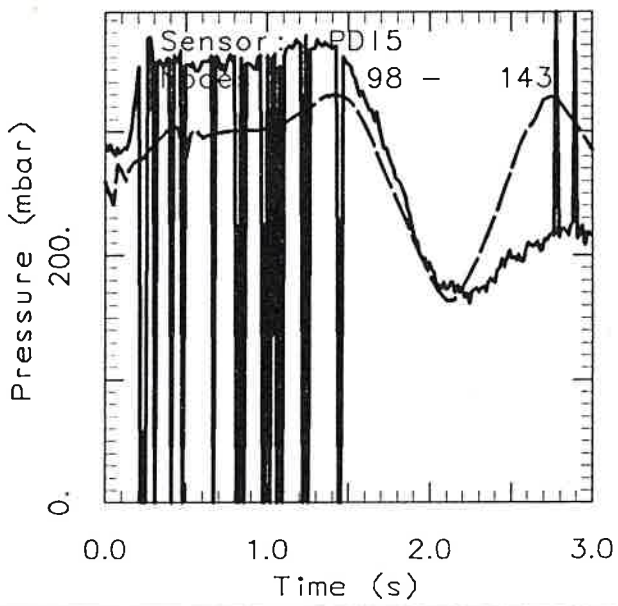

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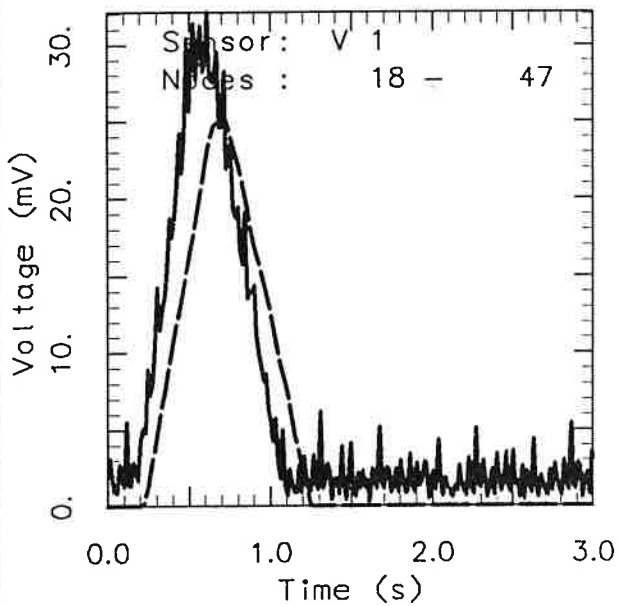
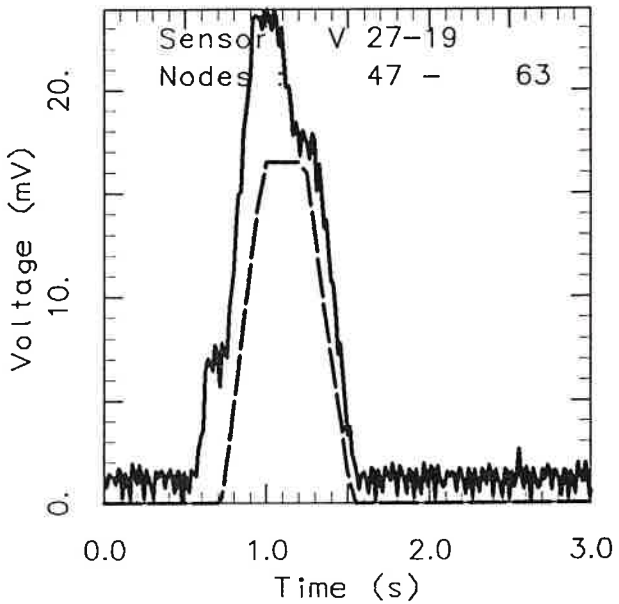
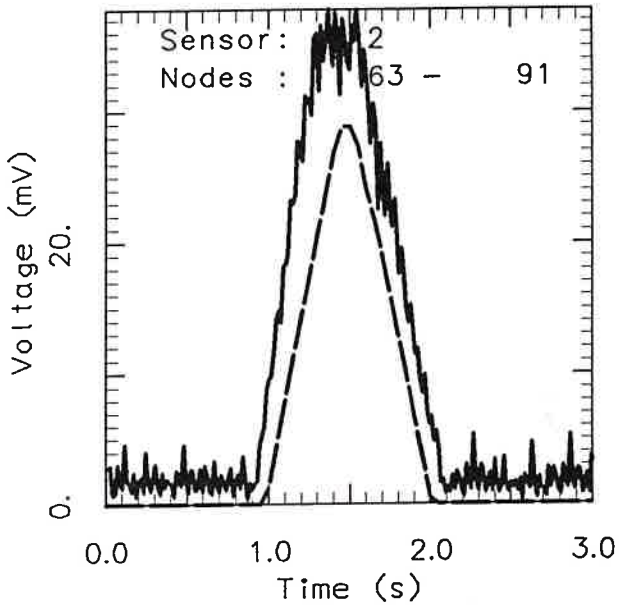
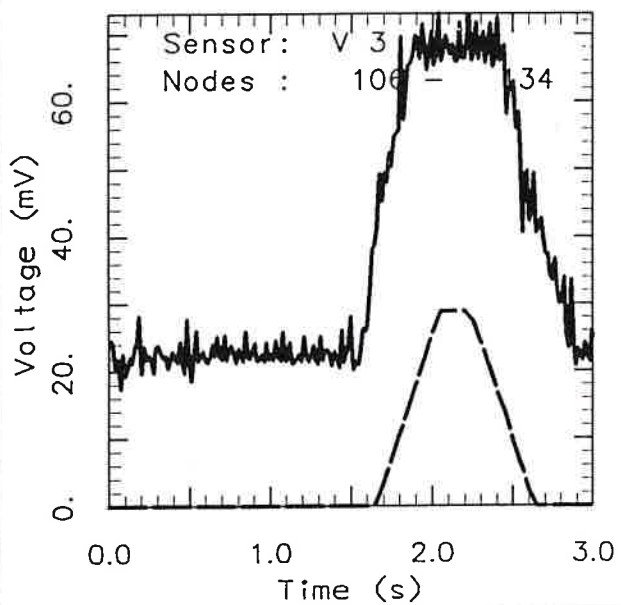
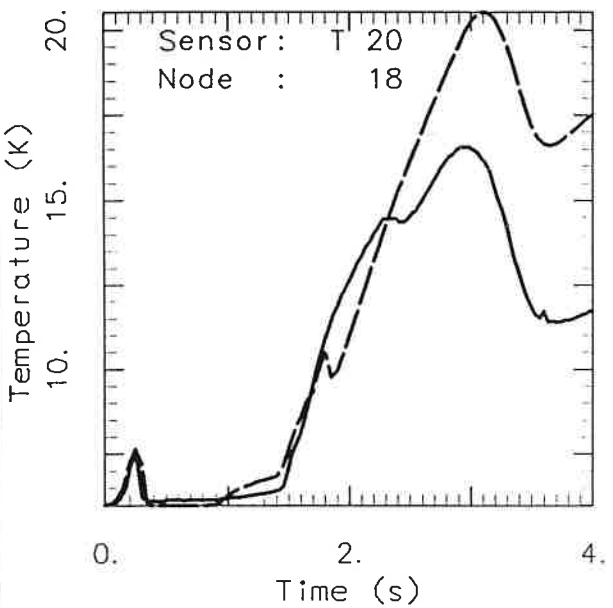


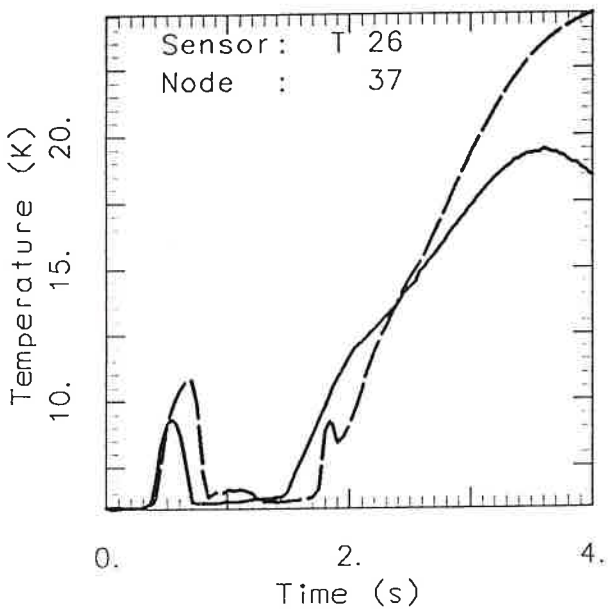


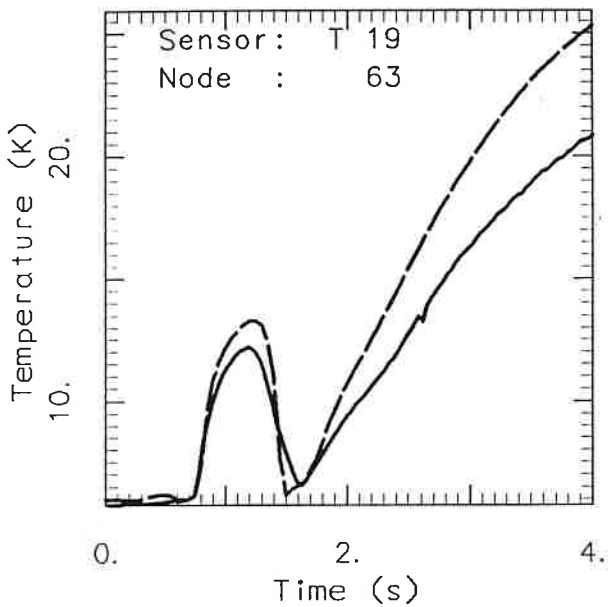


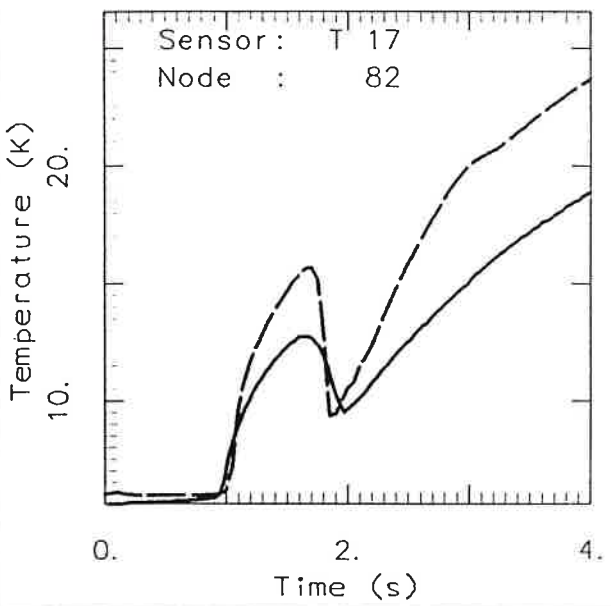


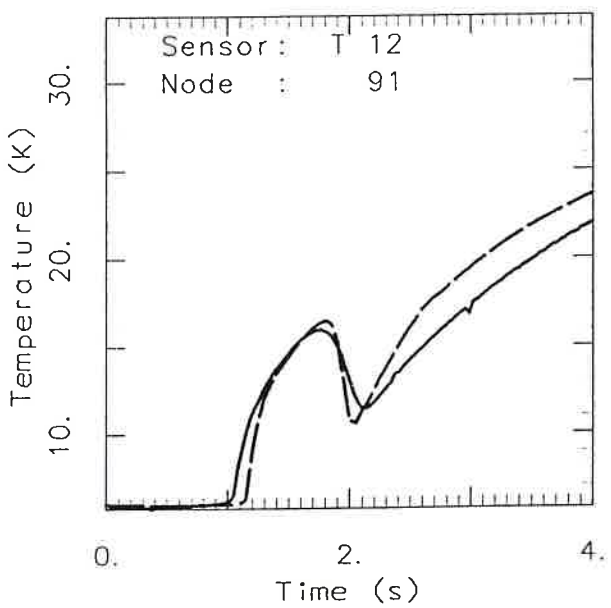
SIM # 48. 0.20 mm ins. TSS 3 mass it. min htc. 0.55*rho. no hyd net

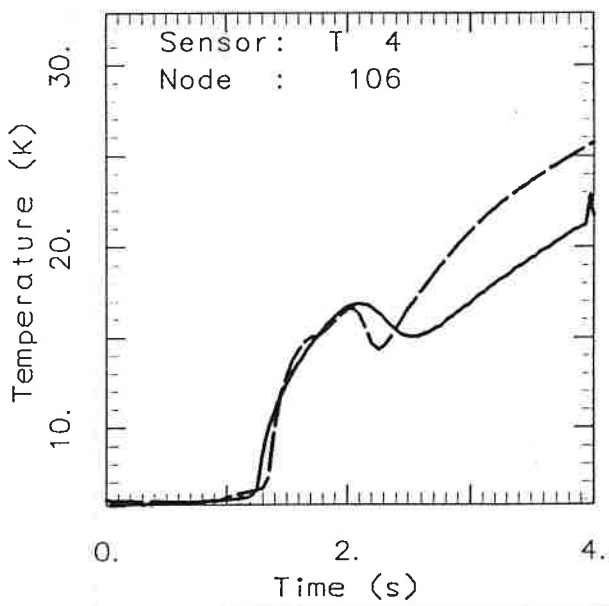












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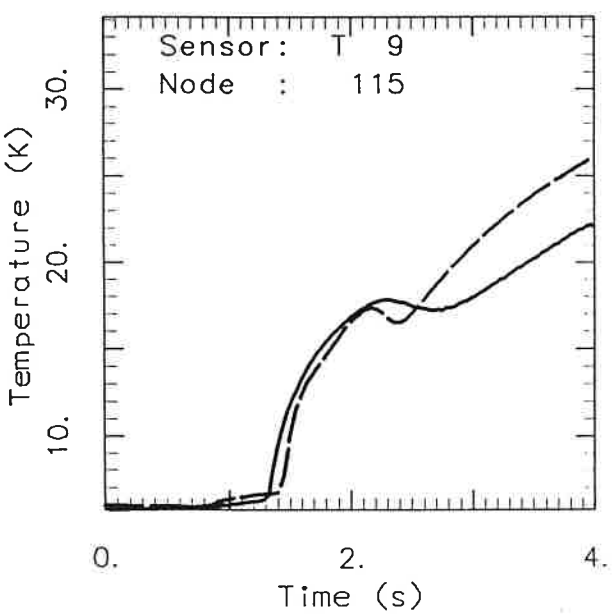

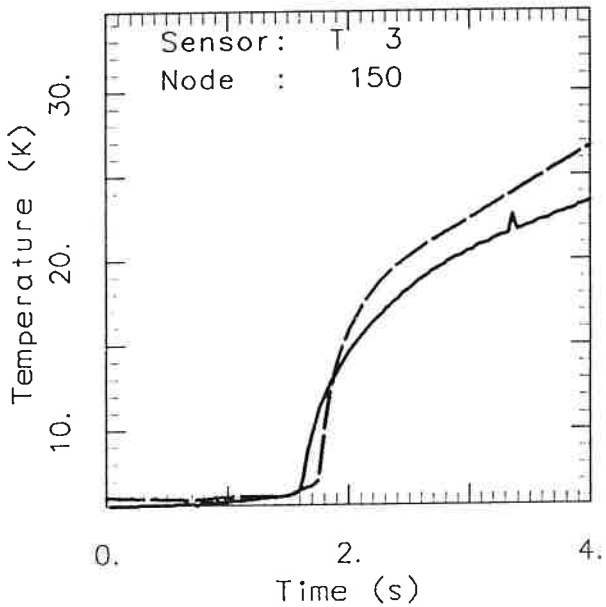

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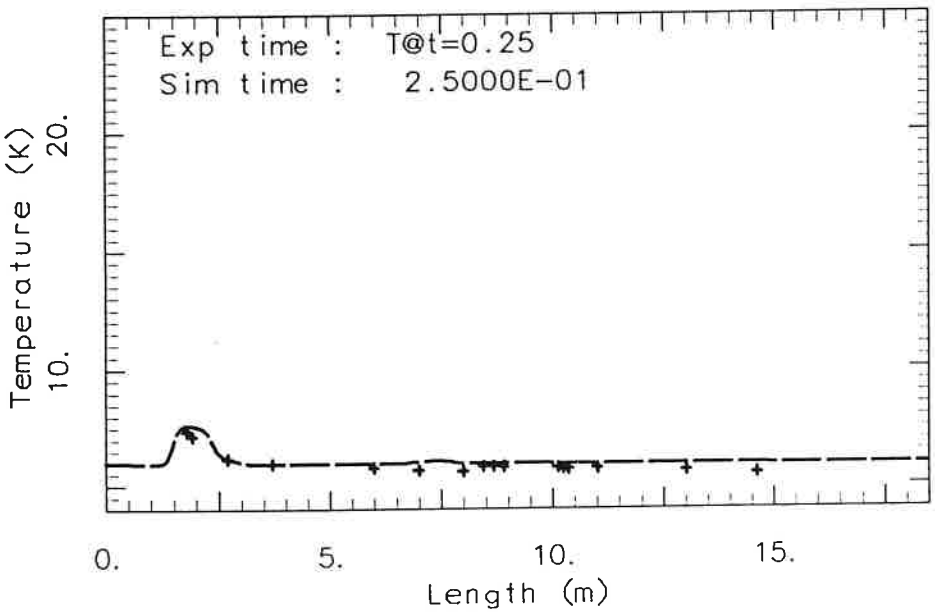

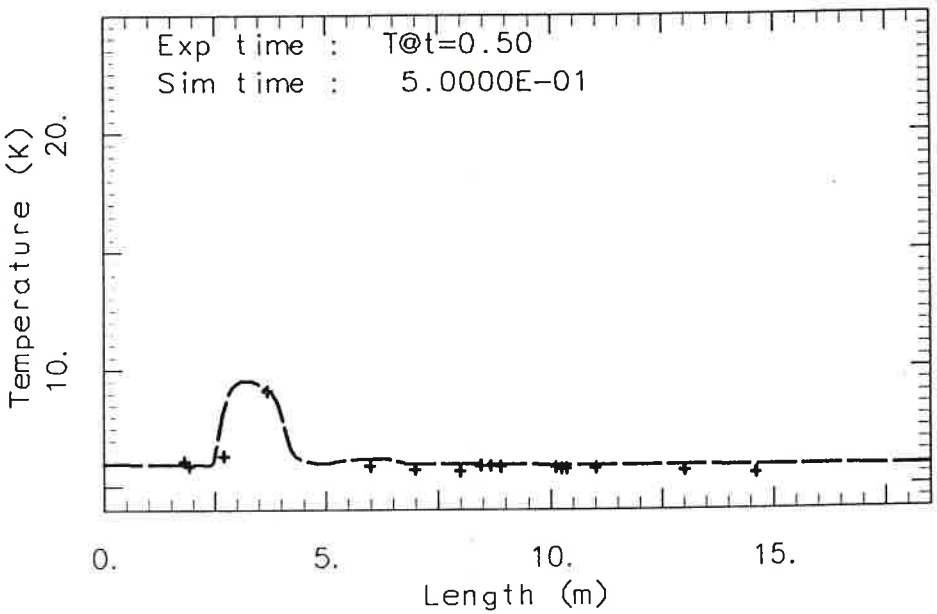

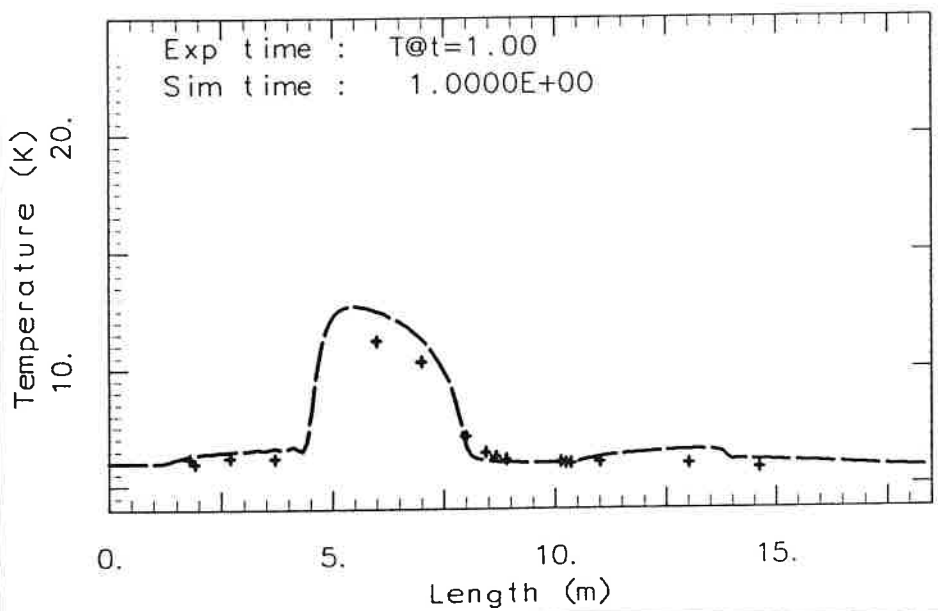

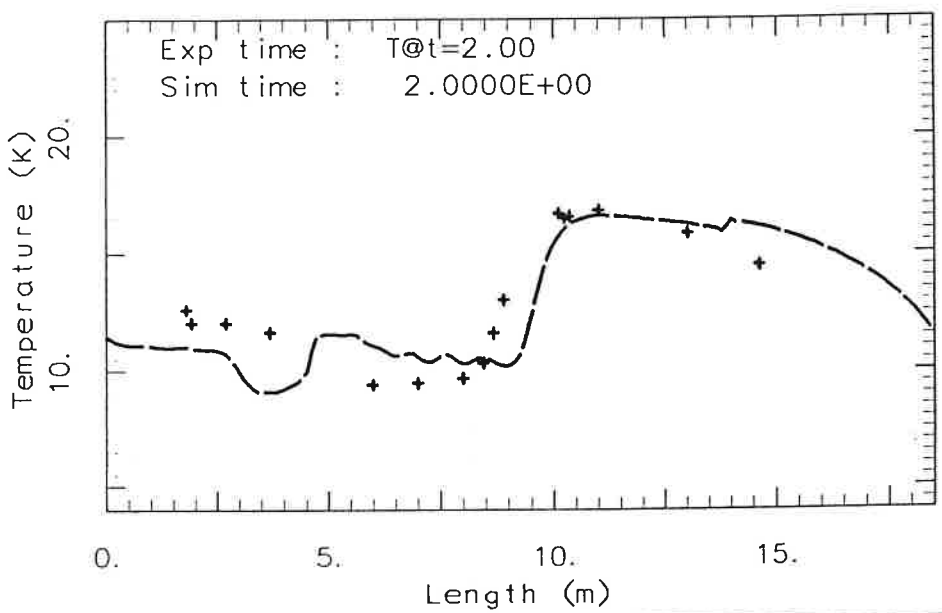

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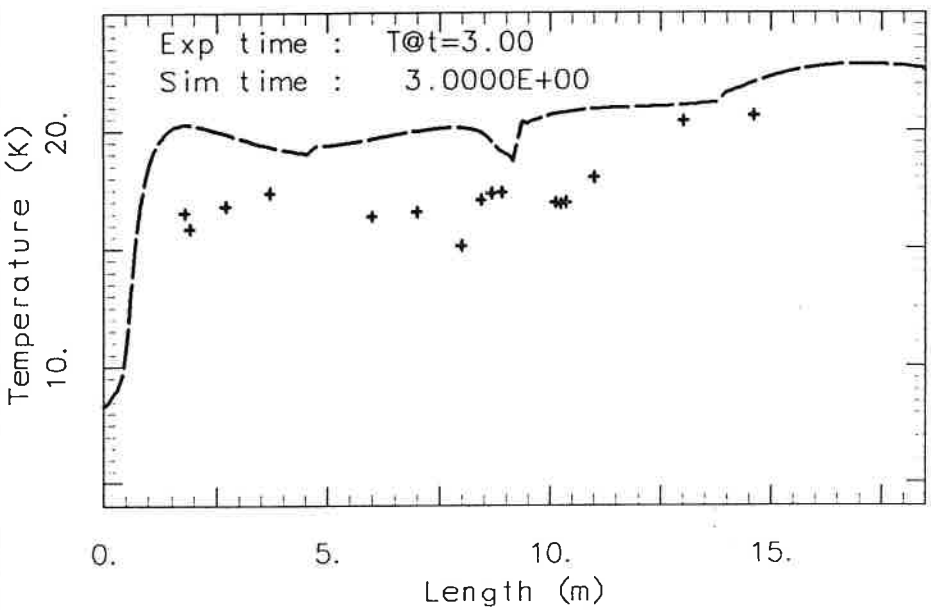

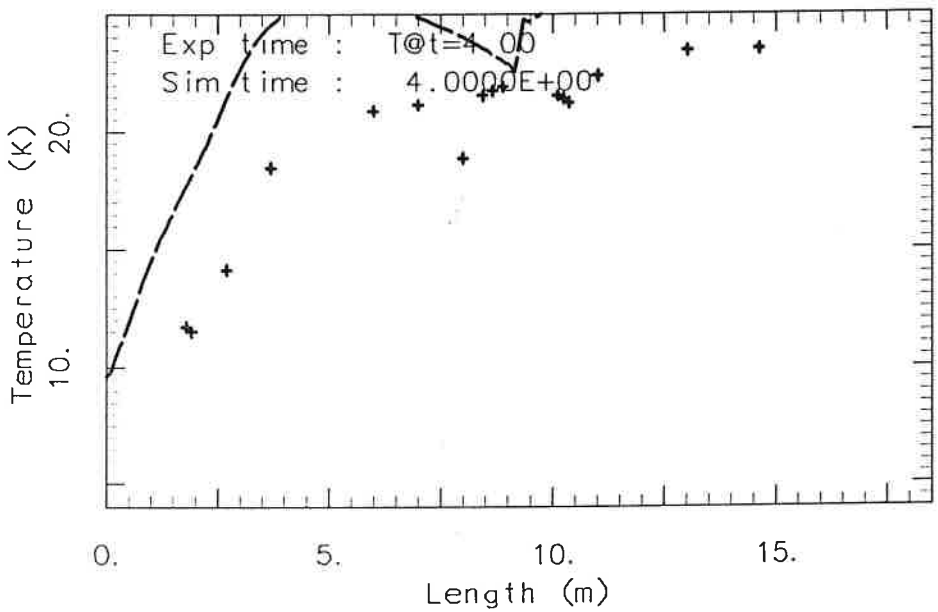

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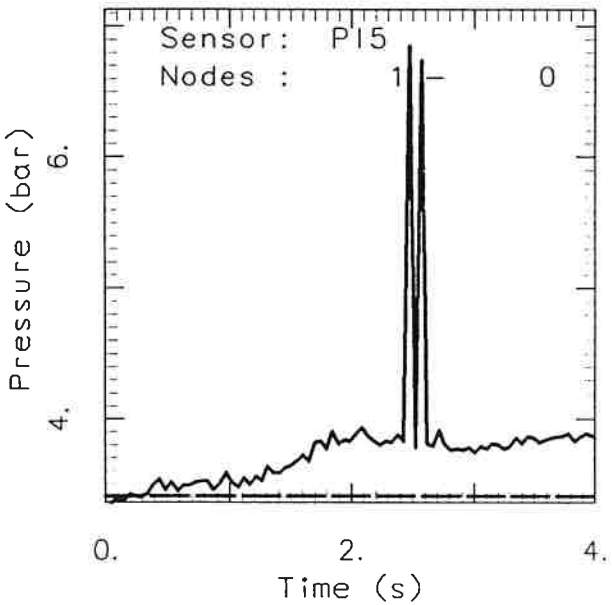

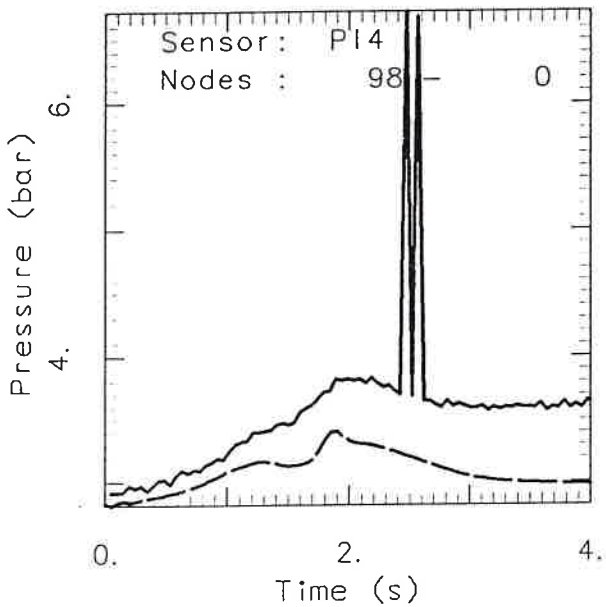

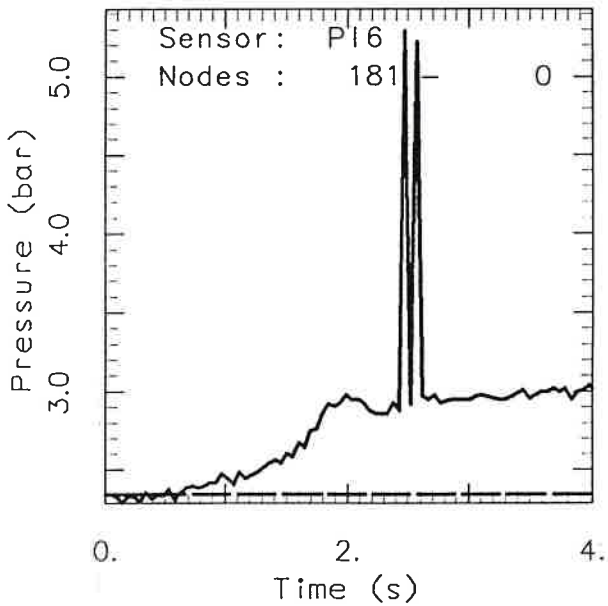

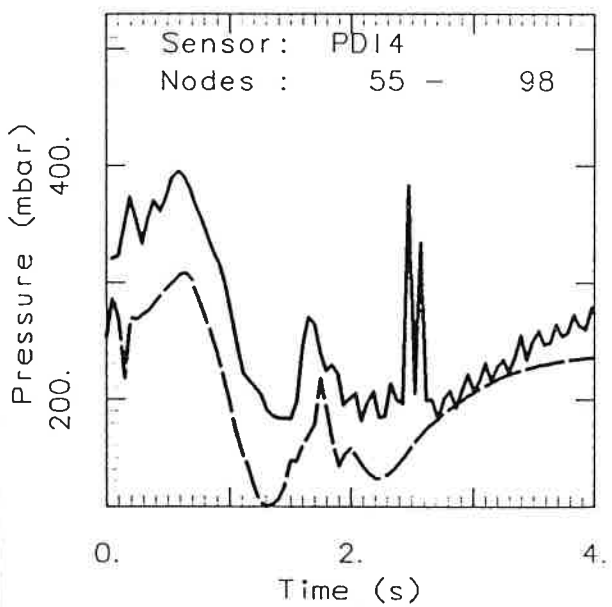

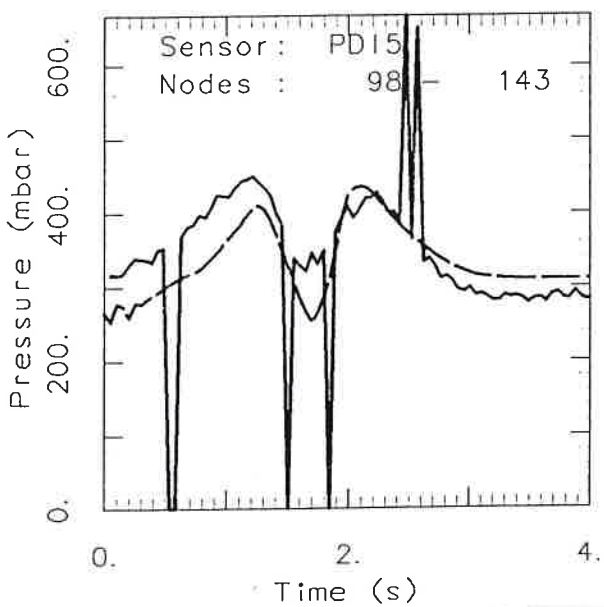

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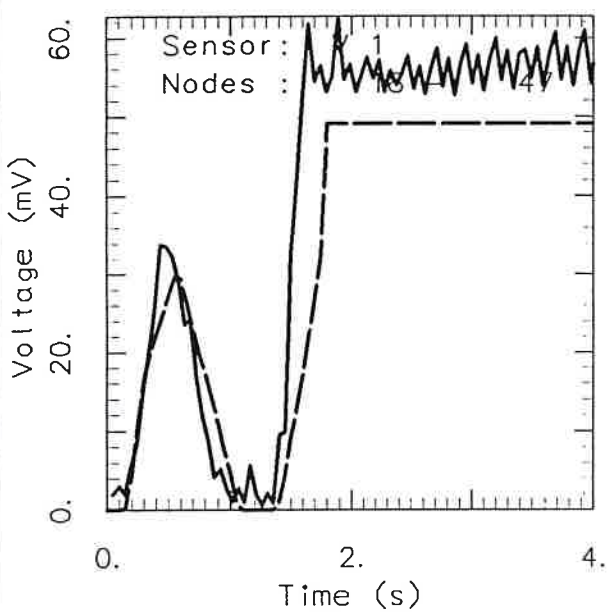
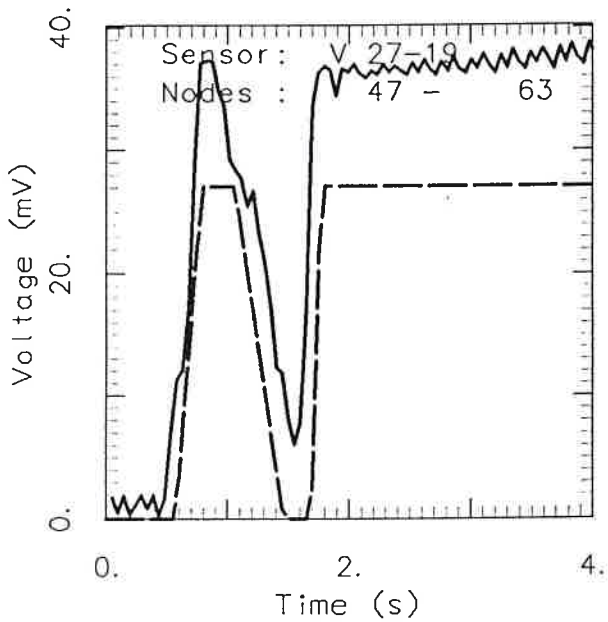
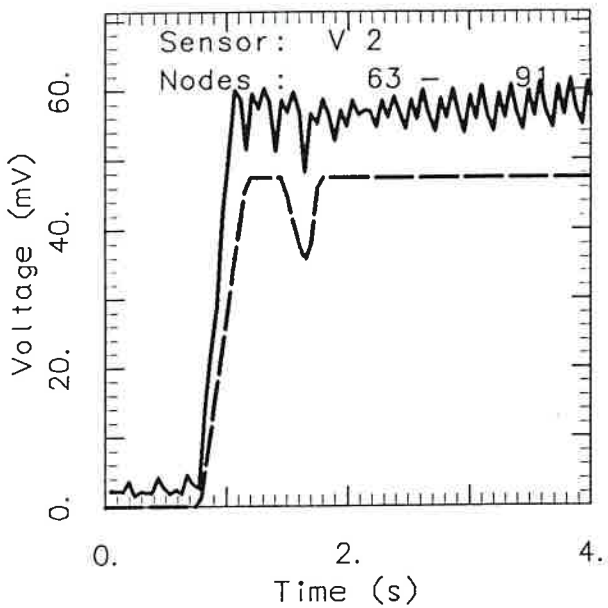
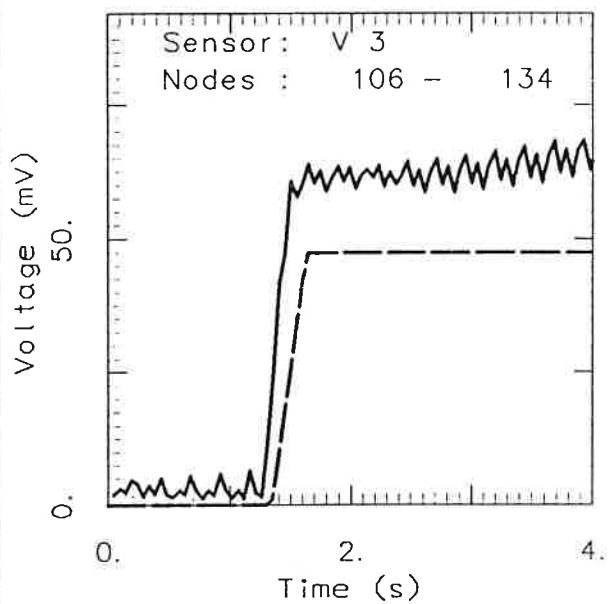
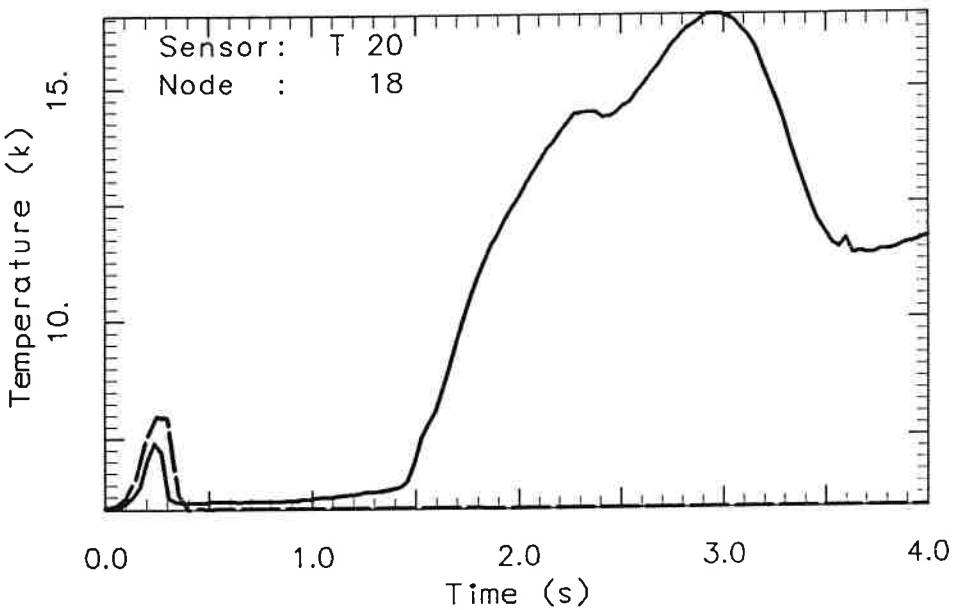


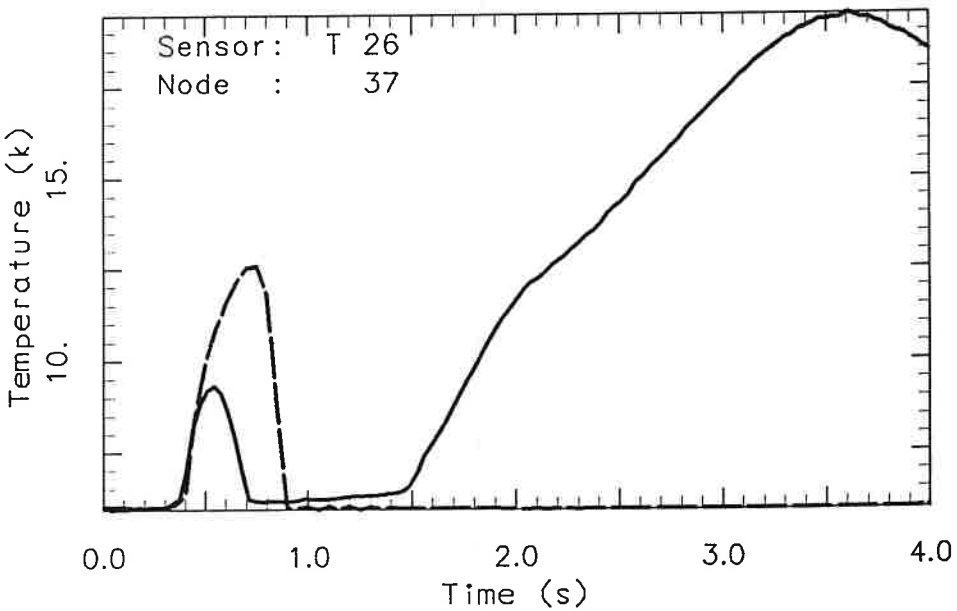


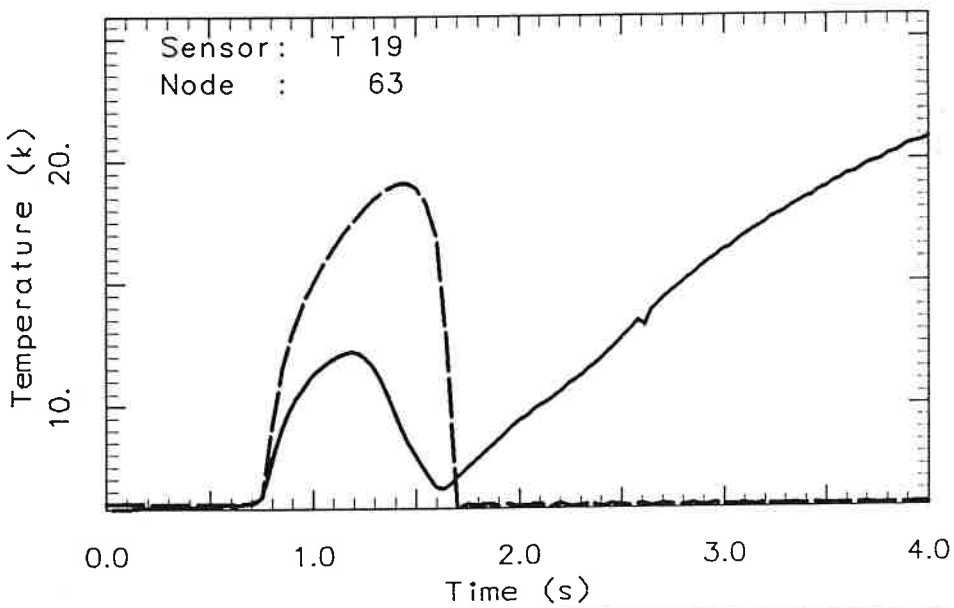


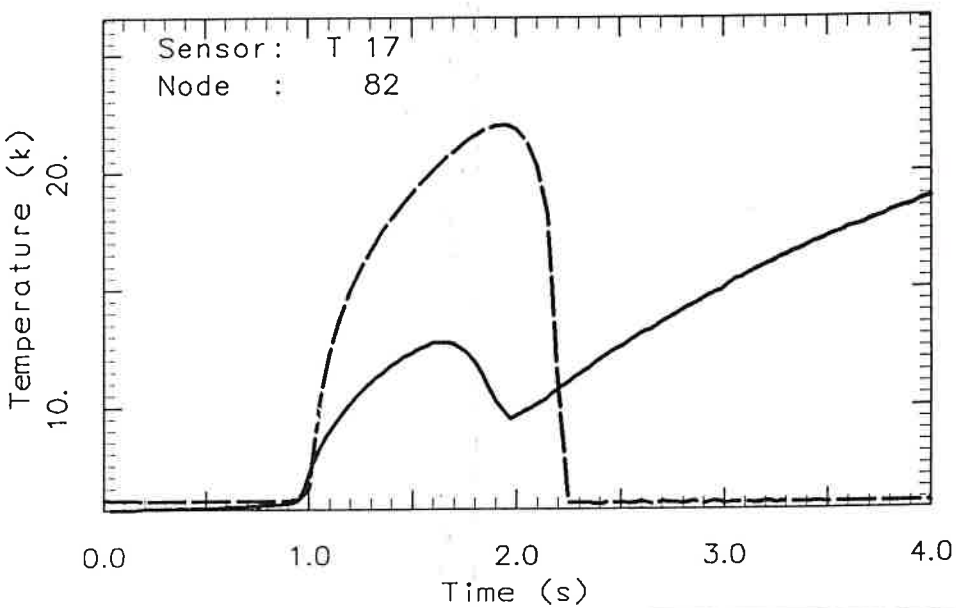


SIM # 48. TSS 3 mass it. min htc. 0.55*rho. no hyd net. 1-D RUN

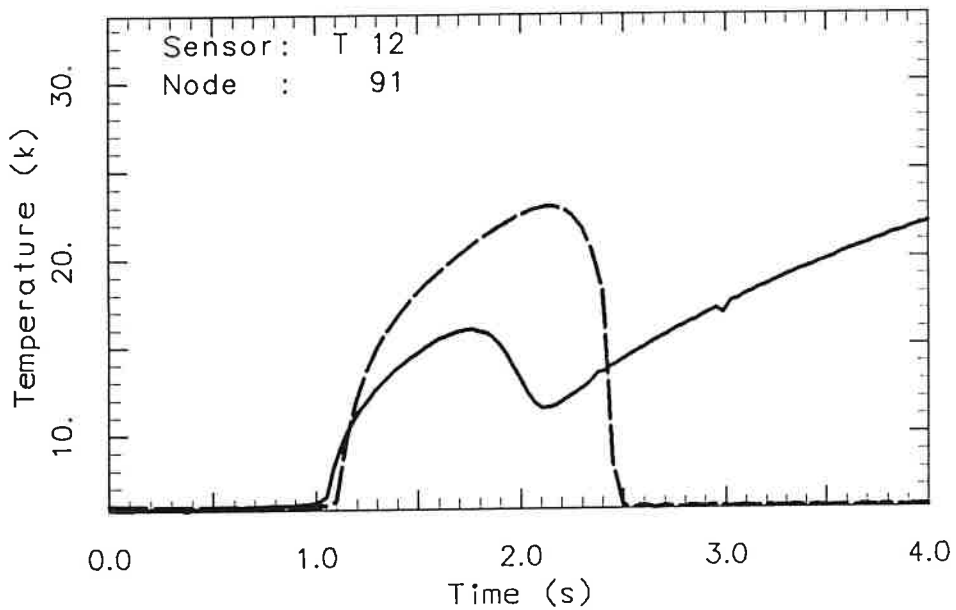


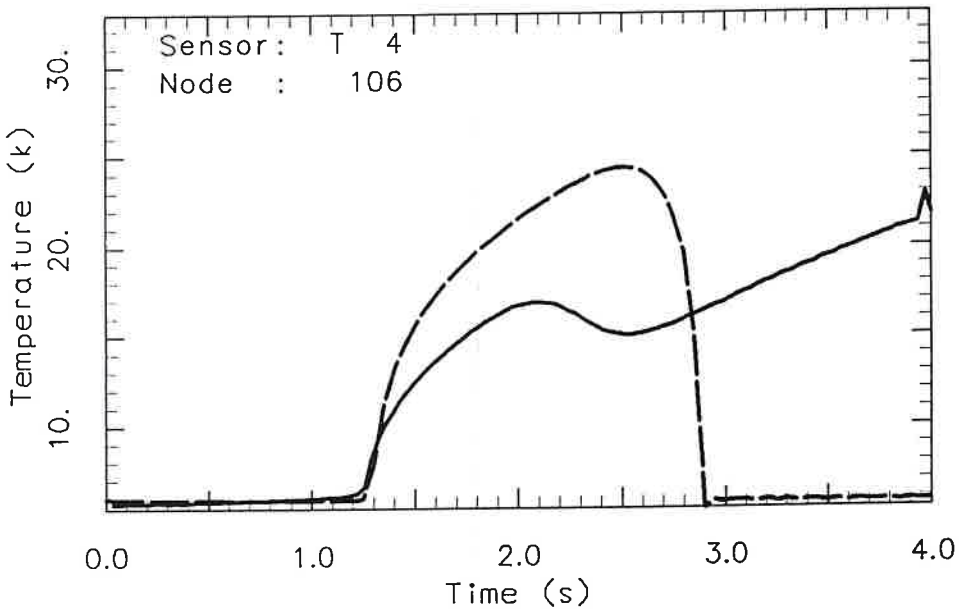


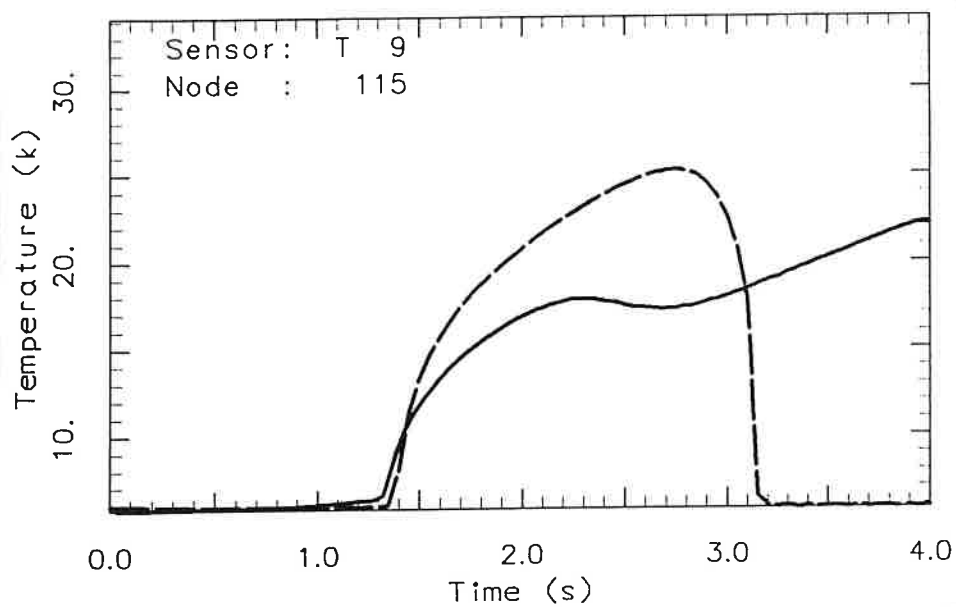


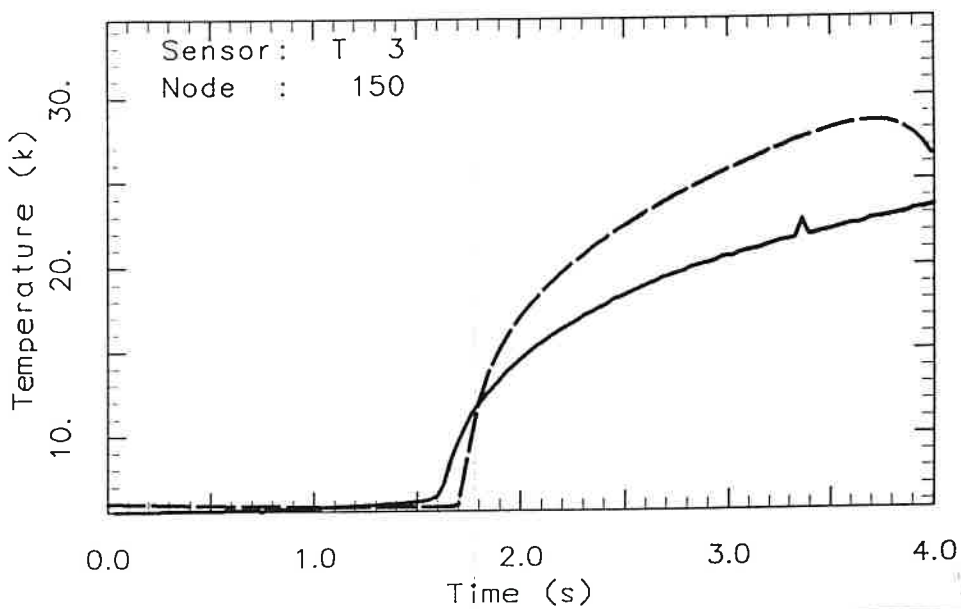


SIM # 48. TSS 3 mass it. min htc. 0.55*rho. no hyd net. 1-D RUN

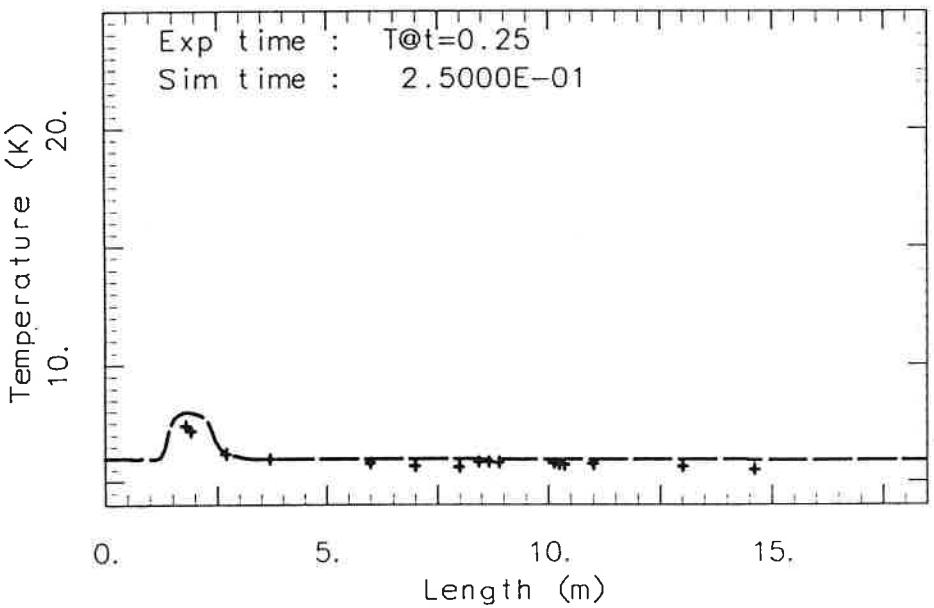


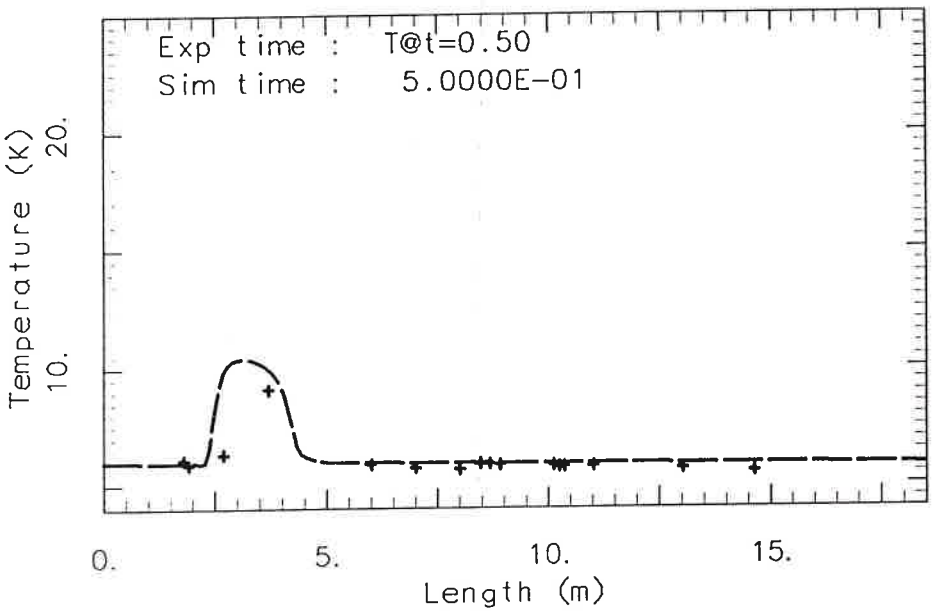


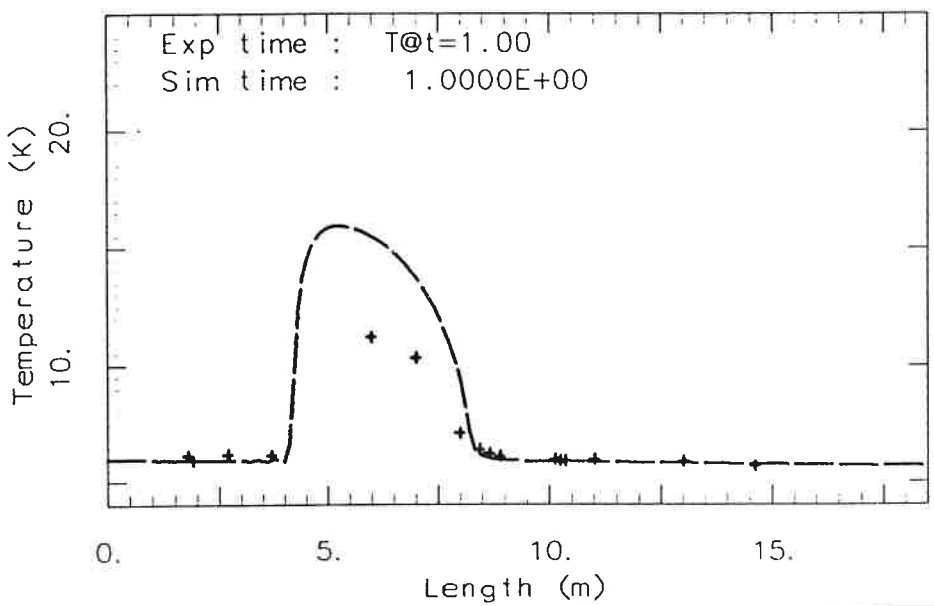


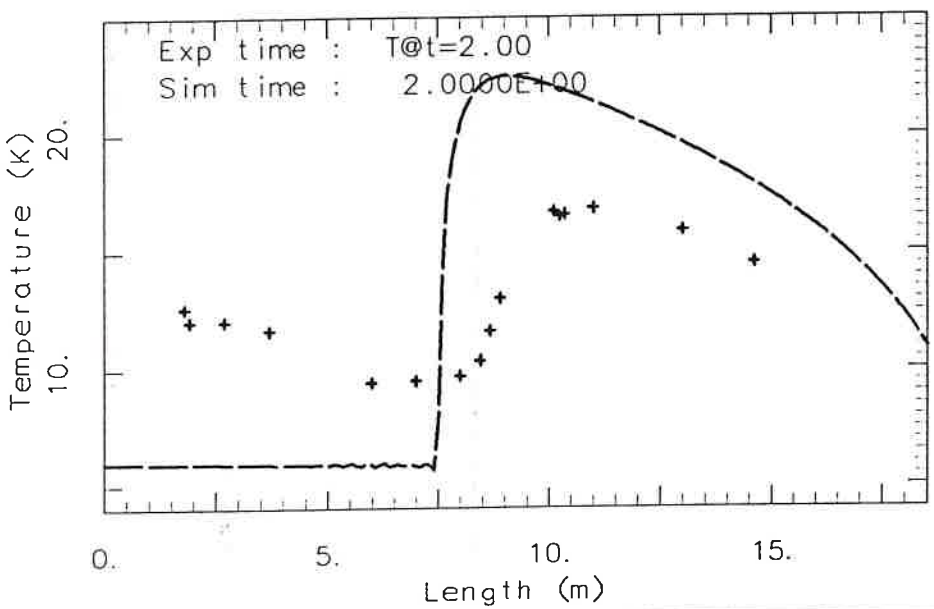


SIM # 48. TSS 3 mass it. min htc. 0.55*rho. no hyd net. 1-D RUN

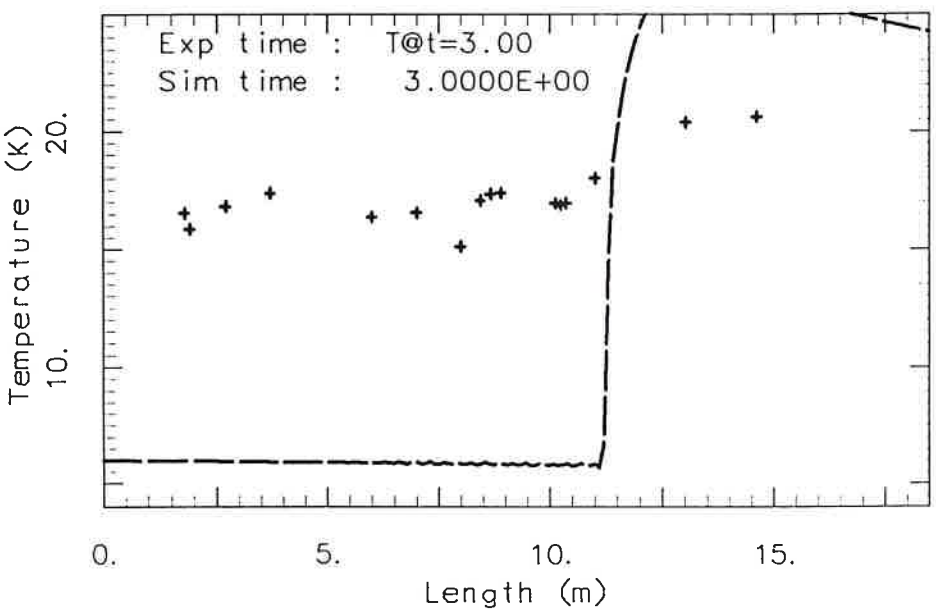


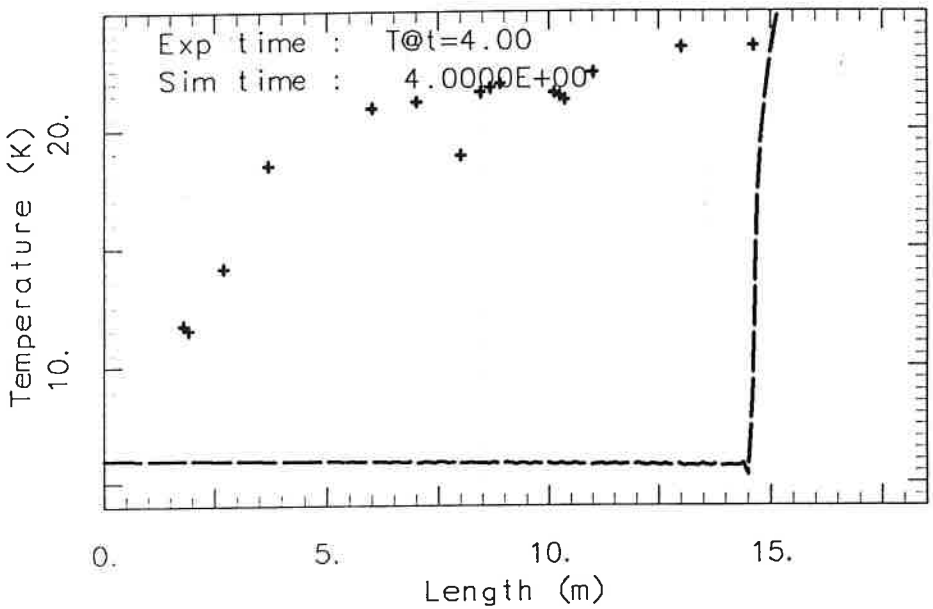




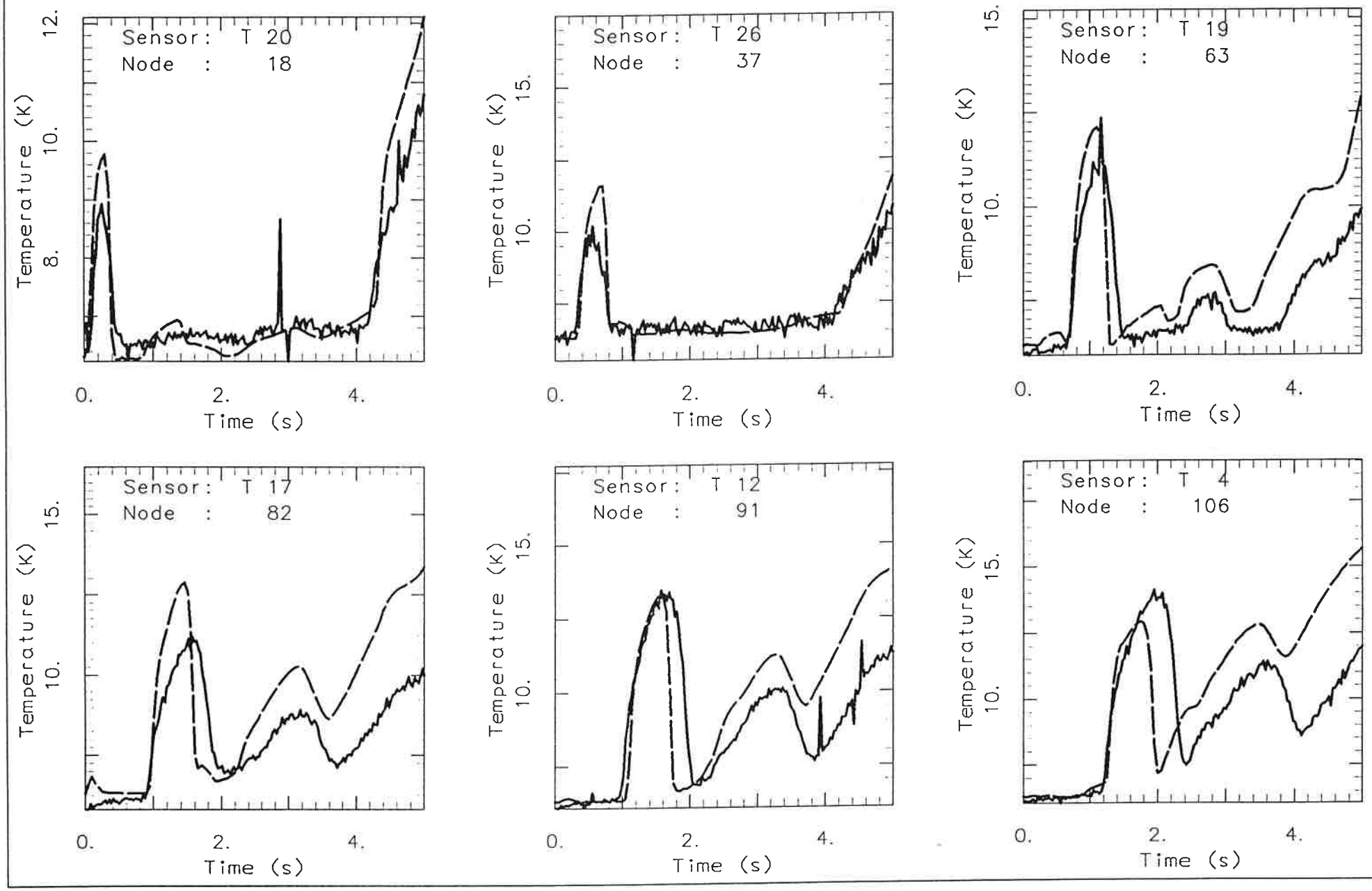


SIM # 48. TSS 3 mass it. min htc. 0.55*rho. no hyd net. 1-D RUN

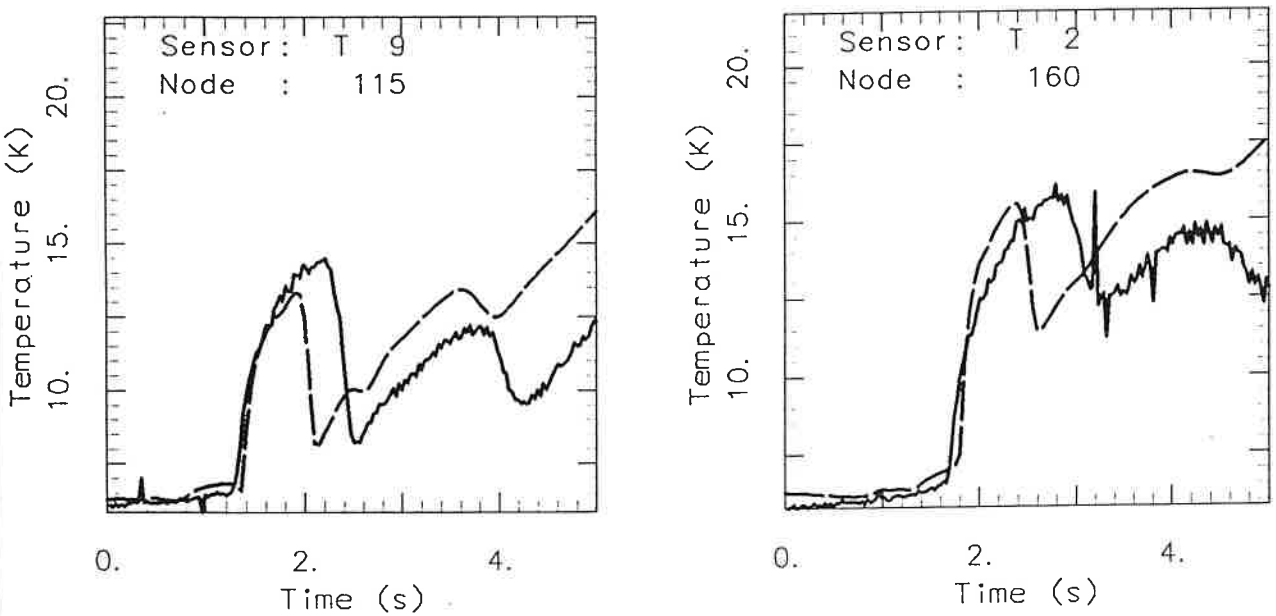




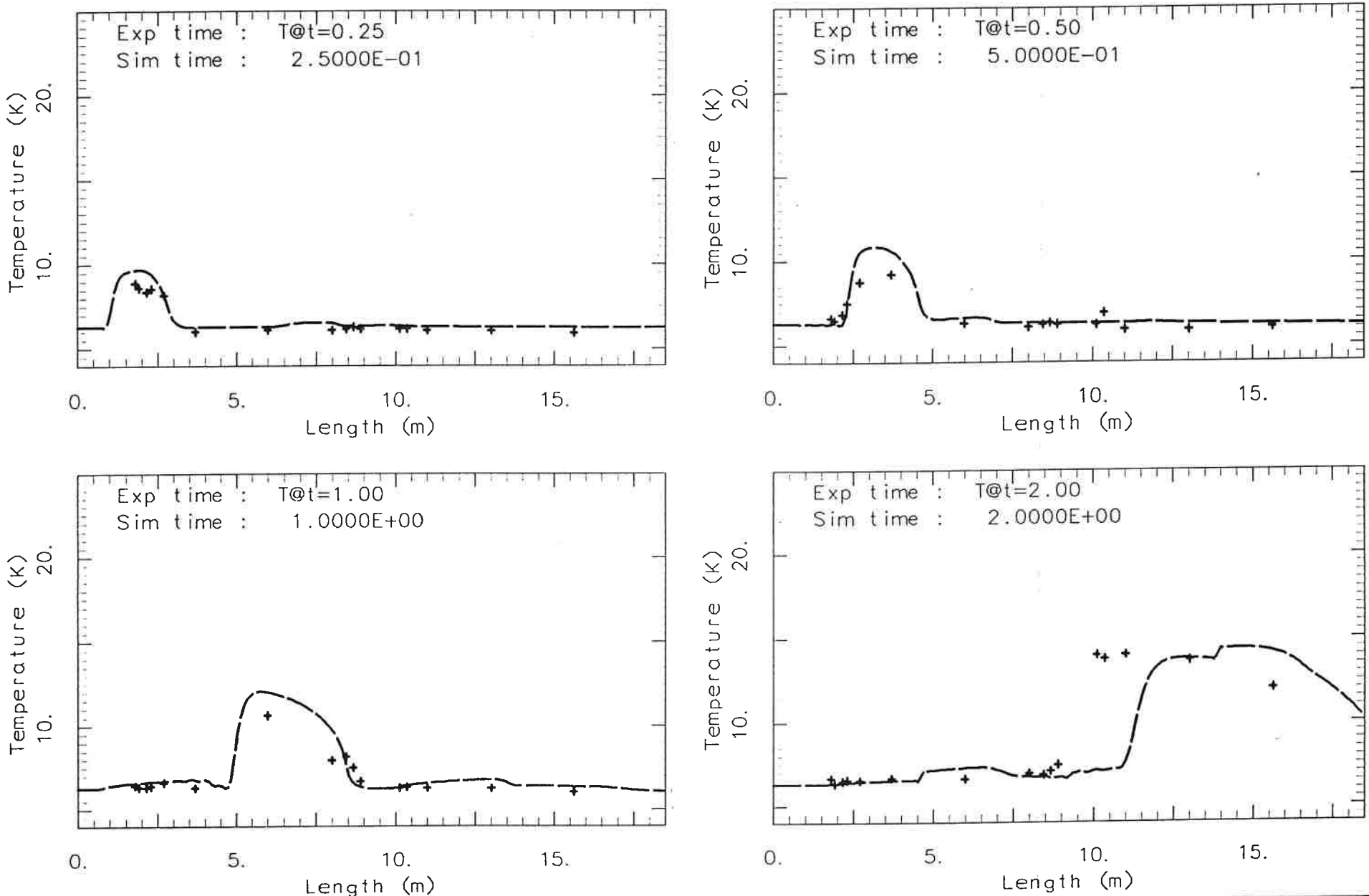
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10



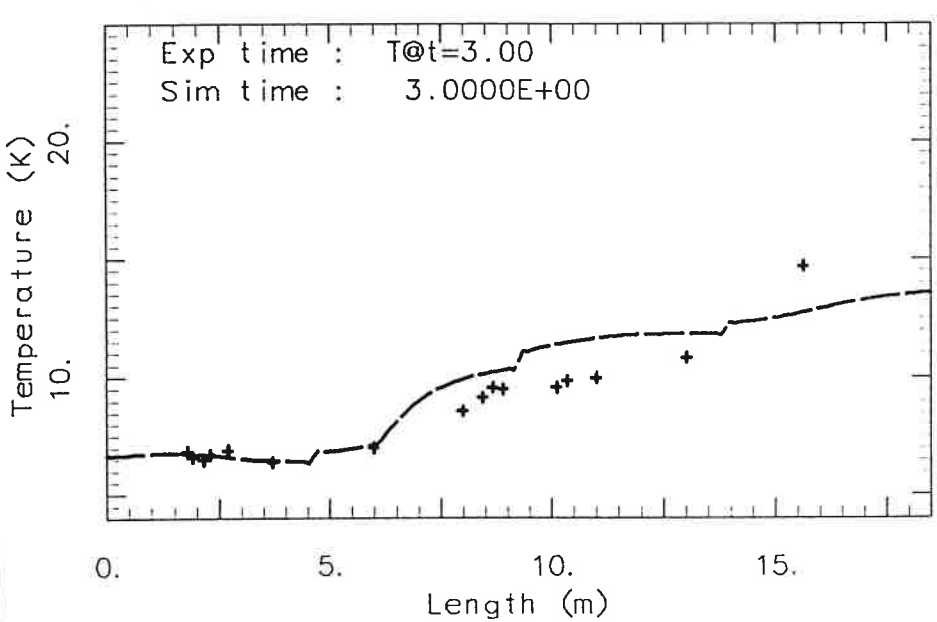
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10

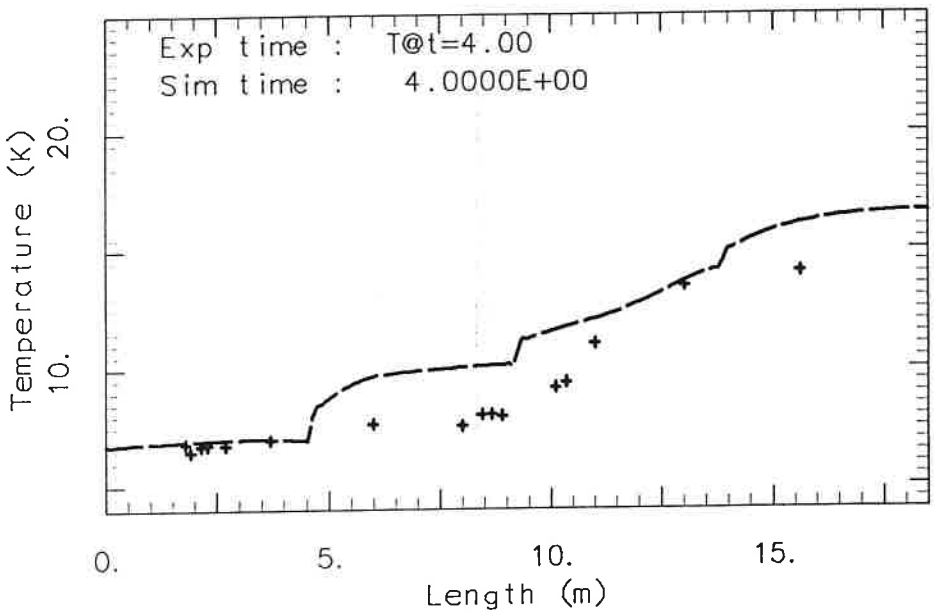


SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10

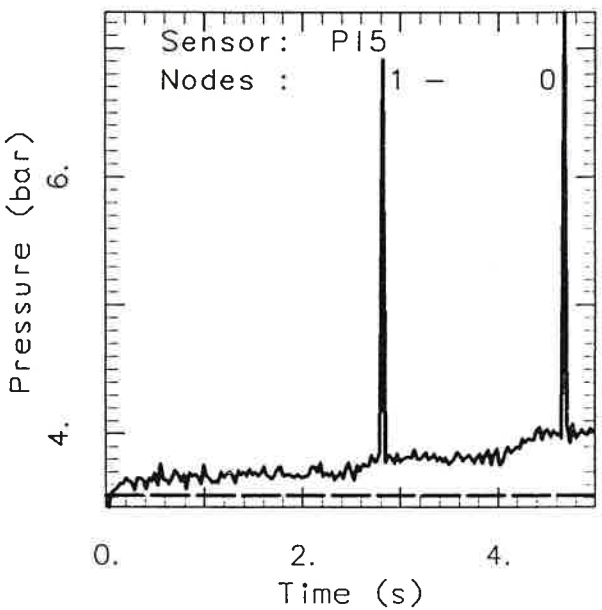


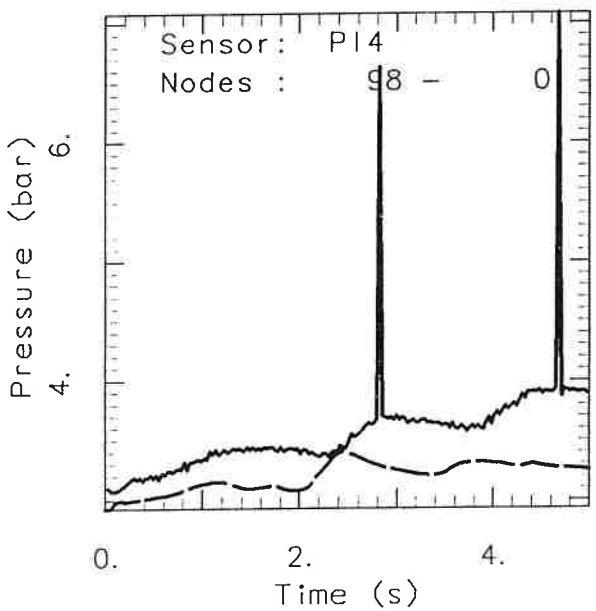
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10

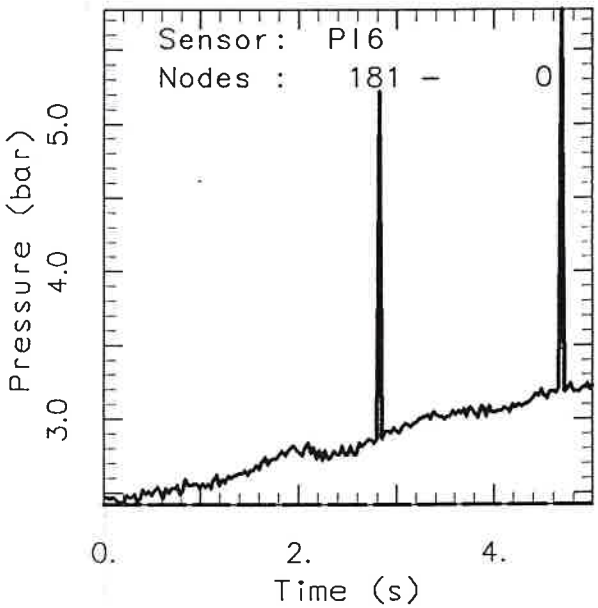


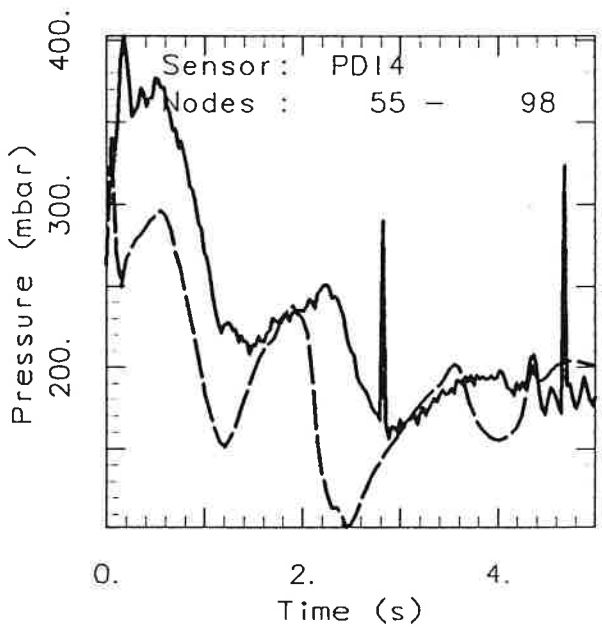


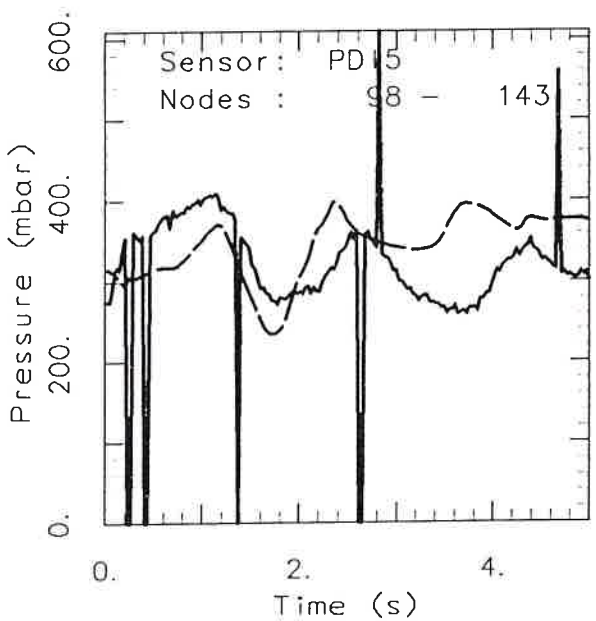
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10



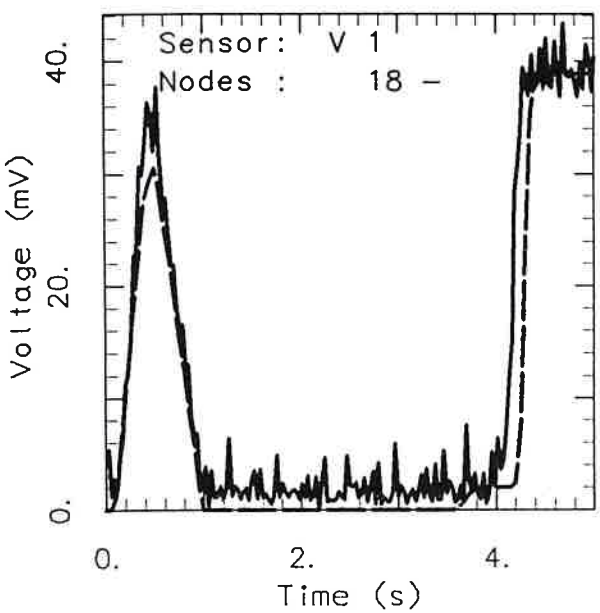


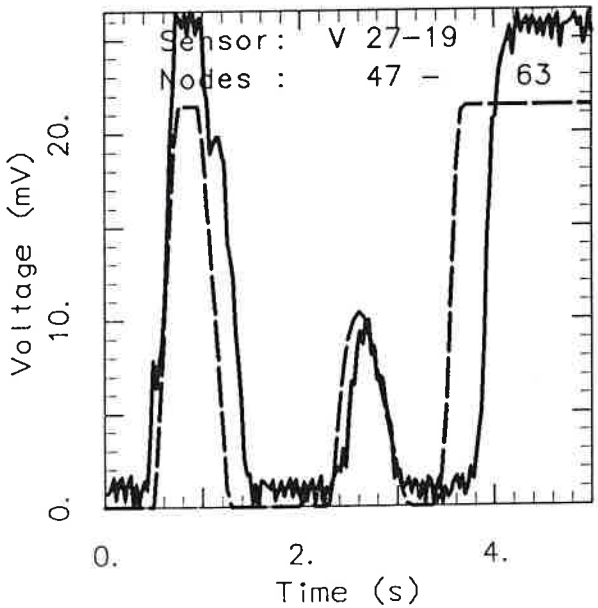


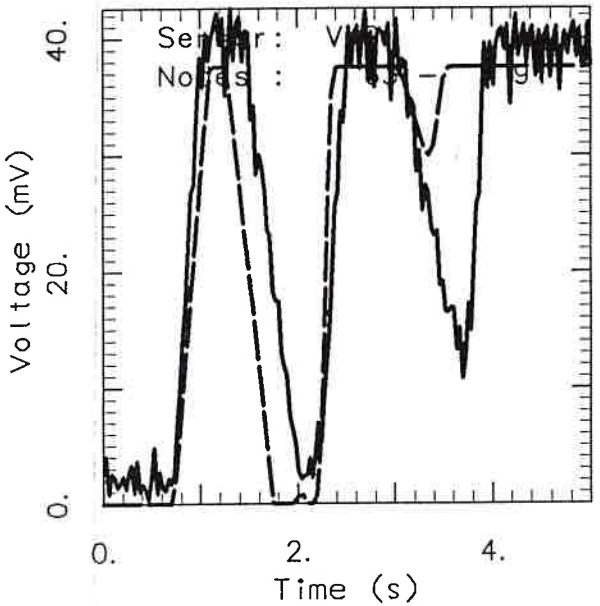


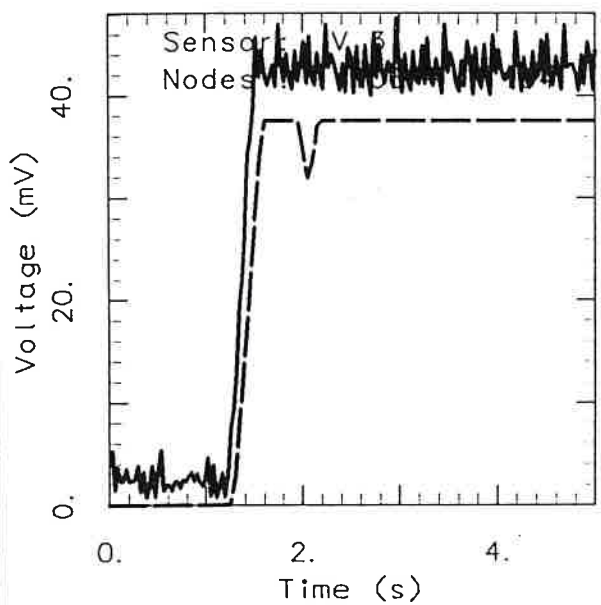


SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10

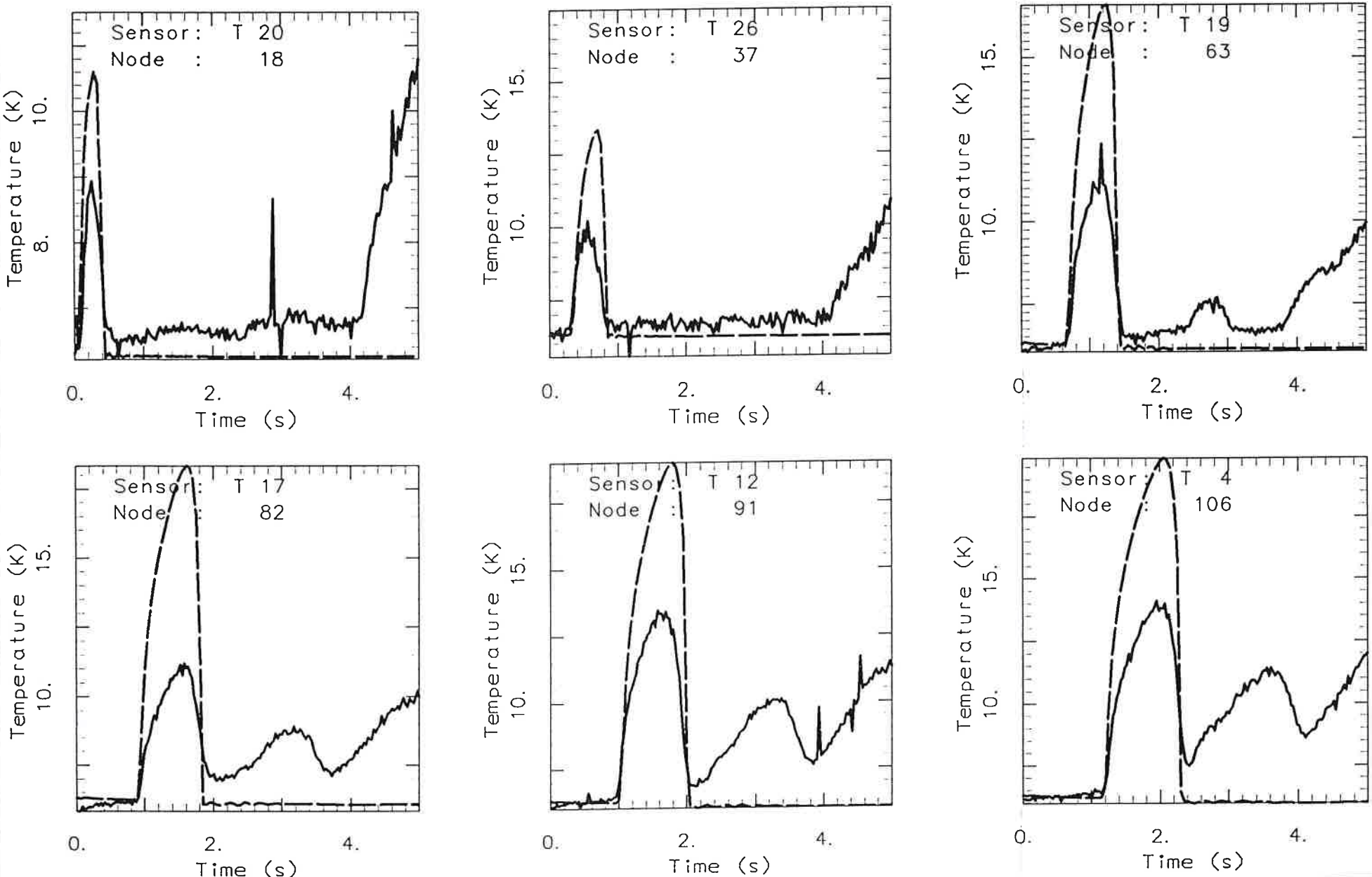




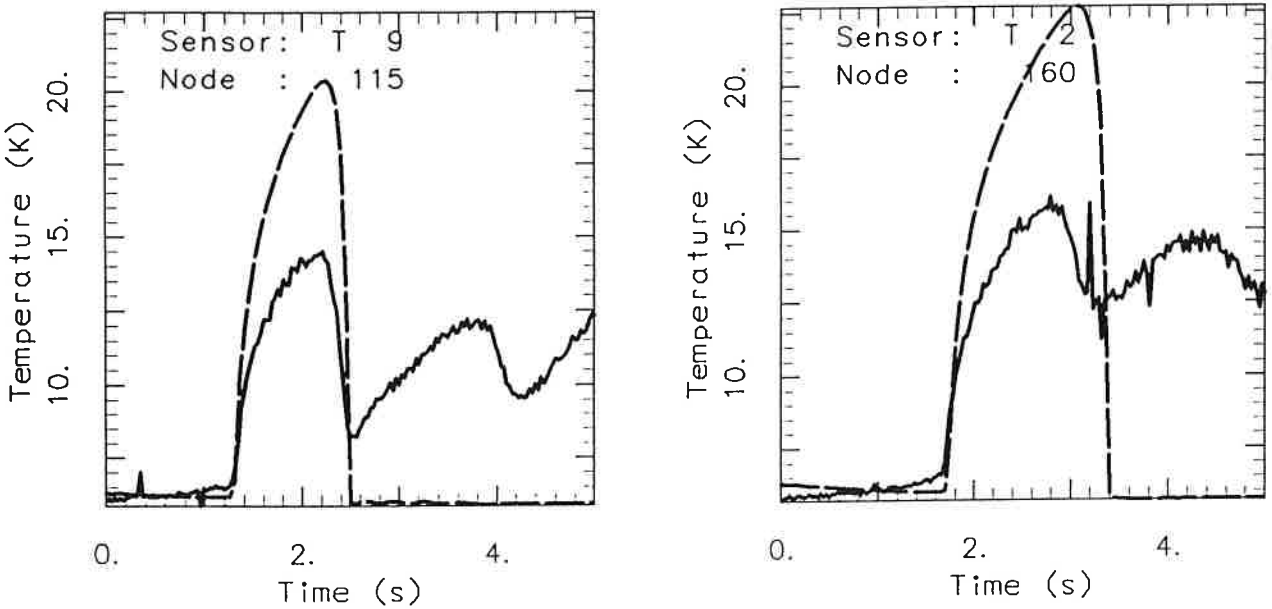




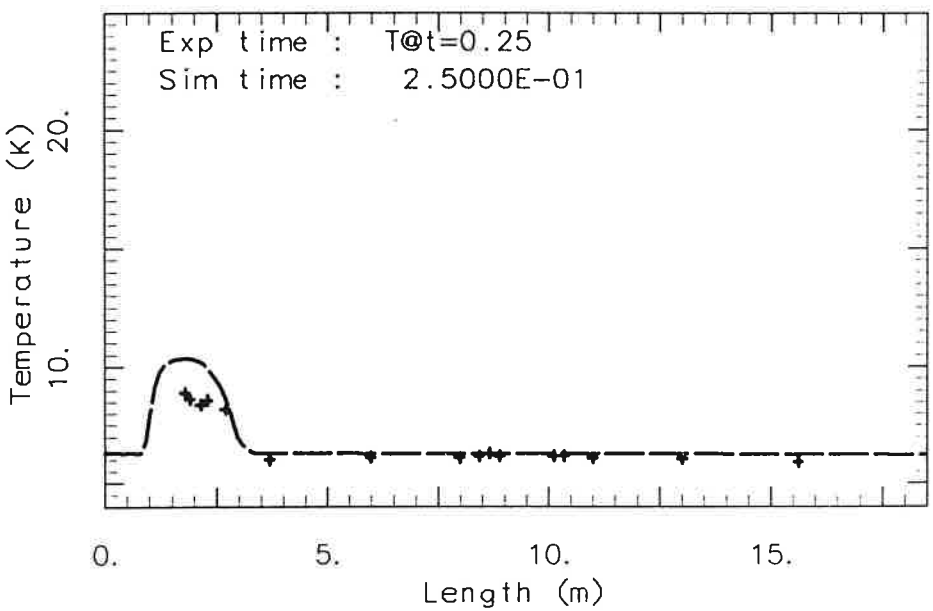
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.90e-10. 1-D run

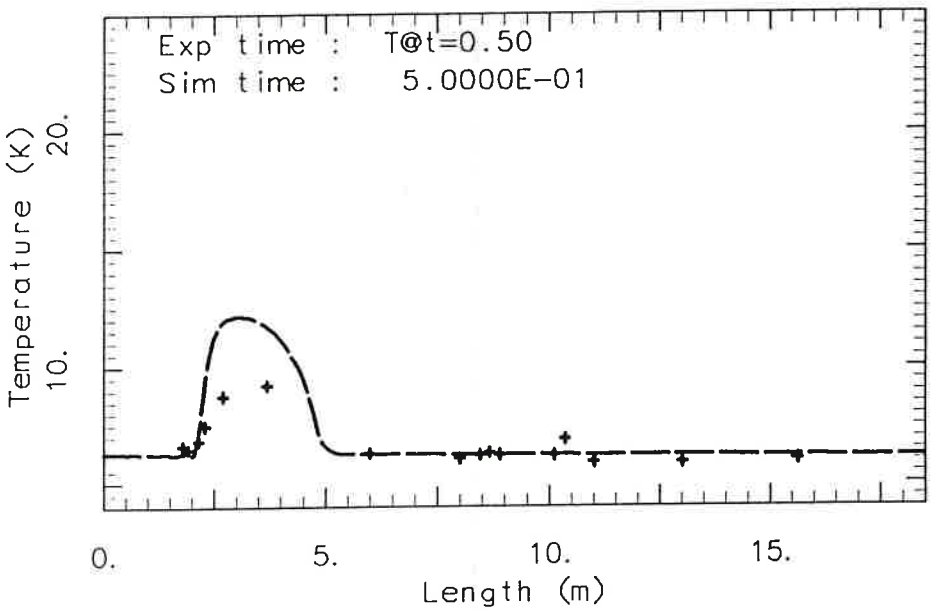


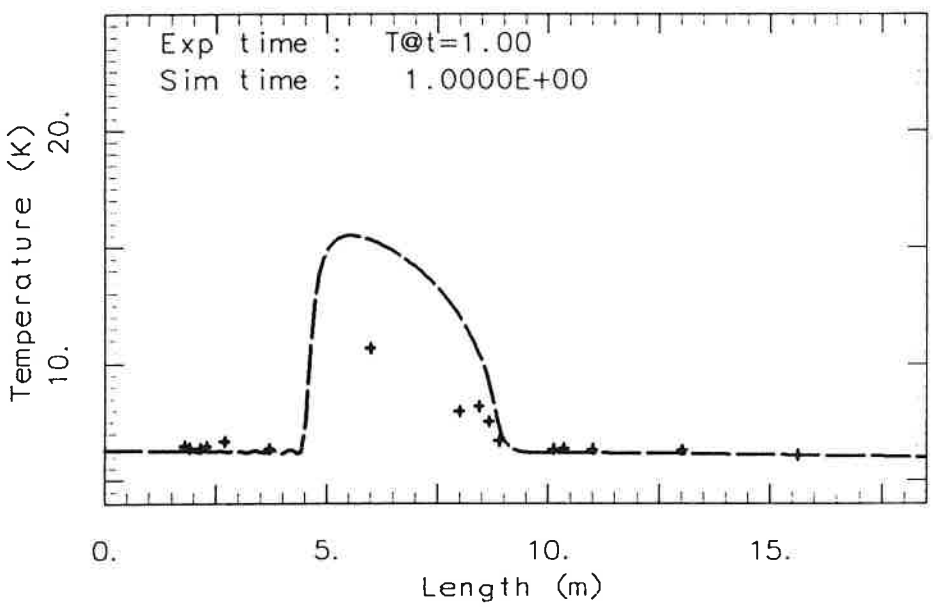
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.80e-10. 1-D run

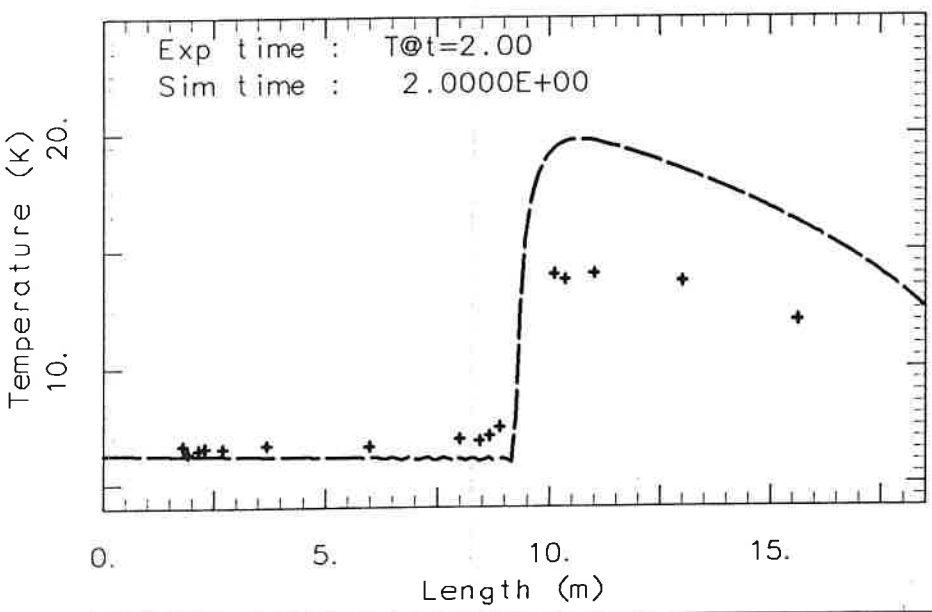


SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.80e-10. 1-D run









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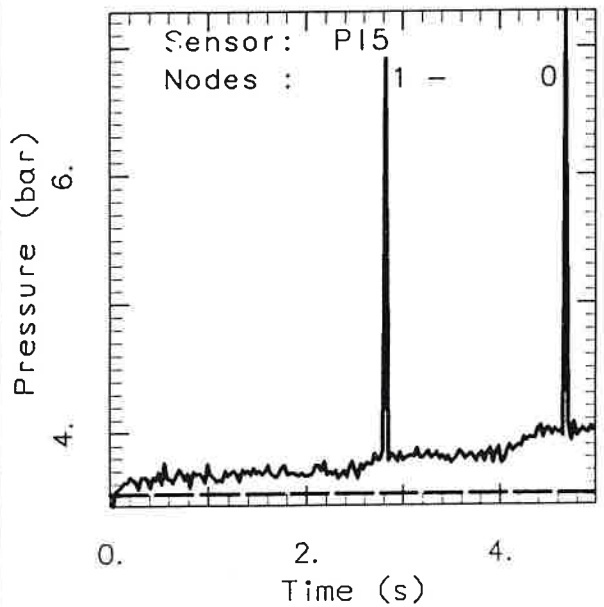
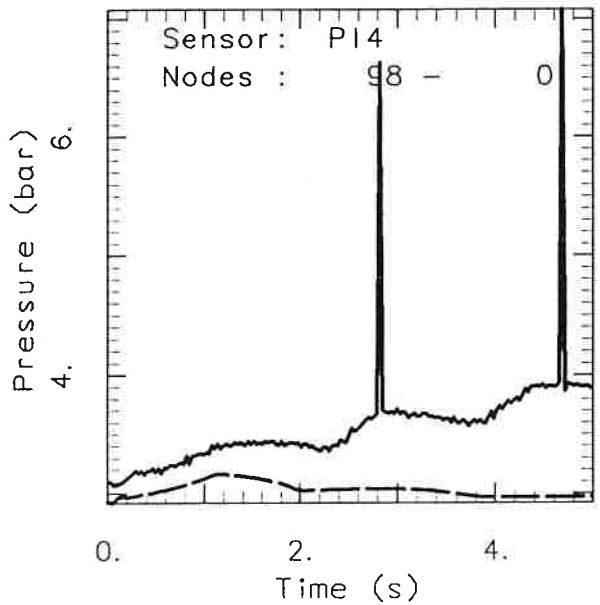
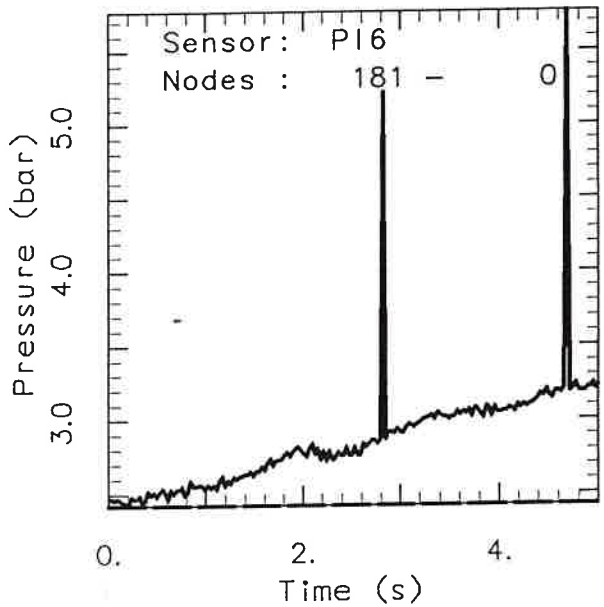
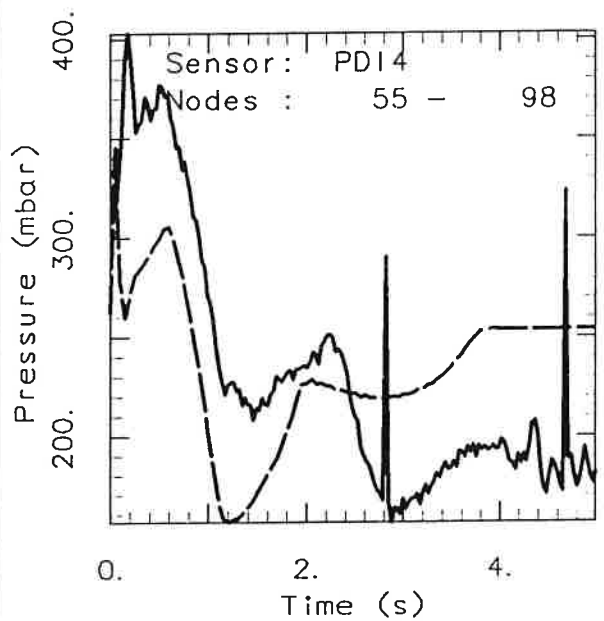
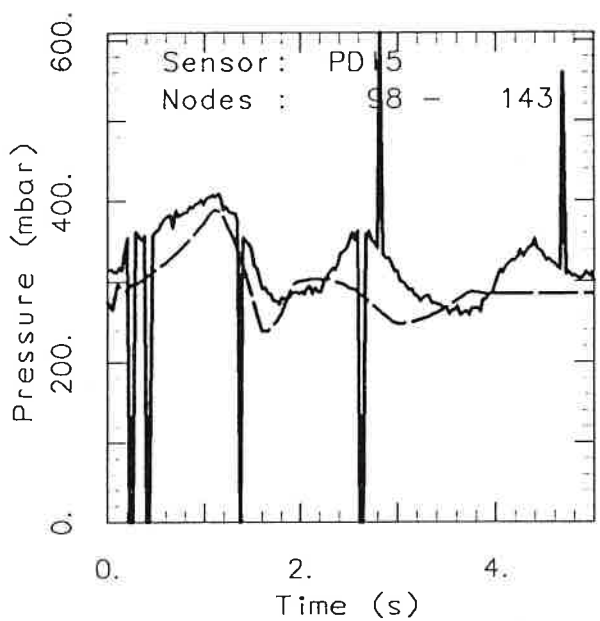
SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.80e-10. 1-D run



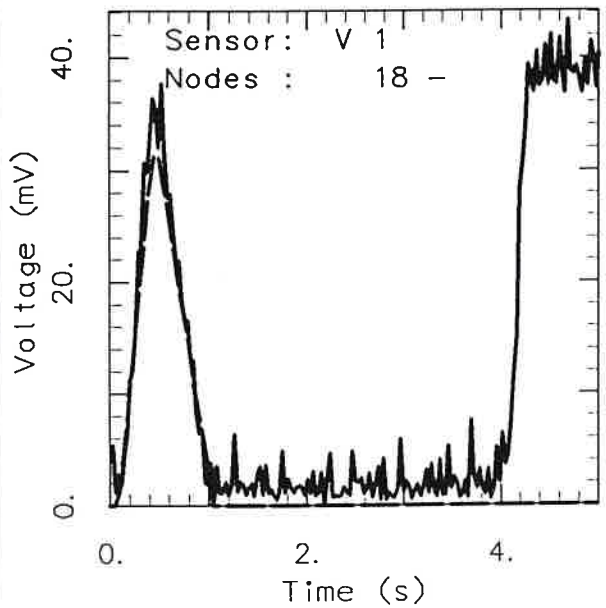


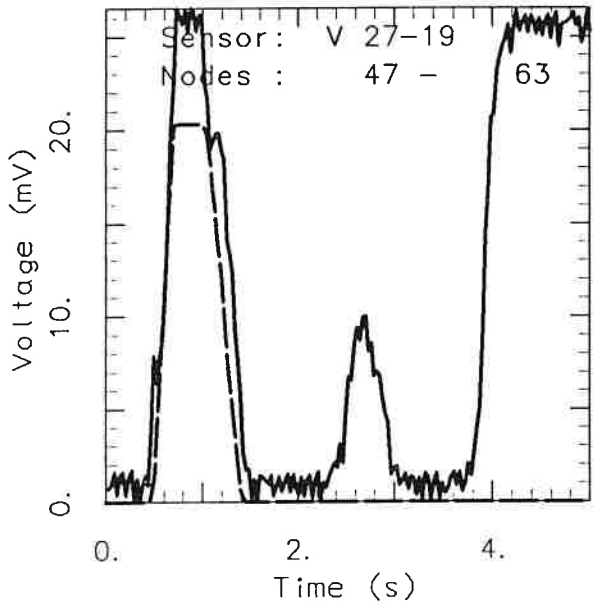


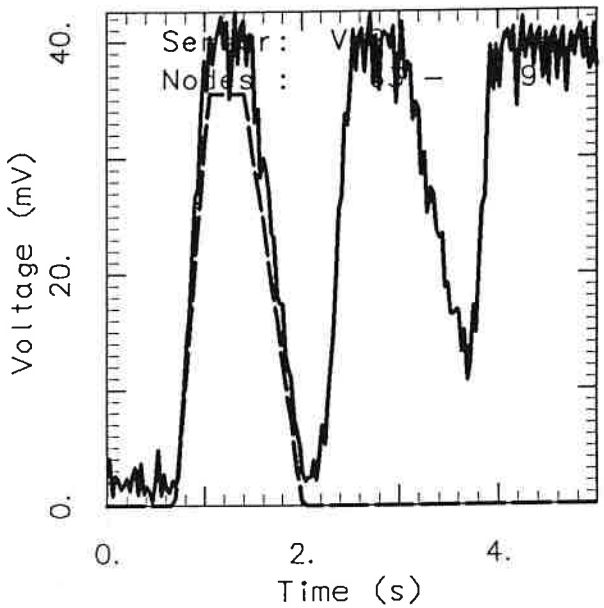


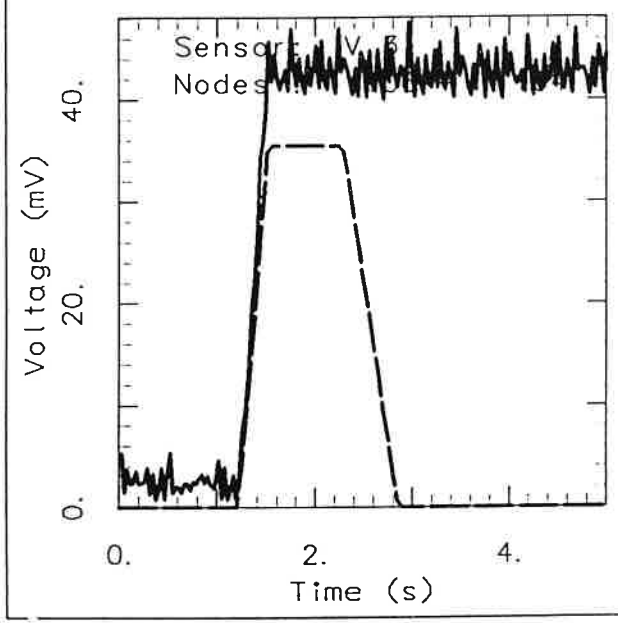


SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.80e-10. 1-D run

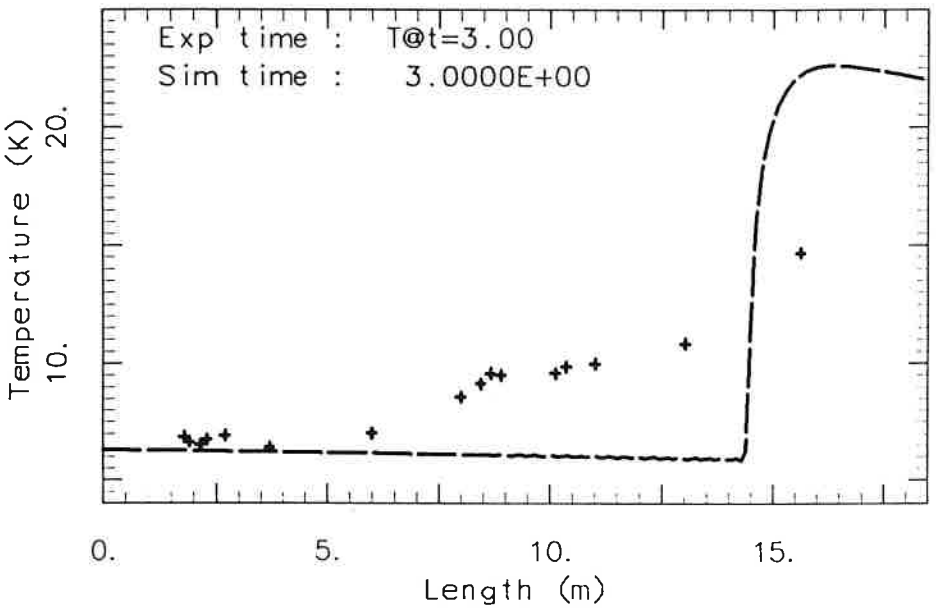


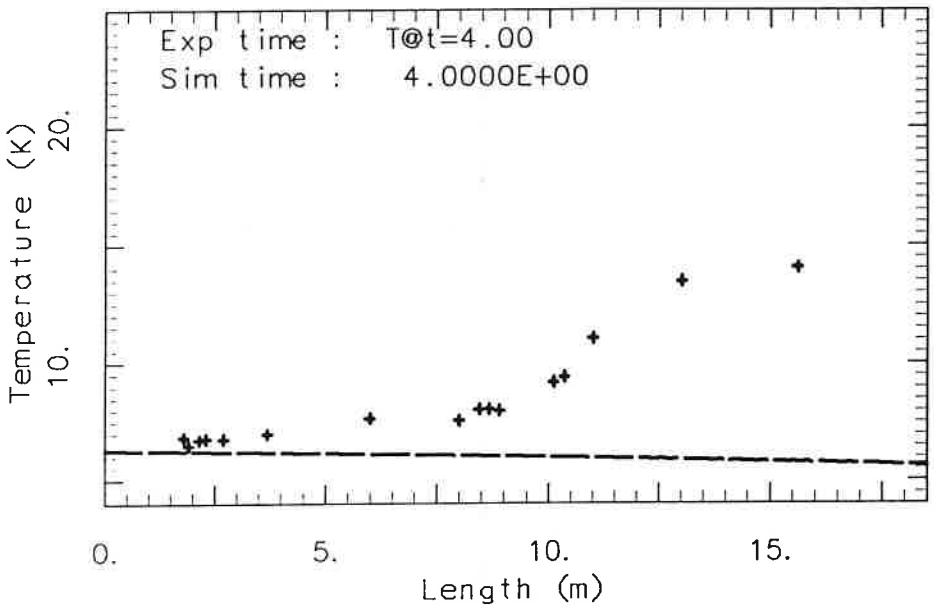






SIM # 45. t→in=0.20 mm. TSS 3 m→it. Min htc. rho=1.80e-10. 1-D run





Conclusion

☞ A good amount of runs already performed (xxx CRAY-hrs)

⇨ nice looking curves

⇨ several things learned on the capabilitites and limitations.

Influence of: conductor properties
boundary conditions

Choice of integrator

Higher confidence in the code

⇨ a nerve-consuming exercise highly recommended

☞ Good inputs (experiments) are needed for good validation

⇨ *stimulating* way of designing experiments (so that data can be used)