Using ANSYS® Based Aluminum Reduction Cell Energy Balance Models to Assist Efforts to Increase Lauralco's Smelter Productivity

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Plan of the Presentation

- Introduction
- The Hall-Héroult Cell
- Modeling the Hall-Héroult Cell
- Thermo-electric Half Anode Model
- Thermo-electric Cathode Slice Model
- Thermo-electric Quarter Cathode Model
- Validation of the Model Results
  - Thermal Blitz
  - Instrumented Cathode Lining
  - Instrumented Anode
- Initial Smelter's Productivity Improvement
- Conclusions

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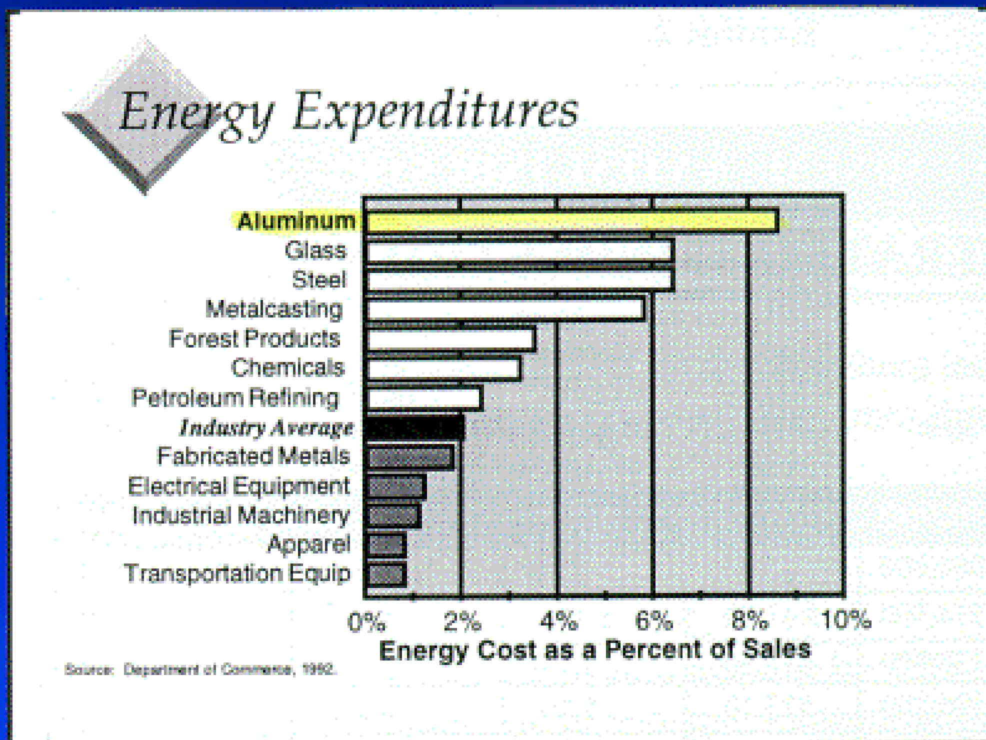
Introduction

Aluminum Production is One of the Most Energy Extensive Industrial Process



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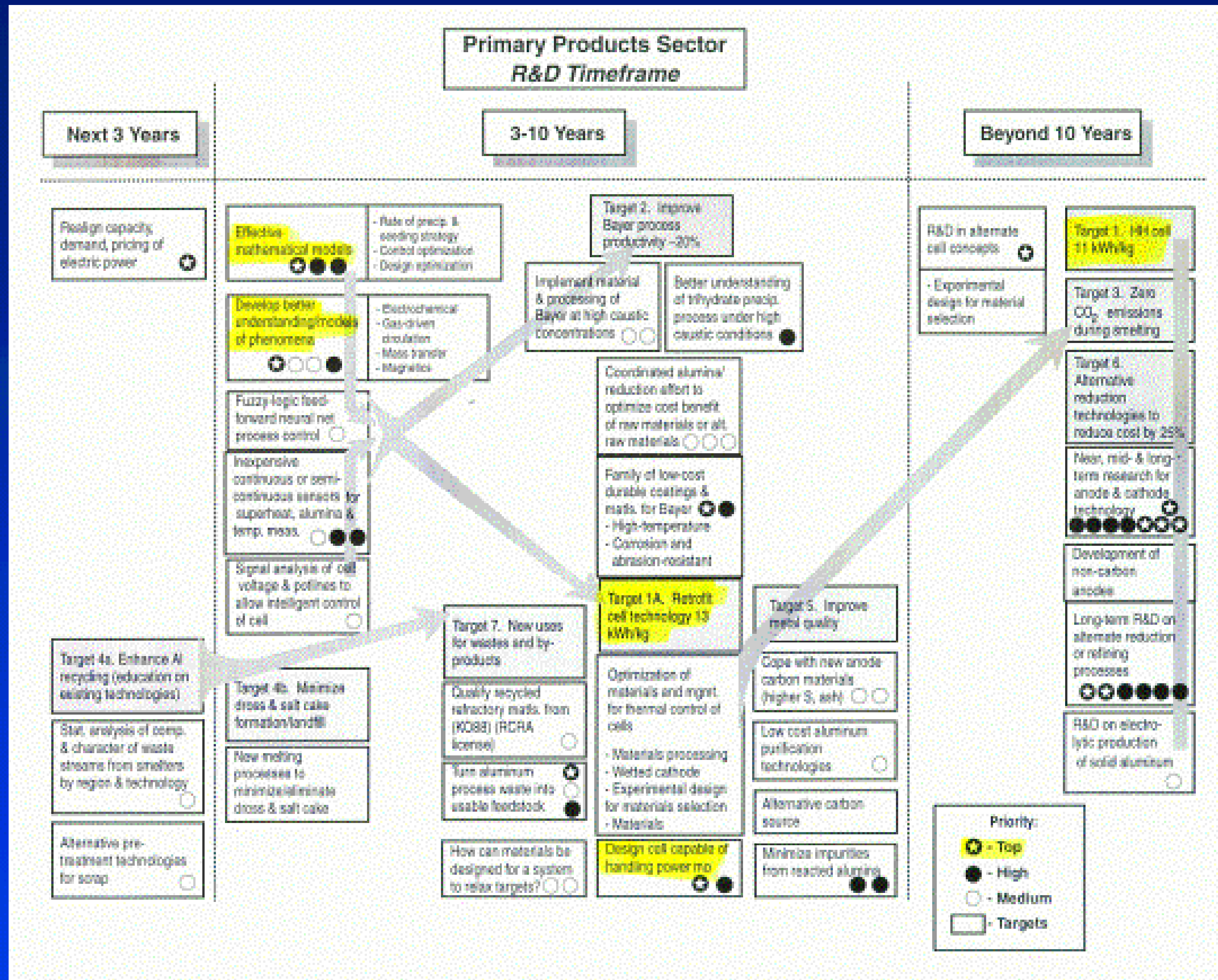
Introduction

US Department of Energy's Technology Road Map to Reduce the Industry Energy Consumption



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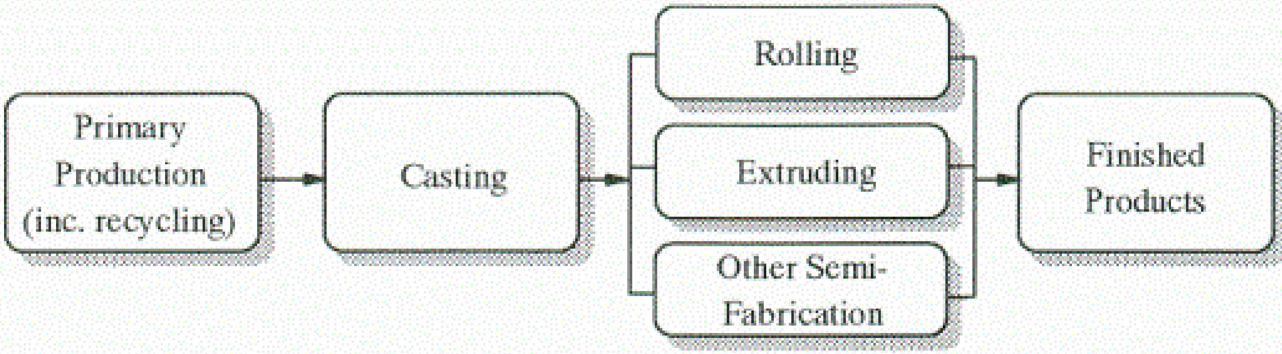
Introduction

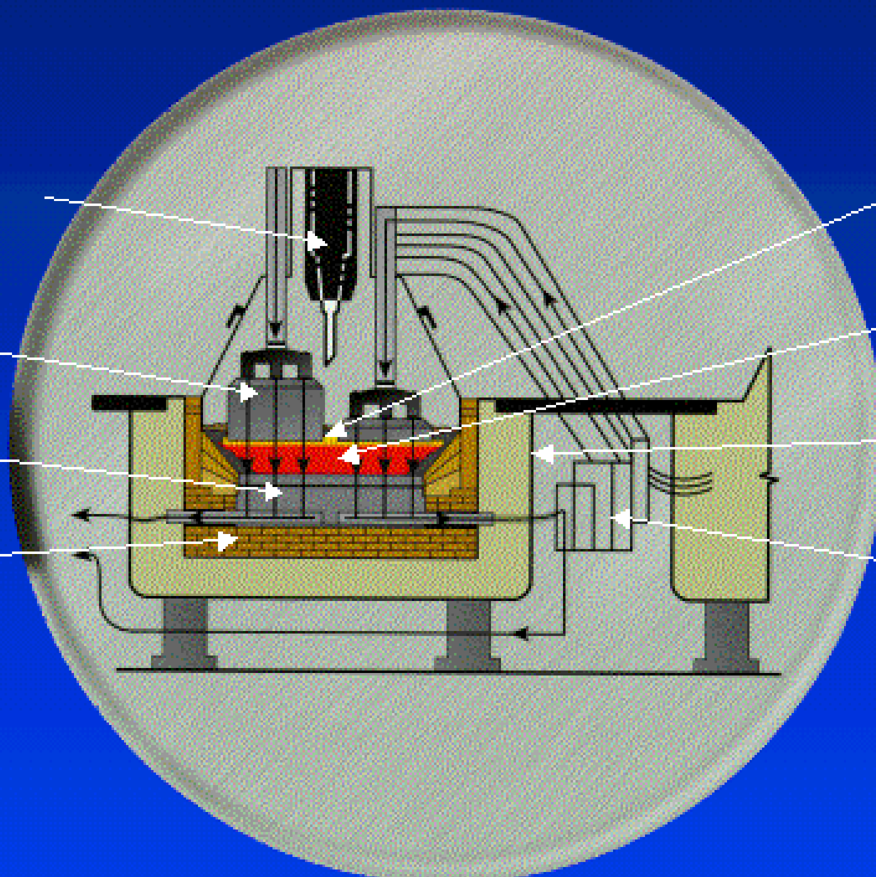
"Effective Mathematical Models" Identified as One of the Key "Enabling Technologies"



<u>NEEDS</u>	Primary Production (inc. recycling)	Casting	Rolling / Extruding / Other Semi-Fabrication	Finished Products
Fundamental Understanding	Physical and chemical phenomena in reduction	Solidification	Materials behavior and chemistry	Structural properties of aluminum and processing interrelationships
Enabling Technologies	Models, sensors, and controls for Bayer process and Hall-Heroult reduction process	Low-cost sensors and solidification models	Comprehensive process models, advanced sensors	Integrated models and better process controls

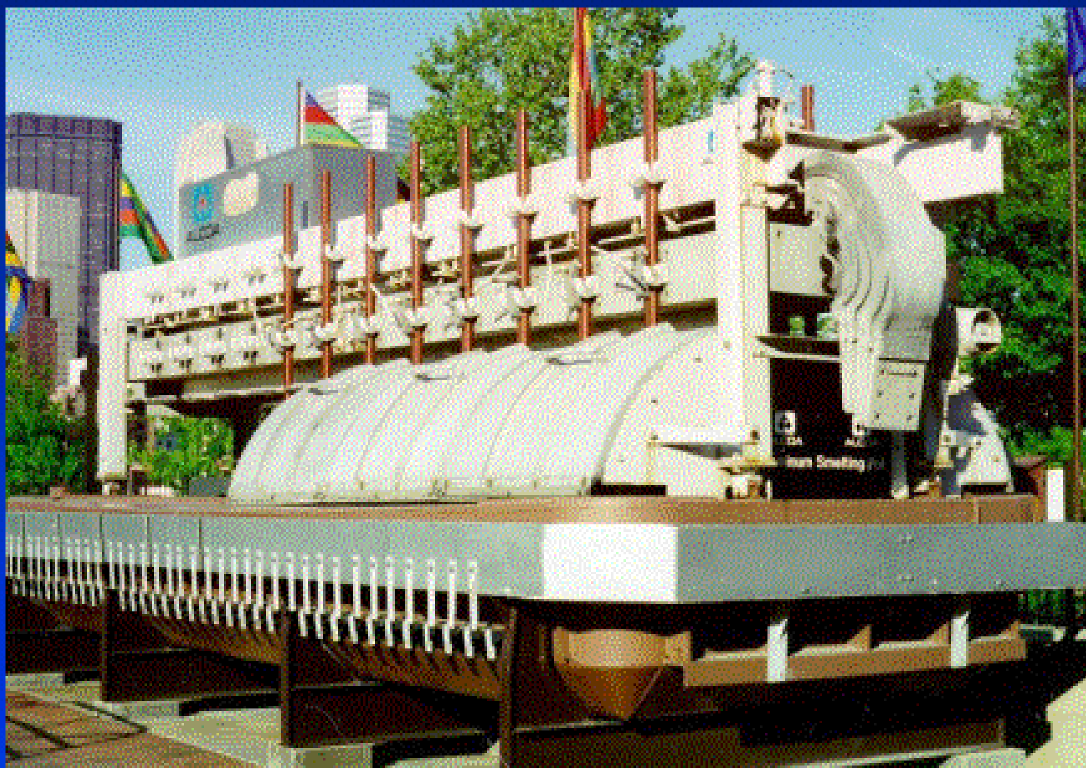
The Hall-Héroult Cell

- Superstructure
- Anode
- Cathode
- Lining Bricks



- Electrolyte
- Liquid Metal
- Steel Shell
- Busbar

The Hall-Héroult Cell



Pictures from Across the River

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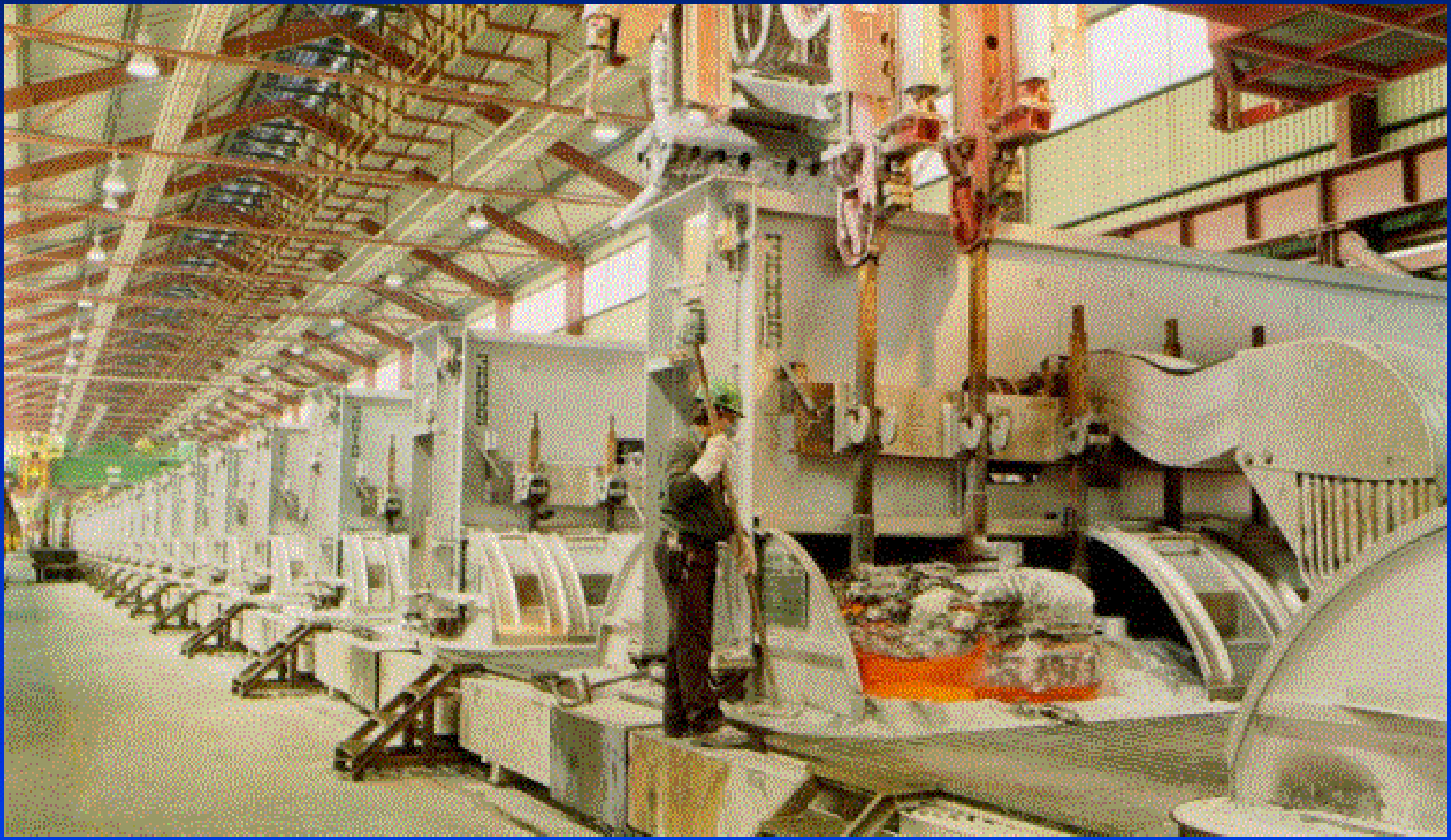
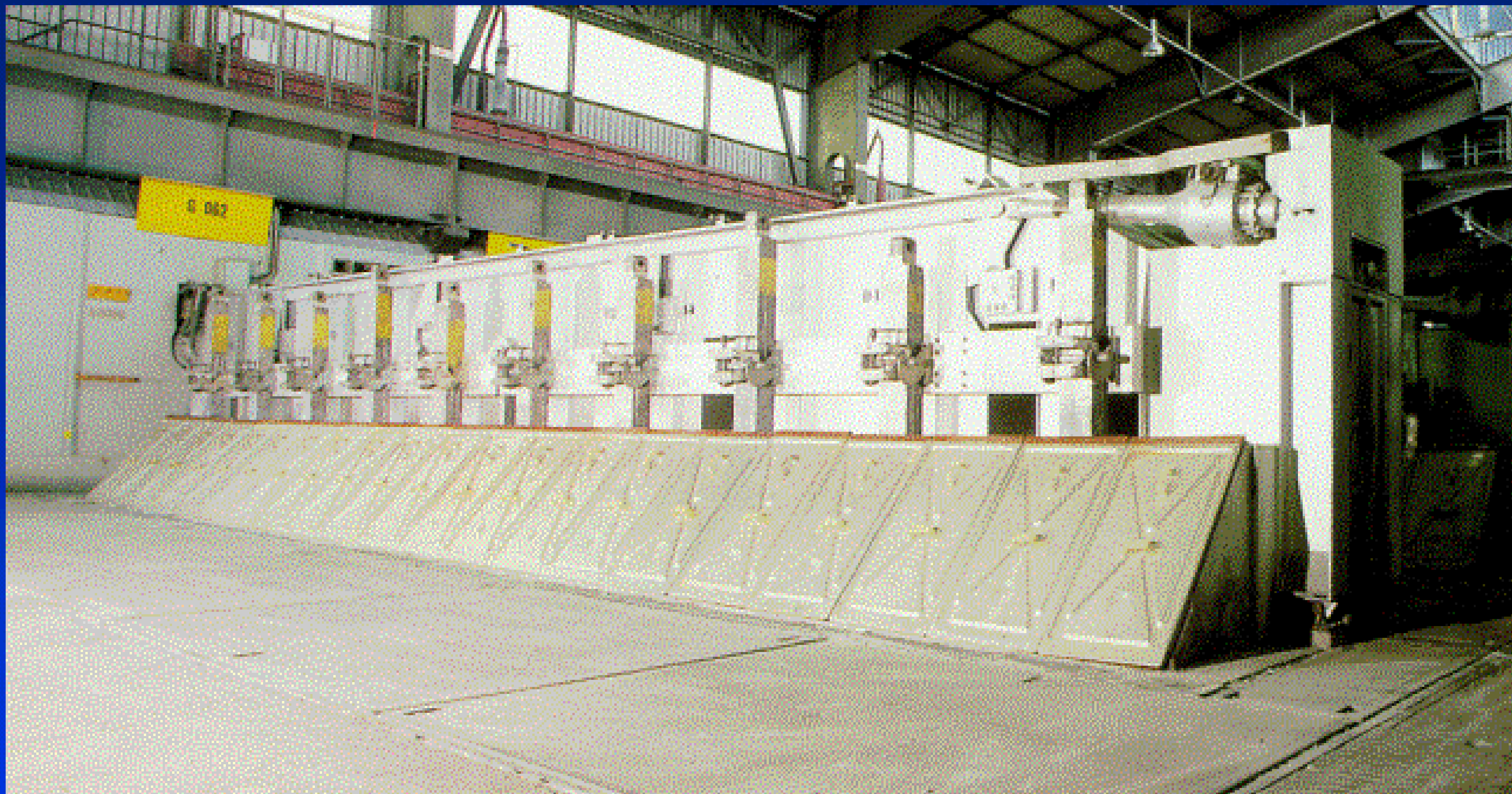
The Hall-Héroult Cell



One of the Last American Design Smelter Built

The Hall-Héroult Cell

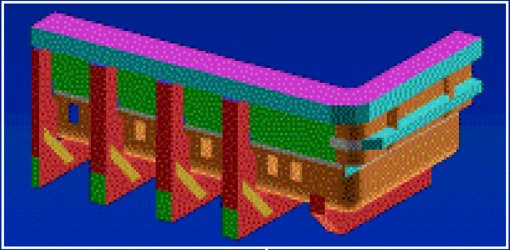


The Most Modern Technology:

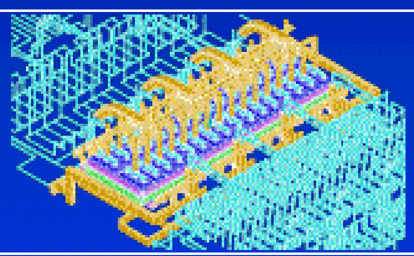
The AP30 from Pechiney France

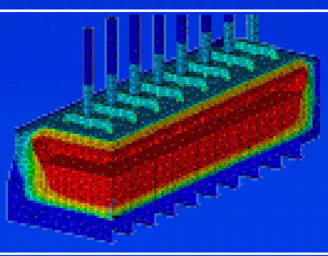
Modeling the Hall-Héroult Cell

Superstructure Design



Point Breaker Feeder Design





Cell Design

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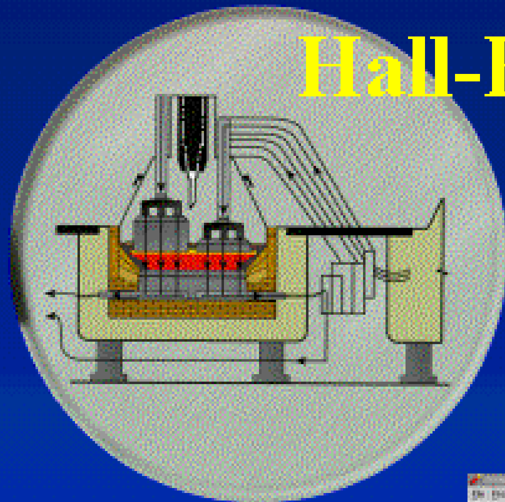
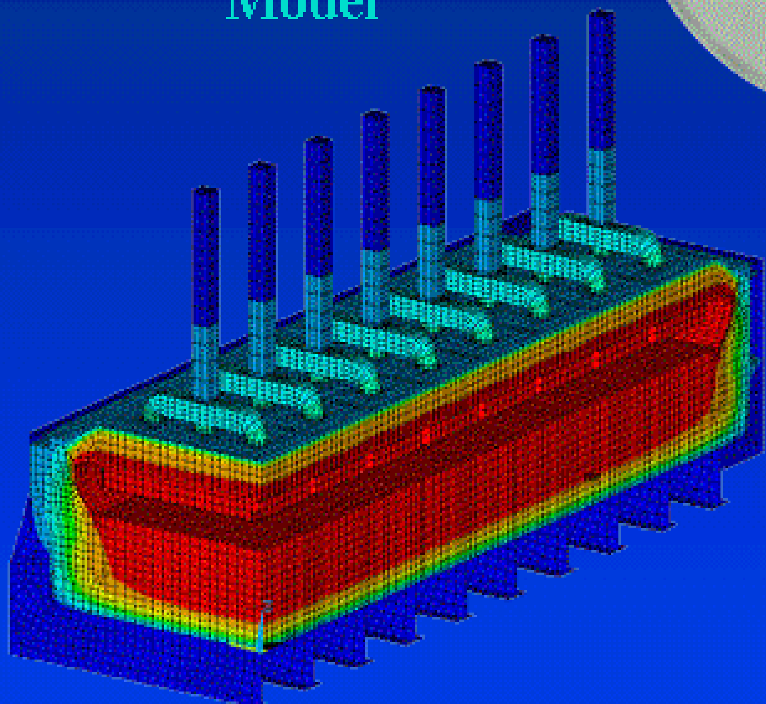
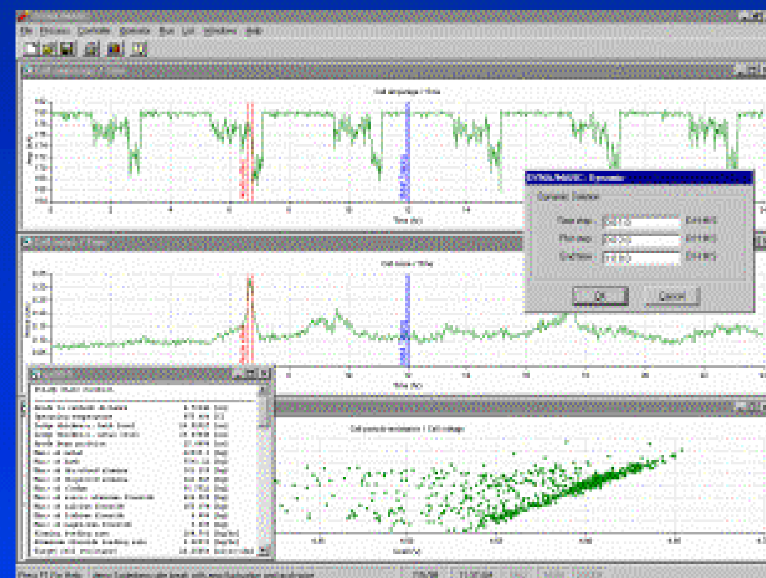
Modeling the Hall-Héroult Cell



Thermo-electric
3D Steady State
Model



Thermo-electric
1D Dynamic Model



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Thermo-electric
Half Anode Model

**** HEAT BALANCE TABLE ****
**** Half Anode Model : "VAW" 300 ****

HEAT INPUT	W	W/m^2	%
Bath to anode carbon	1501.54	1530.60	42.06
Bath to crust	611.64	3304.00	18.81
Joule heat	1396.94		39.13
Total Heat Input	3510.13		100.00

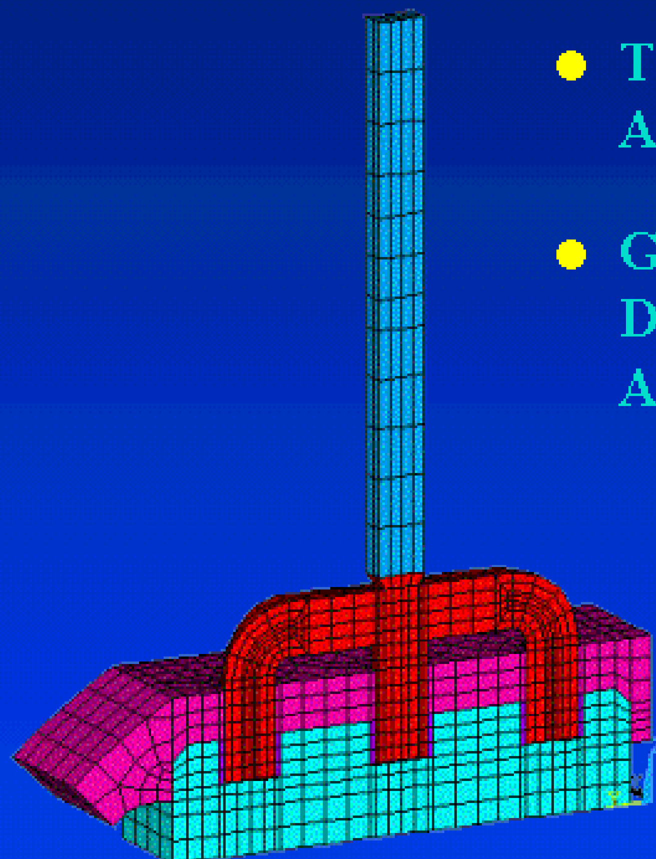
HEAT LOST	W	W/m^2	%
Crust to air	1433.63	1691.41	39.15
Studs to air	1119.63	4060.04	49.69
Aluminum rod to air	400.50	693.10	11.16
Total Heat Lost	3661.16		100.00

Solution Error 2.50 %

ANODE PANEL HEAT LOST	KW	W/m^2	%
Crust to air	91.15	1691.41	39.15
Studs to air	116.46	4060.04	49.69
Aluminum rod to air	26.14	693.10	11.16
Total Anode Panel Heat Lost	234.35		100.00

Avg. Drop at clamp (mV)	Current at anode Surf (Amps)
302.103	4601.500

Targeted cell current: 300000.00 Amps
Obtained cell current: 300000.00 Amps
Solution Error 0.00 %



- Total Voltage Drop Across the Anode
- Global Heat Dissipation Across the Anode Panel

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Thermo-electric Cathode Side Slice Model

Heat balance table
Side slice model : "VAW" 300
Freeze profile converged
after 7. iterations

Heat input	W	W/m^2	%
Bath to freeze	765.88	8888.00	17.24
Metal to freeze	1471.68	14888.86	55.15
Metal to carbon	1002.48	1607.15	22.57
Joule heat	1201.75		27.05
Total heat input	4441.81		100.00

Heat lost	W	W/m^2	%
Shell wall above bath level	641.76	1204.00	14.58
Shell wall opposite to bath	412.06	5161.22	8.26
Shell wall opposite to metal	422.58	7028.48	8.48
Shell wall opposite to block	885.01	5722.22	18.84
Shell wall below block	84.77	665.54	2.15
Shell floor	555.18	414.02	7.47
Cradle above bath level	26.21	1514.57	0.58
Cradle opposite to bath	101.05	2075.57	2.27
Cradle opposite to metal	66.45	2546.87	1.48
Cradle opposite to block	261.85	828.84	5.87
Cradle opposite to brick	45.64	155.06	0.88
Cradle below floor level	202.55	88.25	4.54
Bar and flex to air	627.58	2648.40	14.07
End of flex to busbar	540.52	40514.15	7.65
Total heat lost	4458.68		100.00

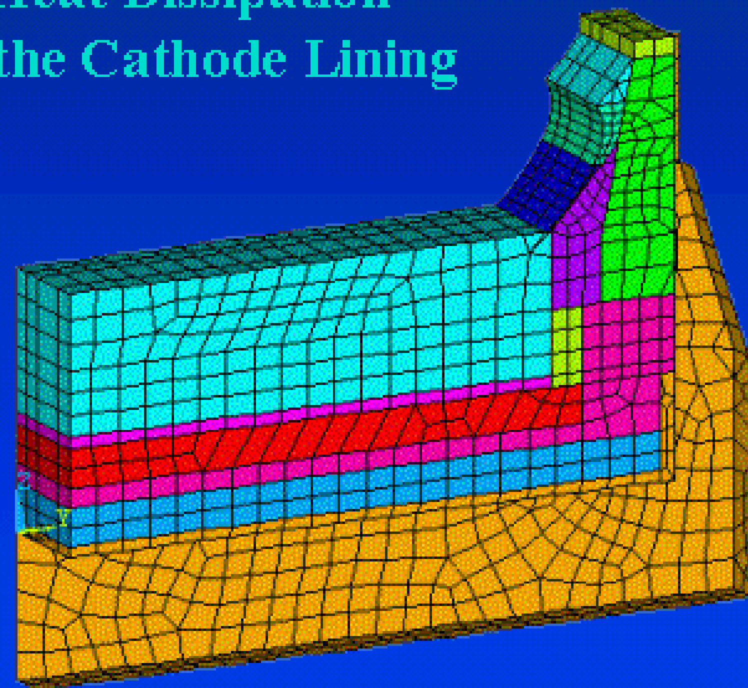
Solution error 0.40 %

Total cathode heat lost 585.52 100.00

Avg. drop at bar end [mV]	Average flex. drop [mV]	Current at cathode surf [Amps]
205.268	7.475	4166.667

Targeted cell current: 500000.00 Amps
Obtained cell current: 500000.00 Amps
Solution error 0.00 %

- Total Voltage Drop Across the Cathode Lining
- Global Heat Dissipation Across the Cathode Lining



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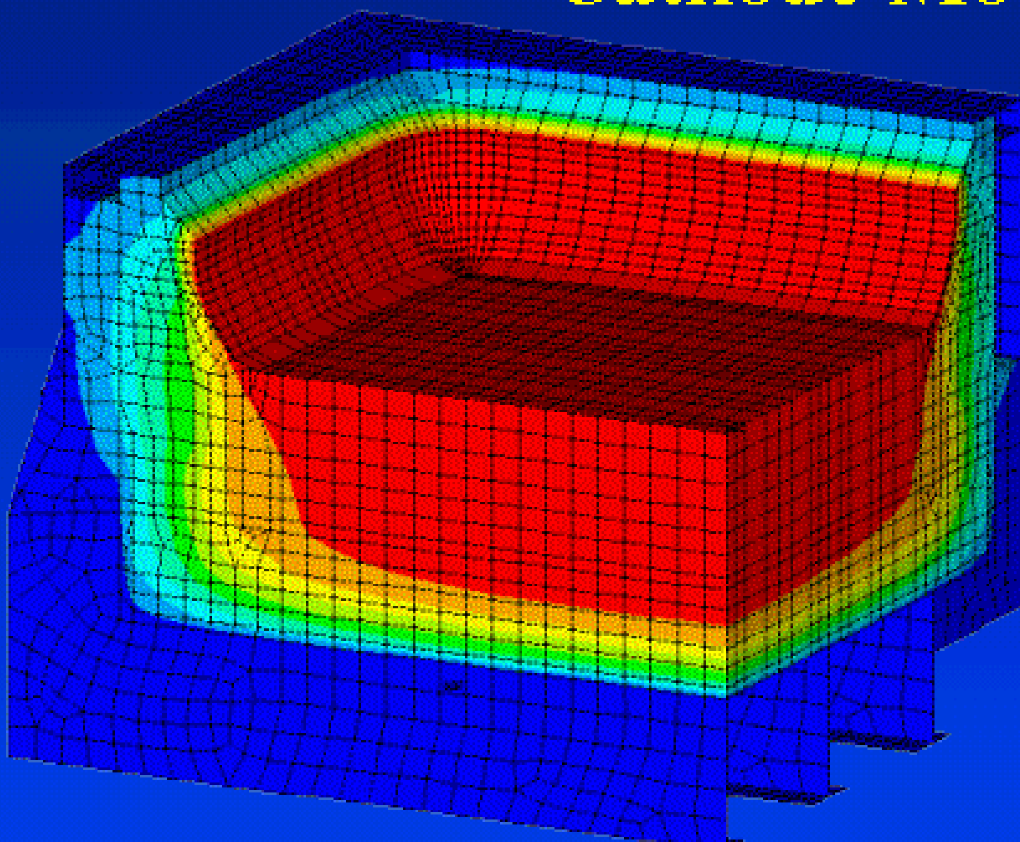
Thermo-electric Corner/Quarter Cathode Model



- More Accurate Global Cathode Heat Dissipation
- Total Voltage Drop Across Cathode Lining
- Corner Ledge Profile

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Validation of the Model Results

Thermal Blitz: Heat Flux Measurements

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Thermal Blitz: Results

Heat Flux Measurements for Cell Heat Balance

date: 8-Sep-97 slice no: A2
cell: "VAW" 300

Description	Flux	Temp
Shell Wall		
Wall above bath level	2000	150
Wall bath level	5500	230
Wall metal level	7500	250
Wall block level above bar	6000	235
Left collector bar	5000	150
Right collector bar	3000	190
Wall collector bar level	1500	50
Wall brick level	1000	60
Floor near centerline	500	50
Floor at quarter point	500	50
Floor near corner	500	50
Cradle web		
Wall above bath level	1000	100
Wall bath level	2165	130
Wall metal level	2880	140
Wall block level above bar	955	125
Wall collector bar level	400	80
Wall brick level	155	50
Floor extension	0	0
In the corner	100	35
Wall extension wide section	0	0
Wall extension narrow section	0	0
Floor near centerline	100	35
Floor at quarter point	100	35
Floor near corner	100	35
Cradle flange		
Wall above bath level	500	65
Wall bath level	1085	80
Wall metal level	1550	50
Wall block level above bar	475	40
Wall collector bar level	200	35
Wall brick level	50	30
Under the floor	50	30

Heat Balance Results

date: 8-Sep-97 Cell: "VAW" 300

Cathode Heat Losses	W/m2	kW	%
Shell side wall above bath level	1000	11.51	1.86
Shell side wall opposite to bath	5500	31.68	5.11
Shell side wall opposite to metal	7500	42.10	6.97
Shell side wall opposite to block above bar	6000	48.78	7.80
Shell side wall opposite to block between bars	1500	6.48	1.05
Collector bars to air	1000	17.28	2.79
Collector bars to flexible		60	9.68
Shell side wall opposite to brick	1000	11.51	1.86
Shell floor close to corner	500	12.54	2.01
Shell floor quarter point region	500	10.44	1.68
Shell floor centerline region	500	8.24	1.24
Cradle above bath level	889	6.08	0.98
Cradle opposite to bath	1915	13.17	2.12
Cradle opposite to metal	2164	16.17	2.61
Cradle opposite to block above bar	848	8.11	1.31
Cradle opposite to block between bars	756	2.41	0.39
Cradle opposite to brick	171	1.80	0.29
Cradle corner	51	1.51	0.25
Cradle below floor close to corner	100	2.76	0.44
Cradle below floor quarter point region	100	2.76	0.44
Cradle below floor centerline region	100	2.76	0.44
Shell end wall opposite to metal	1500	2.61	0.42
Shell end wall opposite to block above bar	1000	7.11	1.15
Shell end wall opposite to block below top of bar	4000	6.96	1.12
Shell end wall opposite to brick	1000	10.44	1.68
Shell coverplate in the ends	500	1.51	0.25
Shell horizontal strip in the ends	1184	18.00	2.90
Shell vertical stiffeners in the ends	898	5.51	0.89
Shell horizontal stiffeners in the ends	100	0.45	0.07
Total for the cathode part		371.76	59.95
Anode Heat Losses			
Crust in side channels	1700	21.48	3.46
Crust above anodes	1800	81.91	13.21
Crust in center channel	1750	3.60	0.58
Studs	4000	27.14	4.38
Yoke	7640	87.87	14.17
Aluminum rod	811	30.31	4.89
Total for the anode part		248.3	40.05
Total for the cell		620.1	100.00

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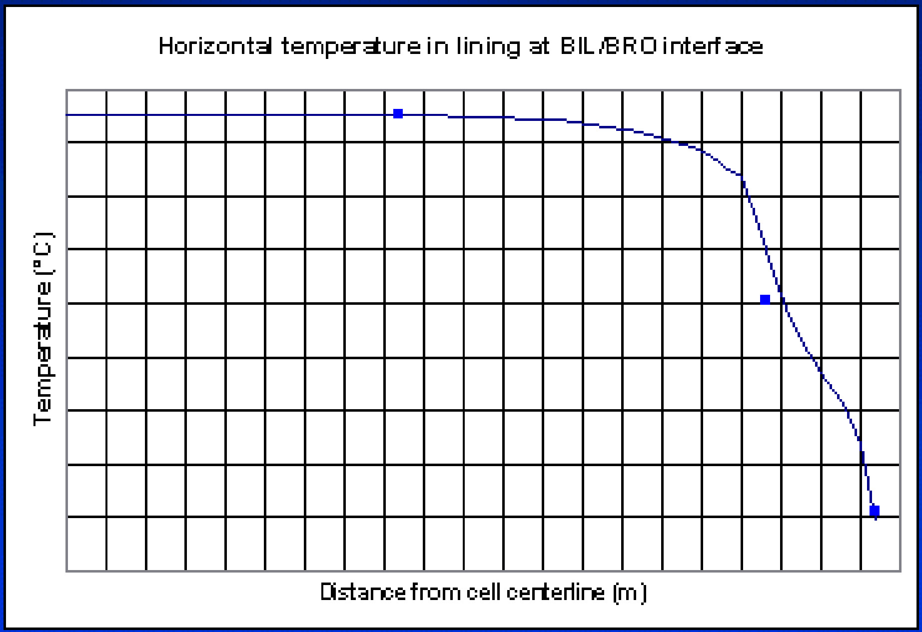
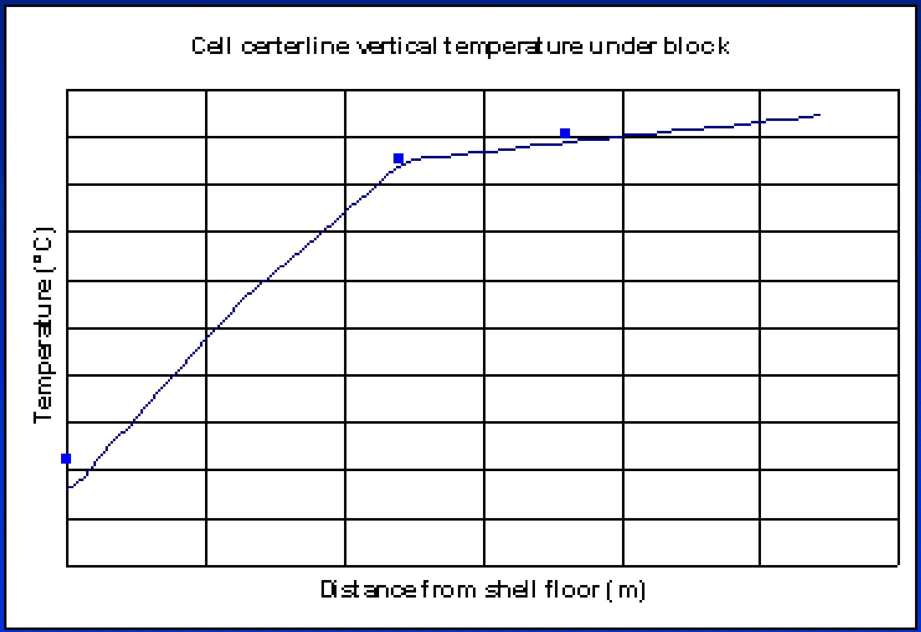
Validation of the Model Results





Instrumented Cathode Lining:
Cathode Lining Temperature Comparison

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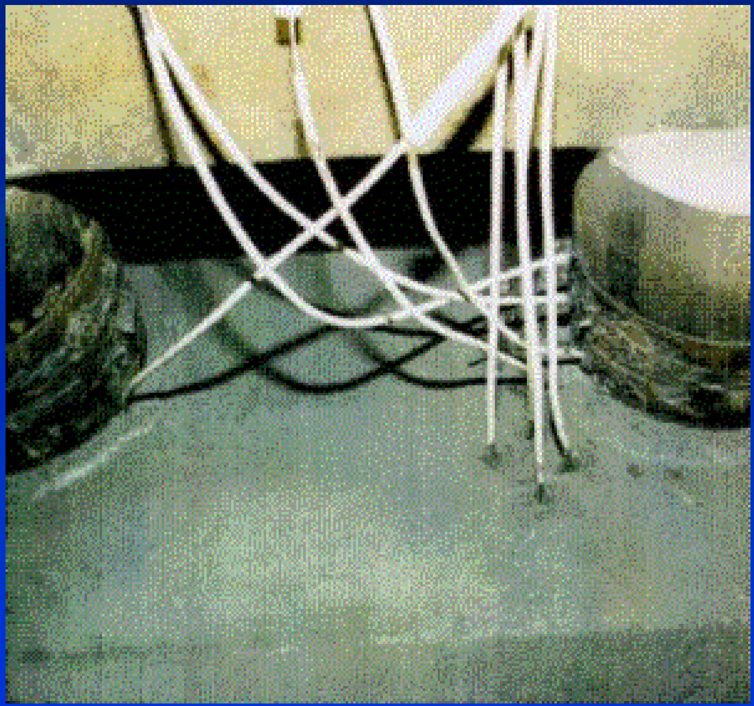
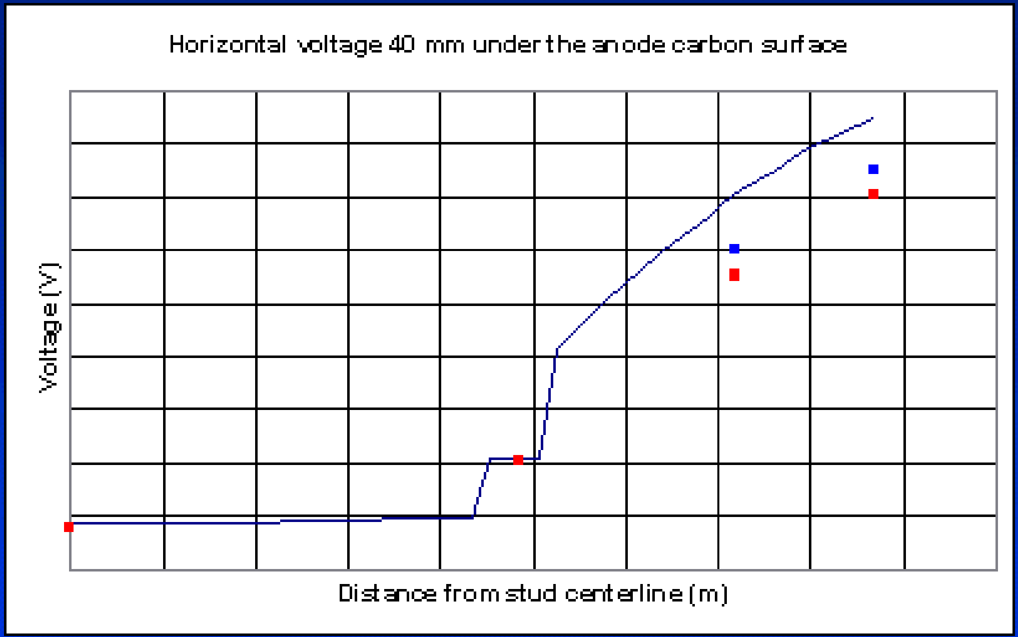
Validation of the Model Results





Instrumented Anode:

Anode Stud Voltage Drop Comparison

Initial Smelter's Productivity Improvement

	START-UP	LATEST POTS
PRODUCTION :		
▪ Production per pot/day (kg)	2245	2466
▪ Current efficiency (%)	94.5	96
POWER :		
▪ Amperage (kA)	295	319
▪ Pot voltage (V)	4.330	4.185
▪ DC kWh/t	13 650	13 000
CONSUMPTIONS :		
▪ Gross carbon (kg/t)	540	493
▪ Net carbon (kg/t)	410	397
▪ Anodes cycle-shifts-8 hours	80	90
METAL PURITY :		
▪ Iron (ppm)	---	700
▪ Silicon (ppm)	---	240
POT CONDITION :		
▪ Anode effects (pot/day)	0.40	0.20

Tableau no. 1 : Lauralco's results

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Conclusions

- The Models represent for Lauralco Powerful Tools to Pursue the Development of the Technology
- The development of the Models was for Lauralco a Strong Learning Process

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