- **Electrochemical Process to Reduce Alumina to Aluminum**
  - Alumina is dissolved in a molten fluoride solvent called cryolite

$$2\ Al_2O_{3(cryolite)} + 3\ C_{(anode)} \rightarrow 4\ Al_{(liquid)} + 3\ CO_{2(g)}$$

12 e^-

T = 960°C

Electrical work is needed:

I = 200-400 kA

E ≈ 4 V

Electrolyte (cryolitic bath)

$Na_3AlF_6 + (AlF_3)_{excess} + CaF_2 + Al_2O_3$

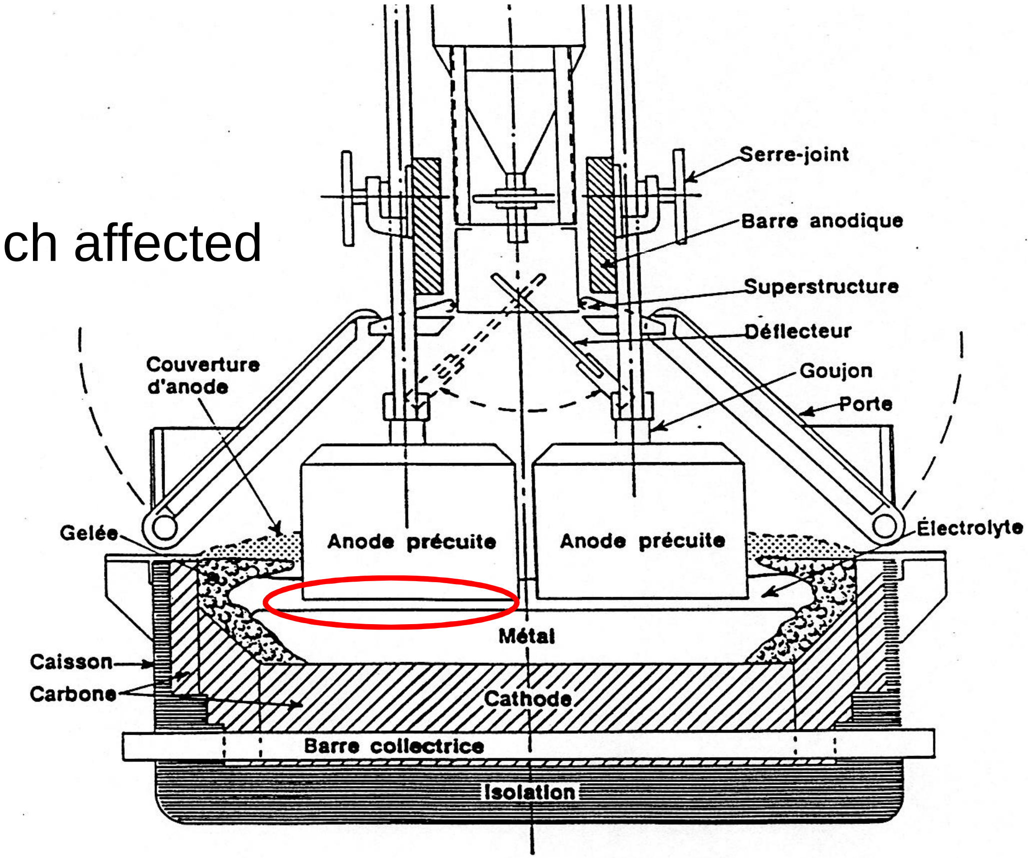
- **Electrochemical Process to Reduce Alumina to Aluminum**
  - Alumina is dissolved in a molten fluoride solvent called cryolite

Electrolyte (cryolitic bath)

$Na_3AlF_6 + (AlF_3)_{excess} + CaF_2 + Al_2O_3$

CR = NaF / AlF_3 (molar)

Operation T of the cell is much affected by **CR** and **%Al_2O_3**



- **Examples:**

1) **Create a "stream" for a standard bath**
2) **Phase Diagrams (CR = 2.2; 5% CaF_2)**
3) **Phase Diagrams (% Al_2O_3 vs xs-AlF_3; 5%CaF_2)**
4) **Adding reactants to the electrolyte (Al_2O_3)**
5) **Adding reactants to the electrolyte (Na_2CO_3)**
6) **Adding reactants to the electrolyte (AlF_3)**
7) **Carbide formation in the cathode blocks**
8) **Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

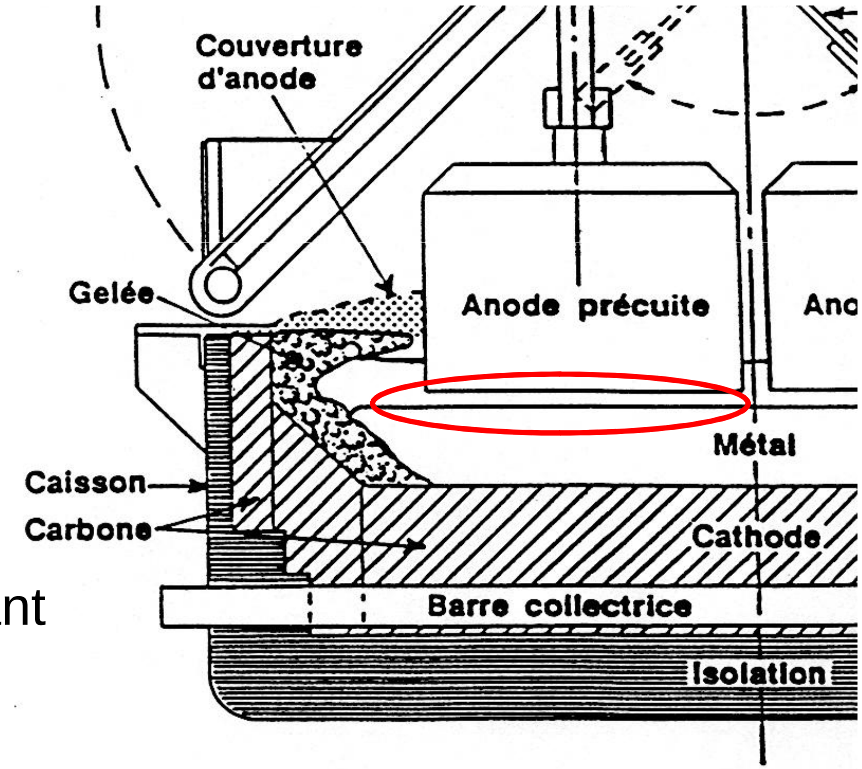
- **Example #1: Create a "stream" for a standard bath**

Create a **stream** of the following electrolyte

Na_3AlF_6
+ 12.2 wt.% AlF_3
+ 5.0% CaF_2
+ 3.0% Al_2O_3

The **stream** will be constrained in enthalpy at 960°C.

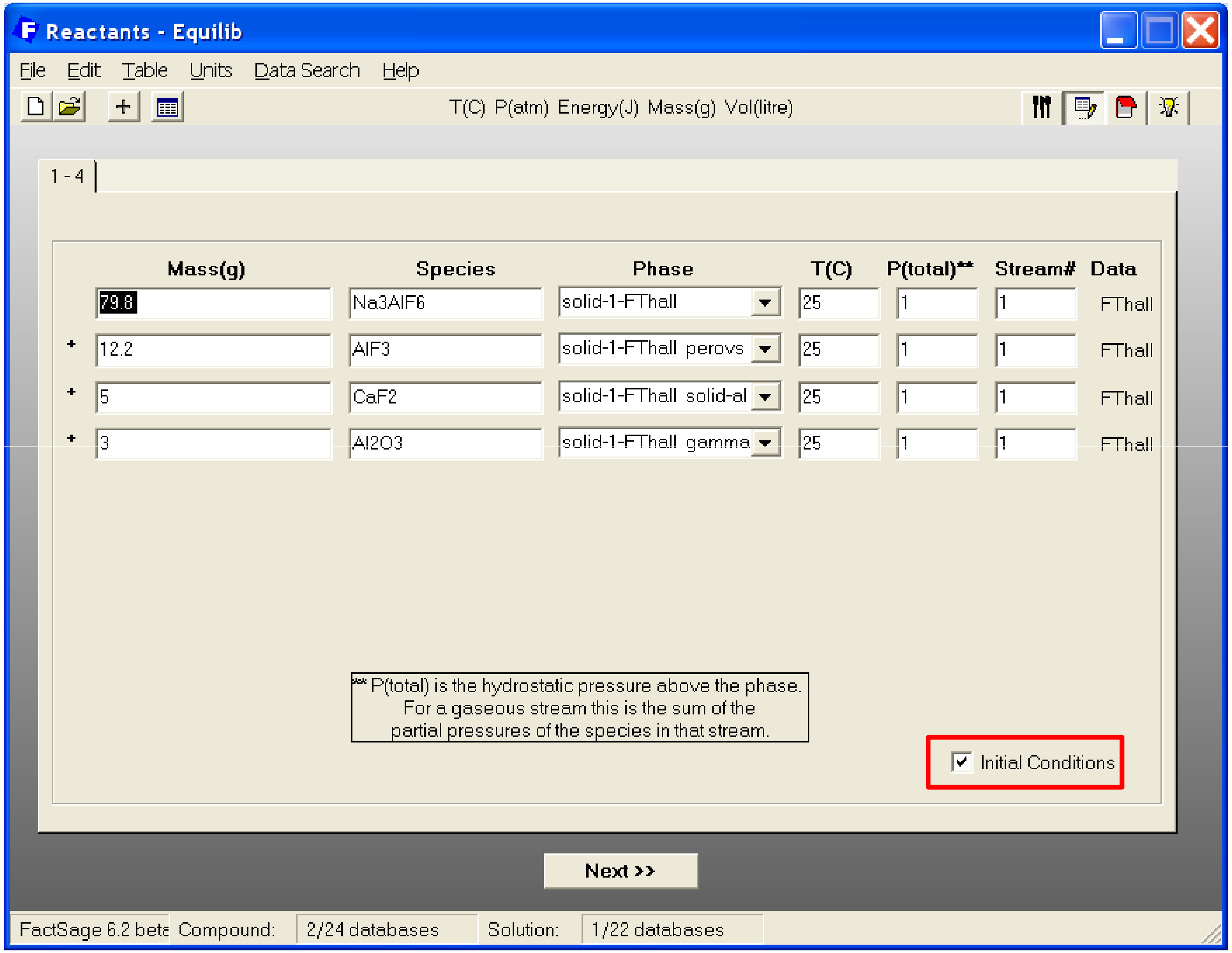
This **stream** will be used as reactant in several following examples.



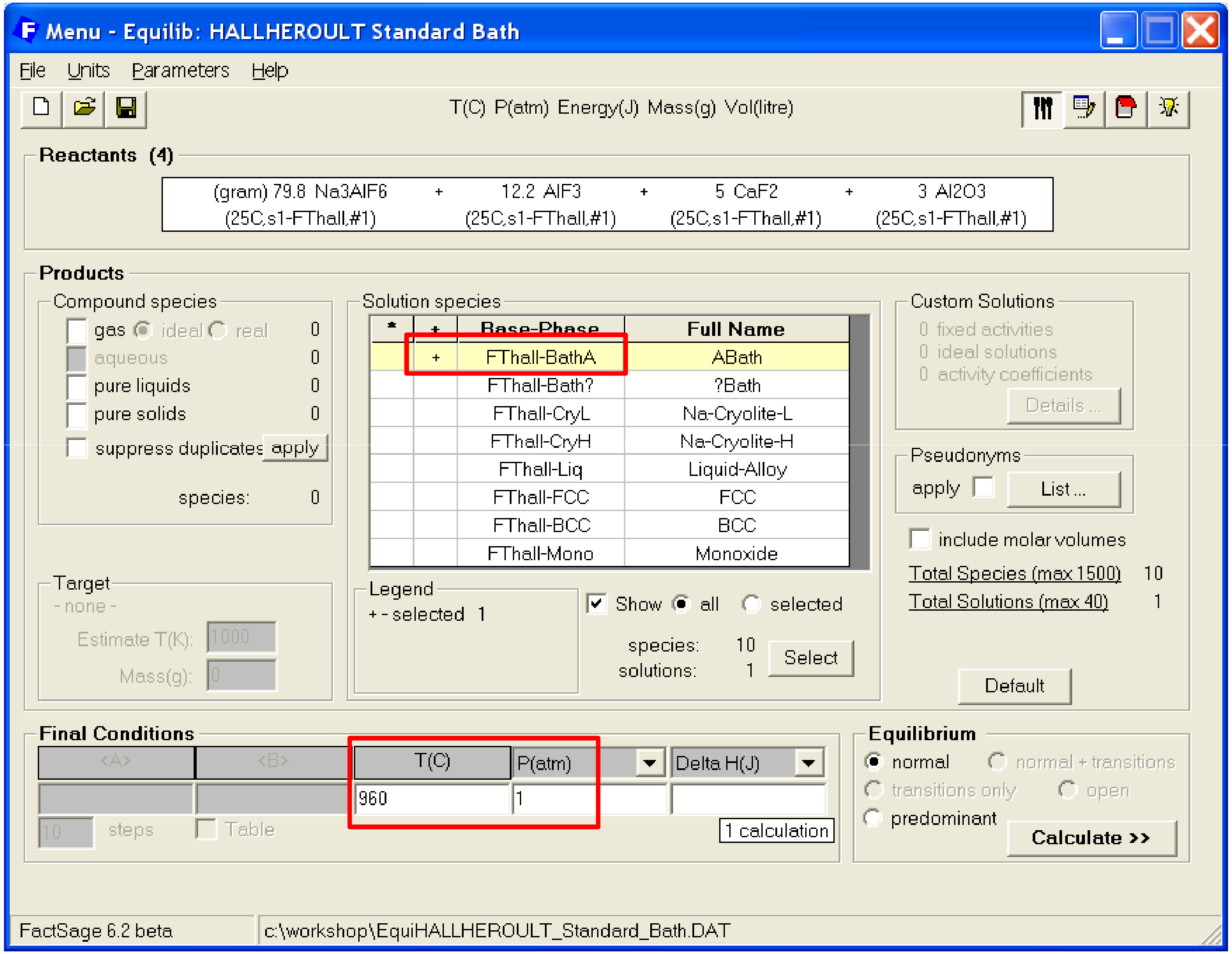
- **Example #1: Create a "stream" for a standard bath**

FThall Database

79.8% Na_3AlF_6
+ 12.2 wt.% AlF_3
+ 5.0% CaF_2
+ 3.0% Al_2O_3



- **Example #1: Create a "stream" for a standard bath**



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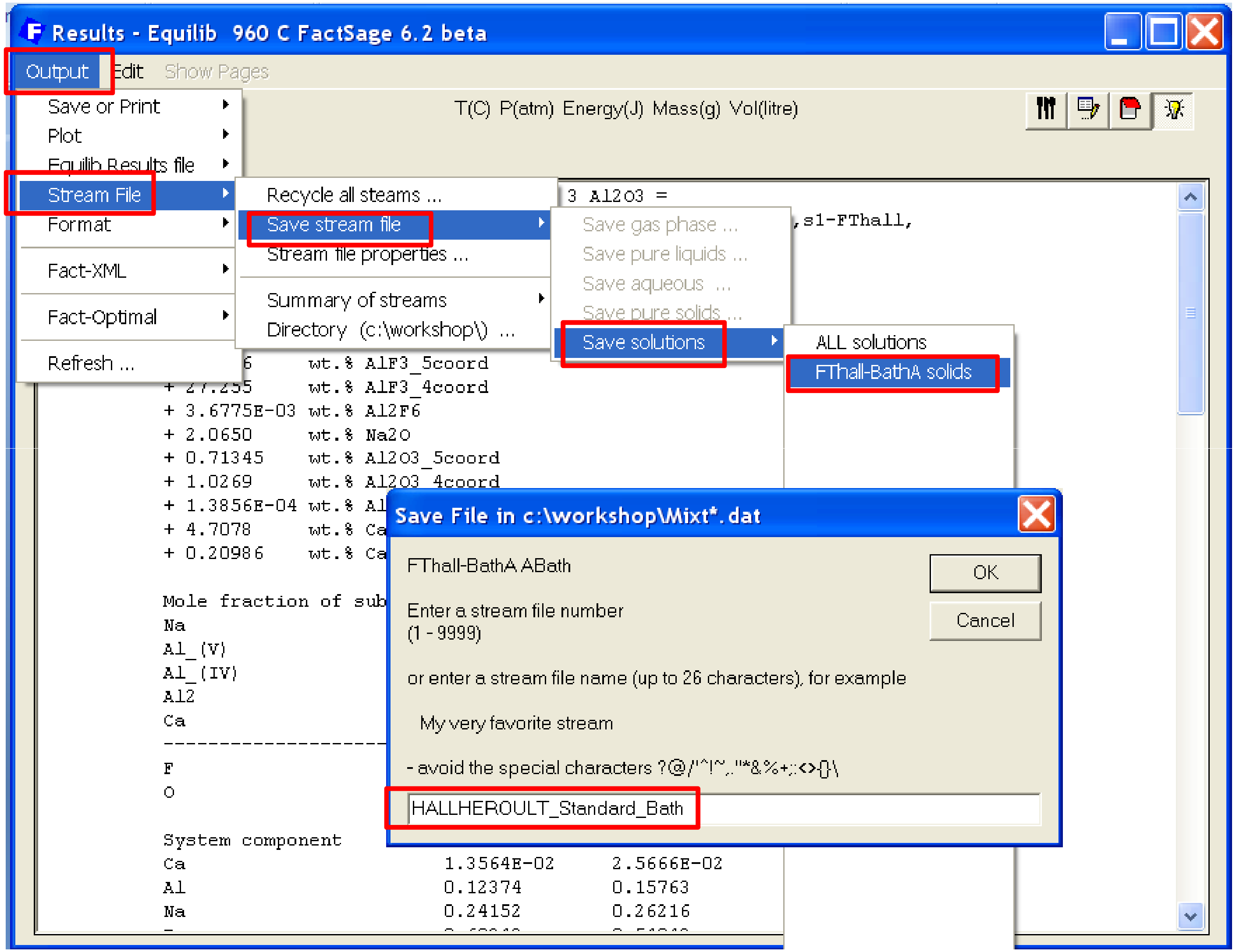
- **Example #1: Create a "stream" for a standard bath**



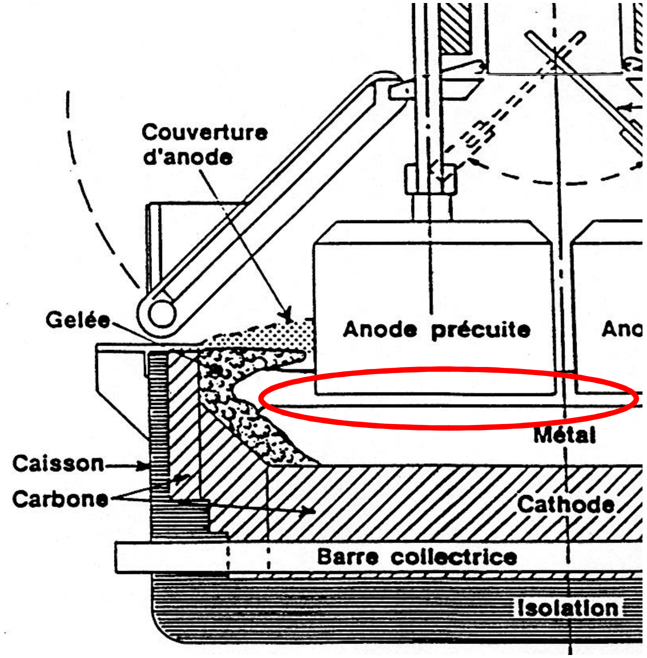
- **Example #2: Phase Diagrams**

The **cryolite (Na_3AlF_6) liquidus** and the **alumina (Al_2O_3) solubility** are very important for the cell operation.

The formation of a **side-ledge** protects the cell lining from the corrosive electrolyte.

Alumina has to be transported in the bath to the reaction site under the anode.
So a **high solubility** is better.

A **mapping** of these **phase diagram** features will be useful.



Hall-Heroult Process

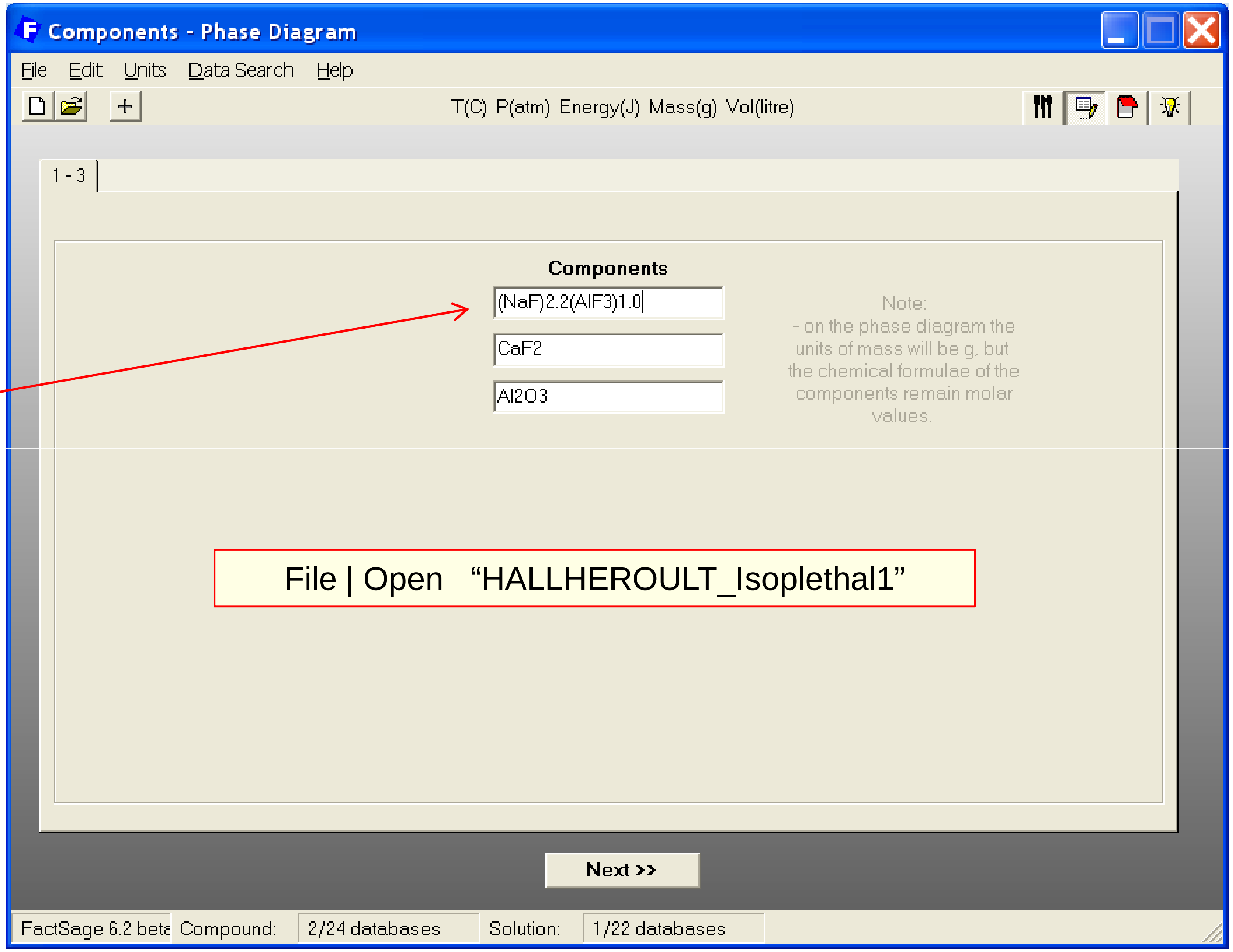
- **Example #2: Phase Diagrams (CR = 2.2; 5% CaF_2)**

FThall database

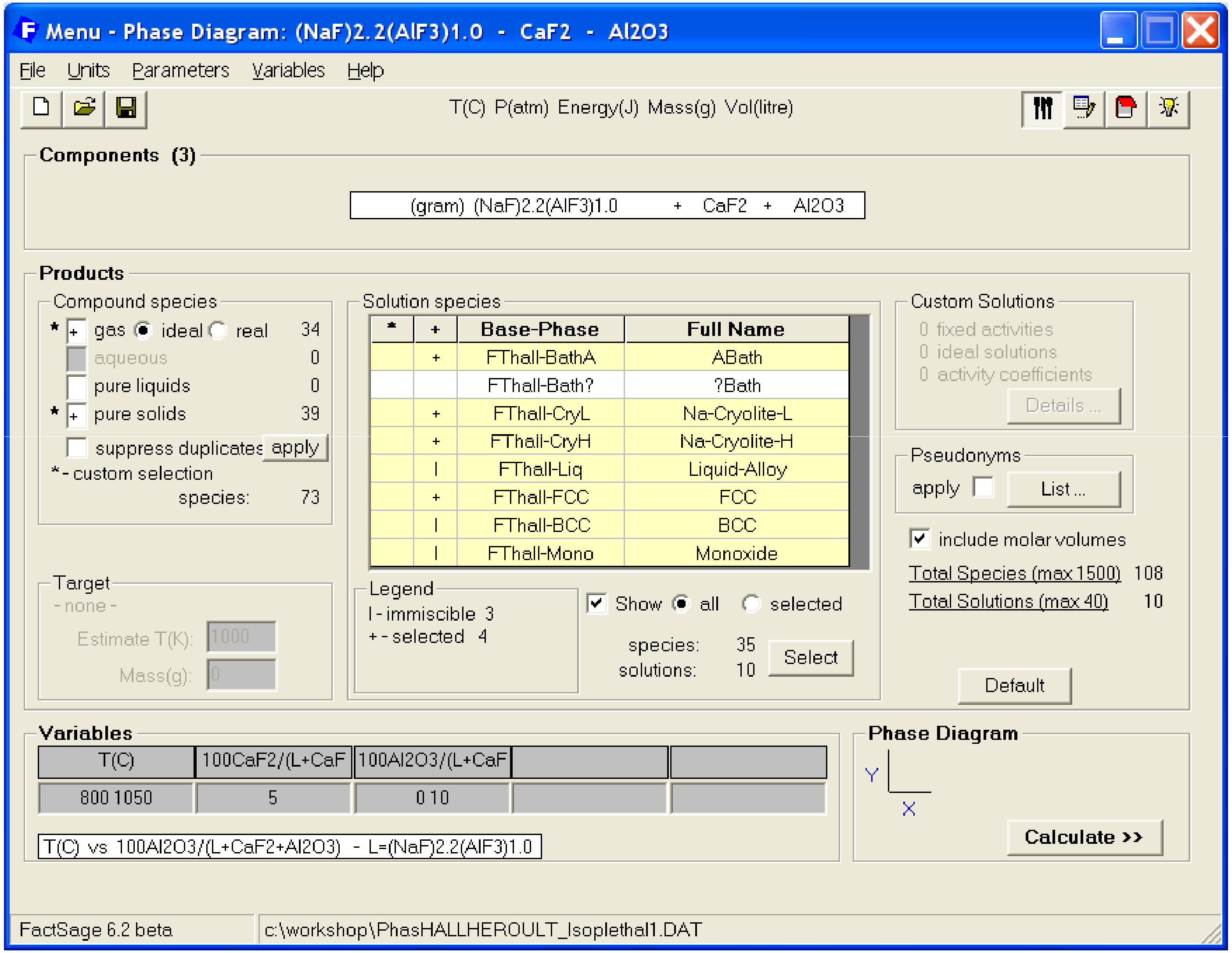
$CR = NaF / AlF_3$

CR = 2.2

$(NaF)_{2.2}(AlF_3)_{1.0}$



- **Example #2: Phase Diagrams (CR = 2.2; 5% CaF_2)**



Example #2: Phase Diagrams (CR = 2.2; 5% CaF_2)

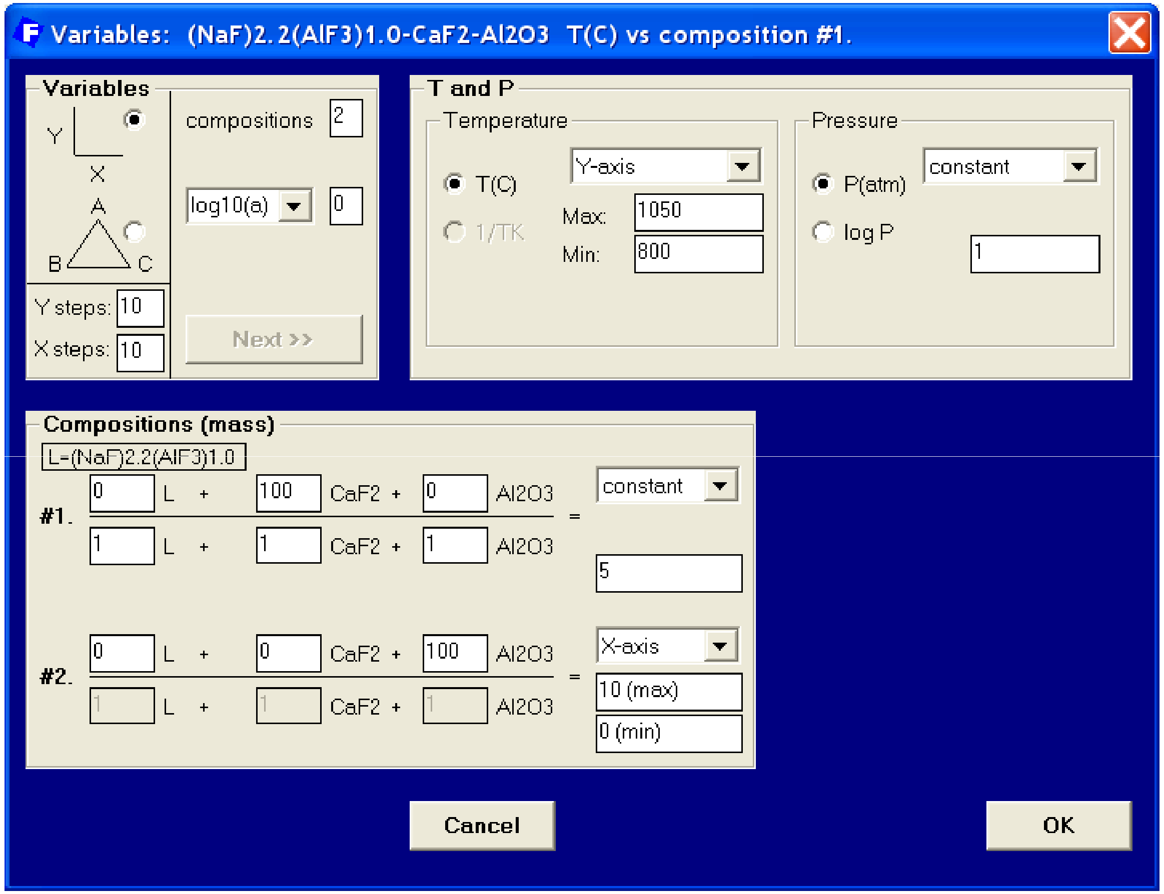
- X-axis

$$\frac{100\,Al_2O_3}{1(NaF)_{2.2}(AlF_3)_{1.0} + 1CaF_2 + 1Al_2O_3} = 0-10$$

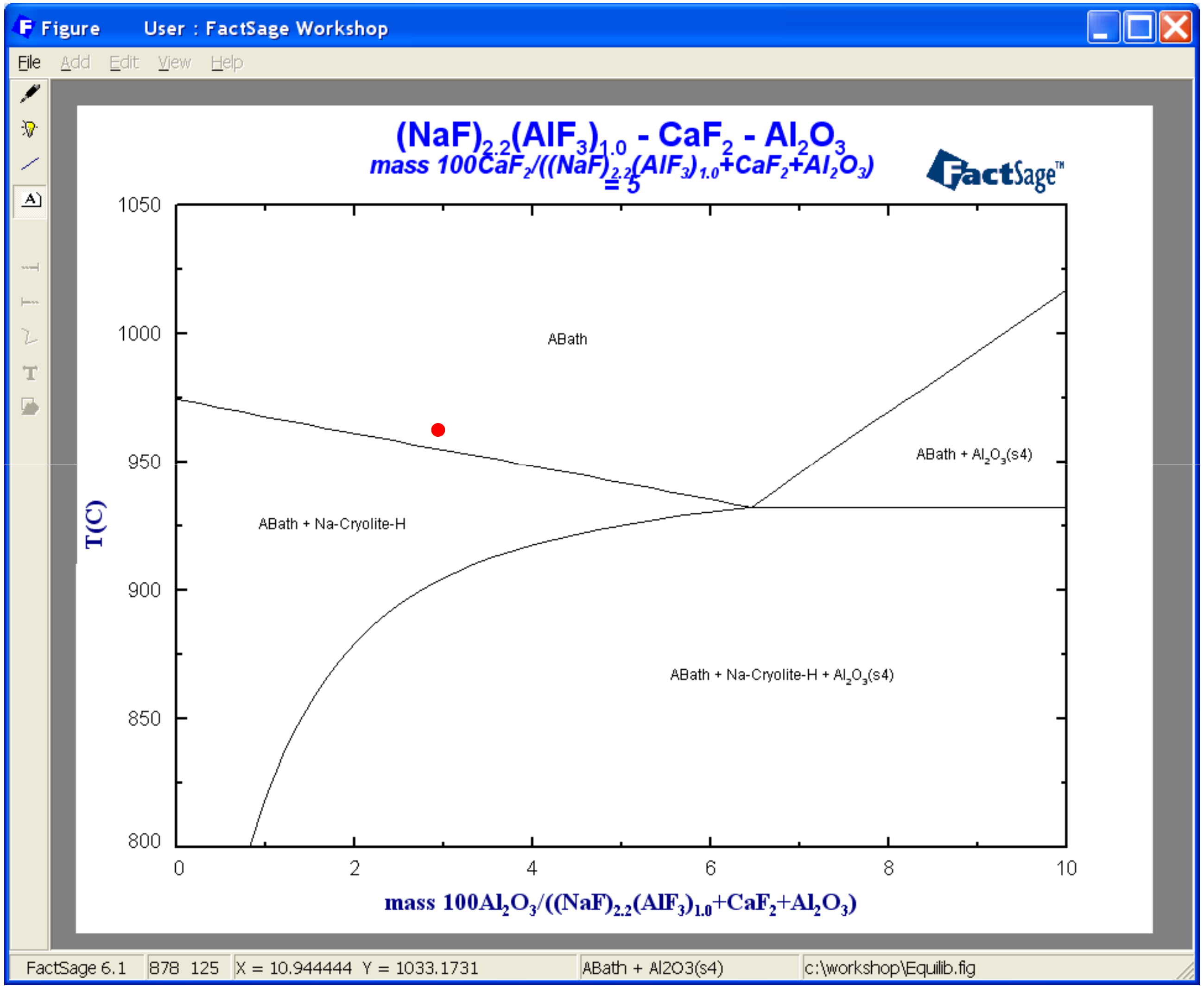
- Y-axis
  - T = 800 – 1050ºC

- Constants
  - P = 1 atm

$$\frac{100\,CaF_2}{1(NaF)_{2.2}(AlF_3)_{1.0} + 1CaF_2 + 1Al_2O_3} = 5.0$$



- **Example #2: Phase Diagrams (CR = 2.2; 5% CaF_2)**



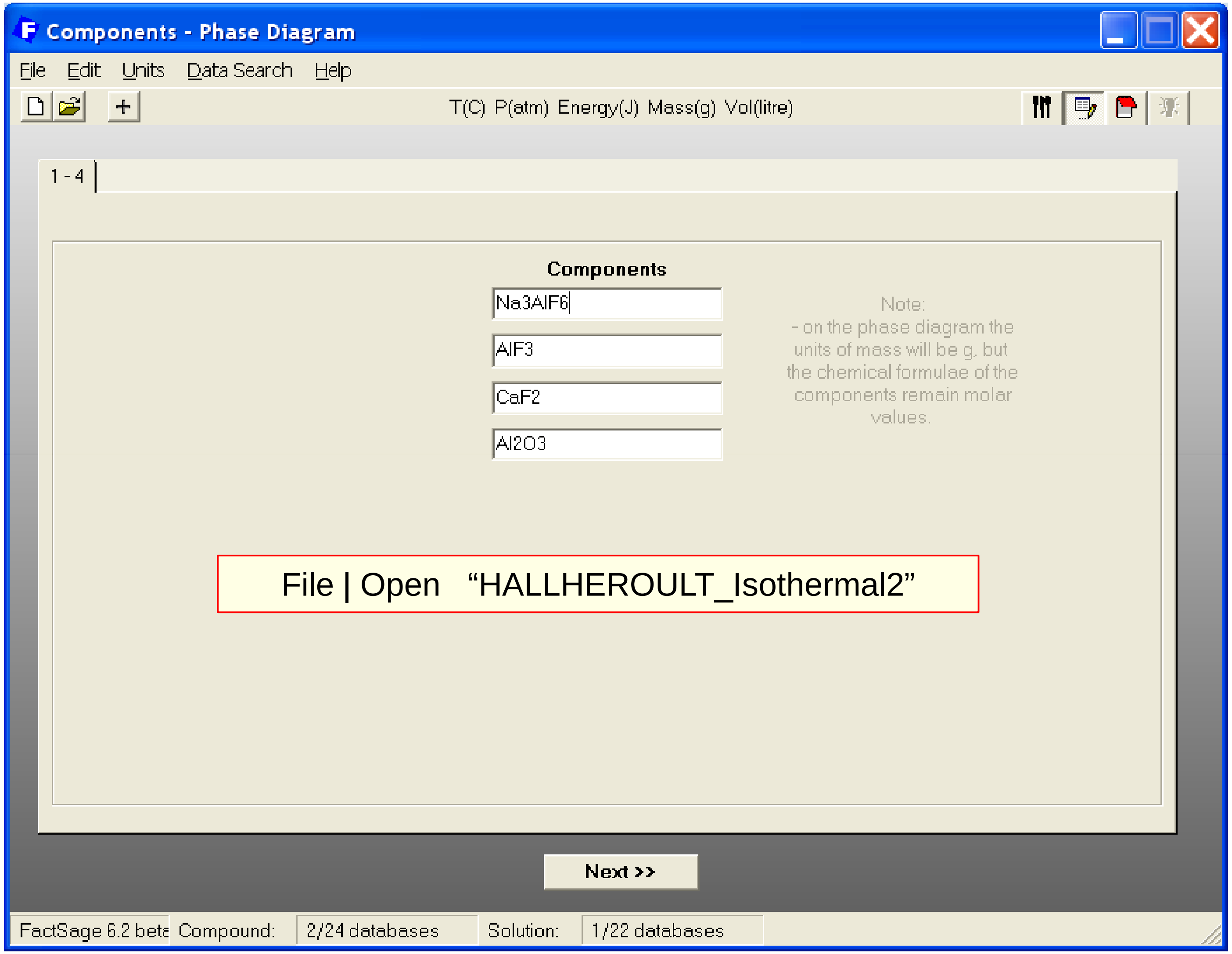
Hall-Herout Process

- **Example #3: Phase Diagrams (% Al_2O_3 vs xs-AlF_3; 5%CaF_2)**

FThall database

Na_3AlF_6
AlF_3(excess)
CaF_2
Al_2O_3

T = 960°C



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- **Example #3: Phase Diagrams (% Al_2O_3 vs xs-AlF_3; 5%CaF_2)**

- X-axis

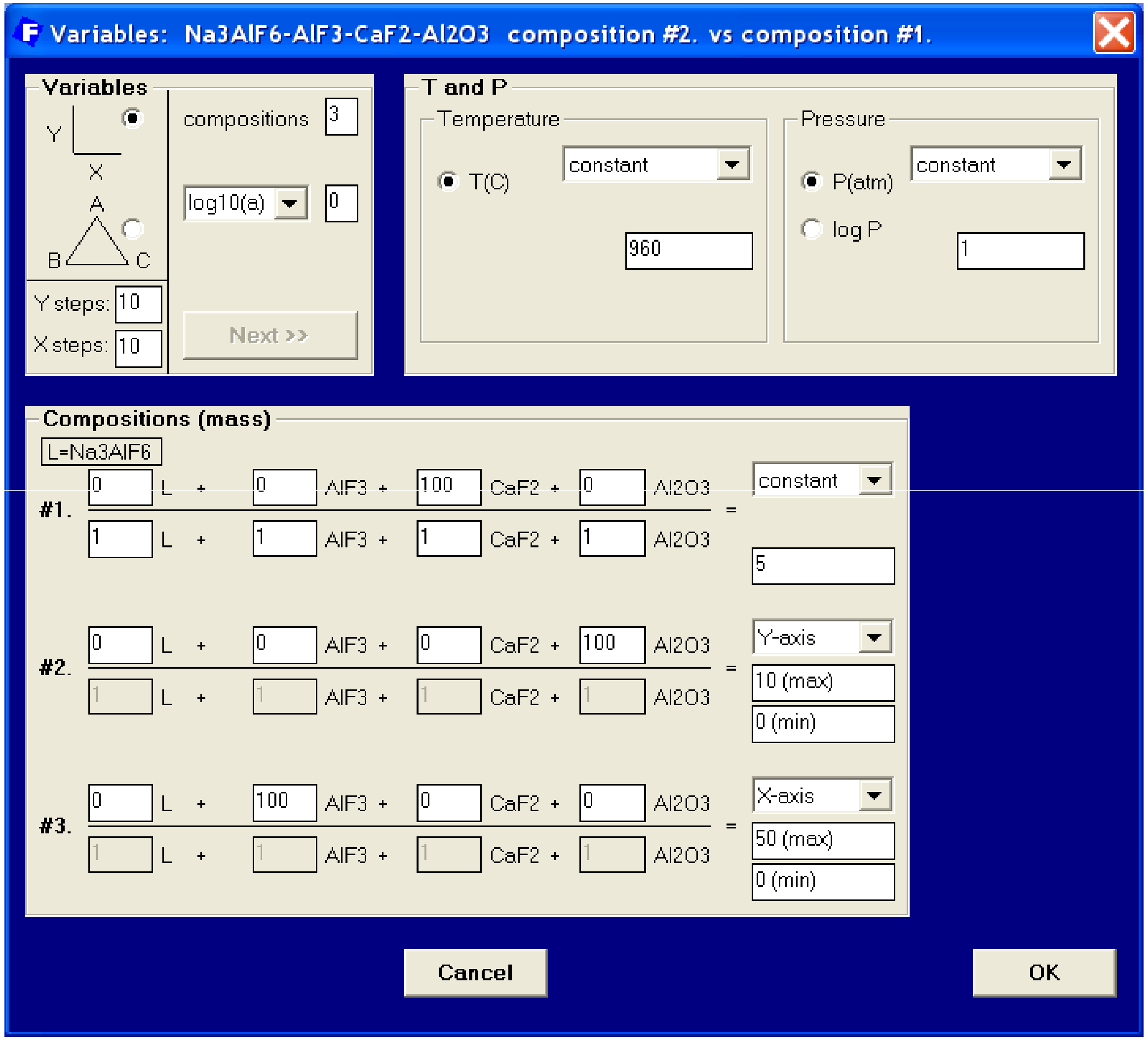
$$\frac{100\,AlF_3}{1\,Na_3AlF_6 + 1\,AlF_3 + 1\,CaF_2 + 1\,Al_2O_3} = 0 - 50$$

- Y-axis

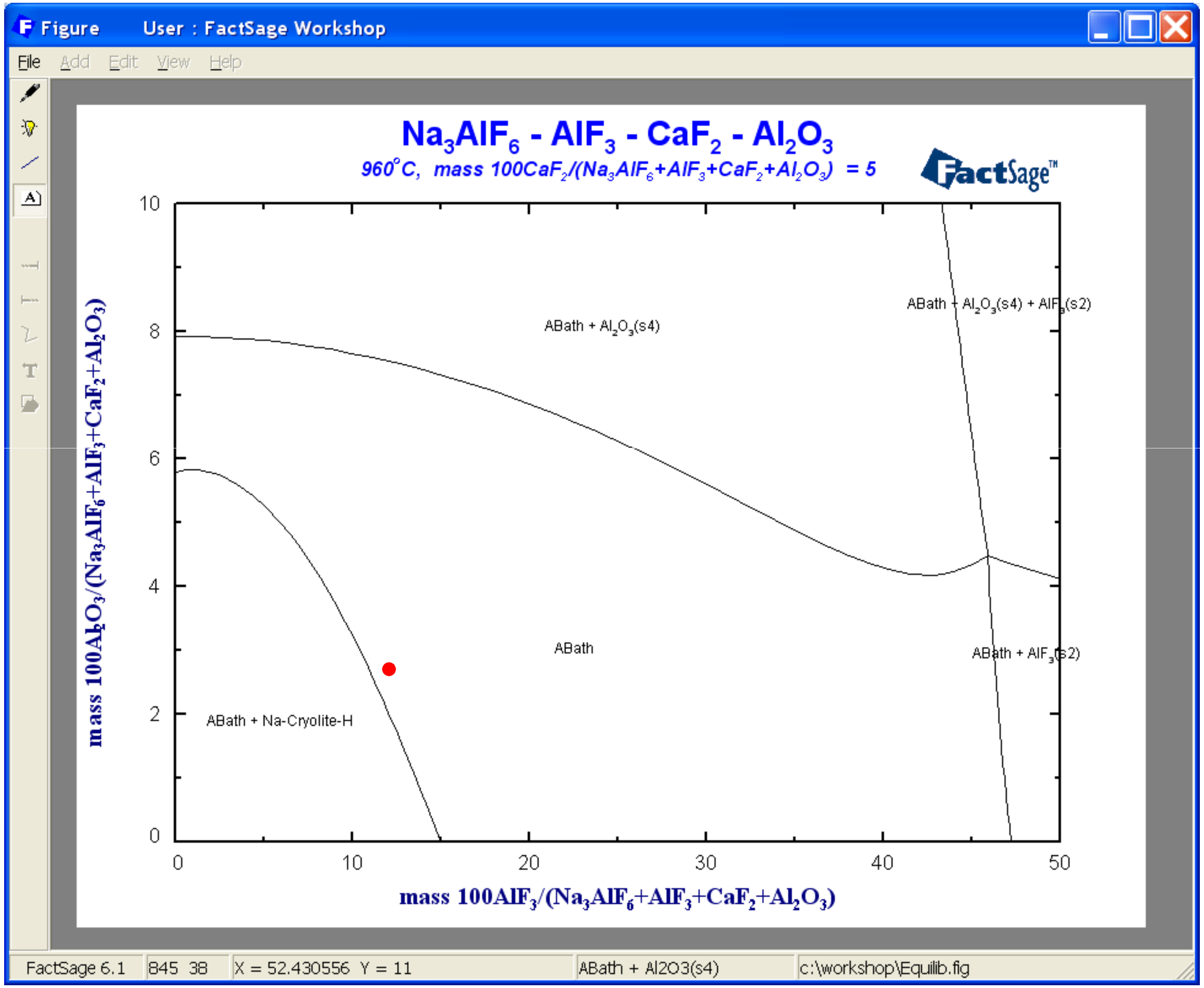
$$\frac{100\,Al_2O_3}{1\,Na_3AlF_6 + 1\,AlF_3 + 1\,CaF_2 + 1\,Al_2O_3} = 0 - 10$$

- Constants
  - T = 960°C
  - P = 1 atm

$$\frac{100\,CaF_2}{1\,Na_3AlF_6 + 1\,AlF_3 + 1\,CaF_2 + 1\,Al_2O_3} = 5.0$$



- **Example #3: Phase Diagrams (% Al_2O_3 vs xs-AlF_3; 5%CaF_2)**



- **Example #4: Adding reactants to the electrolyte**

The **thermal/heat balance** on the electrolytic cell is very important

The following additions are frequent:

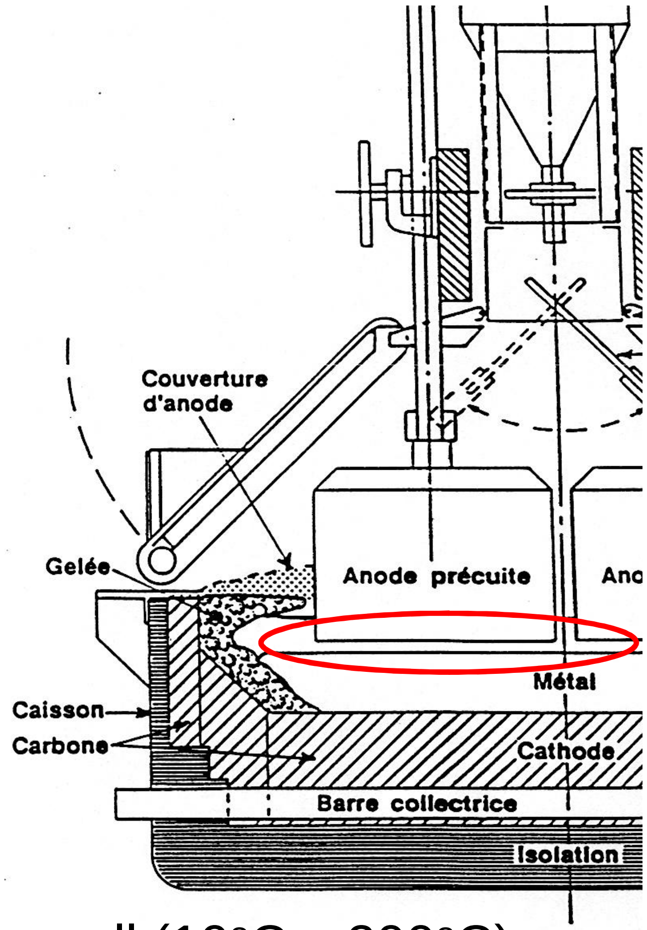
Al_2O_3 for the reduction reaction

Na_2CO_3 to increase **CR**

$3\ Na_2CO_3 + 2\ AlF_3 \rightarrow 6\ NaF + Al_2O_3 + 3\ CO_2$

AlF_3 to decrease **CR**

CR = NaF / AlF_3 (molar)



All these reactants are much **colder** than the cell (10°C – 200°C)

- **Example #4: Adding reactants to the electrolyte (Al_2O_3)**
- File | Open "HALLHEROULT_Add_Alumina"

Directory Equilib (My Files) - file c:\workshop\EquiHALLHEROULT_Add_Alumina.DAT

File Edit Tools

- 16 files -

File	Date	Description
Ex_Al-Mg-Sr-Ternary	18Nov04	Al-Mg-Sr ternary alloy system / Mg + Sr + Al
Ex_CH4-O2	19Feb04	Adiabatic flame temperature, Delta(H)=0 / <1-A> CH4 + <A> O2
Ex_MgCl2_O2_F2	15Jan04	MgCl2 O2 F2 / 1000 MgF2 + 0.001 N2 + 0 O2
HALLHEROULT_Add_AlF3	9May10	standard bath at 960oC / 1.0E+06 [HALLHEROULT_Standard_Bath] + (
HALLHEROULT_Add_Alumina	9May10	Adiabatic; standard bath at 960oC / 1.0E+06 [HALLHEROULT_Standard
HALLHEROULT_Add_Soda	9May10	with/without touching metal; standard bath / 1.0E+06 [HALLHEROULT_S
HALLHEROULT_Cathode_CollectingBar	9May10	C - Fe - SiO2/Al2O3 + variable P(Na) @ 960oC / 1000 Fe + 10000 C
HALLHEROULT_Liquidus	9May10	12.2% AlF3, 5% CaF2, 3% Al2O3 - liquidus temperature / 79.8 Na3AlF6 +
HALLHEROULT_Solubility	9May10	Alumina solubility at 960oC / <82.3-82.3A> Na3AlF6 + <12.5-12.5A> AlF3
HALLHEROULT_Standard_Bath	9May10	HALLHEROULT Standard Bath / 79.8 Na3AlF6 + 12.2 AlF3 + 5 CaF2 +
Metal_Treatment_01	6May10	AZ91 : solubility of H2 at 700oC for log10P(H2) from -5 to -0.5 by 0.1 / 90 M
Metal_Treatment_01b	6May10	AZ91 : Degassing with Ar @ 700oC and 1 atm / 1.0E+06 [_AZ91_H2_01a
Metal_Treatment_2b	6May10	Fluxes : HT-H25C on Flux #1 / <0.42899A> MnCl2 + <0.48318A> KCl + <(
Metal_Treatment_2c	6May10	Fluxes : HT-H25C on the reference flux (KMgCl3) / <0.42899A> MnCl2 +
Metal_Treatment_3	6May10	Fluxes : Efficiency in the removal of Na and Ca in Al-5%Mg / <0.42899A>
_ceramics	6May10	Mg-Al-Zr-TiB2-C / Mg + 98.5 Al + 0.5 Zr + <B> TiB2 + <A> C

FactSage 6.1 | c:\workshop\EquiHALLHEROULT_Add_Alumina.DAT

- **Example #4: Adding reactants to the electrolyte (Al_2O_3)**

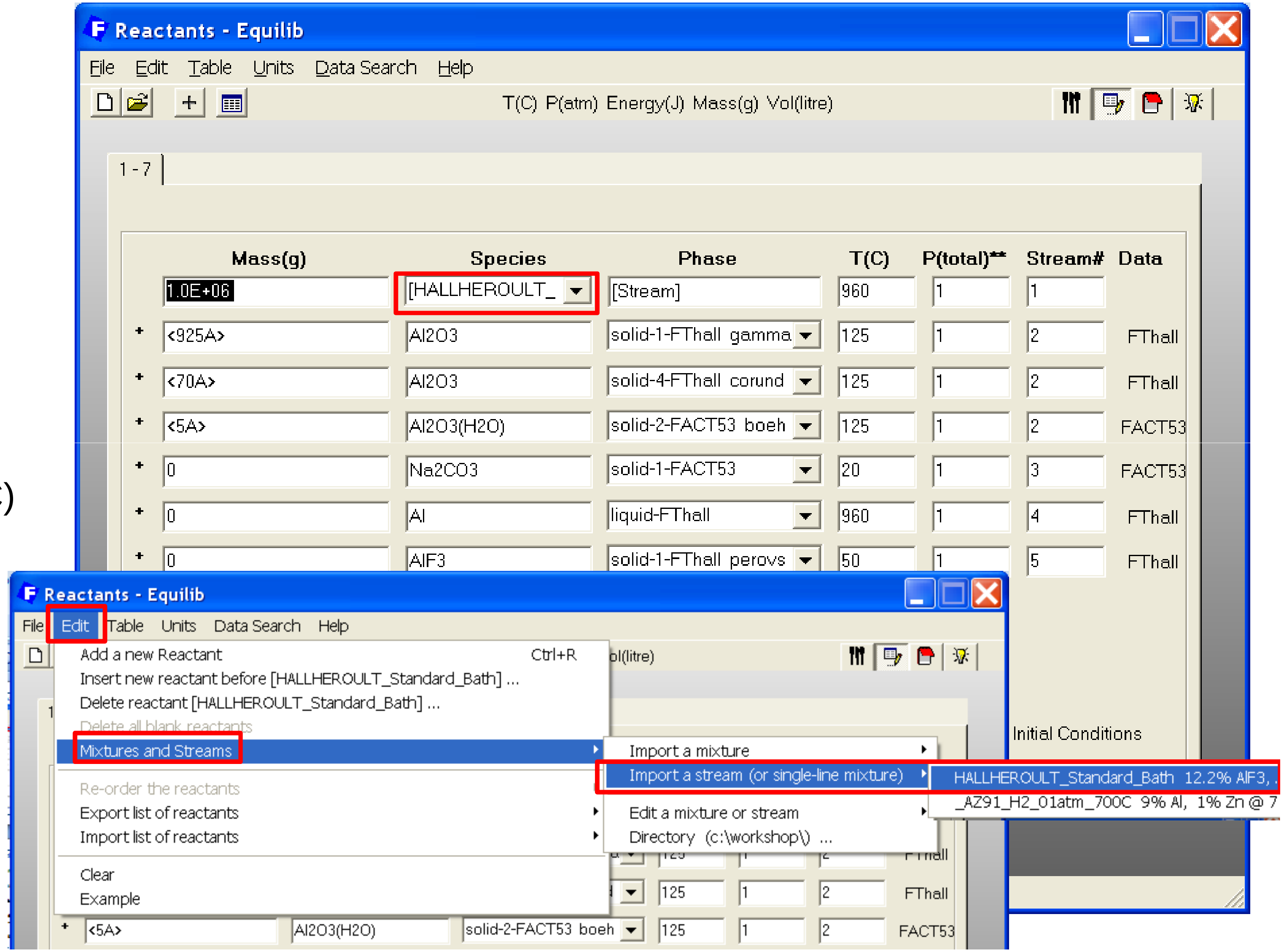
1.0 ton of **Bath**
(**stream** @ 960ºC)

Alumina @ 125ºC
γ-Al_2O_3
α-Al_2O_3
$Al_2O_3(H_2O)$

$Na_2CO_{3(s)}$ (@ 20ºC)

$Al_{(liq.)}$ (@ 960ºC)

$AlF_{3(s)}$ (@ 50ºC)



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- **Example #4: Adding reactants to the electrolyte (Al_2O_3)**

1.0 ton of **Bath**
(**stream** @ 960^{o}C)

+ 5 kg Alumina

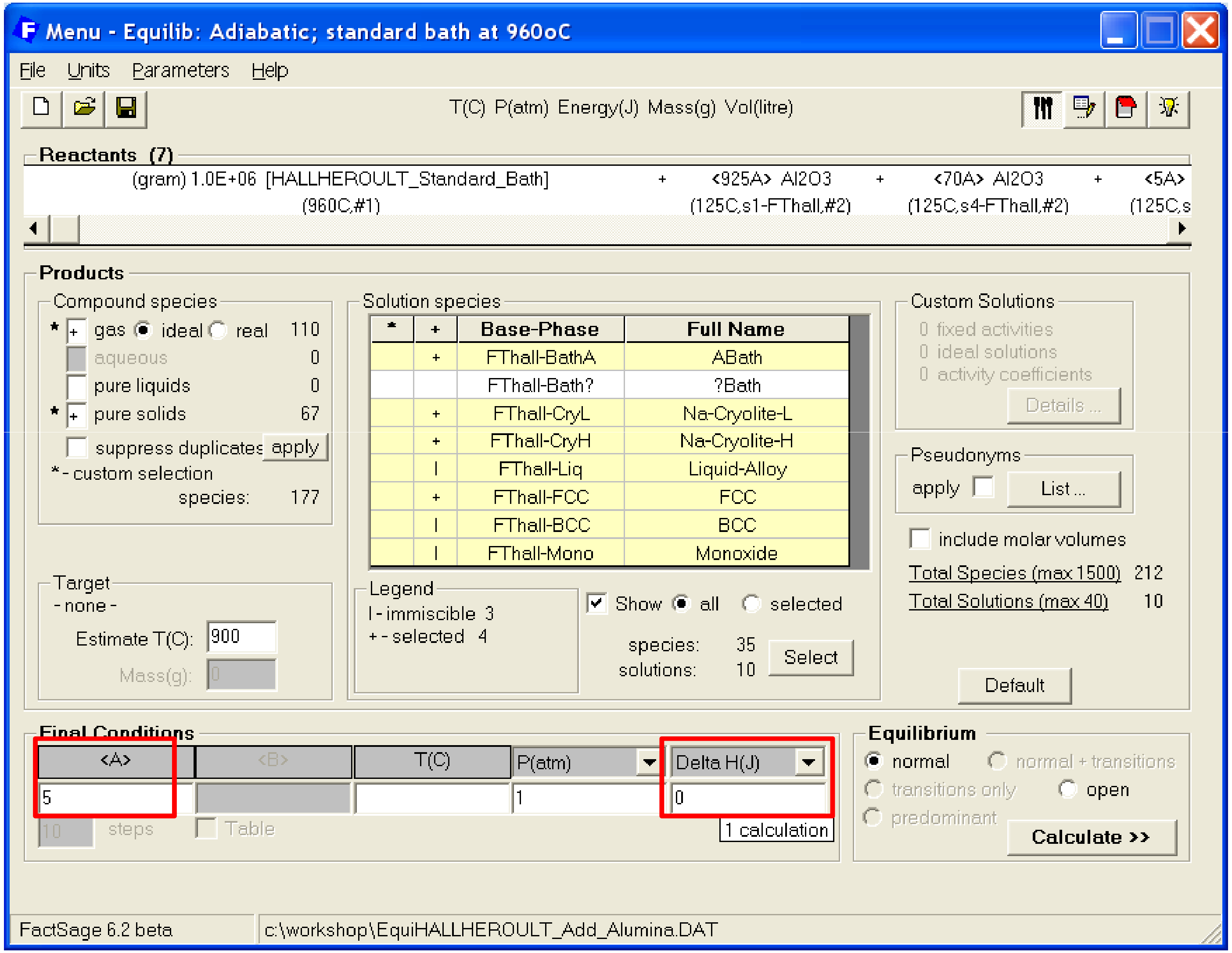
γ-Al_2O_3

α-Al_2O_3

$Al_2O_3(H_2O)$

Adiabatic Addition

Q = ΔH = 0



- **Example #4: Adding reactants to the electrolyte (Al_2O_3)**

Results - Equilib 953.16 C FactSage 6.2 beta

Output Edit Show Pages

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

```
 (gram) 1.0E+06 [HALLHEROULT_Standard_Bath] + <925A> Al2O3 + <70A> A
  (960,1,stream,#1)  (125,1,s1-FThall,#2)  (125,1,s4-FThall,#2)  (125,1
 (gram)  0 Na2CO3 +  0 Al +  0 AlF3 =
  (20,1,s1-FACT53,#3)  (960,1,liq-FThall,#4)  (50,1,s1-FThall,#5)

  0.24523    mol    gas_ideal
  (4.6852 gram, 0.24523 mol, 24.677 litre, 1.8986E-04 g/ml)
          (953.16 C,  1 atm,     a=1.0000)
          ( 0.70402          H2O
          + 0.29139          HF
          + 4.2504E-03       NaAlF4
          + 2.2096E-04       Na2AlF5
          + 7.1324E-05       (NaAlF4)2
          + 2.4232E-05       NaF
          + 7.8358E-06       H2
          + 6.3034E-06       AlF3
          + 3.7294E-06       O2
          + 1.9335E-06       (NaF)2
          + 1.7961E-06       (HF)2
          + 1.6170E-06       NaAl2F7
          + 7.5476E-07       OH
          + 1.3310E-07       NaOH
          + 8.8770E-10       H
          + 5.7273E-10       CaF2
          + 3.4043E-10       (AlF3)2
          + 1.7406E-10       Na
          + 8.2947E-11       O
          + 8.0972E-11       F
          + 4.0619E-11       HOOH
          + 3.6527E-11       HOO
          + 9.4098E-12       H3F3
```

Results - Equilib 953.16 C FactSage 6.2 beta

Output Edit Show Pages

T(C) P(atm) Energy(J) Mass(g) Vol(litre)

```
 + 1.0050E+06 gram  ABath
   (1.0050E+06 gram, 17398. mol)
           (953.16 C,  1 atm,     a=1.0000)
           ( 44.426      wt.% NaF
           + 18.502      wt.% AlF3_5coord
           + 27.780      wt.% AlF3_4coord
           + 3.6720E-03  wt.% Al2F6
           + 2.3739      wt.% Na2O
           + 0.81323     wt.% Al2O3_5coord
           + 1.2210      wt.% Al2O3_4coord
           + 1.6139E-04  wt.% Al2O3
           + 4.6393      wt.% CaF2
           + 0.24125     wt.% CaO

           Mole fraction of sublattice constituents:
           Na                      0.63409
           Al_(V)                  0.13204
           Al_(IV)                 0.19825
           Al2                     1.3103E-05
           Ca                      3.5611E-02
           -----------------------------------
           F                       0.96506
           O                       3.4935E-02

           System component        Mole fraction  Mass fraction
           Ca                      1.3494E-02     2.5539E-02
           Al                      0.12517        0.15948
           Na                      0.24027        0.26085
           F                       0.59937        0.53773
           O                       2.1697E-02     1.6393E-02
```

- **Example #5: Adding reactants to the electrolyte (Na_2CO_3)**

- File | Open "HALLHEROULT_Add_Soda"

Directory Equilib (My Files) - file c:\workshop\EquiHALLHEROULT_Add_Soda.DAT

File Edit Tools

- 16 files -

File	Date	Description
Ex_Al-Mg-Sr-Ternary	18Nov04	Al-Mg-Sr ternary alloy system / Mg + Sr + Al
Ex_CH4-O2	19Feb04	Adiabatic flame temperature, Delta(H)=0 / <1-A> CH4 + <A> O2
Ex_MgCl2_O2_F2	15Jan04	MgCl2 O2 F2 / 1000 MgF2 + 0.001 N2 + 0 O2
HALLHEROULT_Add_AlF3	9May10	standard bath at 960oC / 1.0E+06 [HALLHEROULT_Standard_Bath] + (
HALLHEROULT_Add_Alumina	9May10	Adiabatic; standard bath at 960oC / 1.0E+06 [HALLHEROULT_Standard
HALLHEROULT_Add_Soda	9May10	with/without touching metal; standard bath / 1.0E+06 [HALLHEROULT_S
HALLHEROULT_Cathode_CollectingBar	9May10	C - Fe - SiO2/Al2O3 + variable P(Na) @ 960oC / 1000 Fe + 10000 C
HALLHEROULT_Liquidus	9May10	12.2% AlF3, 5% CaF2, 3% Al2O3 - liquidus temperature / 79.8 Na3AlF6 +
HALLHEROULT_Solubility	9May10	Alumina solubility at 960oC / <82.3-82.3A> Na3AlF6 + <12.5-12.5A> AlF3
HALLHEROULT_Standard_Bath	9May10	HALLHEROULT Standard Bath / 79.8 Na3AlF6 + 12.2 AlF3 + 5 CaF2 +
Metal_Treatment_01	6May10	AZ91 : solubility of H2 at 700oC for log10P(H2) from -5 to -0.5 by 0.1 / 90 M
Metal_Treatment_01b	6May10	AZ91 : Degassing with Ar @ 700oC and 1 atm / 1.0E+06 [_AZ91_H2_01a
Metal_Treatment_2b	6May10	Fluxes : HT-H25C on Flux #1 / <0.42899A> MnCl2 + <0.48318A> KCl + <(
Metal_Treatment_2c	6May10	Fluxes : HT-H25C on the reference flux (KMgCl3) / <0.42899A> MnCl2 + <
Metal_Treatment_3	6May10	Fluxes : Efficiency in the removal of Na and Ca in Al-5%Mg / <0.42899A>
_ceramics	6May10	Mg-Al-Zr-TiB2-C / Mg + 98.5 Al + 0.5 Zr + <B> TiB2 + <A> C

FactSage 6.1 c:\workshop\EquiHALLHEROULT_Add_Soda.DAT

Example #5: Adding reactants to the electrolyte (Na_2CO_3)

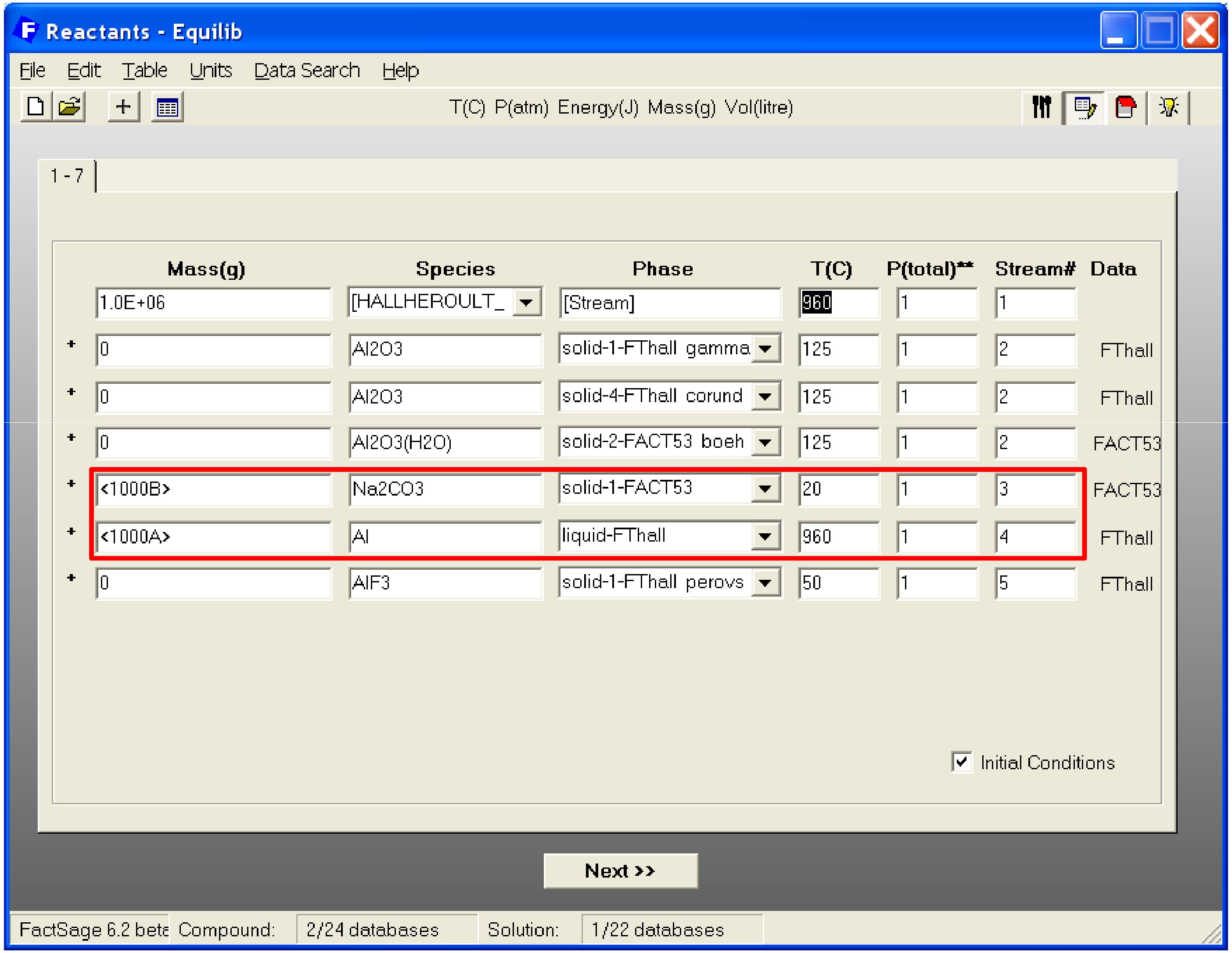
1.0 ton of **Bath** (**stream** @ 960°C)

$Na_2CO_{3(s)}$ (@ 20°C)

$Al_{(liq.)}$ (@ 960°C)

Bags of Na_2CO_3 can added manually to the cell.

A bag can partially touch the **metal pad** below the **bath** and <u>react</u> with it.



- **Example #5: Adding reactants to the electrolyte (Na_2CO_3)**

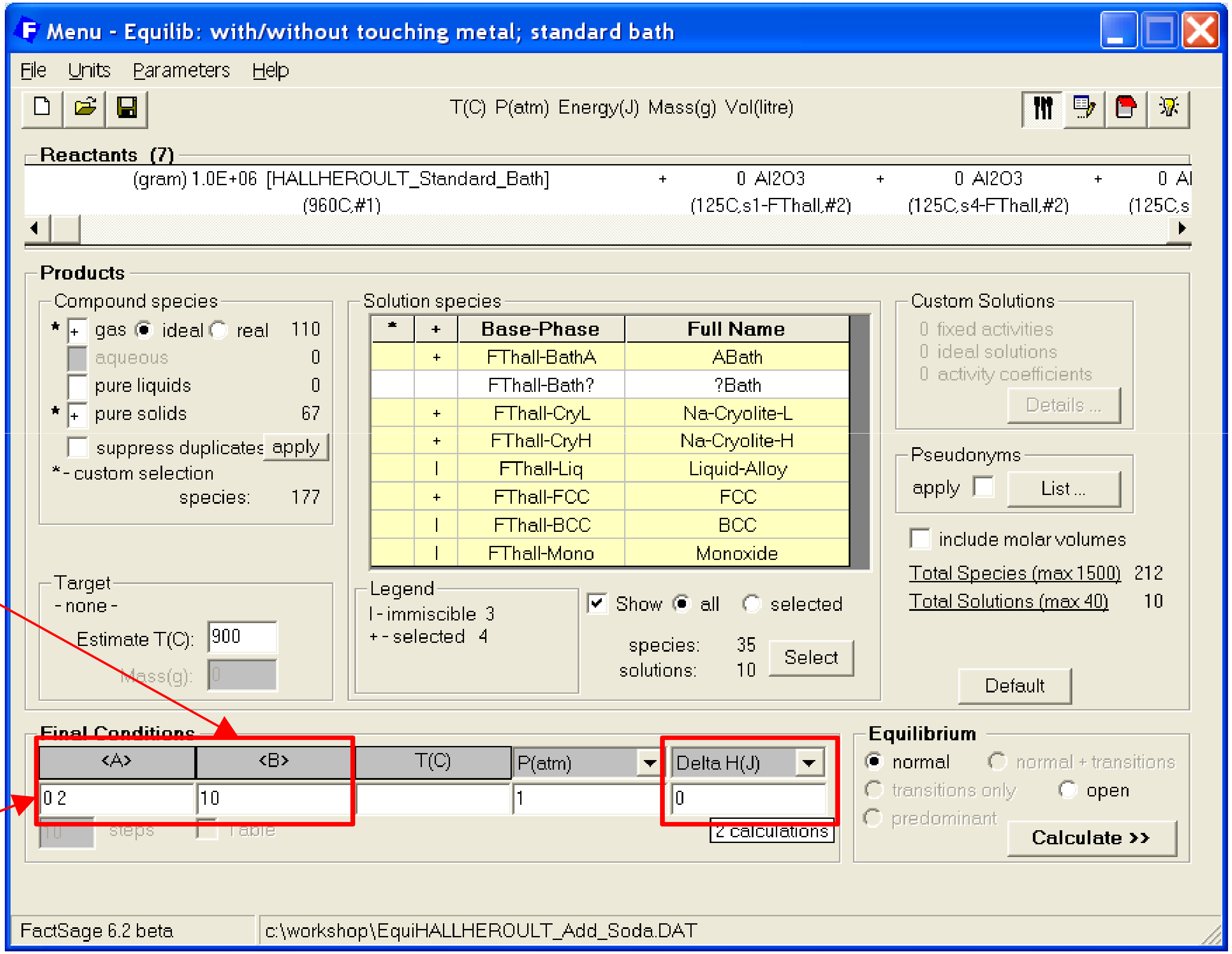
1.0 ton of **Bath** (**stream** @ 960ºC)

$Na_2CO_{3(s)}$ (@ 20ºC)

$Al_{(liq.)}$ (@ 960ºC)

Bags of Na_2CO_3 can added manually to the cell **<B> = 10 kg**

A bag can partially touch the **metal pad** below the **bath** and react with it **<A> = 0 or 2 kg**



- **Example #5: Adding reactants to the electrolyte (Na_2CO_3)**

Bags of Na_2CO_3

<B> = 10 kg

metal pad

<A> = 0 kg

Result

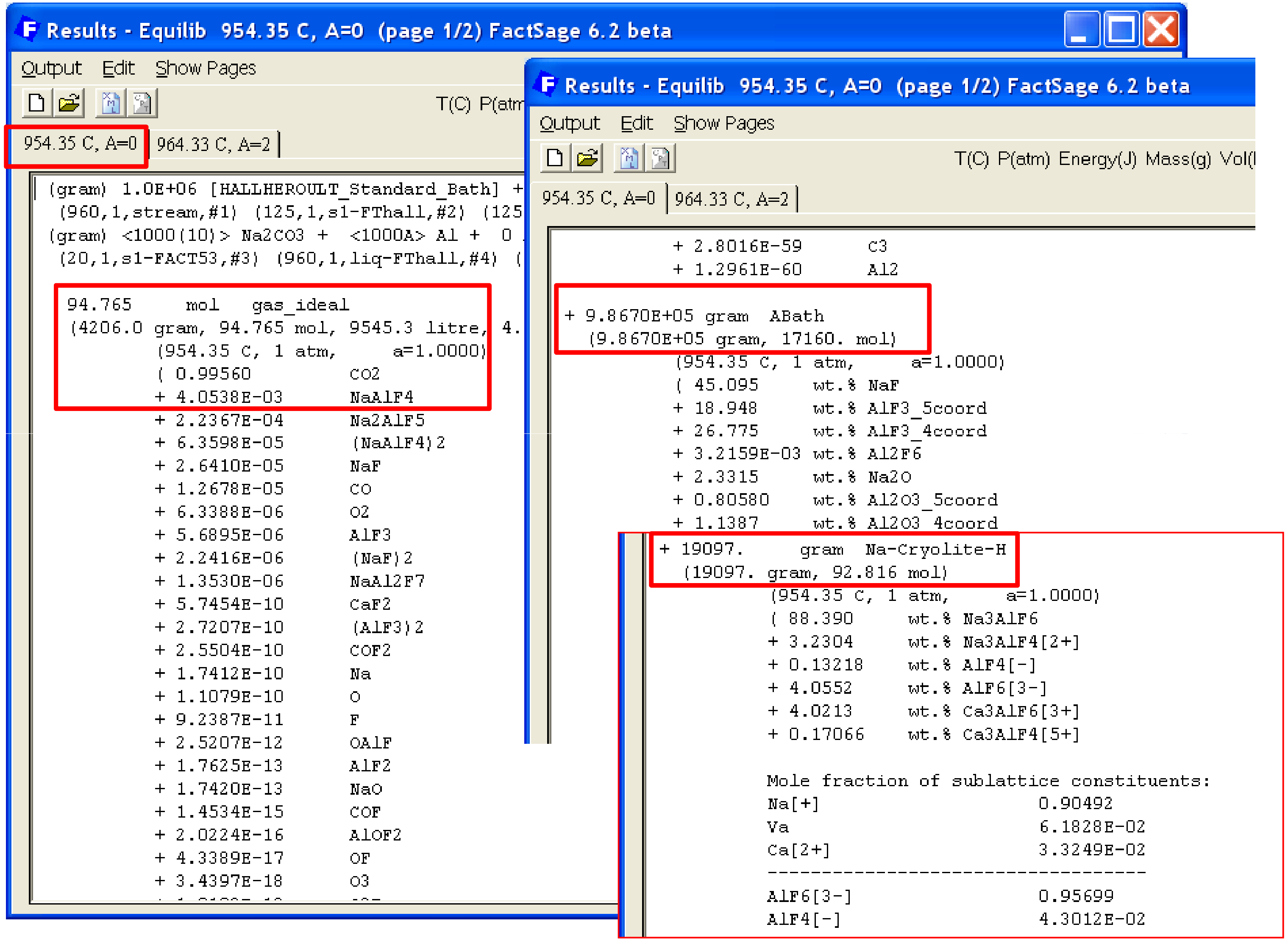
T < 960°C

4.2 kg gas

(9.5 m^3 gas)

986.7 kg bath

19.1 kg Na_3AlF_6



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- **Example #5: Adding reactants to the electrolyte (Na_2CO_3)**

Bags of Na_2CO_3

<B> = 10 kg

metal pad

<A> = 2 kg

Result

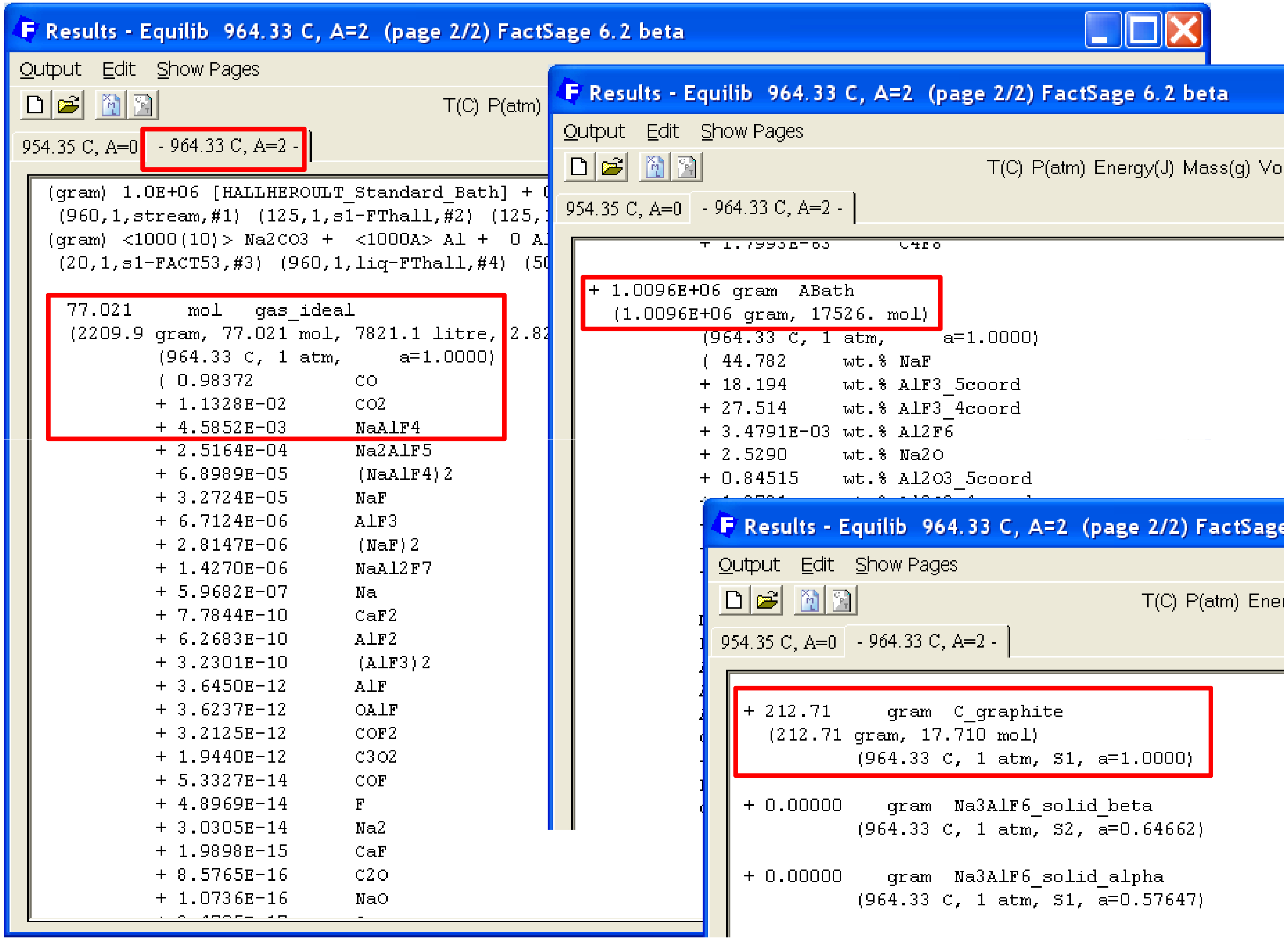
T > 960°C

2.2 kg gas

(7.8 m³ gas)

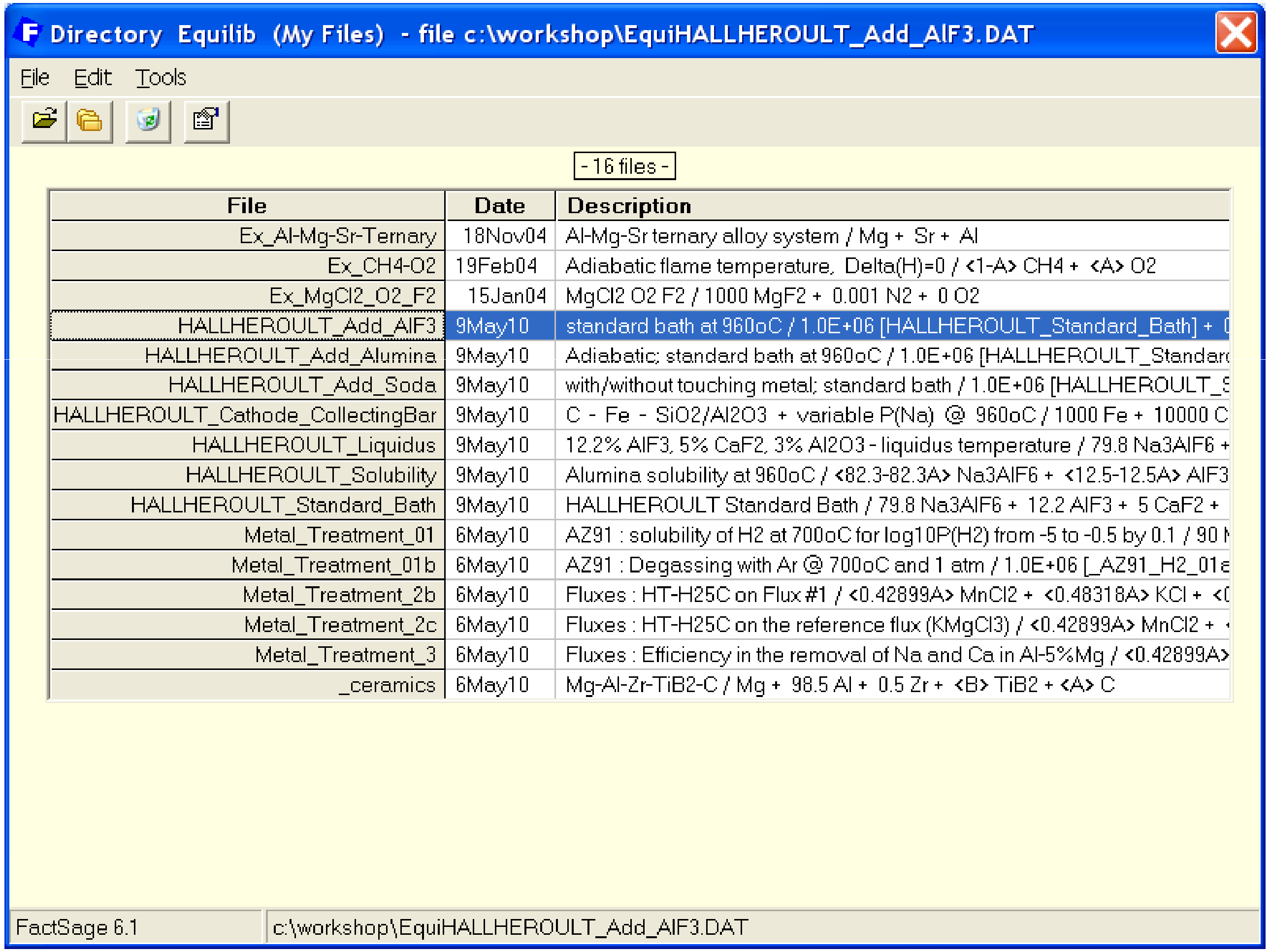
1009.6 kg bath

0.2 kg C



- **Example #6: Adding reactants to the electrolyte (AlF_3)**

- File | Open “HALLHEROULT_Add_AlF3”



Directory Equilib (My Files) - file c:\workshop\EquiHALLHEROULT_Add_AlF3.DAT

File Edit Tools

- 16 files -

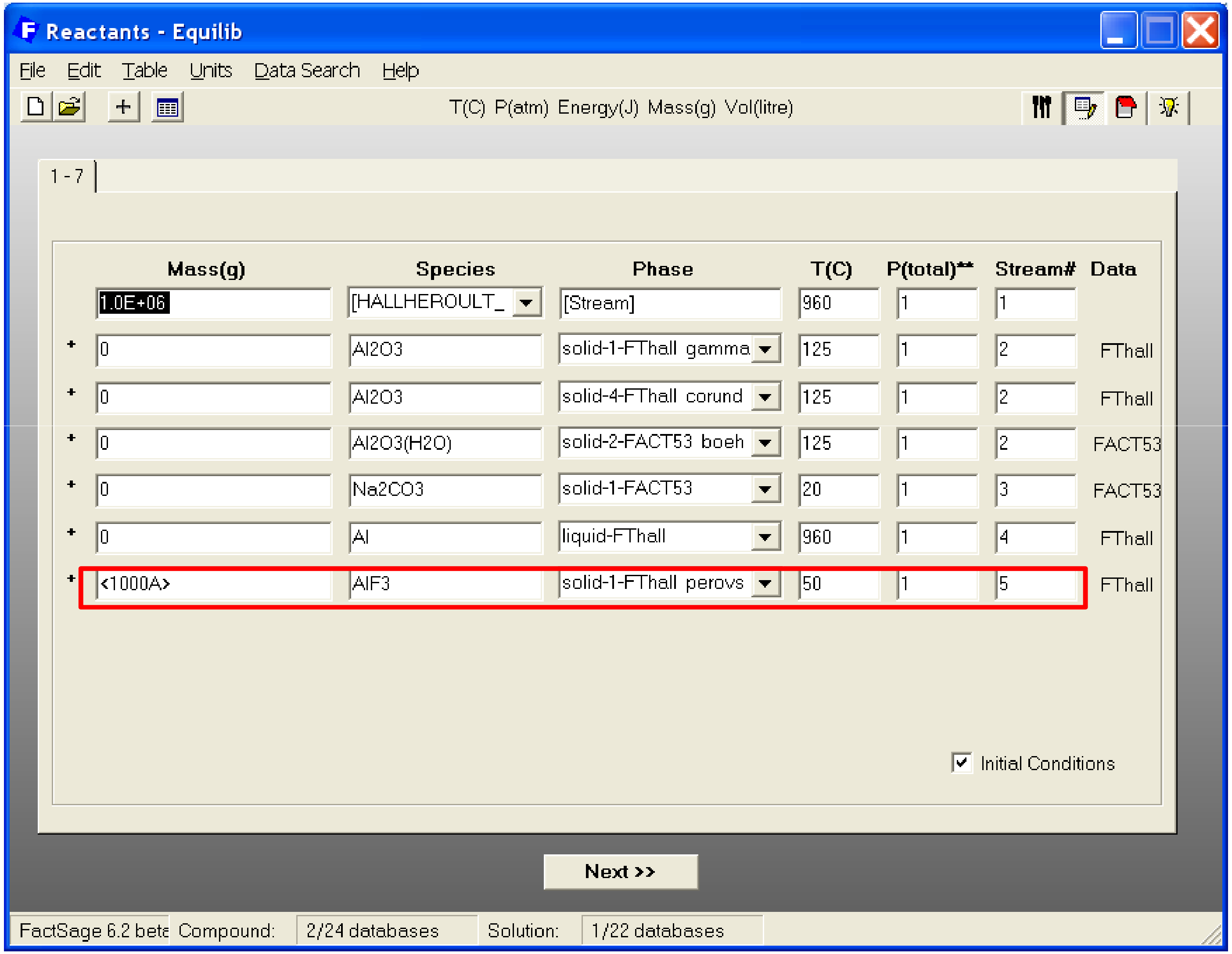
File	Date	Description
Ex_Al-Mg-Sr-Ternary	18Nov04	Al-Mg-Sr ternary alloy system / Mg + Sr + Al
Ex_CH4-O2	19Feb04	Adiabatic flame temperature, Delta(H)=0 / <1-A> CH4 + <A> O2
Ex_MgCl2_O2_F2	15Jan04	MgCl2 O2 F2 / 1000 MgF2 + 0.001 N2 + 0 O2
HALLHEROULT_Add_AlF3	9May10	standard bath at 960oC / 1.0E+06 [HALLHEROULT_Standard_Bath] +
HALLHEROULT_Add_Alumina	9May10	Adiabatic; standard bath at 960oC / 1.0E+06 [HALLHEROULT_Standar
HALLHEROULT_Add_Soda	9May10	with/without touching metal; standard bath / 1.0E+06 [HALLHEROULT_
HALLHEROULT_Cathode_CollectingBar	9May10	C - Fe - SiO2/Al2O3 + variable P(Na) @ 960oC / 1000 Fe + 10000 C
HALLHEROULT_Liquidus	9May10	12.2% AlF3, 5% CaF2, 3% Al2O3 - liquidus temperature / 79.8 Na3AlF6 +
HALLHEROULT_Solubility	9May10	Alumina solubility at 960oC / <82.3-82.3A> Na3AlF6 + <12.5-12.5A> AlF3
HALLHEROULT_Standard_Bath	9May10	HALLHEROULT Standard Bath / 79.8 Na3AlF6 + 12.2 AlF3 + 5 CaF2 +
Metal_Treatment_01	6May10	AZ91 : solubility of H2 at 700oC for log10P(H2) from -5 to -0.5 by 0.1 / 90
Metal_Treatment_01b	6May10	AZ91 : Degassing with Ar @ 700oC and 1 atm / 1.0E+06 [_AZ91_H2_01
Metal_Treatment_2b	6May10	Fluxes : HT-H25C on Flux #1 / <0.42899A> MnCl2 + <0.48318A> KCl +
Metal_Treatment_2c	6May10	Fluxes : HT-H25C on the reference flux (KMgCl3) / <0.42899A> MnCl2 +
Metal_Treatment_3	6May10	Fluxes : Efficiency in the removal of Na and Ca in Al-5%Mg / <0.42899A>
_ceramics	6May10	Mg-Al-Zr-TiB2-C / Mg + 98.5 Al + 0.5 Zr + <B> TiB2 + <A> C

FactSage 6.1 | c:\workshop\EquiHALLHEROULT_Add_AlF3.DAT

- **Example #6: Adding reactants to the electrolyte (AlF_3)**

1.0 ton of **Bath**
(**stream** @ 960ºC)

$AlF_{3(s)}$ (@ 50ºC)



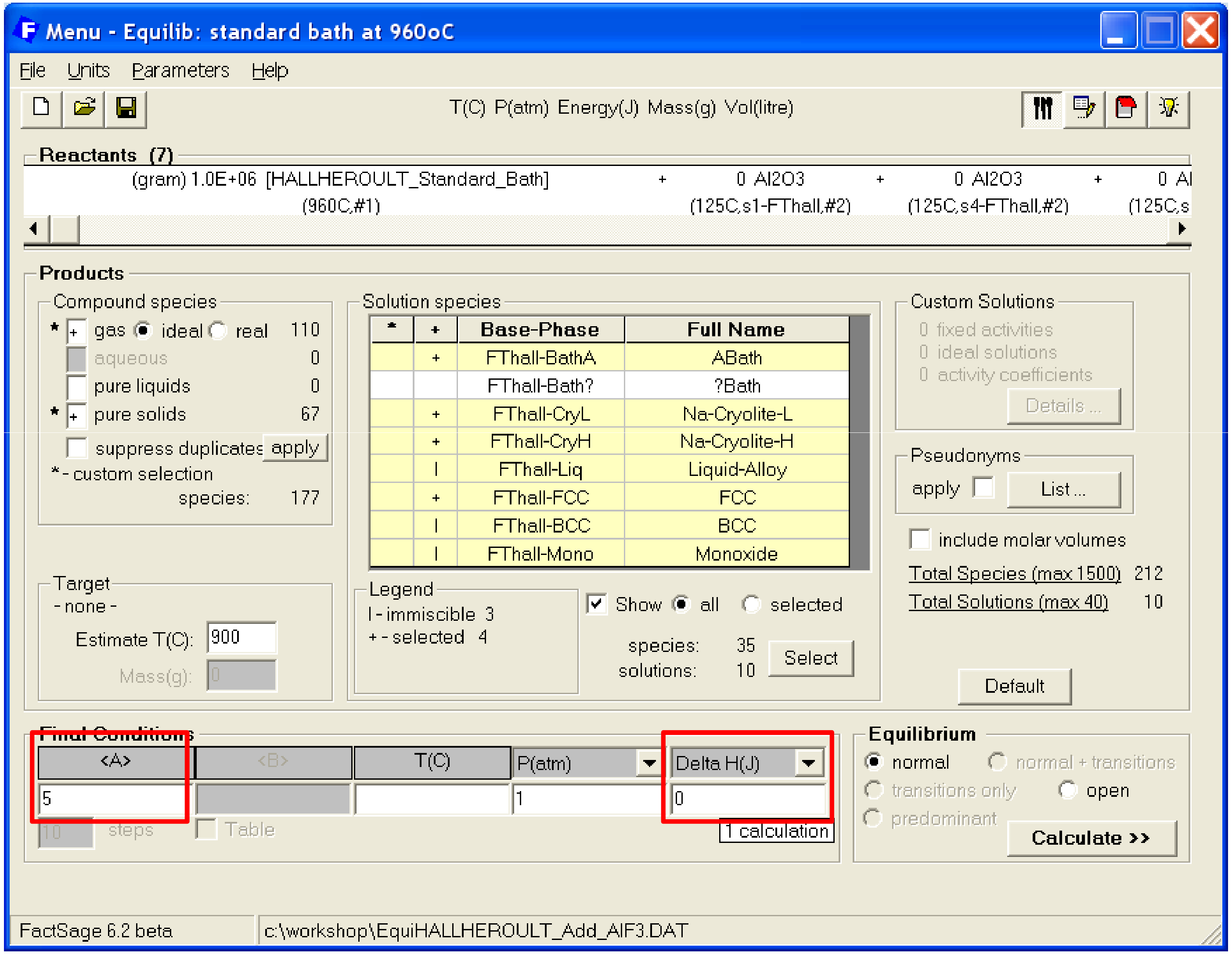
- **Example #6: Adding reactants to the electrolyte (AlF_3)**

1.0 ton of **Bath**
(**stream** @ 960ºC)

+ 5 kg $AlF_{3(s)}$ (@ 50ºC)

Adiabatic Addition

Q = ΔΔH = 0



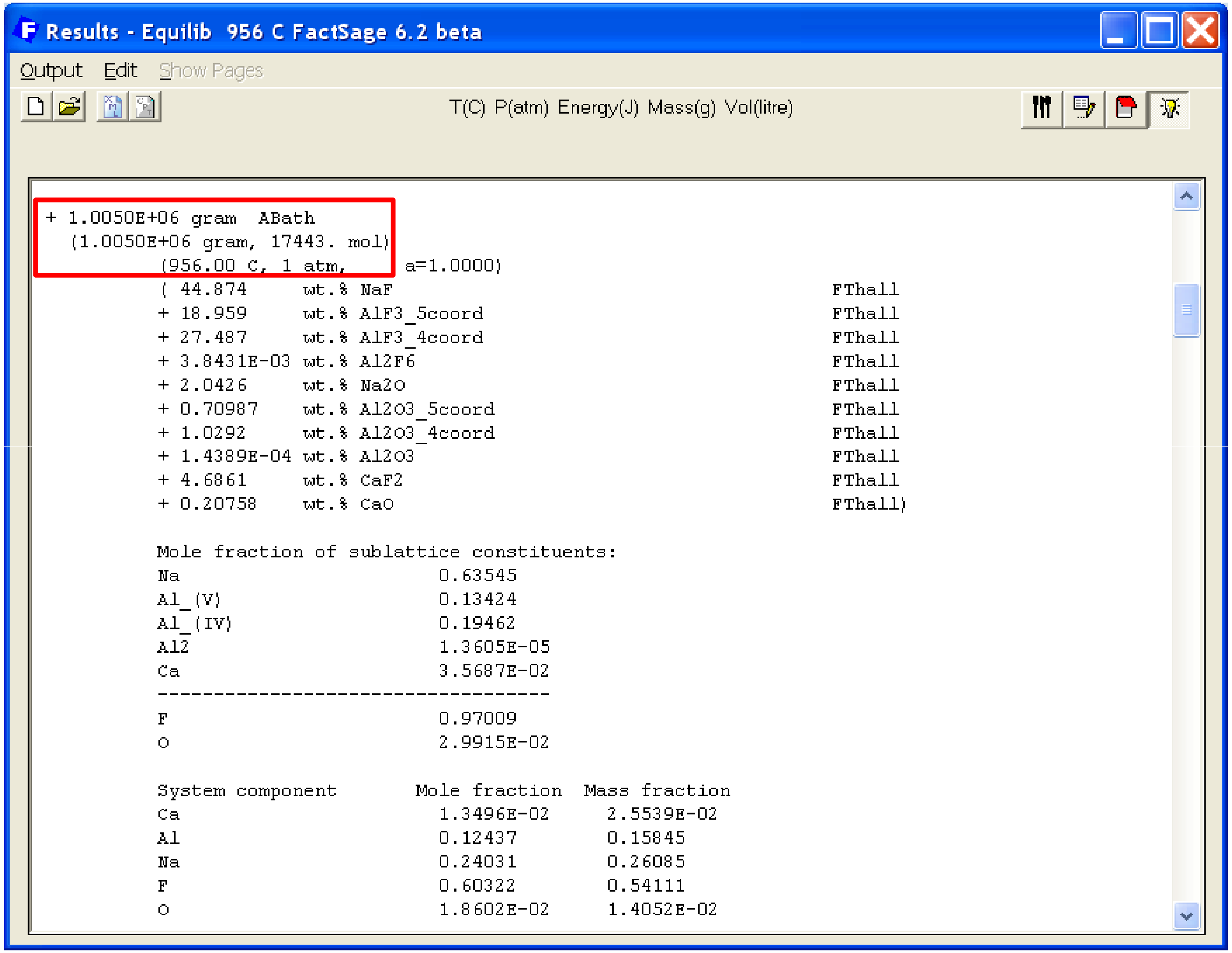
- **Example #6: Adding reactants to the electrolyte (AlF_3)**

1.0 ton of **Bath**
(**stream** @ 960ºC)

+ 5 kg $AlF_{3(s)}$ (@ 50ºC)

T = 956.00ºC

1005.0 kg Bath



• Example #7: Carbide formation in the cathode blocks

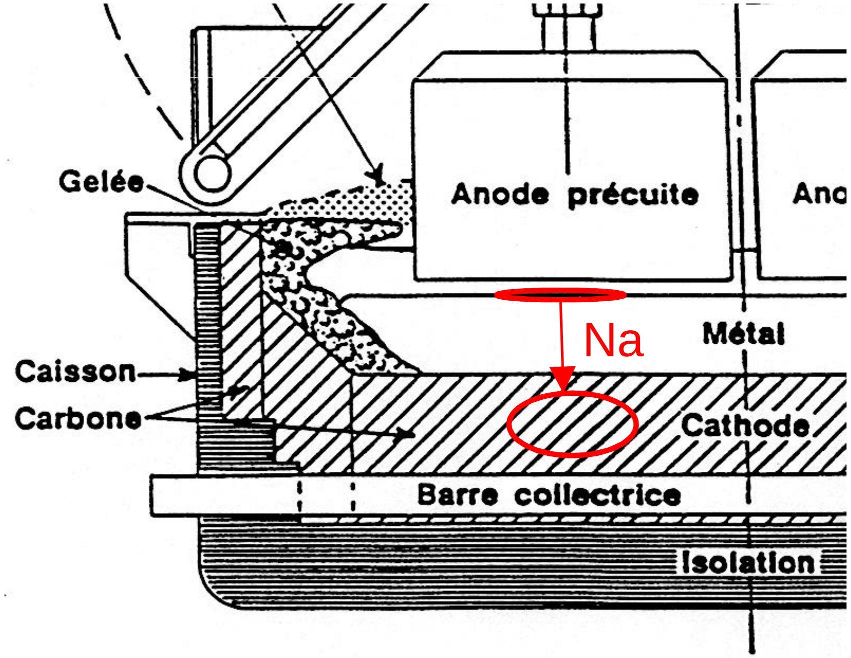
The **lifetime** of the cell is very dependent on the cathode block (graphite) lifetime.

The cathode blocks can be degraded by mechanical erosion, but also by chemical reactions with the penetrating **sodium vapors** and **liquid electrolyte**.

Sodium is generated at the metal bath interface with

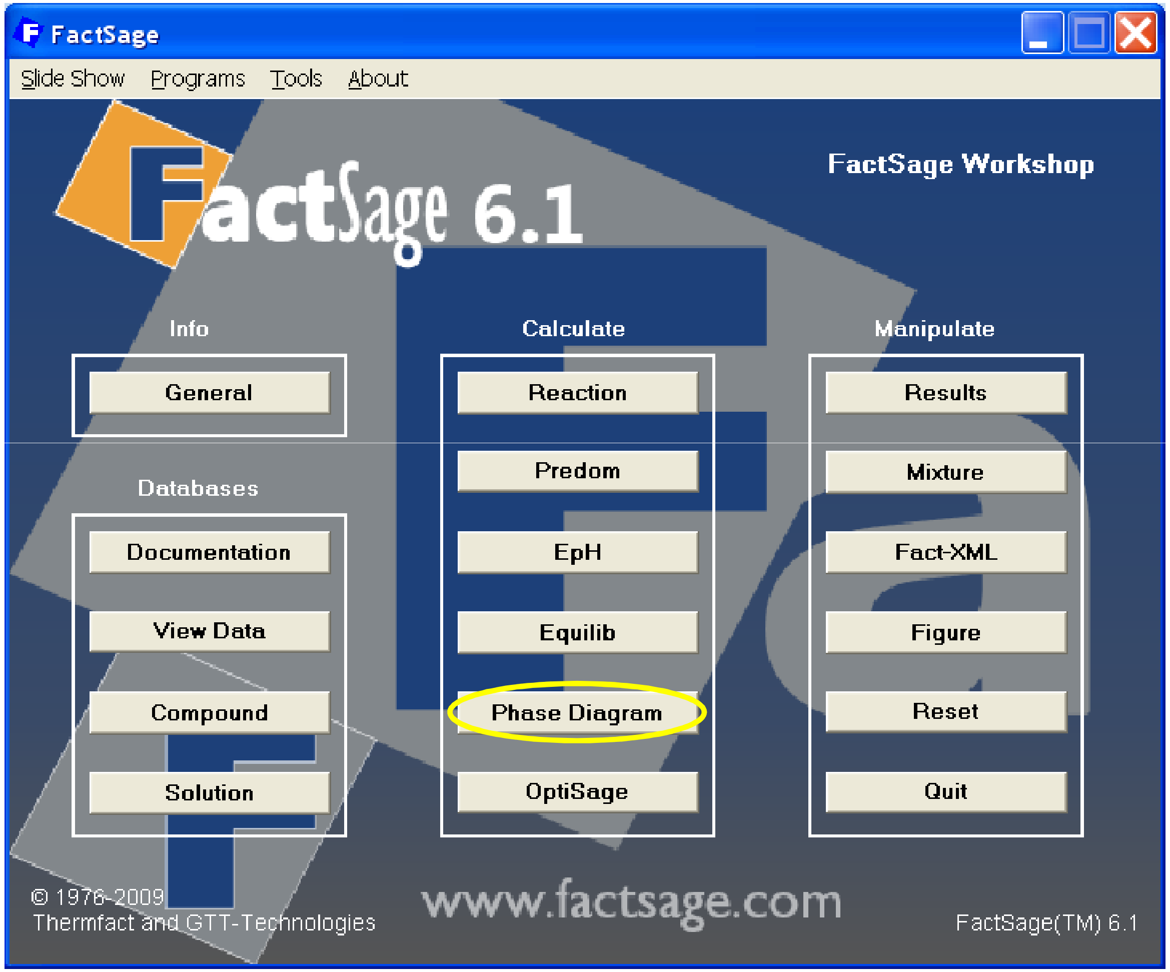
$$3\ NaF + Al \leftrightarrow AlF_3 + 3\ \underline{Na}$$

Residual N_2 and CO can be present in the carbon pores init.



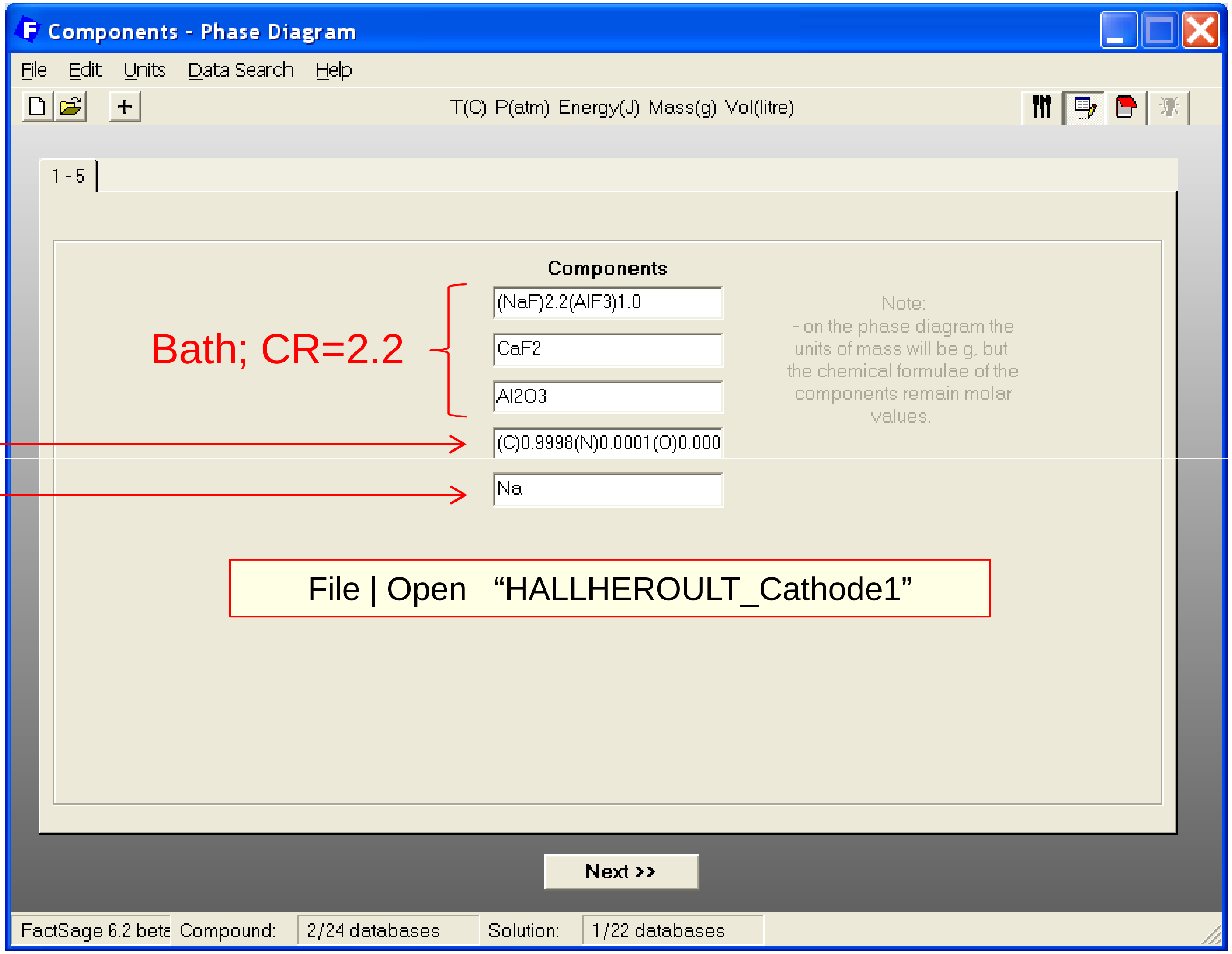
FactSage™ CRCT Montreal 2010

- **Example #7: Carbide formation in the cathode blocks**



- **Example #7: Carbide formation in the cathode blocks**

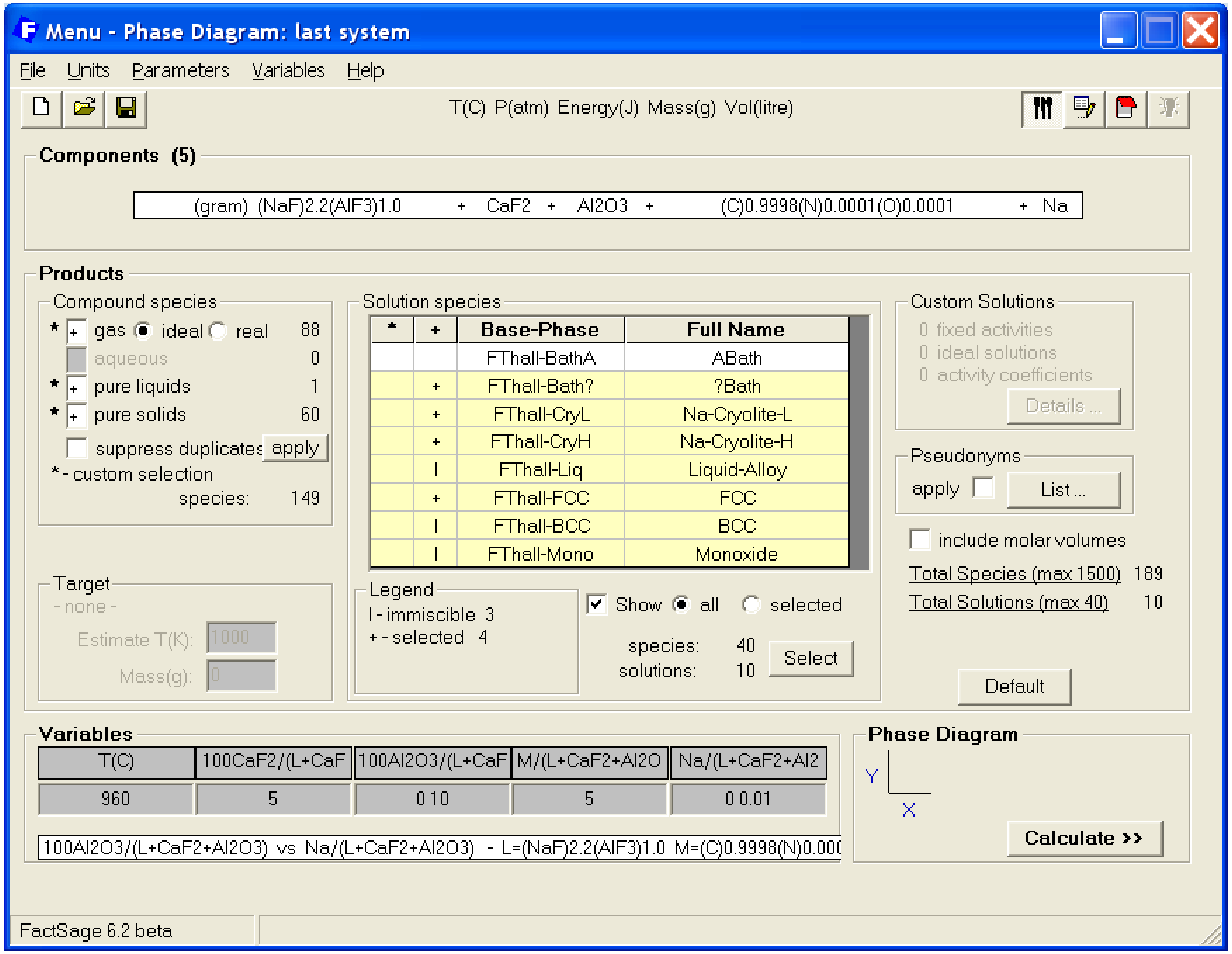
C with small amounts of N & O



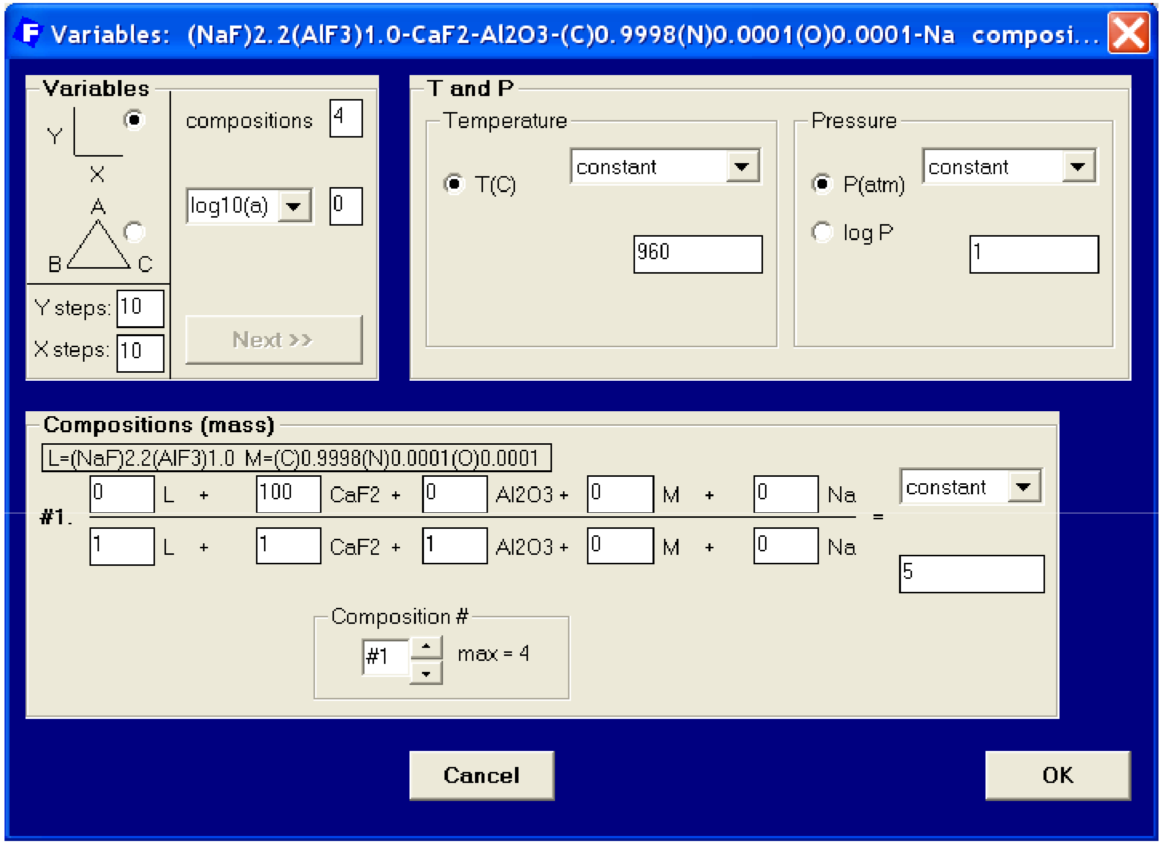
Penetrating Na

Example #7: Carbide formation in the cathode blocks

- FACT53
  - Gas species
  - $NaCN_{(liq.)}$
  - C
- Fthall
  - Bath
  - Metal



• Example #7: Carbide formation in the cathode blocks



- X-axis

$$\frac{1\ Na}{1\,(NaF)_{2.2}(AlF_3)_{1.0} + 1\ CaF_2 + 1\ Al_2O_3} = 0..0.01$$

0–0.01 kg Na / kg of bath

- Y-axis

$$\frac{100\ Al_2O_3}{1\,(NaF)_{2.2}(AlF_3)_{1.0} + 1\ CaF_2 + 1\ Al_2O_3} = 0..10$$

0 – 10% Al_2O_3 in the bath

- Constants
  - T = 960°C & P = 1 atm

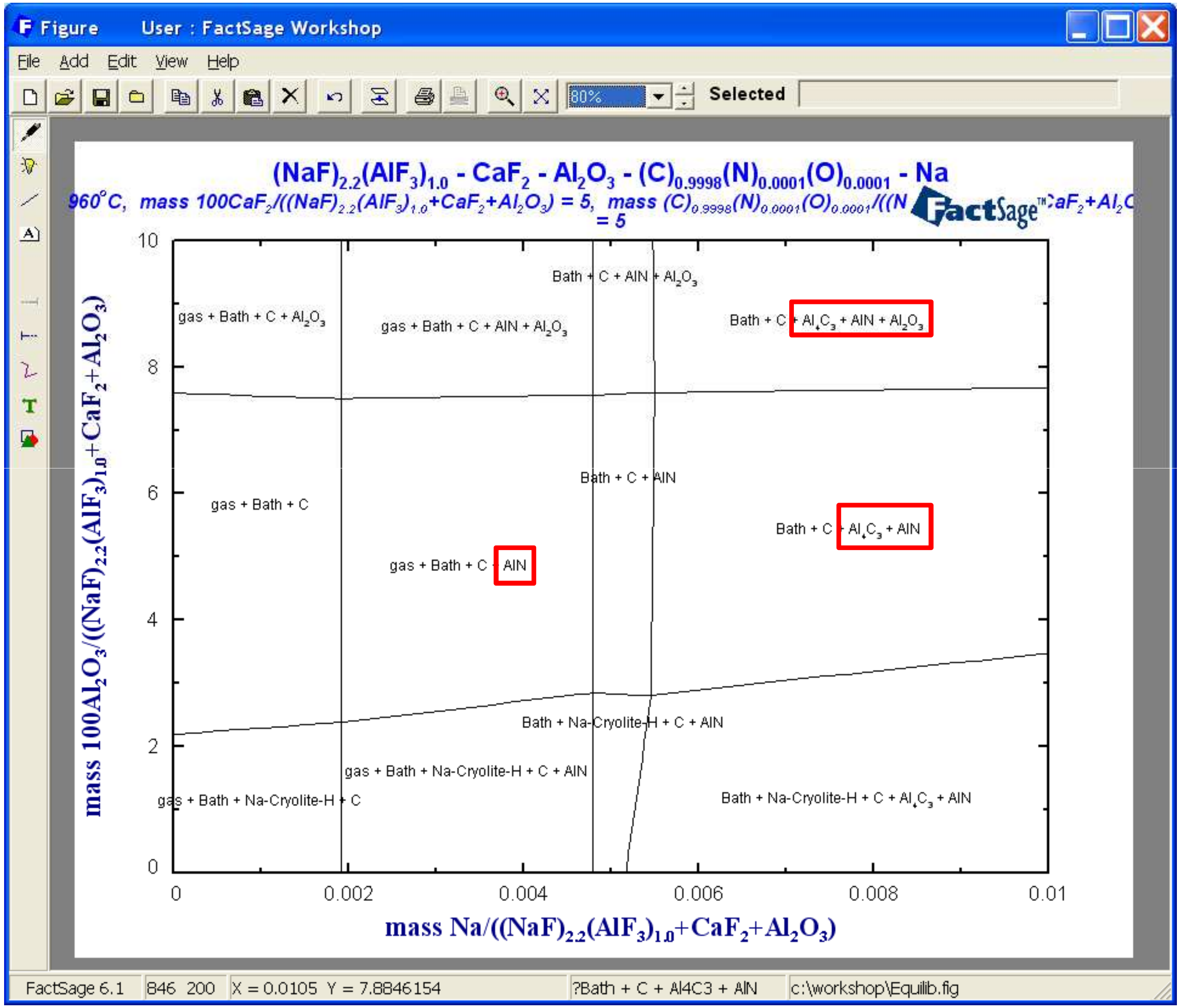
$$\frac{100\ CaF_2}{1\,(NaF)_{2.2}(AlF_3)_{1.0} + 1\ CaF_2 + 1\ Al_2O_3} = 5$$

← CaF_2 is 5% of the mass of the bath

$$\frac{1\ C}{1\,(NaF)_{2.2}(AlF_3)_{1.0} + 1\ CaF_2 + 1\ Al_2O_3} = 5$$

← The carbon to bath mass ratio is fixed at 5.0 (arbitrary)

- **Example #7: Carbide formation in the cathode blocks**



- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

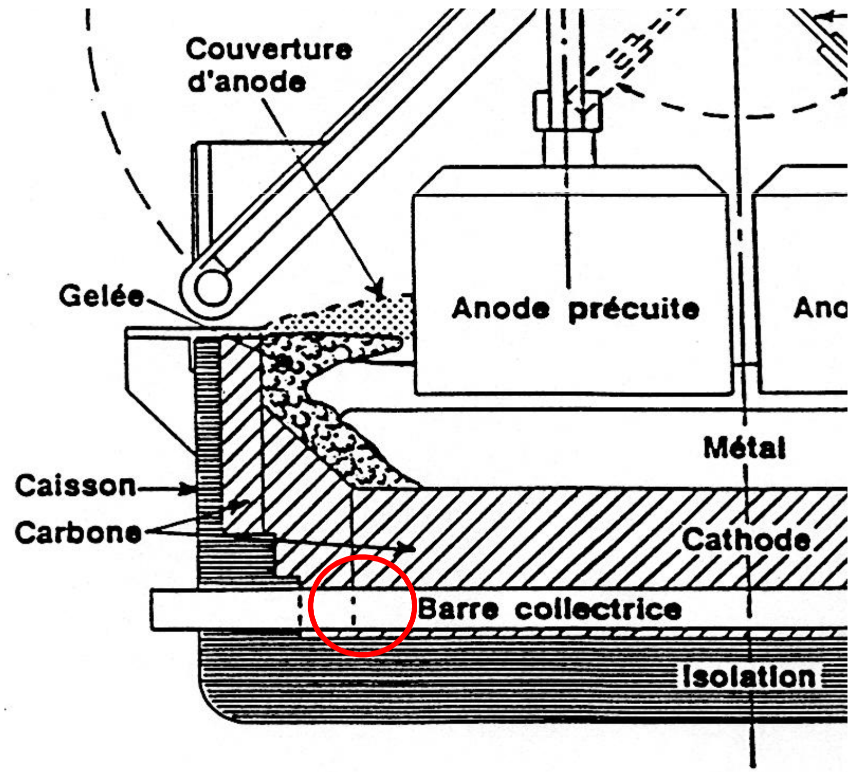
The current collecting bar (steel) entrapped inside the cathode block (C-graphite);

a SiO_2/Al_2O_3 layer is beneath it;

Na(vapors) percolated through the Cathode block from the metal pad;

Unwanted reaction products can increase the electrical resistivity → $$

T ≈ 900-960^{o}C



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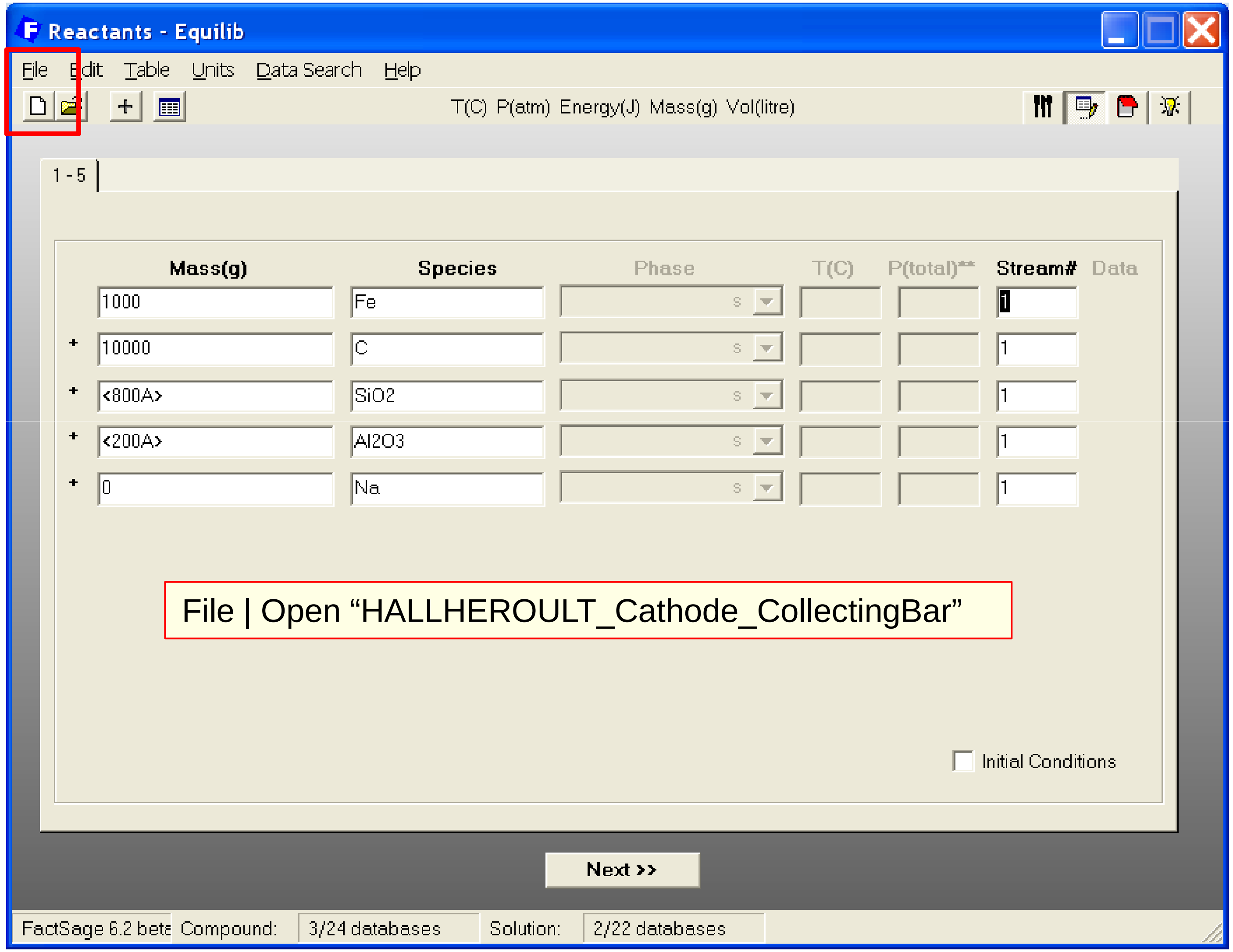
- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

- FACT53
  - Gas species
- FToxid
  - Refractory Mat.
- FSstel
  - Steel



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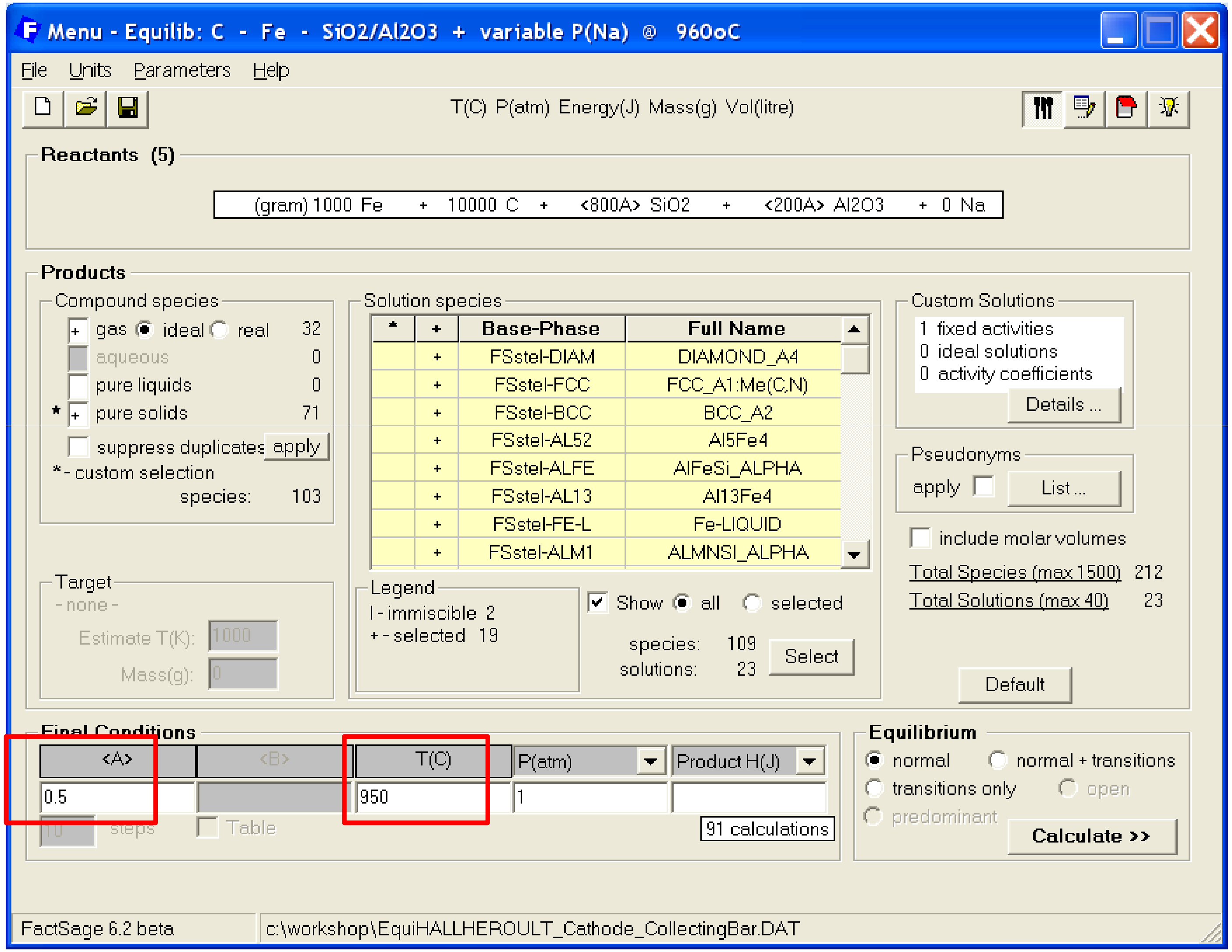
Hall-Heroult Process

- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**



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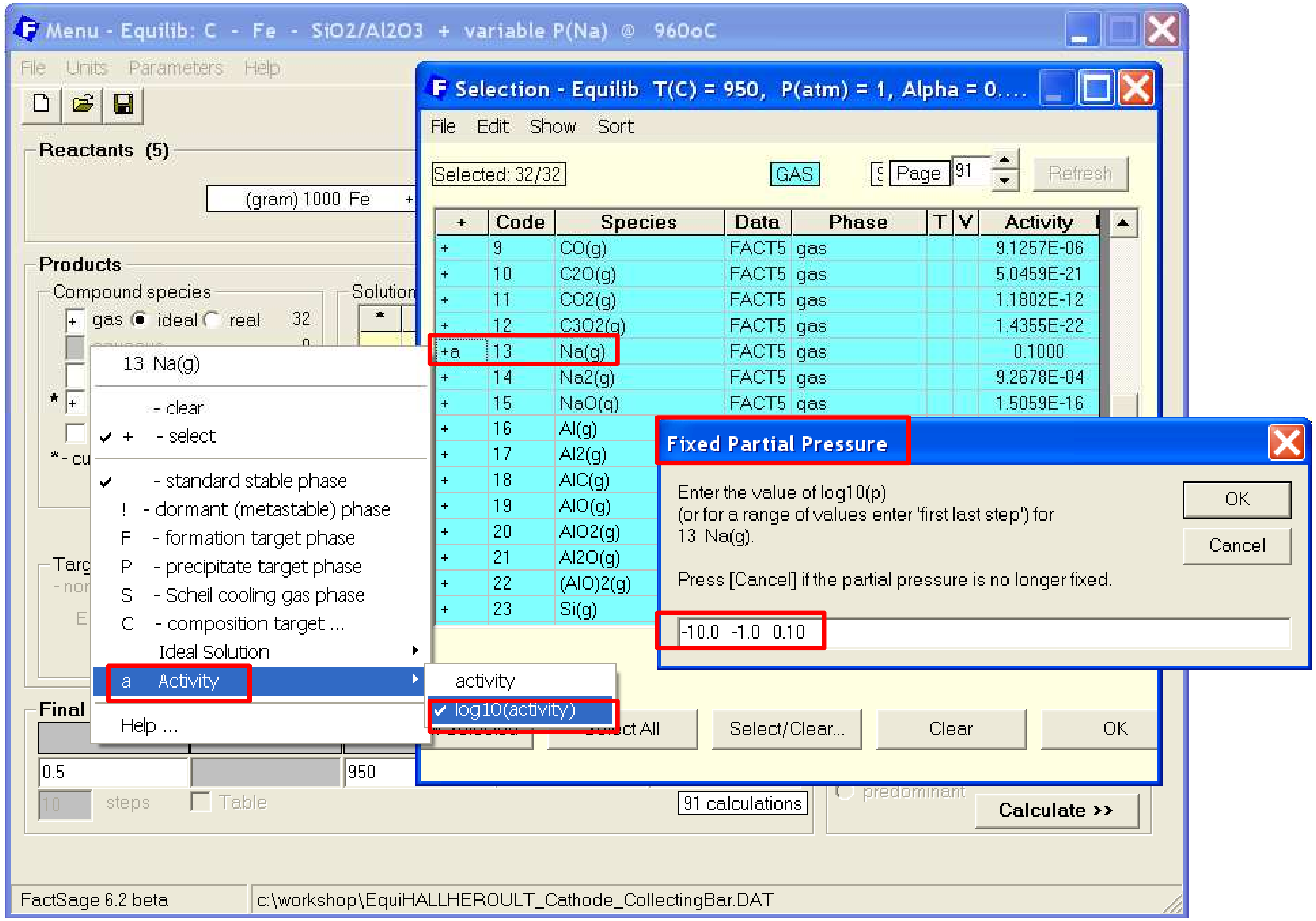
- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

P_{Na} is varied from 10^{-10} atm to 10^{-1} atm



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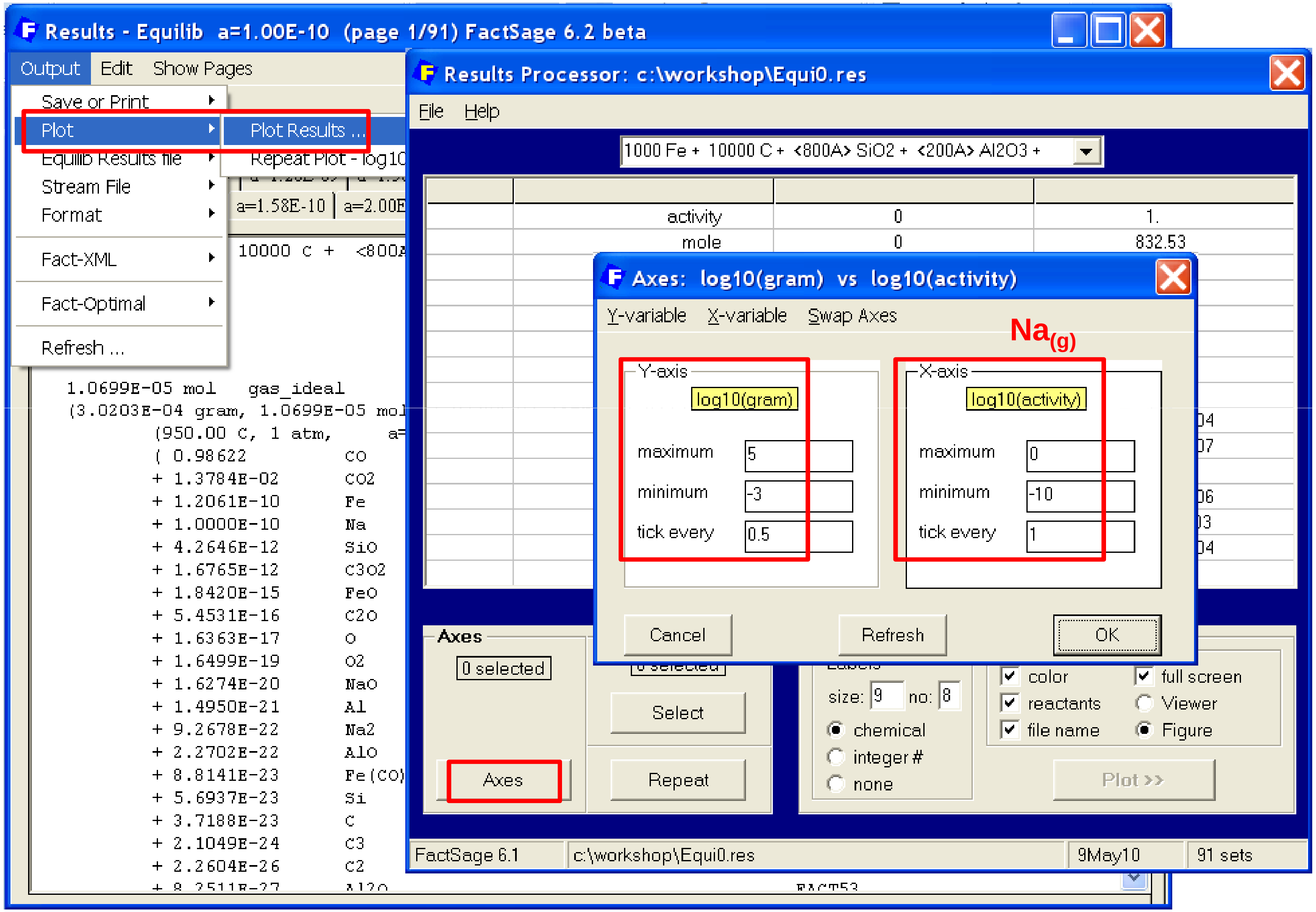
- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

Extract & Plot Results



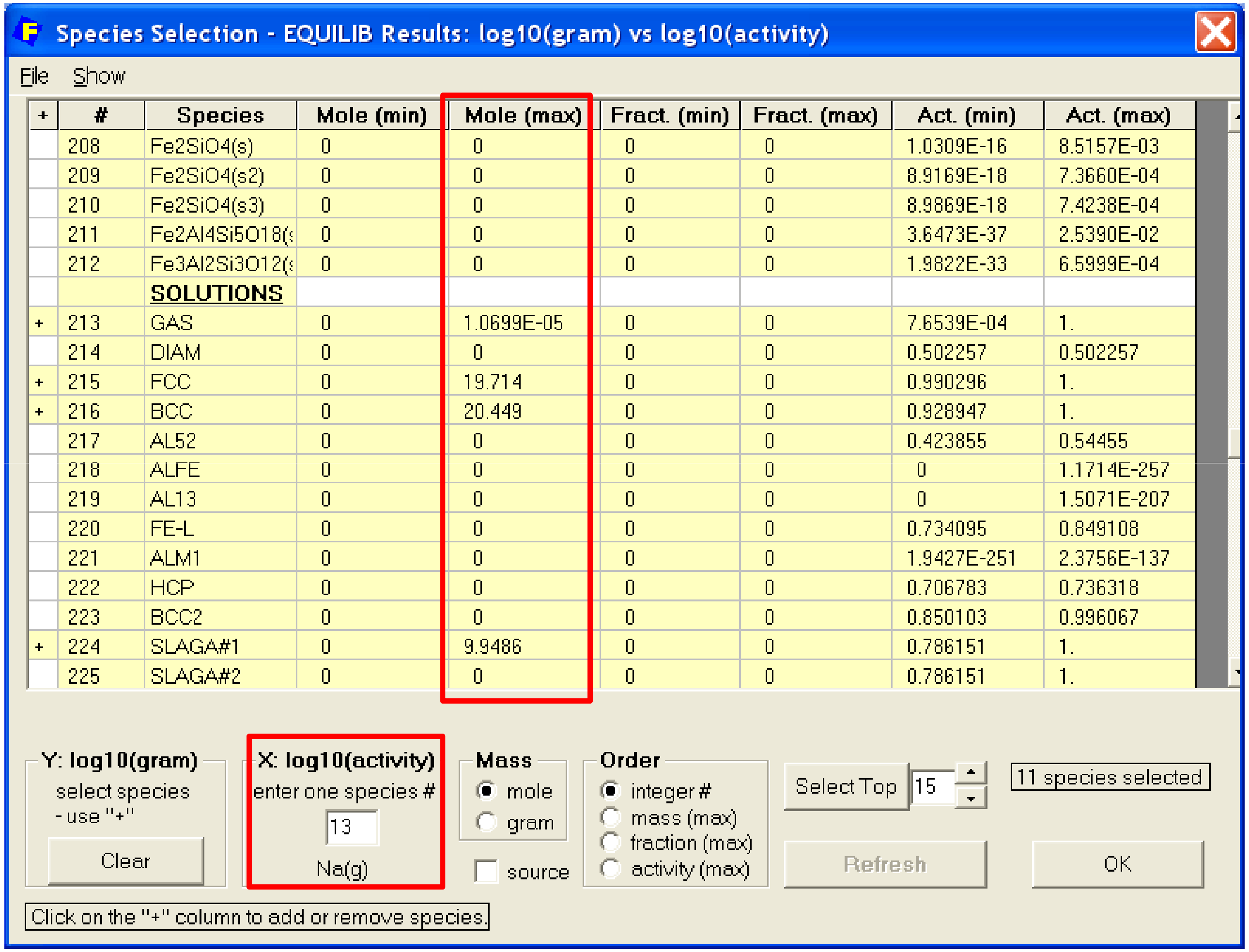
- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

X-axis : $\log_{10}(P_{Na})$

$Na_{(g)}$ is species #13

Y-axis : $\log_{10}$(grams)

Select all species with "Mole (max)" > 0



+	#	Species	Mole (min)	Mole (max)	Fract. (min)	Fract. (max)	Act. (min)	Act. (max)
	208	Fe2SiO4(s)	0	0	0	0	1.0309E-16	8.5157E-03
	209	Fe2SiO4(s2)	0	0	0	0	8.9169E-18	7.3660E-04
	210	Fe2SiO4(s3)	0	0	0	0	8.9869E-18	7.4238E-04
	211	Fe2Al4Si5O18(s	0	0	0	0	3.6473E-37	2.5390E-02
	212	Fe3Al2Si3O12(s	0	0	0	0	1.9822E-33	6.5999E-04
		SOLUTIONS						
+	213	GAS	0	1.0699E-05	0	0	7.6539E-04	1.
	214	DIAM	0	0	0	0	0.502257	0.502257
+	215	FCC	0	19.714	0	0	0.990296	1.
+	216	BCC	0	20.449	0	0	0.928947	1.
	217	AL52	0	0	0	0	0.423855	0.54455
	218	ALFE	0	0	0	0	0	1.1714E-257
	219	AL13	0	0	0	0	0	1.5071E-207
	220	FE-L	0	0	0	0	0.734095	0.849108
	221	ALM1	0	0	0	0	1.9427E-251	2.3756E-137
	222	HCP	0	0	0	0	0.706783	0.736318
	223	BCC2	0	0	0	0	0.850103	0.996067
+	224	SLAGA#1	0	9.9486	0	0	0.786151	1.
	225	SLAGA#2	0	0	0	0	0.786151	1.

- **Example #8: Cathode / Collecting Bar / Refractory / $Na_{(g)}$**

At low $\log_{10}(P_{Na})$

C
+ Austenite(fcc)
+ Refractory (SiO_2 + mullite)

At intermediate $\log_{10}(P_{Na})$

C
+ Austenite(fcc)
+ Albite ($NaAlSi_3O_8$) + SiO_2

<u>Higher</u>:
+ Slag
+ Nepheline ($NaAlSiO_4$)

At high $\log_{10}(P_{Na})$

C
+ Ferrite(bcc)
+ Slag (Na_2SiO_3 + $NaAlO_2$-$NaAlSiO_{4(s.s.)}$)