In-depth Analysis of Lining Designs for Several 420 kA Electrolytic Cells

Zhou Jianfei[1], Marc Dupuis[2]

中铝国际贵阳分公司 / 贵阳铝镁设计研究院 [1]
Guiyang Branch of CHALIECO
guiyang aluminium magnesium design & research institute

GENISIM [2]

Plan of the Presentation

- Introduction
- The four main cell lining zones of high amperage cell:
  - Side wall area at liquids level
  - Side wall area at block level (pier region)
  - Side wall area at lower insulation level
  - Bottom insulation area
- Conclusions

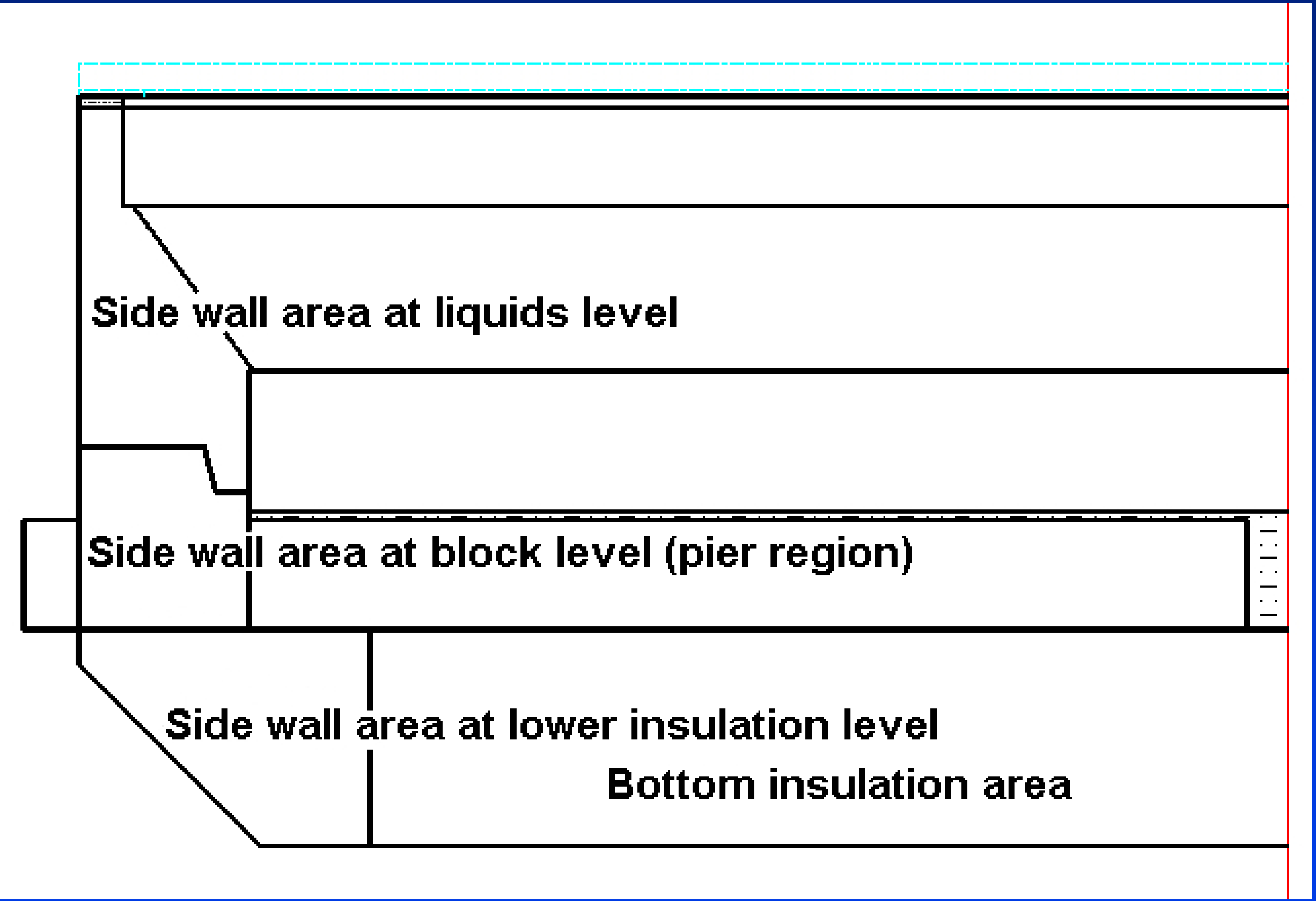
Introduction

- Currently with increasing market demands and technology development, GAMI's high-amperage aluminum electrolysis cell technology has gradually become widely used in China.

- As a result, GAMI's 420 kA cell technology is now available with various lining options.

- This study analyses and compares the various options in order to identify the optimum design of the four main cell lining zones from the angle of maximizing several cell characteristics: productivity, energy efficiency, lining life and safety aspects.

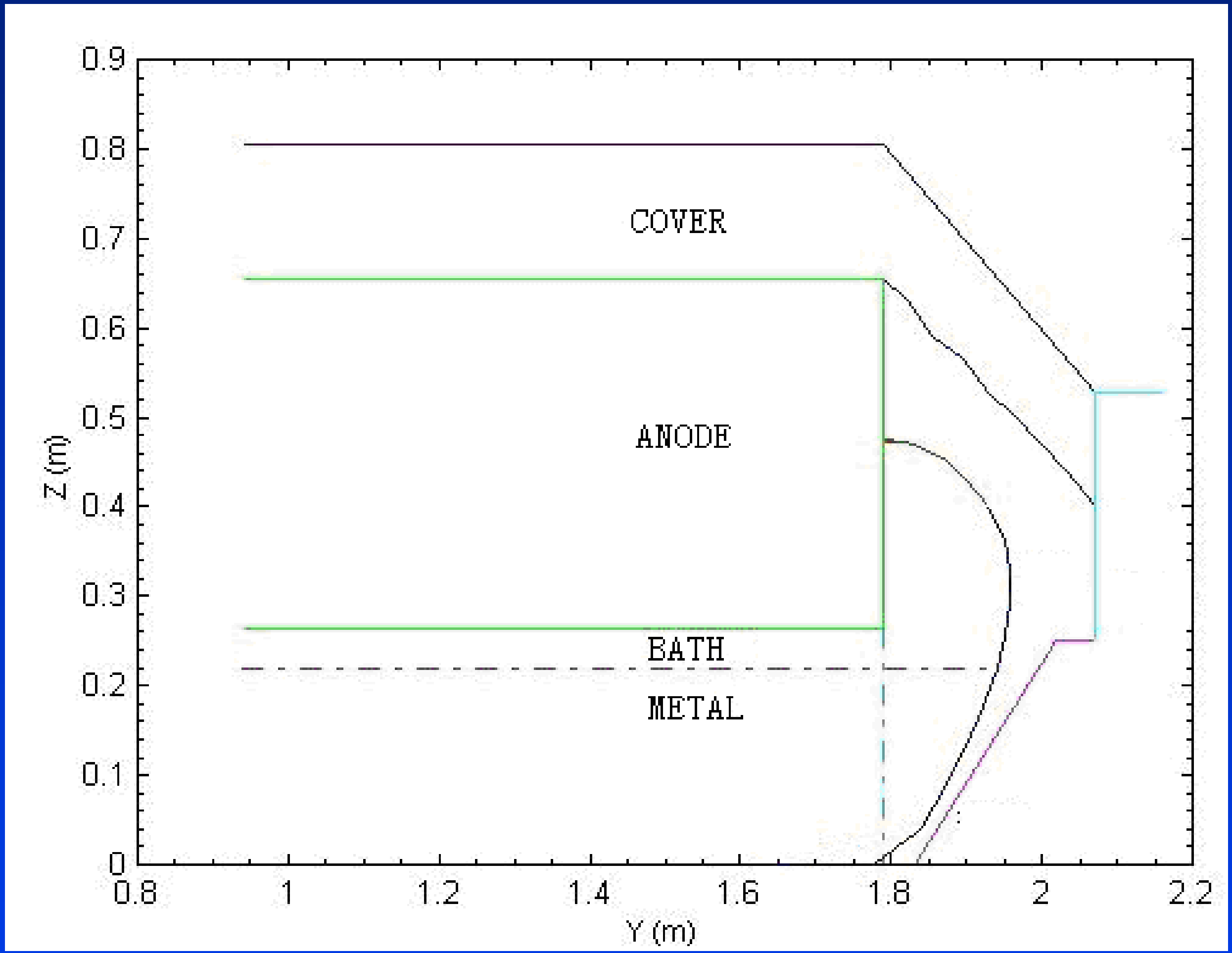
The four main cell lining zones of high amperage cell



Side wall area at liquids level

- The side wall area at liquids level is the key area of those four cell lining areas because the choice of design option and materials selection determines directly the corresponding operating voltage and cell ledge profile formation, thus influencing the process targets such as current efficiency, DC consumption, etc.
- Based on experience, a reasonable side ledge profile should be as follow: ledge thickness at bath level around 8 to 10 cm, thickness of ledge at metal level approx. 3 to 5 cm, ledge toe thickness between 5 and 8 cm and upward crust thickness, less than 15 cm.

Side wall area at liquids level



Optimum ledge profile

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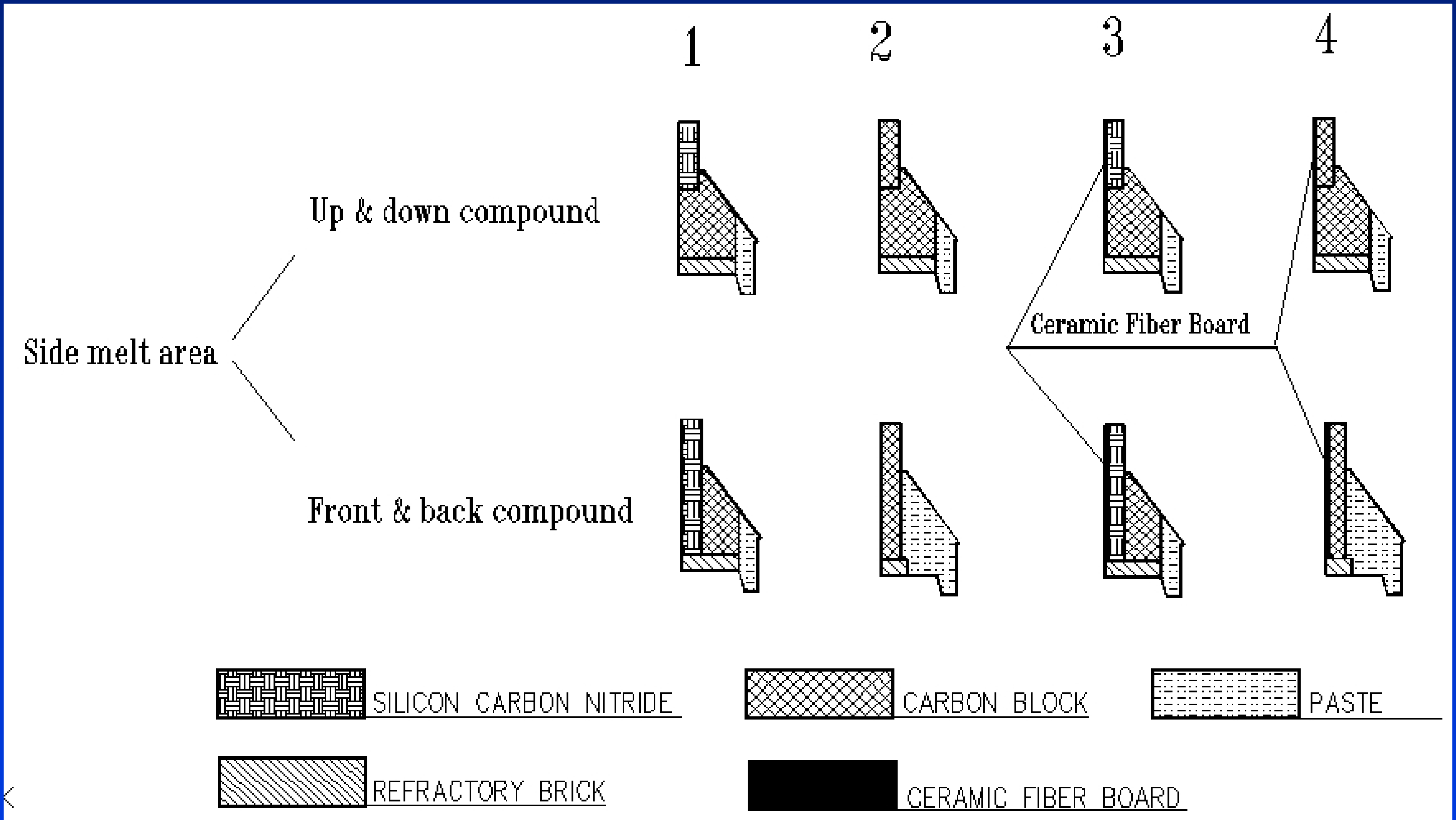
Side wall area at liquids level



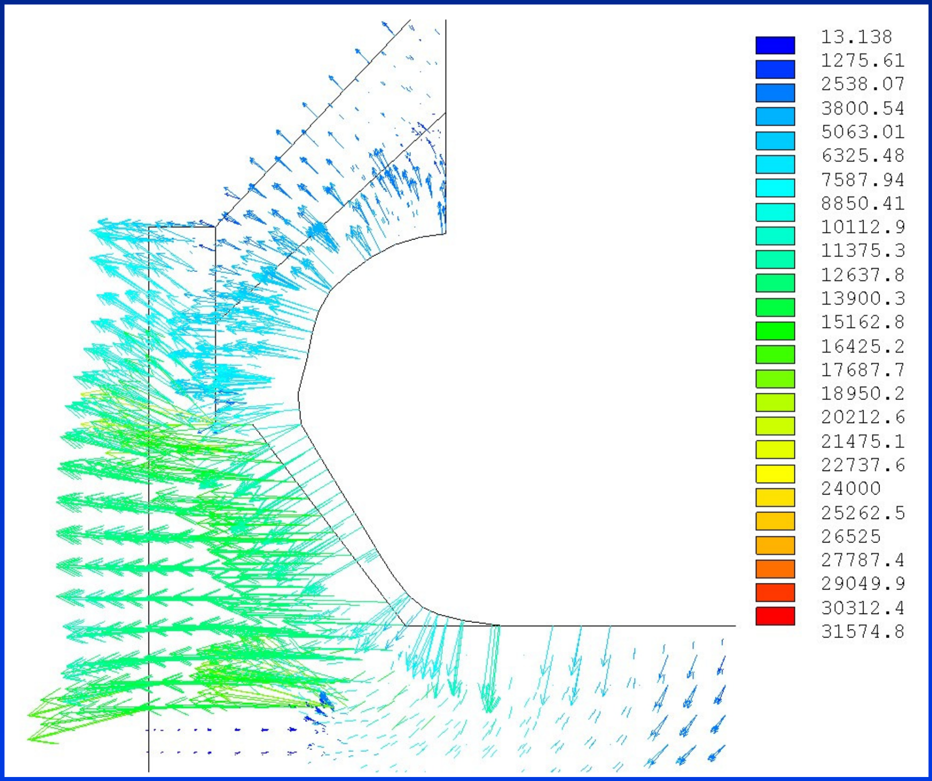
Currently the mainstream design topologies for this area cover top & bottom material combination and front & back material combination. There are four topologies options for each of those two main categories.

Top & bottom material combination or front & back material combination?

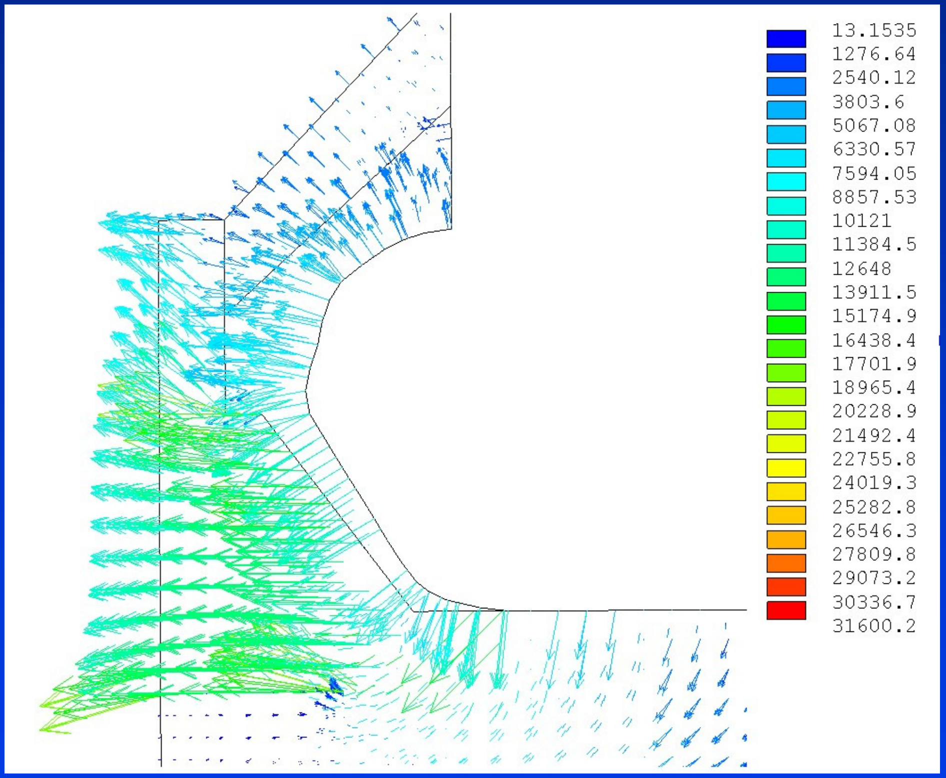
- Taking a position on this issue have been delayed for many years in China, but with the cell enlargement and low voltage production trend, new understanding has been given on those two main design topology options:
- Traditionally, the slope area is all ramming paste which is the front & back material combination. The side profiled carbon block, which is the top & bottom material combination, has arisen in recent years.
- Using side profiled carbon block is more convenient for construction compared to ramming pastes
- Side profiled carbon block heat conduction coefficient is twice that of ramming pastes. So it has good heat dissipation potential, and is also good for ledge formation on the slope.
- In general, many high amperage cells have the top hot and bottom cold trends in different degrees, for which the top & bottom material combination has a big advantage proved in practice.

Top & bottom material combination or front & back material combination?

Heat flux vector graphs of these two material combinations:

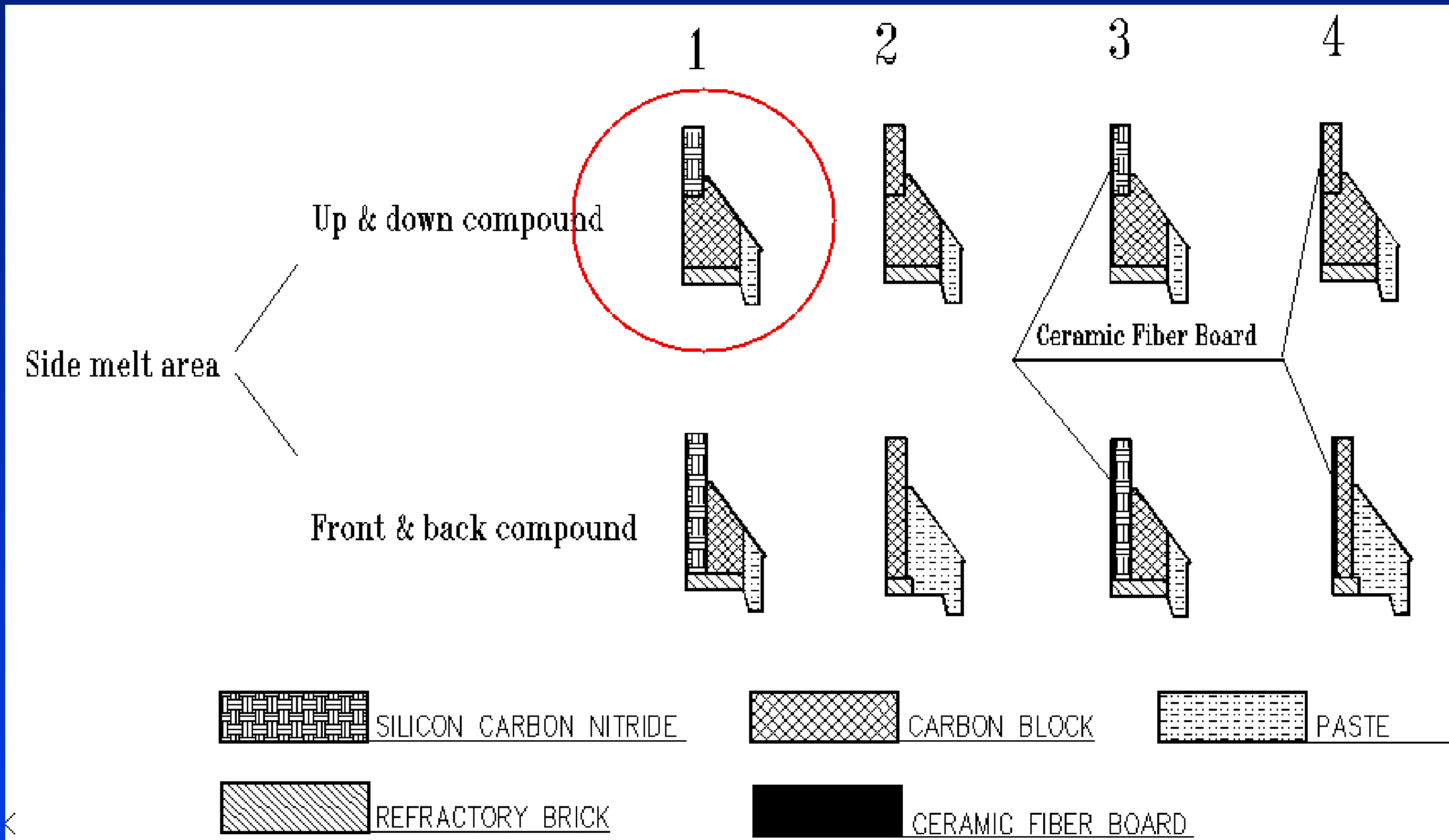


Heat flux of side profiled carbon block



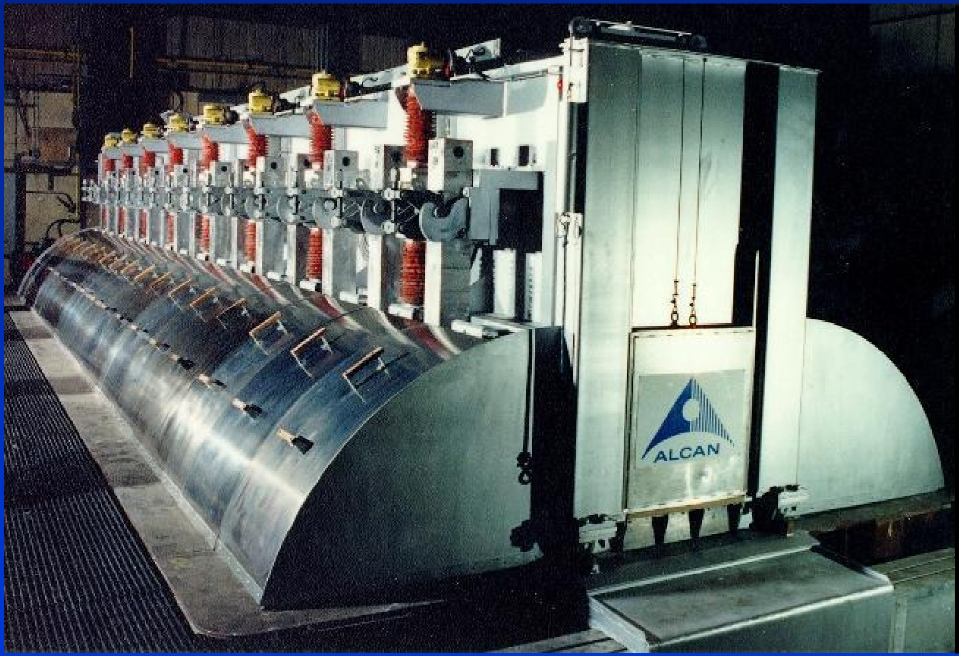
Heat flux of side ramming paste

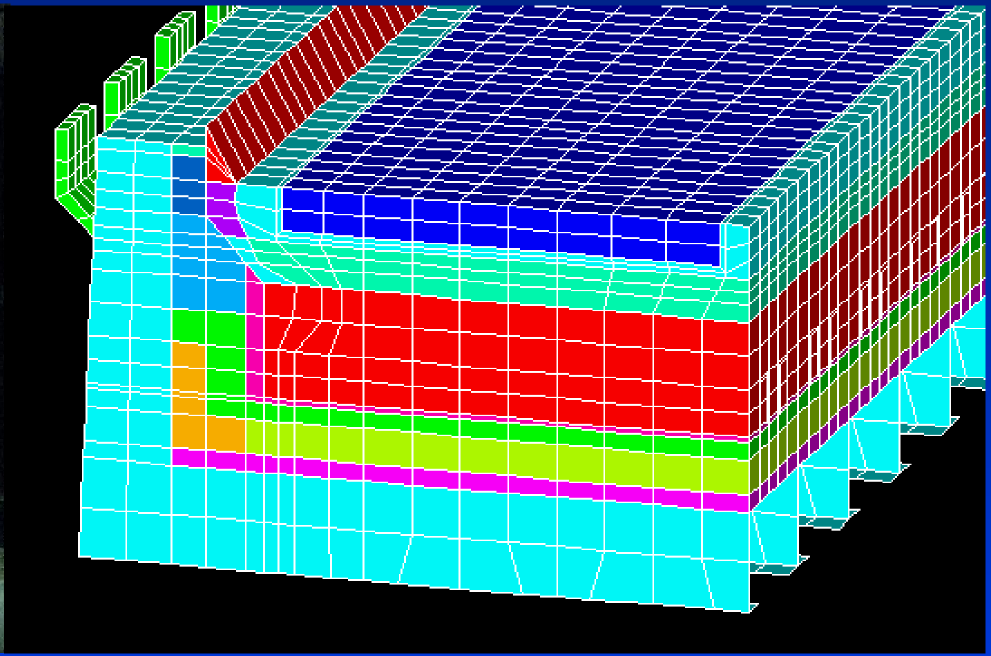
Top & bottom material combination or front & back material combination?



In conclusion, the top & bottom material combination is recommended for side wall area at liquids level for the cell operating over 400 kA.

Top & bottom material combination or front & back material combination?





A310 lining design 1988 (ref: COM 1992)

Adding or not side wall high insulation materials?

Table 1

Correspondence between high side insulation materials thickness and operating voltage with 420 kA cell operating at 0.78 A/cm^2

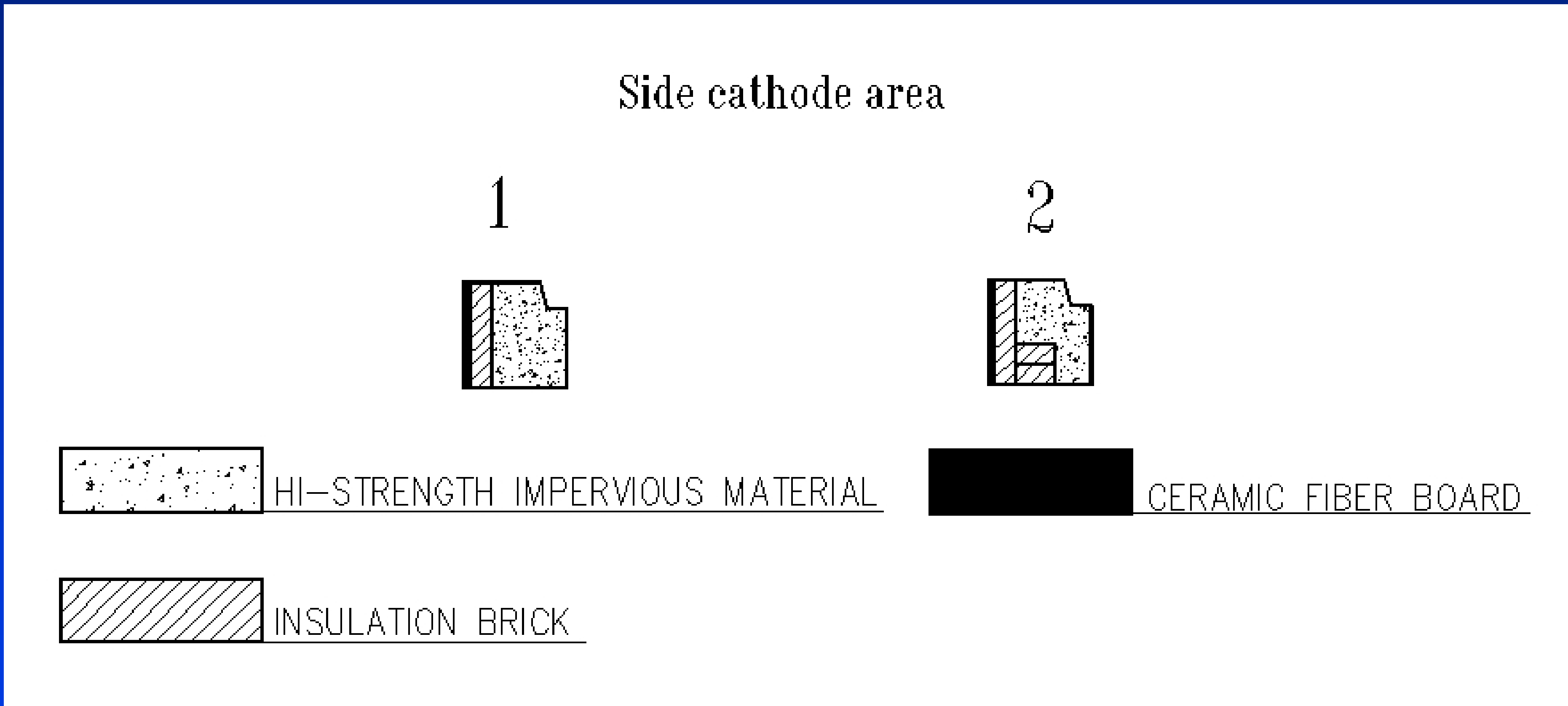
Operating voltage (V)	4.0-4.1	3.9-4.0	3.8-3.9
High insulation materials thickness (mm)	0	6	10

Adding or not side wall high insulation materials?

- If the cell is operated outside the ranges specified in the previous table, the side ledge will be either too thick or too thin. The former will result in increasing metal pad horizontal current which will in turn lower the cell operating stability and make the cell more difficult to operate. The latter can result in cell leakage thus decreasing cell life and increasing safety risk.

- In conclusion, adding or not side wall high insulation material depends on the selected cell operating voltage range.

Side wall area at block level (pier region)



There are two mainstream design options for the pier region at present.

Side wall area at block level (pier region)

- With the prevailing low voltage cell operation, increasing the thermal insulation of the cell in order to prevent excessive ledge toe formation to get stable cell with high current efficiency is now the main design focus for the pier region.

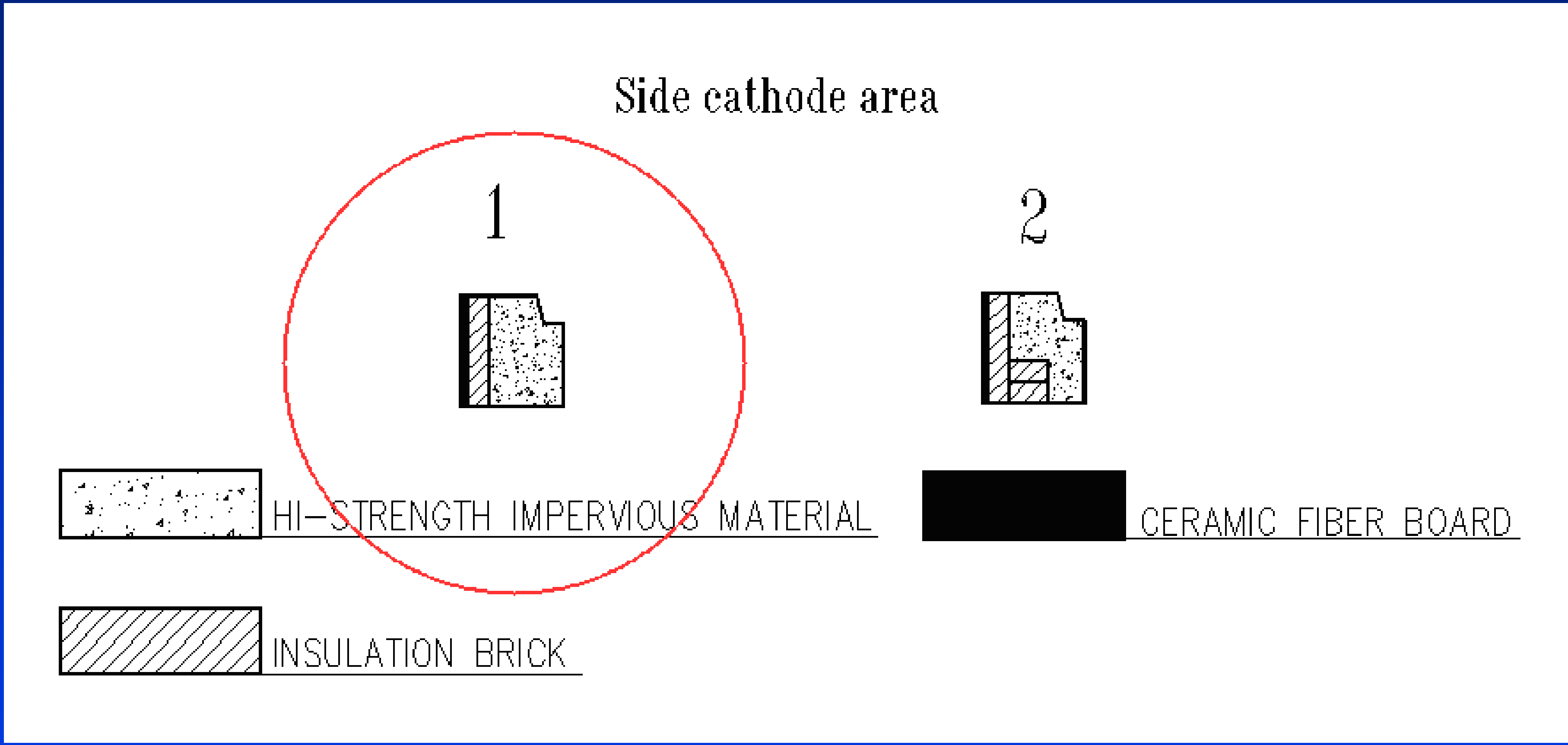
- It shall be said that option 1, the combination of low strength insulation bricks in the back plus high strength castable in front is the classic structure for the pier region. It is very mature and efficient in both preventing metal infiltration and adsorbing stress from the cathode sodium expansion.

Side wall area at block level (pier region)

- The difference between option 1 and option 2 lies in the addition of clay semi-insulating refractory bricks. Those bricks have a thermal conductivity of around 0.1~0.15 W/m2°C while the thermal conductivity of high strength castable is about 0.3~0.5 W/m2°C. So, option 2 has a bigger inhibition on the ledge toe formation. When considering a 420 kA cell operating at 0.78 A/cm2 for example, the ledge toe of option 2 is about 2~3 cm shorter than that of option 1.

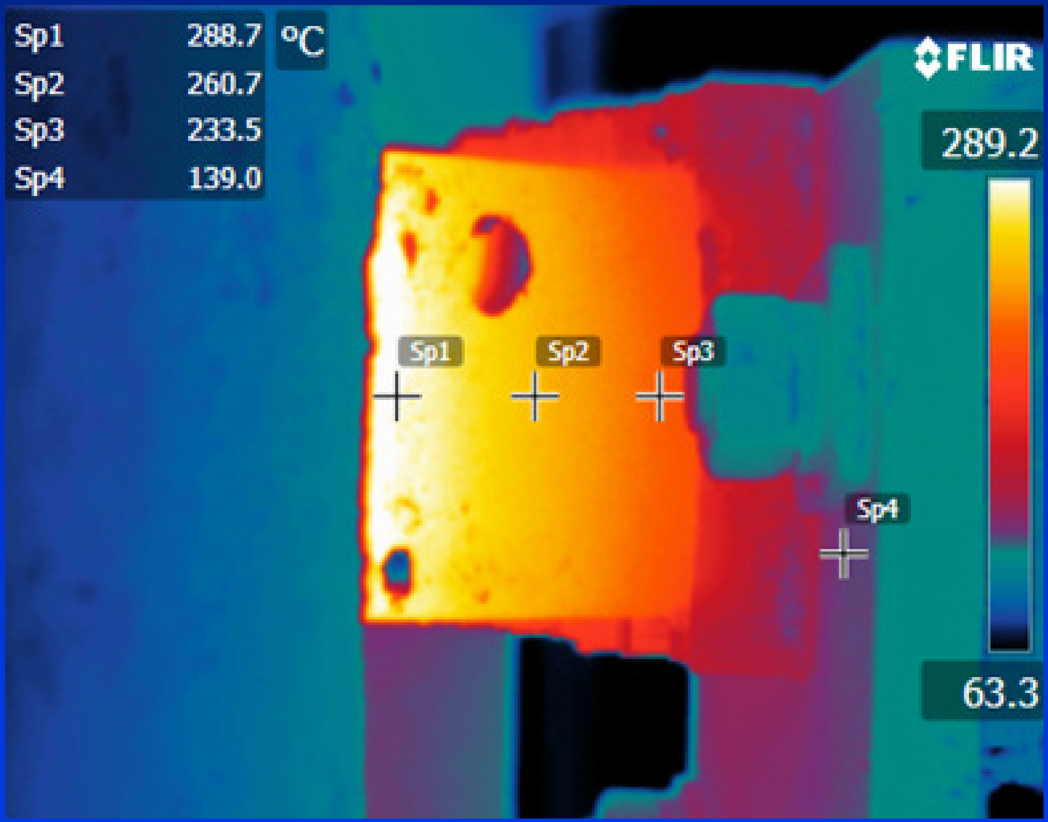
- After actual verification on smelters operating using GAMI's cell technology, the cell current density has been increased steadily, so the inhibition of option 2 on ledge toe formation is now too much. Therefore, currently the semi-insulating refractory bricks in the pier region have been removed and option 1 is preferred again.

Side wall area at block level (pier region)



In conclusion, the option 1 is recommended for side wall area at block level (pier region) for cell operating over 400 kA.

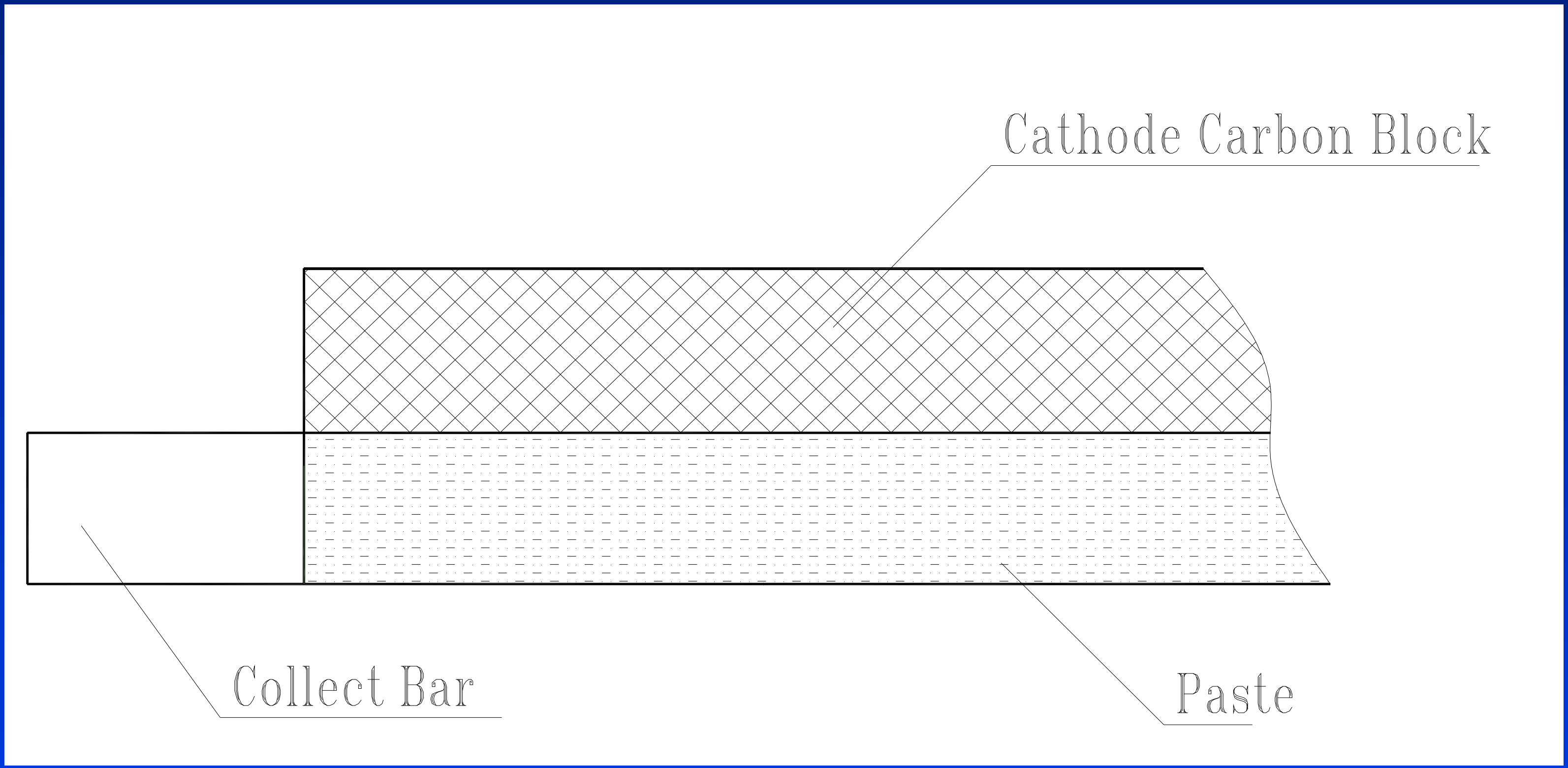
Adding or not side wall high insulation materials?



Overheated steel collector bars started to be observed in many large cells in recent years approaching 280 to 300 °C.

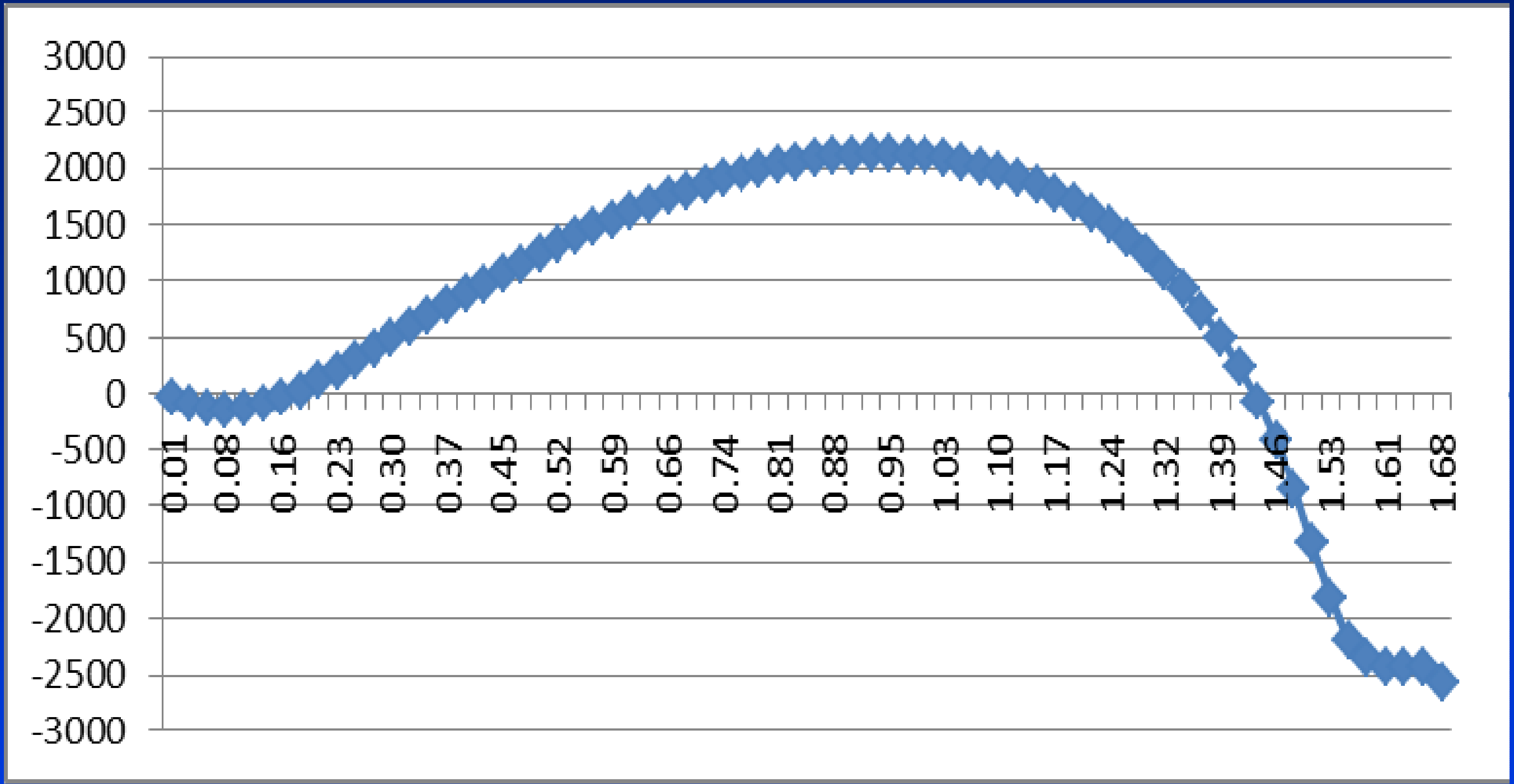
The influence on steel collector bar temperature of the presence of that 2 cm ceramic fiber board is about 10 to 15 °C. Again adding or not side wall high insulation material depends on the selected cell operating voltage range.

Collector bar assembly



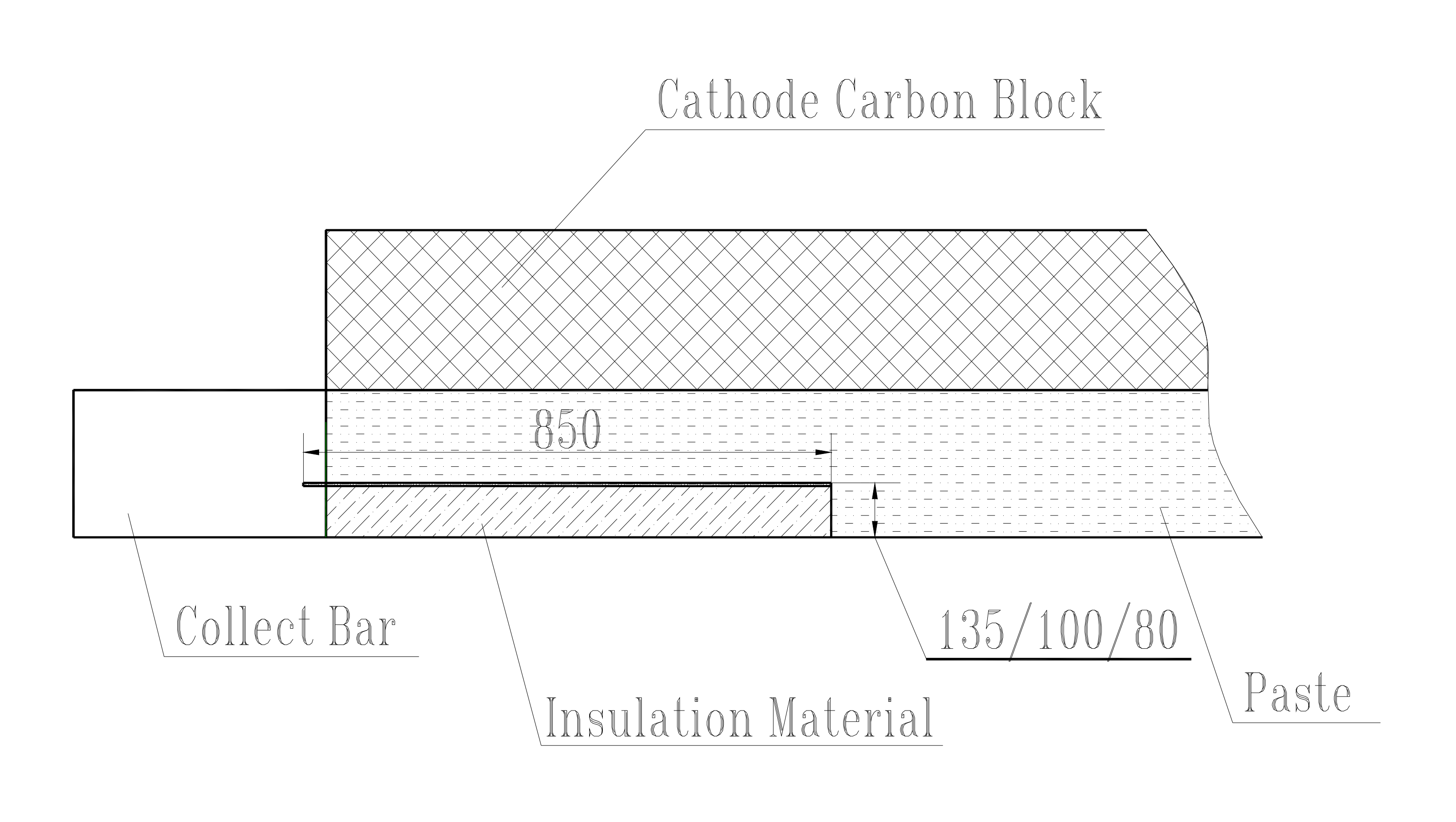
Typically ramming paste is used in China for the cathode block collector bar connection

Collector bar assembly



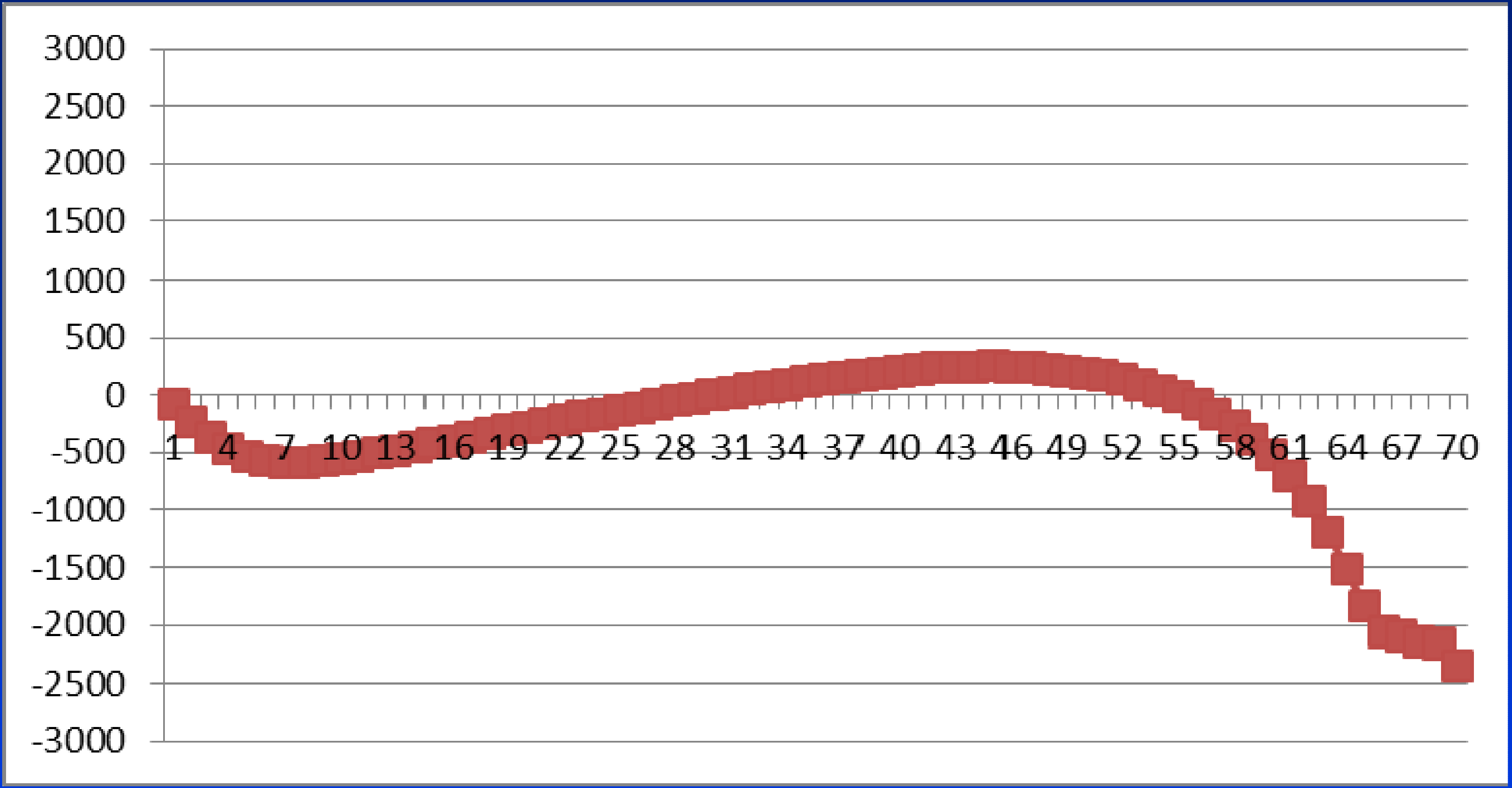
Calculation of metal pad horizontal current for double collector bar connection for a 420 kA cell (current density 0.78 A/cm2) with bar section dimensions of 230 x 100 mm

Collector bar assembly



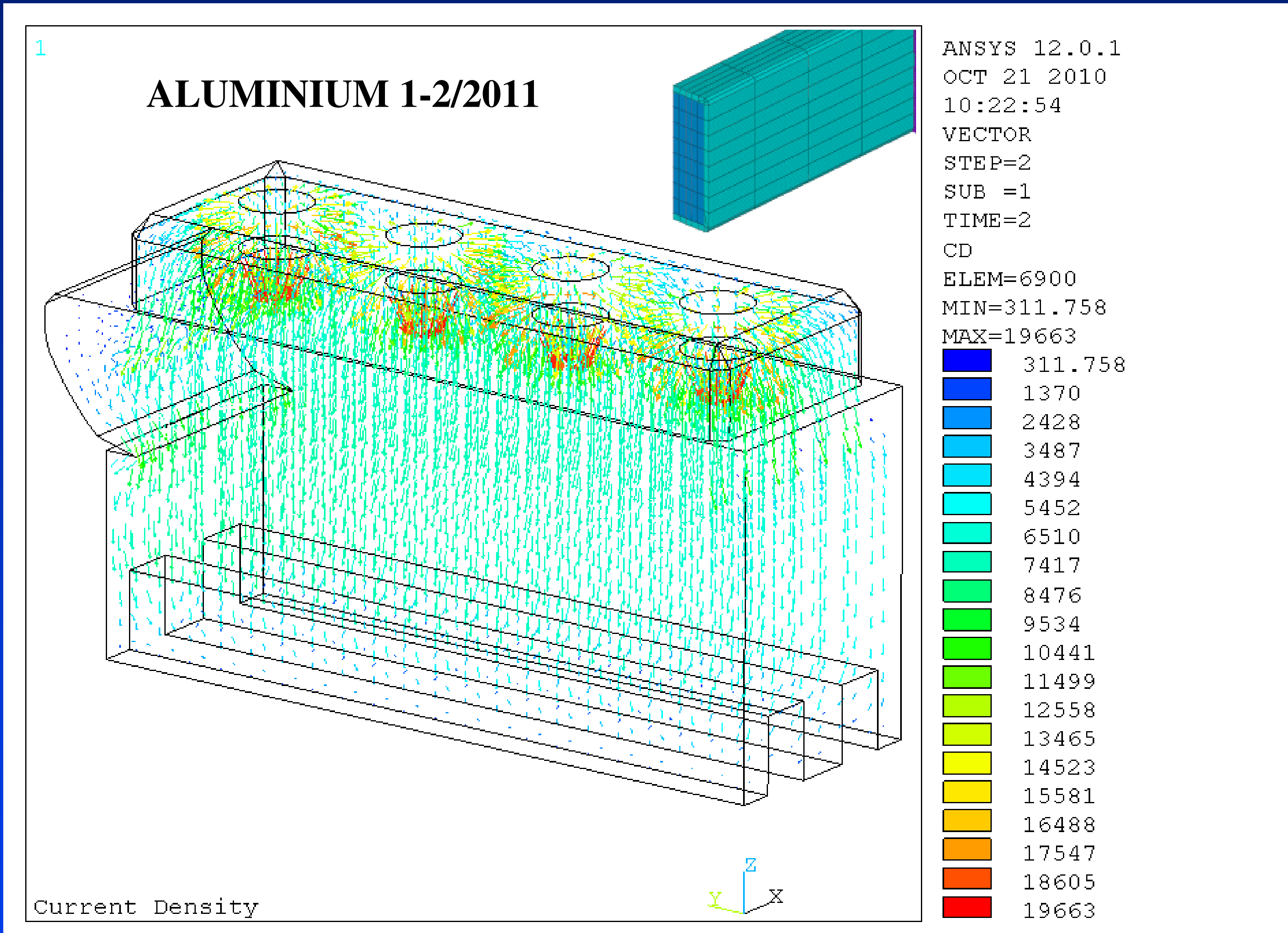
Partial paste ramming connection

Collector bar assembly

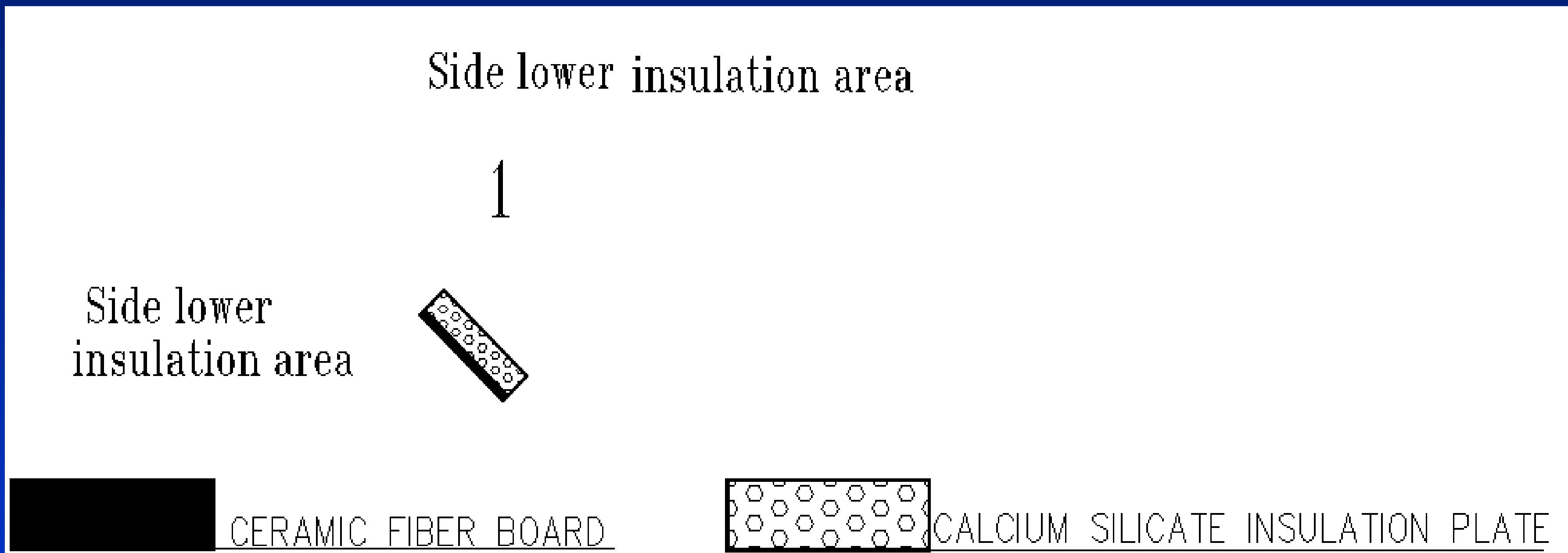


Calculation of metal pad horizontal current for double collector bar connection for a 420 kA cell (current density 0.78 A/cm2) with partial paste ramming connection (insulation height 80)

Collector bar assembly

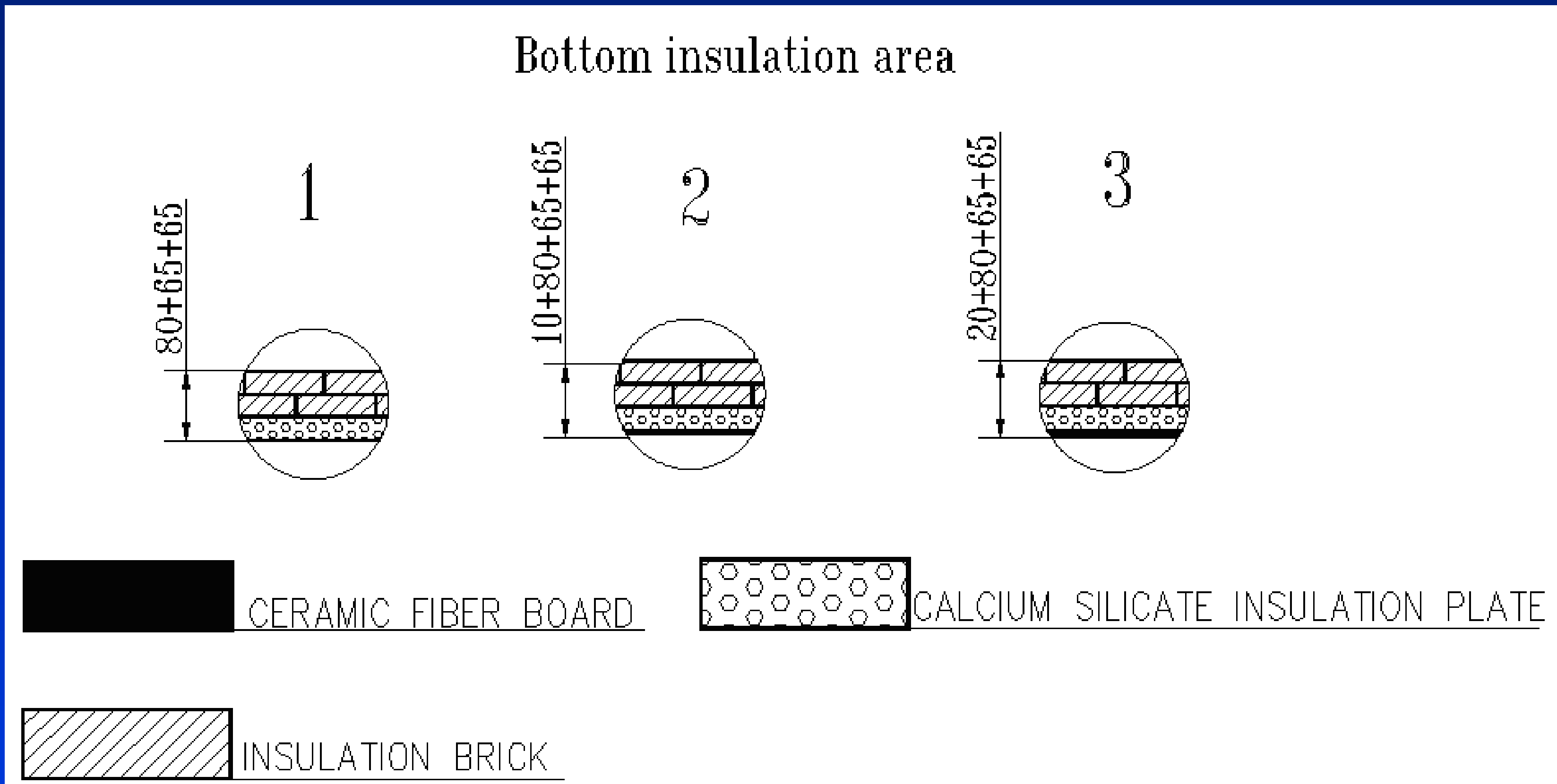


Side wall area at lower insulation level



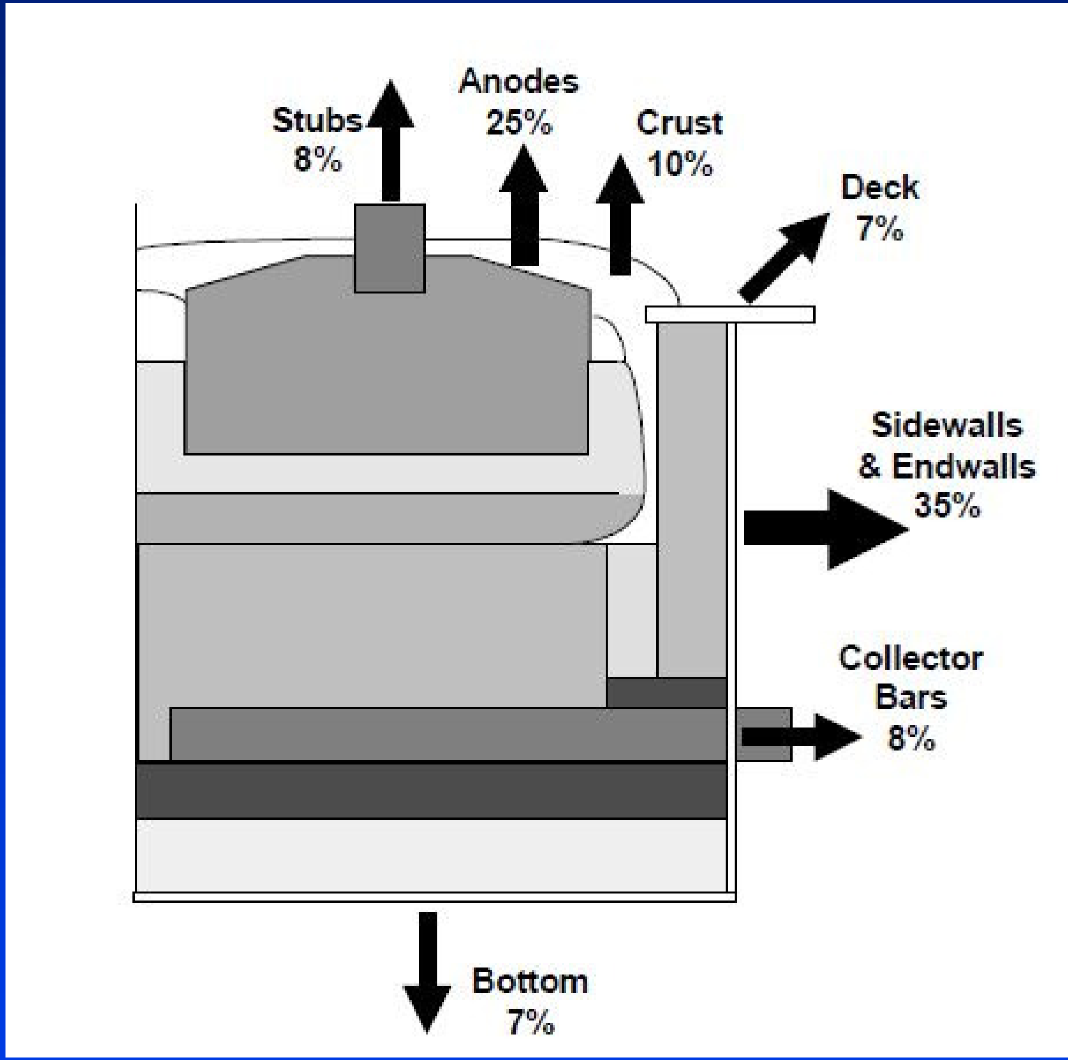
The side lower thermal insulation influences directly the ledge toe extension. The design and choice of materials in this area has also an importance to prevent metal infiltration. After many years of trial and error on many projects, the relatively mature structure has been established, as shown in the above figure. Considering a 420 kA cell operating at 0.78 A/cm2 for example, that design option can reduce the ledge toe extension by 3~5 cm as compared to the traditional dry barrier only design option.

Bottom insulation area



The cell bottom insulation area is not considered important to be able to decrease the cell heat loss in order to operate at lower cell voltage. Indeed, as the cell bottom area is not dissipating a big percentage of the total cell heat loss, it only represents about 6 to 9 % for GAMI's high amperage cell technology.

Bottom insulation area



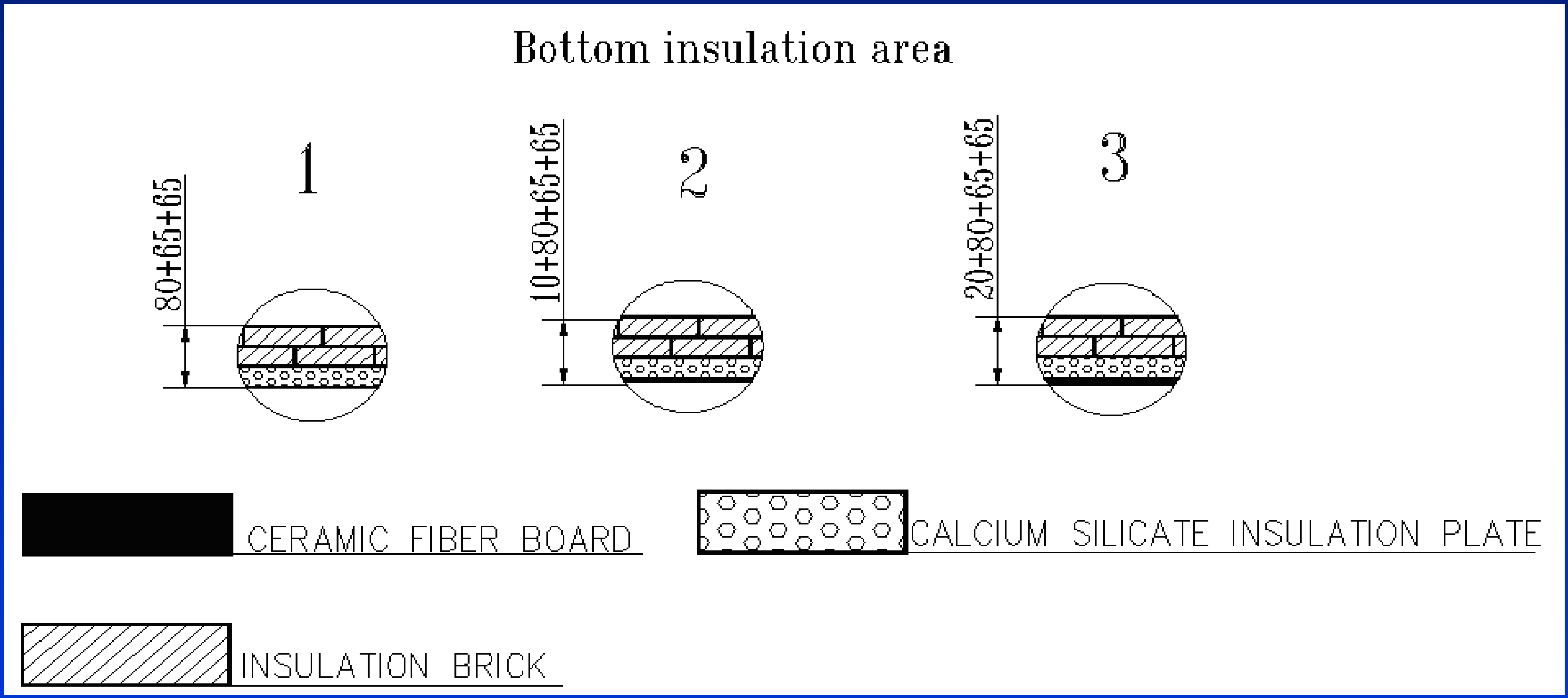
Typical range of cell heat loss distribution has reported by Bruggeman

Bottom insulation area: brick quality

Results of vermiculite (left) and diatomite (right) insulating bricks corrosion test

The results of the test clearly indicate that vermiculite insulating brick has a better bath corrosion resistance than that of diatomite insulating brick.

Bottom insulation area: which option to use?



As the bottom insulation increases from option 1 to option 3, the bottom heat dissipation decreases by about 2 % which is not a big change for the cell heat balance. But the cathode surface increases by about 2 to 3 °C, which is very important for keeping cathode surface clean when the metal pad level is increased.

Bottom insulation area: which option to use?

Table 2

Relationship between metal pad level and cell current

Current (kA)	300	350	400	420	500	600
Metal level (cm)	22	23	26	27	31	37

Bottom insulation area: which option to use?

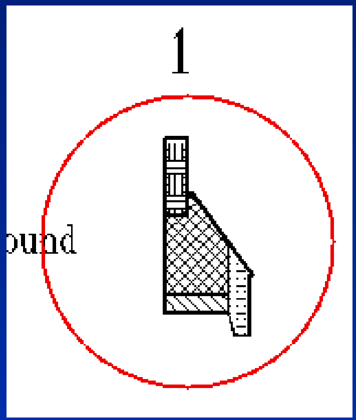
Table 3

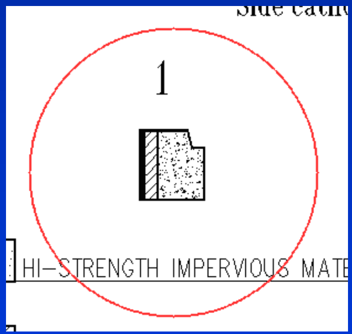
Relationship between the bottom insulation design option and the cell operating voltage

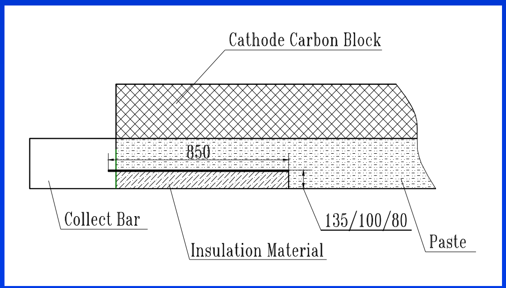
Operating voltage (V)	4.05-4.15	3.95-3.85	3.75-3.85
Applicable option	Option 1	Option 2	Option 3

Conclusions

- Side wall area at liquids level: the top & bottom material combination option 1 is recommended for side wall area at liquids level for cells operating over 400 kA. Adding or not side wall high insulation material depends on the selected cell operating voltage range.
- Side wall area at block level (pier region): the option 1 is recommended for side wall area at block level (pier region) of cells operating over 400 kA.
- Collector bar assembly: it is recommended to use double steel collector bar connection with insulation part 80 mm high and 850 mm long.

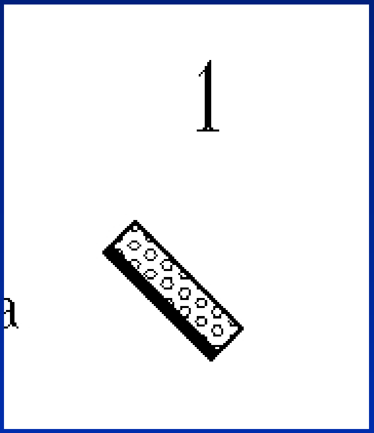






Conclusions

- Side wall area at block level (pier region): the option 1 is recommended for side wall area at block level (pier region) of cells operating over 400 kA.



- Side Bottom insulation area: the side three options are recommended for bottom insulation area of cells over 400 kA. Which is the most suitable depends on the operating voltage range.