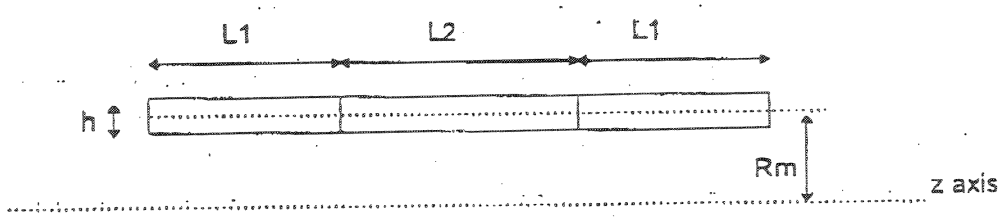
QUENCH HEATING

BABAR 8/1/1996

COIL GEOMETRICAL PARAMETERS:



1 = side cable
2 = central cable

δ_1 = 4.0 mm (insulated, warm)
δ_2 = 6.67 mm " "
h = 32.4 mm " "
(thickness insulation = 0.2 mm)

N_1 = 250 turns
N_2 = 220 turns

L_1 = (1000 + 4) mm
L_2 = (1467.4 + 6.67) mm

R_m = 1515 mm (cold)

$L_{tot} = L_2 + 2\,L_1$ = 3482.07 mm

(factor = 0.996 warm ⇒ cold)
(factor = 1.004 cold ⇒ warm)

I = 6873 A

$N_{tot.}$ = 720 turns

$N_{tot} \cdot I = 4.95 \cdot 10^6$ A-turns

16/02/96 11:38 ANSALDO ENERGIA (PMA) GENOVA → 39 10 313358 NO.030 D07

Inductance : L = 1.14 Henry

Total Energy: E = 27.0 MJ

Axial force on coil: Fz = - 17 tons (zo = + 1.0 mm)

if coil is centered (zo = 0), ⇒ Fz = - 30 tons

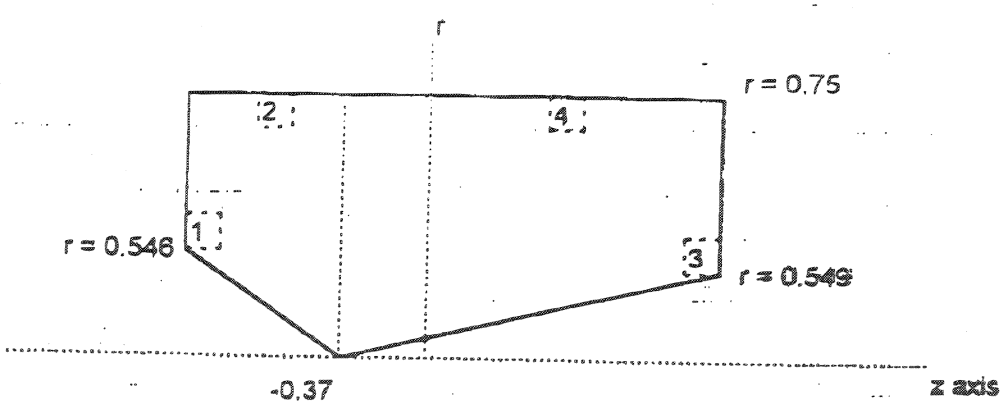
if (zo = 1.0 mm) and we take into account the hole in the backward flange (180° model), ⇒ Fz = - 14 tons

field in the center of the magnet : Bo = 1.5048 T

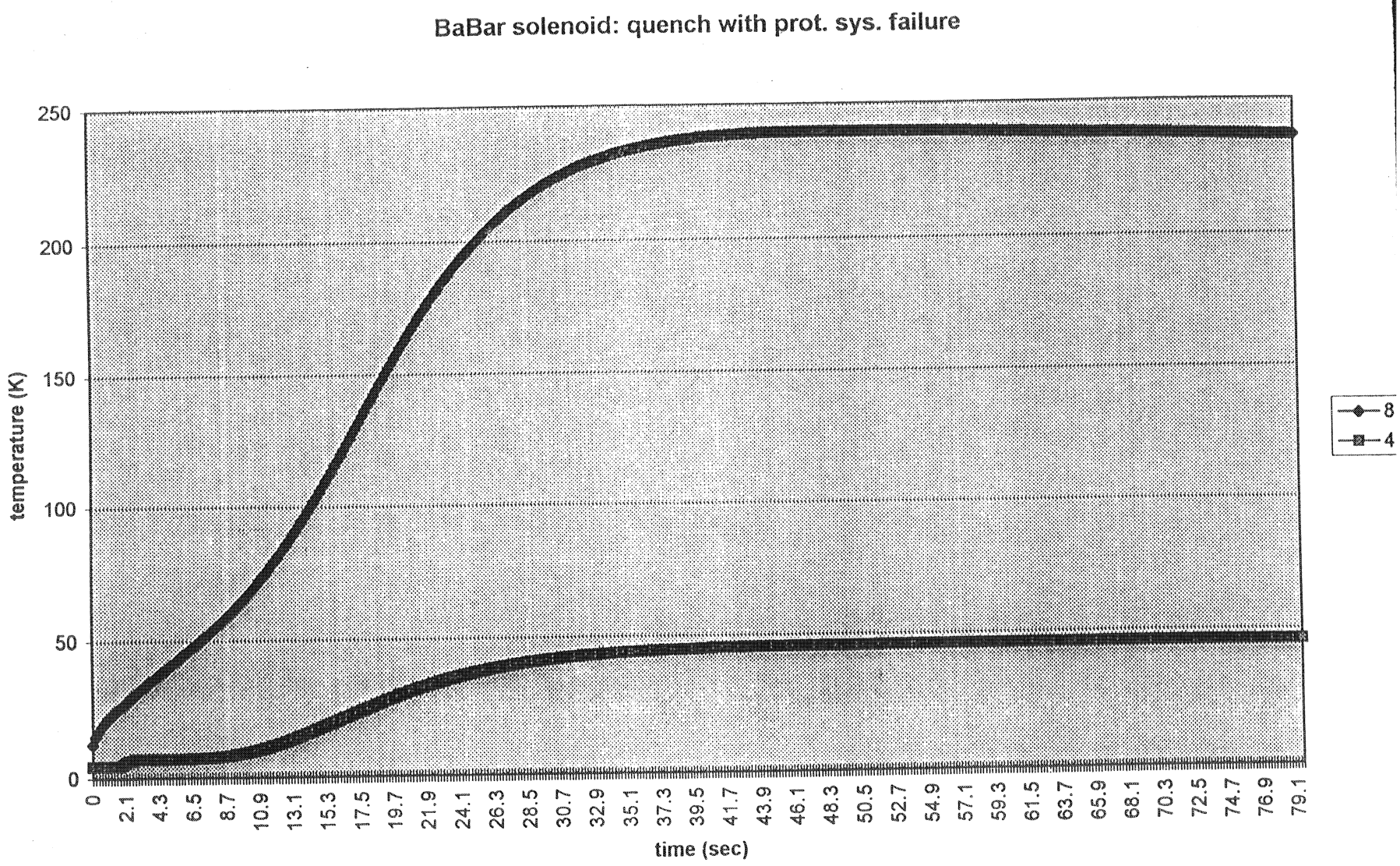
maximum field on conductor : B = 2.2 T

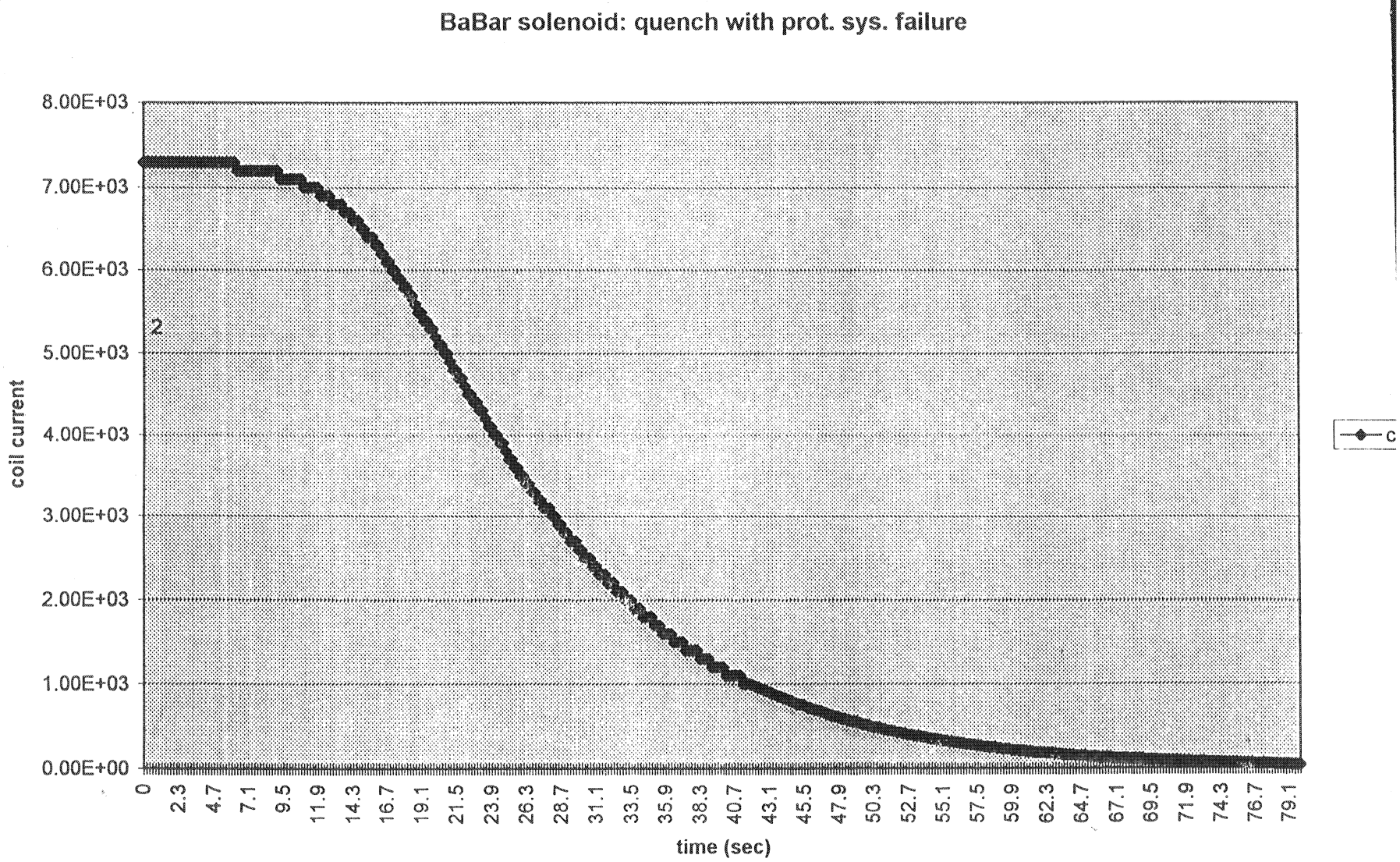
omogeneity in the region of interest:

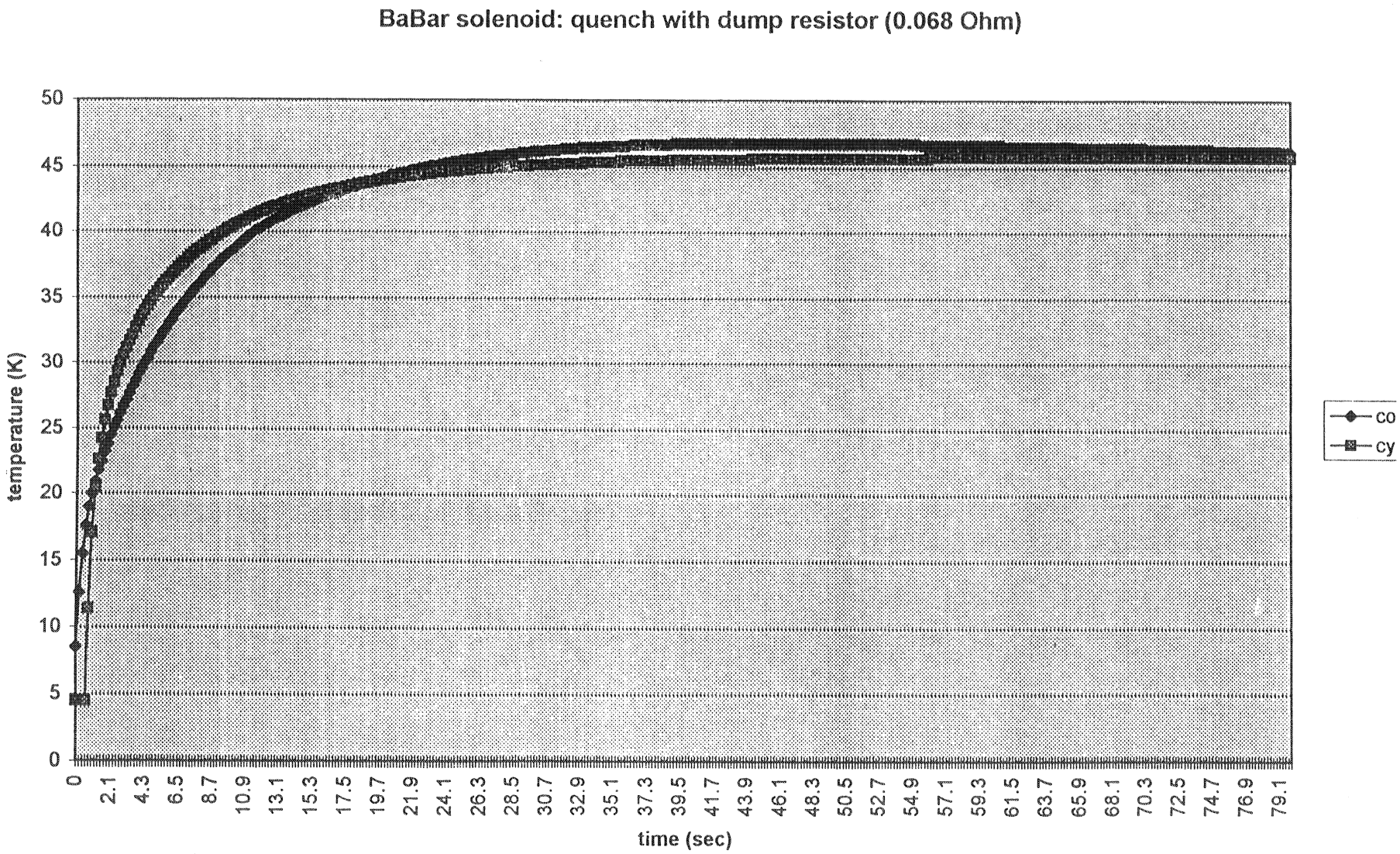
1, 2 = -2.84 % , + 2.84 %
3, 4 = -2.06 % , + 2.74 %

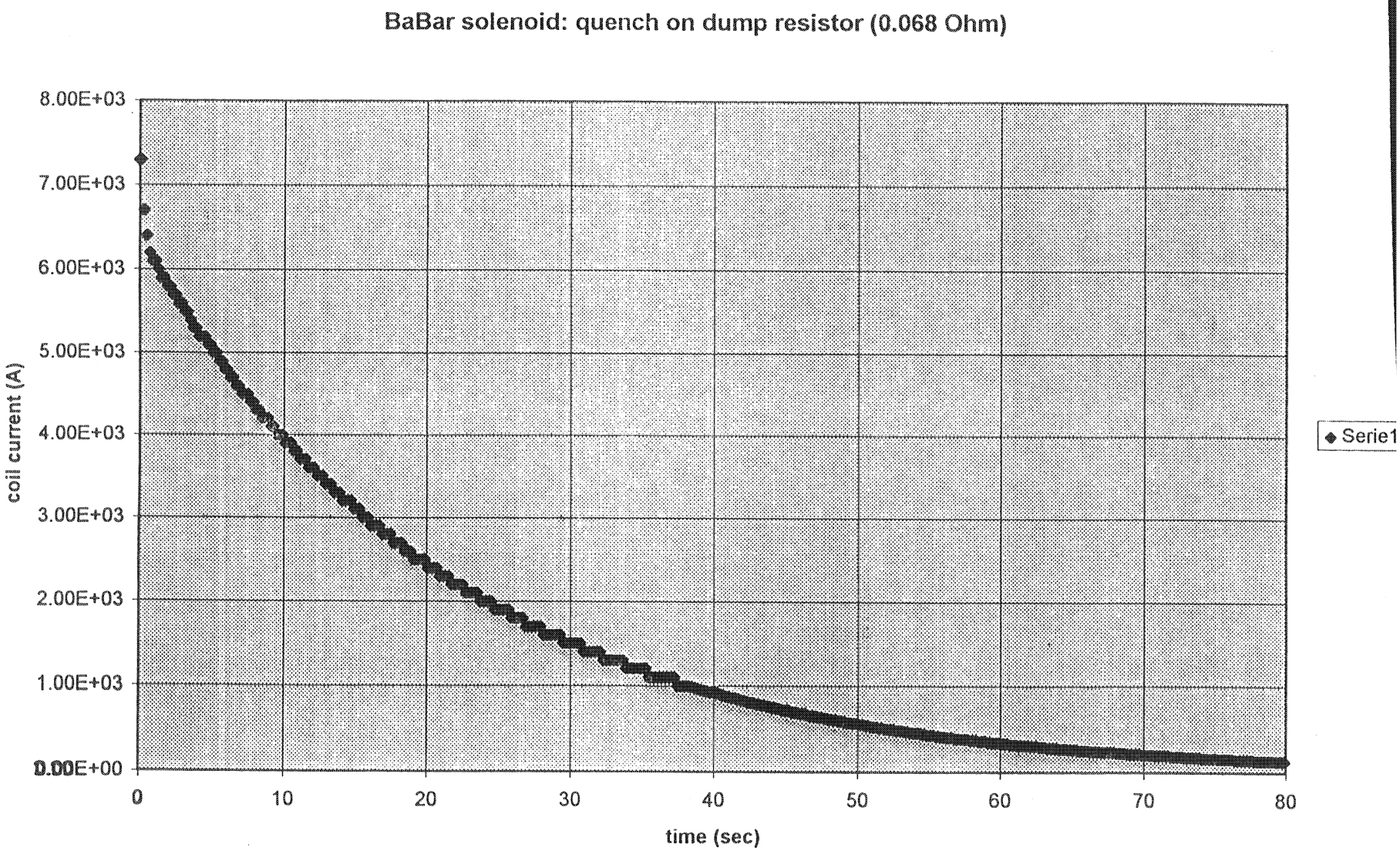


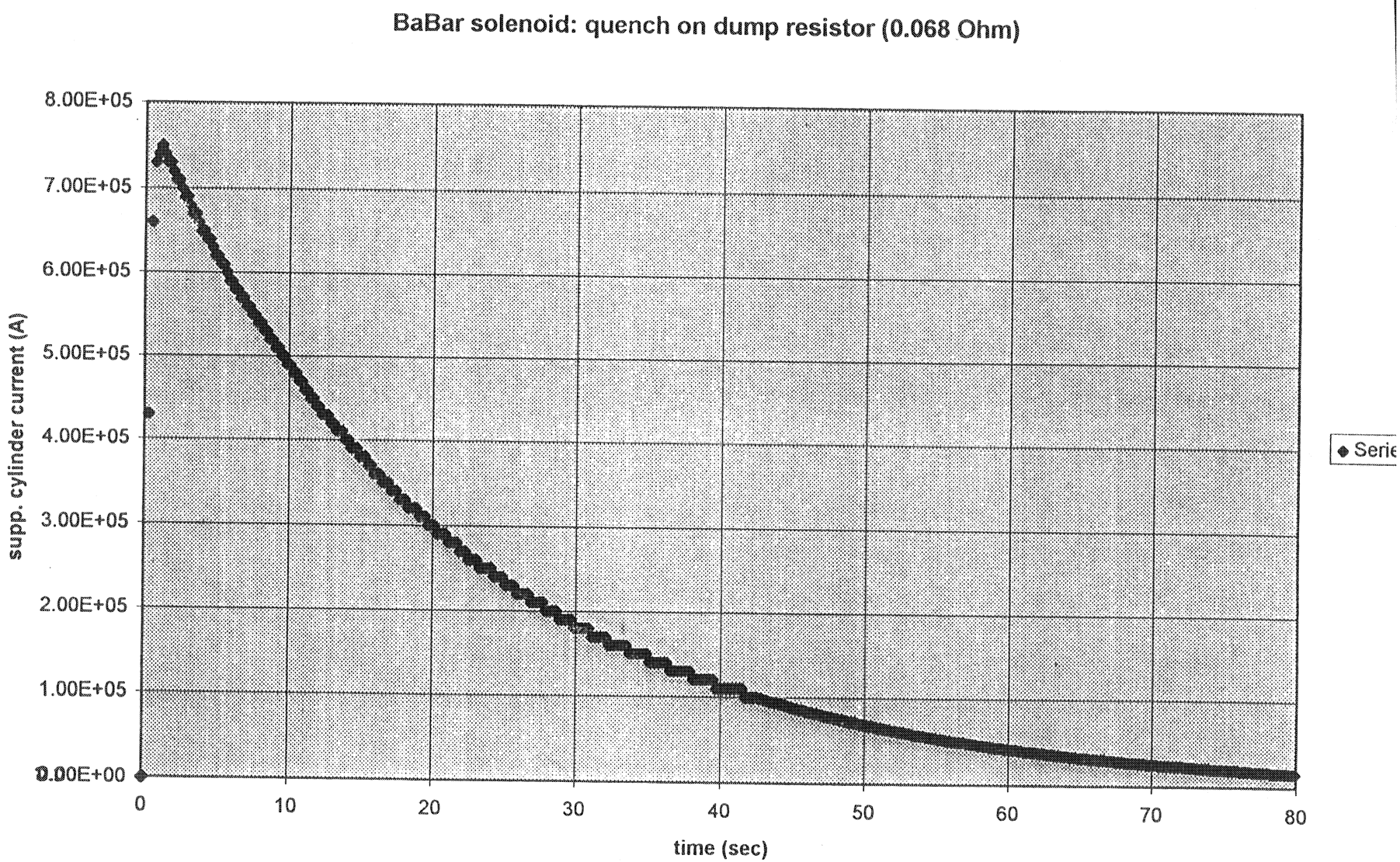
16/02/96 11:38 ANSALDO ENERGIA (PMA) GENOVA → 39 10 313358 NO.030 D08


BaBar solenoid: quench with prot. sys. failure
temperature (K)
250
200
150
100
50
0
0
2.1
4.3
6.5
8.7
10.9
13.1
15.3
17.5
19.7
21.9
24.1
26.3
28.5
30.7
32.9
35.1
37.3
39.5
41.7
43.9
46.1
48.3
50.5
52.7
54.9
57.1
59.3
61.5
63.7
65.9
68.1
70.3
72.5
74.7
76.9
79.1
time (sec)
8
4


BaBar solenoid: quench with prot. sys. failure
coil current
8.00E+03
7.00E+03
6.00E+03
5.00E+03
4.00E+03
3.00E+03
2.00E+03
1.00E+03
0.00E+00
2
0
2.3
4.7
7.1
9.5
11.9
14.3
16.7
19.1
21.5
23.9
26.3
28.7
31.1
33.5
35.9
38.3
40.7
43.1
45.5
47.9
50.3
52.7
55.1
57.5
59.9
62.3
64.7
67.1
69.5
71.9
74.3
76.7
79.1
time (sec)
c


BaBar solenoid: quench with dump resistor (0.068 Ohm)
temperature (K)
50
45
40
35
30
25
20
15
10
5
0
0
2.1
4.3
6.5
8.7
10.9
13.1
15.3
17.5
19.7
21.9
24.1
26.3
28.5
30.7
32.9
35.1
37.3
39.5
41.7
43.9
46.1
48.3
50.5
52.7
54.9
57.1
59.3
61.5
63.7
65.9
68.1
70.3
72.5
74.7
76.9
79.1
time (sec)
co
cy


BaBar solenoid: quench on dump resistor (0.068 Ohm)
8.00E+03
7.00E+03
6.00E+03
5.00E+03
4.00E+03
3.00E+03
2.00E+03
1.00E+03
0.00E+00
coil current (A)
0
10
20
30
40
50
60
70
80
time (sec)
Serie1


BaBar solenoid: quench on dump resistor (0.068 Ohm)
8.00E+05
7.00E+05
6.00E+05
5.00E+05
4.00E+05
3.00E+05
2.00E+05
1.00E+05
0.00E+00
supp. cylinder current (A)
0
10
20
30
40
50
60
70
80
time (sec)
Serie

Ap-i 96
Meeting

2° REVIEW OF BABAR SOLENOID

GENOA, 23-24 April 1996

2) MECHANICAL ANALYSIS OF COLD MASS AND SUPPORT

AEN

- HOOP, RADIAL, AXIAL AND SHEAR STRESS
- THERMAL AND MAGNETIC STRESS
- DEFORMATION OF THE COLD MASS DUE TO THE SUPPORTS

2° REVIEW OF BABAR SOLENOID

GENOA, 23-24 April 1996

3)	QUENCH ANALYSIS	AEN
	STABILITY	INFN
	PROTECTION AND ELECTRICAL SCHEME	AEN

2° REVIEW OF BABAR SOLENOID

GENOA, 23-24 April 1996

4) CRYOGENIC SCHEME AND WAYS OF OPERATION AEN

HEAT LOADS AEN

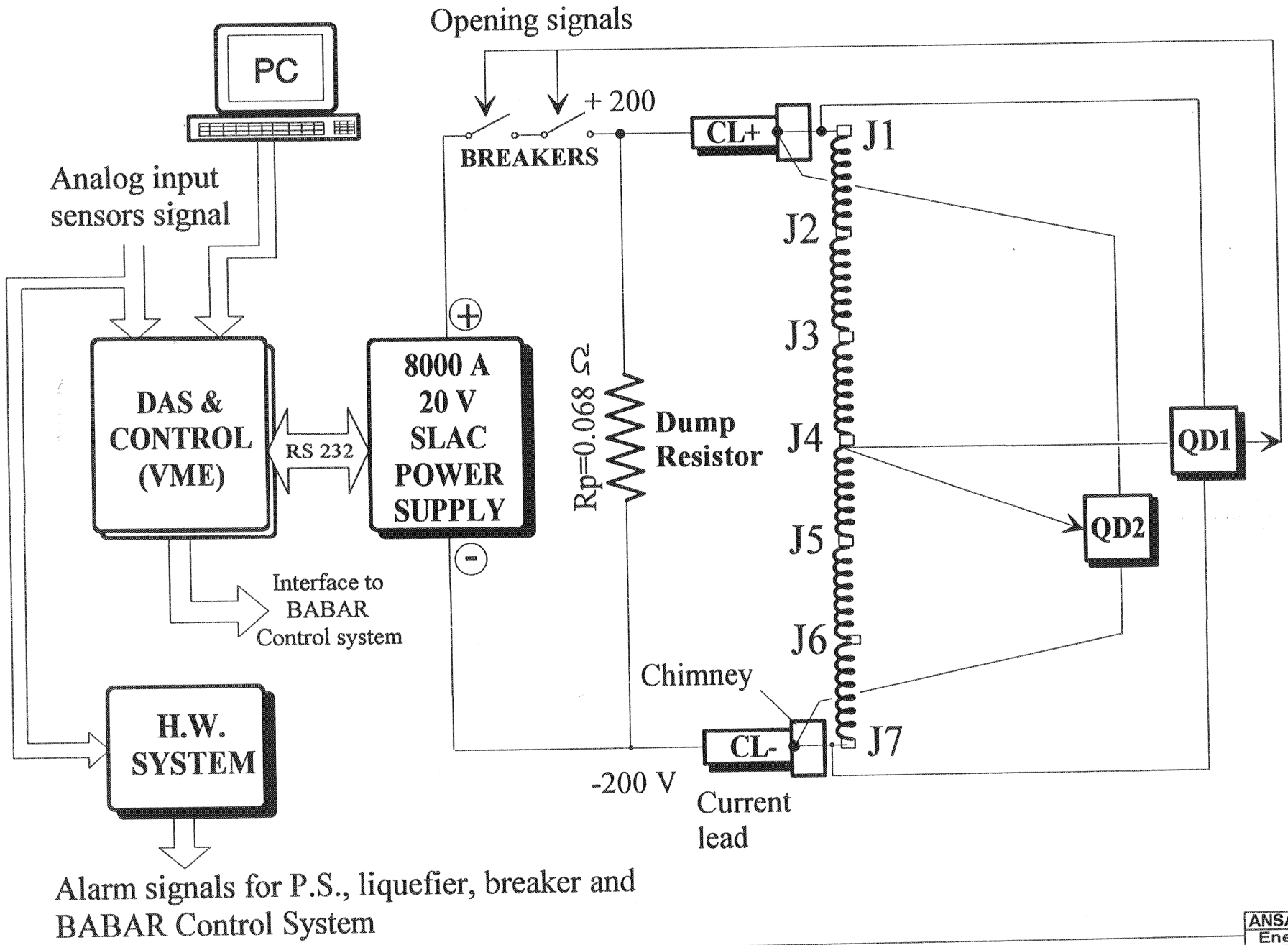
2° REVIEW OF BABAR SOLENOID

GENOA, 23-24 April 1996

5) MECHANICAL ANALYSIS OF THE CRYOSTAT INCLUDING THERMAL, MAGNETIC, MISPOSITIONING, WEIGHT AND HEARTHQUAKE LOADS

AEN

BABAR PROTECTION CONTROL SYSTEM



ANSALDO
Energia

PRINCIPAL DATA

$L = 2.584$ H

$Rp = 0.068\ \Omega$

$In = 4582$ A

$Id = 4811$ A

$Vdisch. = \pm 164$ V

average charge ramp (≤ 30 min) ≥ 2.68 A/s

$Vsol.\ charge \geq 7$ V

$\iota_{disch.} \leq L/Rp = 38$ s

$3\iota \leq 3$ min

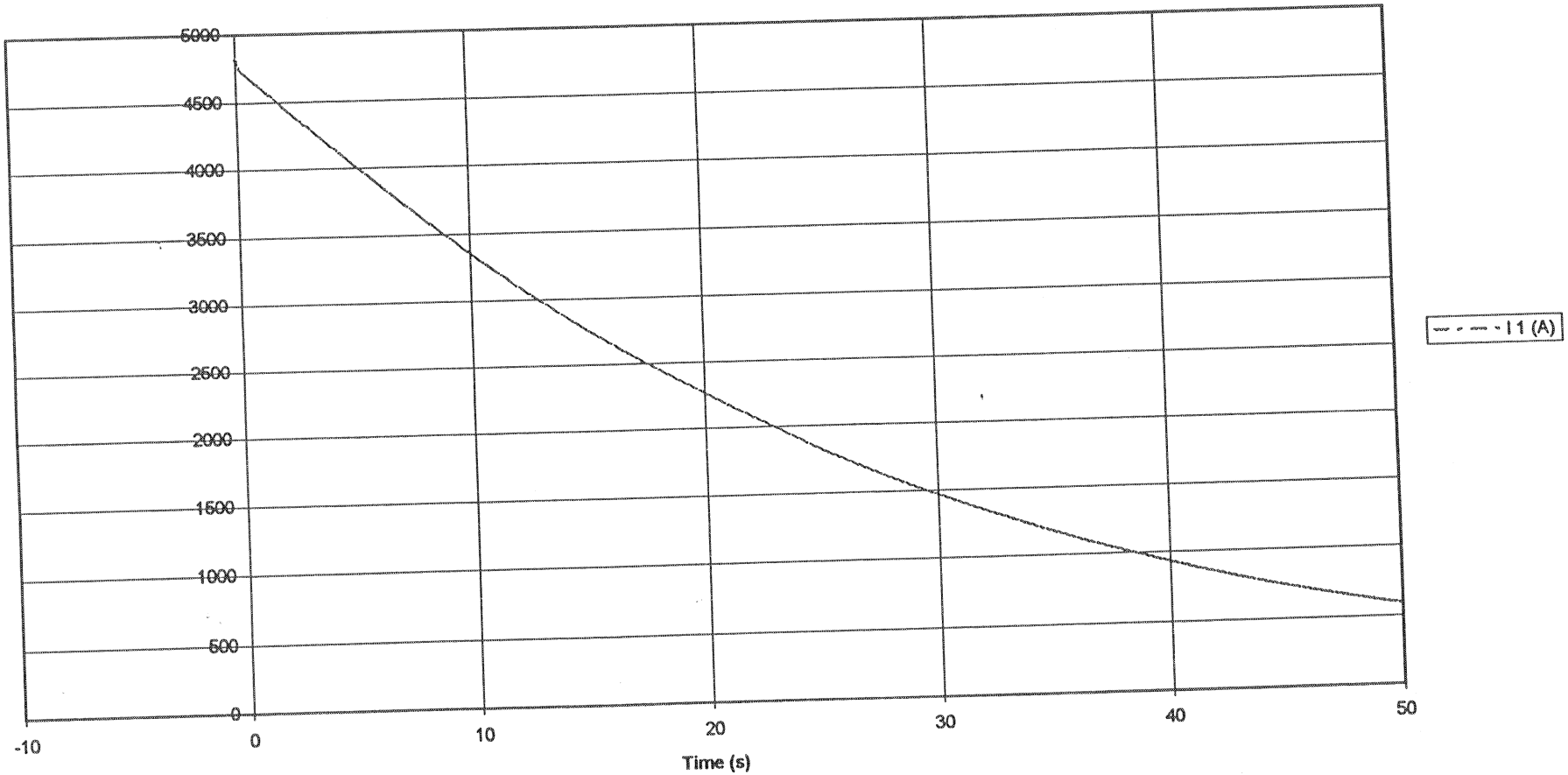
FINAL TEMPERATURE DURING QUENCH

	with Rp = 0.068 Ω	without Rp
FROM CENTER	50 K	160 K
FROM END	55 K	180 K

Solenoid current

CENTRAL PROTECTED

I 1 (A)

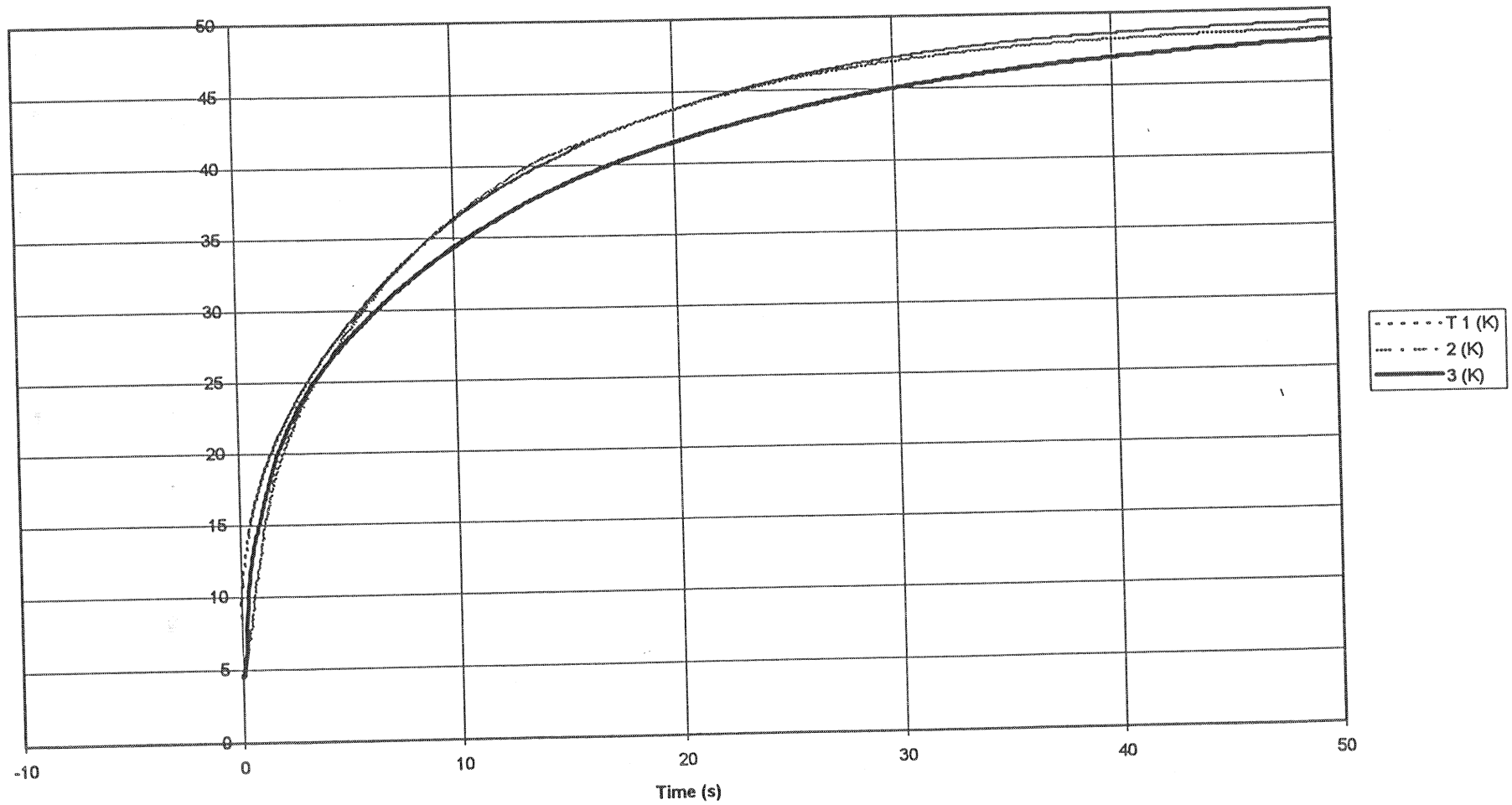


22/04/96

P. Valente

B_P_2S_1.XLS

Temperatures

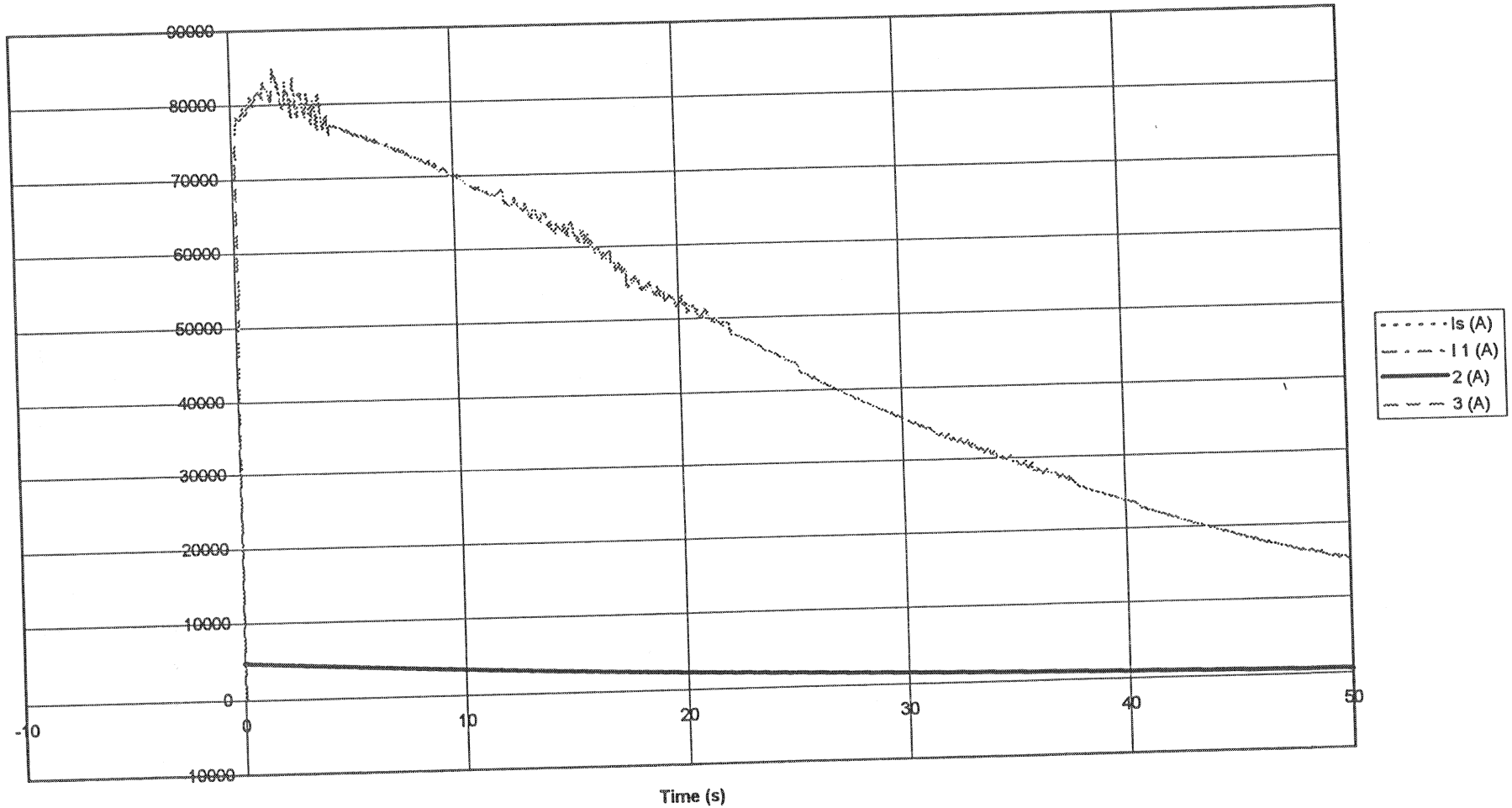


P. Valente

01/03/96

B_P_2S_1.XLS

Currents



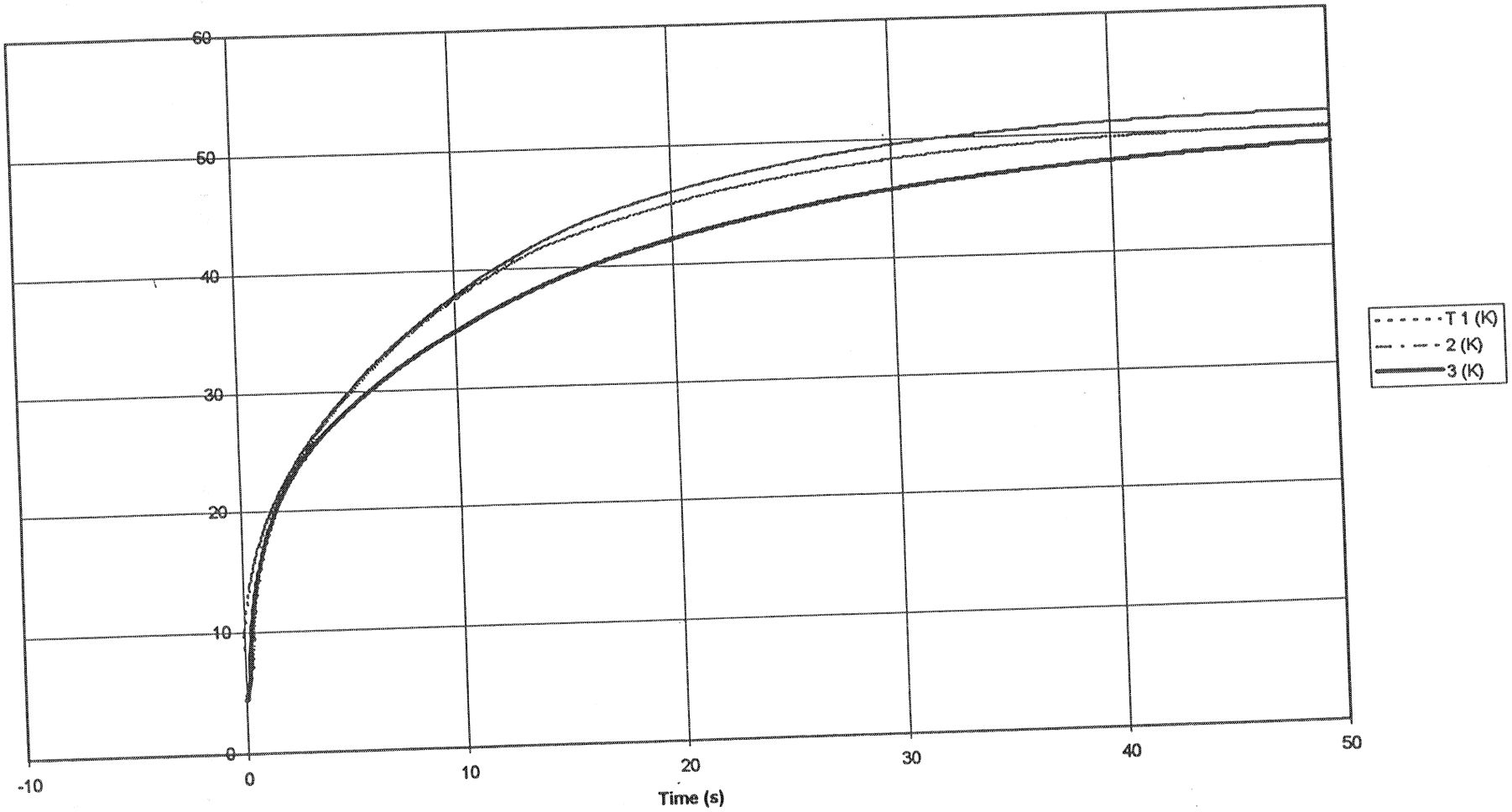
01/03/96

P. Valente

B_P_2S_1.XLS

END PROTECTED

Temperatures

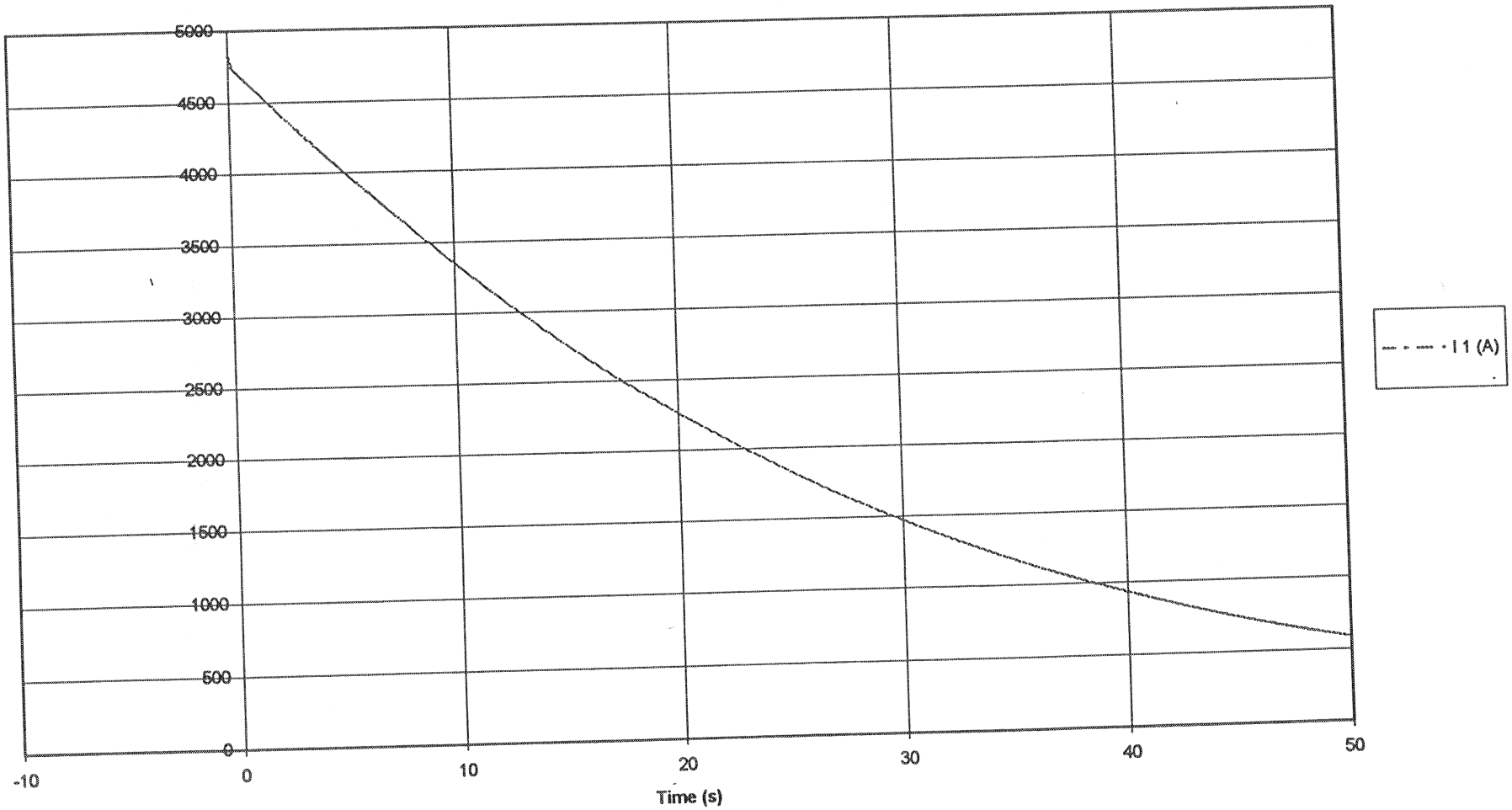


21/03/96

P. Valente

B_P_2S_3.XLS

Solenoid current

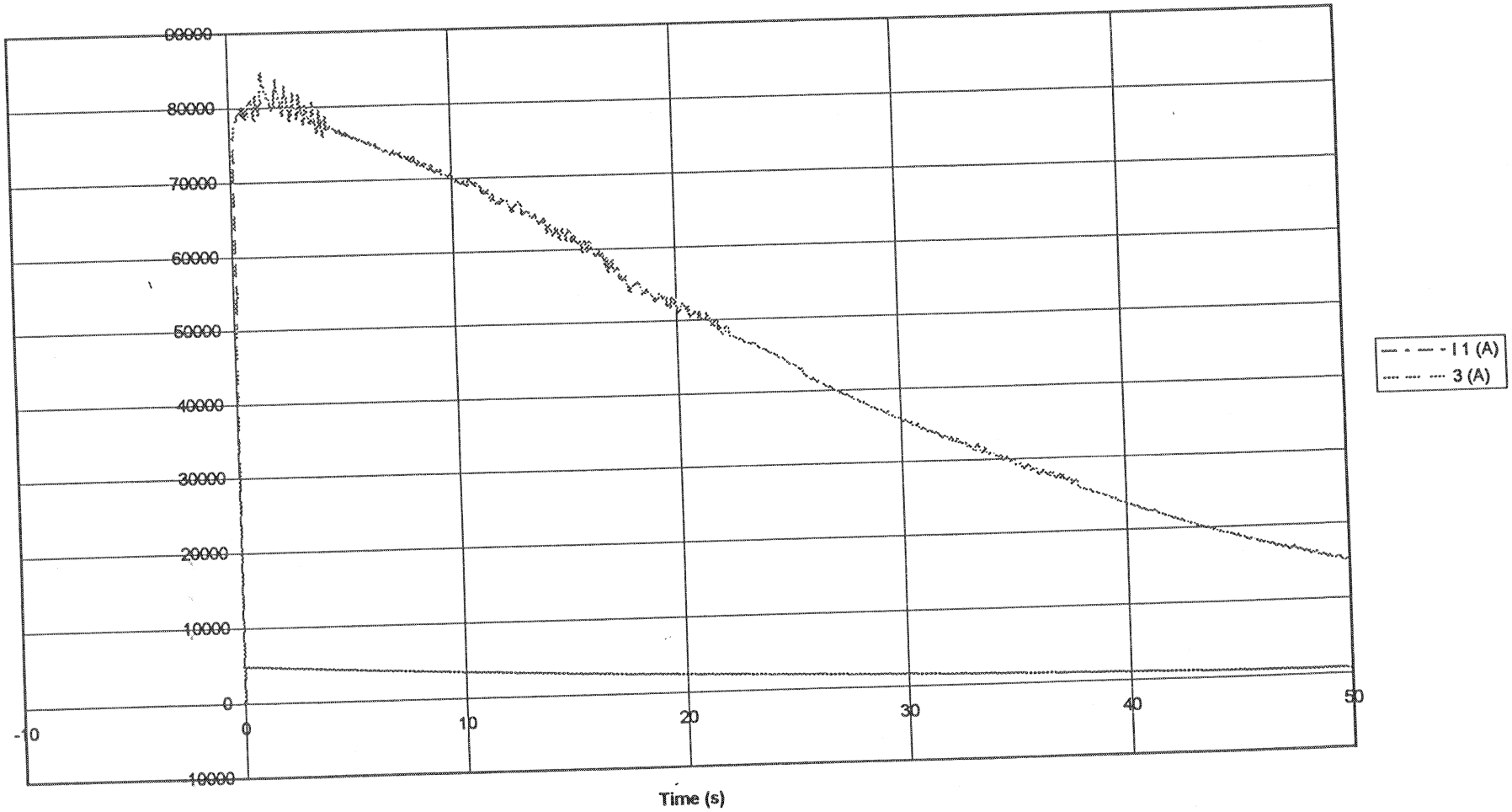


21/03/96

P. Valente

B_P_2S_3.XLS

Currents



21/03/96

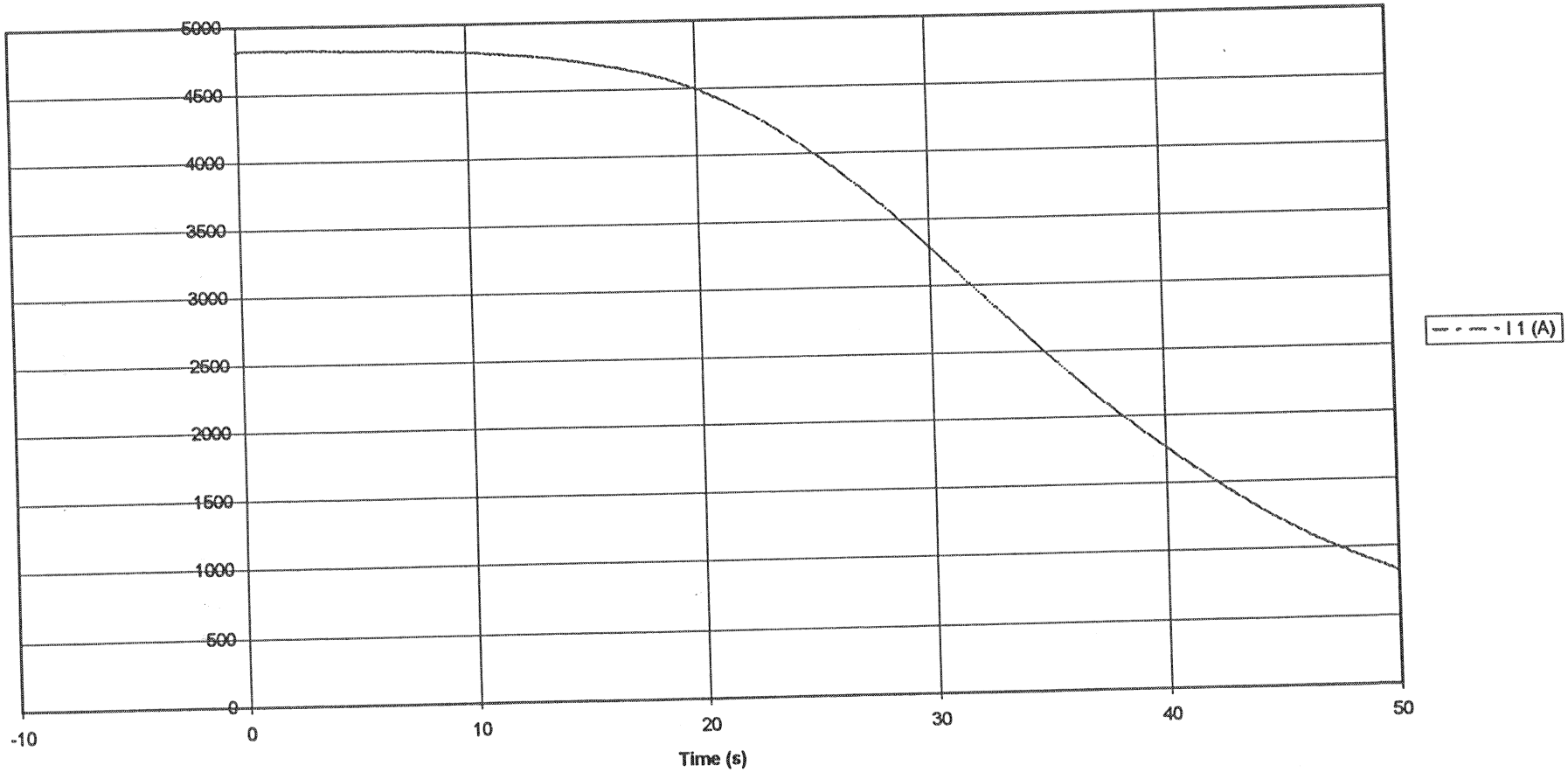
P. Valente

B_P_2S_3.XLS

Solenoid current

CENTRAL UNPROTECTED

I 1 (A)

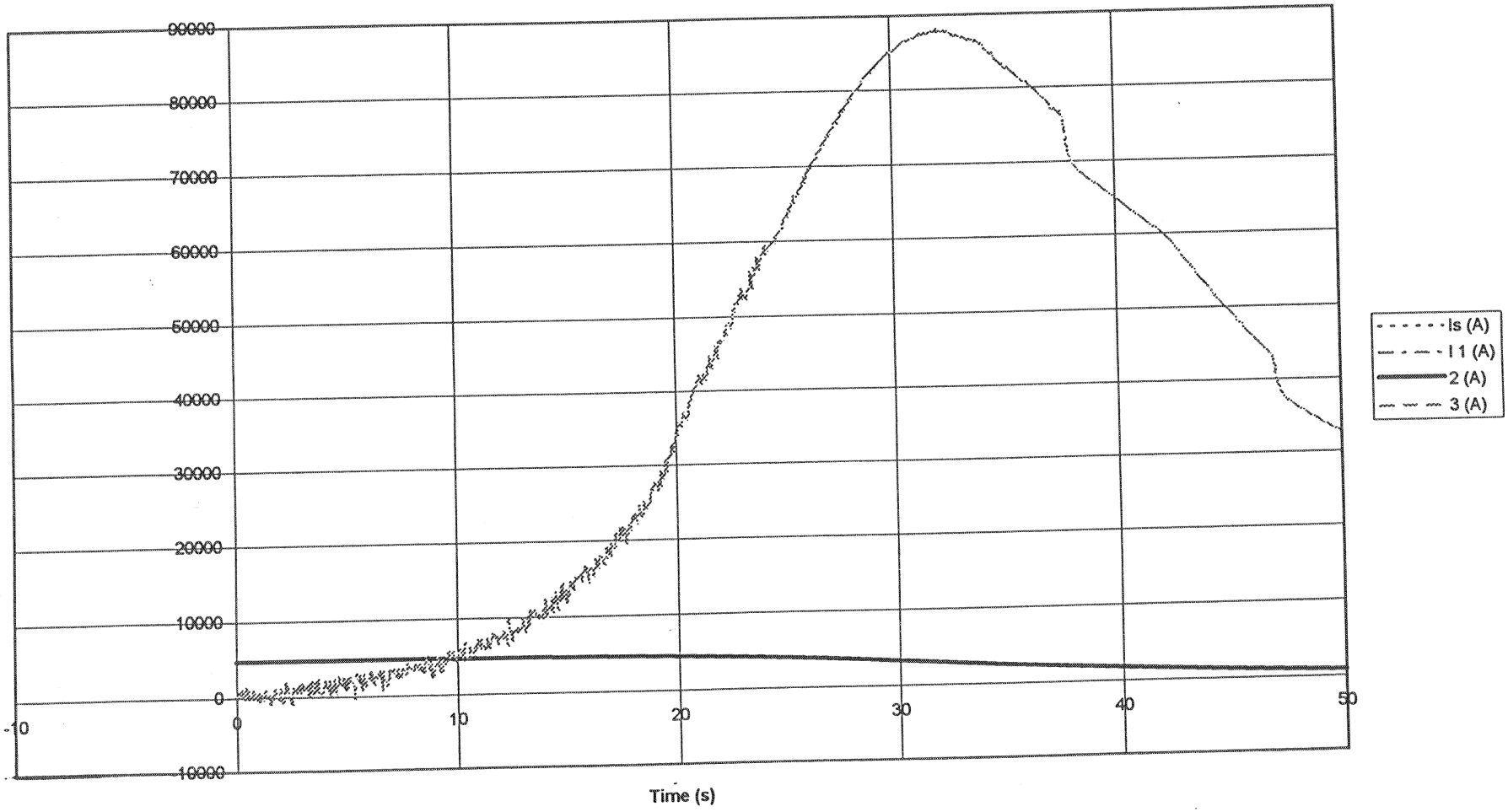


P. Valente

22/04/96

BAB_2S_7.XLS

Currents

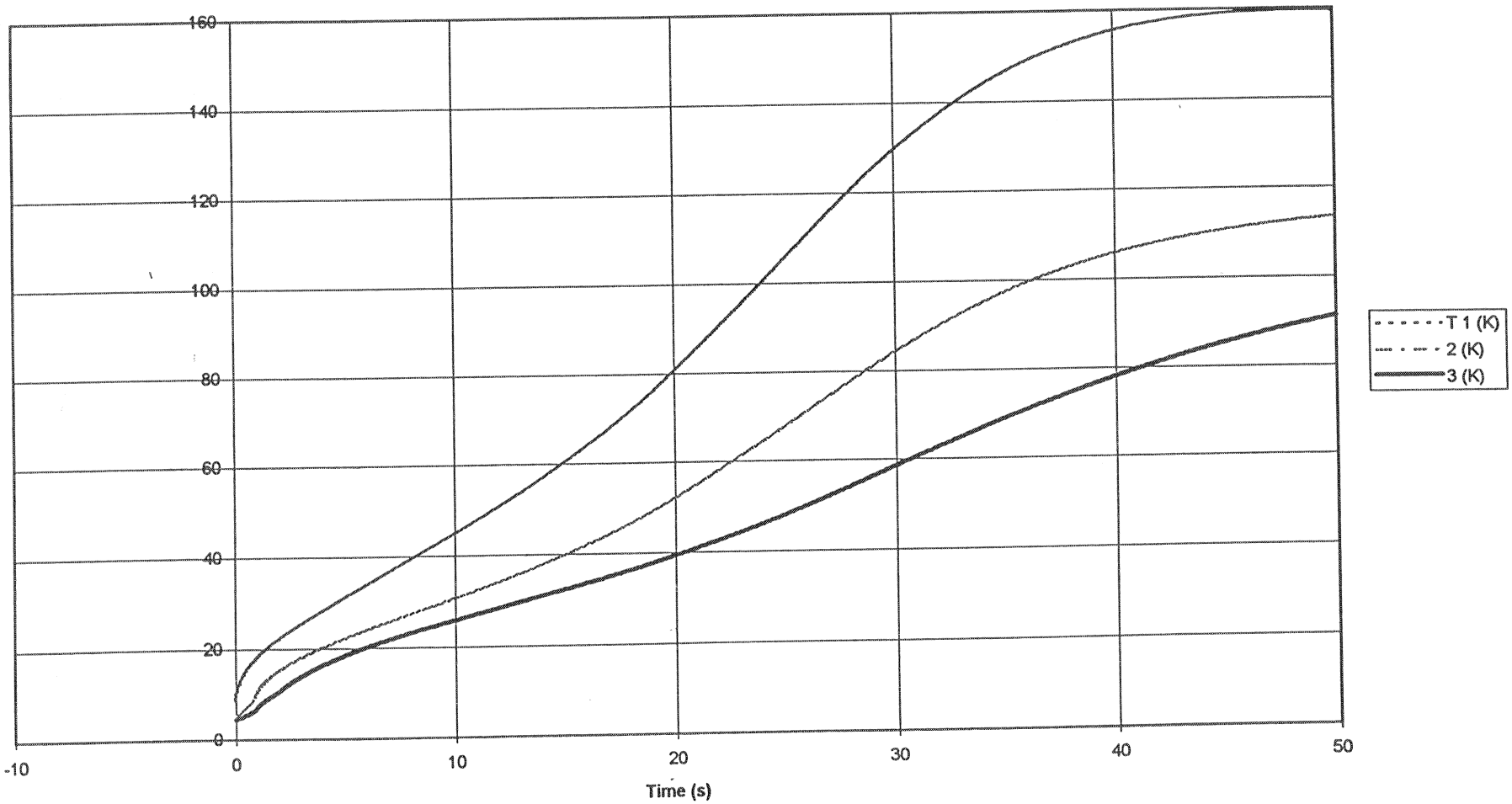


P. Valente

20/02/96

BAB_2S_7.XLS

Temperature



P. Valente

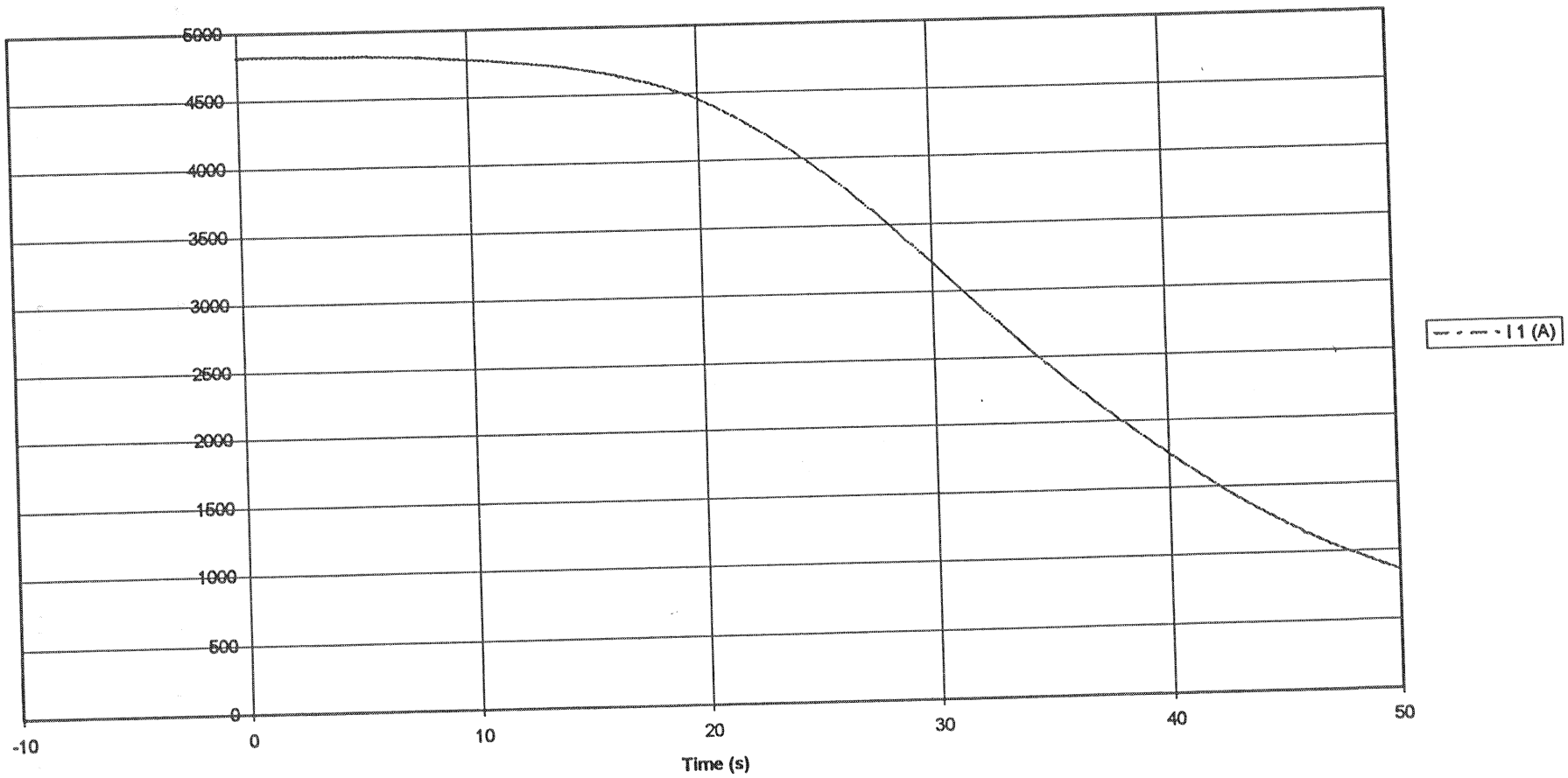
20/02/96

BAB_2S_7.XLS

Solenoid current

END UNPROTECTED

I 1 (A)

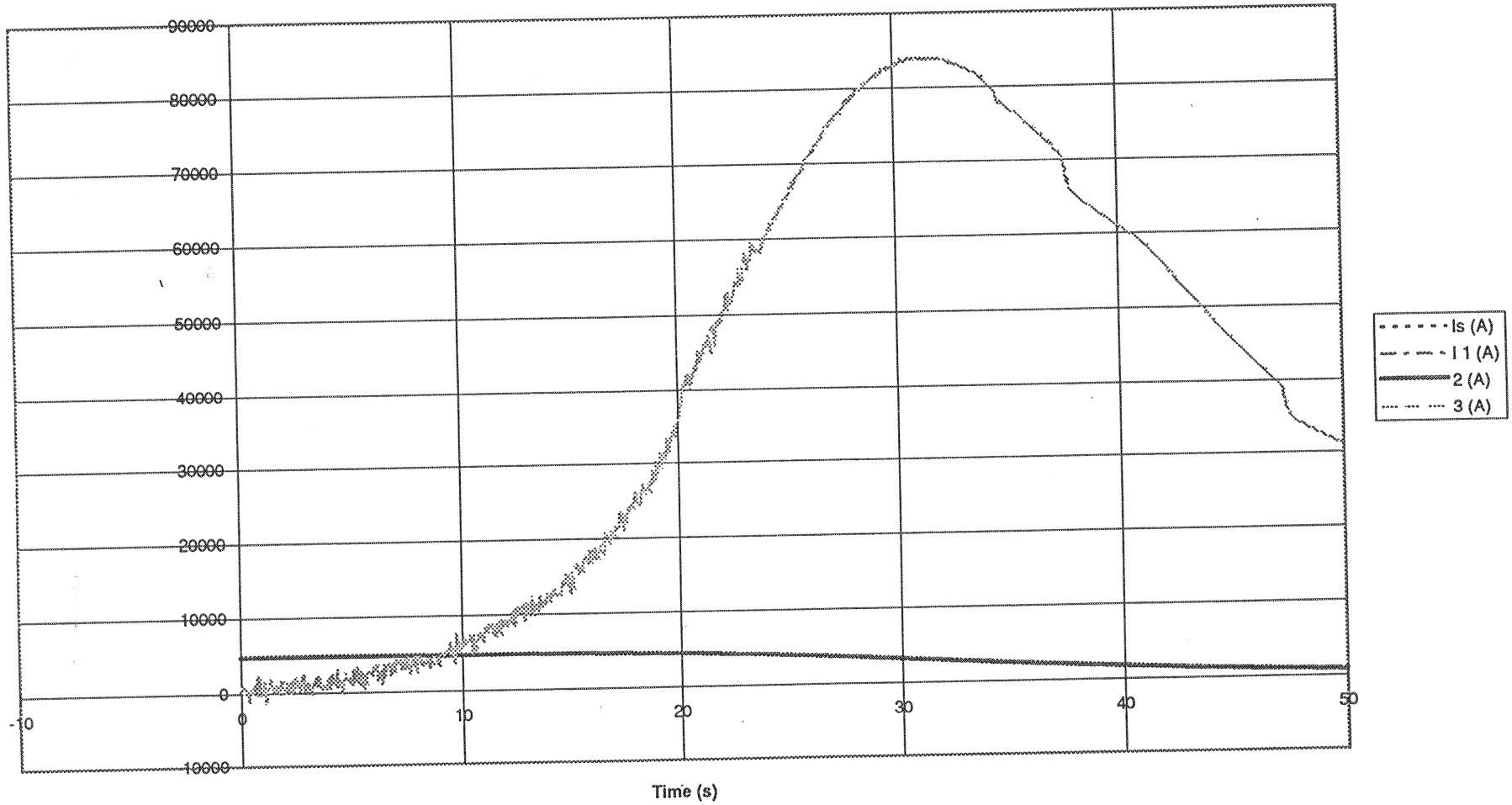


22/04/96

P. Valente

BAB_2S_8.XLS

Currents

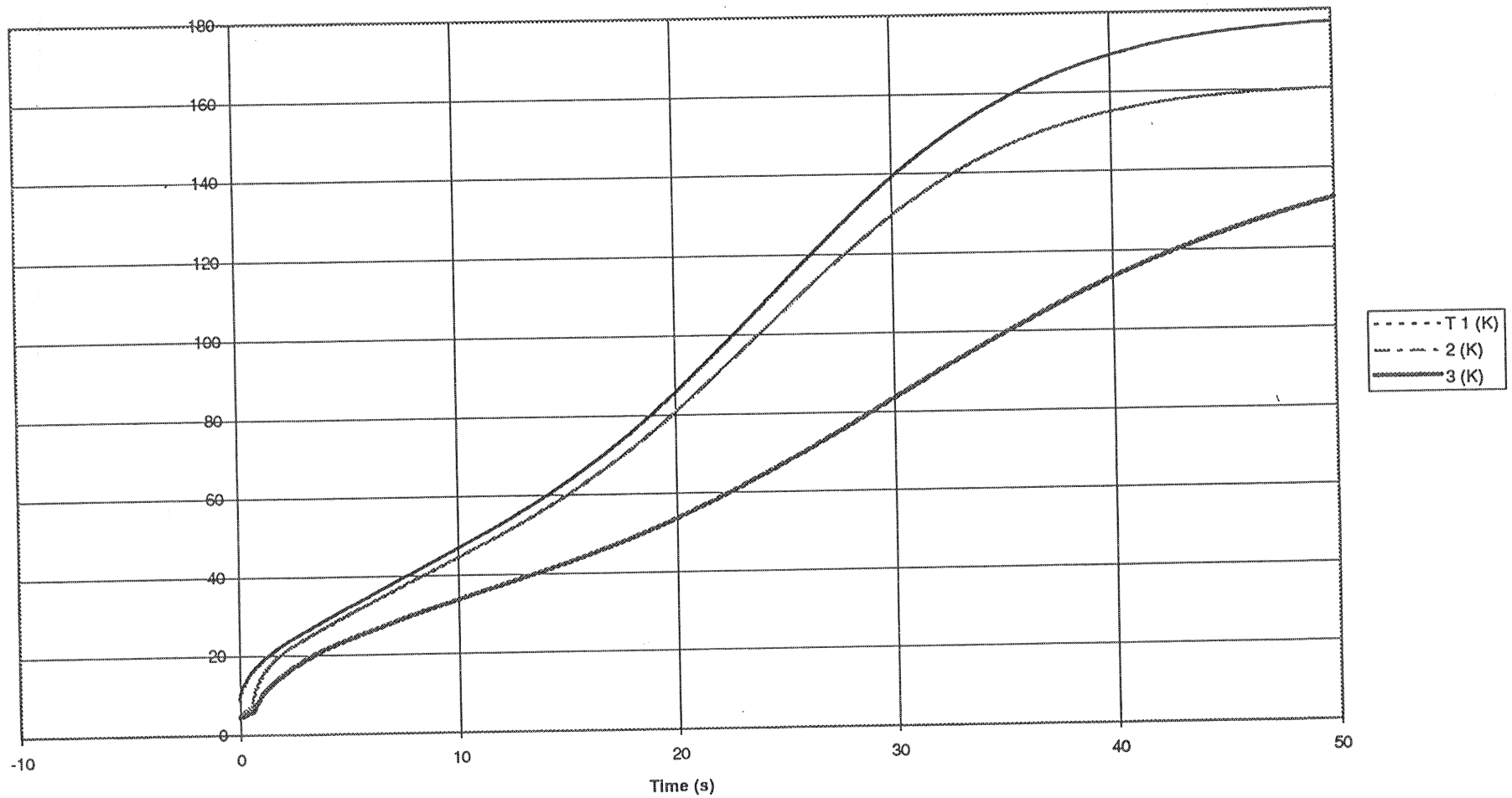


P. Valente

22/02/96

3AB_2S_8.XLS

Temperatures



BAB_2S_8.XLS

P. Valente

22/02/96

heat losses

		AlV64	AlV64	AISI316LN	AISI316LN
		80K	4.2K	80K	4.2K
Heat cond radial	W	15.34	1.27	63.85	5.50
Heat cond axial	W	10.01	0.83	32.82	2.83
Heat cond total	W	25.36	2.10	96.68	8.32

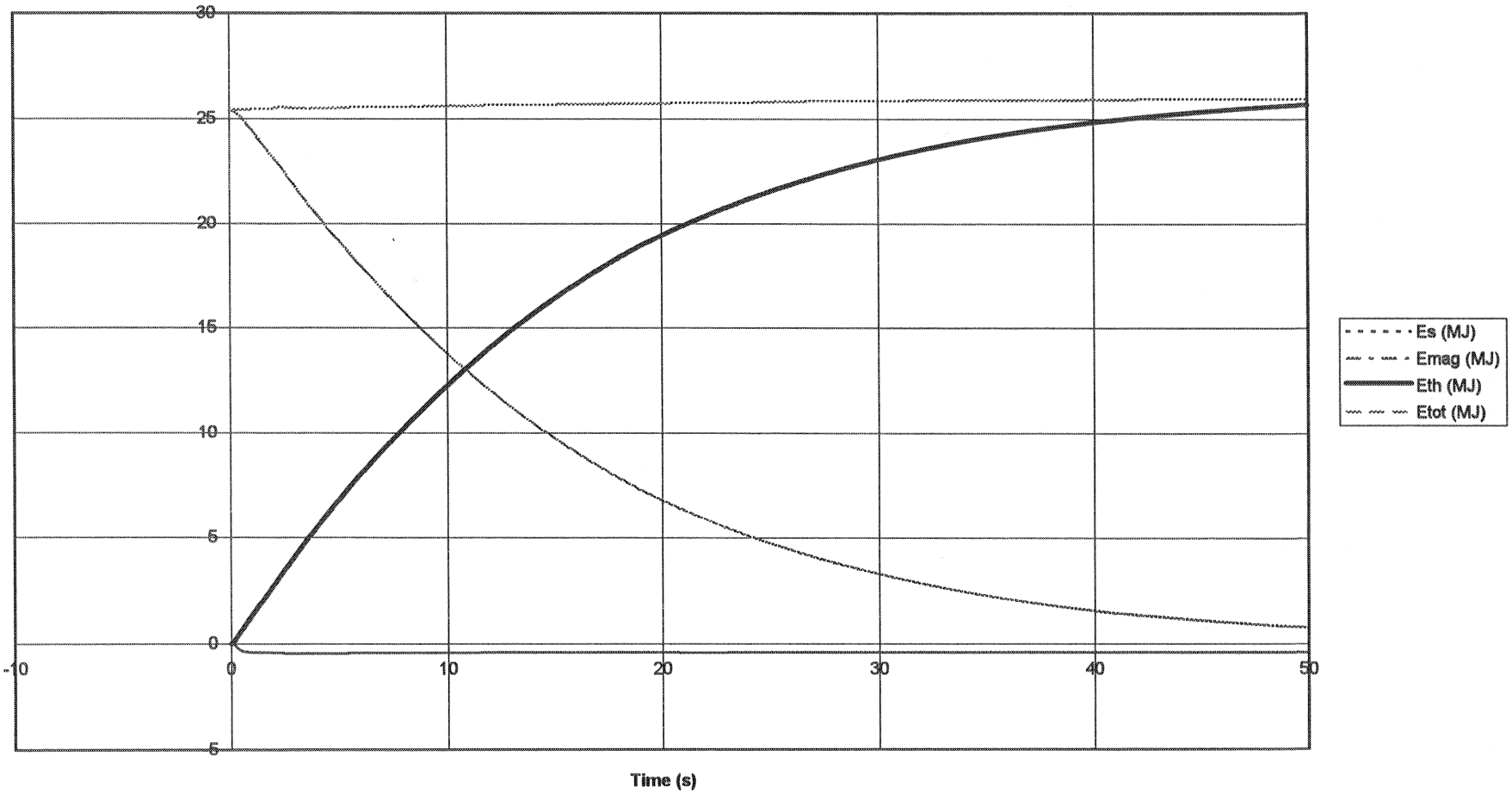
Con cilindro fluido
e [illegible] Senza Fo[illegible]

```
*Read ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
bab_2S_1.ind
bab_2S_1.mag
*Read output files
b2p_2S_1.I
b2p_2S_1.T
b2p_2S_1.R
b2p_2S_1.V
b2p_2S_1.th
*Read(title)
 babar 2 STRATI con cilindro 35 mm e non 6mm (sbagliato) con Rp dal centro
*Read(# of coils and coils grouping)
*  NbSn    NbTi Nrest   ngroup,      (ncc(i),i=1,ngroup)
   0      2     1     3          1 1 1
*nr1,nz1 for inductance accuracy calculations.
*s  ss  nr1  nz1  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are
intially shorted.
 1   1e6  2   400  1  1  0
 *Ti   dt    ntp  nl   tf    Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
 4.2  5.e-4   100 1000  50.0  .0  0   1    0   0   80.0 80.0   1      1    1      0     0     0
*
* i  a1   a2    Zmin    Zmax   Nt or j   cur  rrr  rcusc      fb   fpack    nr  nz  nl  rs   rsi   thb  thr   tins
i1i2itib Ti
1 1.5    1.521   -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.0006  0 0 0 0 4.5
2 1.521  1.5414  -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.001   0 0 0 0 4.5
3 1.5414 1.5774  -1.74   1.74    1       0.0    3    1.E5    0.0  1.0     1   80   1  0.0   0.0   0.0  0.0   0
0 0 0 0 4.5
*Nb3Sn coils(mat=3)
*i  mat  df   pitch   an    ap   bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
*NbTi coils (mat=1)
*i  mat  df   pitch   Bc2   T1T   TCRT     Pincont  alstab  RRRal   ratioa matb matr
 1   1  40e-6  .020   10.6  4.2   9.2    .38460E09   0.918   1000  .254    12   12
 2   1  40e-6  .020   10.6  4.2   9.2    .38460E09   0.918   1000  .254    12   12
*other windings
* i  mat  alstab RRRal  ratioa matb matr
 3   6    1.0    3      1.0    12   12
*
*  Read bore tube material and reinforcment material resistivities
*       Mat 1(ss)    Mat 2(Al)
        50e-8        3e-8
*
* ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
  1   1   1    40     41       8.5       0.0
*
*  xlength   diam,   xcus   Rs    ts    Temps   Rh(1)  2     3
    30000.  150    0.80    0.068  0.1    20.    1e10  1e10  1.e10
*Read generator properties if source is not zero
*Igen          Rx   freq. or Ramp rate   phase    Amplitude
  0           1e7            8      0.0     1000
*  Initial Currents(Currti(ig),ig=1,Ngroup)
      0 0 0
```

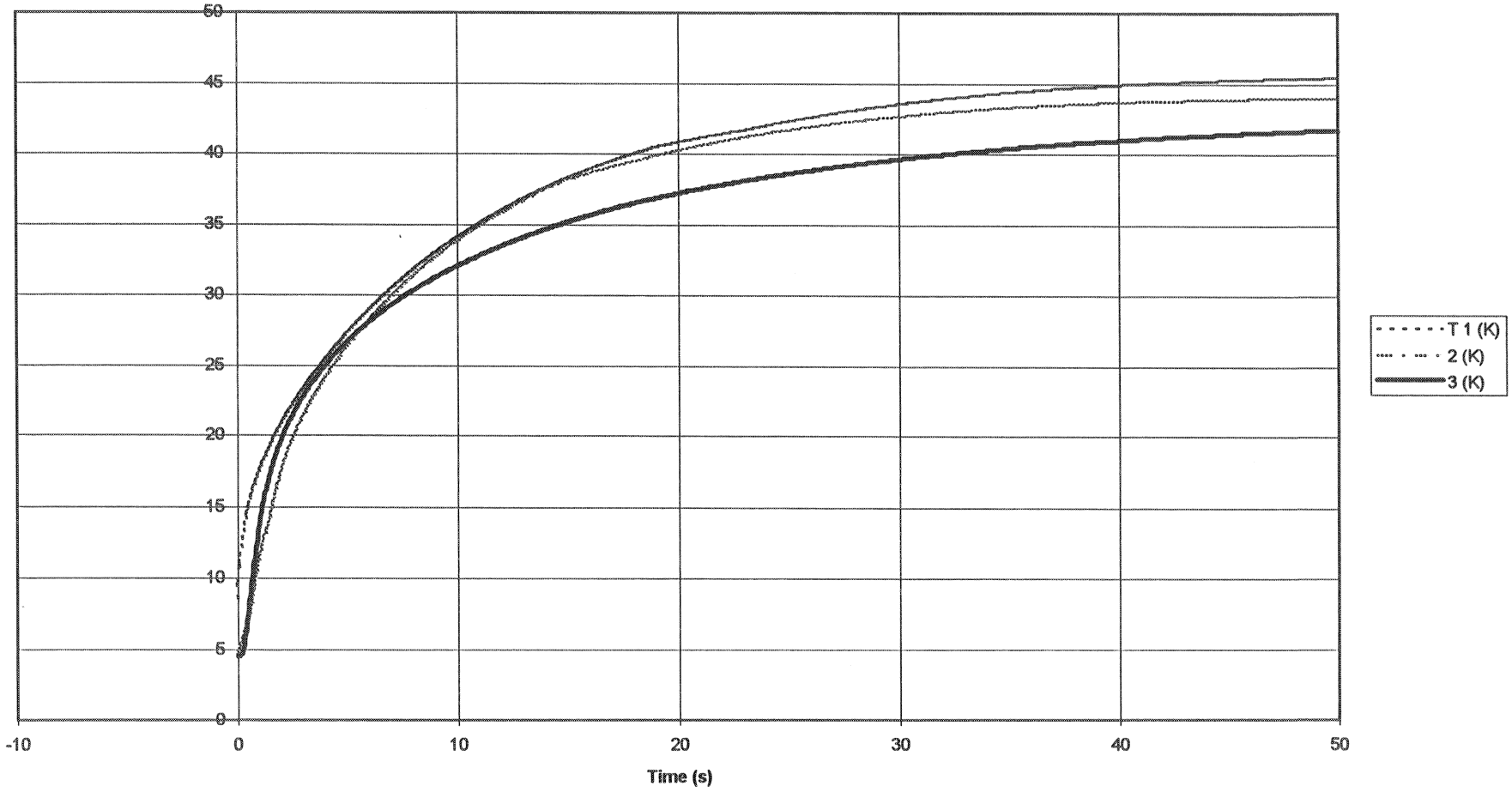
---

1 0.5477000000E+00 0.5440000000E+00 0.9900000000E-03
2 0.5440000000E+00 0.5570000000E+00 0.1020000000E-02
3 0.9900000000E-03 0.1020000000E-02 0.1900000000E-05

Energies

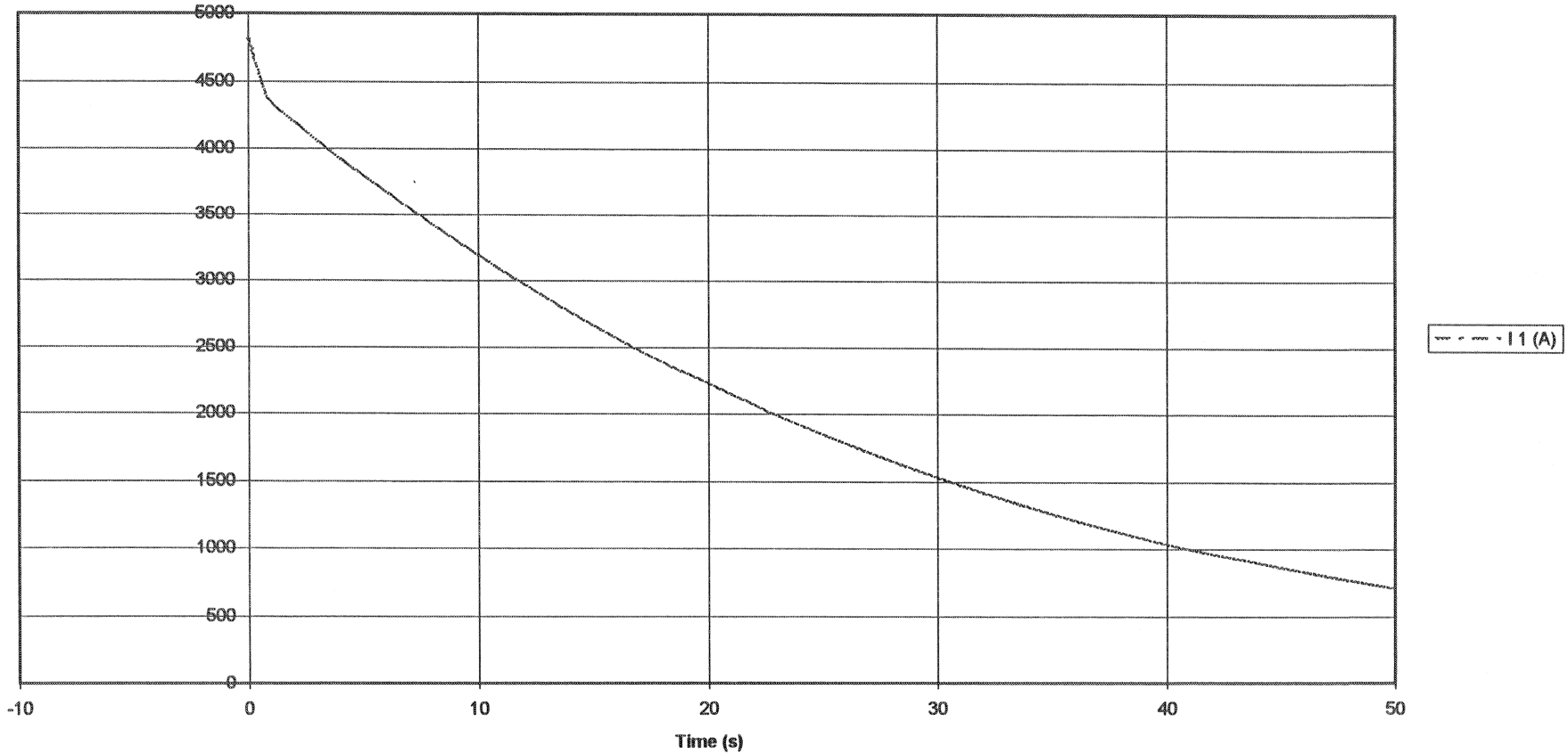

30
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
Time (s)
Es (MJ)
Emag (MJ)
Eth (MJ)
Etot (MJ)

Temperatures

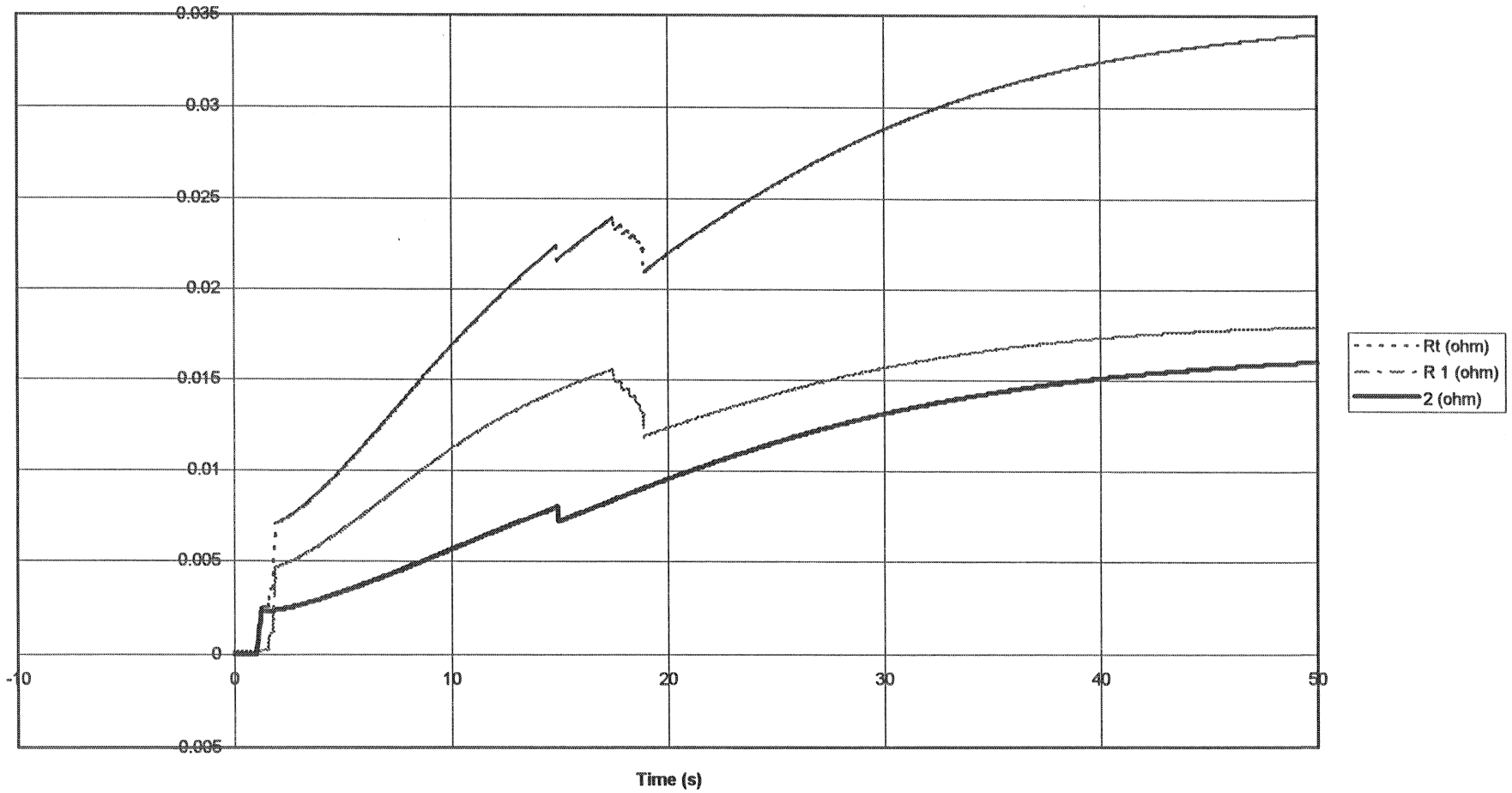


Solenoid current

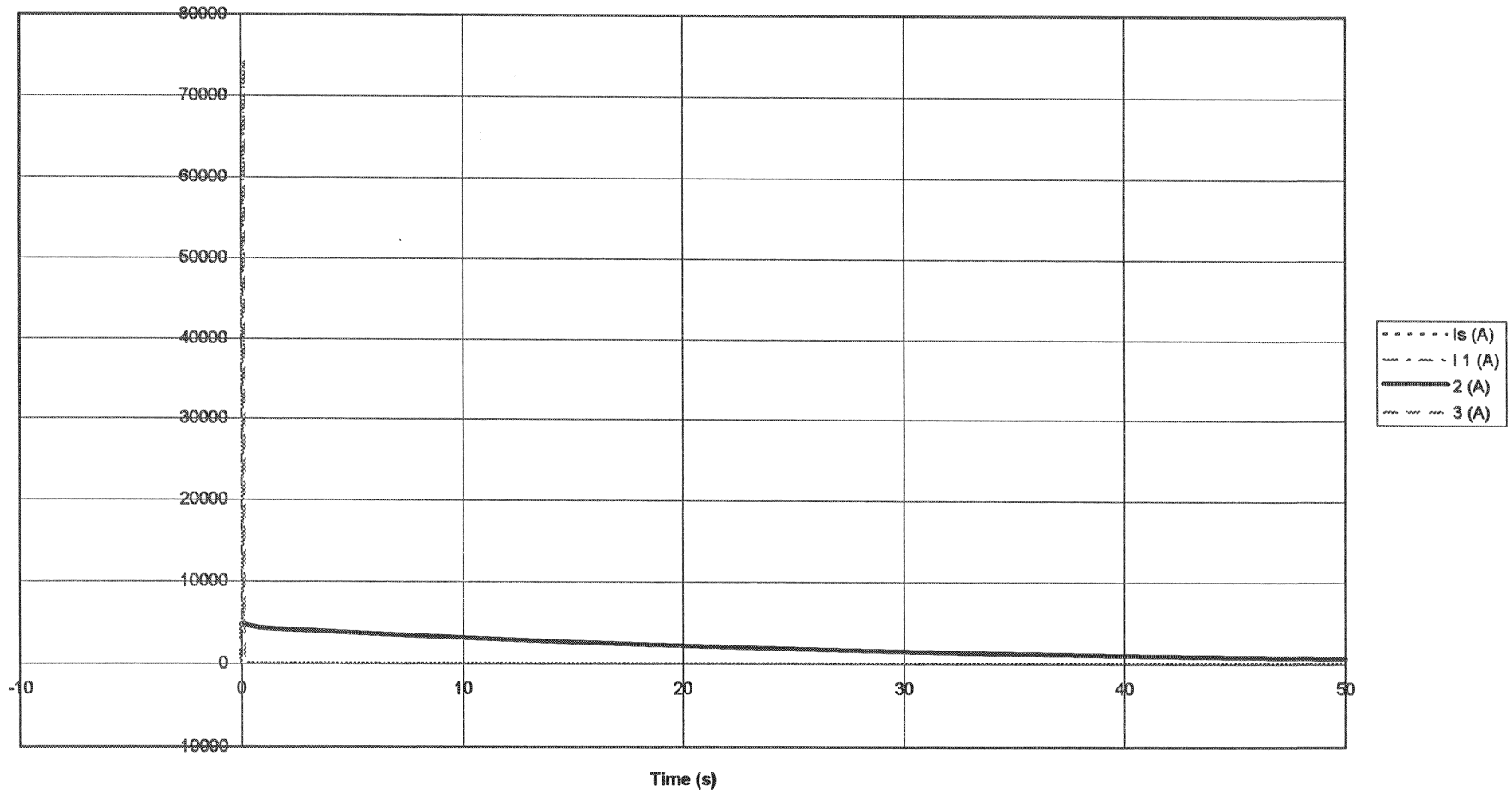
I 1 (A)



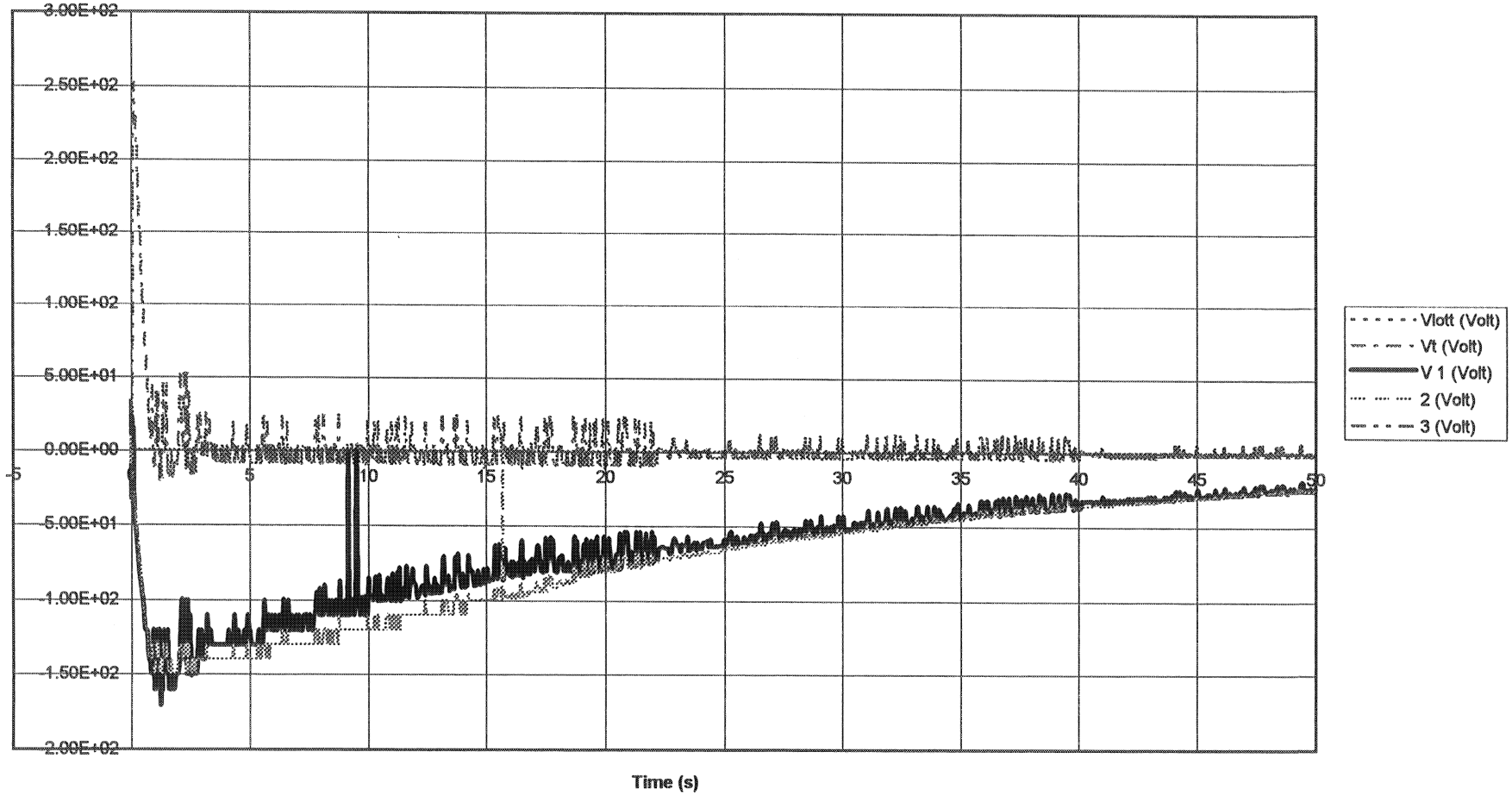
Resistances



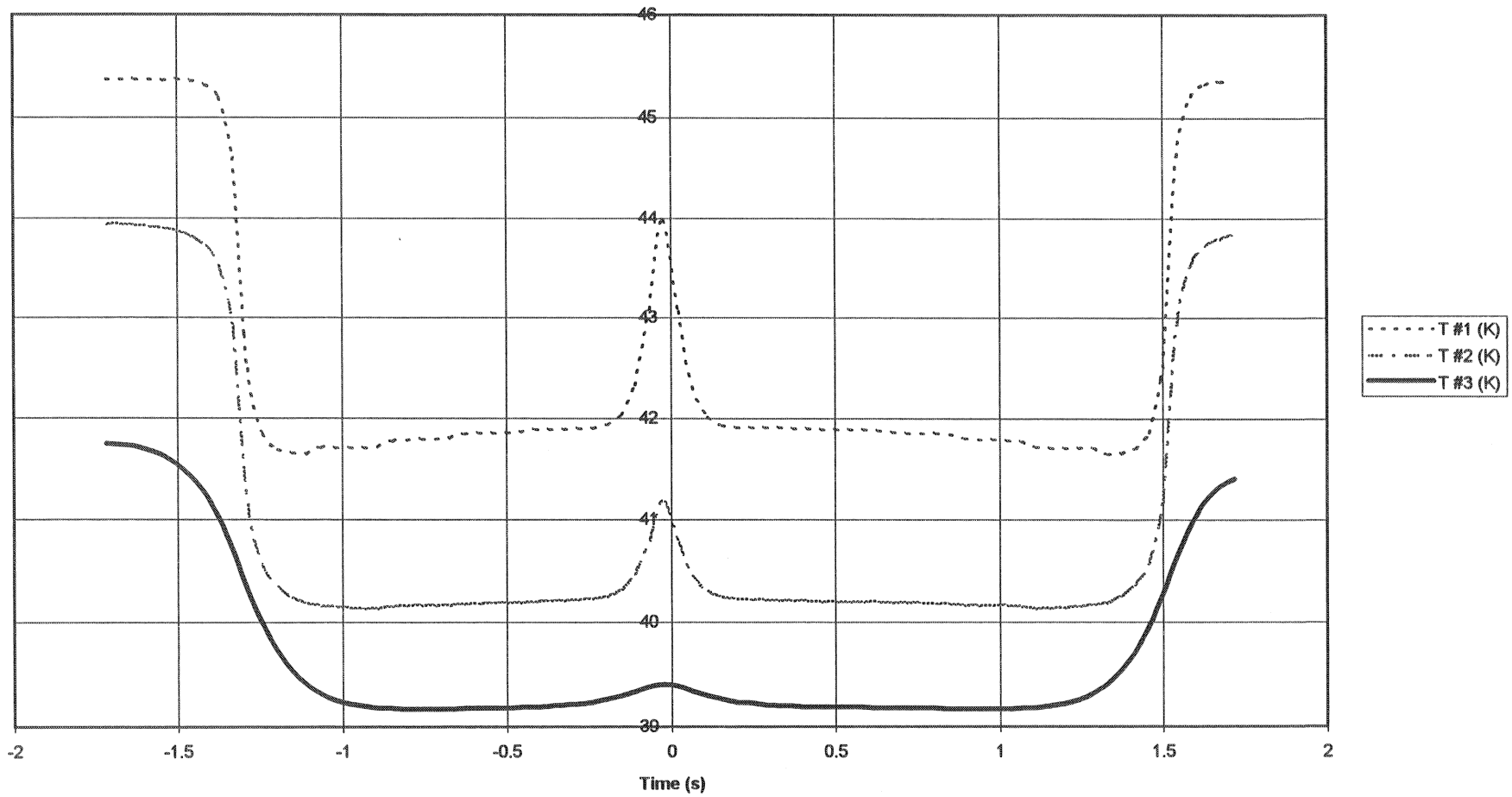
Currents


80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
-10
0
10
20
30
40
50
Time (s)
Is (A)
I 1 (A)
2 (A)
3 (A)

Voltages


3.00E+02
2.50E+02
2.00E+02
1.50E+02
1.00E+02
5.00E+01
0.00E+00
5.00E+01
1.00E+02
1.50E+02
2.00E+02
-5
5
10
15
20
25
30
35
40
45
50
Time (s)
Vlott (Volt)
Vt (Volt)
V 1 (Volt)
2 (Volt)
3 (Volt)

Temp. distrib. along z



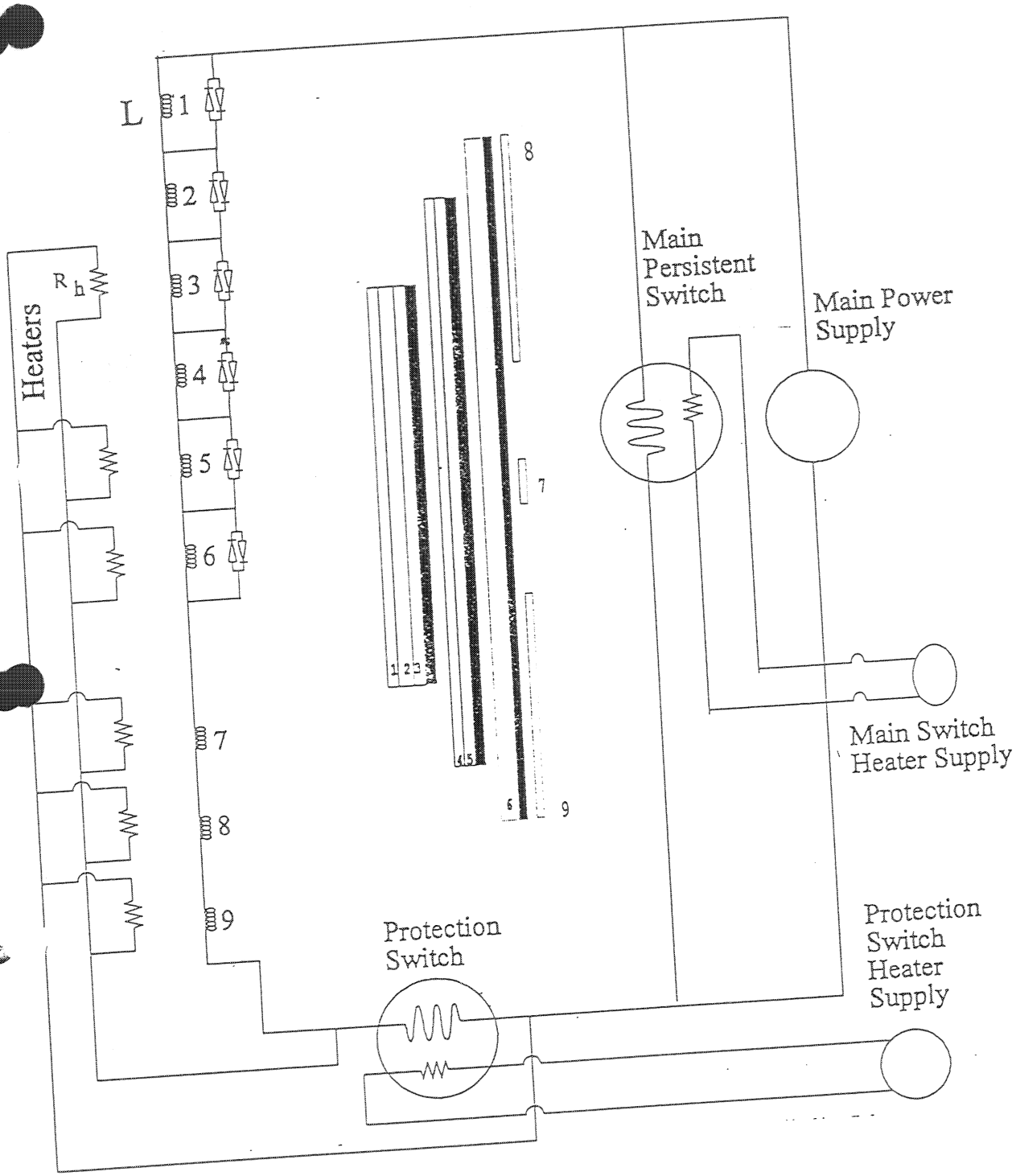


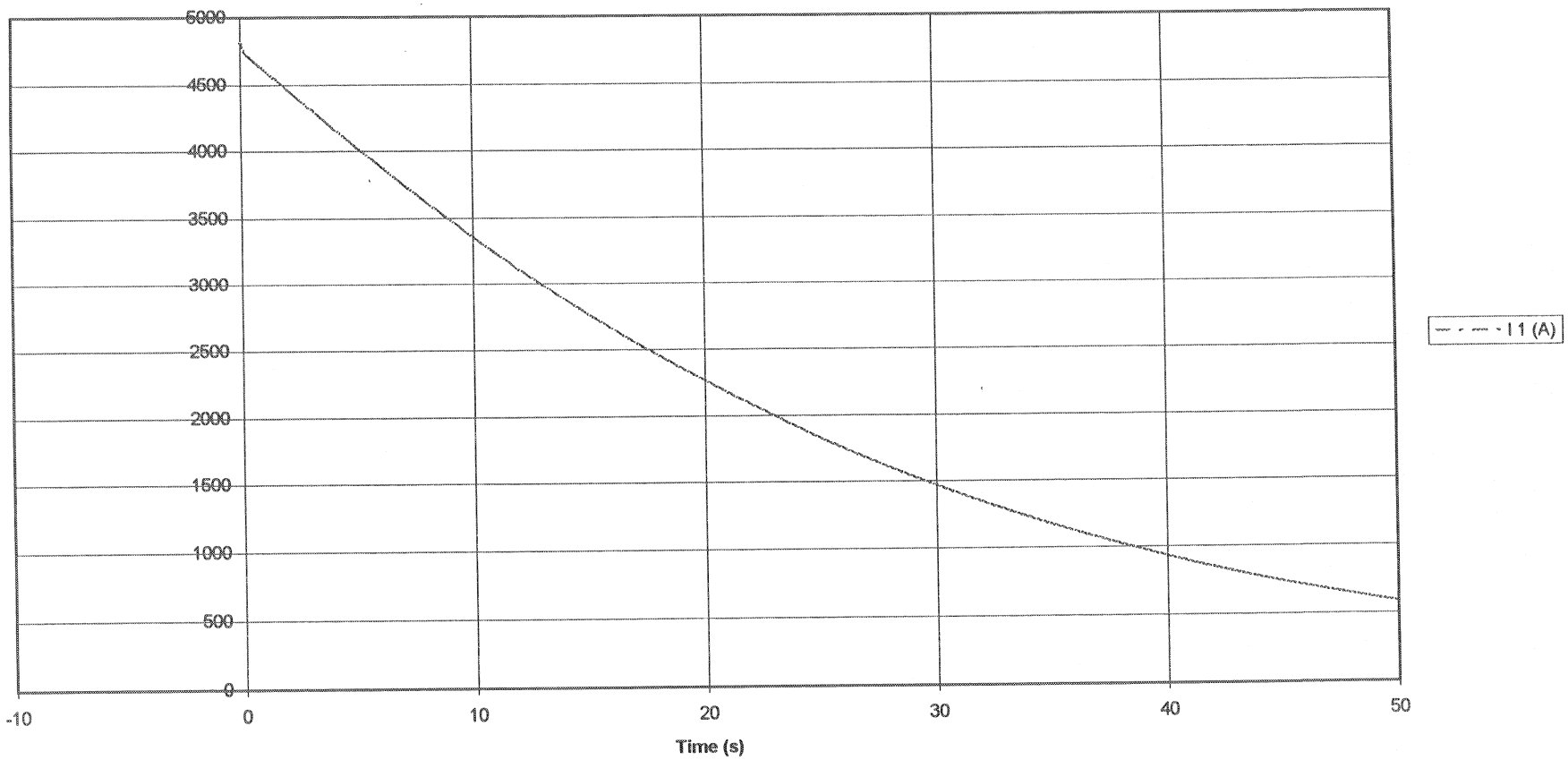
Fig.5 Examples 1 and 2; 9 coupled coils forming 7 circuits.

DATA: 01/03/96

```
*Read ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
bab_2S_1.ind
bab_2S_1.mag
*Read output files
b_p_2S_1.I
b_p_2S_1.T
b_p_2S_1.R
b_p_2S_1.V
b_p_2S_1.th
*Read(title)
 babar 2 STRATI quench con Rp=0.068 dal centro
*Read(# of coils and coils grouping)
* NbSn   NbTi Nrest   ngroup,     (ncc(i),i=1,ngroup)
   0     2     1     3          1 1 1
*nr1,nz1 for inductance accuracy calculations.
*s  ss  nr1  nz1  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are
intially shorted.
 1  1e6  2   400  1  1  0
 *Ti   dt   ntp  nl   tf   Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
 4.2  5.e-4   100 1000  50.0  .0  0  1   0  0  80.0 80.0  1     1   1     0    0    0
*
* i  a1   a2    Zmin    Zmax   Nt or j   cur  rrr  rcusc     fb   fpack    nr  nz  nl  rs   rsi   thb  thr   tins
i1i2itib Ti
1 1.5   1.521   -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.0006  0 0 0 0 4.5
2 1.521  1.5414  -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.001   0 0 0 0 4.5
3 1.5414 1.5474  -1.74   1.74    1       0.0    3    1.E5    0.0  1.0     1   80   1  0.0   0.0   0.0  0.0   0
0 0 0 0 4.5
*Nb3Sn coils(mat=3)
*i  mat  df   pitch   an    ap   bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
*NbTi coils (mat=1)
*i  mat  df   pitch   Bc2   T1T   TCRT     Pincont  alstab  RRRal   ratioa matb matr
 1   1  40e-6  .020   10.6  4.2   9.2    .38460E09   0.918   1000  .254    12   12
 2   1  40e-6  .020   10.6  4.2   9.2    .38460E09   0.918   1000  .254    12   12
*other windings
* i  mat  alstab RRRal  ratioa matb matr
 3   6    1.0    3      1.0    12   12
*
*  Read bore tube material and reinforcment material resistivities
*       Mat 1(ss)    Mat 2(Al)
         50e-8        3e-8
*
* ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
   1   1   1    40      41      8.5       0.0
*
*  xlength   diam,   xcus   Rs     ts   Temps   Rh(1)   2     3
    30000.  150    0.80    0.068  0.1    20.    1e10  1e10  1.e10
*Read generator properties if source is not zero
*Igen          Rx   freq. or Ramp rate   phase    Amplitude
  0           1e7            8      0.0     1000
*  Initial Currents(Currrti(ig),ig=1,Ngroup)
       0 0 0
```

Solenoid current

I 1 (A)

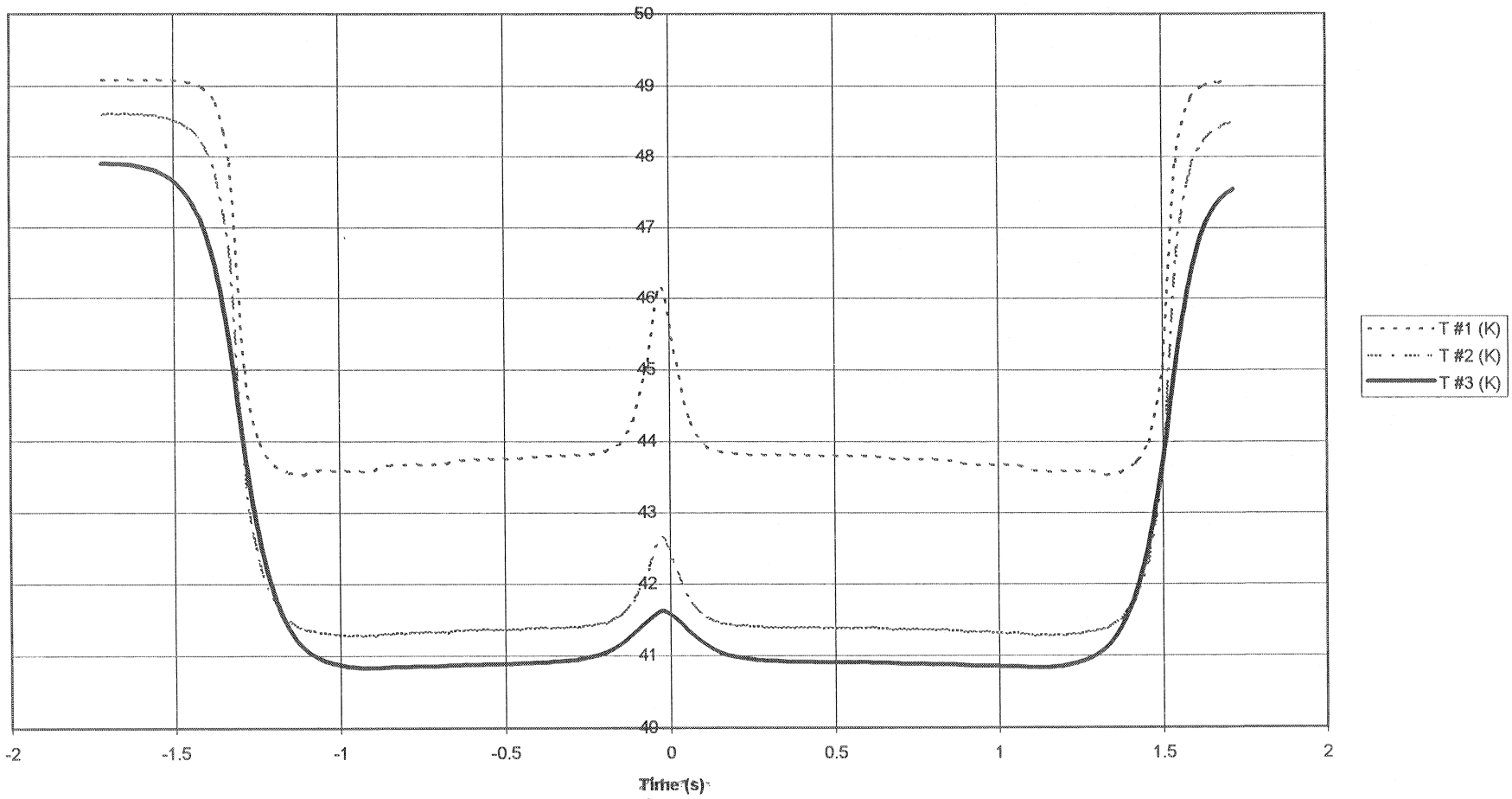


B_P_2S_1.XLS

P. Valente

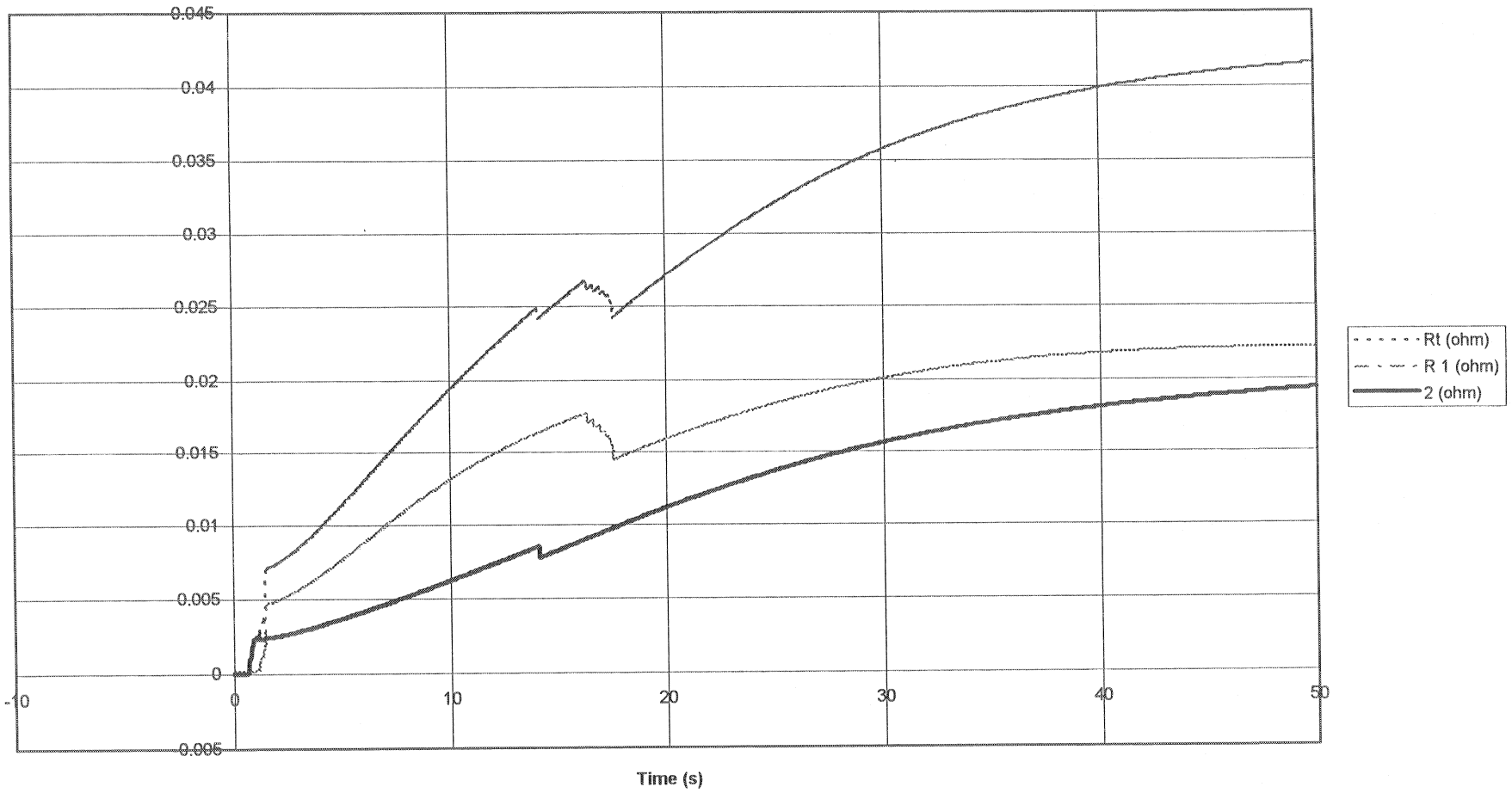
22/04/96

Temp. distrib. along z

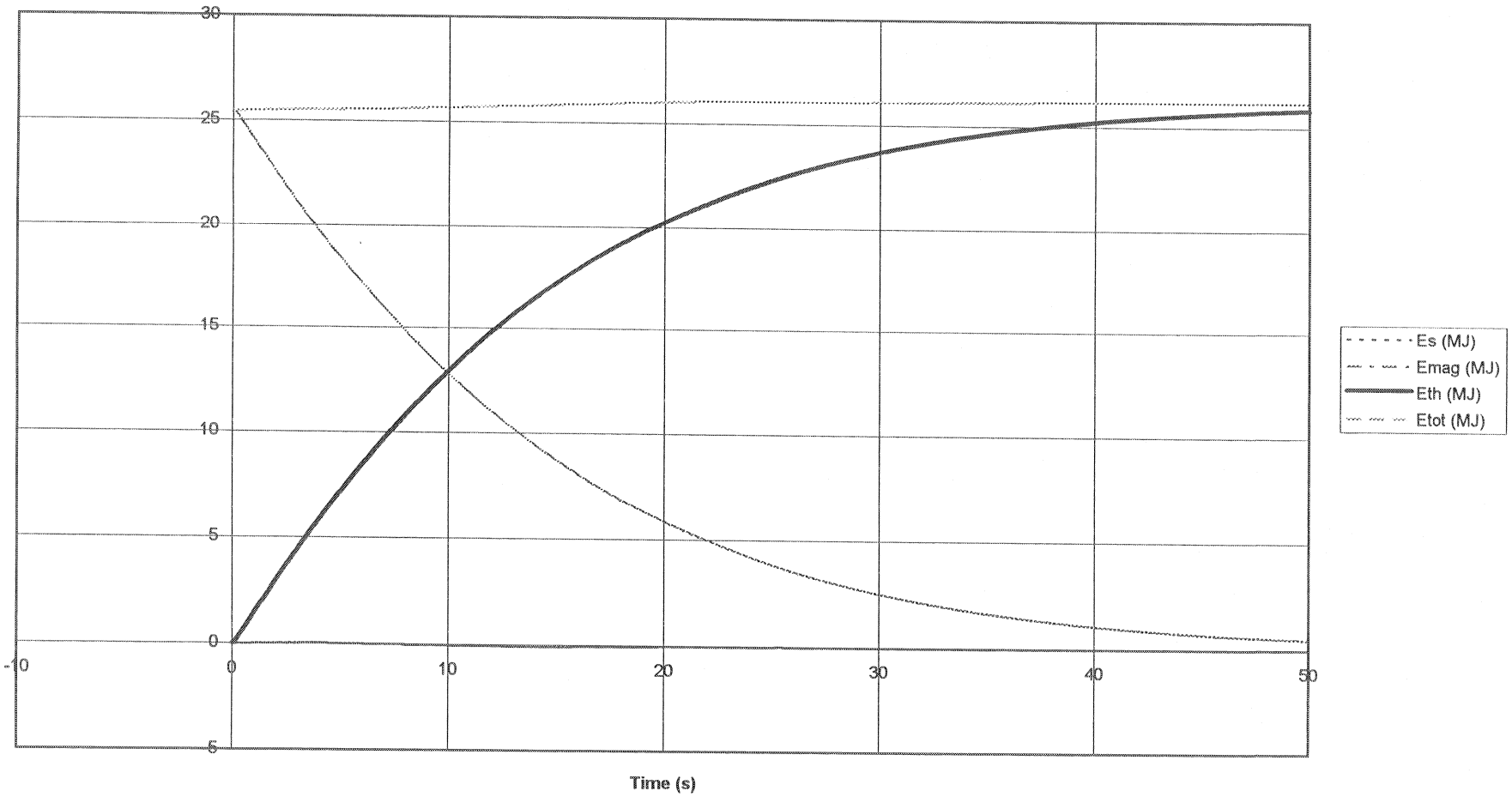


z axis

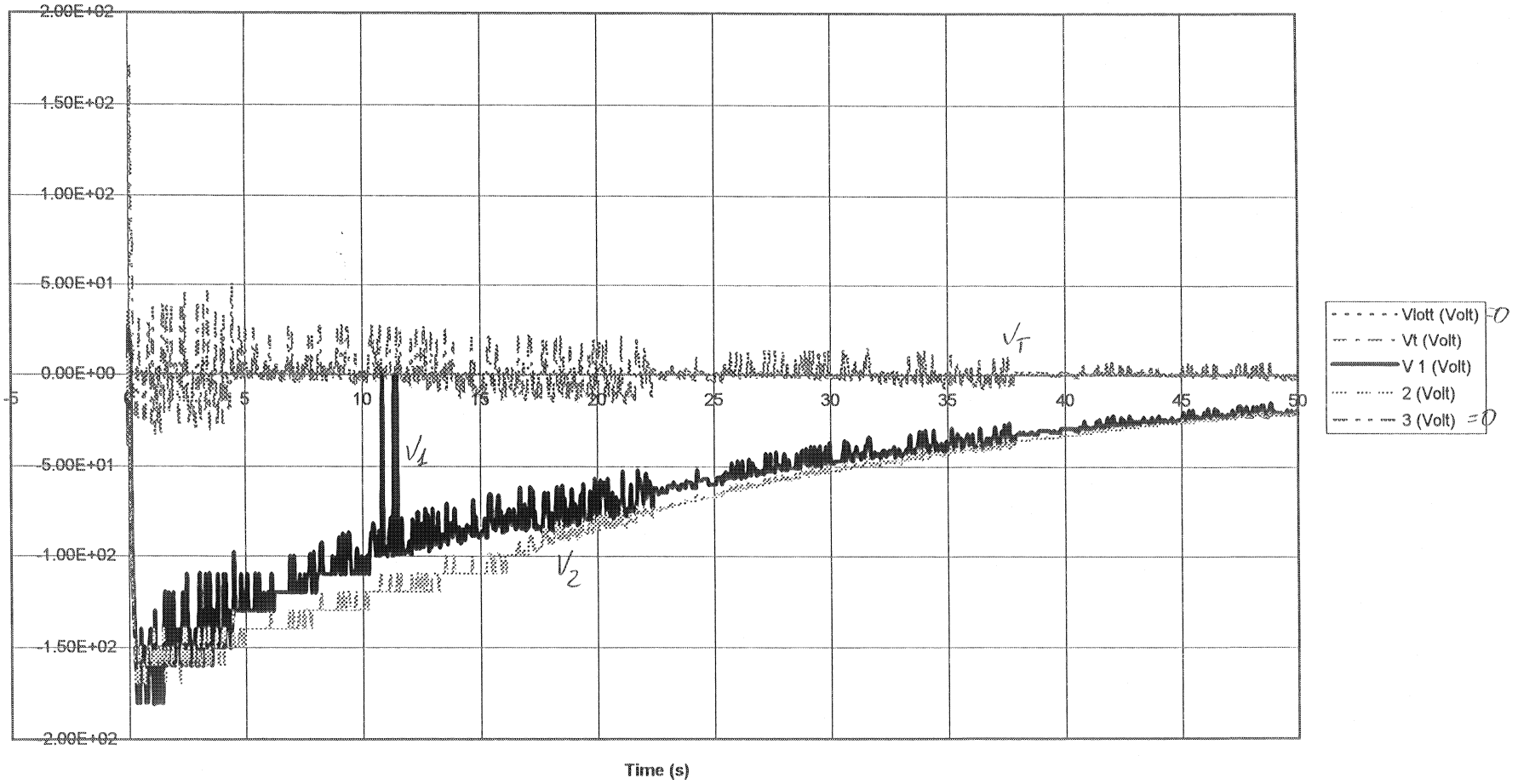
Resistances



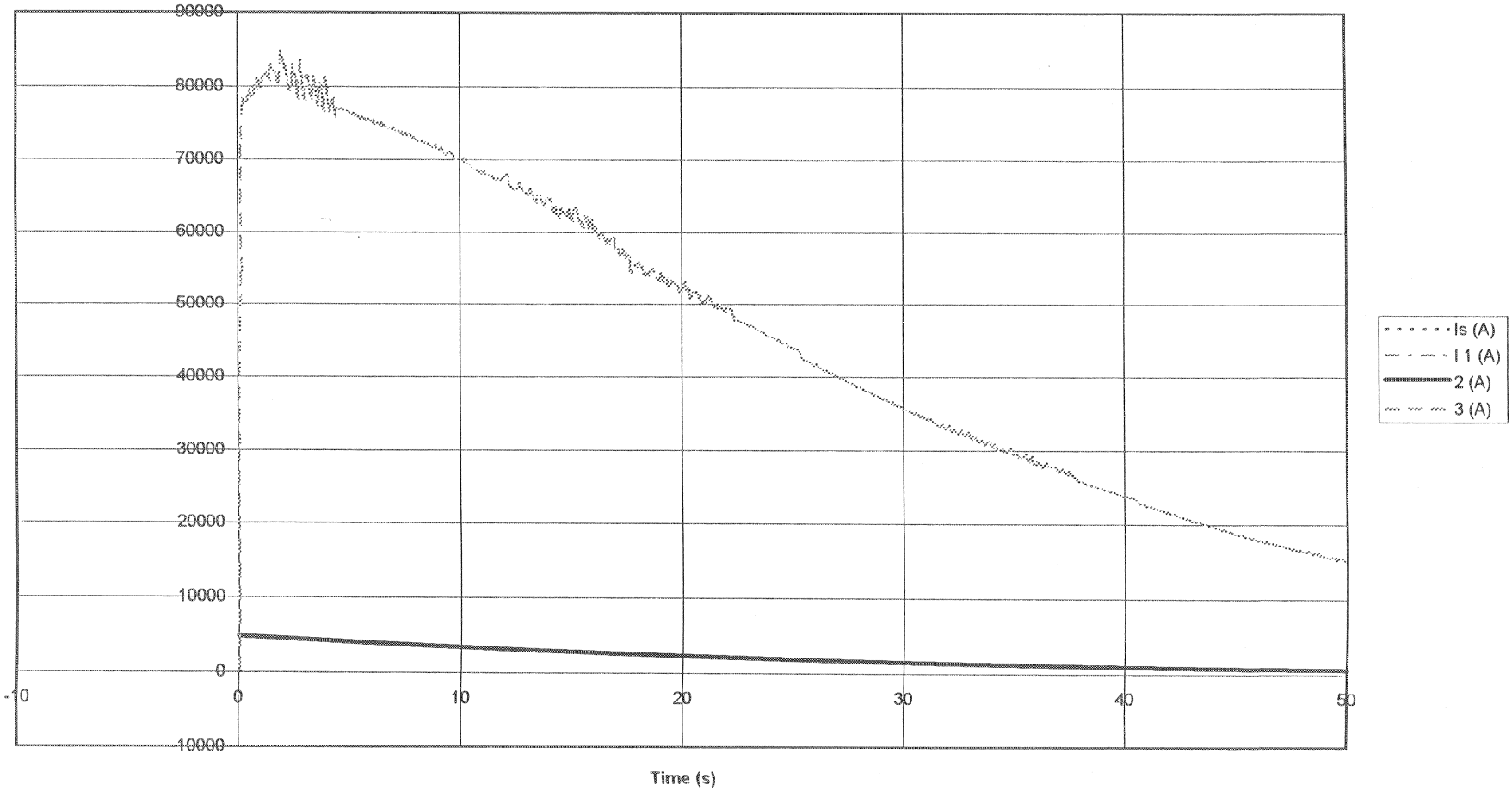
Energies


30
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
Time (s)
Es (MJ)
Emag (MJ)
Eth (MJ)
Etot (MJ)

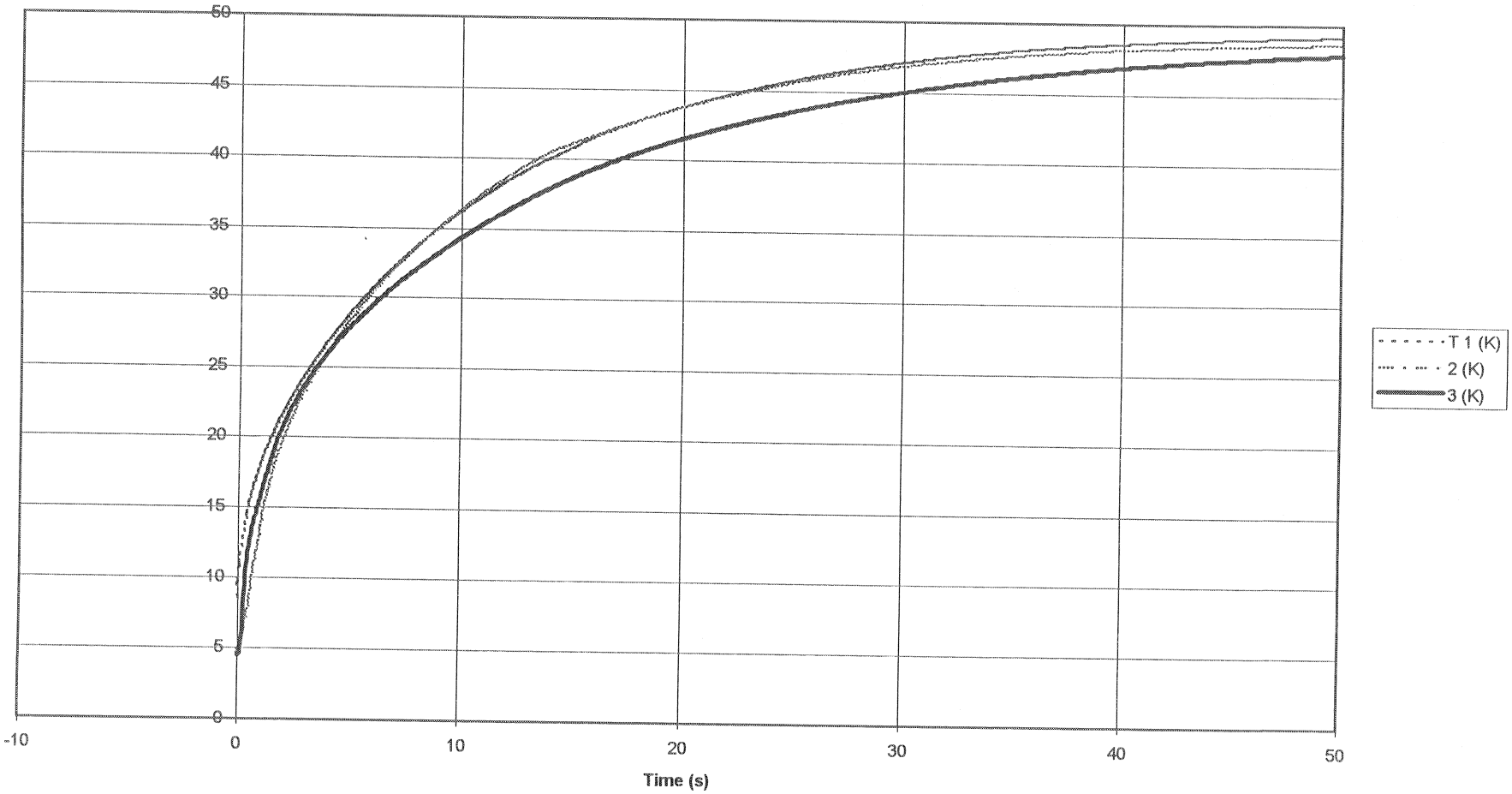
Voltages


2.00E+02
1.50E+02
1.00E+02
5.00E+01
0.00E+00
-5.00E+01
-1.00E+02
-1.50E+02
-2.00E+02
-5
5
10
15
20
25
30
35
40
45
50
Time (s)
Vlott (Volt)
Vt (Volt)
V 1 (Volt)
2 (Volt)
3 (Volt)
V_T
V_1
V_2

Currents


90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
-10
0
10
20
30
40
50
Time (s)
Is (A)
I 1 (A)
2 (A)
3 (A)

Temperatures



B_P_2S_1.XLS

P. Valente

01/03/96

```
*Read ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
bab_2S_1.ind
bab_2S_1.mag
*Read output files
bAB_2S_7.I
bAB_2S_7.T
bAB_2S_7.R
bAB_2S_7.V
bAB_2S_7.th
*Read(title)
 babar 2 STRATI
*Read(# of coils and coils grouping)
* NbSn   NbTi Nrest   ngroup,      (ncc(i),i=1,ngroup)
   0     2    1     3          1 1 1
*nr1,nz1 for inductance accuracy calculations.
*s  ss  nr1  nz1  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are
intially shorted.
 1  1e6  2   400  1  1  0
 *Ti   dt   ntp  nl   tf   Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
 4.2  5.e-4   100 1000  50.0  .0  0   1   0   0   80.0 80.0  1      1   1      0    0     0
 *
 * i  a1   a2    Zmin    Zmax   Nt or j   cur  rrr  rcusc     fb   fpack    nr  nz  nl  rs   rsi   thb  thr   tins
i1i2itib Ti
1 1.5    1.521   -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.0006  0 0 0 0 4.5
2 1.521  1.5414  -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.001   0 0 0 0 4.5
3 1.5414 1.5474  -1.74   1.74    1       0.0    3    1.E5    0.0  1.0     1   80   1  0.0   0.0   0.0  0.0   0
0 0 0 0 4.5
*Nb3Sn coils(mat=3)
*i  mat  df   pitch   an    ap   bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
*NbTi coils (mat=1)
*i  mat  df   pitch   Bc2   T1T   TCRT    Pincont  alstab  RRRal   ratioa matb matr
 1   1  40e-6  .020   10.6  4.2   9.2    .38460E09  0.918   1000  .254    12   12
 2   1  40e-6  .020   10.6  4.2   9.2    .38460E09  0.918   1000  .254    12   12
*other windings
* i  mat  alstab RRRal  ratioa matb matr
 3  6    1.0   3      1.0   12   12
*
*  Read bore tube material and reinforcment material resistivities
*       Mat 1(ss)    Mat 2(Al)
        50e-8        3e-8
*
* ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
   1   1   1    40     41       8.5      0.0
*
*  xlength  diam,  xcus   Rs    ts   Temps  Rh(1)  2     3
    30000.  150   0.80   0.0001  0.1   20.   1e10  1e10  1.e10
*Read generator properties if source is not zero
*Igen          Rx   freq. or Ramp rate   phase    Amplitude
  0          1e7            8      0.0     1000
*  Initial Currents(Currrti(ig),ig=1,Ngroup)
       0 0 0
```

babar 2 STRATI

AC loss is not considered
Heaters are turned off
Winding sharing boundaries are thermally connected

Input data for coils and coil groups
Dimensions are in mm, A, A/mm2, ohms

#	ig	i	a1	a2	a3	Zc	H	J	I	Nturn	RRR	rcusc	fb	fpac	thi	Ti
1	1	1	*****	*****	*****	0.	3480.	42.99	4811.0	653	100.	1.100	0.000	0.907	0.60	4.50
2	2	1	*****	*****	*****	0.	3480.	44.25	4811.0	653	100.	1.100	0.000	0.907	1.00	4.50
3	3	1	*****	*****	*****	0.	3480.	0.00	0.0	1	3.	*****	0.000	1.000	0.00	4.50

Nb3Sn Coils

i mat df(mm)pitch an ap bc2t1e1 T1i Tcrmi E1i Pinconi str Alstab RRRal ratio matb matr

NbTi Coils

i	mat	df(um)	p(mm)	BC2T1T	T1T	TCRT	Pincont	Alstab	RRRal	ratio	matb	matr
1	1	40.0	20.	10.60	4.20	9.20	0.3846E+09	0.918	1000.	0.25	12	12
2	1	40.0	20.	10.60	4.20	9.20	0.3846E+09	0.918	1000.	0.25	12	12

Other non superconducting windings

i	mat	Alstab	ratio	matb	matr
3	6	1.000	3.	1.00	12	12

Initial normal zones in coils

Coil#	ir(i)	irf(i)	iz(i)	iz(f)	T(k)	Time(ms)
1	1	1	40	41	8.5	0.0

Inductance Matrix of all coils

1 0.548E+00 0.544E+00 0.990E-03
2 0.544E+00 0.557E+00 0.102E-02
3 0.990E-03 0.102E-02 0.190E-05

Inductance Matrix of coil groups

1 0.548E+00 0.544E+00 0.990E-03
2 0.544E+00 0.557E+00 0.102E-02
3 0.990E-03 0.102E-02 0.190E-05

---

time = 0.0Bmax= 1.901 1.653 1.481
Ic =12537.812546.2 0.0
Tc = 8.465 8.563 0.000
Tcs= 6.943 7.005 0.000

fnor= 0.000 0.000 1.000
I = 4811.0 4811.0 0.0

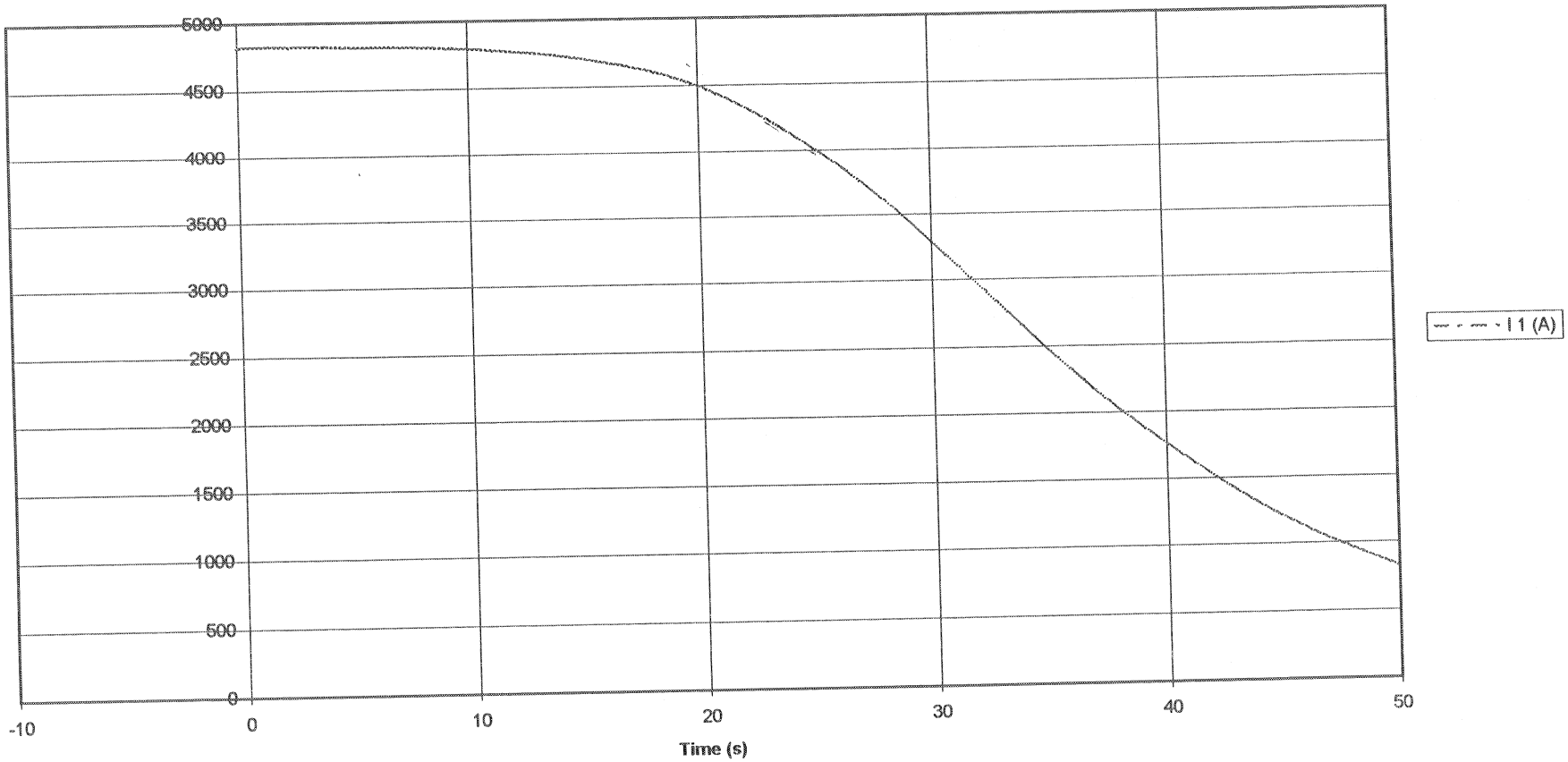
```
        A/mm2  42.99  44.25   0.00
        Tmax=   8.50   4.50   4.50
        Res =   0.00   0.00   0.00
  Total Voltage=    0.0    0.0    0.0
Inductive Voltage=    0.0    0.0    0.0
Diode short(ngroup)=1 1 1
 ----------------------------------------------------------------------------
time =   0.0Bmax=  1.901  1.653  1.481
        Ic =12536.512546.0    0.0
        Tc =  8.465  8.563  0.000
        Tcs=  6.943  7.005  0.000

        fnor=  0.013  0.000  1.000
        I   = 4811.3 4811.2    3.6
        A/mm2  42.99  44.25   0.00
        Tmax=   9.72   4.73   4.53
        Res =   0.00   0.00   0.00
  Total Voltage=   19.2    7.7    0.0
Inductive Voltage=   19.0    7.7    0.0
Diode short(ngroup)=1 1 1
 ----------------------------------------------------------------------------
time =   0.1Bmax=  1.901  1.654  1.481
        Ic =12532.612545.7    0.0
        Tc =  8.465  8.563  0.000
        Tcs=  6.943  7.005  0.000

        fnor=  0.013  0.000  1.000
        I   = 4811.6 4811.5   41.5
        A/mm2  42.99  44.26   0.00
        Tmax=  10.69   4.99   4.61
        Res =   0.00   0.00   0.00
  Total Voltage=   15.5    5.4    0.0
Inductive Voltage=   15.3    5.4    0.0
Diode short(ngroup)=1 1 1
 ----------------------------------------------------------------------------
```

Solenoid current

I 1 (A)

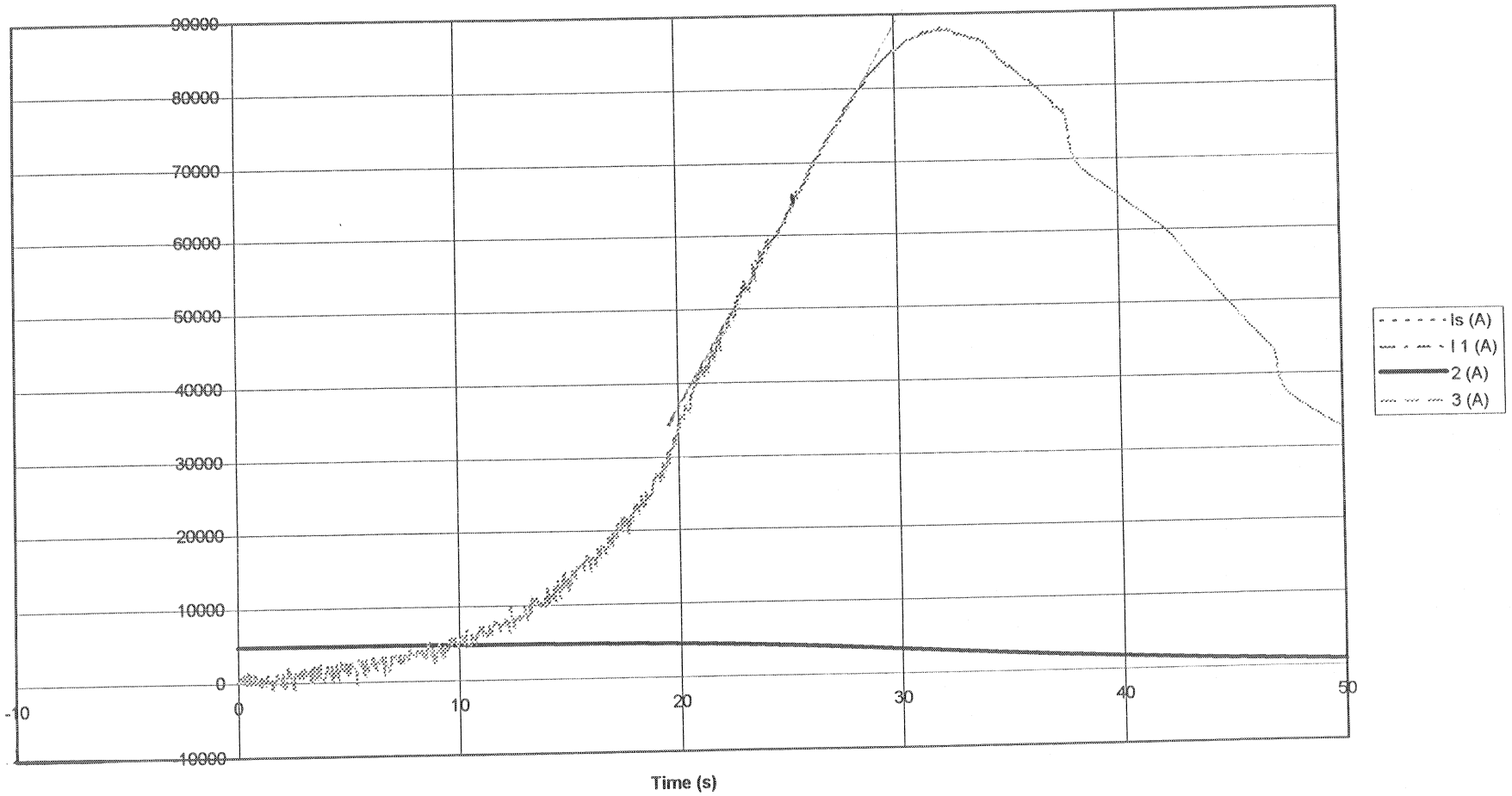


BAB_2S_7.XLS

P. Valente

22/04/96

Currents

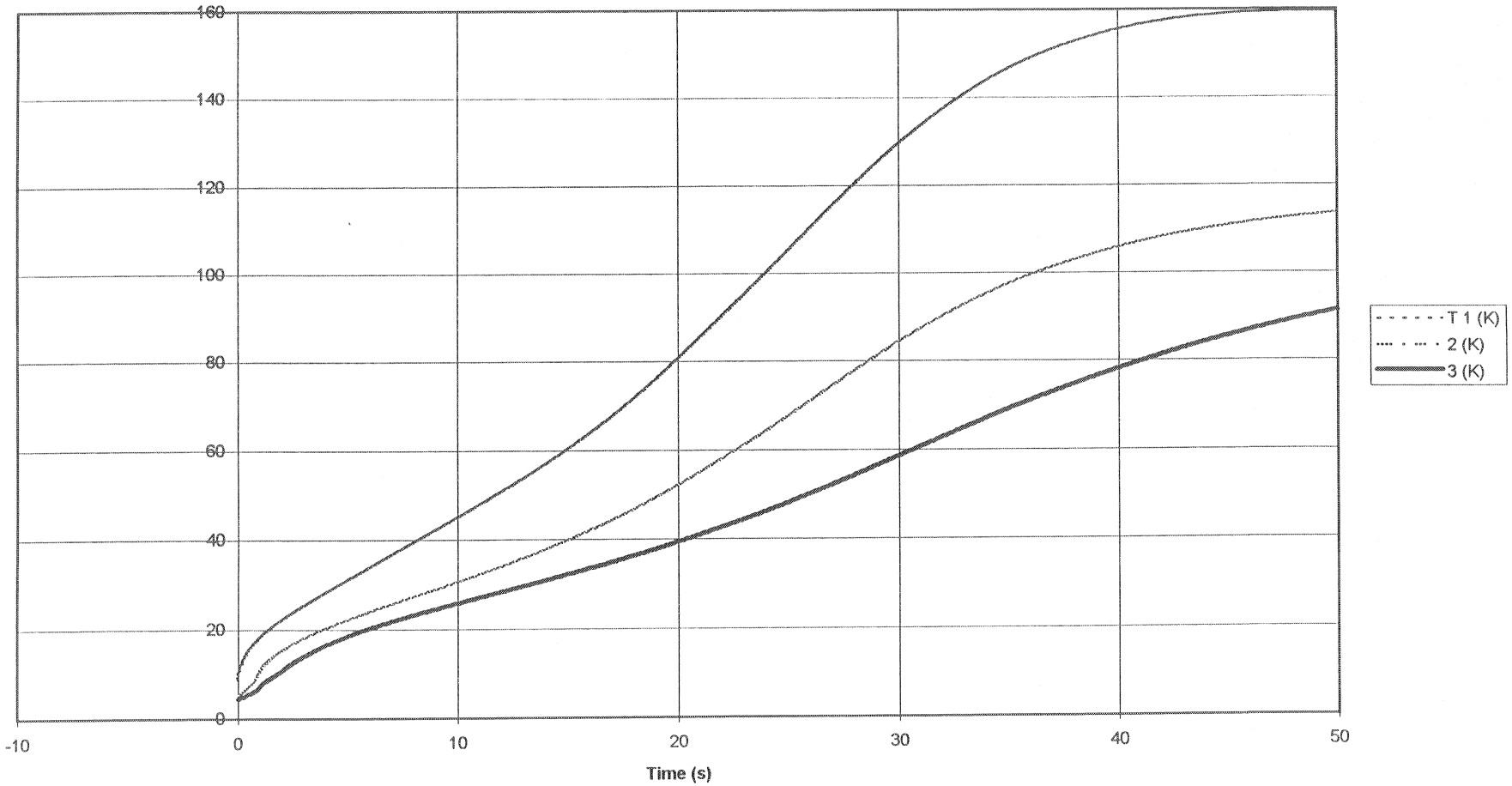


BAB_2S_7.XLS

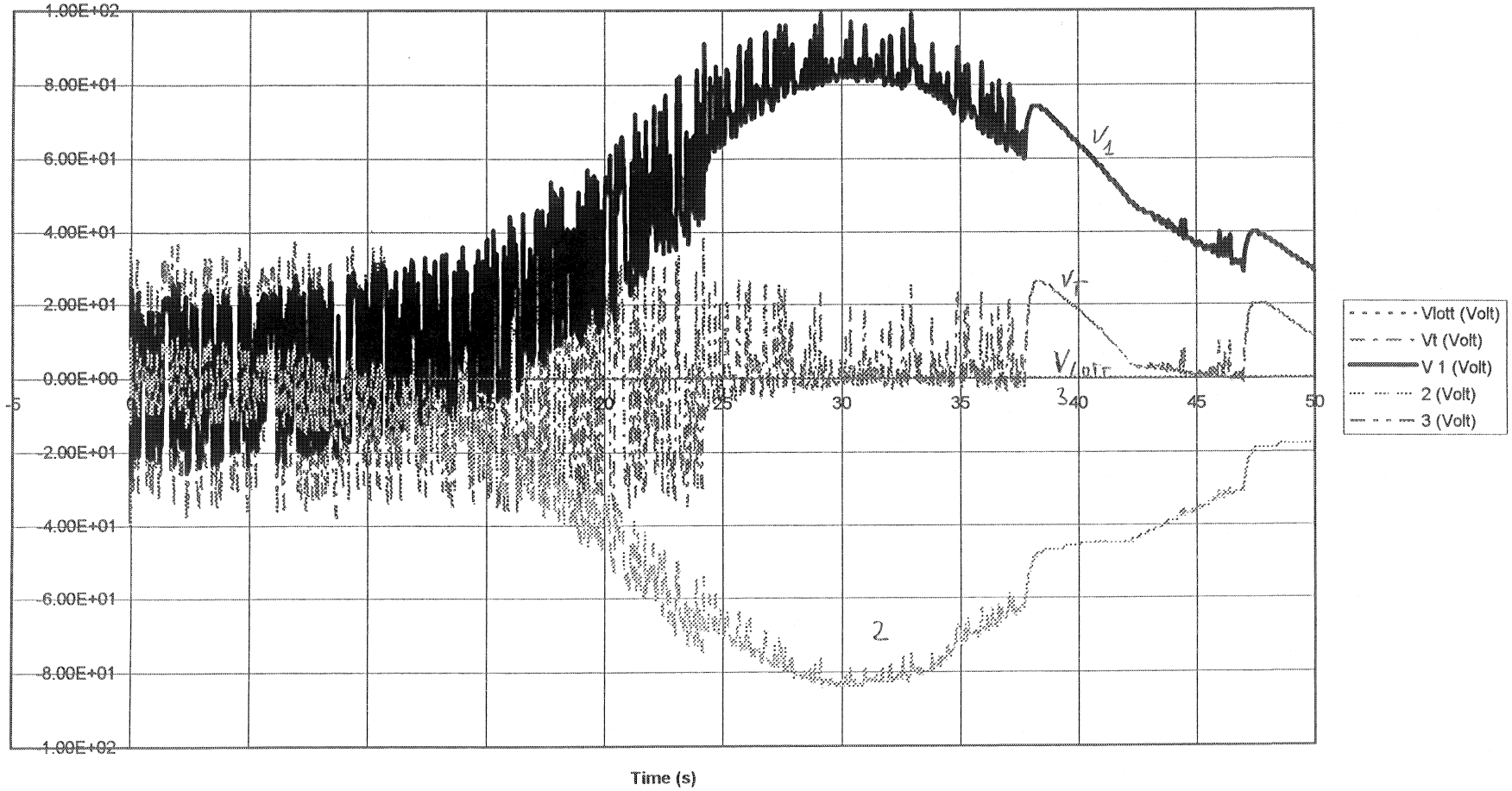
P. Valente

20/02/96

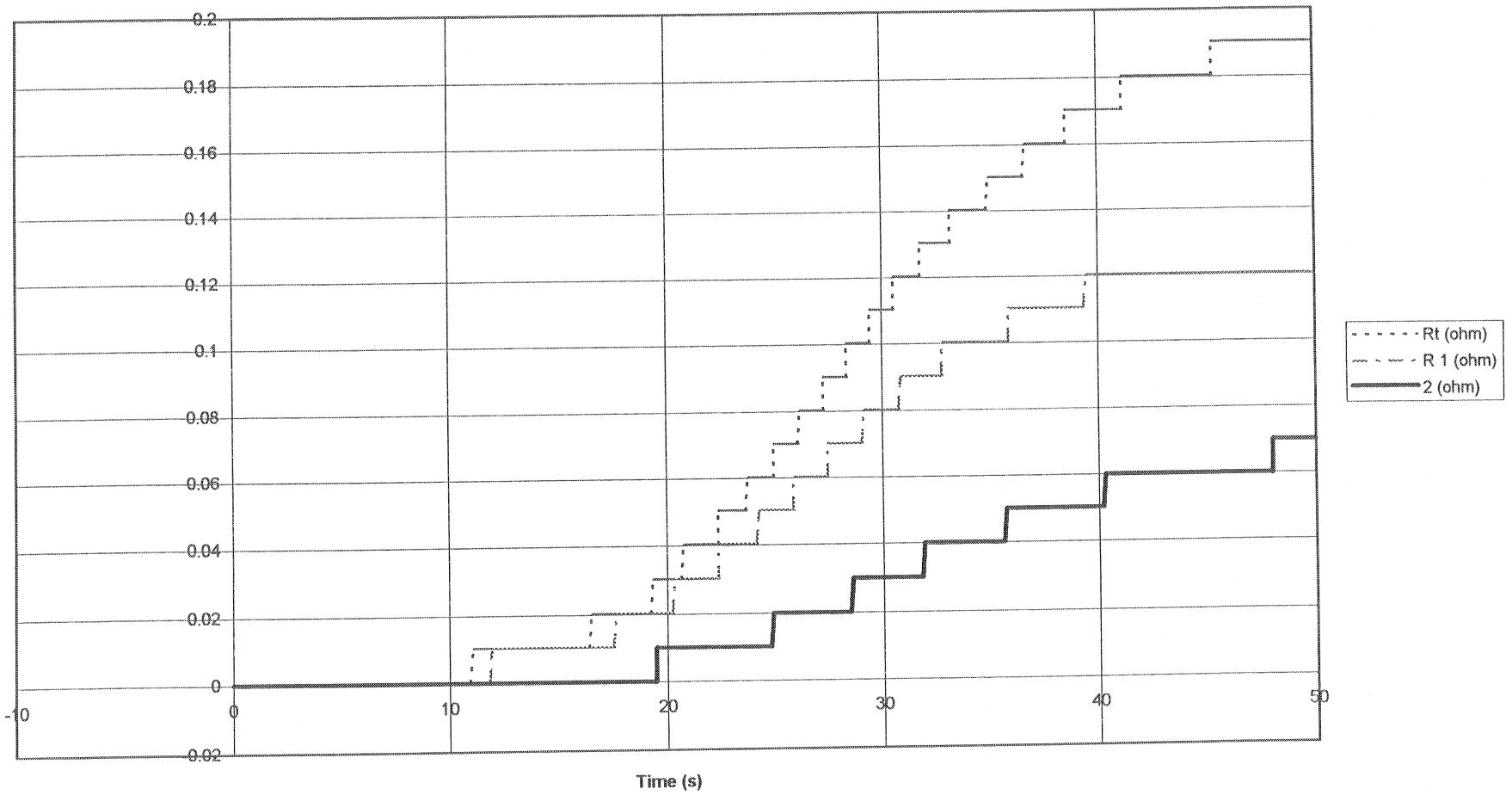
Temperature



Voltages


1.00E+02
8.00E+01
6.00E+01
4.00E+01
2.00E+01
0.00E+00
-2.00E+01
-4.00E+01
-6.00E+01
-8.00E+01
-1.00E+02
-5
0
5
10
15
20
25
30
35
40
45
50
Time (s)
V1
Vt
Vlott
3
2
Vlott (Volt)
Vt (Volt)
V 1 (Volt)
2 (Volt)
3 (Volt)

Resistances

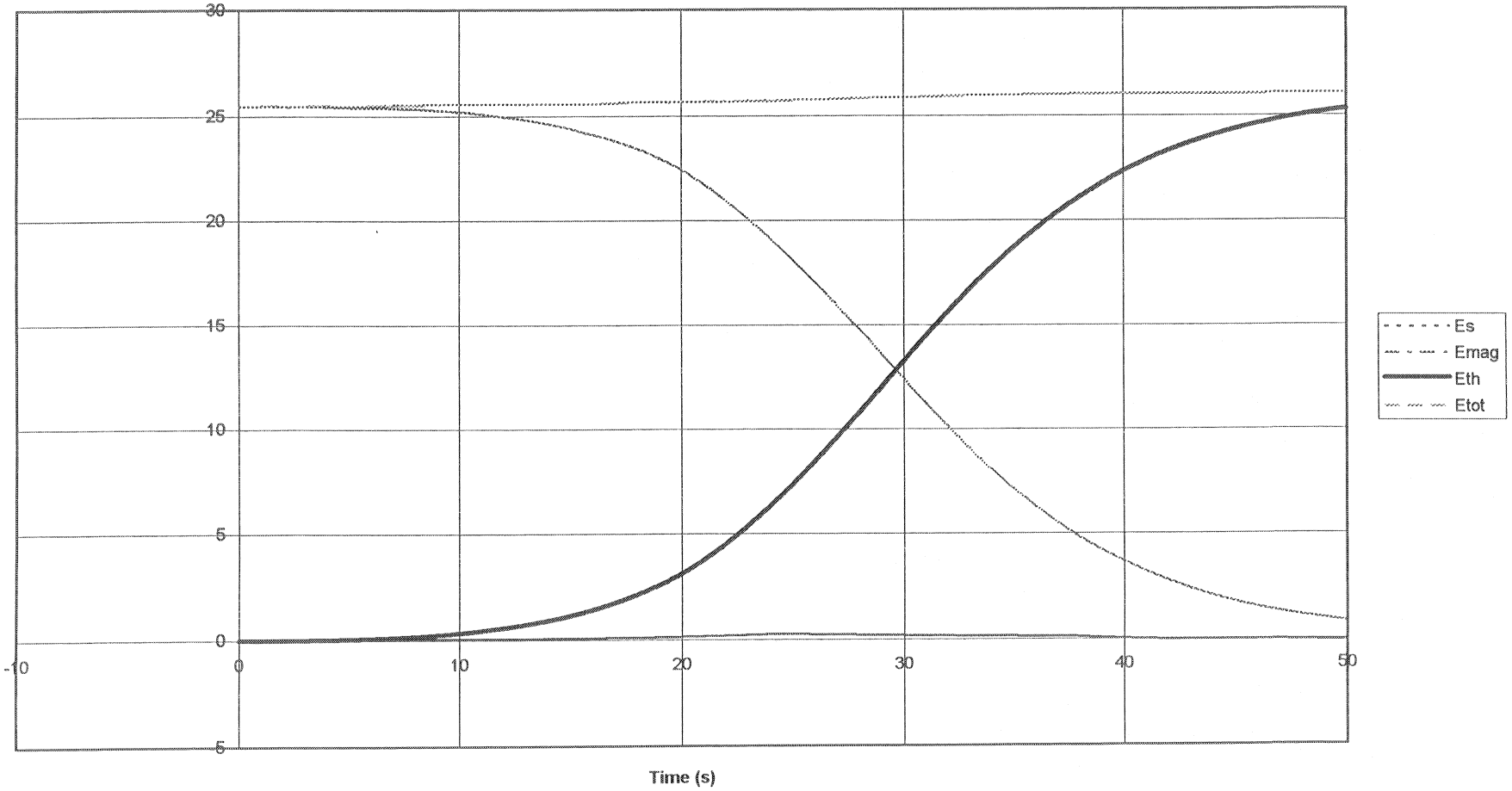


BAB_2S_7.XLS

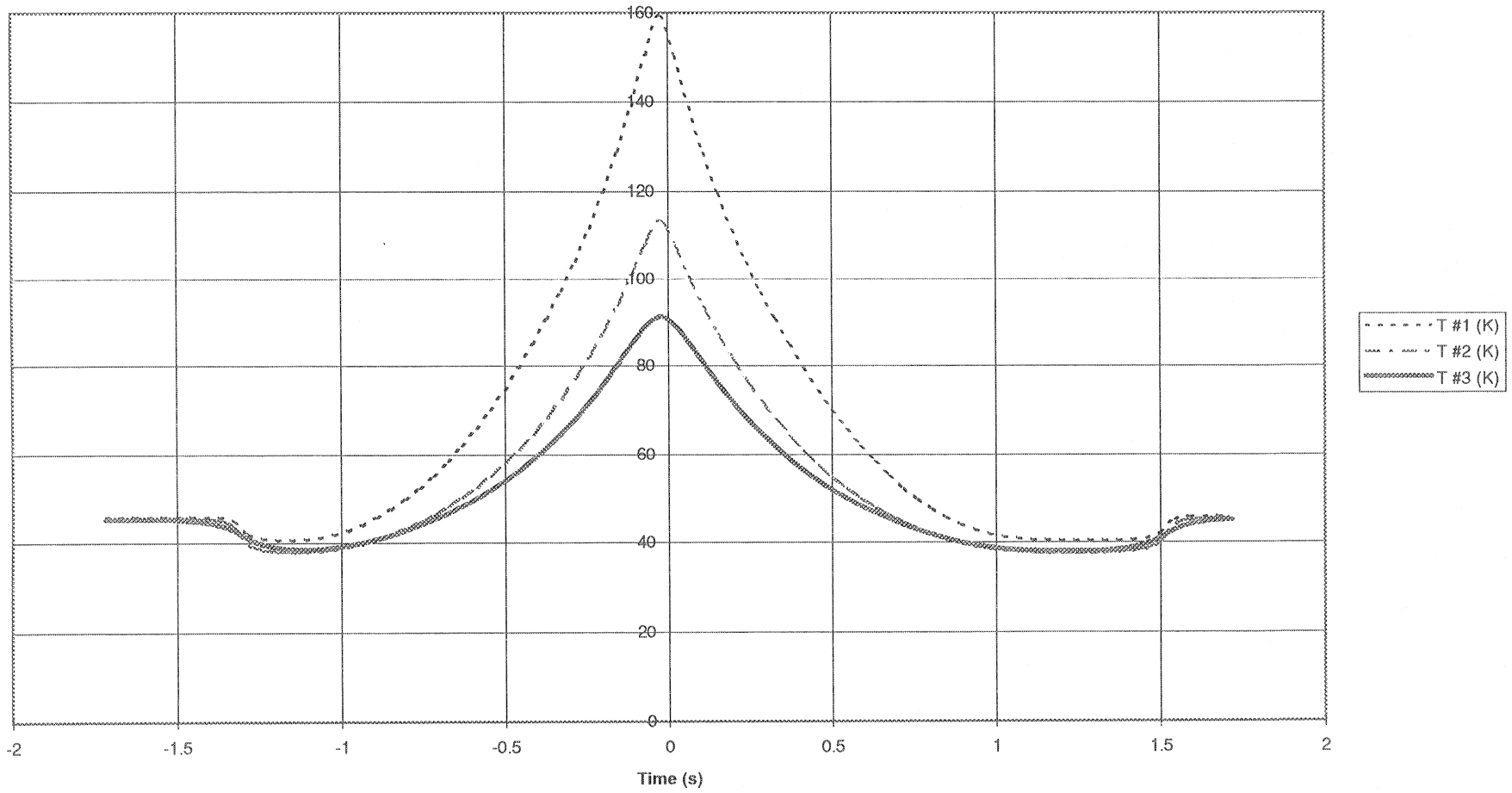
P. Valente

20/02/96

Grafico1



Temp. distrib. along z



20/02/96

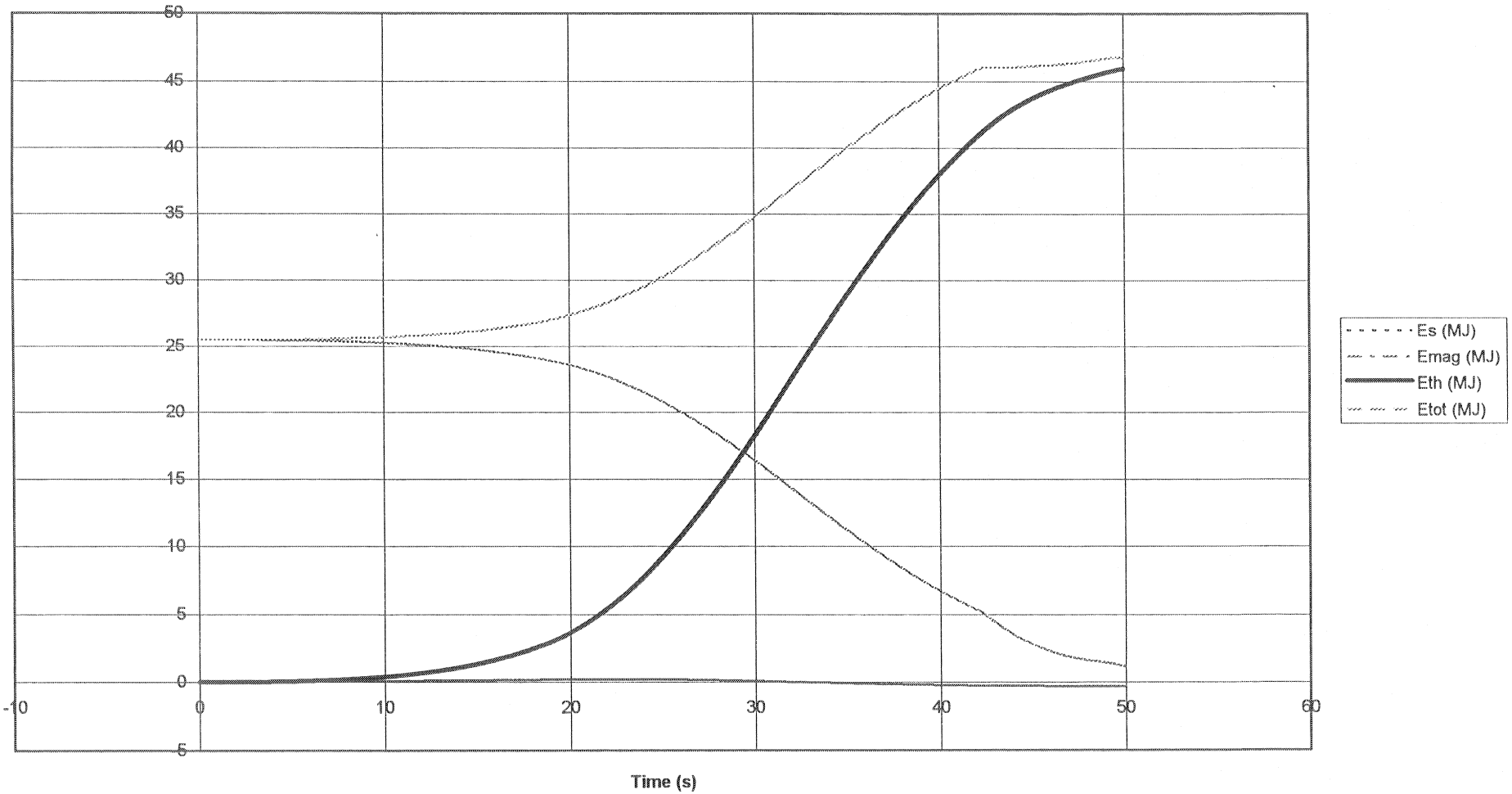
EMERGA PULSA

```
*Read ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
bab_2S_1.ind
bab_2S_1.mag
*Read output files
bAB_2S_7.I
bAB_2S_7.T
bAB_2S_7.R
bAB_2S_7.V
bAB_2S_7.th
*Read(title)
 babar 2 STRATI
*Read(# of coils and coils grouping)
* NbSn   NbTi Nrest   ngroup,      (ncc(i),i=1,ngroup)
   0     2     1     3          1 1 1
*nr1,nz1 for inductance accuracy calculations.
*s  ss  nr1  nz1  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are
intially shorted.
 1  1e6  2   400  1  1  0
 *Ti   dt    ntp  nl   tf    Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
 4.2  5.e-4  100 1000  50.0  .0  0  1   0  0  80.0 80.0  1     1   1     0    0     0
*
* i  a1   a2    Zmin    Zmax   Nt or j   cur  rrr  rcusc     fb   fpack    nr  nz  nl  rs   rsi   thb  thr   tins
i1i2itib Ti
1 1.5   1.521   -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.0006  0 0 0 0 4.5
2 1.521  1.5414  -1.74   1.74   653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.001   0 0 0 0 4.5
3 1.5414 1.5474  -1.74   1.74    1       0.0   3    1.E5    0.0  1.0     1   80   1  0.0   0.0   0.0  0.0   0
0 0 0 0 4.5
*Nb3Sn coils(mat=3)
*i  mat  df   pitch   an    ap   bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
*NbTi coils (mat=1)
*i  mat  df   pitch   Bc2   T1T   TCRT     Pincont  alstab  RRRal   ratioa matb matr
 1   1  40e-6  .020   10.6  4.2   9.2    .38460E09  0.918   1000  .254    12   12
 2   1  40e-6  .020   10.6  4.2   9.2    .38460E09  0.918   1000  .254    12   12
*other windings
* i  mat  alstab RRRal  ratioa matb matr
 3  6    1.0   3      1.0    12   12
*
*  Read bore tube material and reinforcment material resistivities
*       Mat 1(ss)    Mat 2(Al)
         50e-8        3e-8
*
* ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
   1   1   1    40     41      8.5      0.0
*
*  xlength   diam,  xcus   Rs    ts    Temps   Rh(1)  2     3
    30000.  150    0.80   0.0001  0.1    20.    1e10  1e10  1.e10
*Read generator properties if source is not zero
*Igen          Rx   freq. or Ramp rate   phase    Amplitude
  0          1e7            8      0.0     1000
*  Initial Currents(Currrti(ig),ig=1,Ngroup)
       0 0 0
```

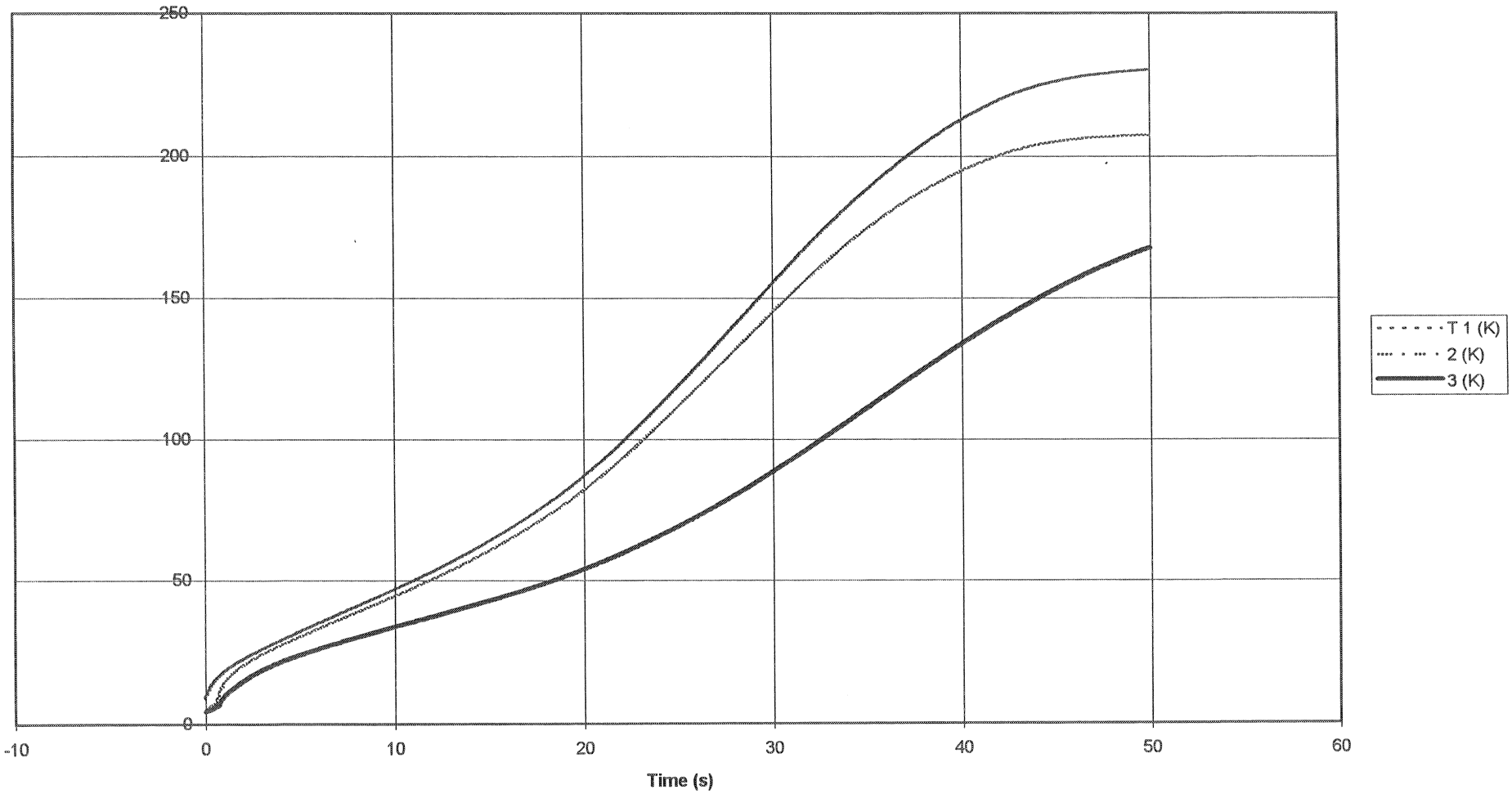
E_{TOT} NO

```
*Read ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
bab_2S_1.ind
bab_2S_1.mag
*Read output files
b_s_2S_2.I
b_s_2S_2.T
b_s_2S_2.R
b_s_2S_2.V
b_s_2S_2.th
*Read(title)
babar 2 STRATI quench con Rp=0 dal bordo tempo integr.2e-4
*Read(# of coils and coils grouping)
* NbSn   NbTi Nrest  ngroup,     (ncc(i),i=1,ngroup)
0     2     1     3          1 1 1
*nr1,nz1 for inductance accuracy calculations.
*s  ss  nr1  nz1  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are intially shorted.
1  1e6  2   400  1  1  0
*Ti   dt   ntp  nl  tf   Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
4.2  2.e-4  100 1000  50.0  .0  0  1   0  0  80.0 80.0  1      1   1      0    0     0
*
* i  a1   a2    Zmin    Zmax  Nt or j  cur  rrr  rcusc     fb  fpack    nr  nz  nl  rs   rsi   thb  thr   tins   i1i2itib Ti
1 1.5    1.521  -1.74   1.74  653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0   0.0006  0 0 0 0 4.5
2 1.521  1.5414 -1.74   1.74  653      4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0   0.001   0 0 0 0 4.5
3 1.5414 1.5474 -1.74   1.74   1       0.0   3    1.E5    0.0  1.0     1   80   1  0.0   0.0   0.0  0.0   0       0 0 0 0 4.5
*Nb3Sn coils(mat=3)
*i  mat  df   pitch   an    ap   bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
*NbTi coils (mat=1)
*i  mat  df   pitch   Bc2   T1T   TCRT    Pincont  alstab  RRRal   ratioa matb matr
1   1  40e-6  .020   10.6  4.2   9.2    .38460E09   0.918   1000  .254    12   12
2   1  40e-6  .020   10.6  4.2   9.2    .38460E09   0.918   1000  .254    12   12
*other windings
* i  mat  alstab RRRal  ratioa matb matr
3  6    1.0   3      1.0    12   12
*
*  Read bore tube material and reinforcment material resistivities
*      Mat 1(ss)    Mat 2(Al)
50e-8        3e-8
*
* ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
1   1   1     1       2       8.5       0.0
*
*  xlength   diam,  xcus   Rs     ts   Temps  Rh(1)  2     3
30000.  150    0.80     0.0001  0.1   20.   1e10  1e10  1.e10
*Read generator properties if source is not zero
*Igen          Rx  freq. or Ramp rate  phase   Amplitude
0          1e7            8     0.0    1000
*  Initial Currents(Currrti(ig),ig=1,Ngroup)
0 0 0
```

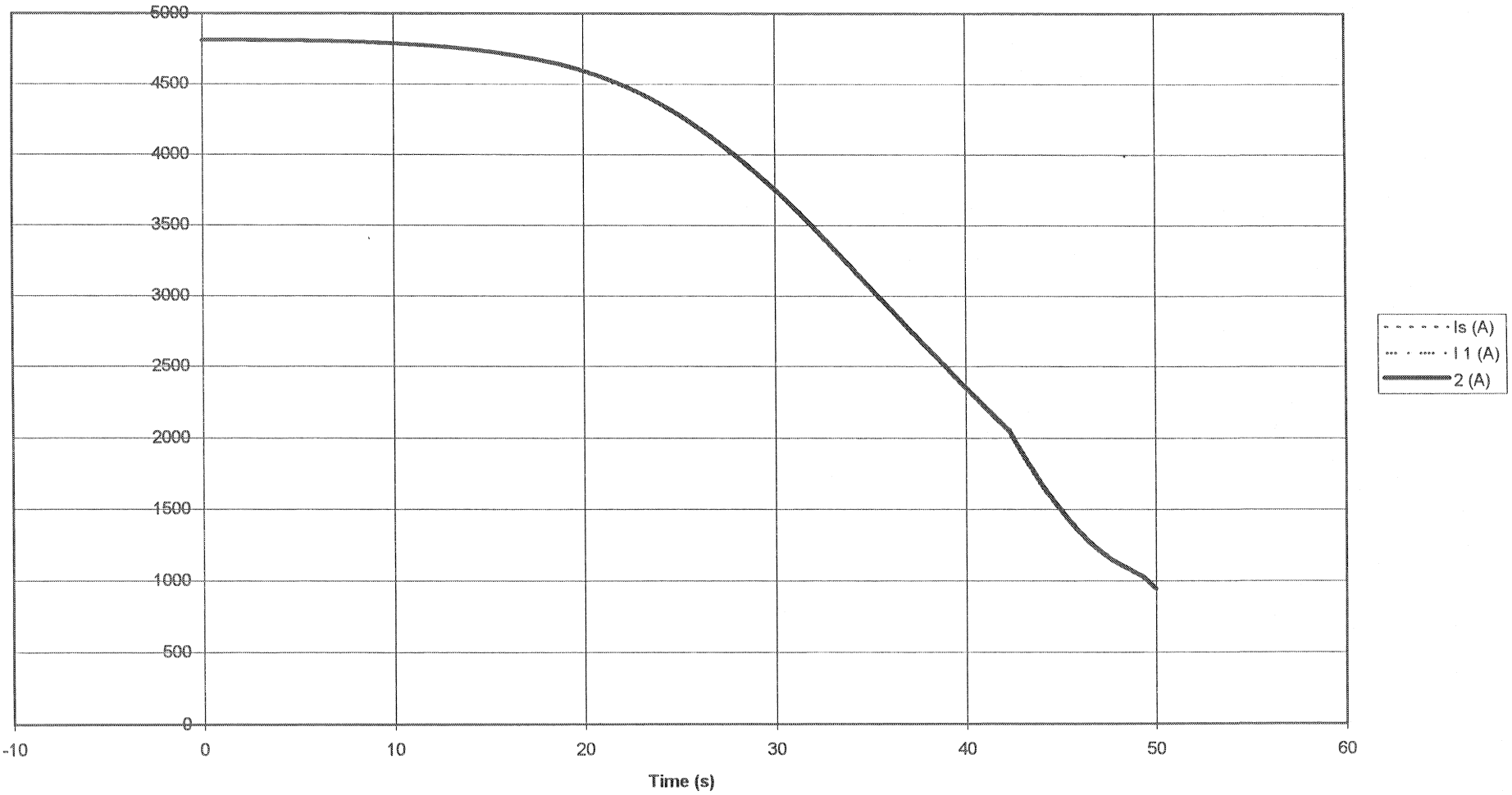
Energies


50
45
40
35
30
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
60
Time (s)
Es (MJ)
Emag (MJ)
Eth (MJ)
Etot (MJ)

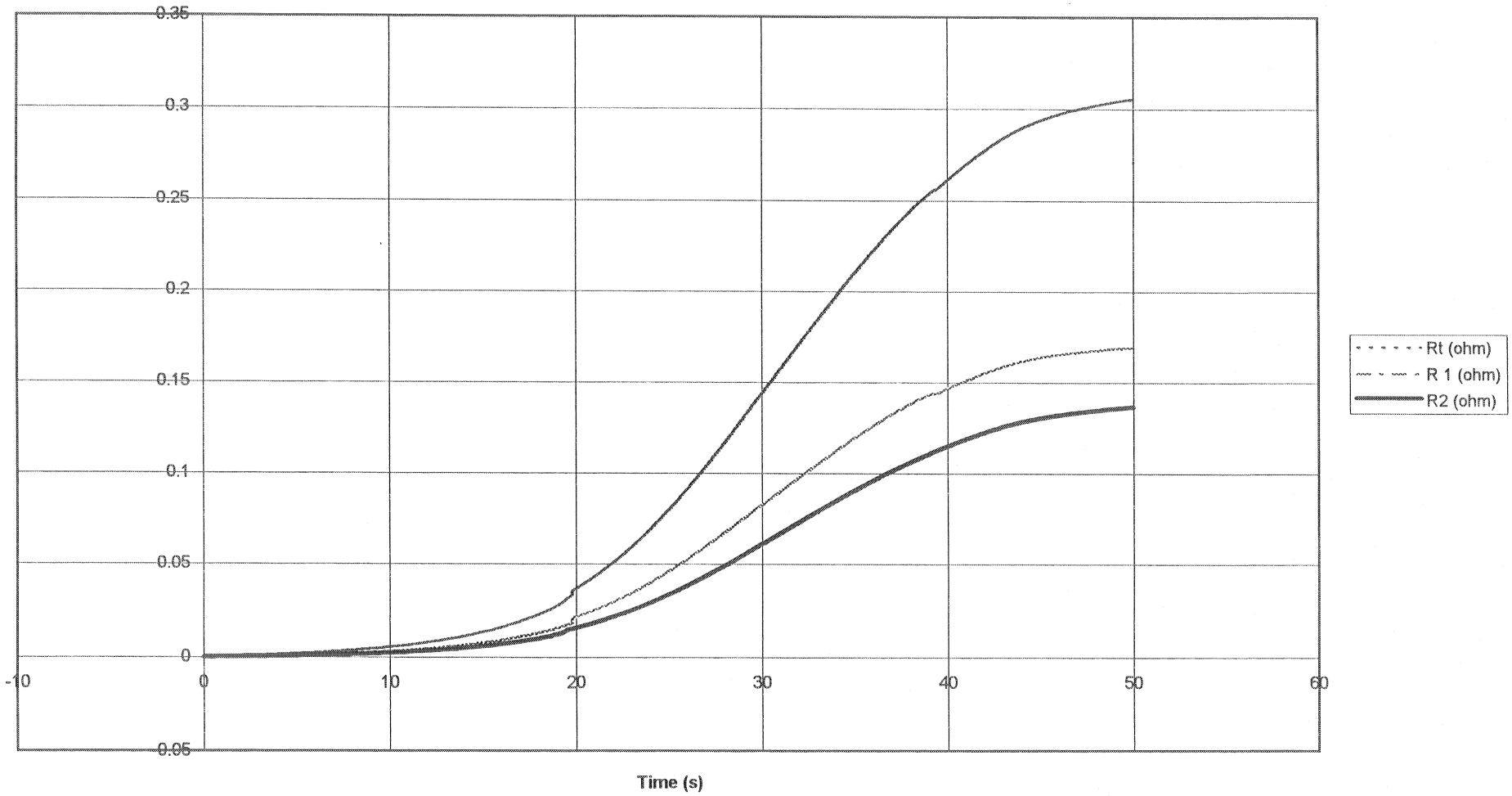
Temperatures



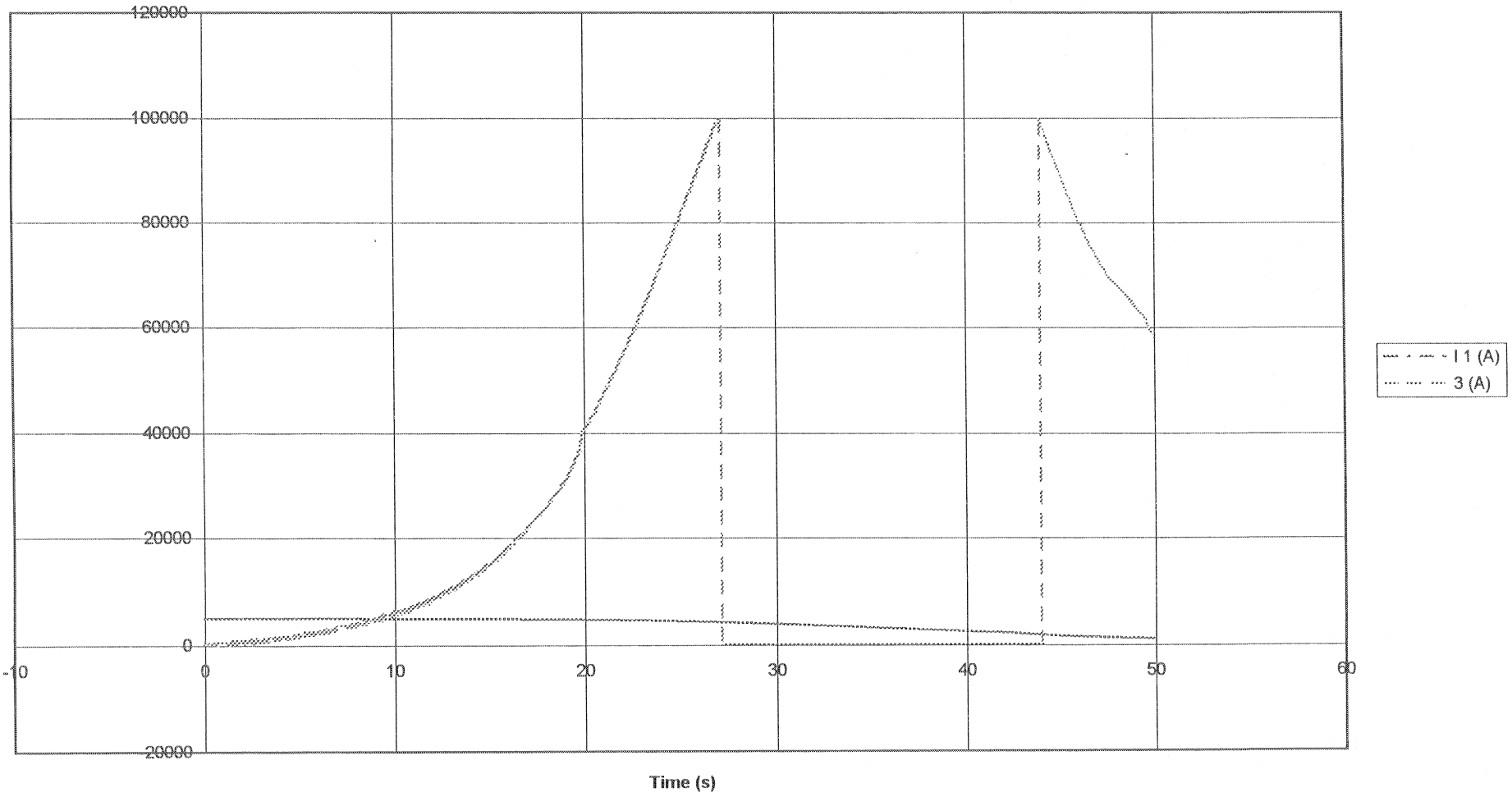
Solenoid current



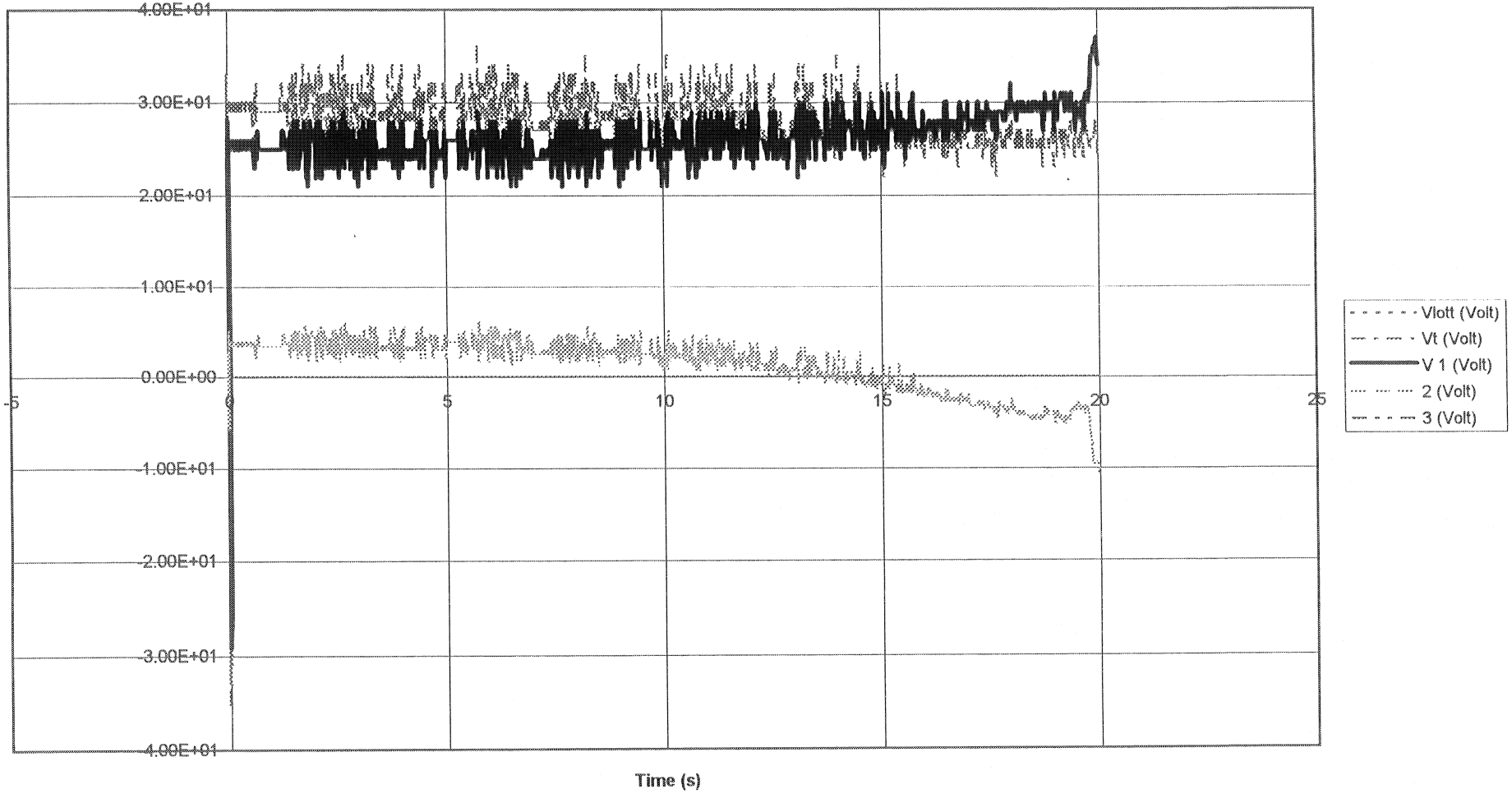
Resistances



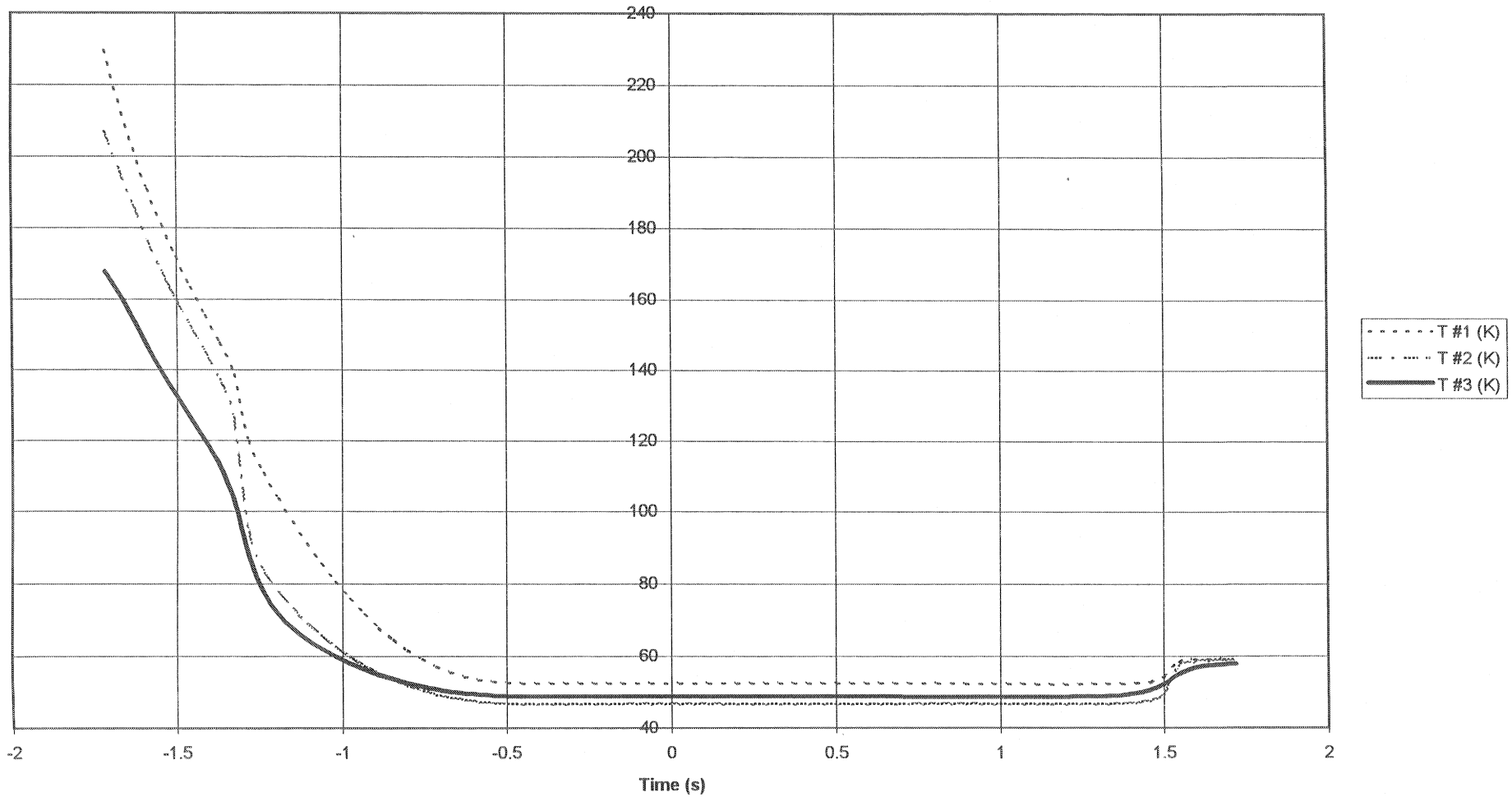
Currents


120000
100000
80000
60000
40000
20000
0
-20000
-10
0
10
20
30
40
50
60
Time (s)
I 1 (A)
3 (A)

Voltages


4.00E+01
3.00E+01
2.00E+01
1.00E+01
0.00E+00
-1.00E+01
-2.00E+01
-3.00E+01
-4.00E+01
-5
0
5
10
15
20
25
Time (s)
Vlott (Volt)
Vt (Volt)
V 1 (Volt)
2 (Volt)
3 (Volt)

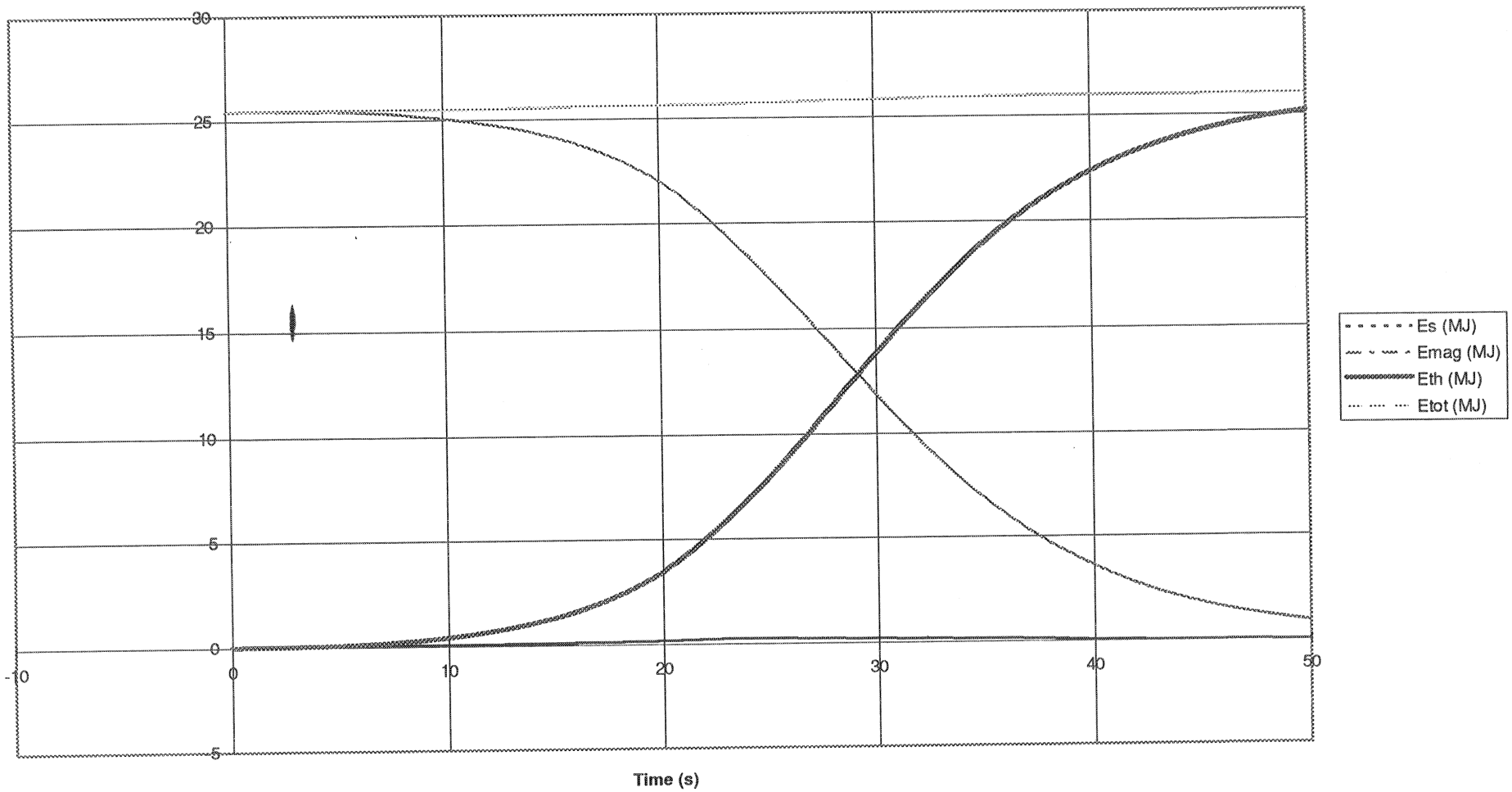
Temp. distrib. along z



Enter Hustra

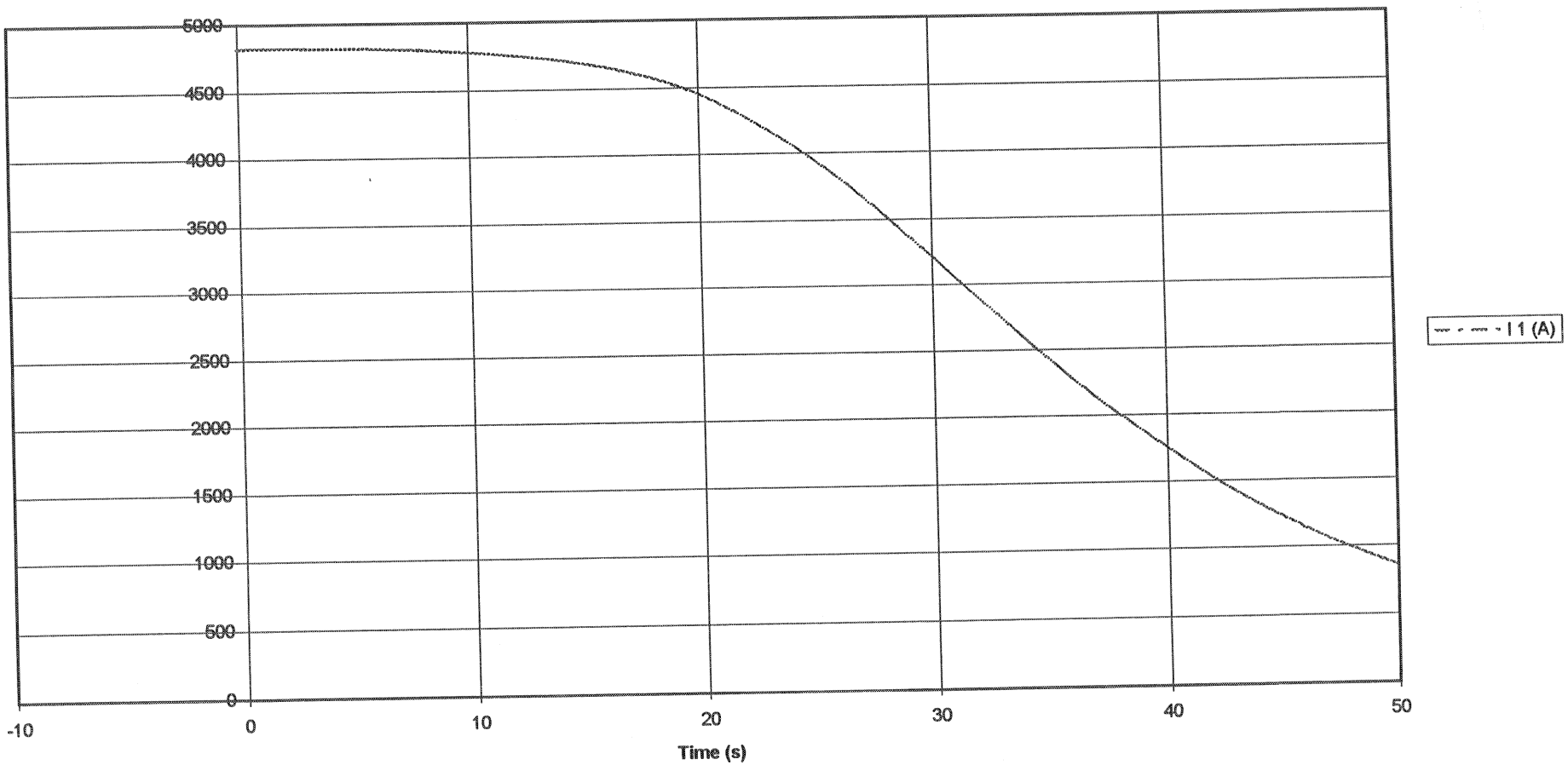
```
*Read ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
bab_2S_1.ind
bab_2S_1.mag
*Read output files
bAB_2S_8.I
bAB_2S_8.T
bAB_2S_8.R
bAB_2S_8.V
bAB_2S_8.th
*Read(title)
 babar 2 STRATI quench su fine
*Read(# of coils and coils grouping)
* NbSn   NbTi Nrest   ngroup,      (ncc(i),i=1,ngroup)
   0      2     1     3          1 1 1
*nr1,nz1 for inductance accuracy calculations.
*s  ss  nr1  nz1  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are
intially shorted.
 1   1e6  2   400  1  1  0
 *Ti   dt   ntp  nl   tf   Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
 4.2  5.e-4  100 1000  50.0  .0  0   1   0   0   80.0 80.0  1      1   1      0    0     0
*
* i  a1   a2    Zmin    Zmax   Nt or j   cur  rrr  rcusc     fb   fpack    nr  nz  nl  rs   rsi   thb  thr   tins
i1i2itib Ti
1 1.5    1.521   -1.74   1.74   653       4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.0006  0 0 0 0 4.5
2 1.521  1.5414  -1.74   1.74   653       4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0
0.001   0 0 0 0 4.5
3 1.5414 1.5474  -1.74   1.74    1        0.0    3    1.E5    0.0  1.0     1   80   1  0.0   0.0   0.0  0.0   0
0 0 0 0 4.5
*Nb3Sn coils(mat=3)
*i  mat  df   pitch   an    ap   bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
*NbTi coils (mat=1)
*i  mat  df   pitch   Bc2   T1T   TCRT    Pincont  alstab  RRRal   ratioa matb matr
 1   1  40e-6  .020   10.6  4.2   9.2    .38460E09  0.918   1000  .254.   12   12
 2   1  40e-6  .020   10.6  4.2   9.2    .38460E09  0.918   1000  .254    12   12
*other windings
* i  mat  alstab RRRal  ratioa matb matr
 3   6    1.0    3      1.0    12   12
*
*  Read bore tube material and reinforcment material resistivities
*       Mat 1(ss)    Mat 2(Al)
         50e-8        3e-8
*
* ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
   1   1   1    1      2      8.5       0.0
*
*  xlength   diam,   xcus    Rs      ts    Temps   Rh(1)  2     3
    30000.  150    0.80     0.0001  0.1    20.    1e10  1e10  1.e10
*Read generator properties if source is not zero
*Igen          Rx   freq. or Ramp rate   phase    Amplitude
  0           1e7            8      0.0     1000
*  Initial Currents(Currrti(ig),ig=1,Ngroup)
       0 0 0
  ---------------------------------------------------------------------------
```

Energies


30
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
Time (s)
Es (MJ)
Emag (MJ)
Eth (MJ)
Etot (MJ)

Solenoid current

I 1 (A)

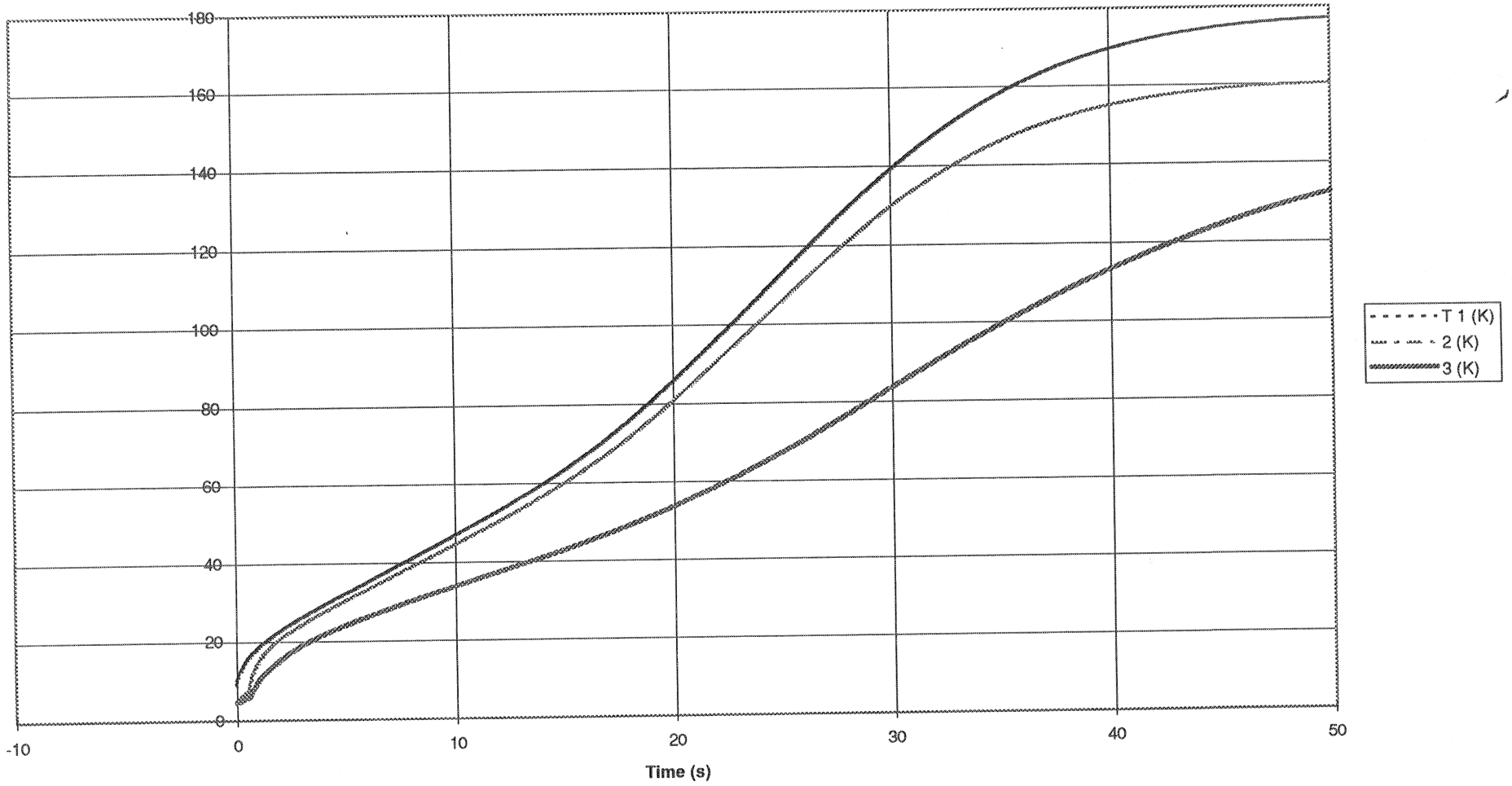


BAB_2S_8.XLS

P. Valente

22/04/96

Temperatures

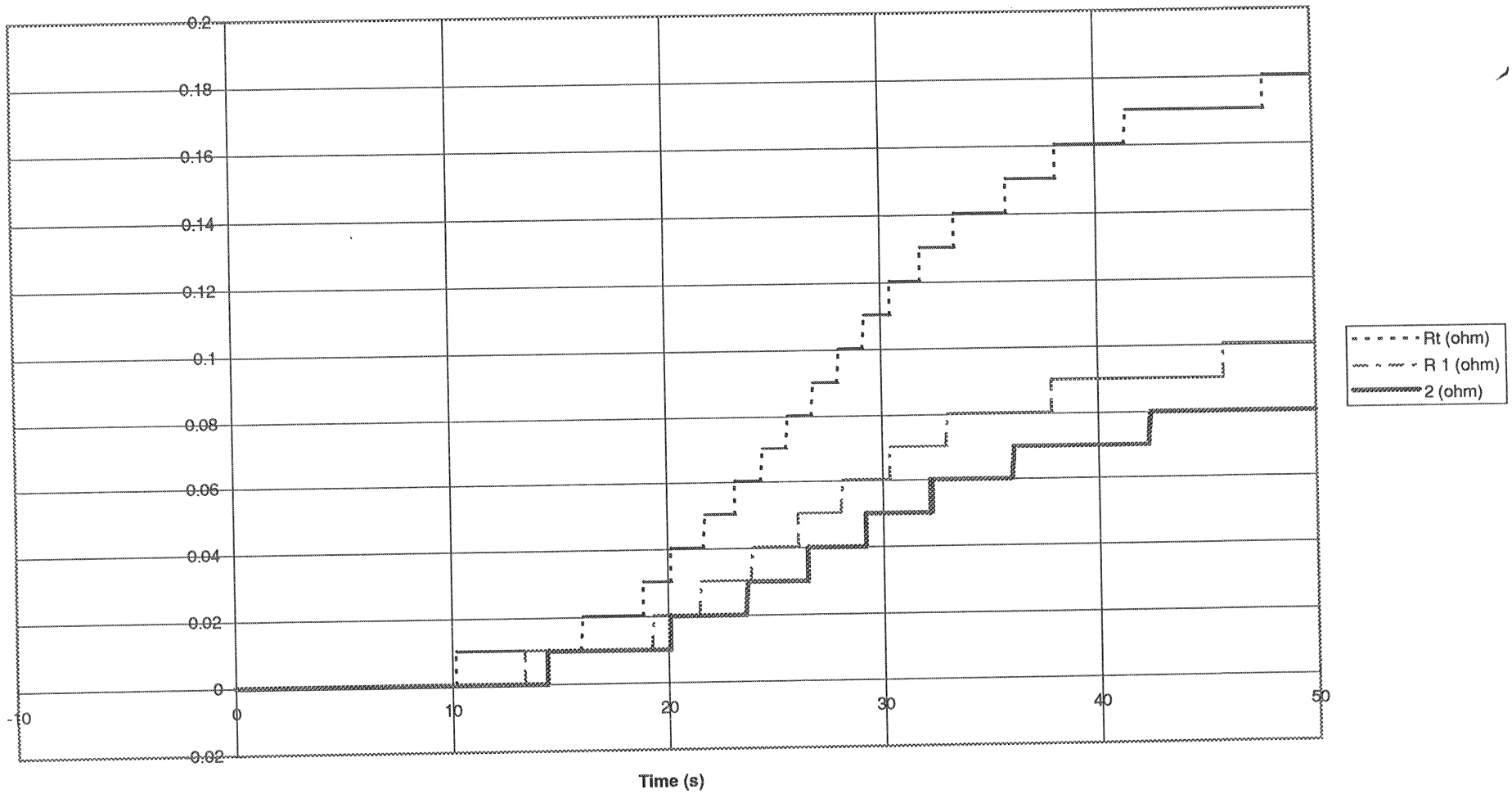


BAB_2S_8.XLS

P. Valente

22/02/96

Resistances

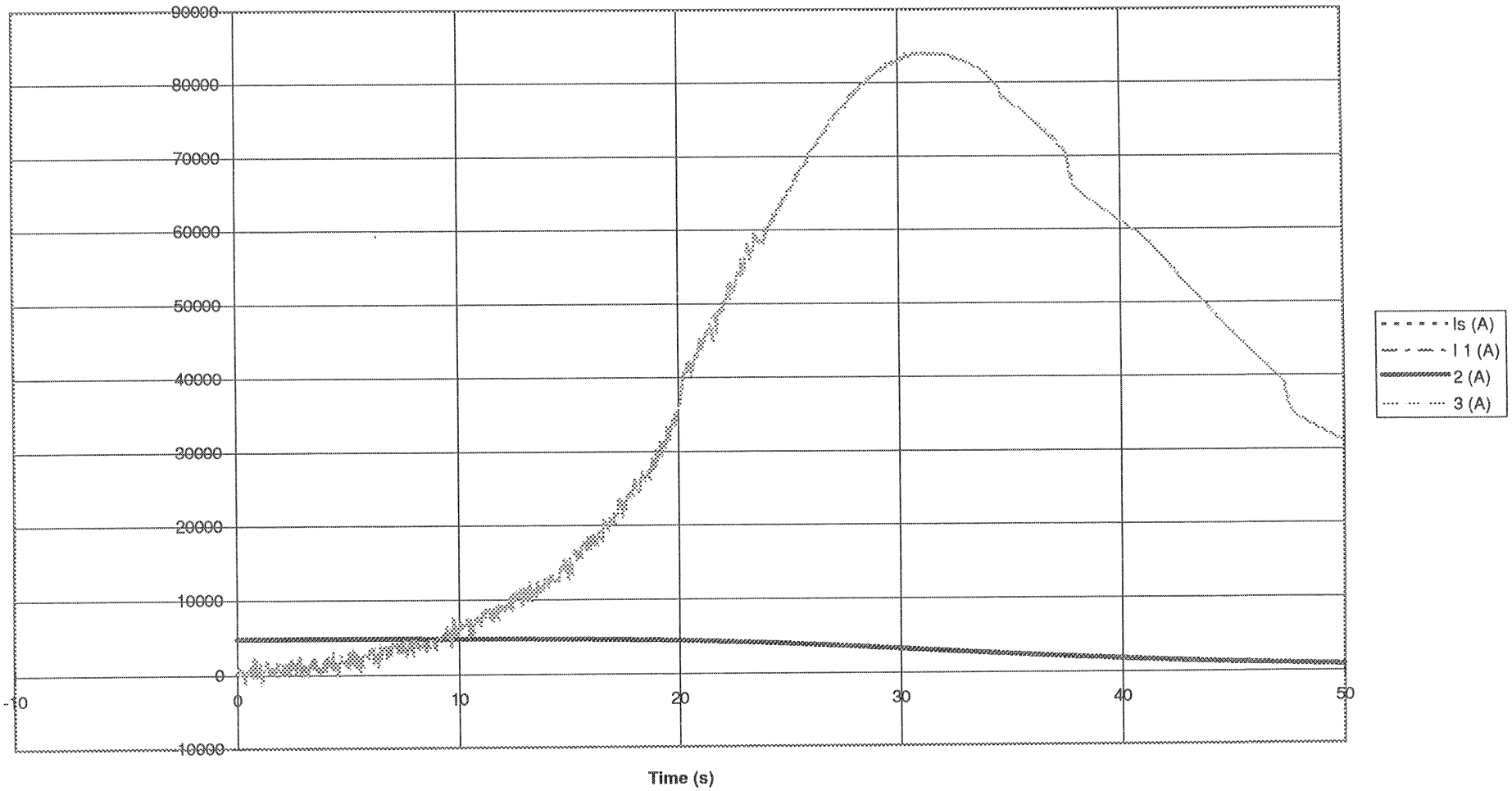


BAB_2S_8.XLS

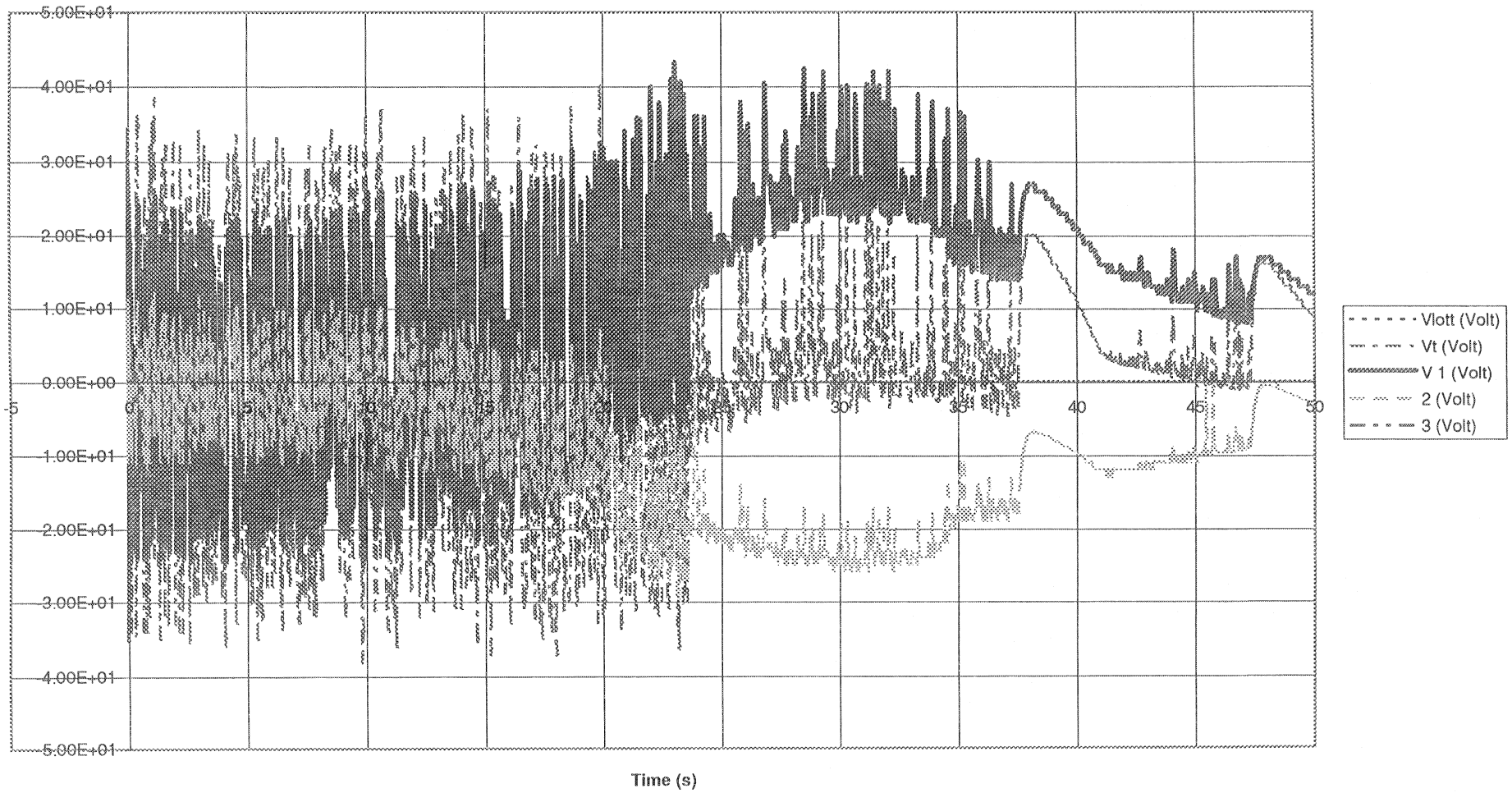
P. Valente

22/02/96

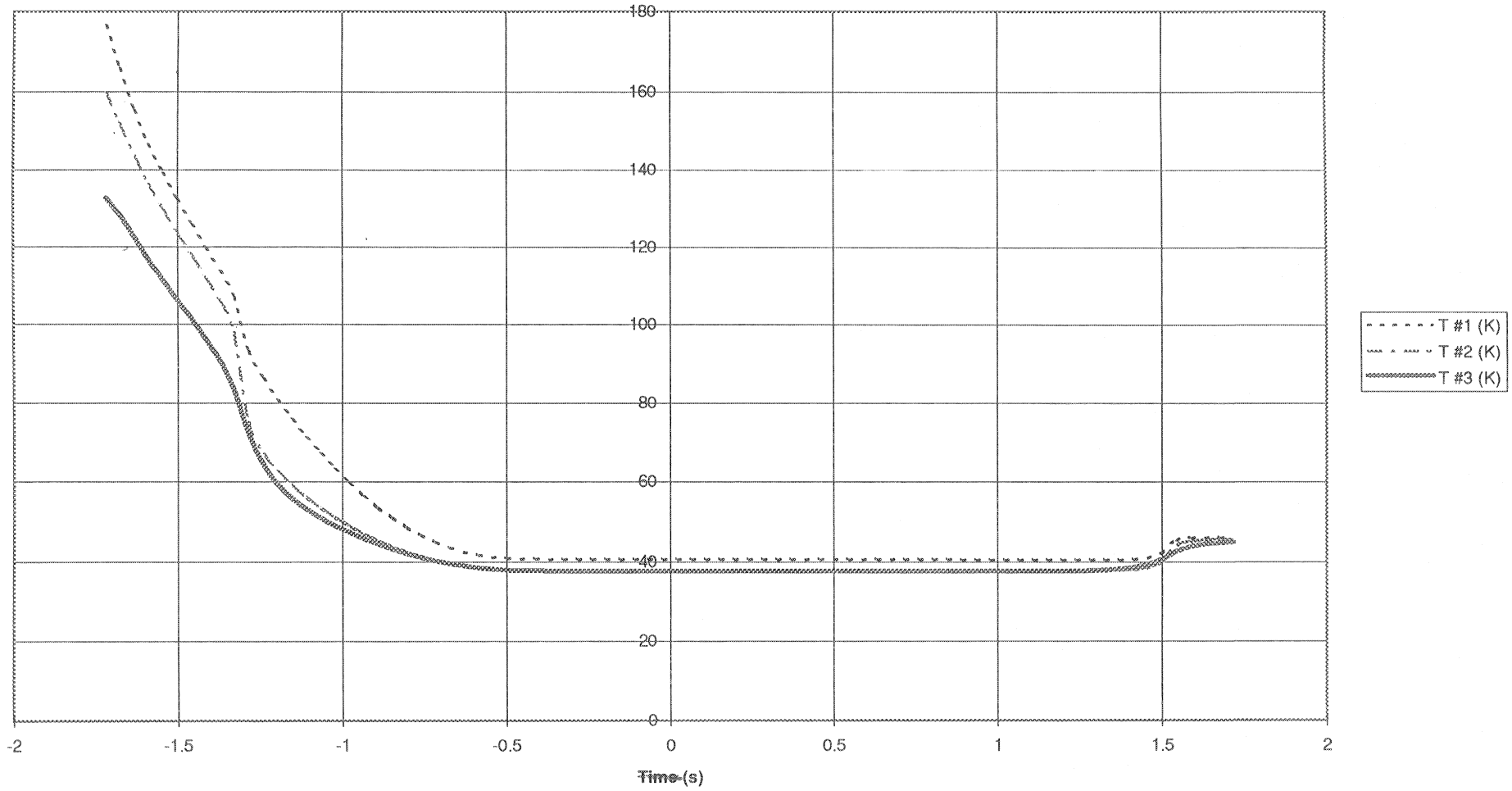
Currents

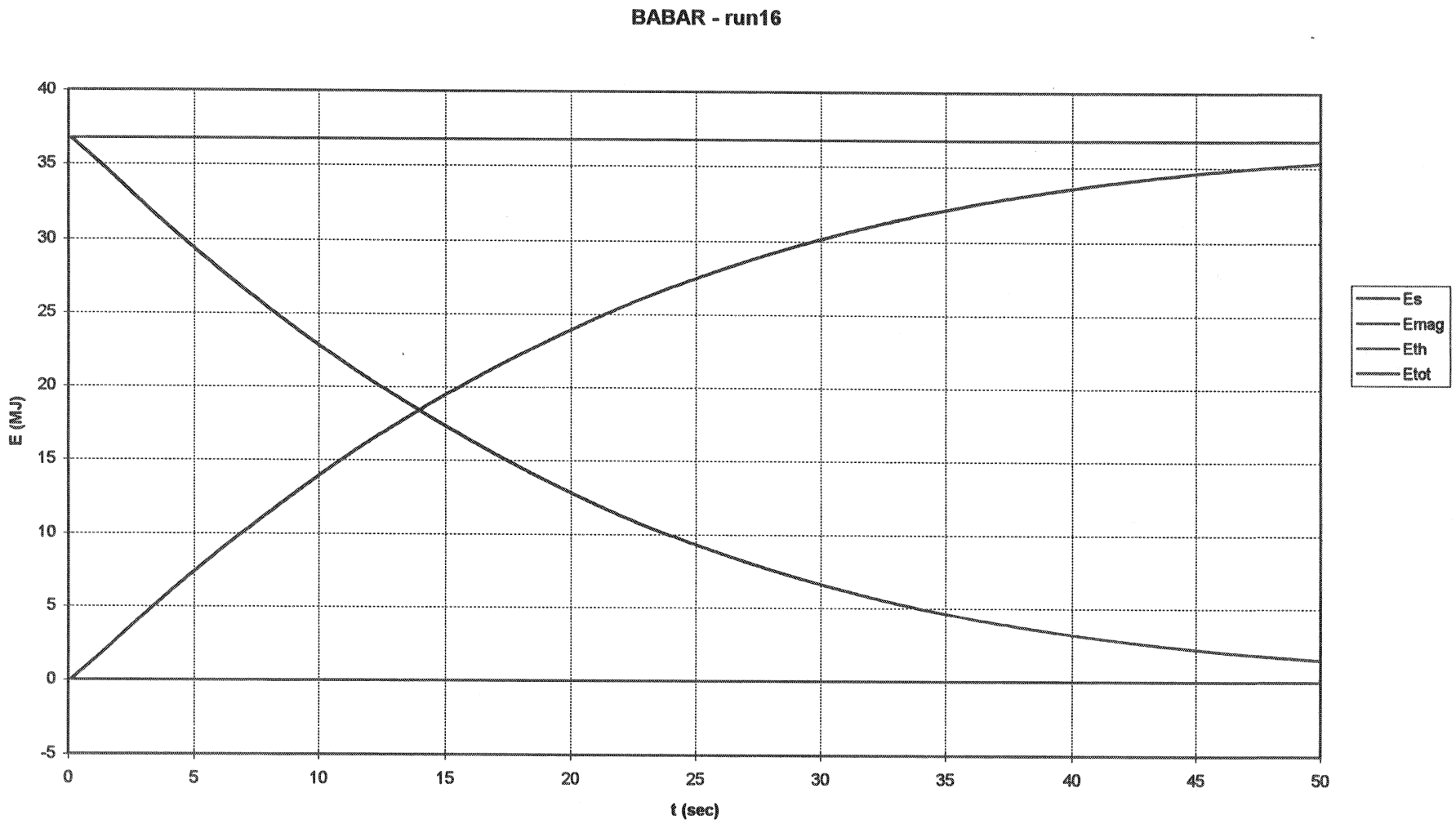

90000
80000
70000
60000
50000
40000
30000
20000
10000
0
-10000
-10
0
10
20
30
40
50
Time (s)
Is (A)
I 1 (A)
2 (A)
3 (A)

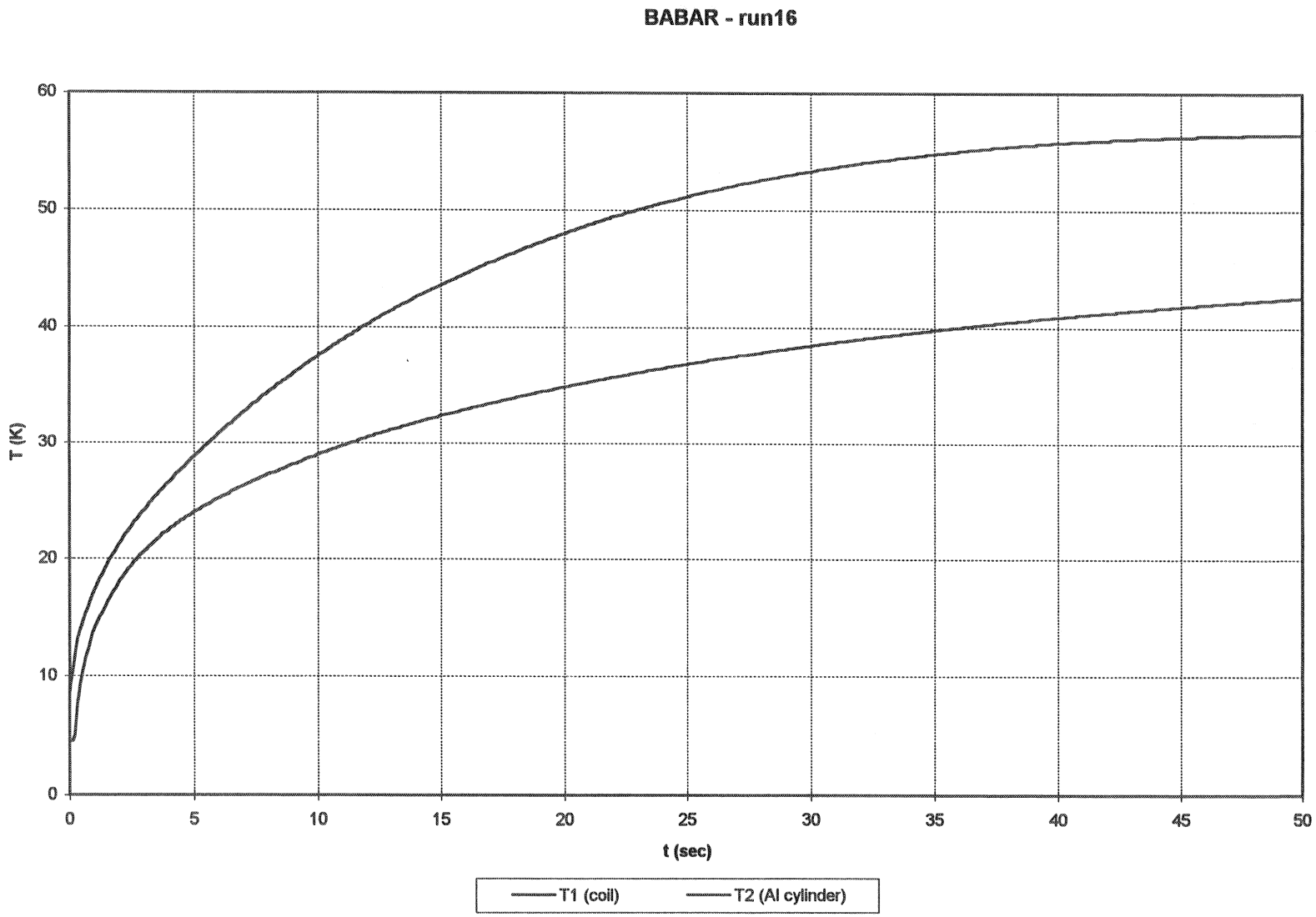
Voltages

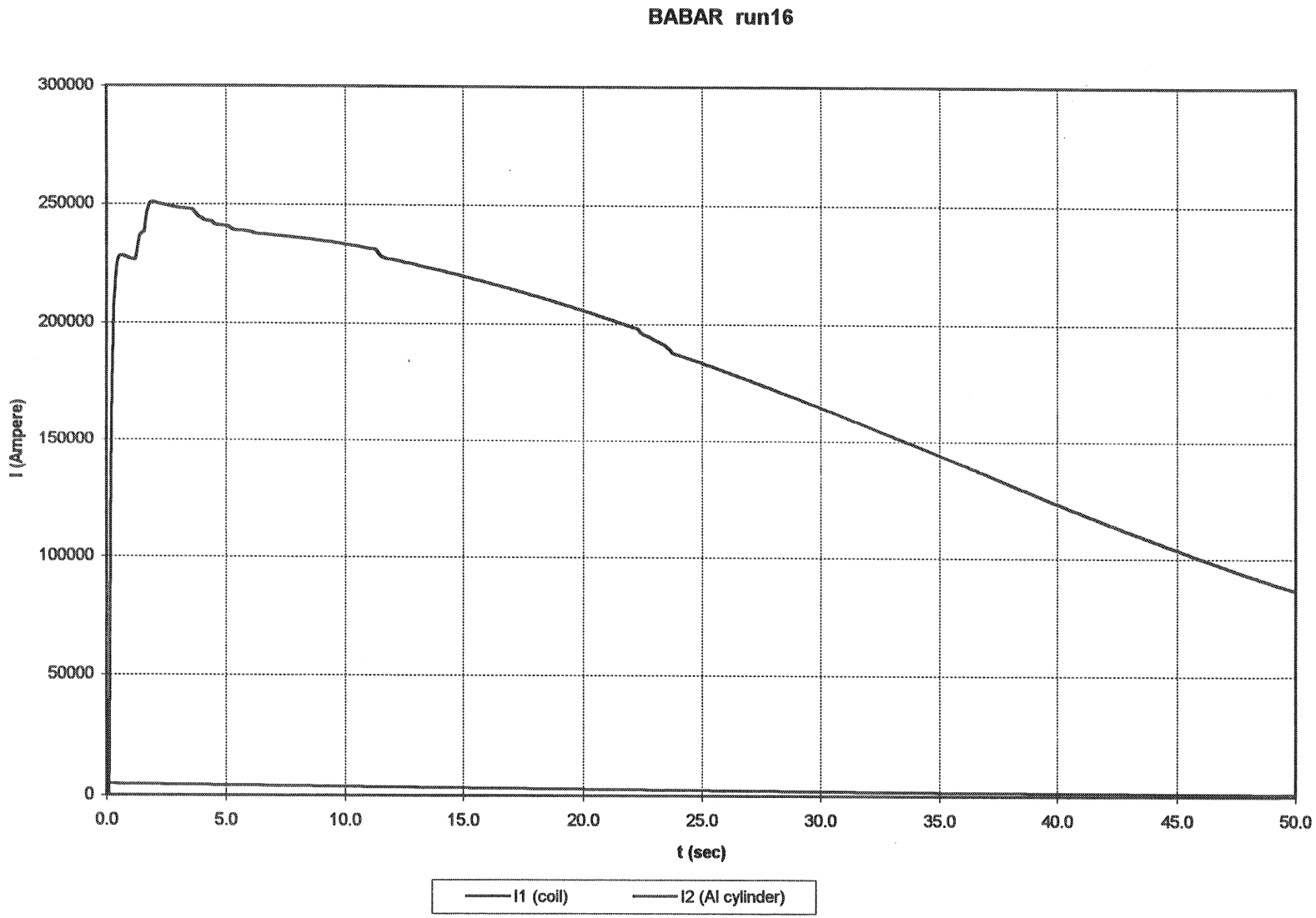

5.00E+01
4.00E+01
3.00E+01
2.00E+01
1.00E+01
0.00E+00
-1.00E+01
-2.00E+01
-3.00E+01
-4.00E+01
-5.00E+01
-5
0
5
10
15
20
25
30
35
40
45
50
Time (s)
Vlott (Volt)
Vt (Volt)
V 1 (Volt)
2 (Volt)
3 (Volt)

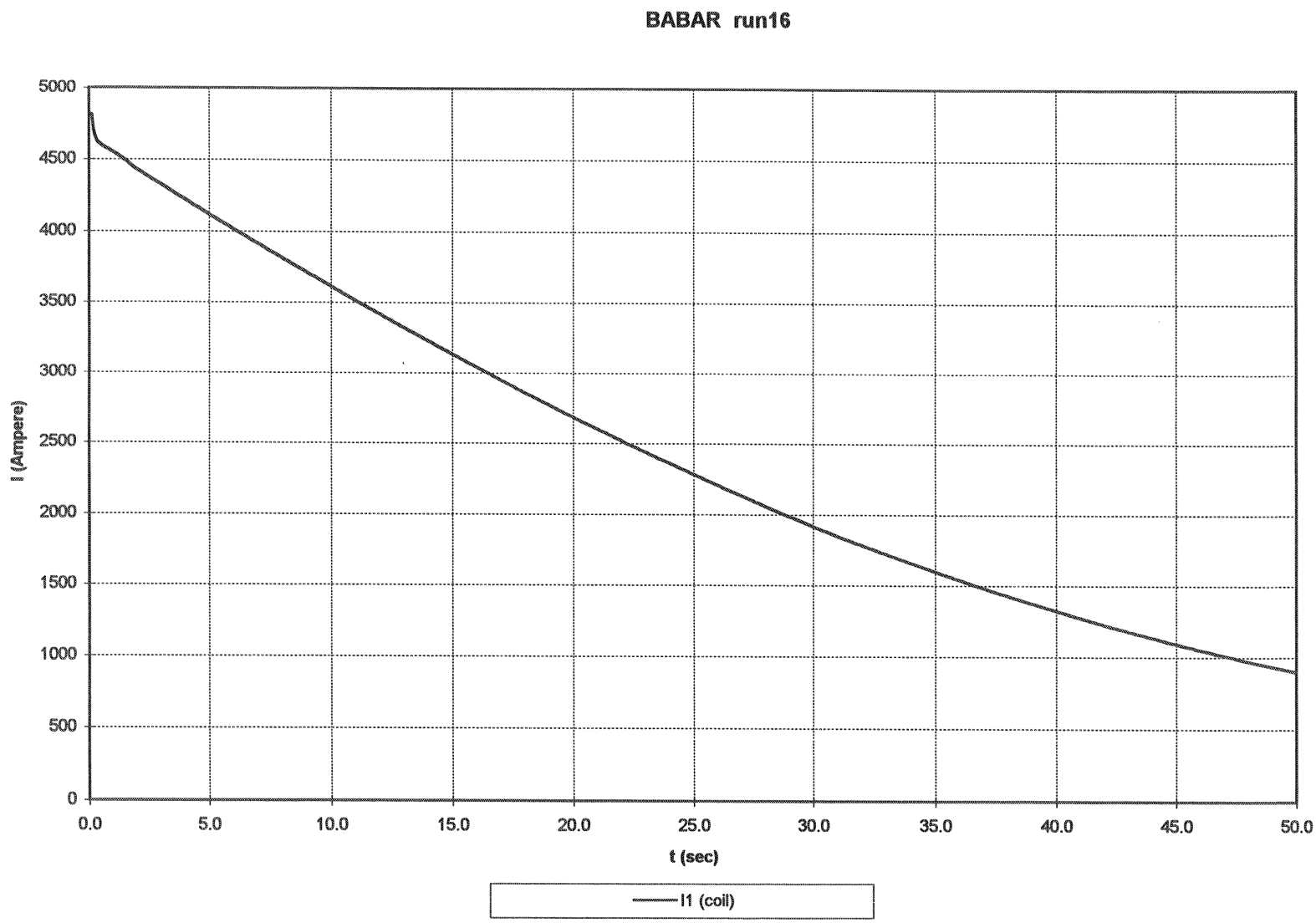
Temp. distrib. along z

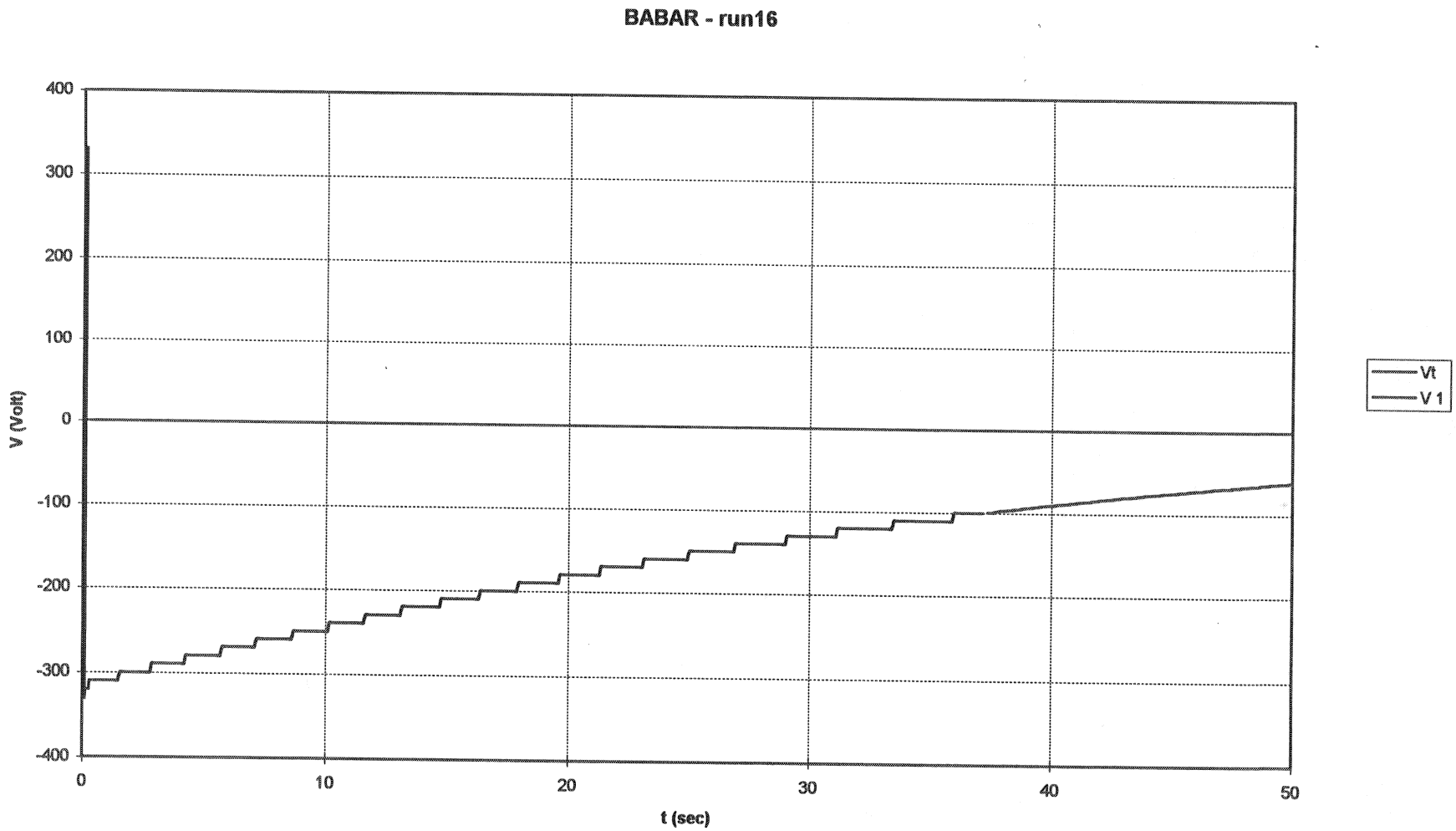


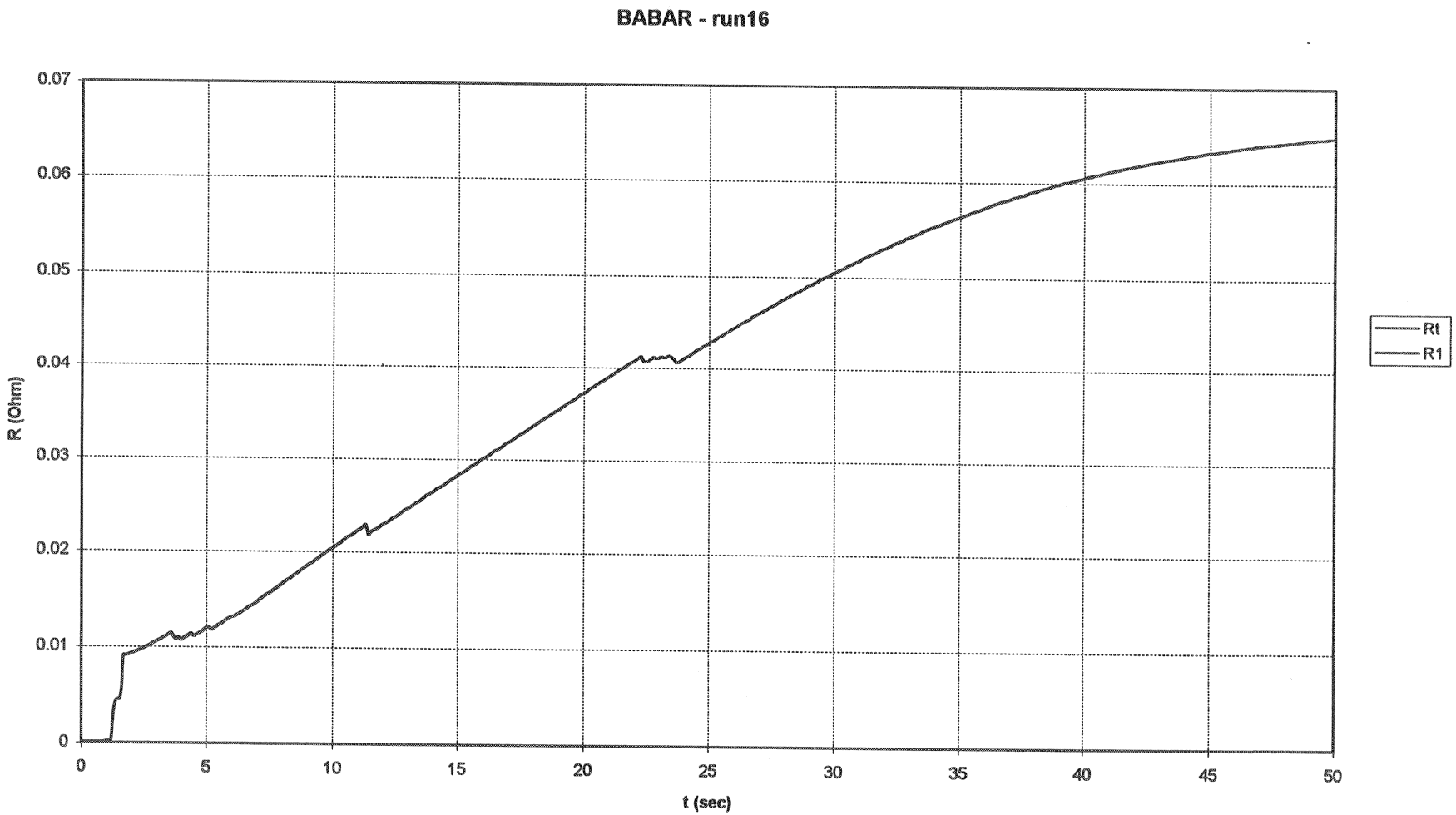

BABAR - run16
E (MJ)
t (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45
50
Es
Emag
Eth
Etot

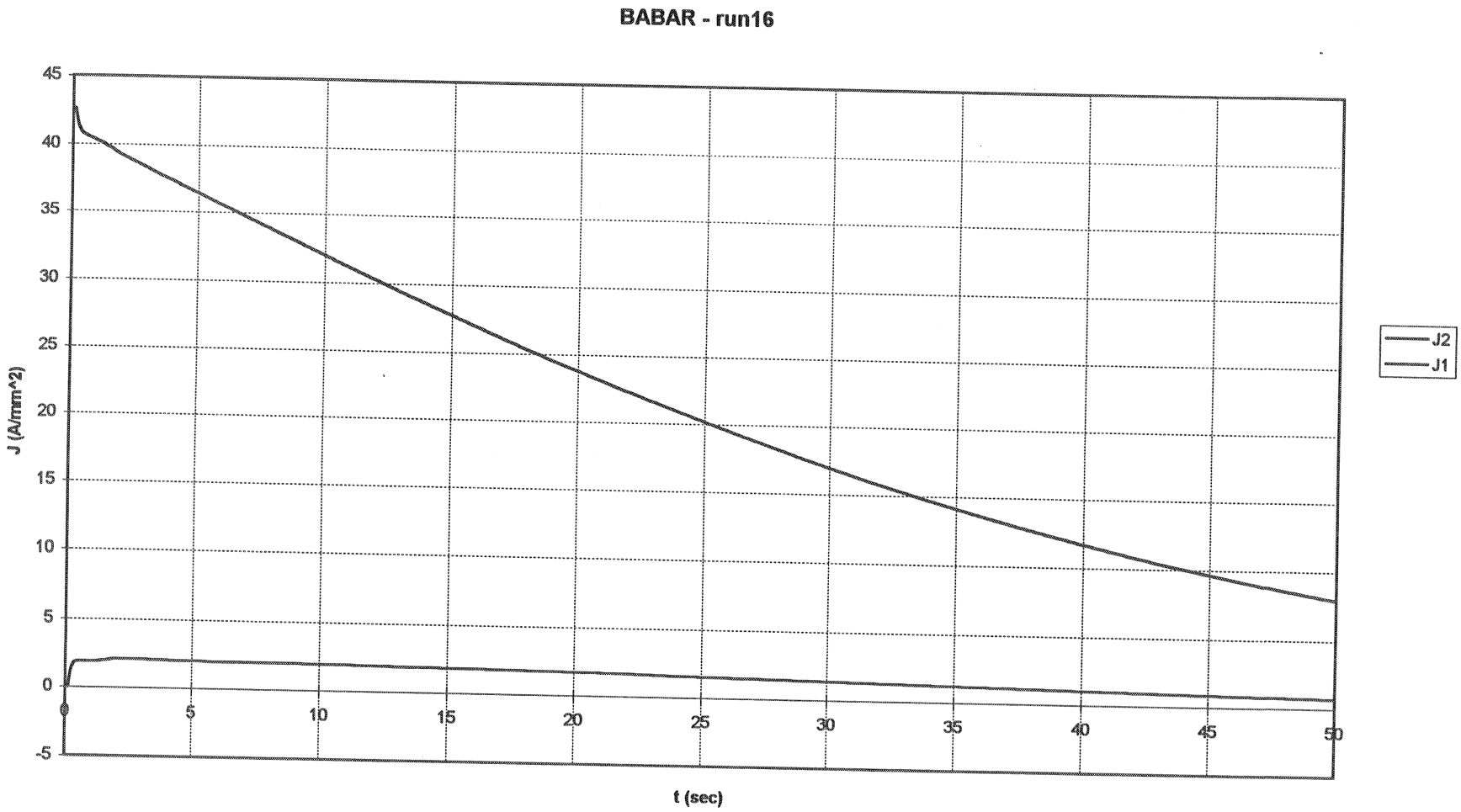

BABAR - run16
T (K)
t (sec)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50
T1 (coil)
T2 (Al cylinder)

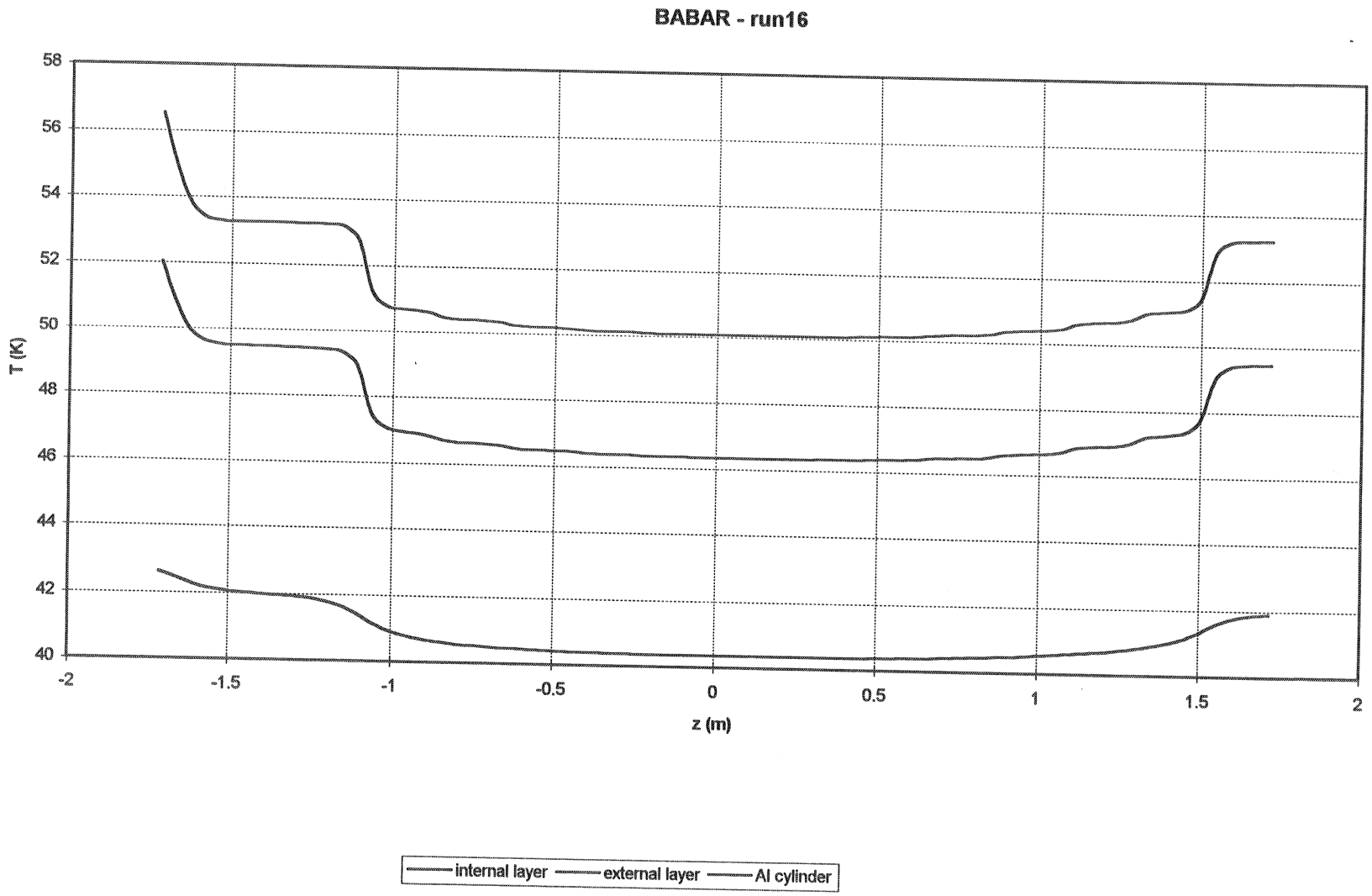

BABAR run16
300000
250000
200000
150000
100000
50000
0
I (Ampere)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
t (sec)
I1 (coil)
I2 (Al cylinder)

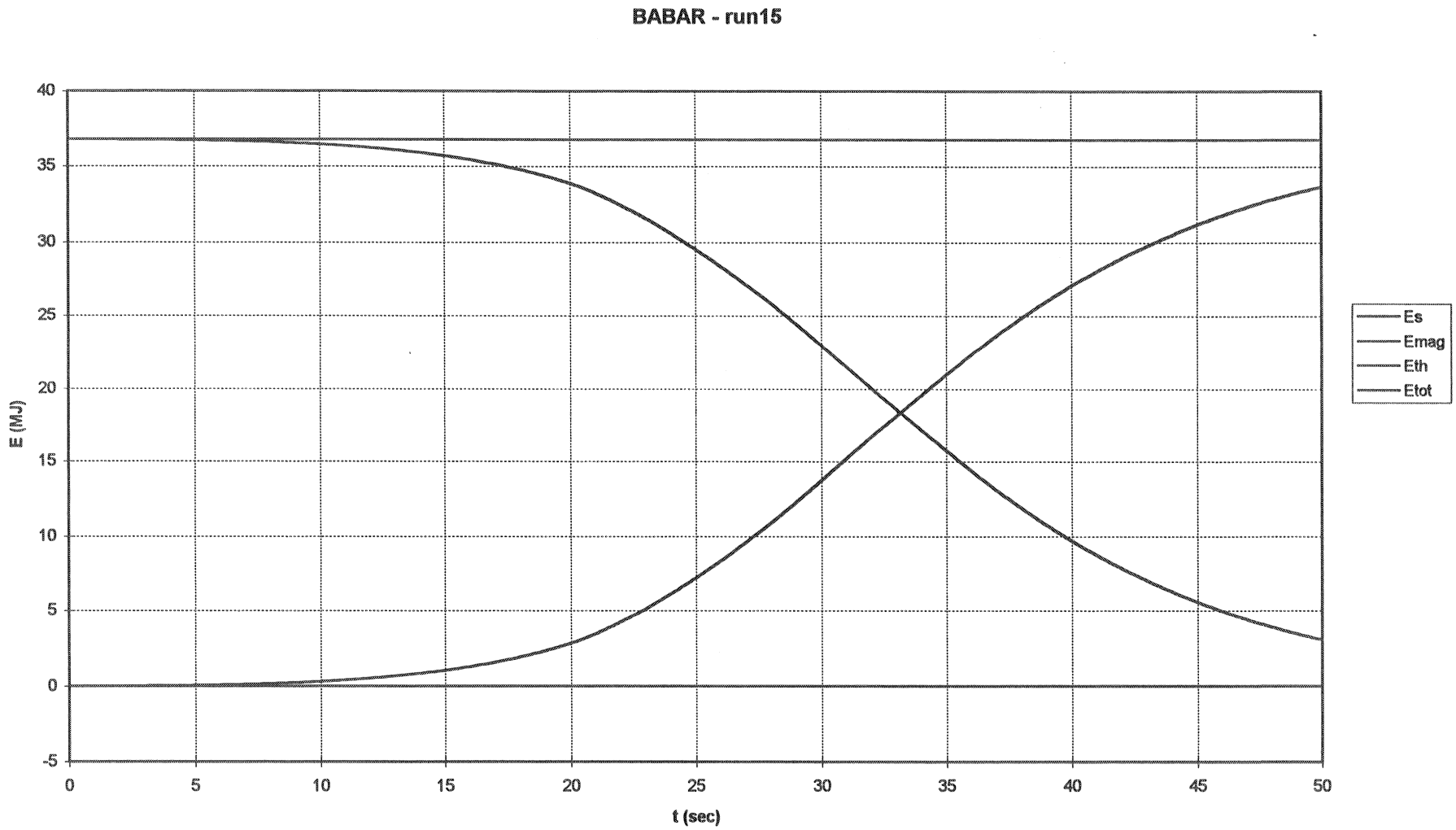

BABAR run16
I (Ampere)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
t (sec)
I1 (coil)

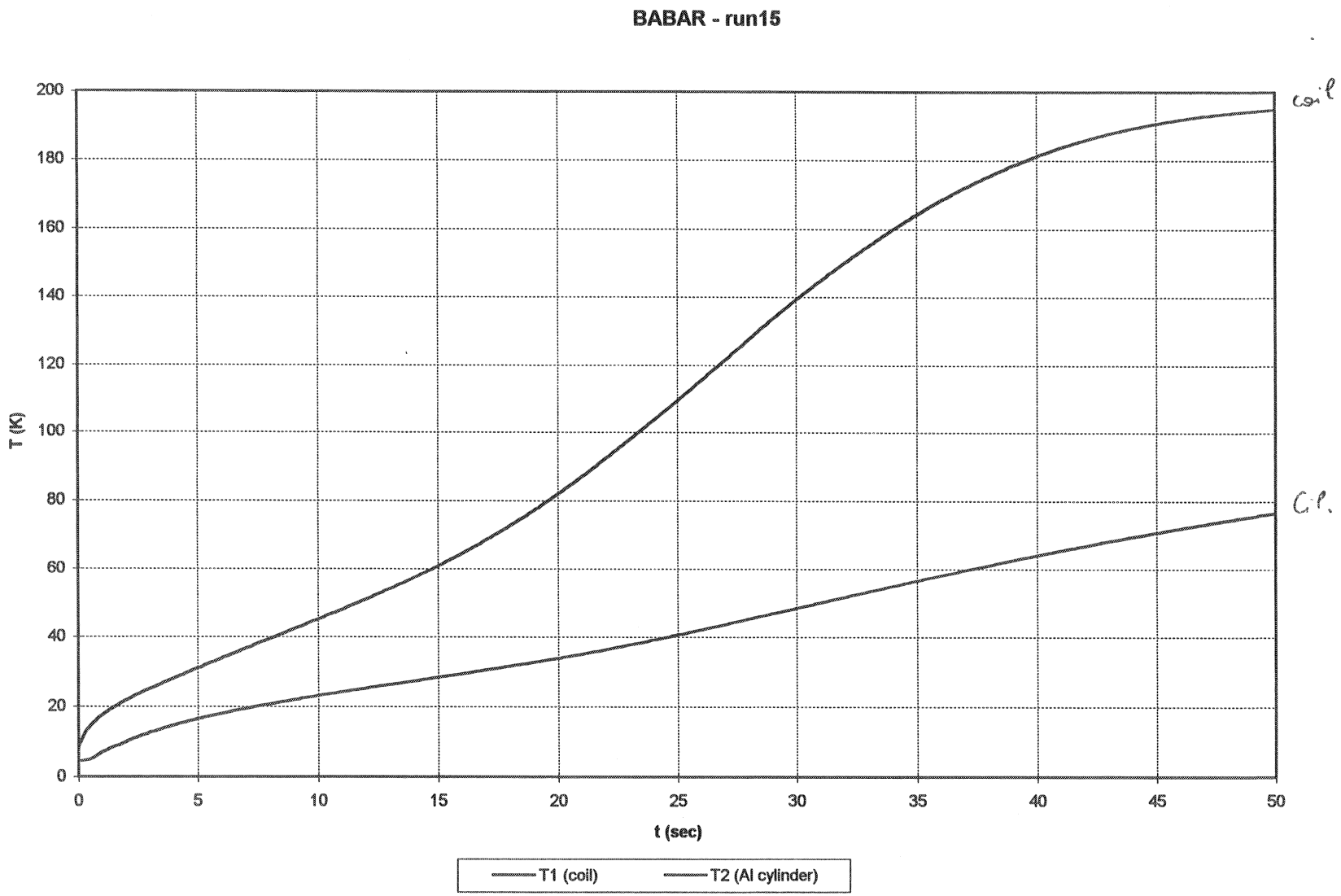

BABAR - run16
400
300
200
100
0
-100
-200
-300
-400
V (Volt)
0
10
20
30
40
50
t (sec)
Vt
V 1

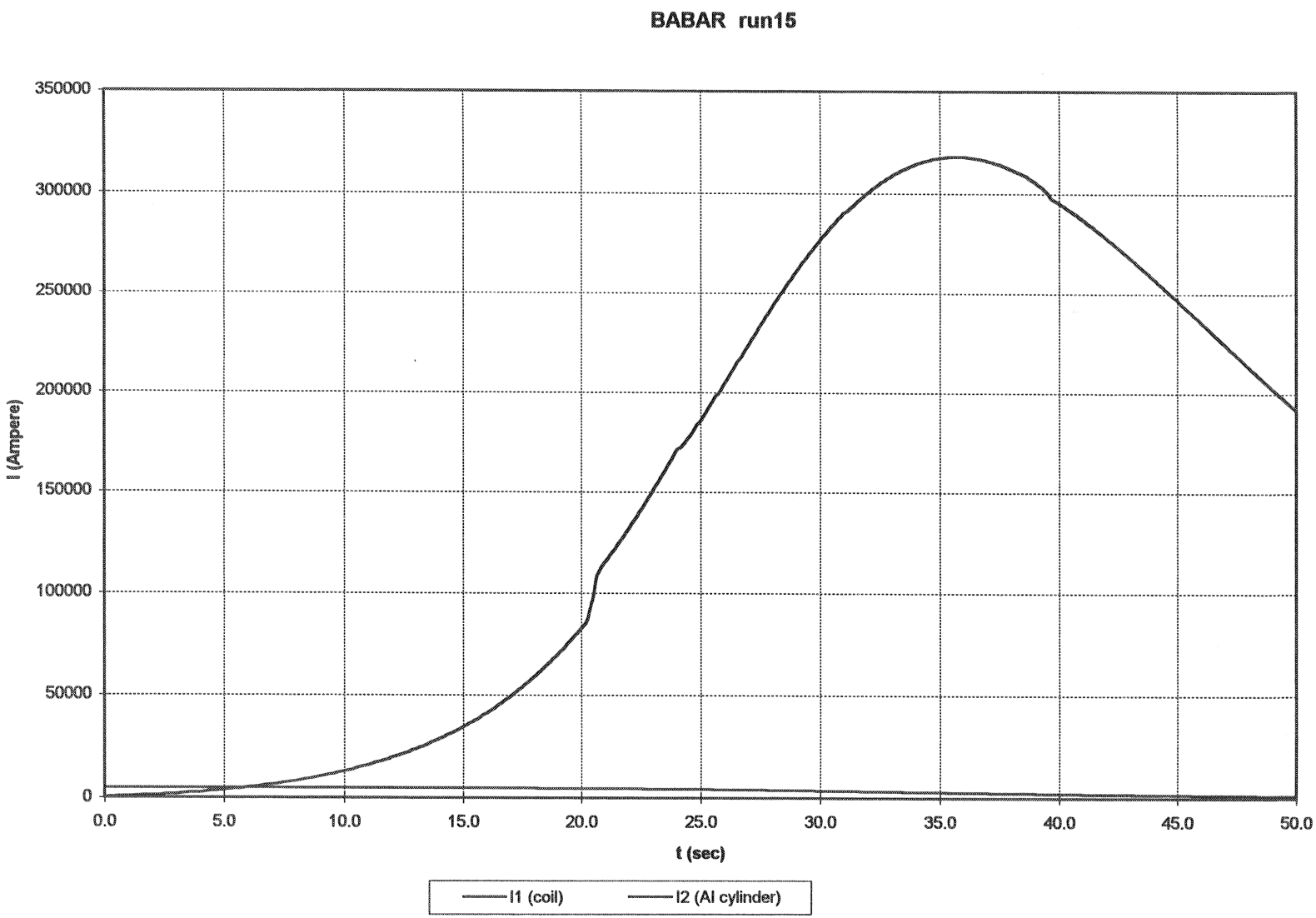

BABAR - run16
R (Ohm)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
30
35
40
45
50
t (sec)
Rt
R1

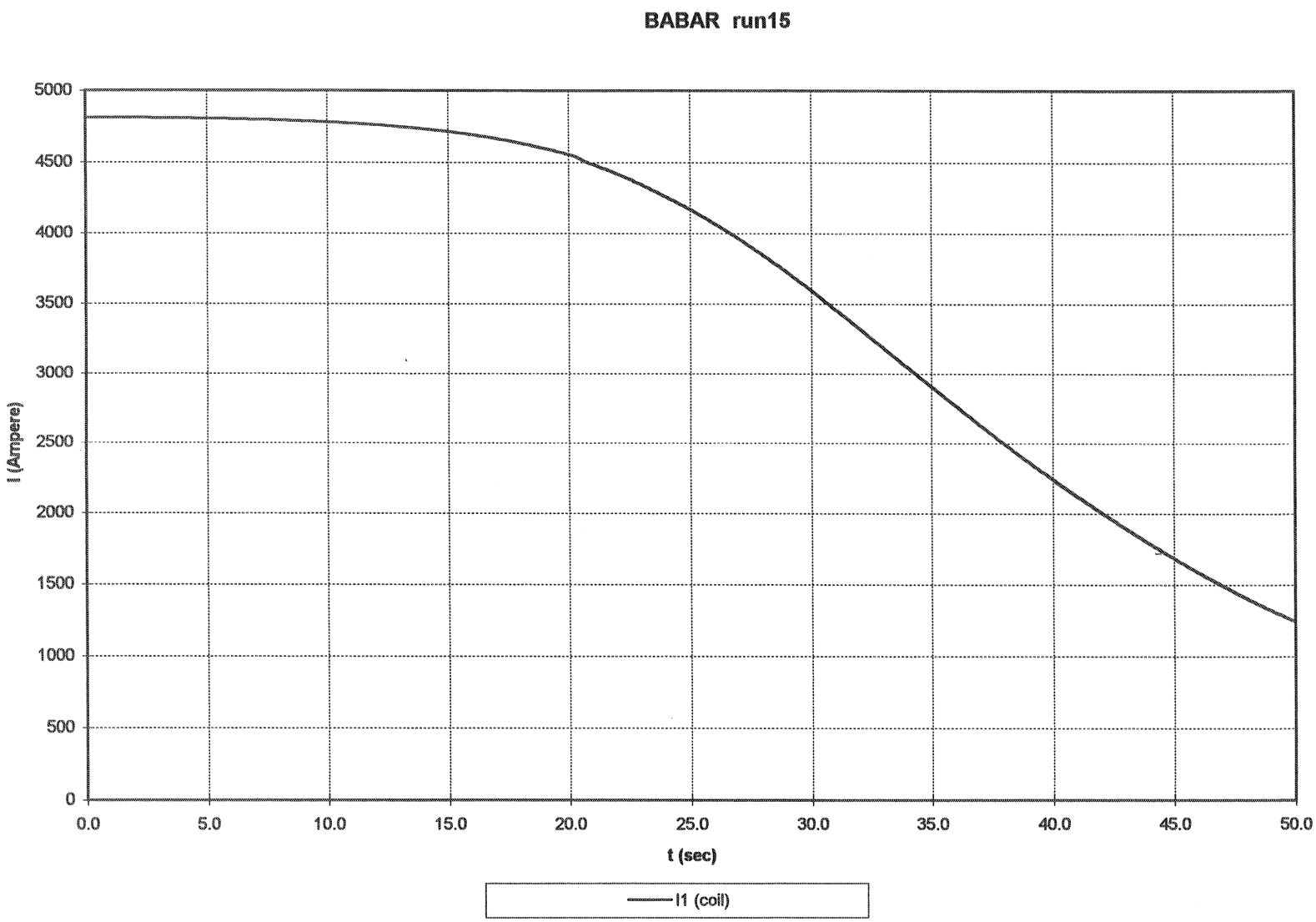

BABAR - run16
J (A/mm^2)
45
40
35
30
25
20
15
10
5
0
-5
5
10
15
20
25
30
35
40
45
50
t (sec)
J2
J1

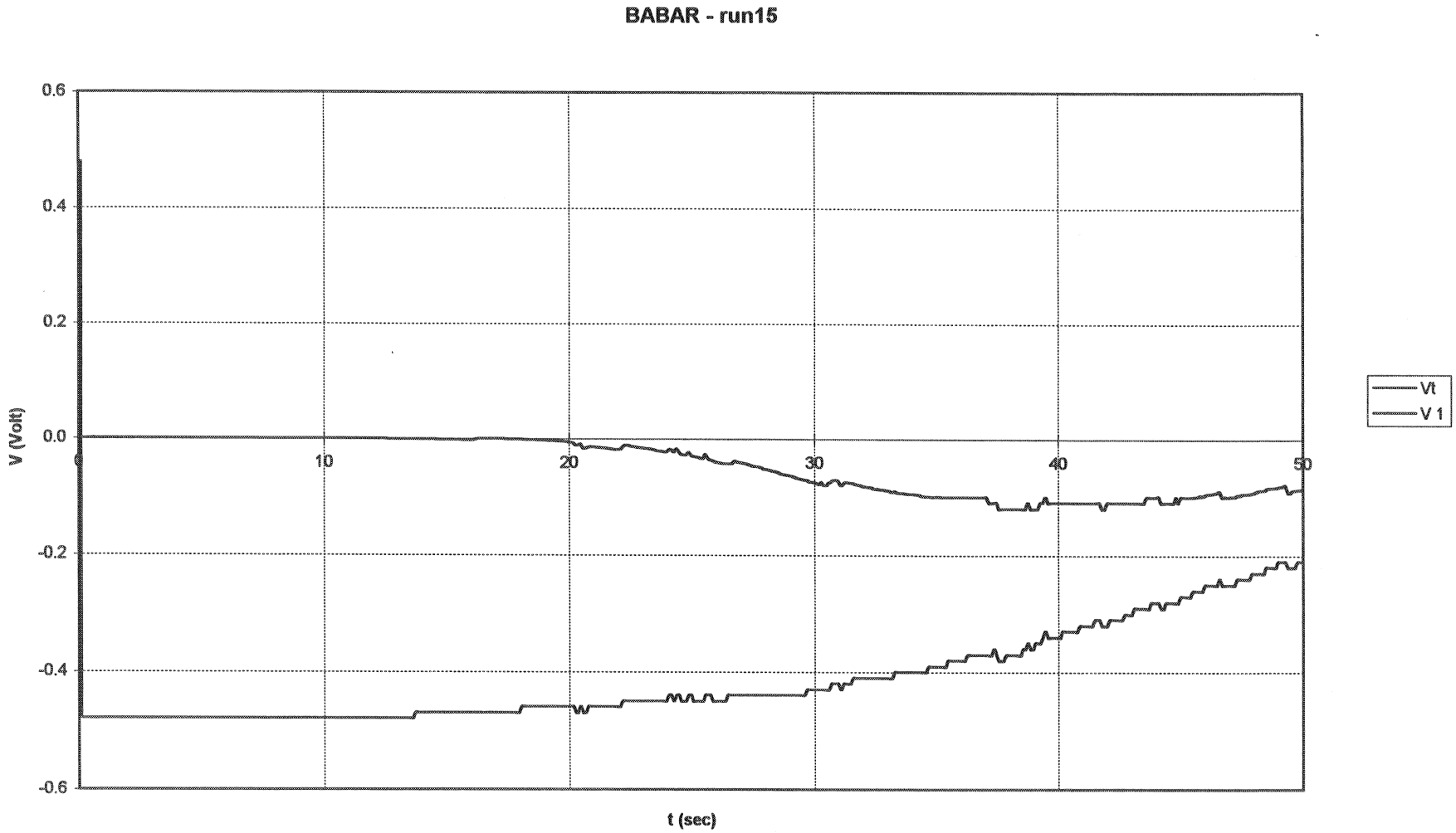

BABAR - run16
T (K)
58
56
54
52
50
48
46
44
42
40
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
z (m)
internal layer
external layer
Al cylinder

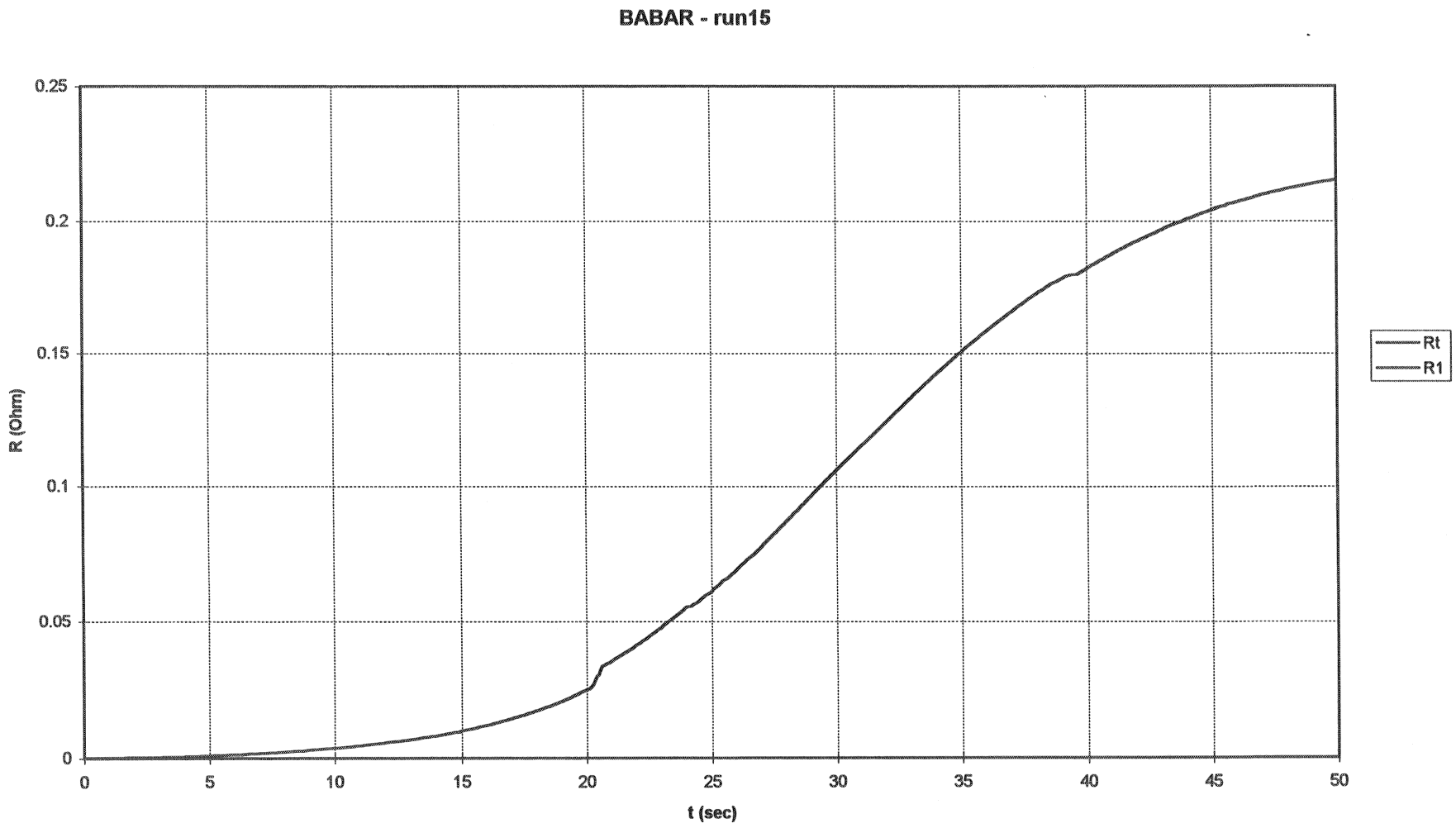

BABAR - run15
E (MJ)
t (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45
50
Es
Emag
Eth
Etot

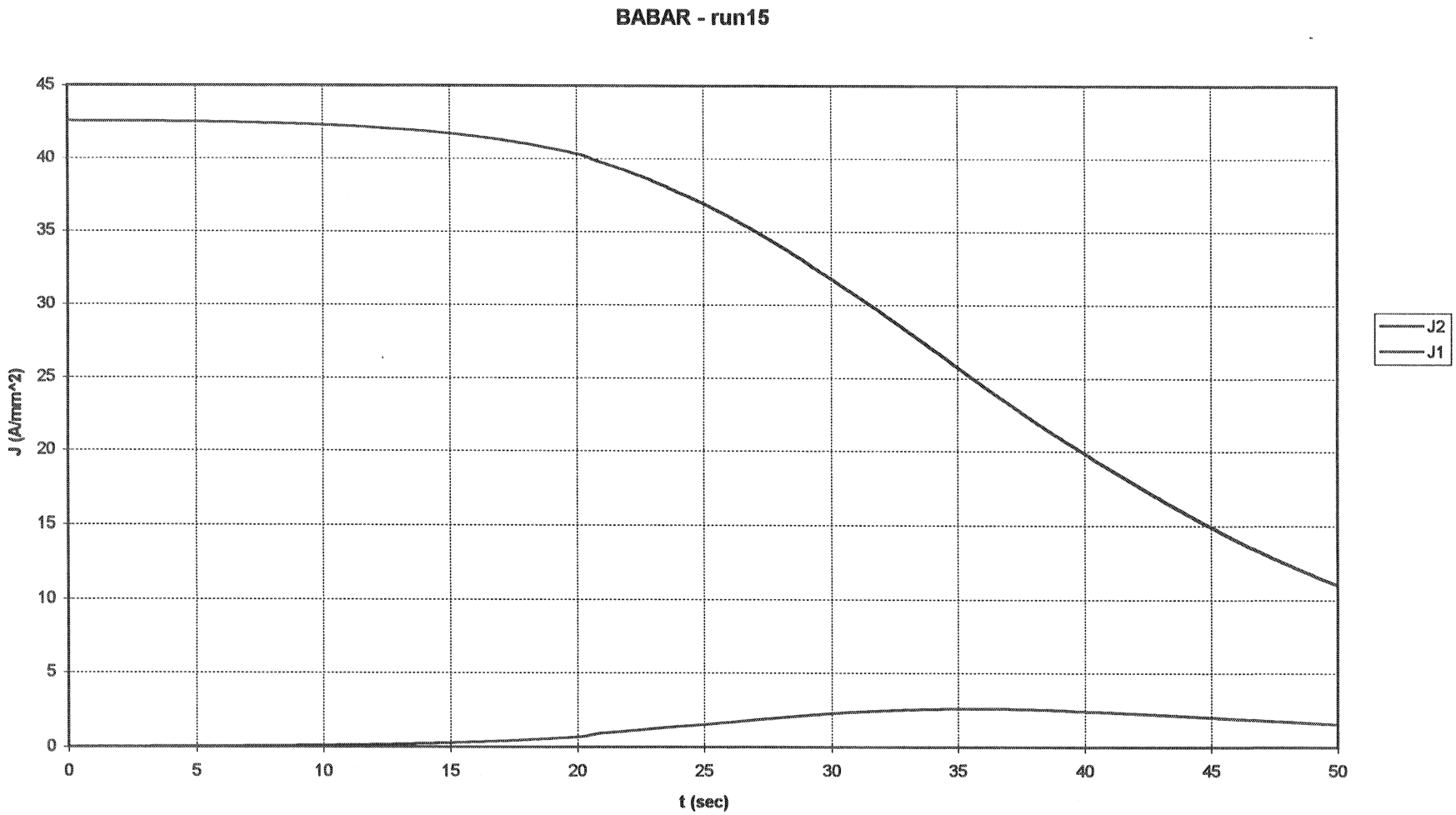

BABAR - run15
T (K)
t (sec)
0
20
40
60
80
100
120
140
160
180
200
0
5
10
15
20
25
30
35
40
45
50
coil
C.l.
T1 (coil)
T2 (Al cylinder)

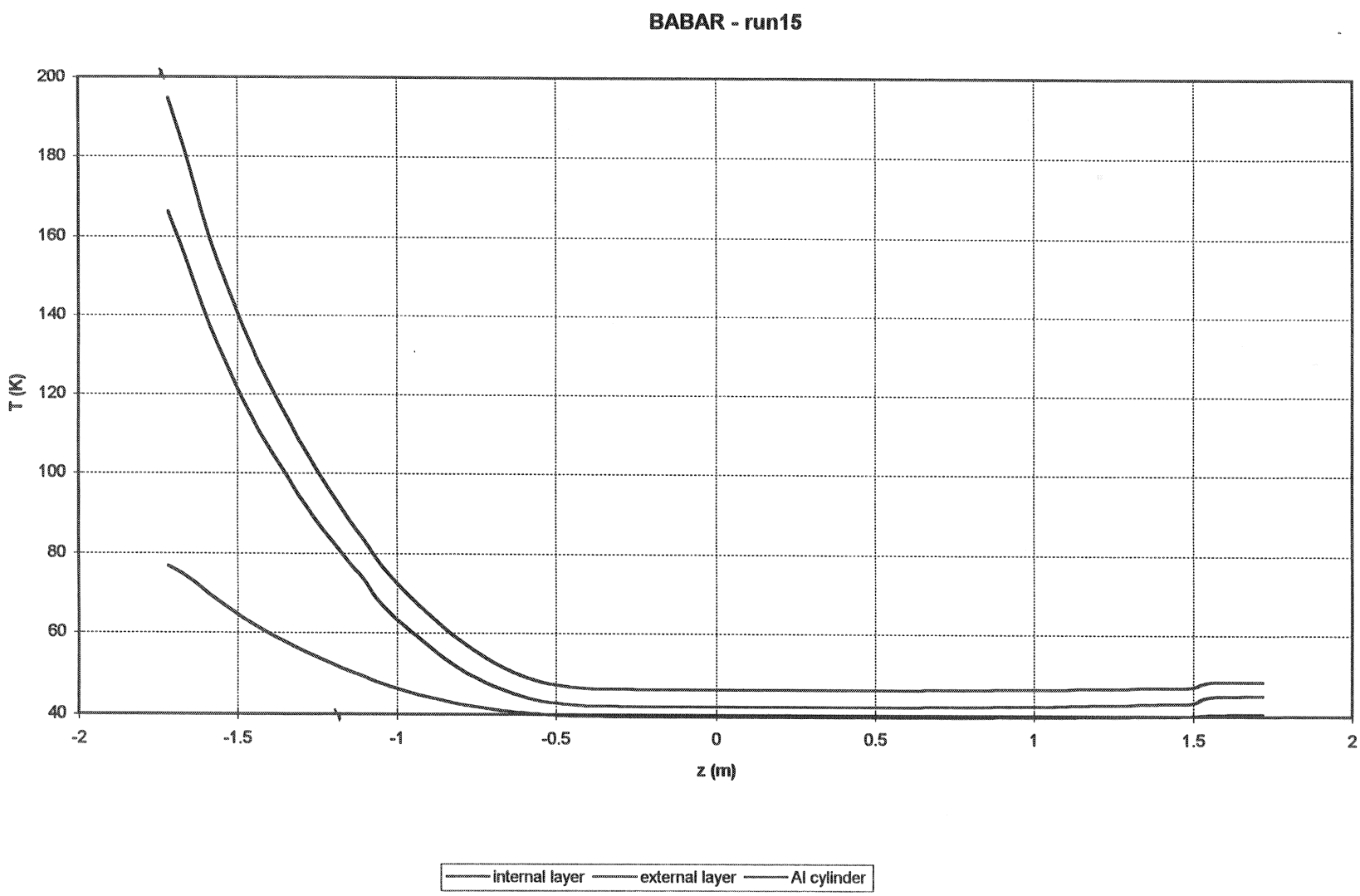

BABAR run15
350000
300000
250000
200000
150000
100000
50000
0
I (Ampere)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
t (sec)
I1 (coil)
I2 (Al cylinder)

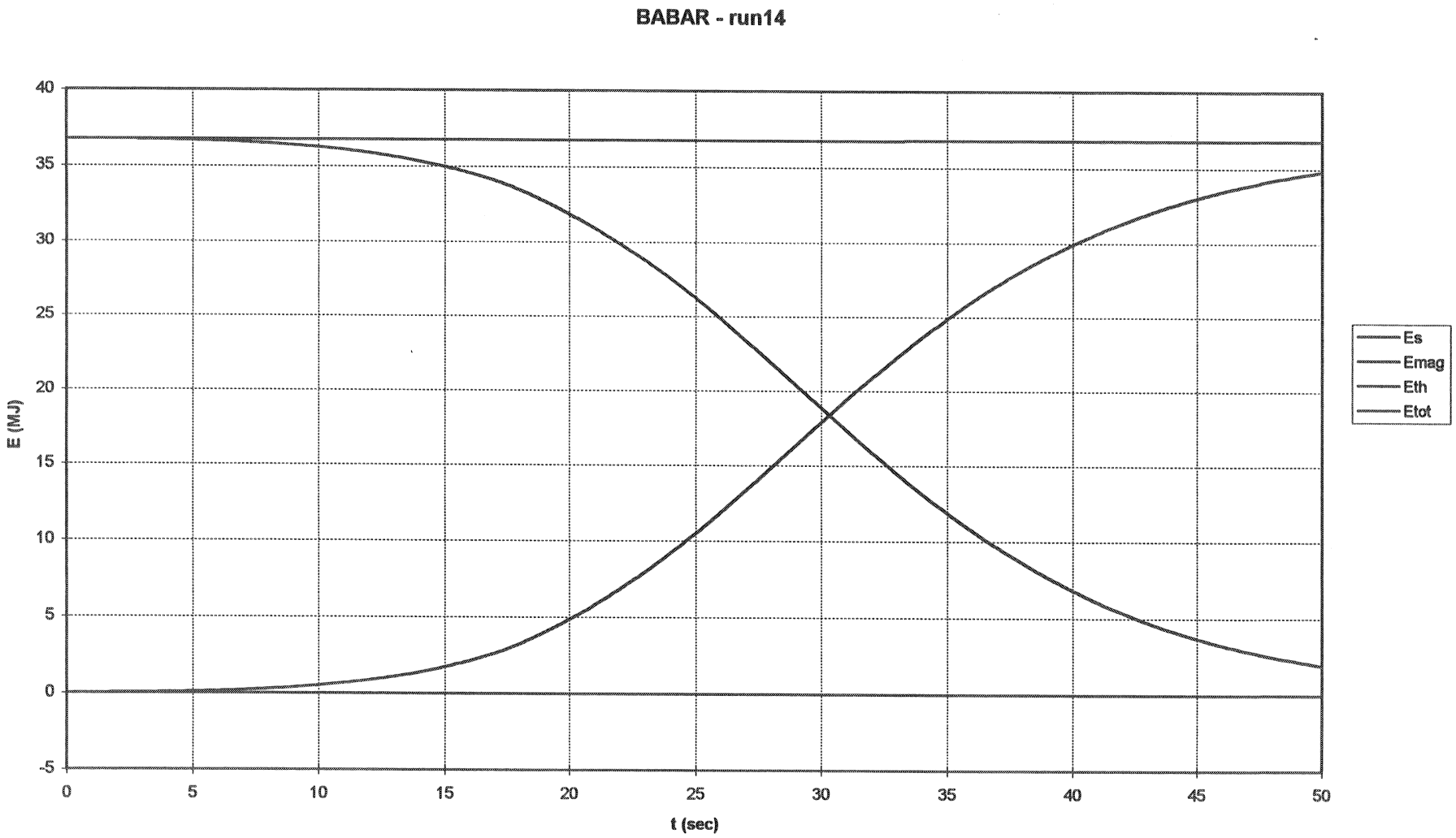

BABAR run15
I (Ampere)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
t (sec)
I1 (coil)

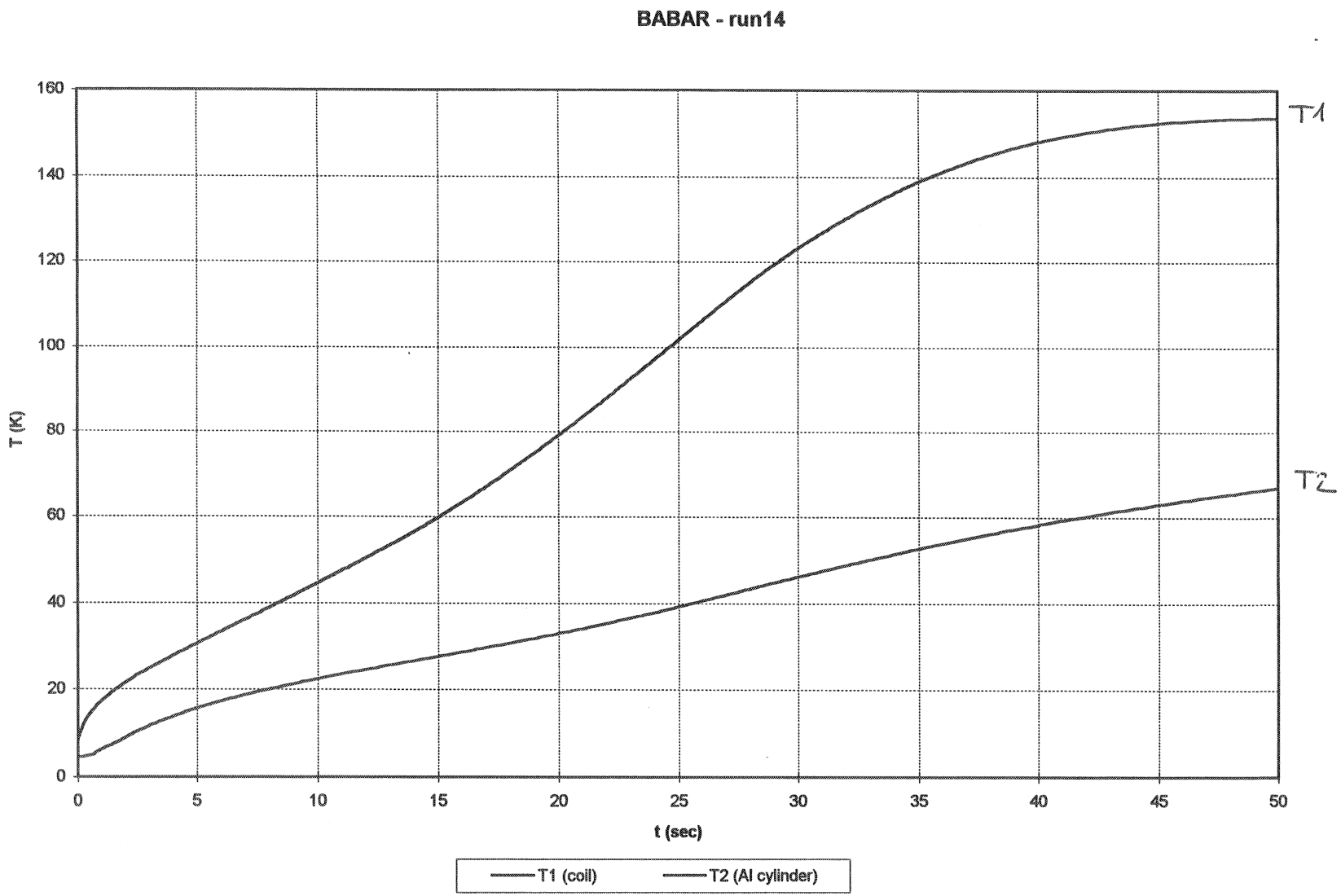

BABAR - run15
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
V (Volt)
10
20
30
40
50
t (sec)
Vt
V 1

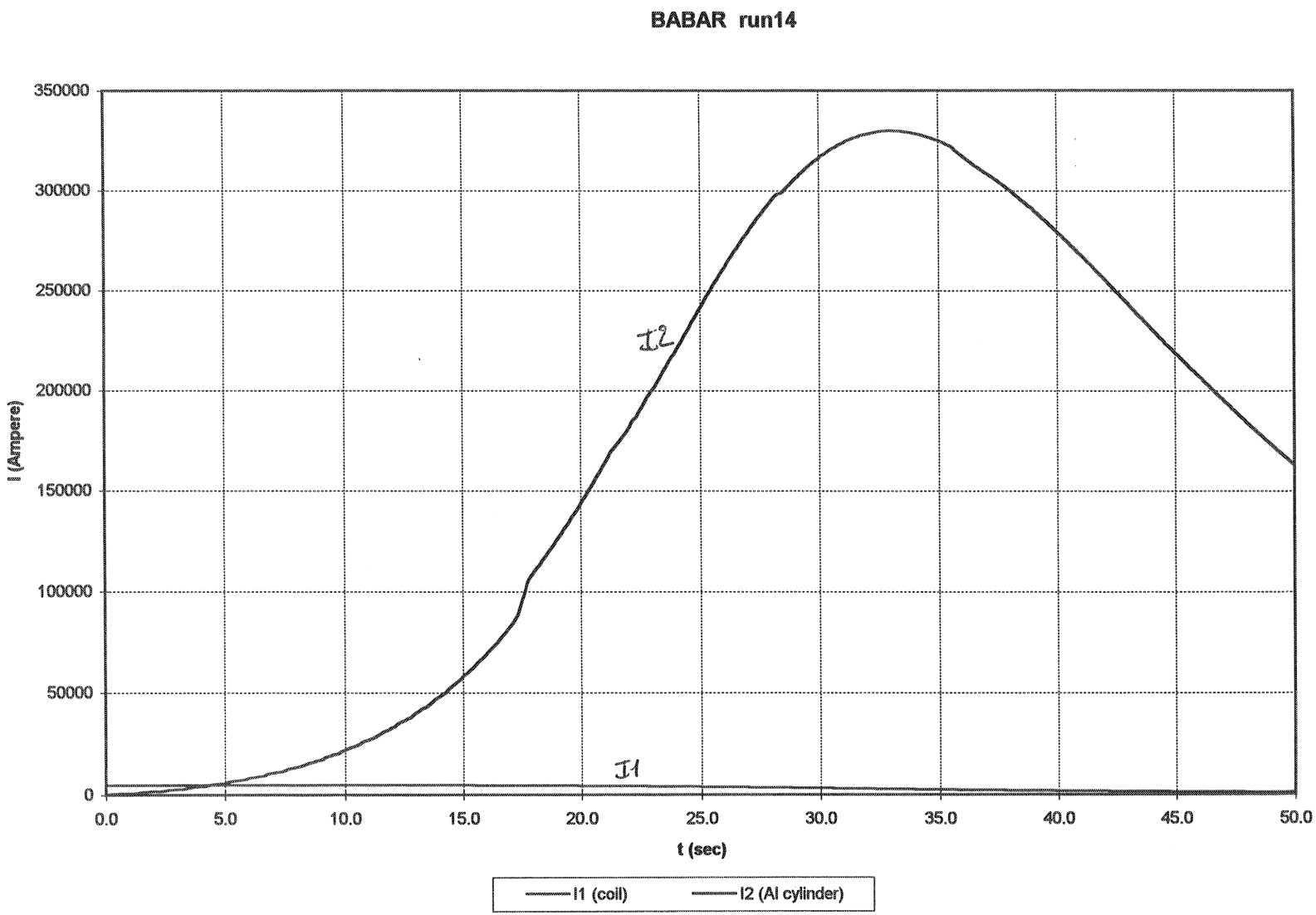

BABAR - run15
0.25
0.2
0.15
0.1
0.05
0
R (Ohm)
0
5
10
15
20
25
30
35
40
45
50
t (sec)
Rt
R1

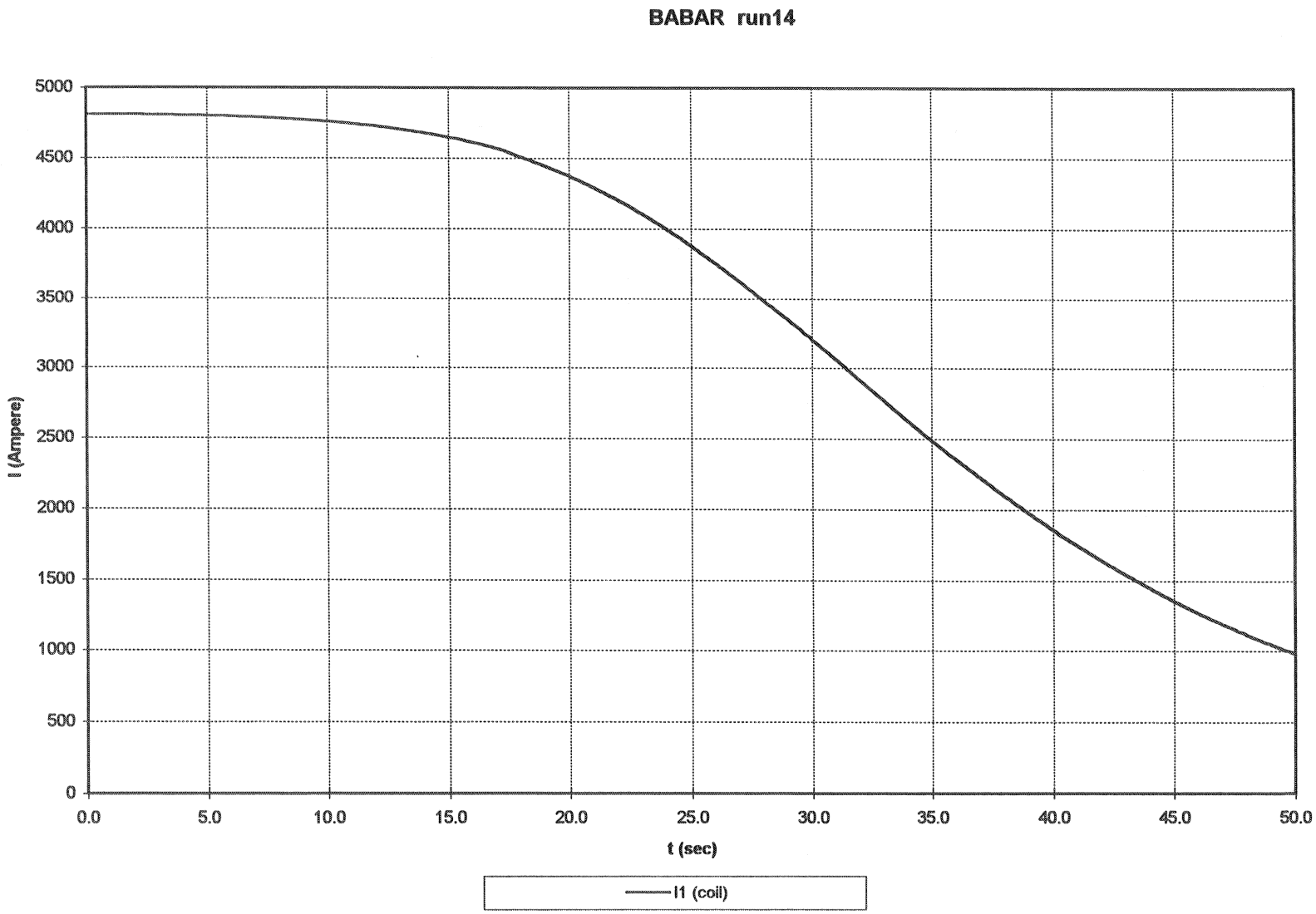

BABAR - run15
J (A/mm^2)
t (sec)
0
5
10
15
20
25
30
35
40
45
50
J2
J1

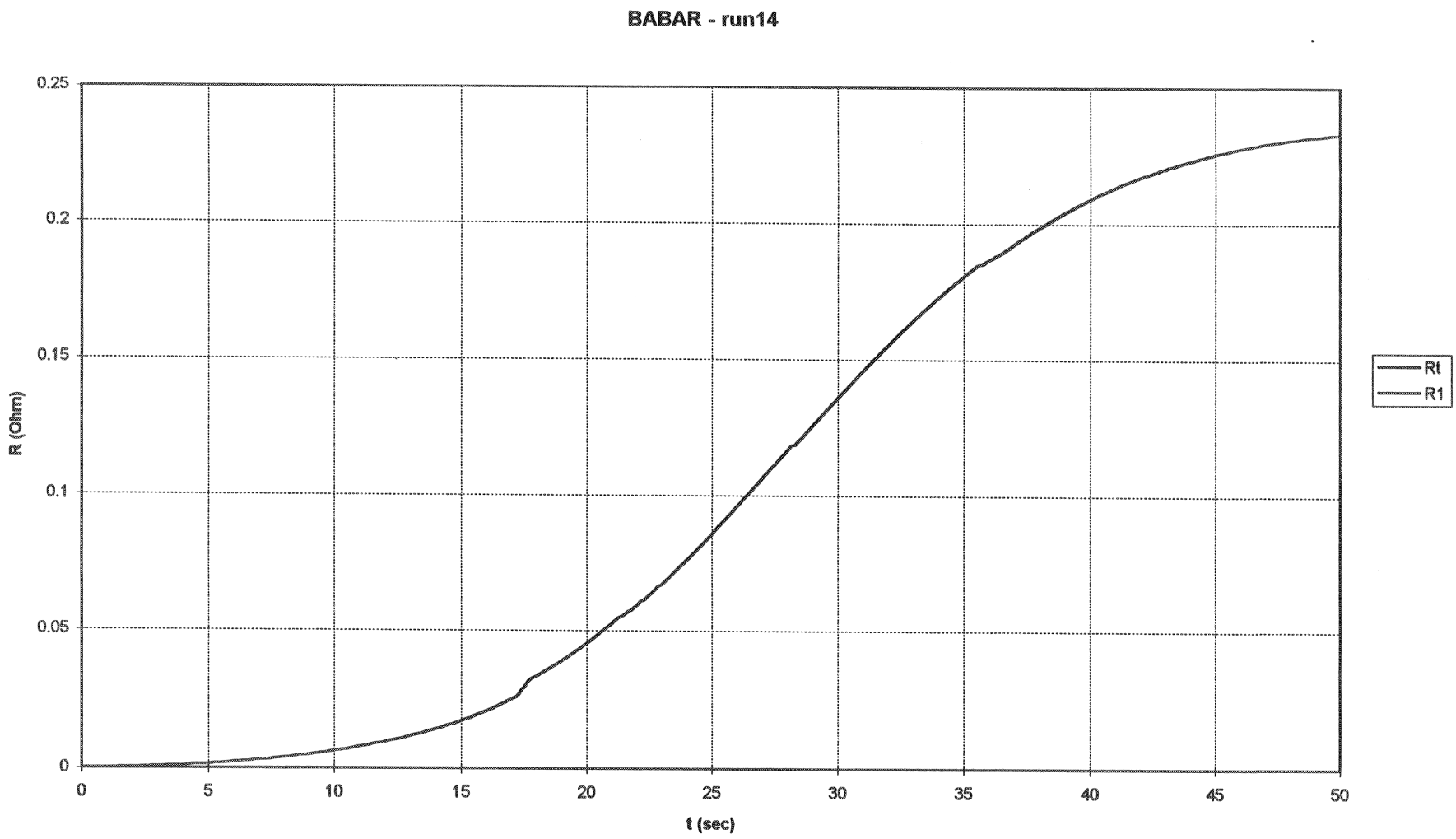

BABAR - run15
T (K)
200
180
160
140
120
100
80
60
40
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
z (m)
internal layer
external layer
Al cylinder

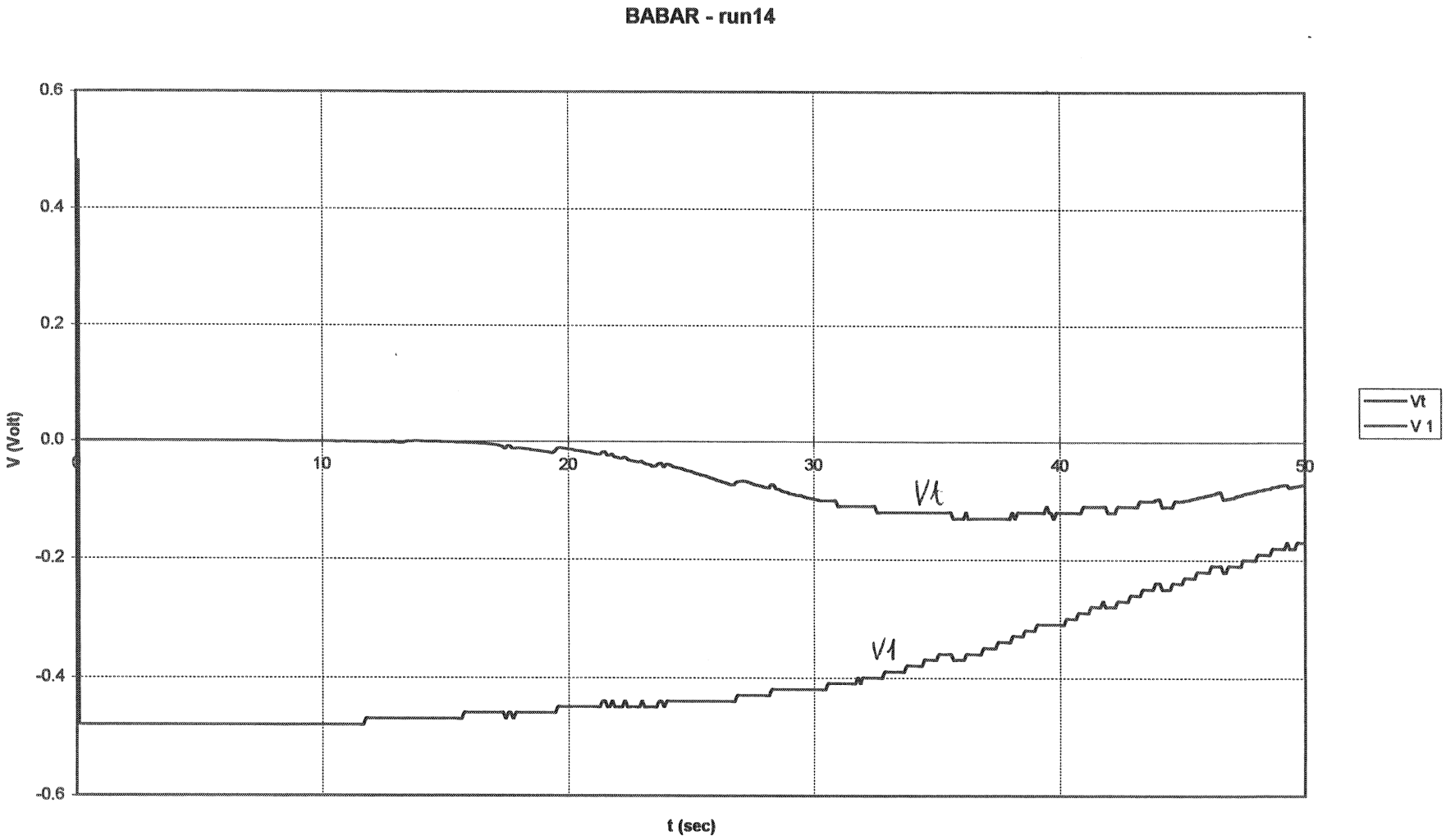

BABAR - run14
E (MJ)
t (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45
50
Es
Emag
Eth
Etot

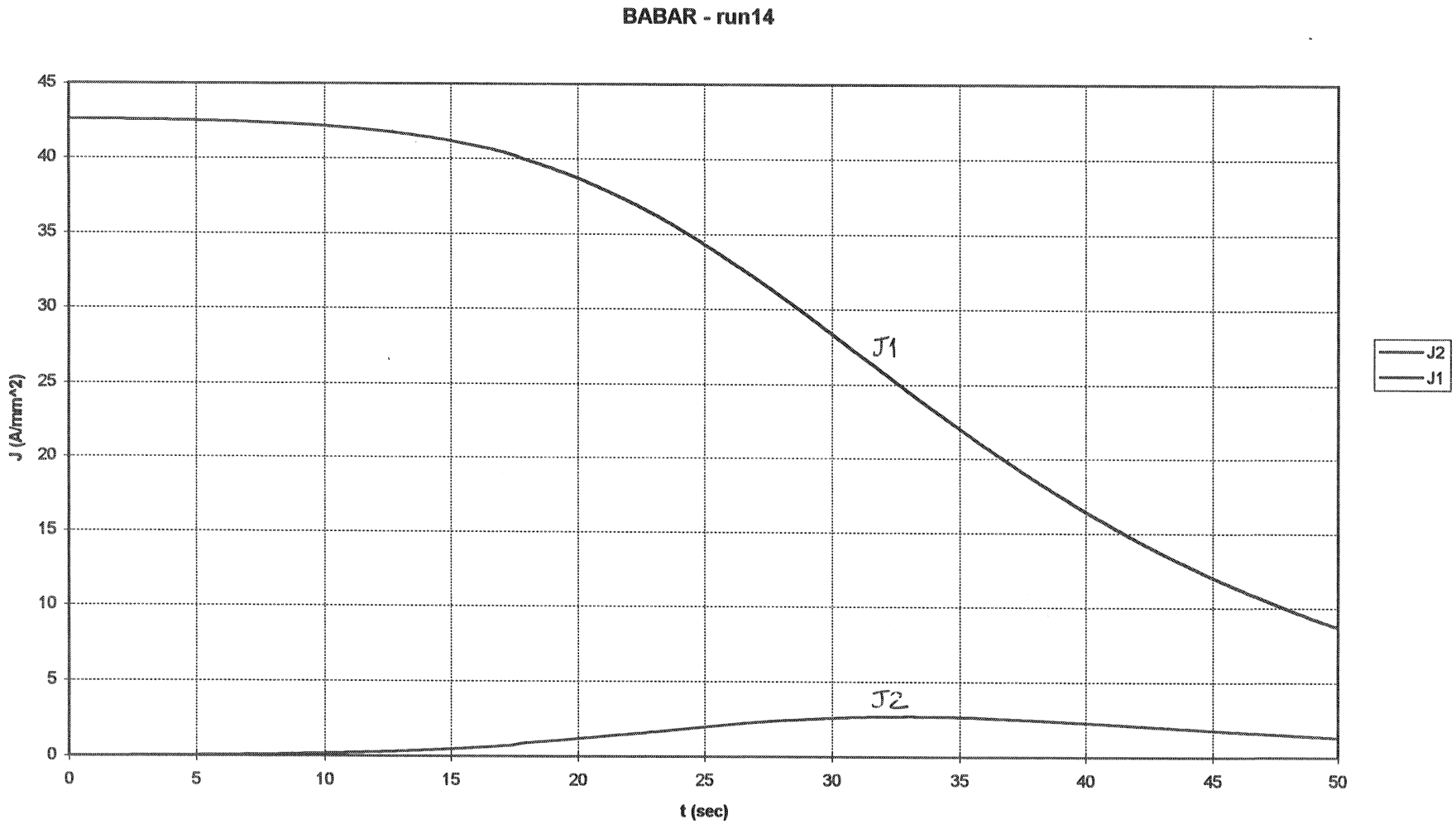

BABAR - run14
T (K)
t (sec)
0
20
40
60
80
100
120
140
160
0
5
10
15
20
25
30
35
40
45
50
T1
T2
T1 (coil)
T2 (Al cylinder)

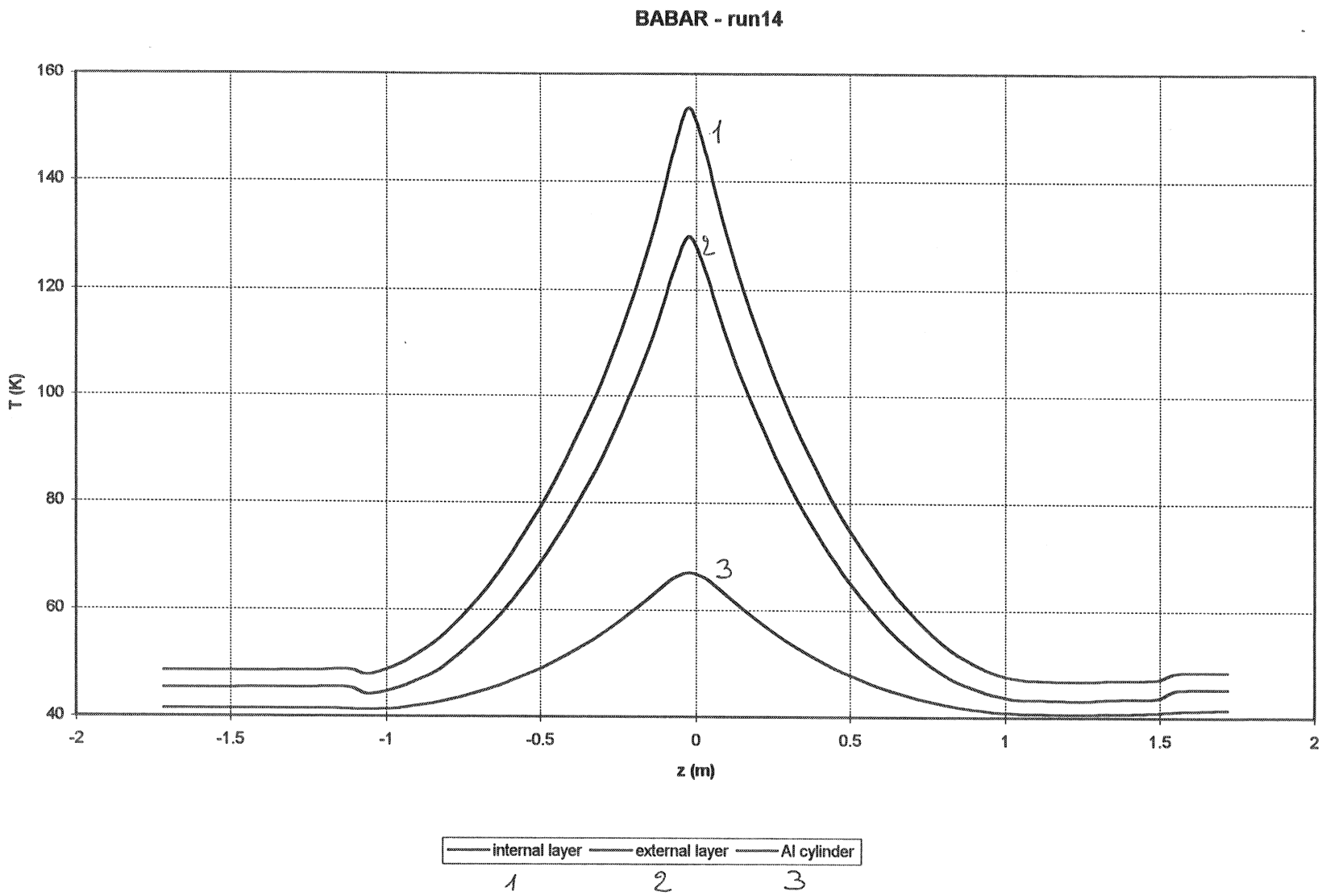

BABAR run14
350000
300000
250000
200000
150000
100000
50000
0
I (Ampere)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
t (sec)
I2
I1
I1 (coil)
I2 (Al cylinder)

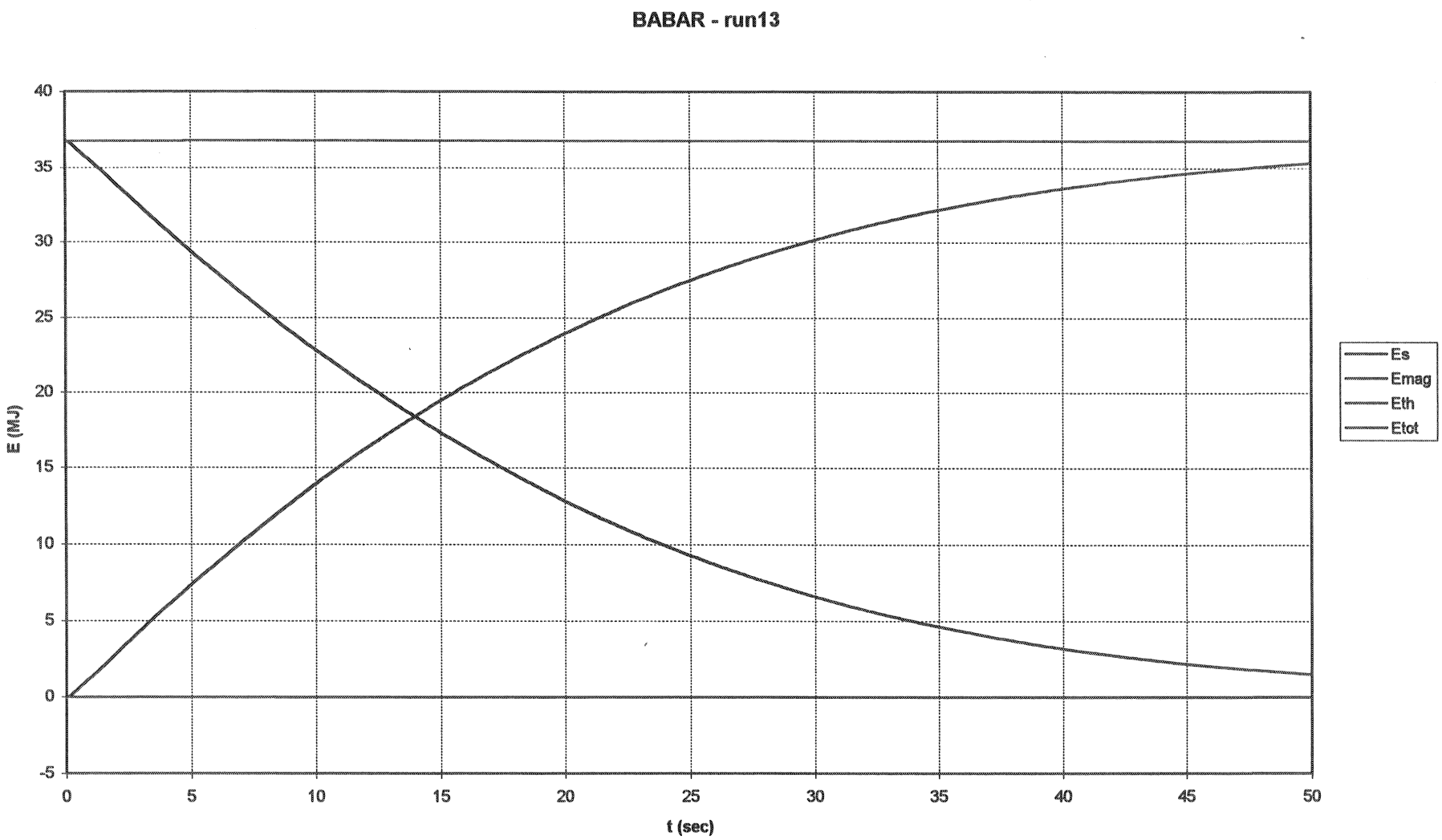

BABAR run14
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
I (Ampere)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
t (sec)
I1 (coil)

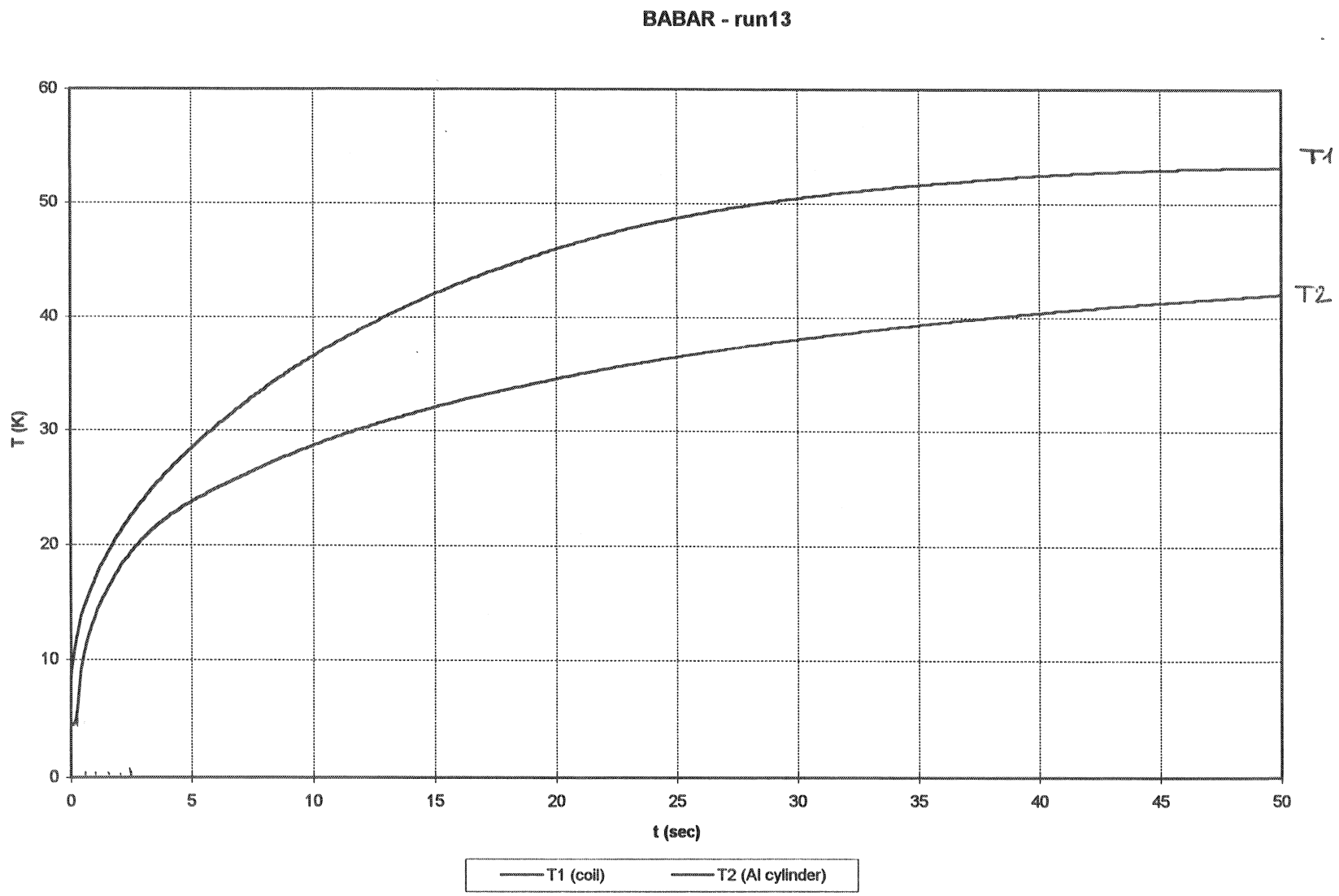

BABAR - run14
0.25
0.2
0.15
0.1
0.05
0
R (Ohm)
0
5
10
15
20
25
30
35
40
45
50
t (sec)
Rt
R1

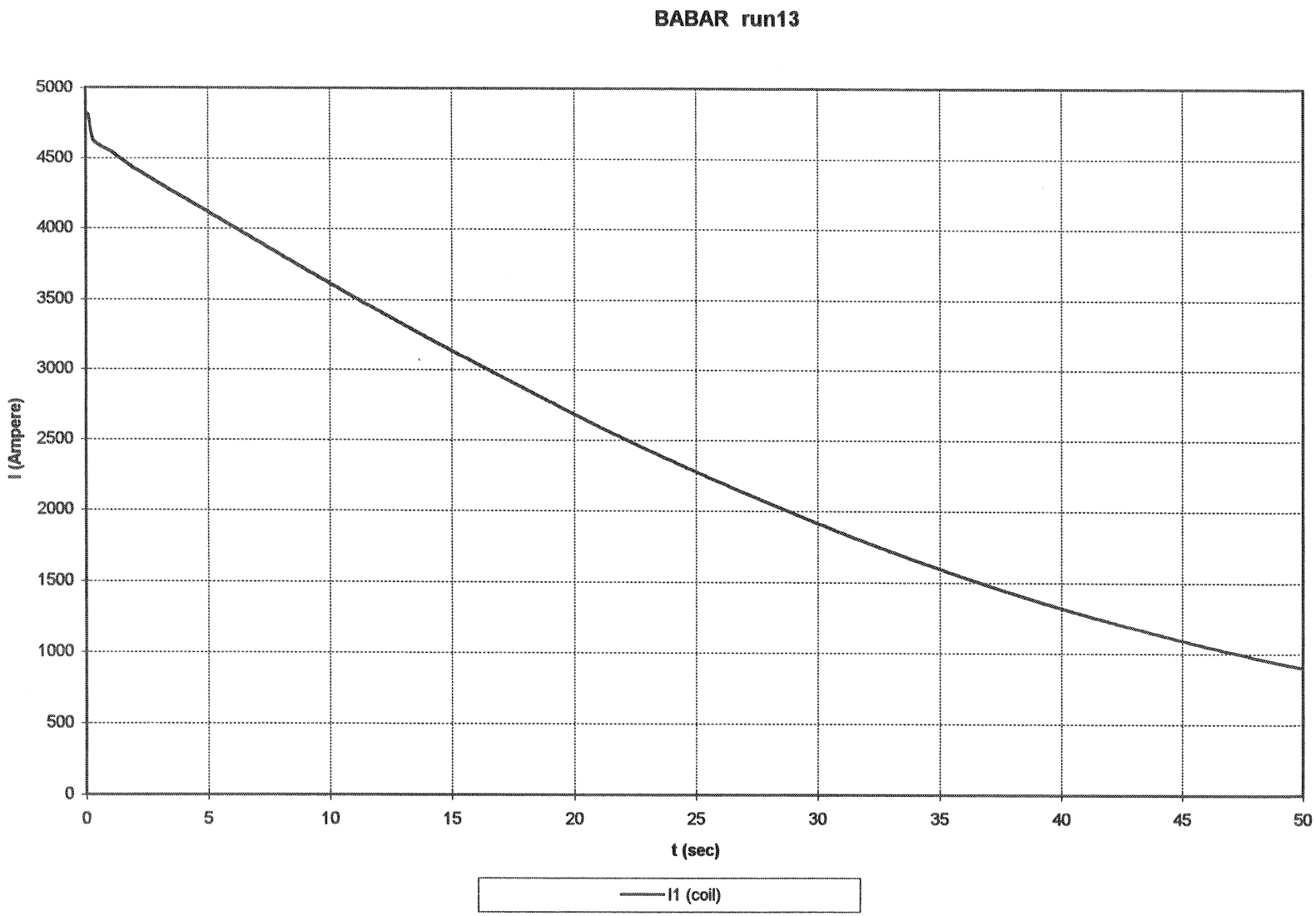

BABAR - run14
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
V (Volt)
10
20
30
40
50
t (sec)
Vt
V1
Vt
V 1

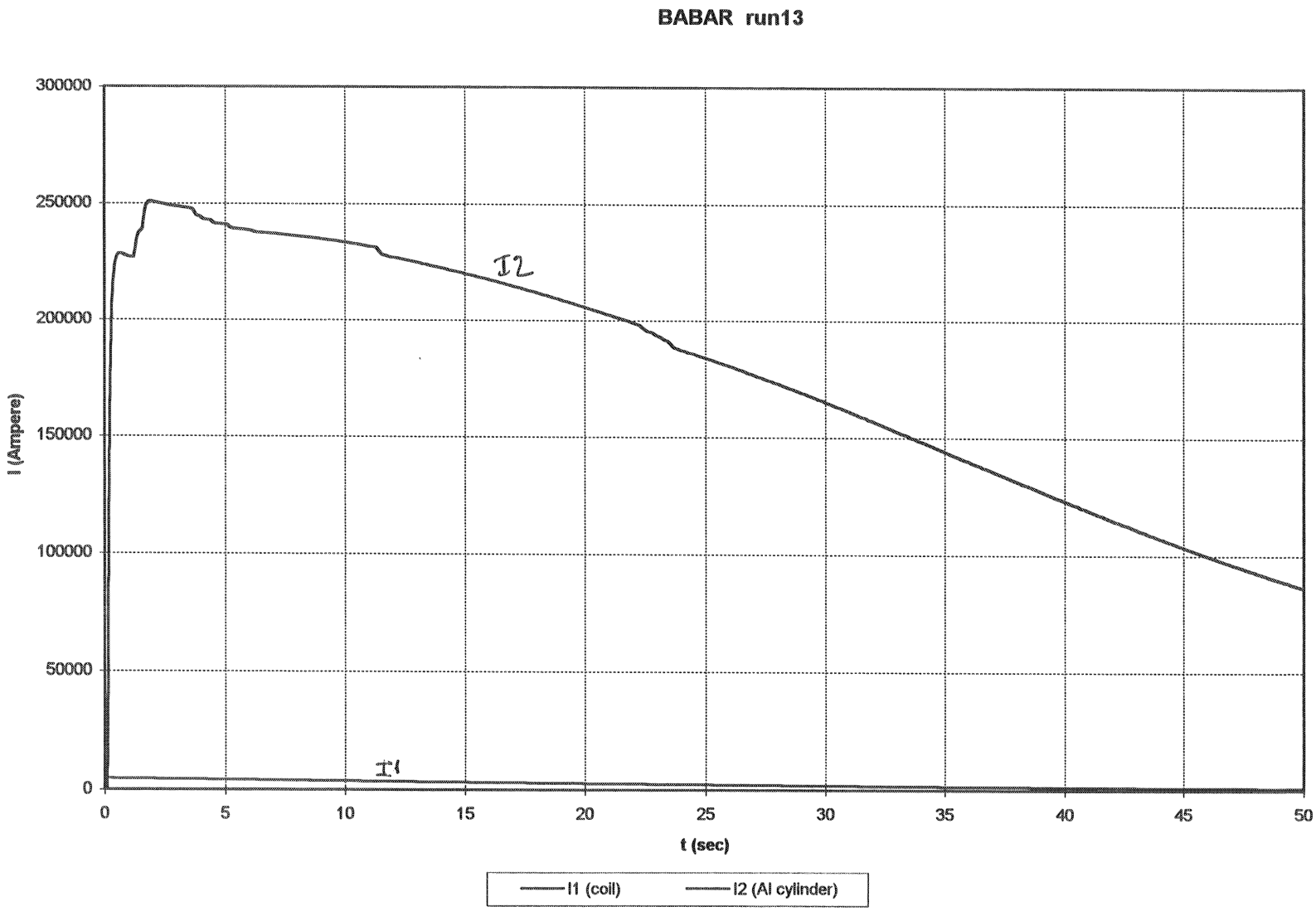

BABAR - run14
J (A/mm^2)
t (sec)
J1
J2
0
5
10
15
20
25
30
35
40
45
50

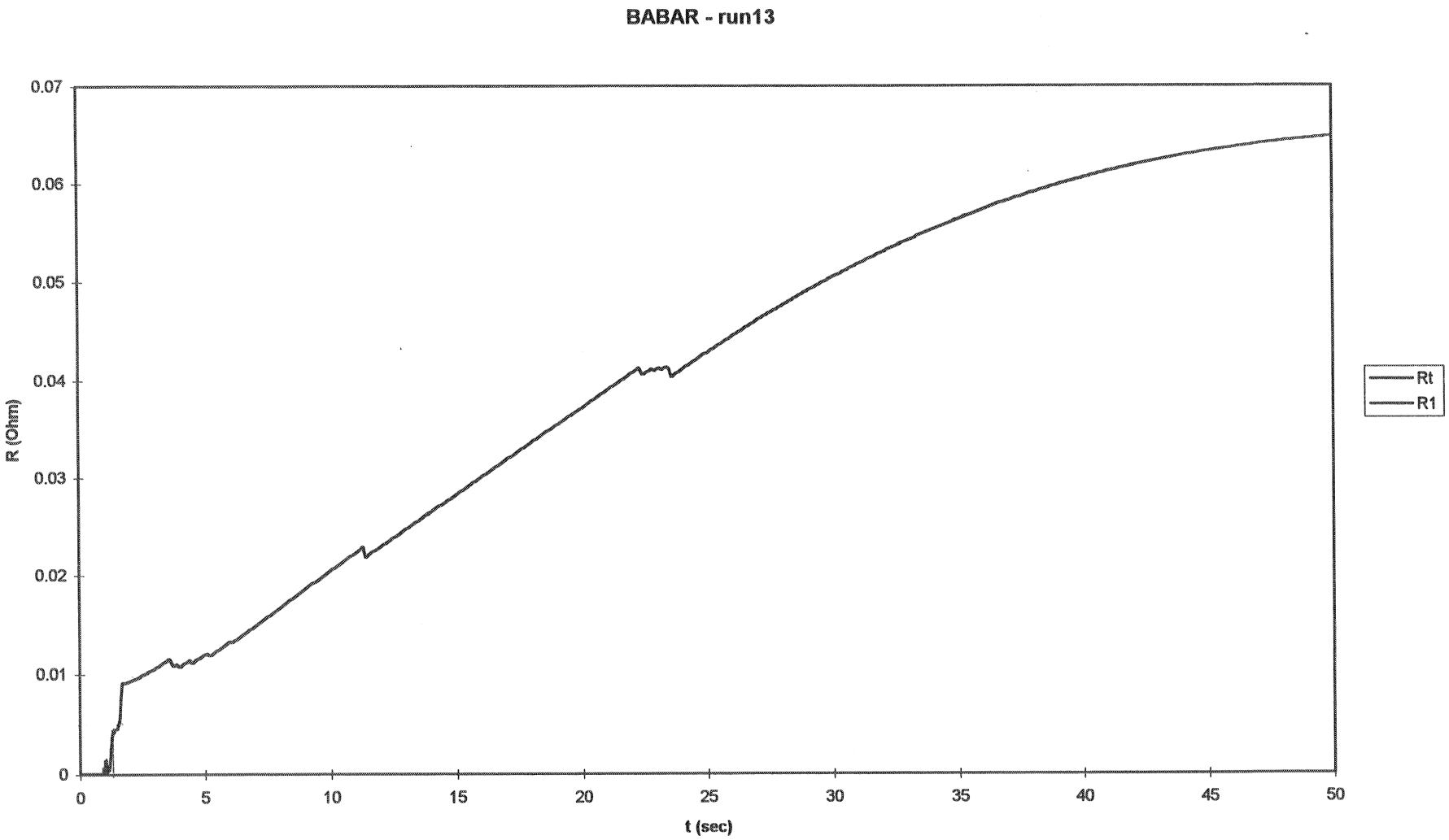

BABAR - run14
T (K)
160
140
120
100
80
60
40
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
z (m)
1
2
3
internal layer
external layer
Al cylinder
1
2
3

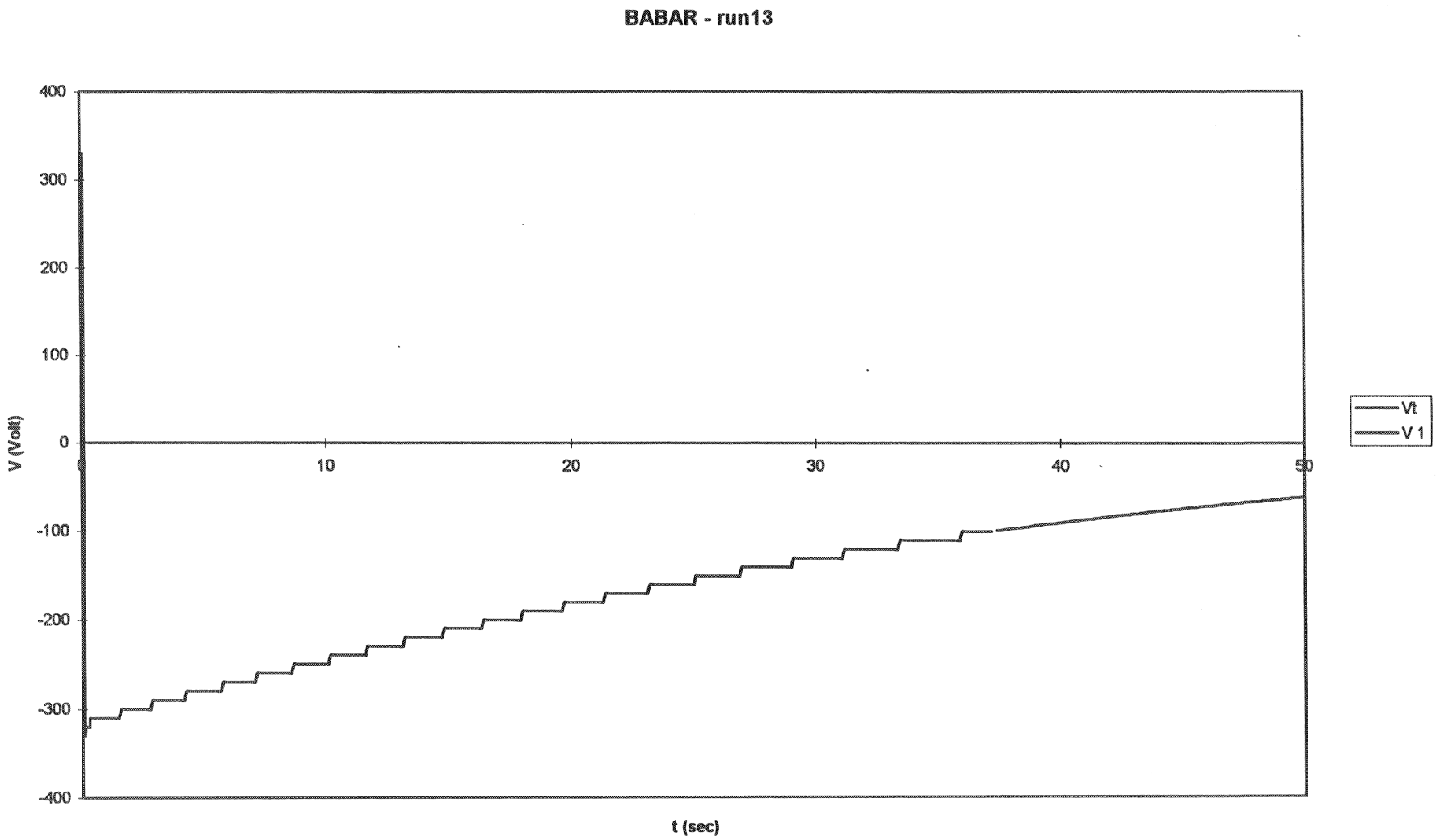

BABAR - run13
E (MJ)
t (sec)
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45
50
Es
Emag
Eth
Etot

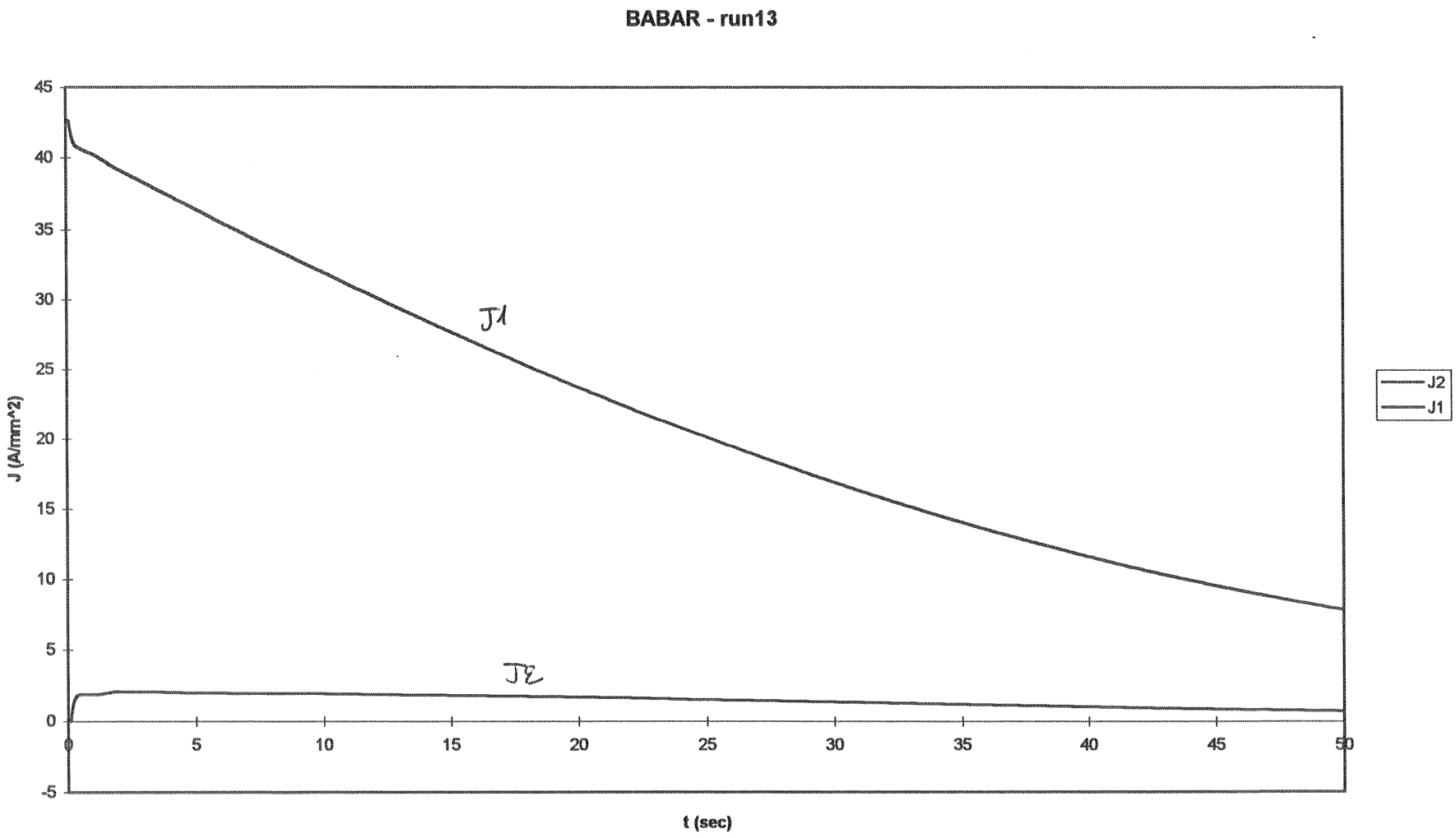

BABAR - run13
T (K)
t (sec)
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50
T1
T2
T1 (coil)
T2 (Al cylinder)

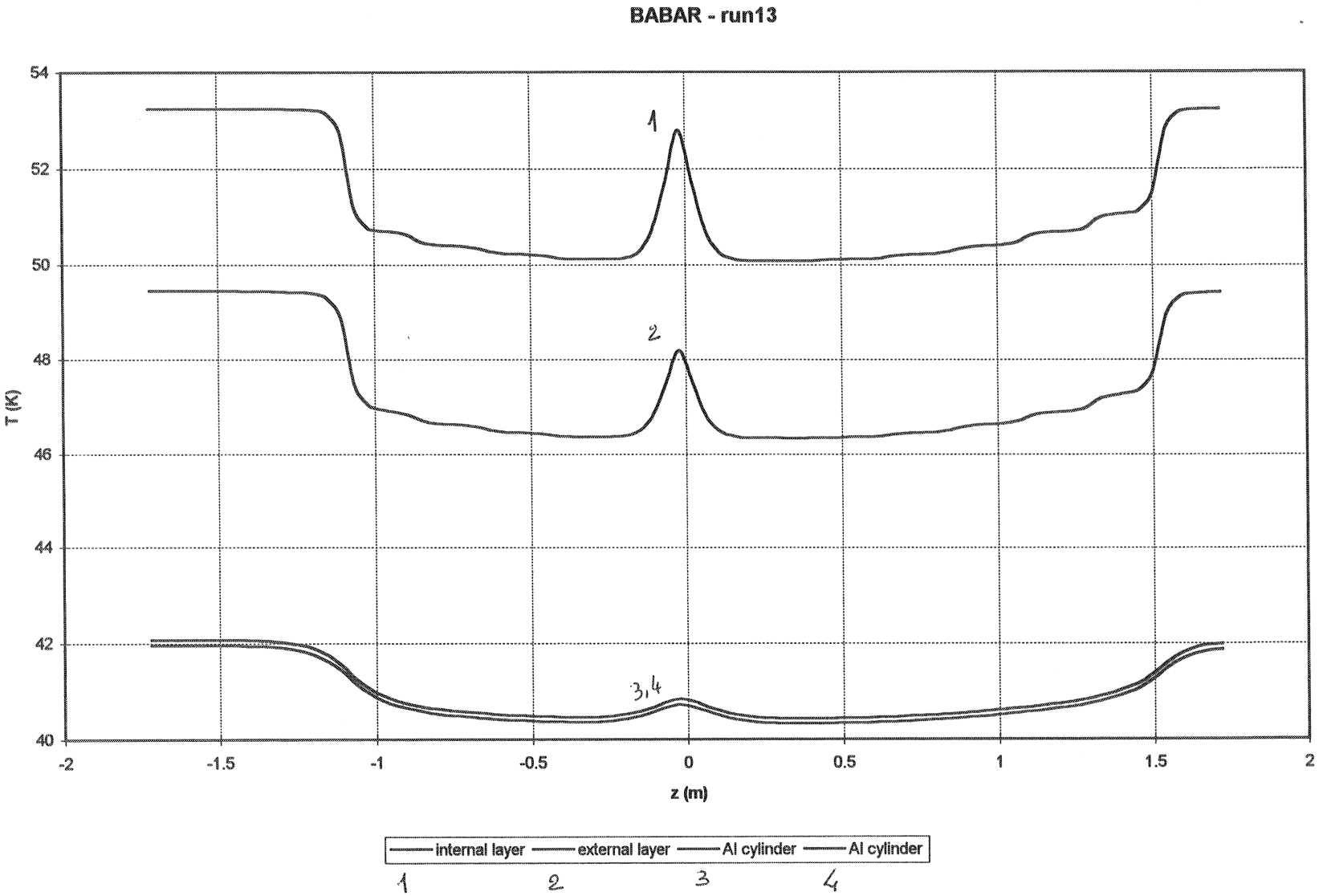

BABAR run13
I (Ampere)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
50
t (sec)
I1 (coil)


BABAR run13
300000
250000
200000
150000
100000
50000
0
I (Ampere)
0
5
10
15
20
25
30
35
40
45
50
t (sec)
I2
I1
I1 (coil)
I2 (Al cylinder)


BABAR - run13
R (Ohm)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
30
35
40
45
50
t (sec)
Rt
R1


BABAR - run13
400
300
200
100
0
-100
-200
-300
-400
V (Volt)
0
10
20
30
40
50
t (sec)
Vt
V 1


BABAR - run13
J (A/mm^2)
t (sec)
J1
J2
45
40
35
30
25
20
15
10
5
0
-5
0
5
10
15
20
25
30
35
40
45
50


BABAR - run13
T (K)
z (m)
54
52
50
48
46
44
42
40
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
1
2
3,4
internal layer
external layer
Al cylinder
Al cylinder
1
2
3
4

```
ead ind and mag files [if you want to fill these files with data use Ind.eq.0 and Imag.eq.0]
> 2S 1.ind
>-2S-1.mag
ead output files
3 2S 4.I
3-2S-4.T
3-2S-4.R
3-2S-4.V
3-2S-4.th
ead(title)
abar 2 STRATI
ead(# of coils and coils grouping)
 NbSn     NbTi Nrest    ngroup,        (ncc(i),i=1,ngroup)
  0        2     1       3              1 1 1
rl,nzl for inductance accuracy calculations.
   ss  nrl  nzl  (Icic(i),i=1,ngroup)  all coils having Icir=1 are initially connected in series. Others are intially shorted.
   1e6  2    400  1  1  0
Ti    dt     ntp  nI   tf    Vd  Ix Iind Imag,Iac  tt1  tt2  Nzones Iturn Ilink Iheater Ipeaks Icool
.2  5.e-3    100 1000  50.0   .0  0   1    0   0   80.0 80.0   1       1    1       0     0      0

i  al    a2      Zmin    Zmax   Nt or j   cur  rrr  rcusc      fb   fpack    nr  nz  nl  rs   rsi   thb  thr   tins   i1i2itib Ti
1.5     1.521   -1.74   1.74   653       4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0   0.0006  0 0 0 0 4.5
1.521  1.5414   -1.74   1.74   653       4811  100    1.1     0.0  0.9068  1   80   1  1.e3  1.e3  0.0  0.0   0.001   0 0 0 0 4.5
1.5414 1.5474   -1.74   1.74     1       0.0    3     1.E5    0.0  1.0     1   80   1  0.0   0.0  0.0  0.0   0       0 0 0 0 4.5
b3Sn coils(mat=3)
  mat  df    pitch    an     ap    bc2t1e1  T1i Tcrmi  E1i  Pinconi str-jc alstab RRRal ratioa matb matr
bTi coils (mat=1)
  mat  df    pitch    Bc2    T1T    TCRT     Pincont  alstab  RRRal   ratioa matb matr
   1  40e-6  .020    10.6   4.2    9.2     .38460E09  0.833   1000   .254    12   12
   1  40e-6  .020    10.6   4.2    9.2     .38460E09  0.833   1000   .254    12   12
ther windings
i  mat  alstab RRRal  ratioa matb matr
   6     1.0    3       1.0    12   12

 Read bore tube material and reinforcment material resistivities
       Mat 1(ss)     Mat 2(Al)
        50e-8          3e-8

ic  iri irf  izzi(ic) izzf(ic)  Tempi(iz,ic) timei (nzones lines one for each initial normal zone)
 1   1   1     40      41        8.5          0.0

  xlength   diam,   xcus    Rs      ts    Temps   Rh(1)   2      3
   30000.  150    0.80     0.0001   0.1    20.    1e10  1e10  1.e10
ead generator properties if source is not zero
gen            Rx   freq. or Ramp rate   phase    Amplitude
 0             1e7              8        0.0      1000
 Initial Currents(Currrti(ig),ig=1,Ngroup)
       0 0 0
 ------------------------------------------------------------------------------
```

$7.1 \cdot 10^{-2}$

1

$dz = 0.0204$ $A_{tot} = 3.57 \cdot 10^{-2}$

$A_i = 5.4 \cdot 10^{-5}$ $\Rightarrow A_{tot} = 4.7 \cdot$

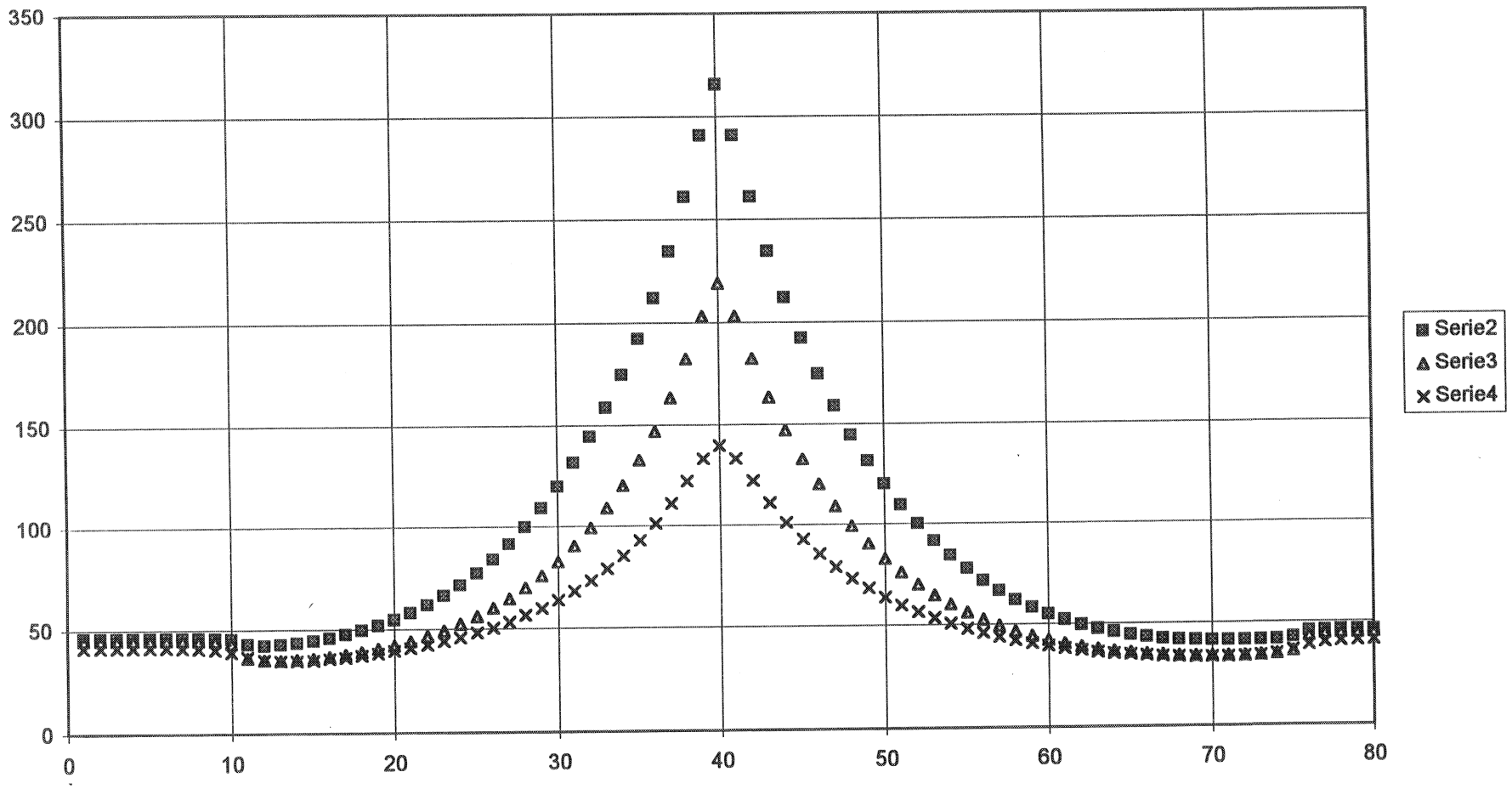
$A_{cusa} = 8.23 \cdot 10^{-6}$ $A_{cu} = 3.2 \cdot$

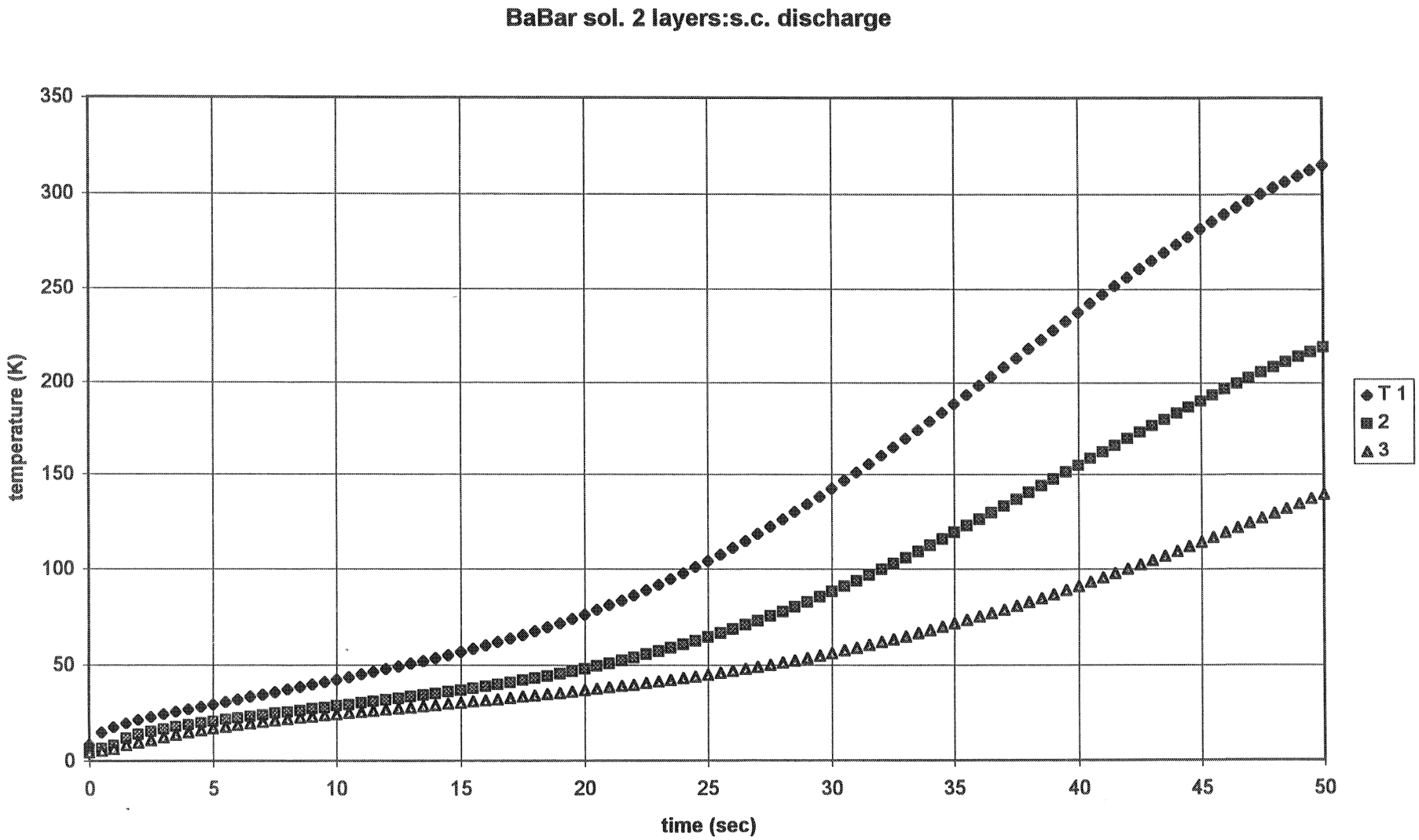
abar 2 STRATI

(ms)	Es	Emag	Eth	Etot	T 1	2	3
0.0	0.000	25.376	0.000	25.376	8.5	4.5	4.5
0.5	-0.002	25.376	0.002	25.376	14.8	6.6	5.3
1.0	-0.004	25.376	0.004	25.376	17.6	8.2	6.3
1.5	-0.005	25.376	0.006	25.376	19.7	11.8	8.3
2.0	-0.007	25.376	0.008	25.377	21.4	14.0	9.7
2.5	-0.008	25.372	0.012	25.377	22.9	15.5	10.9
3.0	-0.001	25.367	0.017	25.382	24.4	16.8	12.4
3.5	0.006	25.359	0.022	25.387	25.7	18.0	13.7
4.0	0.014	25.349	0.028	25.392	27.0	19.0	14.9
4.5	0.014	25.346	0.036	25.396	28.3	19.9	15.9
5.0	0.011	25.343	0.044	25.398	29.6	20.8	16.9
5.5	0.014	25.332	0.055	25.401	30.9	21.7	17.8
6.0	0.014	25.326	0.066	25.406	32.2	22.5	18.7
6.5	0.012	25.319	0.079	25.410	33.5	23.3	19.5
7.0	0.007	25.313	0.095	25.414	34.7	24.1	20.3
7.5	0.002	25.307	0.111	25.420	36.0	24.9	21.0
8.0	-0.004	25.297	0.131	25.424	37.3	25.6	21.7
8.5	-0.012	25.289	0.153	25.430	38.6	26.4	22.4
9.0	-0.021	25.277	0.177	25.434	39.9	27.2	23.0
9.5	-0.031	25.266	0.205	25.440	41.2	27.9	23.7
10.0	-0.043	25.255	0.235	25.447	42.5	28.7	24.3
10.5	-0.057	25.240	0.269	25.452	43.8	29.5	24.9
11.0	-0.073	25.226	0.307	25.460	45.2	30.2	25.5
11.5	-0.089	25.213	0.348	25.471	46.5	31.0	26.1
12.0	-0.113	25.199	0.395	25.481	47.9	31.8	26.7
12.5	-0.138	25.185	0.445	25.491	49.3	32.6	27.3
13.0	-0.168	25.168	0.501	25.501	50.7	33.5	27.9
13.5	-0.201	25.151	0.562	25.512	52.2	34.3	28.5
14.0	-0.237	25.127	0.629	25.519	53.6	35.2	29.1
14.5	-0.275	25.104	0.703	25.533	55.2	36.1	29.7
15.0	-0.313	25.072	0.784	25.543	56.8	37.0	30.3
15.5	-0.356	25.041	0.873	25.558	58.4	38.0	31.0
16.0	-0.400	25.004	0.970	25.574	60.1	38.9	31.6
16.5	-0.451	24.961	1.076	25.586	61.8	39.9	32.2
17.0	-0.508	24.915	1.193	25.600	63.7	41.0	32.8
17.5	-0.577	24.868	1.320	25.611	65.5	42.1	33.5
18.0	-0.653	24.816	1.459	25.621	67.5	43.2	34.1
18.5	-0.737	24.758	1.610	25.631	69.5	44.3	34.8
19.0	-0.833	24.697	1.776	25.640	71.7	45.6	35.5
19.5	-0.937	24.631	1.957	25.652	73.9	46.8	36.2
20.0	-1.049	24.557	2.154	25.662	76.1	48.1	36.9
20.5	-1.170	24.472	2.369	25.671	78.5	49.5	37.6
21.0	-1.301	24.378	2.603	25.680	81.0	50.9	38.3
21.5	-1.445	24.278	2.858	25.691	83.6	52.4	39.1
22.0	-1.607	24.172	3.135	25.700	86.2	53.9	39.9
22.5	-1.782	24.055	3.436	25.709	89.0	55.5	40.6
23.0	-1.974	23.925	3.763	25.714	91.9	57.2	41.4
23.5	-2.186	23.787	4.117	25.717	94.9	58.9	42.3
24.0	-2.414	23.632	4.500	25.719	98.0	60.7	43.1
24.5	-2.658	23.462	4.914	25.719	101.1	62.5	44.0
25.0	-2.919	23.277	5.361	25.720	104.4	64.5	45.0
25.5	-3.207	23.084	5.842	25.720	107.8	66.5	45.9
26.0	-3.525	22.885	6.360	25.721	111.3	68.6	46.9
26.5	-3.877	22.683	6.916	25.722	114.9	70.8	48.0
27.0	-4.263	22.472	7.512	25.722	118.6	73.0	49.0
27.5	-4.681	22.253	8.150	25.723	122.4	75.3	50.1
28.0	-5.139	22.031	8.832	25.724	126.2	77.7	51.3
28.5	-5.637	21.801	9.560	25.724	130.2	80.2	52.5
29.0	-6.175	21.563	10.336	25.724	134.3	82.8	53.7
29.5	-6.754	21.318	11.160	25.725	138.4	85.5	54.9
30.0	-7.379	21.065	12.038	25.724	142.7	88.2	56.2
30.5	-8.054	20.802	12.976	25.724	147.0	91.0	57.6
31.0	-8.780	20.528	13.976	25.724	151.4	93.9	58.9

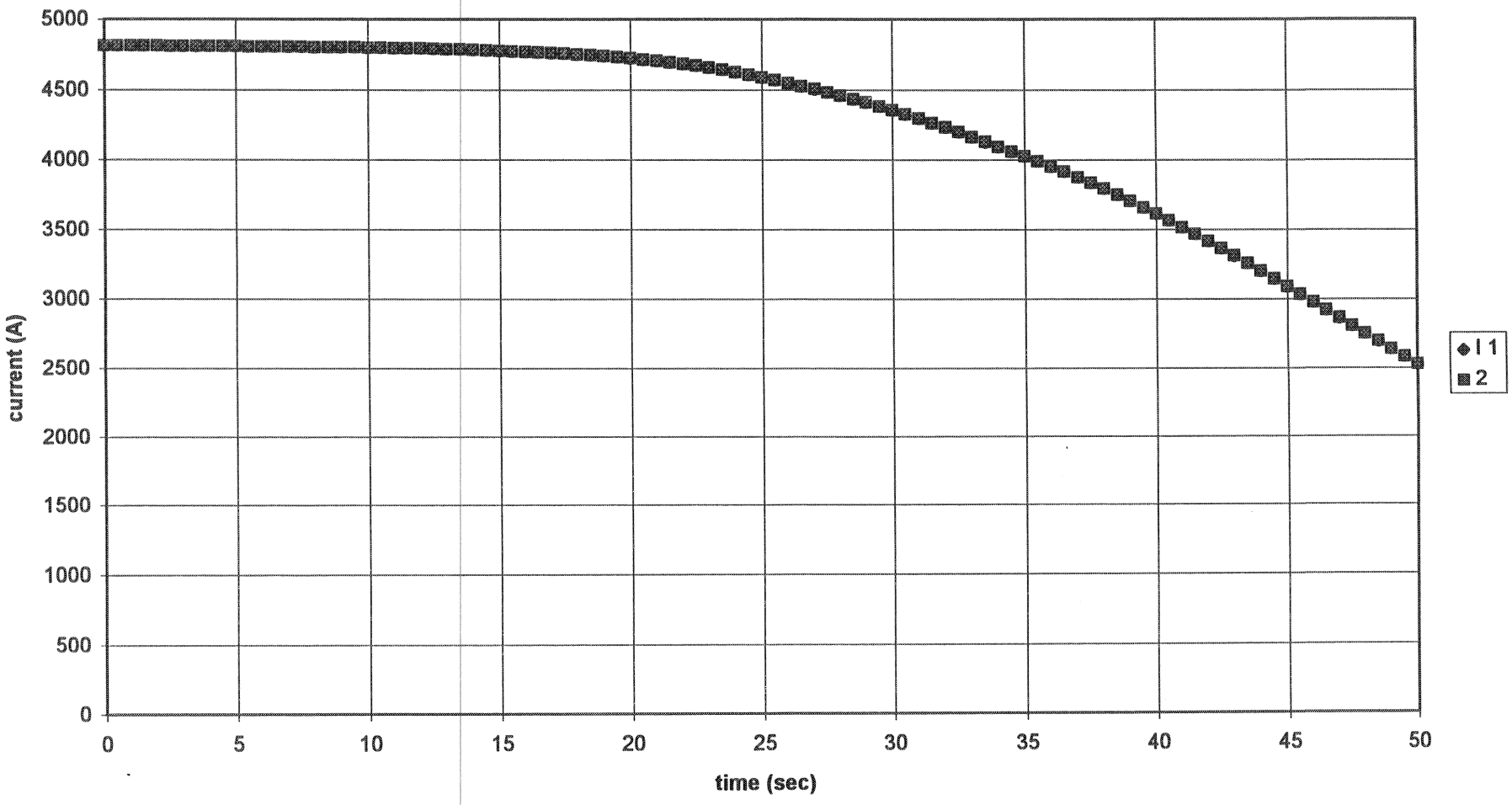
31.5	-9.553	20.244	15.033	25.724	155.9	96.9	60.4
32.0	-10.370	19.949	16.145	25.724	160.4	99.9	61.8
32.5	-11.231	19.644	17.311	25.724	165.0	103.0	63.3
33.0	-12.136	19.330	18.530	25.724	169.7	106.2	64.9
33.5	-13.090	19.011	19.803	25.724	174.4	109.4	66.5
34.0	-14.089	18.684	21.129	25.724	179.2	112.7	68.1
34.5	-15.157	18.373	22.509	25.725	184.0	116.0	69.8
35.0	-16.290	18.072	23.944	25.726	188.8	119.4	71.5
35.5	-17.473	17.766	25.433	25.726	193.7	122.9	73.3
36.0	-18.701	17.453	26.975	25.727	198.7	126.4	75.1
36.5	-19.971	17.131	28.567	25.727	203.6	129.9	76.9
37.0	-21.281	16.800	30.208	25.728	208.6	133.5	78.8
37.5	-22.628	16.461	31.896	25.728	213.5	137.1	80.8
38.0	-24.011	16.114	33.626	25.729	218.5	140.7	82.8
38.5	-25.426	15.759	35.396	25.729	223.4	144.3	84.8
39.0	-26.872	15.398	37.204	25.730	228.3	148.0	86.9
39.5	-28.345	15.031	39.044	25.730	233.2	151.7	89.0
40.0	-29.842	14.660	40.913	25.731	238.0	155.3	91.1
40.5	-31.360	14.283	42.808	25.731	242.8	159.0	93.3
41.0	-32.895	13.903	44.724	25.732	247.5	162.6	95.5
41.5	-34.442	13.519	46.656	25.732	252.2	166.2	97.8
42.0	-36.000	13.132	48.600	25.732	256.8	169.8	100.1
42.5	-37.565	12.745	50.552	25.732	261.3	173.4	102.4
43.0	-39.132	12.356	52.508	25.732	265.7	176.9	104.8
43.5	-40.697	11.968	54.462	25.733	270.0	180.4	107.2
44.0	-42.259	11.580	56.411	25.733	274.3	183.8	109.6
44.5	-43.813	11.195	58.350	25.733	278.4	187.2	112.1
45.0	-45.356	10.812	60.277	25.733	282.4	190.5	114.5
45.5	-46.885	10.432	62.186	25.733	286.3	193.7	117.0
46.0	-48.397	10.057	64.073	25.733	290.1	196.9	119.5
46.5	-49.889	9.686	65.937	25.733	293.7	200.0	122.0
47.0	-51.358	9.320	67.772	25.734	297.3	203.1	124.6
47.5	-52.799	8.960	69.574	25.735	300.7	206.0	127.1
48.0	-54.213	8.606	71.342	25.735	304.0	208.9	129.7
48.5	-55.599	8.260	73.074	25.735	307.2	211.7	132.2
49.0	-56.953	7.921	74.768	25.736	310.2	214.4	134.8
49.5	-58.273	7.589	76.420	25.736	313.1	217.0	137.3
50.0	-59.557	7.266	78.027	25.736	315.9	219.6	139.9

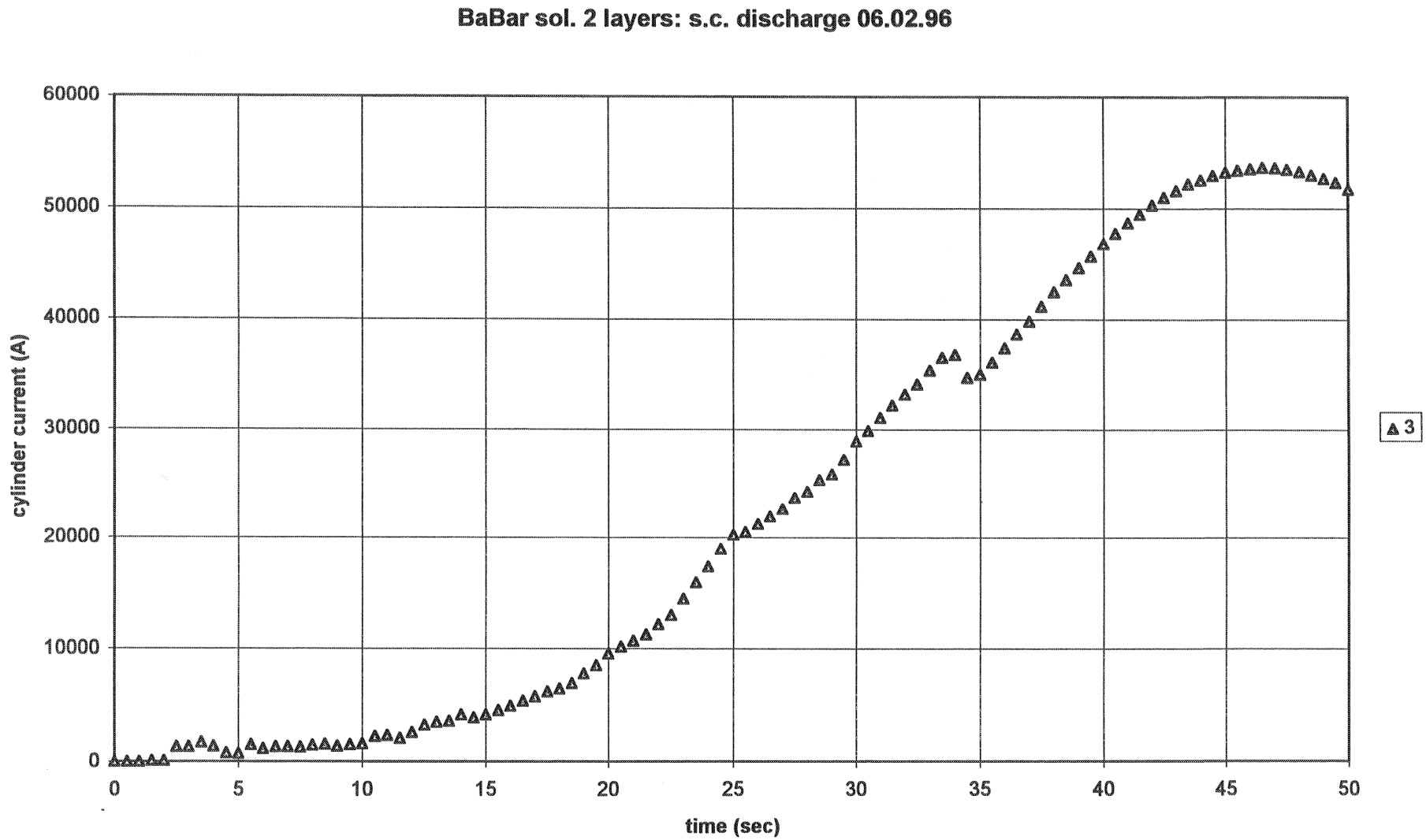
BaBar sol. 2 layers: s.c. discharge 06.02.96




BaBar sol. 2 layers:s.c. discharge
temperature (K)
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
time (sec)
T 1
2
3

BaBar sol. 2 layers :s.c discharge 06.02.96

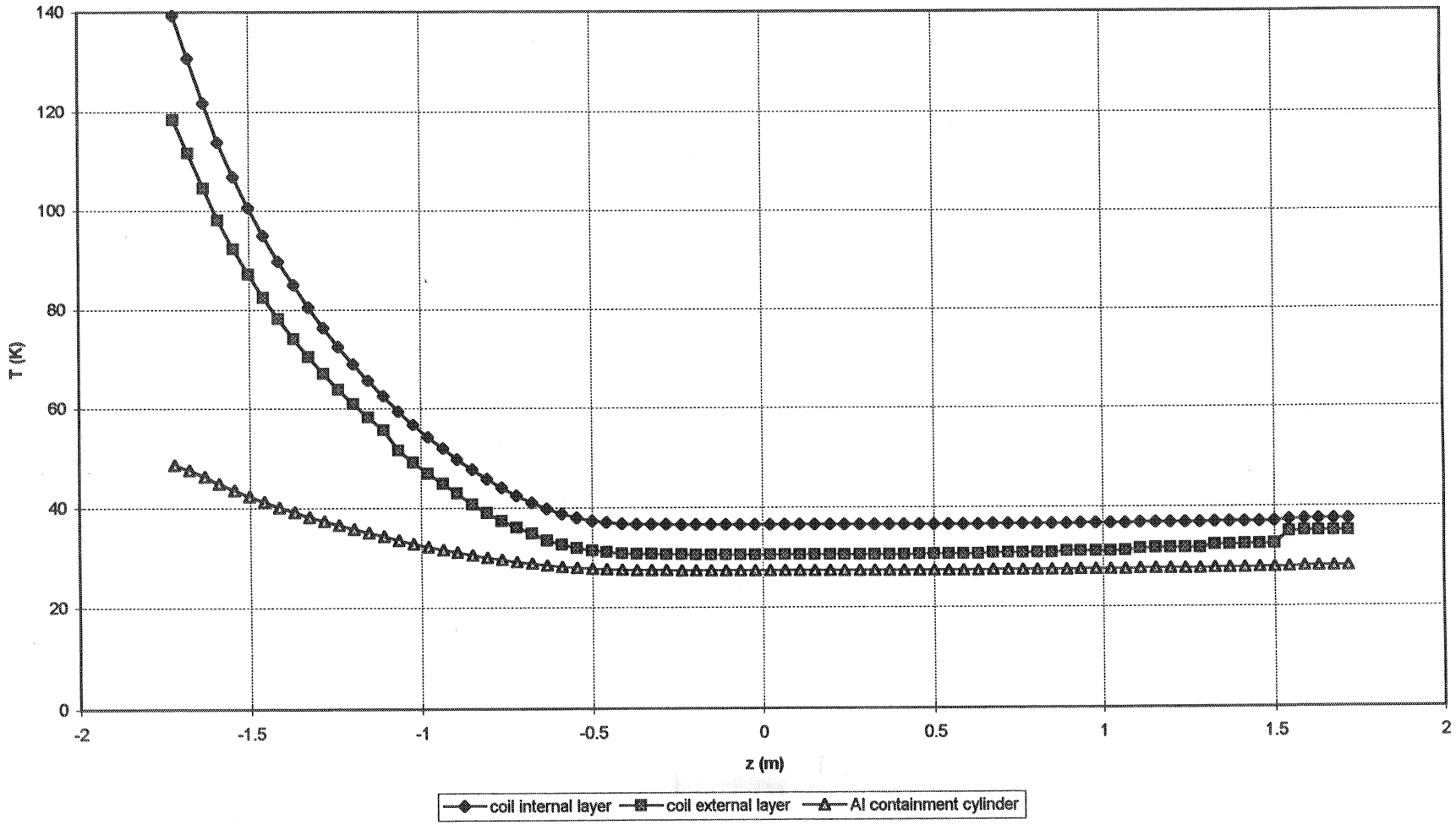



BaBar sol. 2 layers: s.c. discharge 06.02.96
cylinder current (A)
60000
50000
40000
30000
20000
10000
0
0
5
10
15
20
25
30
35
40
45
50
time (sec)
3

75% Fe

Aspetto valori da ANSO 25/04/06

BABAR - run15b



BABAR MAGNET

CURRENT = 75% initial value

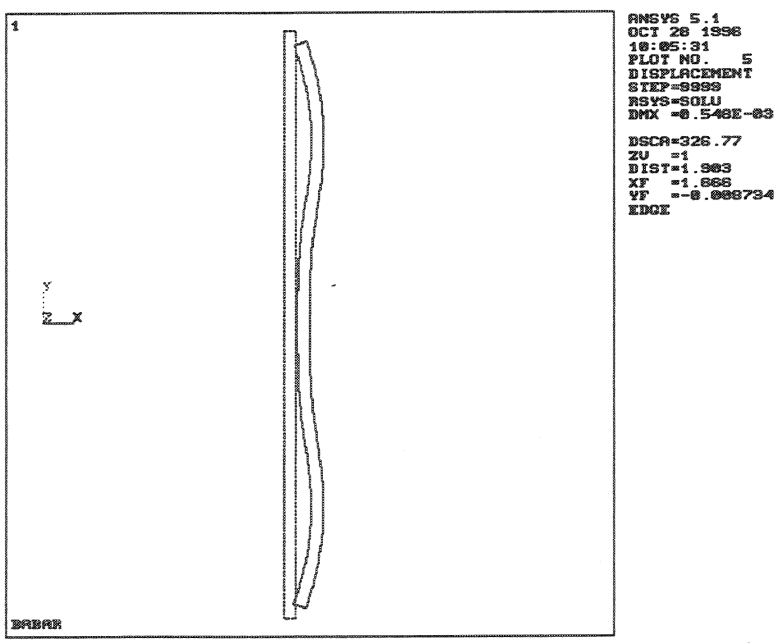
only stress by current effects, not thermal effect

From "coarse model", excluding flanges:

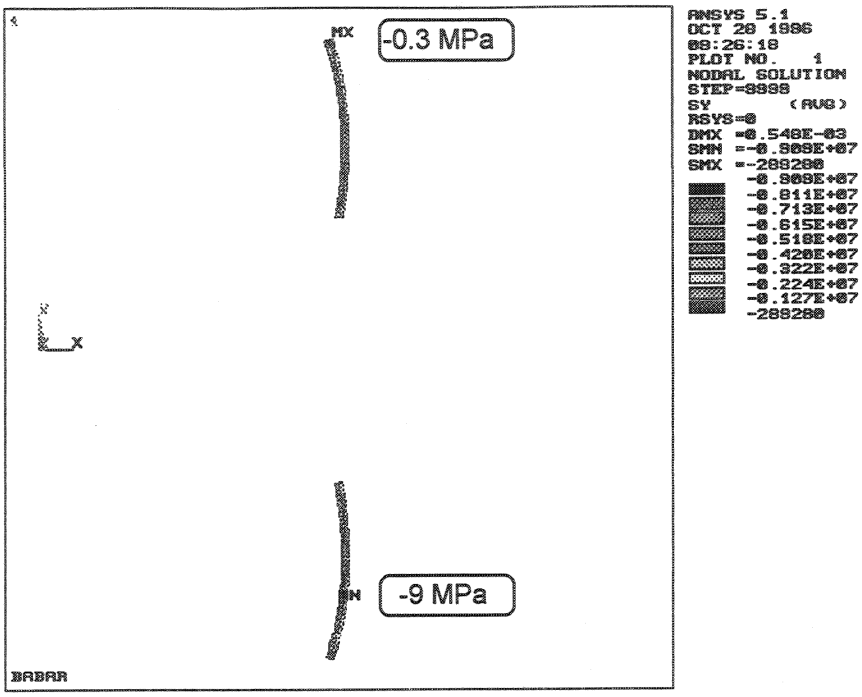
minima & maxima	mat.1 (lateral cable)	mat.2 (interlayer insulation)	mat.3 (central cable)	mat.4 (insulation)	mat.5 (aluminum containment cylinder)
Sx (MPa)	-0.8,-0.04	-0.7, -0.2	-0.5, +0.06	-0.6, -0.2	-0.5, +0.5
Sy (MPa)	**-9**,-0.3	**-5**, -1	**-4**, +0.7	**-4**, -0.8	**-7, +3**
Sz (MPa)	+11, **+24**	+5, **+11**	+12, **+20**	+5, **+11**	+9, **+25**
Sxy (MPa)	-0.5, +0.4	-0.4, +0.4	-0.6, +0.6	-0.4, +0.4	-0.5, +0.7
Sint (MPa)					9, 30

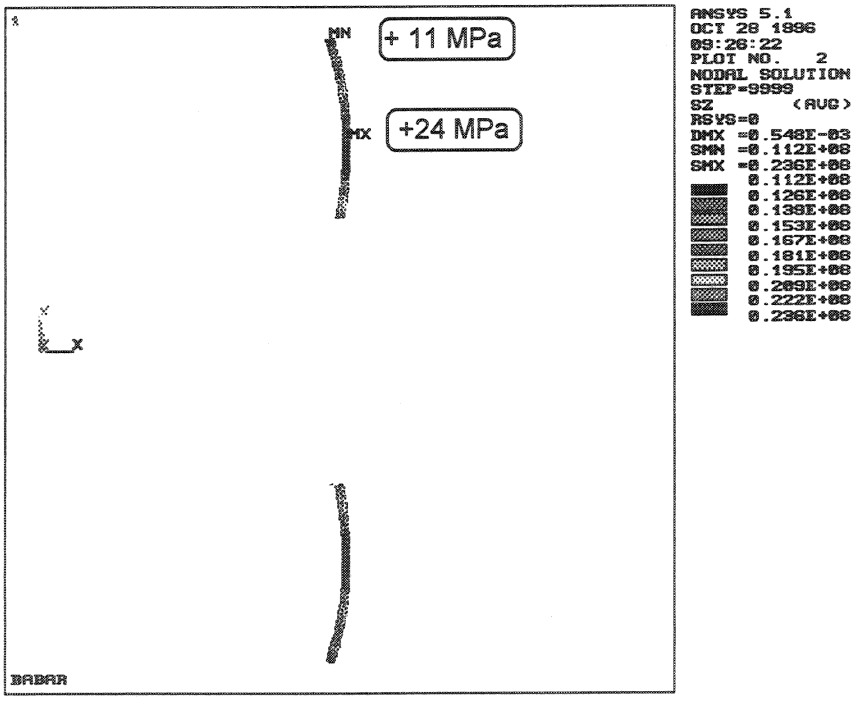
- x = radial, y = axial, z = hoop, xy = shear
- Sx and Sxy are low
- Sy and Sz are higher but still low
- Sy: negative (compression)

Deformed / undeformed shape of model under current load:
(current density in the central part is about half the lateral part)

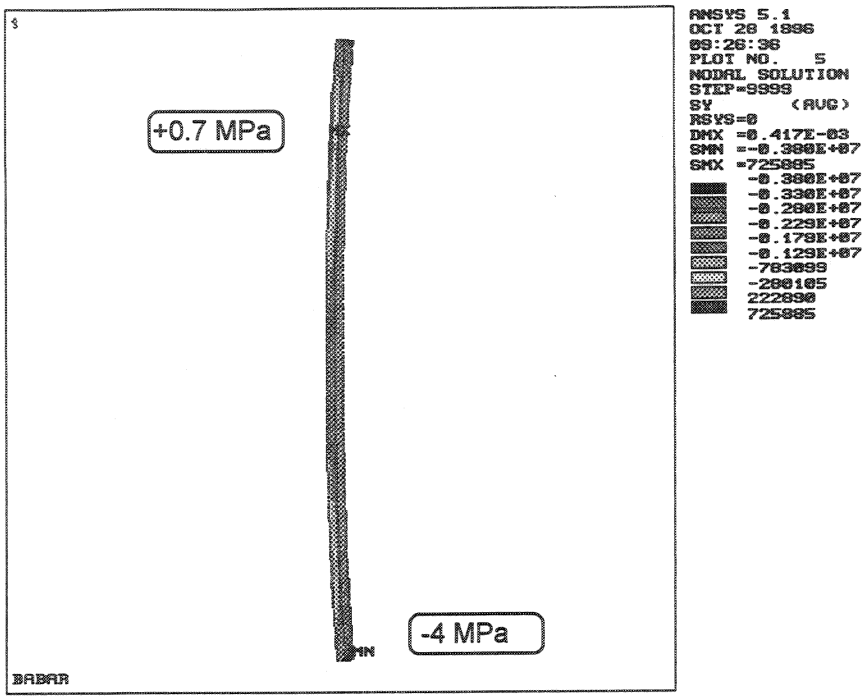


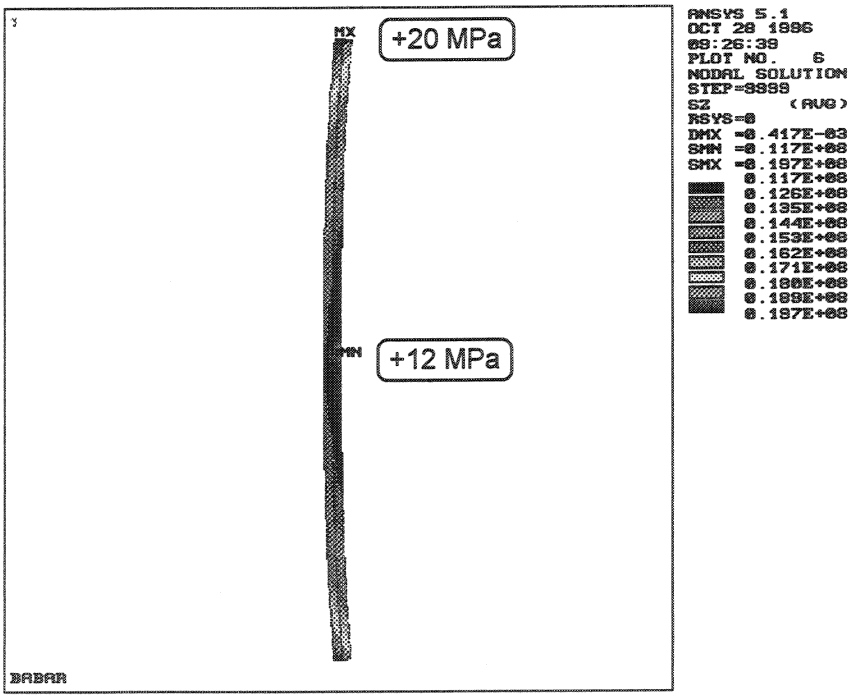
Minima of absolute values of stress components are at the ends of model and also at the centre; maxima are at the greatest swelling points.



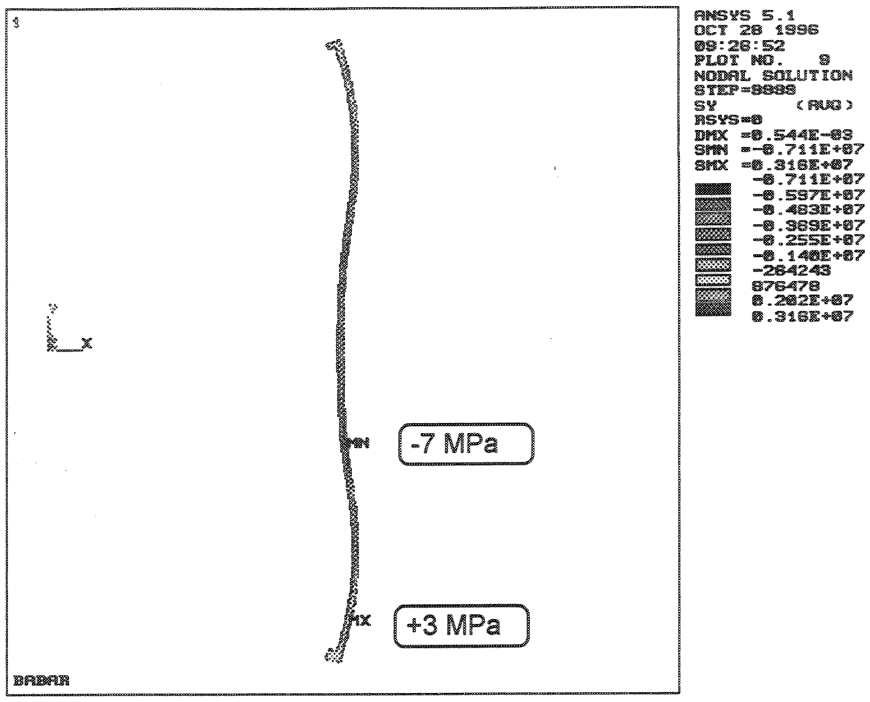


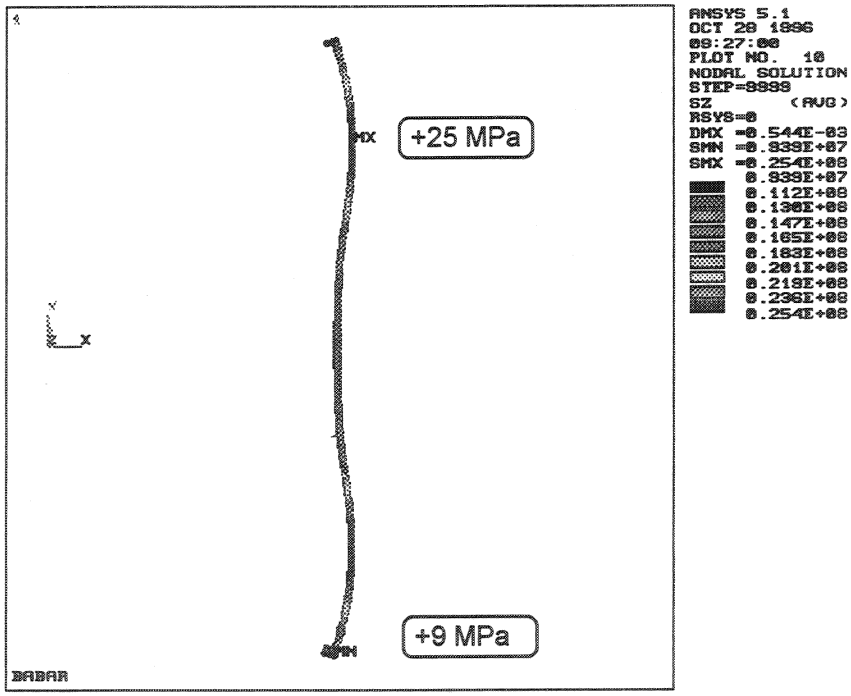
Axial stress and hoop stress for mat.1 (lateral cable) under 75% current.





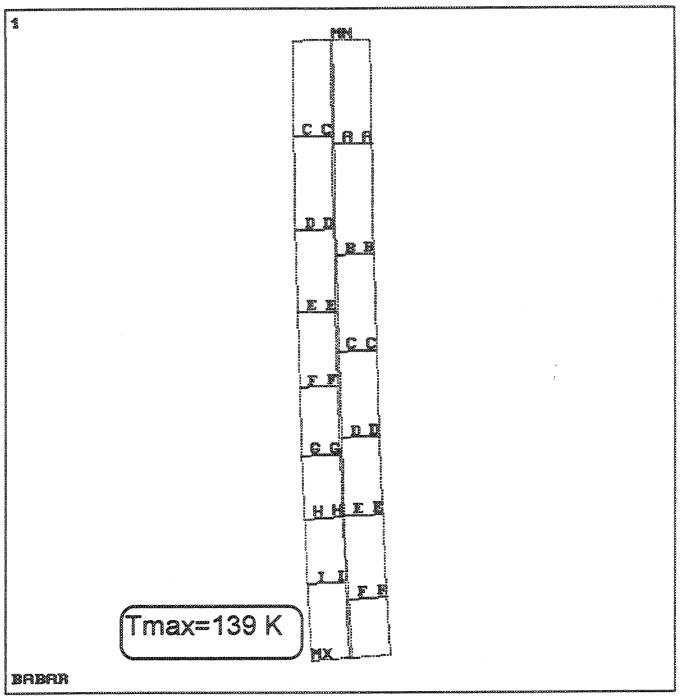
Axial stress and hoop stress for mat.2 (central cable) under 75% current.





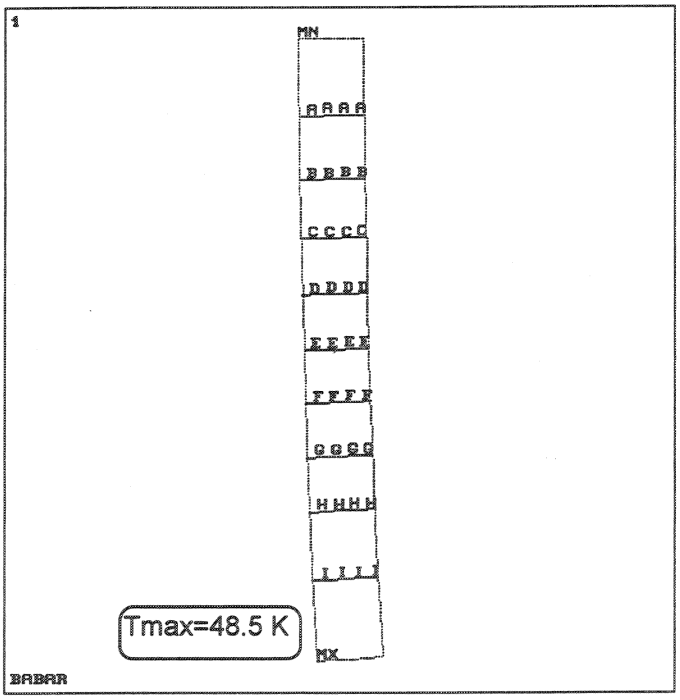
Axial stress and hoop stress for mat.5 (Al containment cylinder) under 75% current.

TEMPERATURE DISTRIBUTION IN THE MODEL AT TIME t=30 sec



ANSYS 5.1
OCT 29 1996
07:59:01
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
BFETEMP (AVG)
DMX =0.953E-03
SMN =82.42
SMX =139.29
A =85.578
B =91.898
C =98.217
D =104.536
E =110.855
F =117.174
G =123.493
H =129.812
I =136.131

COIL, warm end



ANSYS 5.1
OCT 29 1996
11:06:49
PLOT NO. 1
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
BFETEMP (AVG)
DMX =0.936E-03
SMN =41.22
SMX =48.54
A =41.627
B =42.44
C =43.253
D =44.067
E =44.88
F =45.693
G =46.507
H =47.32
I =48.133

Al CYLINDER, warm end

BABAR MODEL WITHOUT FLANGES

Stress by thermal effect (temperature distribution after 30 secs from quench start from one end, without dump resistor):

THERMAL (Tref=4 K)

minima & maxima	mat.1 (lateral cable)	mat.2 (interlayer insulation)	mat.3 (central cable)	mat.4 (insulation)	mat.5 (aluminum containment cylinder)
Sx (MPa)	-3, +3	-3, +4	-0.03, +0.3	-6, +1	-8, +3
Sy (MPa)	**-22, +11**	-7, +1	-2, +0.4	-5, -0.4	**-17, +30**
Sz (MPa)	**-29, +3**	-10, -0.9	-2, +0.7	-2, +5	**-0.5, +44**
Sxy (MPa)	-2, +4	-0.2, +3	-0.2, +0.02	-0.5, +10	-3, +4
Sint (MPa)	---	---	---	---	

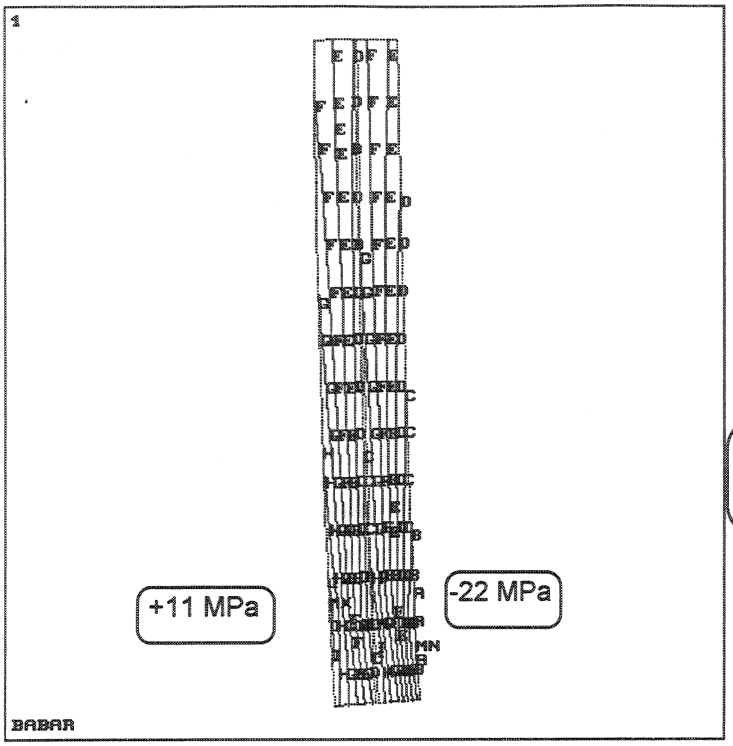
CURRENT

minima & maxima	mat.1 (lateral cable)	mat.2 (interlayer insulation)	mat.3 (central cable)	mat.4 (insulation)	mat.5 (aluminum containment cylinder)
Sx (MPa)	-2, -0.2	-2, +0.1	-0.8, +0.2	-0.9, +0.05	-0.7, +0.1
Sy (MPa)	**-12, +0.09**	-6, -1	-5, +4	-5, -1	**-15, +0.8**
Sz (MPa)	**+15, +28**	+7, +13	+14, +23	+6, +13	**+12, +30**
Sxy (MPa)	-0.5, +1	-0.7, +1	-0.8, +2	-0.9, +1	-0.8, +1
Sint (MPa)	16, 38	8, 19	16, 28	8, 18	15, 36

THERMAL+CURRENT

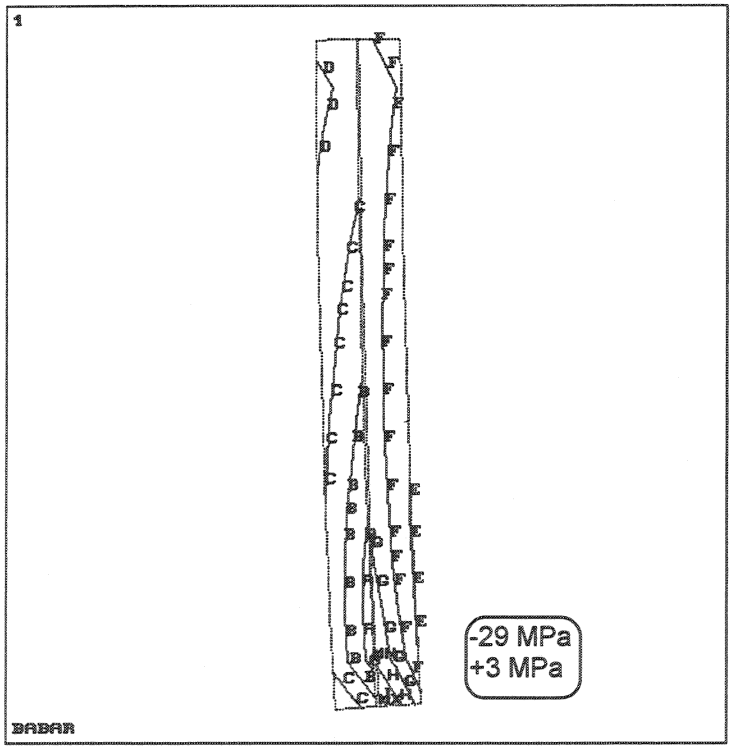
minima & maxima	mat.1 (lateral cable)	mat.2 (interlayer insulation)	mat.3 (central cable)	mat.4 (insulation)	mat.5 (aluminum containment cylinder)
Sx (MPa)	-3, +1	-4, +2	-0.6, +0.2	-6, +0.5	-9, +3
Sy (MPa)	**-23, +8**	-12, -1	-7, +3	-7, -2	**-17, +28**
Sz (MPa)	**-8, +28**	+0.7, +12	-13, +23	+6, +14	**+13, +66**
Sxy (MPa)	-2, +4	-0.7, +3	-1, +2	-1, +10	-3, +3
Sint (MPa)	---	---	---	---	17, 74

{75% current} +{ temperature distribution from quench at t=30 sec}



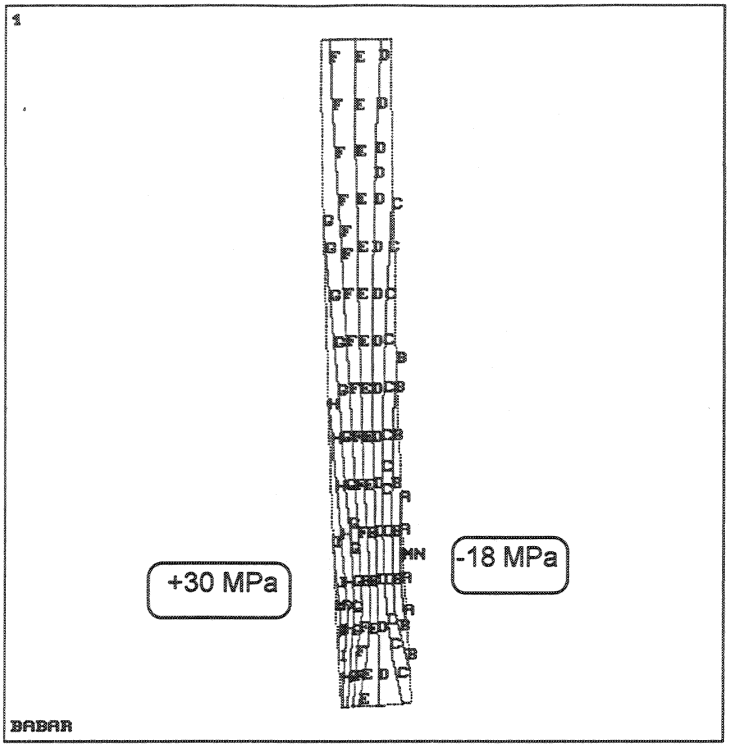
ANSYS 5.1
OCT 29 1996
08:00:41
PLOT NO. 2
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SY (AVG)
RSYS=0
DMX =0.953E-03
SMN =-0.223E+08
SMX =0.106E+08
A =-0.205E+08
B =-0.168E+08
C =-0.132E+08
D =-0.951E+07
E =-0.585E+07
F =-0.220E+07
G =0.146E+07
H =0.512E+07
I =0.877E+07

AXIAL STRESS ON COIL
WARM END
- ONLY THERMAL EFFECT



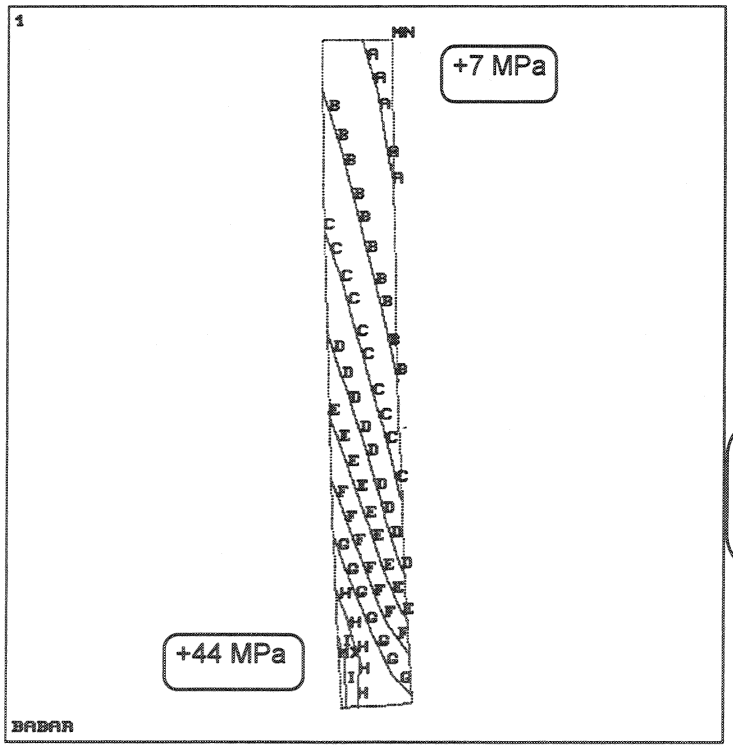
ANSYS 5.1
OCT 29 1996
08:00:45
PLOT NO. 3
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SZ (AVG)
RSYS=0
DMX =0.953E-03
SMN =-0.280E+08
SMX =0.284E+07
A =-0.273E+08
B =-0.237E+08
C =-0.202E+08
D =-0.166E+08
E =-0.131E+08
F =-0.956E+07
G =-0.601E+07
H =-0.247E+07
I =0.107E+07

HOOP STRESS ON COIL
WARM END
- ONLY THERMAL EFFECT



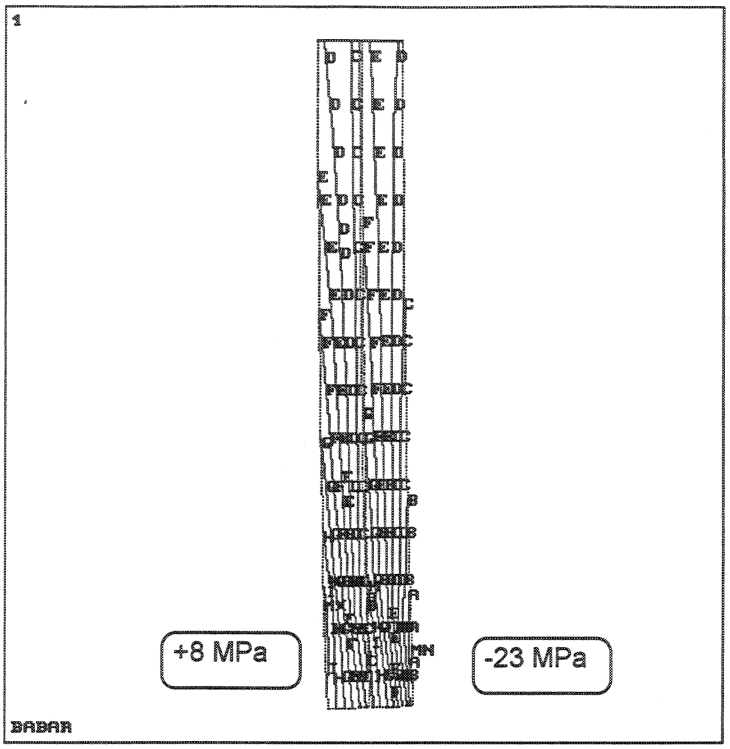

```
ANSYS 5.1
OCT 29 1996
08:03:07
PLOT NO.    4
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SY        (AVG)
RSYS=0
DMX =0.936E-03
SMN =-0.175E+08
SMX =0.301E+08
A    =-0.148E+08
B    =-0.957E+07
C    =-0.428E+07
D    =0.101E+07
E    =0.629E+07
F    =0.116E+08
G    =0.169E+08
H    =0.222E+08
I    =0.274E+08
```

AXIAL STRESS ON
ALUMINUM CYLINDER
WARM END
- ONLY THERMAL EFFECT



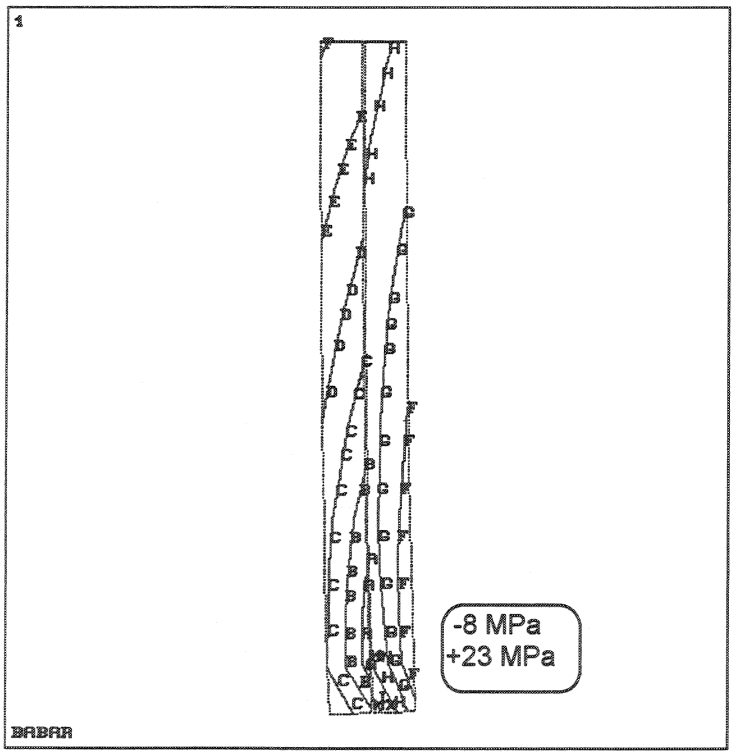

```
ANSYS 5.1
OCT 29 1996
08:03:10
PLOT NO.    5
NODAL SOLUTION
STEP=1
SUB =1
TIME=1
SZ        (AVG)
RSYS=0
DMX =0.936E-03
SMN =0.857E+07
SMX =0.437E+08
A    =0.884E+07
B    =0.128E+08
C    =0.169E+08
D    =0.210E+08
E    =0.251E+08
F    =0.293E+08
G    =0.334E+08
H    =0.375E+08
I    =0.416E+08
```

HOOP STRESS ON
ALUMINUM CYLINDER
WARM END
- ONLY THERMAL EFFECT



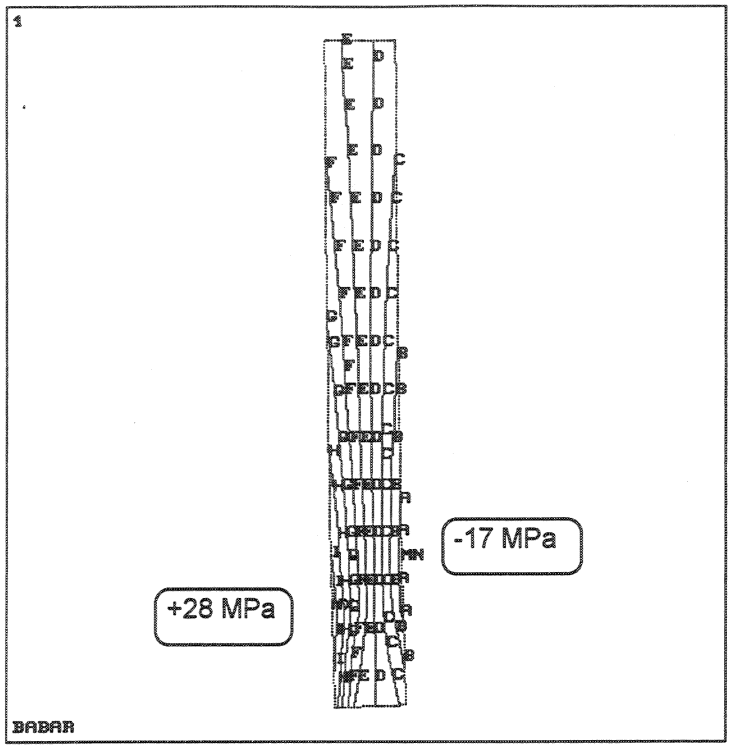

```
ANSYS 5.1
OCT 29 1996
08:05:08
PLOT NO.   6
NODAL SOLUTION
STEP=2
SUB =1
TIME=2
SY        (AVG)
RSYS=0
DMX =0.001366
SMN =-0.231E+08
SMX =0.796E+07
A   =-0.214E+08
B   =-0.179E+08
C   =-0.145E+08
D   =-0.110E+08
E   =-0.756E+07
F   =-0.411E+07
G   =-659633
H   =0.279E+07
I   =0.624E+07
```

AXIAL STRESS ON COIL WARM END, THERMAL+CURRENT EFFECT



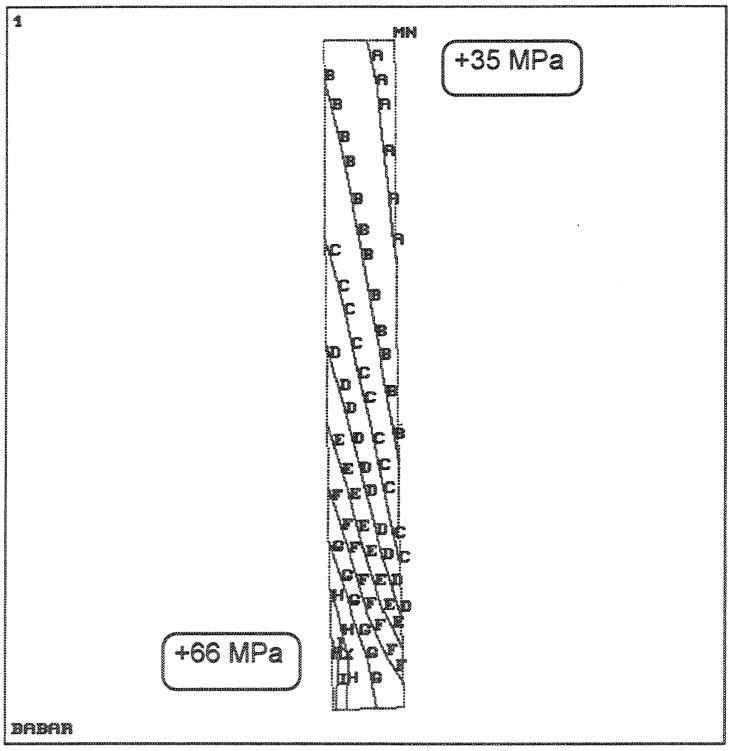

```
ANSYS 5.1
OCT 29 1996
08:05:21
PLOT NO.   7
NODAL SOLUTION
STEP=2
SUB =1
TIME=2
SZ        (AVG)
RSYS=0
DMX =0.001366
SMN =-0.826E+07
SMX =0.228E+08
A   =-0.653E+07
B   =-0.308E+07
C   =367215
D   =0.382E+07
E   =0.727E+07
F   =0.107E+08
G   =0.142E+08
H   =0.176E+08
I   =0.211E+08
```

HOOP STRESS ON COIL WARM END, THERMAL+CURRENT EFFECT



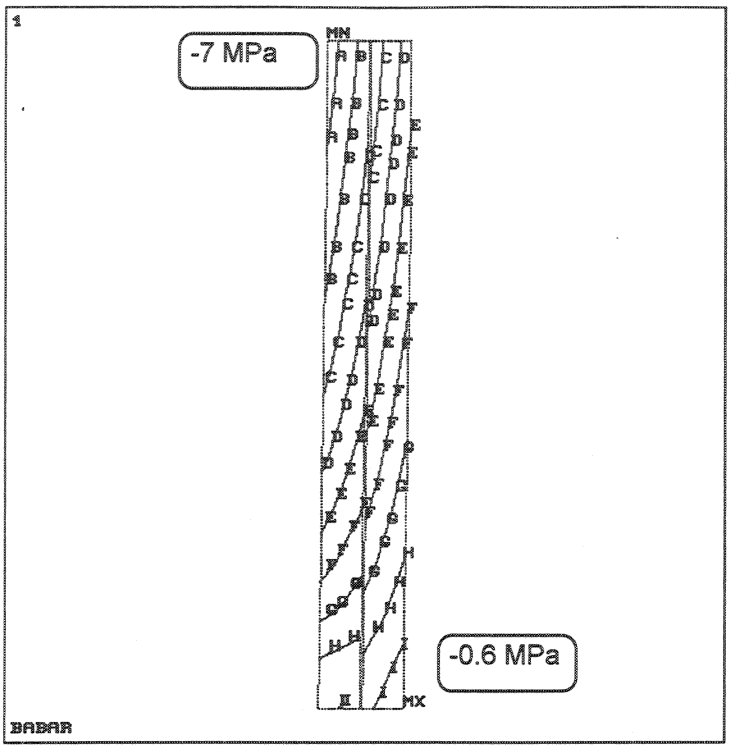

```
ANSYS 5.1
OCT 29 1996
08:05:46
PLOT NO.   8
NODAL SOLUTION
STEP=2
SUB =1
TIME=2
SY        (AVG)
RSYS=0
DMX =0.001374
SMN =-0.173E+08
SMX =0.283E+08
A   =-0.147E+08
B   =-0.966E+07
C   =-0.460E+07
D   =470997
E   =0.554E+07
F   =0.106E+08
G   =0.157E+08
H   =0.207E+08
I   =0.258E+08
```

AXIAL STRESS ON ALUMINUM CYLINDER WARM END, THERMAL+CURRENT EFFECT



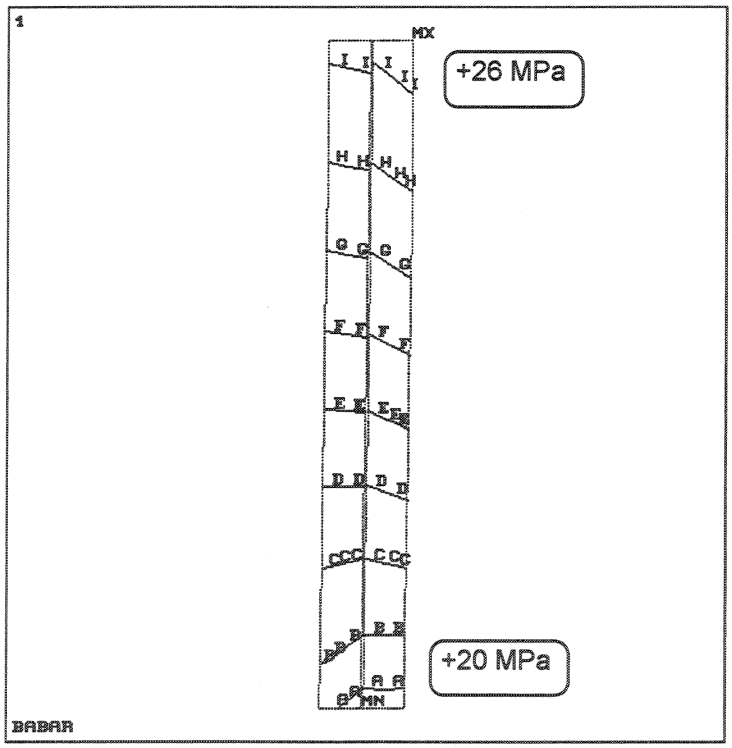

```
ANSYS 5.1
OCT 29 1996
08:05:49
PLOT NO.   9
NODAL SOLUTION
STEP=2
SUB =1
TIME=2
SZ        (AVG)
RSYS=0
DMX =0.001374
SMN =0.347E+08
SMX =0.658E+08
A   =0.364E+08
B   =0.399E+08
C   =0.433E+08
D   =0.468E+08
E   =0.503E+08
F   =0.537E+08
G   =0.572E+08
H   =0.606E+08
I   =0.641E+08
```

HOOP STRESS ON ALUMINUM CYLINDER WARM END, THERMAL+CURRENT EFFECT



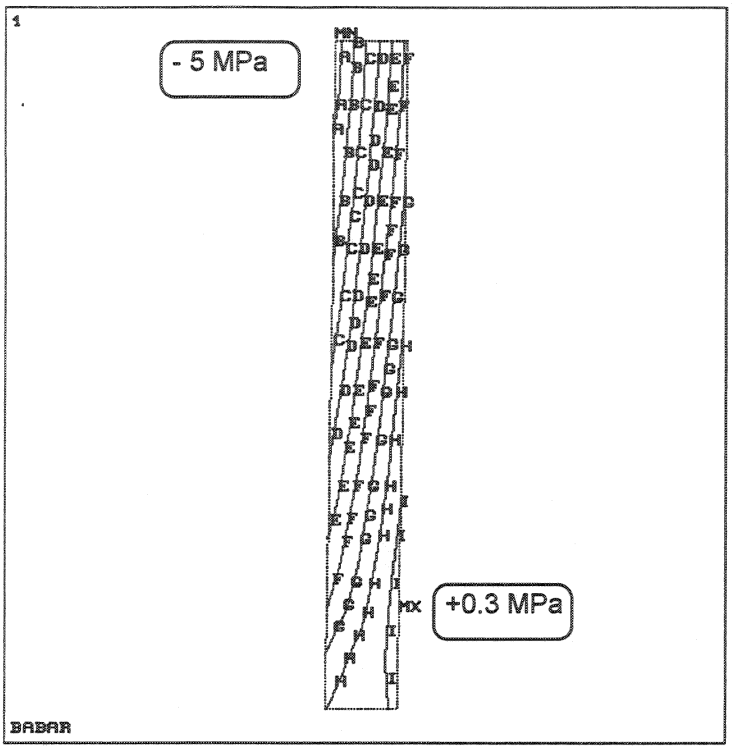

```
ANSYS 5.1
OCT 29 1996
08:07:49
PLOT NO.   1
NODAL SOLUTION
STEP=9999
SY        (AVG)
RSYS=0
DMX =0.651E-03
SMN =-0.729E+07
SMX =-576087
A   =-0.691E+07
B   =-0.617E+07
C   =-0.542E+07
D   =-0.468E+07
E   =-0.393E+07
F   =-0.319E+07
G   =-0.244E+07
H   =-0.169E+07
I   =-948848
```

AXIAL STRESS OF COIL
WARM END,
ONLY CURRENT EFFECT



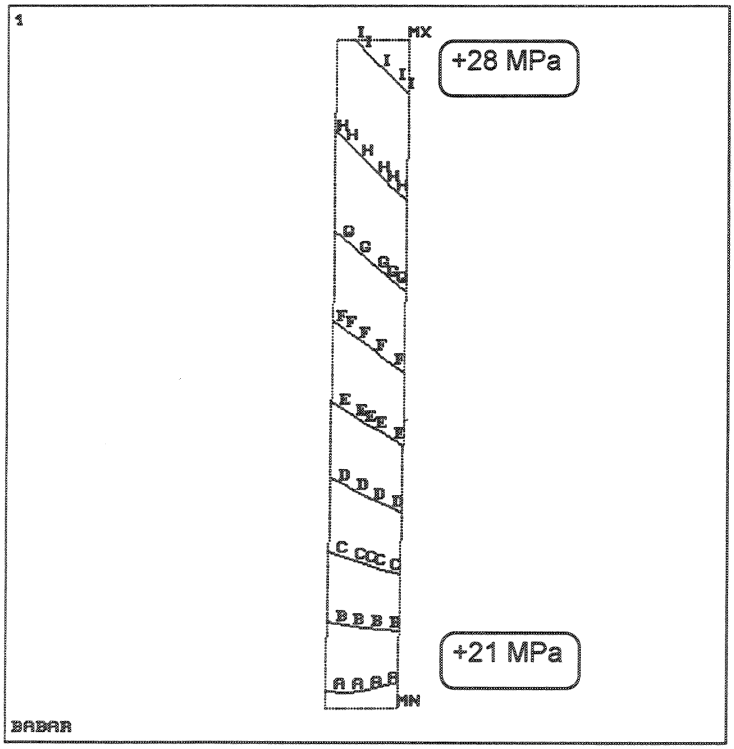

```
ANSYS 5.1
OCT 29 1996
08:07:53
PLOT NO.   2
NODAL SOLUTION
STEP=9999
SZ        (AVG)
RSYS=0
DMX =0.651E-03
SMN =0.200E+08
SMX =0.263E+08
A   =0.203E+08
B   =0.210E+08
C   =0.217E+08
D   =0.224E+08
E   =0.231E+08
F   =0.239E+08
G   =0.246E+08
H   =0.253E+08
I   =0.260E+08
```

AXIAL STRESS OF COIL
WARM END,
ONLY CURRENT EFFECT




```
ANSYS 5.1
OCT 29 1996
08:08:16
PLOT NO.    3
NODAL SOLUTION
STEP=9999
SY        (AVG)
RSYS=0
DMX =0.642E-03
SMN =-0.511E+07
SMX =321678
A    =-0.481E+07
B    =-0.420E+07
C    =-0.360E+07
D    =-0.300E+07
E    =-0.239E+07
F    =-0.179E+07
G    =-0.118E+07
H    =-583484
I    =19864
```

AXIAL STRESS ON
ALUMINUM CYLINDER
WARM END,
ONLY CURRENT EFFECT




```
ANSYS 5.1
OCT 29 1996
08:08:20
PLOT NO.    4
NODAL SOLUTION
STEP=9999
SZ        (AVG)
RSYS=0
DMX =0.642E-03
SMN =0.214E+08
SMX =0.281E+08
A    =0.218E+08
B    =0.225E+08
C    =0.233E+08
D    =0.240E+08
E    =0.248E+08
F    =0.255E+08
G    =0.263E+08
H    =0.270E+08
I    =0.277E+08
```

HOOP STRESS ON
ALUMINUM CYLINDER
WARM END,
ONLY CURRENT EFFECT

CONCLUSIONS

CASE: QUENCH STARTED FROM ONE END, WITHOUT DUMP RESISTOR; t=30 sec FROM BEGINNING OF QUENCH (CURRENT IS STILL 0.75 TIMES THE INITIAL VALUE)

STRESS ANALYSIS:

C	:= "only-current" stress
T	:= "only-thermal" stress
C+T	:= "current + thermal" stress
	Sy = axial stress
	Sz = hoop stress

- *C+T* ≅ *T* as to Sy (Sy is low for C case);
  T case (t=30sec) is lower than the (t=50 sec) case.

- *C+T* as to Sz: compensation for coil (opposite values),
  addition for aluminum cylinder.
  So coil material is less stressed than the (t=50 sec) case, while aluminum alloy cylinder has a higher but acceptable level of stress.

Note: quench analysis was performed without the thermal aid of aluminum strips on internal radius of coil.
In aluminum strips are added, thermal gradient is lower and stress is lower (how much lower depends on the RRR of aluminum strips).