Development of a Lump Parameter+ Model

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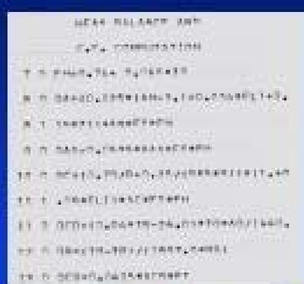
Plan of the Presentation

- Introduction
- Base Case Data
- Model Development
  - Cell internal heat parameters setup
  - Cell heat loss parameters setup
  - Selection of the "Target" variable
  - Convergence of the steady state
- Conclusions

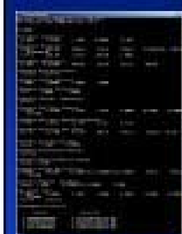
Introduction

The lump parameters+ model concept dates from the very beginning of the computer age. More precisely from the pioneer work of Warren Haupin in the late 1950's.

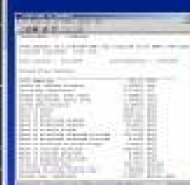
A lump parameters+ model, can be used as a standalone modeling tool to carry out a complete retrofit study without significant loss of accuracy in predicting operational results



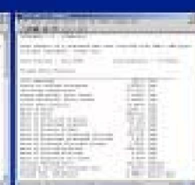
The 3 Implementations of the Lump Parameter+ Model



DOS/MARC



Steady/MARC



Dyna/MARC

Dyna/MARC Lump Parameters+ Model

Dyna/MARC is composed of three different models.

The first is the Process model that solves the heat and mass balance in the cell. It also takes into account the evolution of the ACD (anode to cathode distance) and the line amperage fluctuation.

The second model is the Controller model. This reproduces the plant controller response based on all the programmed algorithms taking into account the current cell state.

Finally the Operator model allows the software to simulate the actions undertaken by the operator on his schedule or when the controller requires his intervention.

Steady/MARC and DOS/MARC are only composed of the Process model which is all that is required to perform cell lining T/E retrofit studies

Base Case Data

Amperage	300 kA
No. of anodes	32
Anode size	1.6 m X 0.8 m
No. of anode studs	3 per anode
Anode stud diameter	18 cm
Anode cover thickness	16 cm
No. of cathode blocks	18
Cathode block length	3.47 m
Type of cathode block	HC5
Type of side block	HC5
Side block thickness	15 cm +
ASD	35 cm
Inside potshell size	14.0m X 4.35m

ACD	5 cm
Excess AlF_3	11.0 %
Anode drop	304 mV
Cathode drop	287 mV
Anode panel heat loss	231 kW
Cathode bottom heat loss	163 kW
Operating temperature	975.5 °C
Liquidus superheat	7.5 °C
Bath ledge thickness	7.0 cm
Metal ledge thickness	2.2 cm
Current efficiency	94.0 %
Internal heat	628 kW
Energy consumption	13.75

From drawings, operation data, thermal bits and validated 3D thermo-electric model results

Steady/MARC Model Development

Steady/MARC loads by default a "Demo" model,
we want to start modifying that "Demo" model to our base case model

Steady/MARC Model Development

This panel is simply to give the model/project a name
and a description for future reference

DOS/MARC Model Development

DOS/MARC is the DOS batch mode equivalent of Steady/MARC, the user define the model parameters in a file called input.dat instead of using a graphic user interface.

Yet, some features of Steady/MARC have no equivalent in DOS/MARC the project description entry is one of them.

Steady/MARC Model Development

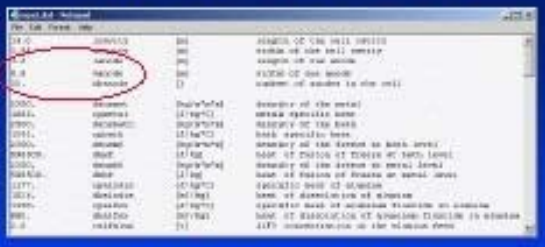
The following group of 3 panels are used to enter parameters related
to the evaluation of the cell internal heat

Steady/MARC Model Development

Equations that compute the
bath current density

Because the "Demo" model is very similar to our base case model,
there are no need to modify the "Bath Current Density" panel

DOS/MARC Model Development



In DOS/MARC, the anode dimensions are defined here:

Steady/MARC Model Development

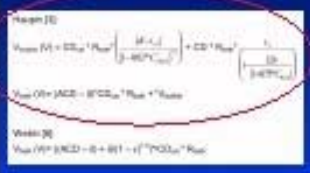
Equation that compute the bath resistivity

In the "Bath & Electrolysis Voltage" panel, it is recommended to keep the default Wang bath ration equation to compute the bath resistivity

DOS/MARC Model Development

In DOS/MARC, the bath resistivity mode is selected here.

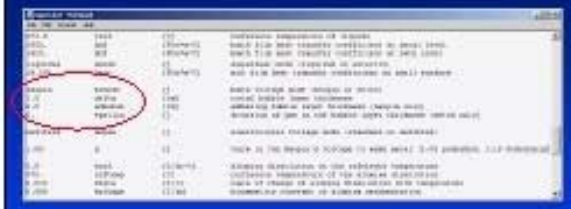
Steady/MARC Model Development



Equations that compute the bath voltage

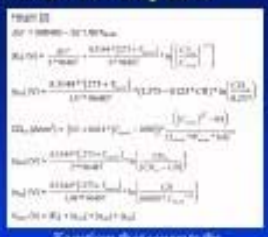
In the "Bath & Electrolysis Voltage" panel, it is recommended to select the Hoopis bath voltage equation and use 1.5 cm for the bubble thickness

DOS/MARC Model Development



In DOS/MARC, the bath voltage mode is selected here.

Steady/MARC Model Development



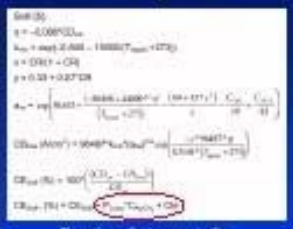
Equations that compute the electrolysis voltage

In the "Bath & Electrolysis Voltage" panel, it is recommended to select the modified Hoopis electrolysis voltage

DOS/MARC Model Development

In DOS/MARC, the electrolysis voltage mode is selected here.

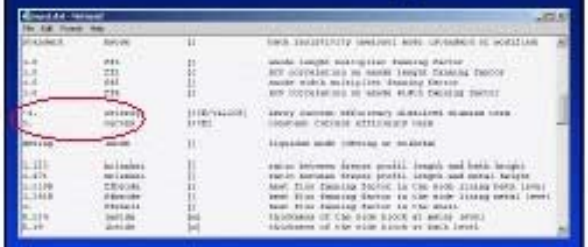
Steady/MARC Model Development



Equations that compute the current efficiency (Solli)

In the "Ohmic Voltages& CE" panel, it is recommended to keep the Solli+ CE model with -1 for the alumina slope and 3 as constant

DOS/MARC Model Development



In DOS/MARC, only the Solli+ current efficiency mode is available and the 2 extra parameters are dialmed here:

Steady/MARC Model Development

Advanced coupling equations

In the "Ohmic Voltages & CE" panel, it is recommended to deactivate the advanced coupling options

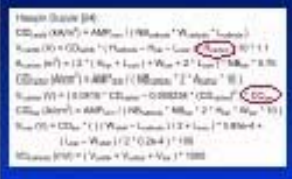
DOS/MARC Model Development

Advanced coupling mode is not available in DOS/MARC

Steady/MARC Model Development

Instead of fixing the cathode drop value in the "Ohmic Voltages & CE" panel, it is recommended to activate the new cathode drop sub-model

Steady/MARC Model Development



Equations that compute the cathode drop

In the "Advance Cathode Drop" panel, again because the "Dorin" model is very similar to our base case model, only the cathode resistivity and the calibration coefficient need to be adjusted

DOS/MARC Model Development

Cathode drop sub-model is not available in DOS/MARC

Steady/MARC Model Development

Instead of fixing the anode drop value in the "Ohmic Voltages & CE" panel, it is recommended to activate the new anode drop sub-model.

Steady/MARC Model Development

Equations that compute the anode drop

In the "Advance Anode Drop" panel, again because the "Demo" model is very similar to our base case model, only the reference voltage from top of avail to anode beam need to be adjusted

DOS/MARC Model Development

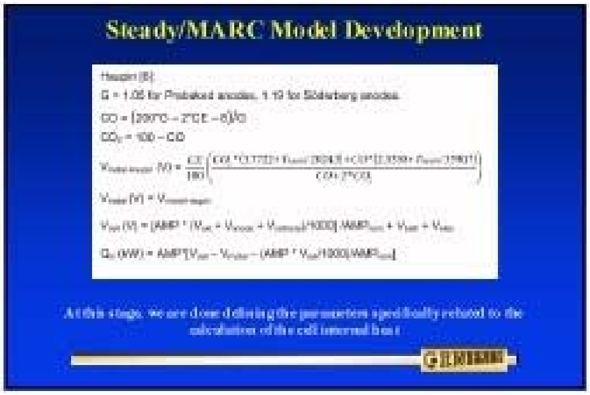
Anode drop sub-model is not available in DOS/MARC

Steady/MARC Model Development

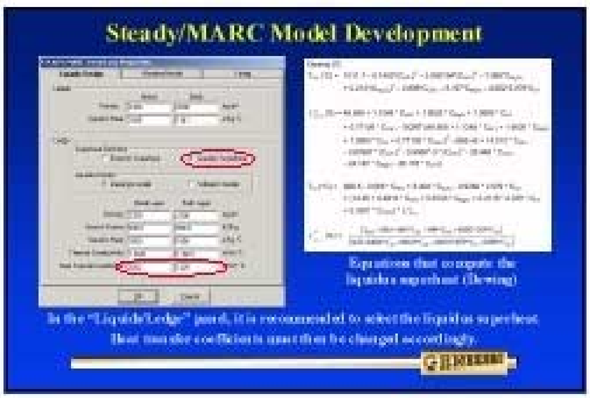
Once the cathode and the anode voltage drop sub-models have been activated, the computed values are displayed in the "Ohmic Voltages & CE" panel

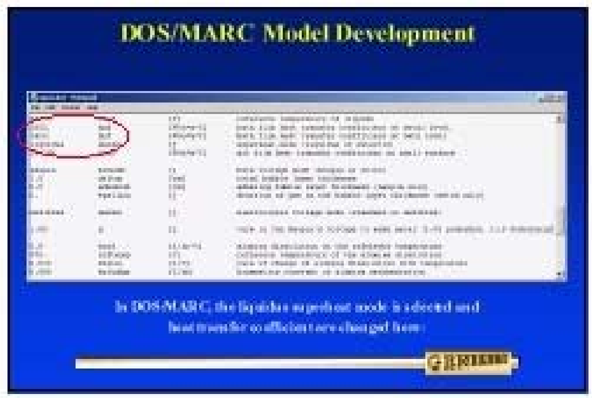
DOS/MARC Model Development

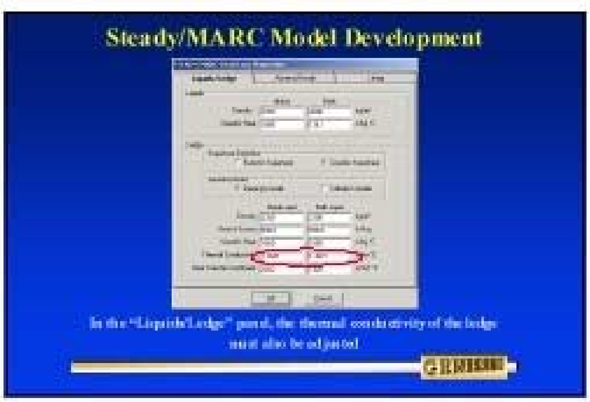
In DOS/MARC, the cathode and anode drop are defined here:


Steady/MARC Model Development
G = 1.05 for Prebaked anodes, 1.19 for Söderberg anodes
CO₂ = 100 – CO
At this stage, we are done defining the parameters specifically related to the calculation of the cell internal heat


Steady/MARC Model Development
The following group of 5 panels are used to enter parameters related to the evaluation of the cell heat loss


Steady/MARC Model Development
Equations that compute the liquidus superheat (Dewing)
In the "Liquids/Ledge" panel, it is recommended to select the liquidus superheat. Heat transfer coefficients must then be changed accordingly.


DOS/MARC Model Development
In DOS/MARC, the liquidus superheat mode is selected and heat transfer coefficients are changed here:


Steady/MARC Model Development
In the "Liquids/Ledge" panel, the thermal conductivity of the ledge must also be adjusted


DOS/Marc Model Development
In DOS/MARC, the equivalent properties are found here:

Steady/MARC Model Development

In the "Alumina/Anode" panel, there are nothing to be changed

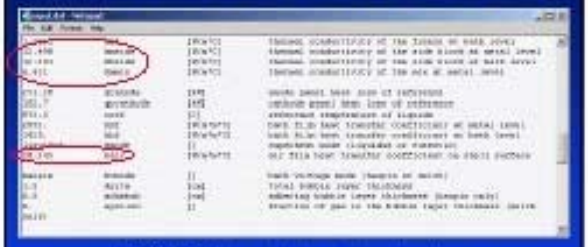
DOS/MARC Model Development

In DOS/MARC, the equivalent properties are found here:

Steady/MARC Model Development

In the "Lining" panel, all properties must be adjusted

DOS/MARC Model Development

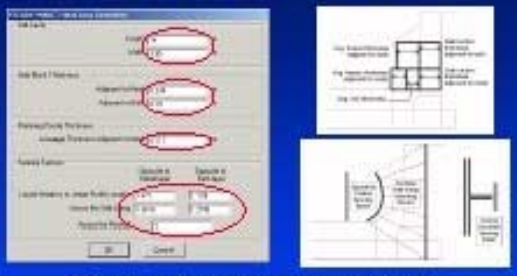


In DOS/MARC, the equivalent properties are found here:

Steady/MARC Model Development

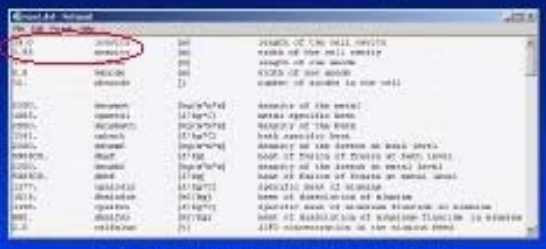
After the properties adjustment, the next step is adjusting the geometric parameters

Steady/MARC Model Development



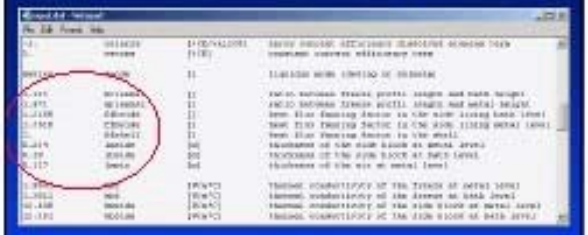
In the "Geometry" panel, all parameters must be adjusted

DOS/MARC Model Development



In DOS/MARC, the equivalent parameters are found here:

DOS/MARC Model Development



And here:

Steady/MARC Model Development

After the geometry adjustment, the next step is adjusting the heat flux parameters

Steady/MARC Model Development

In the "Heat Loss Data" panel, the cell reference operating temperature is adjusted,
it is also recommended to deactivate the advance coupling term

DOS/MARC Model Development

In DOS/MARC, the cell reference operating temperature is found here:
The advanced coupling term is not available

Steady/MARC Model Development

Instead of fixing the cathode bottom heat loss value in the "Heat Flux" panel,
it is recommended to activate the new cathode bottom heat loss sub-model

Steady/MARC Model Development

Equations that compute the cathode bottom heat loss

In the "Advance Cathode Heat Loss" panel, again because the "Demo" model is very similar to our base case model, only shell walls heat loss at pier level need to be adjusted

DOS/MARC Model Development

Cathode heat loss sub-model is not available in DOS/MARC

Steady/MARC Model Development

Instead of fixing the anode panel heat loss value in the "Heat Flux" panel, it is recommended to activate the new anode panel heat loss sub-model

Steady/MARC Model Development

Equations that compute the anode panel heat loss

In the "Advance Anode Panel Heat Loss" panel, again because the "Demo" model is very similar to our base case model, only a few parameters need to be adjusted

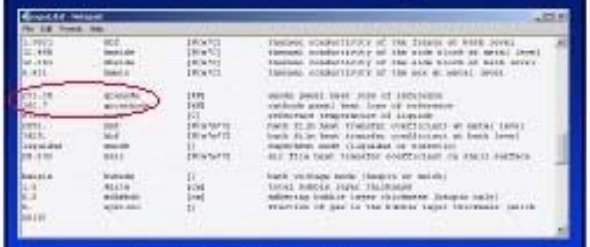
DOS/MARC Model Development

Anode panel heat loss sub-model is not available in DOS/MARC

Steady/MARC Model Development

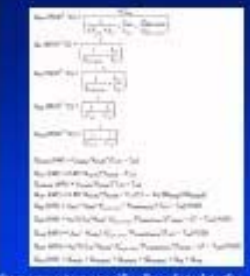
Once the cathode bottom and the anode panel heat loss sub-models have been activated, the computed values are displayed in the "Heat Flux" panel

DOS/MARC Model Development



In DOS/MARC, the cathode and anode drop are defined here:

Steady/MARC Model Development



At this stage, we are done defining the parameters specifically related to the calculation of the cell heat loss

Steady/MARC Model Development

The following group of 4 panels are used to enter parameters related to the evaluation of the cell different mass balances. We can skip them for now as the advanced coupling options are not active (no impact on heat balance).

Steady/MARC Model Development

The last panel in the Process drop down menu is used to enter parameters related to the evaluation of the ACD noise. We can also skip it for now as the advanced coupling options are not active (no impact on heat balance).

Steady/MARC Model Development

The final panel is the Steady State panel in the Run drop down menu.

Steady/MARC Model Development

Any parameters in that panel can be selected to be the "Target" variable to converge the steady state conditions. Often, it is very convenient to select the concentration of dissolved alumina in the bath as target variable.

DOS/MARC Model Development

In DOS/MARC, the "Target" variable is defined here:

Steady/MARC Model Development

By clicking the Run button, Steady/MARC converges the Target variable to the steady state conditions where:

Qin = Qout

DOS/MARC Model Development

DOS/MARC performs the same task when it is executed

DOS/MARC Model Development

DOS/MARC prints the results in the marc.lst file

Conclusions

- It is quite simple to develop a lump parameter+ model once you know the value of all the required input parameters.
- At least a thermal blitz must be carried on the cell in order to know the value of all those parameters.
- Many parameter values are best evaluated by using the results of validated 3D thermo-electric models.
- As demonstrated in the paper presented at the TMS 2003 conference, once available, a lump parameters+ model can be use stand alone to very rapidly carry out a preliminary retrofit study.
- In the "classic" retrofit study approach, DOS/MARC is used in tandem with a 3D cathode side slice model or a 3D half anode model.