THERMO-ELECTRIC DESIGN OF A 500 kA CELL

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Introduction

It is important to well understand the physic of the heat dissipation inside the lining of an aluminum reduction cell to be able to do the thermo-electric design of a new cell.

The key feature to take into consideration is the 2 zones heat loss mechanism [1,2]. In one zone, the driving force is the global thermal gradient between the cell operating temperature and the cell ambient temperature. While in the other zone, the driving force is the cell superheat!

These days, no one would attempt to design a cell without the support of mathematical modeling tools. The simplest possible model that is representative of the two zones heat dissipation mechanism of the cell is the lump parameters+ model [3,4]. That model is so simple, that you can get answer to “what if” design questions in a fraction of second. Nevertheless, as demonstrated in [5,6], the accuracy of the lump parameters+ model predictions are surprisingly accurate considering its simplicity.

As described in [7], the lump parameters+ model has been recently upgraded by adding to it four new sub-models that computed the anode panel heat loss, the cathode bottom heat loss, the anode drop and the cathode drop. With the addition of these new sub-models, the lump parameters+ model also called Dyna/Marc 1.7 cell simulator [8] can be use stand-alone to do per example the thermo-electric design of a 500 kA cell starting from an existing design at 300 kA. Figure 1 and 2 respectively present Dyna/Marc 1.7 “What if” panel and the results of a trend analysis.

From 300 to 400 kA

The initial steps going from 300 to 400 kA have already been presented twice so far. In reference [5,7], the step-by-step retrofit study of a 300 kA cell into a 350 kA cell is first presented. In total 9 changes were required to be able to push the amperage up to 350 kA, they are:

1) Decreasing the ACD from 5 to 4 cm
2) Increasing the anode length from 1.6 to 1.7 m
3) Increasing the excess AlF_3 from 10.9 to 13.5 %
4) Substituting the cathode block grade from HC3 to HC10
5) Increasing the cathode length from 3.47 to 3.67 m
6) Substituting the side block material from HC3 carbon to silicon carbide
7) Decreasing the side block thickness from 15 to 10 cm
8) Decreasing the anode cover thickness from 16 to 10 cm
9) Increasing the stud diameter from 18 to 19 cm

The retrofitted 350 kA cell design is then extended into a 400 kA cell by increasing the cell length by 1.7 m, going from 14.4 to 16.1 m, to be able to add four new anodes and two new cathode blocks. The summary of the results obtained is presented in table I.

From 400 to 500 kA

Now for the first time, a step-by-step study of the extension of this 400 kA cell into a 500 kA cell is presented. In total four changes were required to be able to push the amperage up to 500 kA, they are:

1) Increasing the cell length by 1.7 m, going from 16.1 to 17.8m, adding four new anodes and two new cathode blocks

2) Increasing the cell width by 0.5 m, going from 4.35 to 4.85 m in order to be able to increase the anode length by 0.25m going from 1.7 to 1.95 m

3) Increasing the number of studs per anode going from three 19 cm diameter studs to four 17.5 cm diameter ones

4) Increasing the number of cathode blocks from 22 to 24 by decreasing their width, effectively decreasing the current density in the collector bars.

The summary of the results obtained is presented in table II. Obviously, this is only one possible way to get there; the MHD stability study could dictate that other choices for the length to width ratio of the cell are preferable.

Conclusions

It was demonstrated that with enough experience and a good modeling tool, it is fairly simple to do the thermo-electric design of a 500 kA cell. Apart from its quite impressive size, there is really nothing special about the design because as far as the thermo-electric aspect of the cell design is concerned, there is no specific challenges preventing the design of even bigger cell.

References

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Figure 1: Dyna/Marc 1.7 “What if” panel

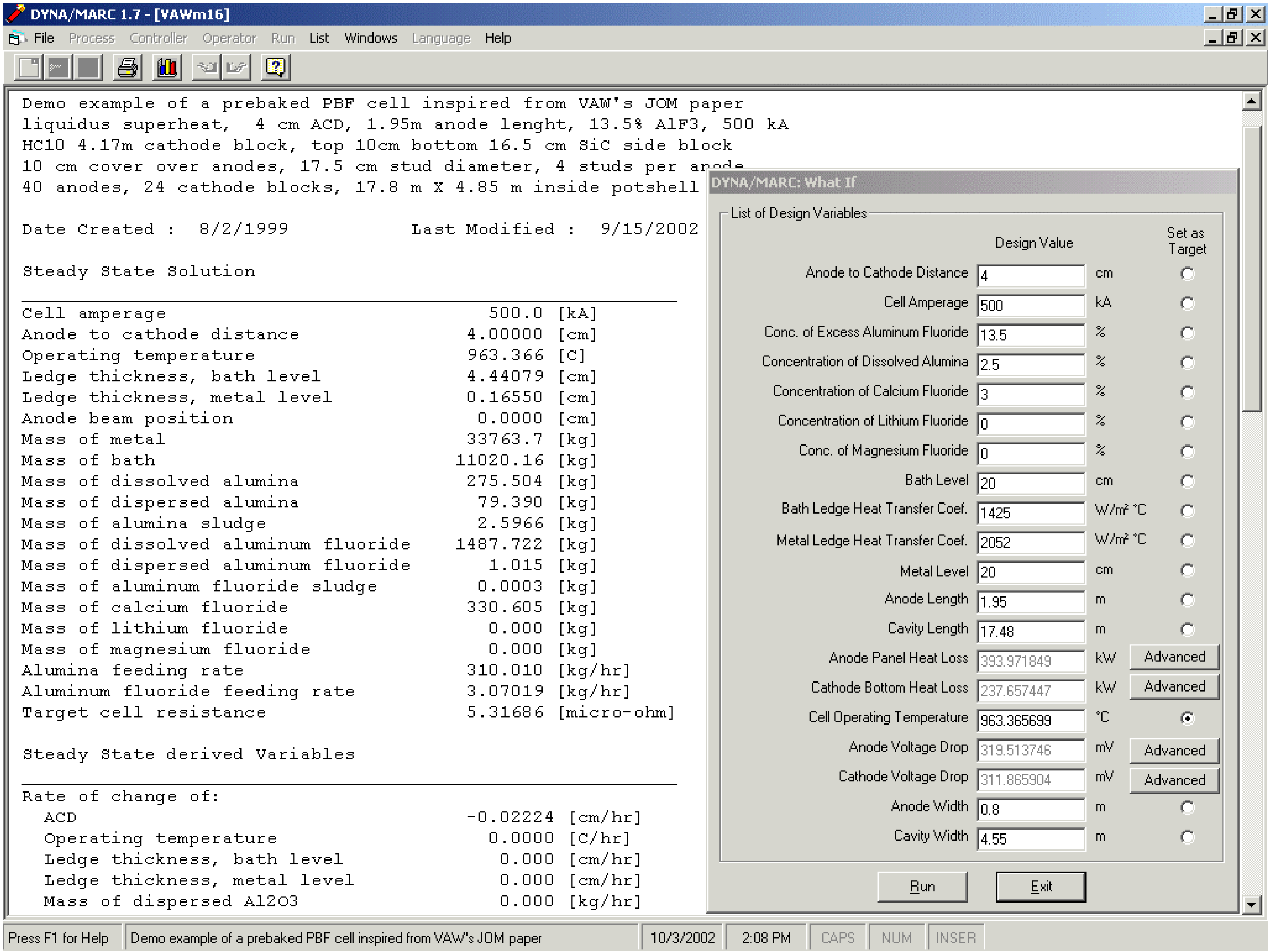

Figure 2: Dyna/Marc 1.7 Trend Analysis Results

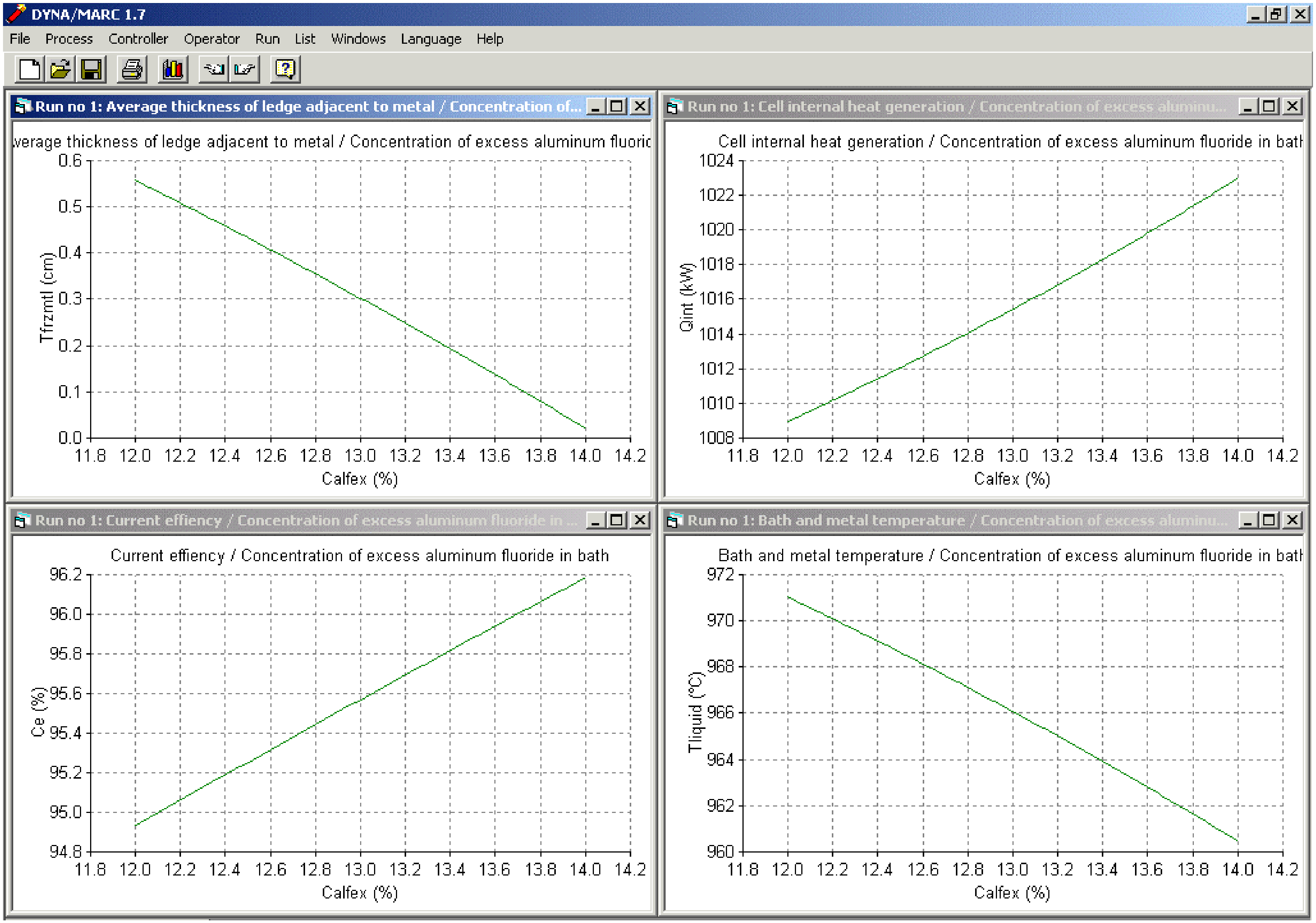

Table I : Going from 300 to 400 kA

	Base case	Step 1	Step 2	Step 3	Step 4-5	Step 6-7	Step 8	Step 9	Step 10
Modeling tool	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7
Amperage	300 kA	**322 kA**	**330 kA**	330 kA	330 kA	330 kA	**335 kA**	**350 kA**	**400 kA**
Nb. of anodes	32	32	32	32	32	32	32	32	**36**
Anode size	1.6 m X 0.8 m	1.6 m X 0.8 m	**1.7 m X 0.8 m**	1.7 m X 0.8 m	1.7 m X 0.8 m	1.7 m X 0.8 m	1.7 m X 0.8 m	1.7 m X 0.8 m	1.7 m X 0.8 m
Nb. of anode studs	3 per anode	3 per anode	3 per anode	3 per anode	3 per anode	3 per anode	3 per anode	3 per anode	3 per anode
Anode stud diameter	18 cm	18 cm	18 cm	18 cm	18 cm	18 cm	18 cm	**19 cm**	19 cm
Anode cover thickness	16 cm	16 cm	16 cm	16 cm	16 cm	16 cm	**10 cm**	10 cm	10 cm
Nb. of cathode blocks	18	18	18	18	18	18	18	18	**20**
Cathode block length	3.47 m	3.47 m	3.47 m	3.47 m	**3.67 m**	3.67 m	3.67 m	3.67 m	3.67 m
Type of cathode block	HC3	HC3	HC3	HC3	**HC10**	HC10	HC10	HC10	HC10
Type of side block	HC3	HC3	HC3	HC3	HC3	**SiC**	SiC	SiC	SiC
Side block thickness	15 cm +	15 cm +	15 cm +	15 cm +	15 cm +	**10 cm +**	10 cm +	10 cm +	10 cm +
ASD	35 cm	35 cm	**25 cm**	25 cm	25 cm	**30 cm**	30 cm	30 cm	30 cm
Inside potshell size	14.4 X 4.35 m	14.4 X 4.35 m	14.4 X 4.35 m	14.4 X 4.35 m	14.4 X 4.35 m	14.4 X 4.35 m	14.4 X 4.35 m	14.4 X 4.35 m	**16.1 X 4.35 m**
ACD	5 cm	**4 cm**	4 cm	4 cm	4 cm	4 cm	4 cm	4 cm	4 cm
Excess AlF_3	10.9 %	10.9 %	10.9 %	**13.5 %**	13.5 %	13.5 %	13.5 %	13.5 %	13.5 %
Anode drop	306 mV	**325 mV**	**328 mV**	328 mV	328 mV	328 mV	**331 mV**	**330 mV**	335 mV
Cathode drop	290 mV	**311 mV**	**319 mV**	319 mV	**277 mV**	277 mV	**281 mV**	**293 mV**	301 mV
Anode panel heat loss	239 kW	**244 kW**	**247 kW**	247 kW	247 kW	**250 kW**	**275 kW**	**284 kW**	311 kW
Cathode bottom heat loss	166 kW	**167 kW**	**168 kW**	168 kW	**171 kW**	171 kW	**172 kW**	**173 kW**	193 kW
Operating temperature	973.3 °C	973.3 °C	973.3 °C	**960.8 °C**	**960.3 °C**	**960.2 °C**	**960.0 °C**	**961.5 °C**	**962.7 °C**
Liquidus superheat	6.8 °C	6.8 °C	6.8 °C	**7.2 °C**	**6.6 °C**	**6.5 °C**	**6.3 °C**	**7.8 °C**	**9.0 °C**
Bath ledge thickness	7.61 cm	**7.75 cm**	**7.71 cm**	**6.85 cm**	**7.81 cm**	**9.02 cm**	**9.34 cm**	**6.69 cm**	**5.11 cm**
Metal ledge thickness	2.79 cm	**2.93 cm**	**2.88 cm**	**2.03 cm**	**2.98 cm**	**4.75 cm**	**5.07 cm**	**2.42 cm**	**0.83 cm**
Current efficiency	94.0 %	**94.4 %**	**94.2 %**	**95.9 %**	**95.9 %**	95.9 %	**96.0 %**	96.0 %	96.0 %
Internal heat	628 kW	**633 kW**	**637 kW**	**647 kW**	**633 kW**	633 kW	**652 kW**	**712 kW**	**825 kW**
Energy consumption	13.75 kWh/kg	**13.32 kWh/kg**	**13.20 kWh/kg**	**13.14 kWh/kg**	**13.01 kWh/kg**	**13.00 kWh/kg**	**13.10 kWh/kg**	**13.37 kWh/kg**	**13.49 kWh/kg**

Table II : Going from 400 to 500 kA

	Base case	Step 1	Step 2	Step 3	Step 4
Modeling tool	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7	Dyna/Marc 1.7
Amperage	400 kA	**440 kA**	**480 kA**	**490 kA**	**500 kA**
Nb. of anodes	36	**40**	40	40	40
Anode size	1.7 m X 0.8 m	1.7 m X 0.8 m	**1.95 m X 0.8 m**	1.95 m X 0.8 m	1.95 m X 0.8 m
Nb. of anode studs	3 per anode	3 per anode	3 per anode	**4 per anode**	4 per anode
Anode stud diameter	19 cm	19 cm	19 cm	**17.5 cm**	17.5 cm
Anode cover thickness	10 cm	10 cm	10 cm	10 cm	10 cm
Nb. of cathode blocks	20	**22**	22	22	**24**
Cathode block length	3.67 m	3.67 m	**4.17 m**	4.17 m	4.17 m
Type of cathode block	HC10	HC10	HC10	HC10	HC10
Type of side block	SiC	SiC	SiC	SiC	SiC
Side block thickness	10 cm +	10 cm +	10 cm +	10 cm +	10 cm +
ASD	30 cm	30 cm	30 cm	30 cm	30 cm
Inside potshell size	16.1 X 4.35 m	**17.8 X 4.35 m**	**17.8 X 4.85 m**	17.8 X 4.85 m	17.8 X 4.85 m
ACD	4 cm	4 cm	4 cm	4 cm	4 cm
Excess AlF_3	13.5 %	13.5 %	13.5 %	13.5 %	13.5 %
Anode drop	335 mV	**332 mV**	**347 mV**	**314 mV**	**320 mV**
Cathode drop	301 mV	**331 mV**	**324 mV**	**331 mV**	**312 mV**
Anode panel heat loss	311 kW	**335 kW**	**367 kW**	**391 kW**	**394 kW**
Cathode bottom heat loss	193 kW	**202 kW**	**231 kW**	**231 kW**	**238 kW**
Operating temperature	962.7 °C	**963.4 °C**	**962.8 °C**	962.8 °C	**963.4 °C**
Liquidus superheat	9.0 °C	**9.7 °C**	**9.1 °C**	9.1 °C	**9.7 °C**
Bath ledge thickness	5.11 cm	**4.43 cm**	**4.97 cm**	**4.99 cm**	**4.44 cm**
Metal ledge thickness	0.83 cm	**0.15 cm**	**0.70 cm**	**0.71 cm**	**0.17 cm**
Current efficiency	96.0 %	**95.9 %**	**95.8 %**	**95.9 %**	95.9 %
Internal heat	825 kW	**916 kW**	**964 kW**	**988 kW**	**1019 kW**
Energy consumption	13.49 kWh/kg	**13.53 kWh/kg**	**13.31 kWh/kg**	**13.33 kWh/kg**	**13.39 kWh/kg**