

# Excess $\text{AlF}_3$ Concentration in Bath Control Logic

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# Plan of the Presentation

- $\text{AlF}_3$  mass balance
- $\text{AlF}_3$  deposit
- Control logic based on bath sampling
- Control logic based on bath temperature measurement
- Control logic based on both bath sampling and bath temperature measurement
- Conclusions

# AlF<sub>3</sub> Mass Balance

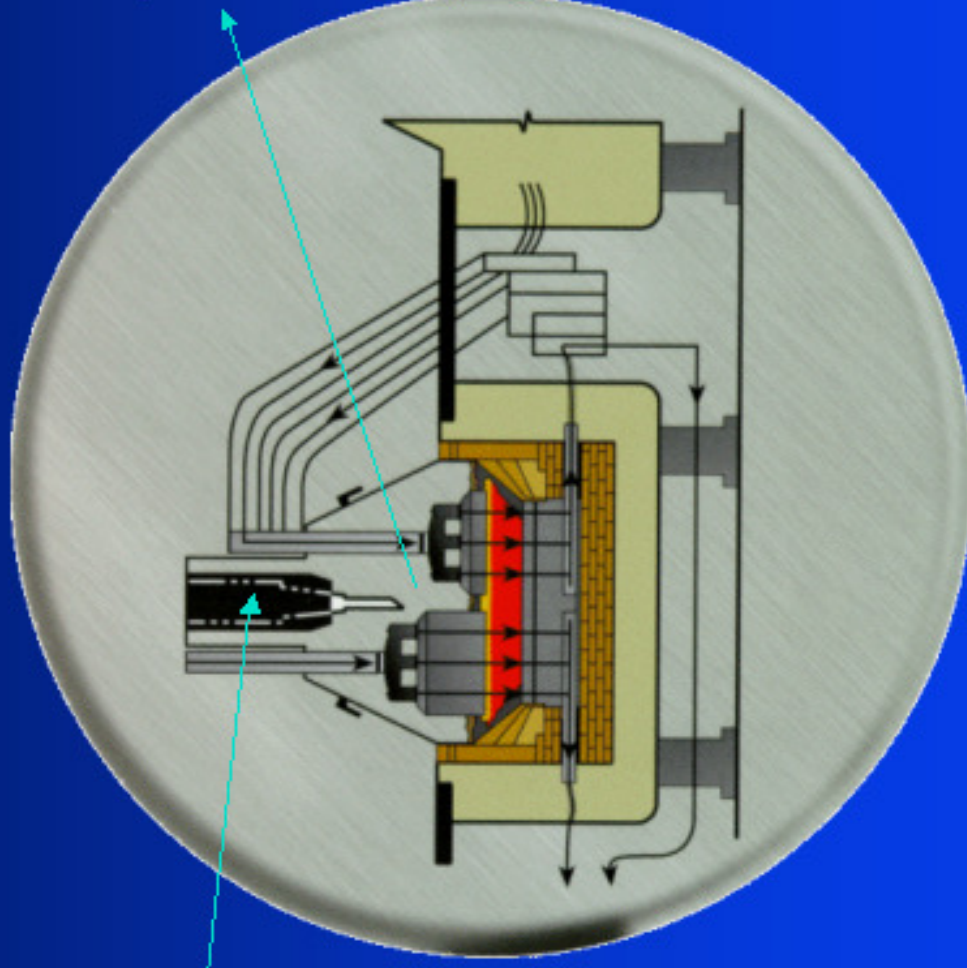
In:

Alumina

$$\frac{2}{102} \times 175.9 = 3.45 \frac{\text{kg}}{\text{hr}} \text{AlF}_3$$

Direct feeding

$$1.19 \frac{\text{kg}}{\text{hr}} \text{AlF}_3$$

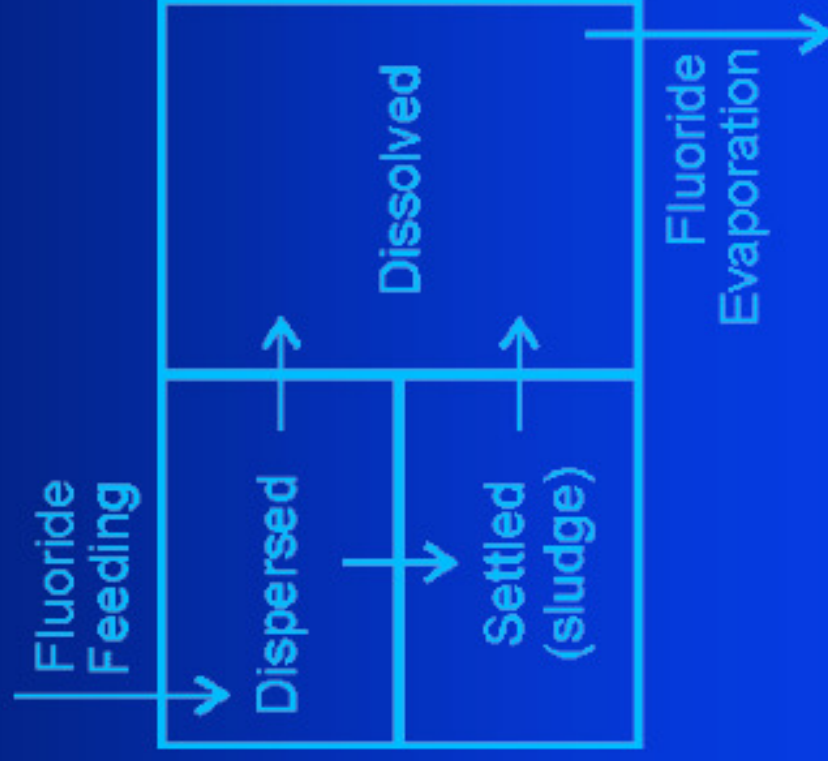


Out:

AlF<sub>3</sub> evolution

$$338 \times \frac{93.13}{1000} \times \frac{84}{57} = 464 \frac{\text{kg}}{\text{hr}} \text{AlF}_3$$

# $\text{AlF}_3$ Deposit



The observed time lag between the time of the direct  $\text{AlF}_3$  addition and its impact on the excess  $\text{AlF}_3$  concentration in the bath is explained by a form of  $\text{AlF}_3$  “deposit”. If we assume that  $\text{AlF}_3$ , like alumina, when added to the cell forms first a dispersed phase in the bath before dissolving, it is also normal to assume that that dispersed phase can also, like alumina, settle down as sludge on the cathode surface.



# AlF<sub>3</sub> Deposit

**DYNARE: Mass Balance AlF<sub>3</sub> Dissolution**

Dissolution Rate of Dispersed AlF<sub>3</sub>

Dissolution Constant  1/hr

Reference Temperature  °C

Rate of Change with Temperature  1/°C

Sedimentation Rate of Dispersed AlF<sub>3</sub>

Kinematic Constant of Sedimentation  1/hr

Dissolution Rate of Sludge

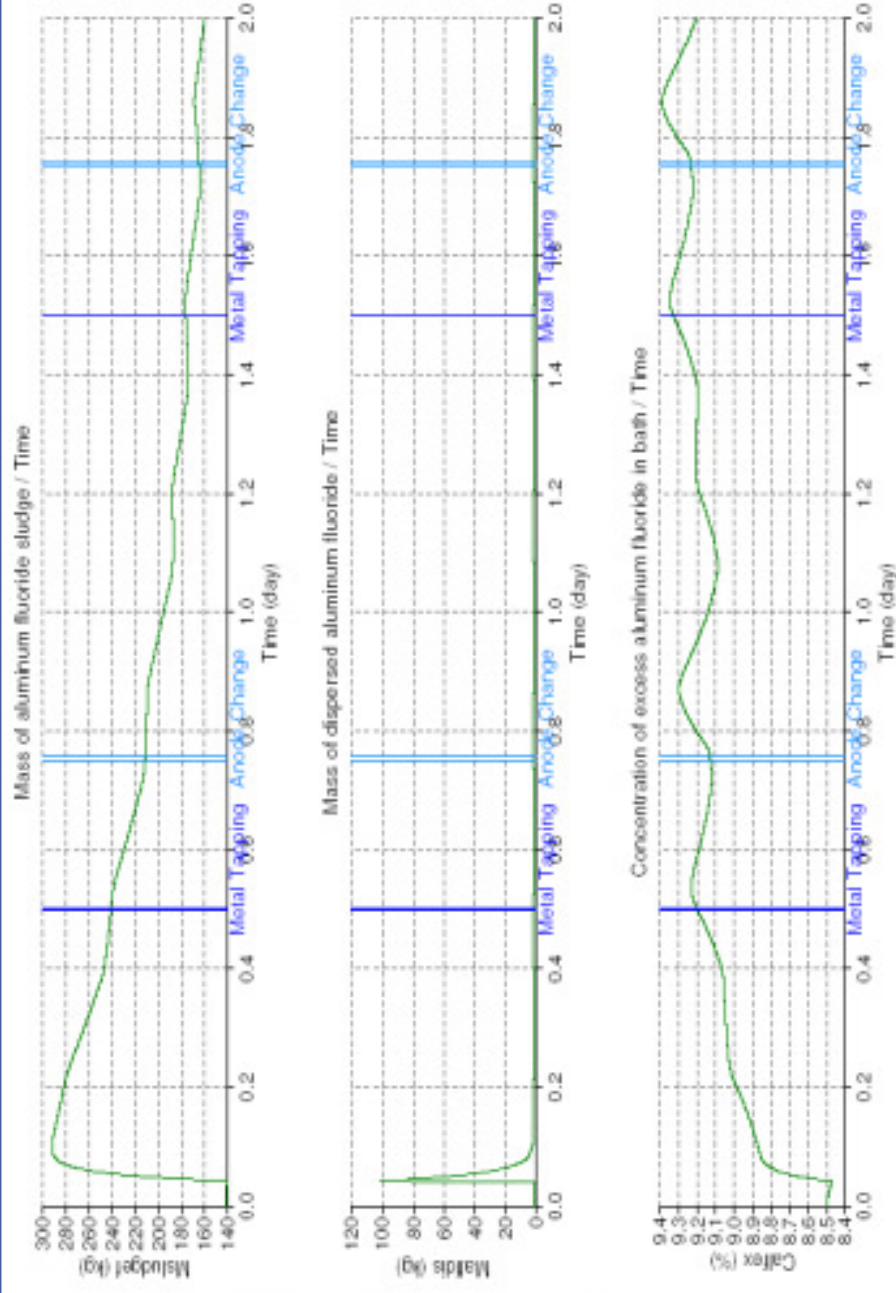
Sludge Dissolution Factor

Physical Characteristics

Density of Dispersed AlF<sub>3</sub> in Bath  kg/m<sup>3</sup>

Density of AlF<sub>3</sub> Sludge  kg/m<sup>3</sup>

Concentration of AlF<sub>3</sub> in Sludge  %



Cell response to an instantaneous 100 kg AlF<sub>3</sub> addition

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# Control logic based on bath sampling

**DYNA/MARC: Ratio Control**

**AlF3 Additions**

☒ Event is Continuous  
Rate  kg/hr

☐ Event is Periodic  
Amount  kg  
Frequency  D:H:M:S  
Duration  M:S  
Start Time  D:H:M:S

**Physical Properties**

Temperature  °C  
Specific Heat  J/kg °C  
Heat of Dissolution  kJ/kg

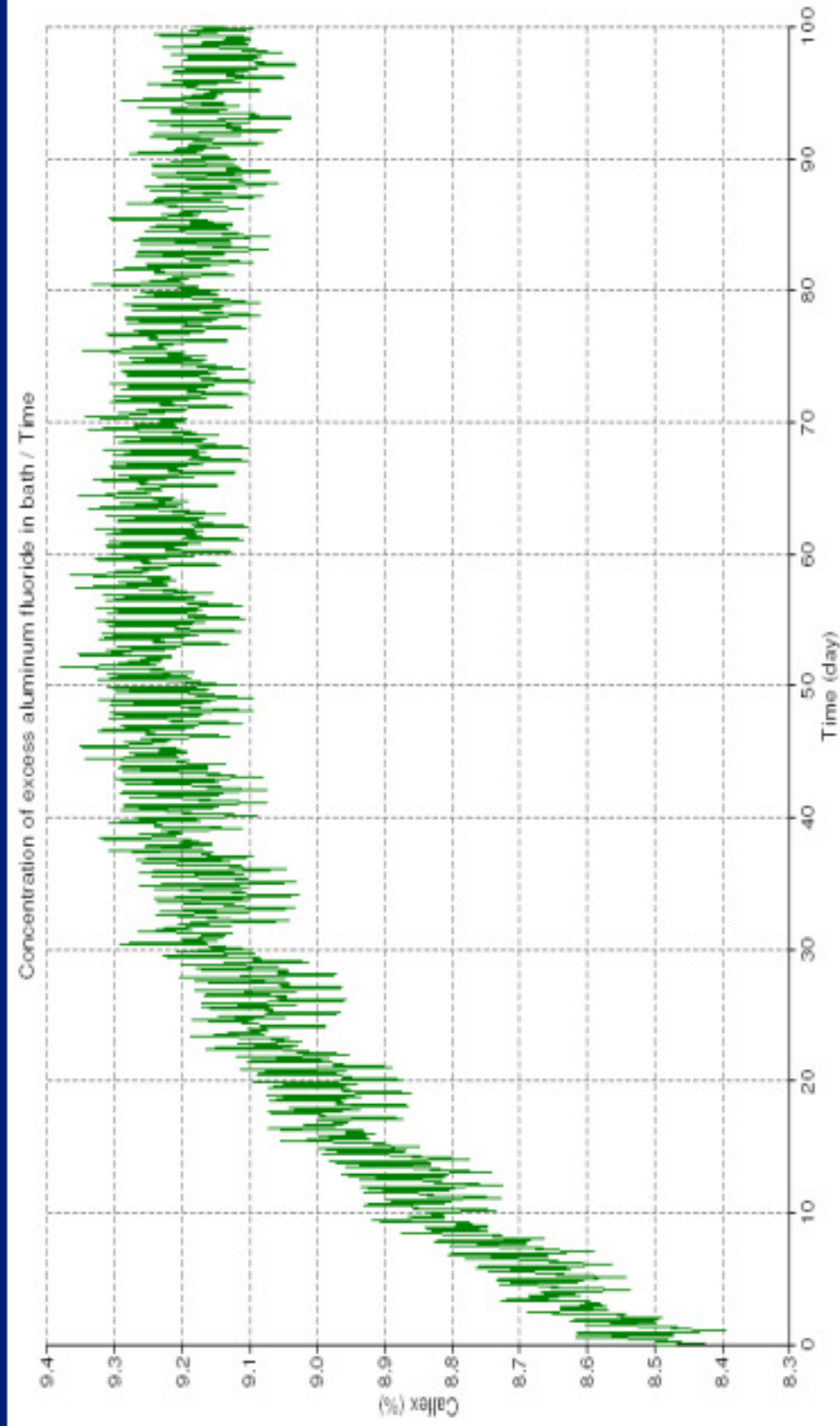
**AlF3 (Bath) Sampling**

Frequency  D:H:M:S  
Start Time  D:H:M:S  
AlF3 Conc. Target  %  
% Feed Change per % Off  % / %  
AlF3 Conc. Proportional Constant  kg/hr %  
Temperature Proportional Constant  kg/hr °C  
Target temperature  °C

Starting with a constant 1.2 kg per hour direct AlF3 feeding rate

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# Control logic based on bath sampling

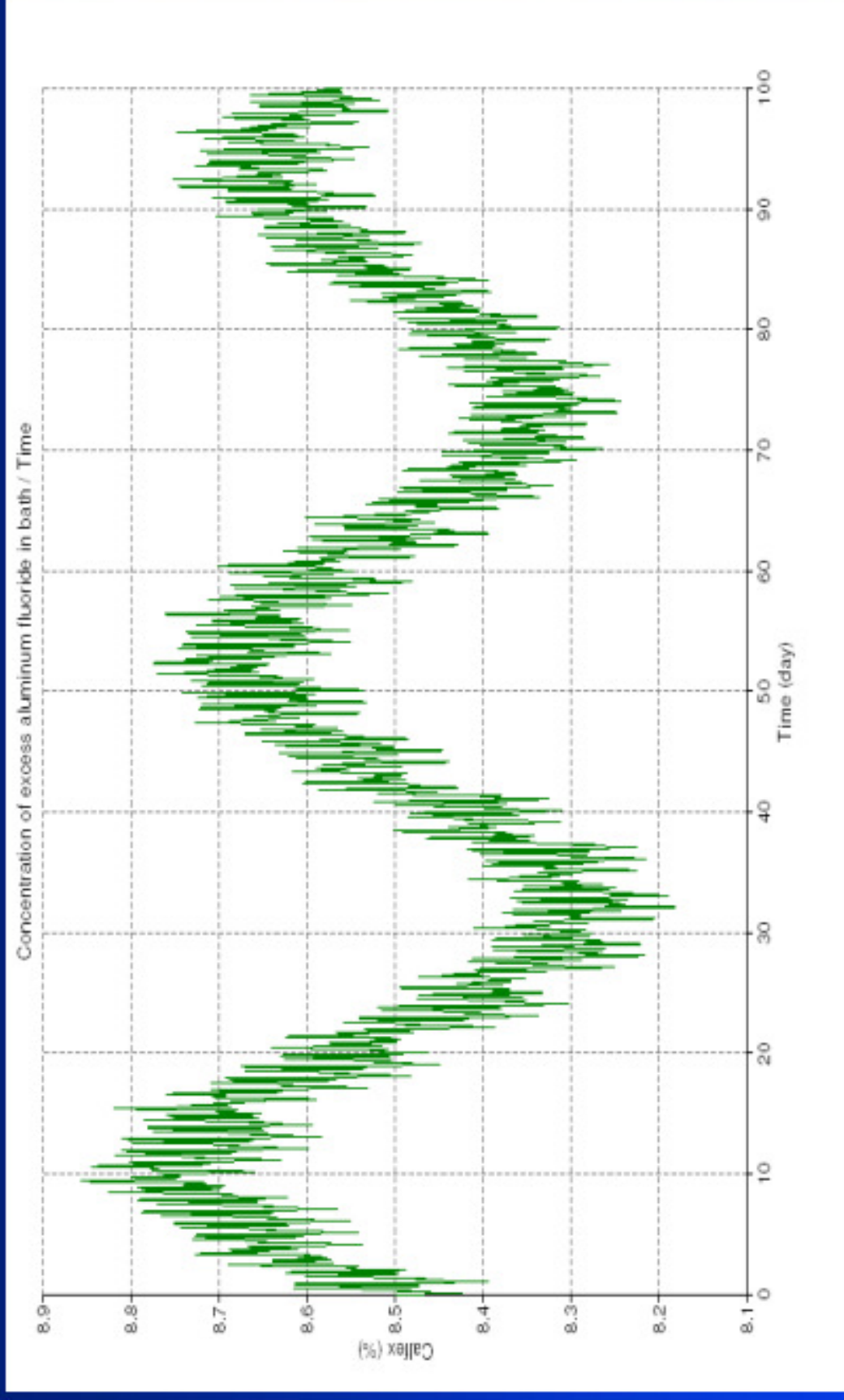


100 days response without feedback control

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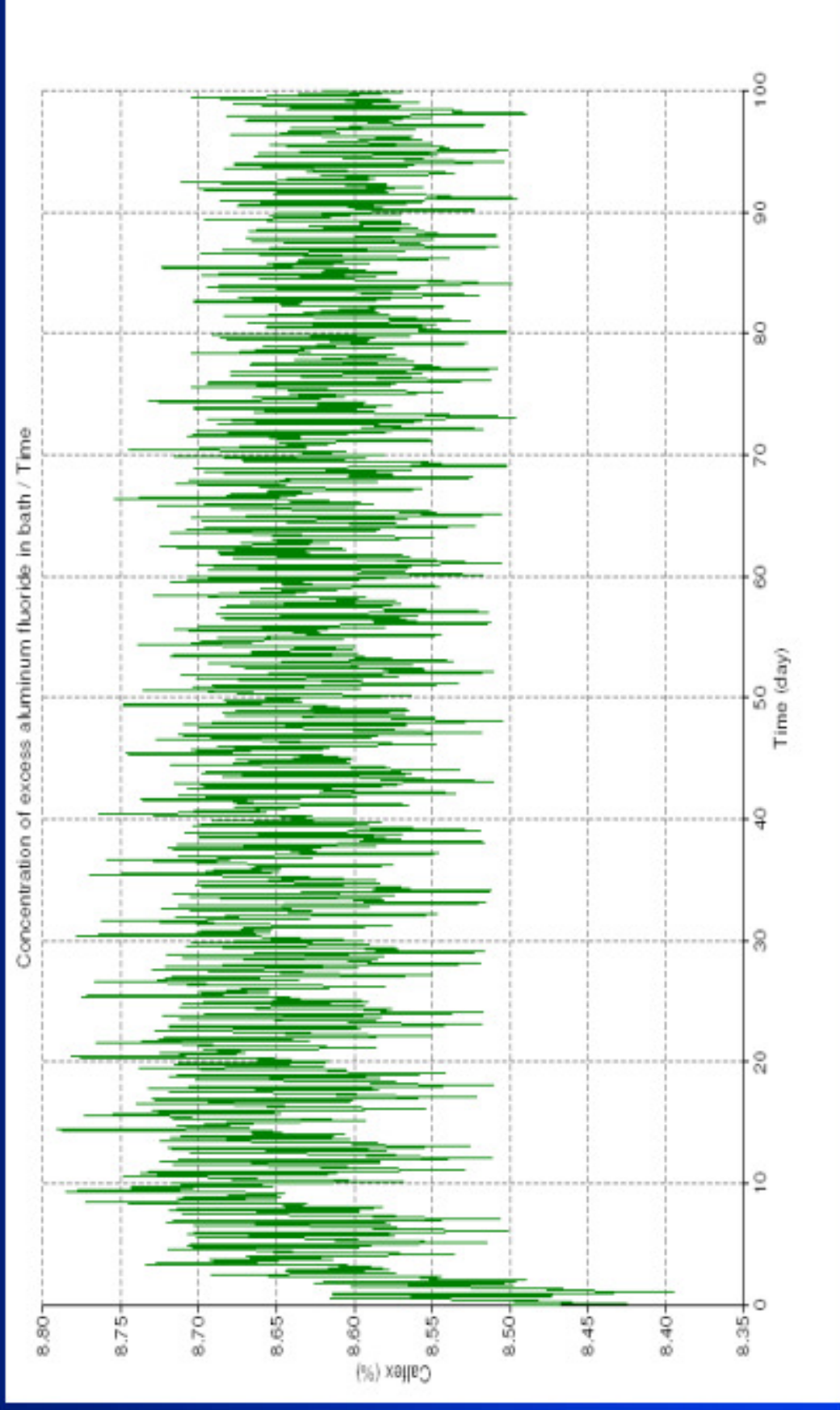
# Control logic based on bath sampling



Integral control 10%/%, 1 sample per day, 1 day delay



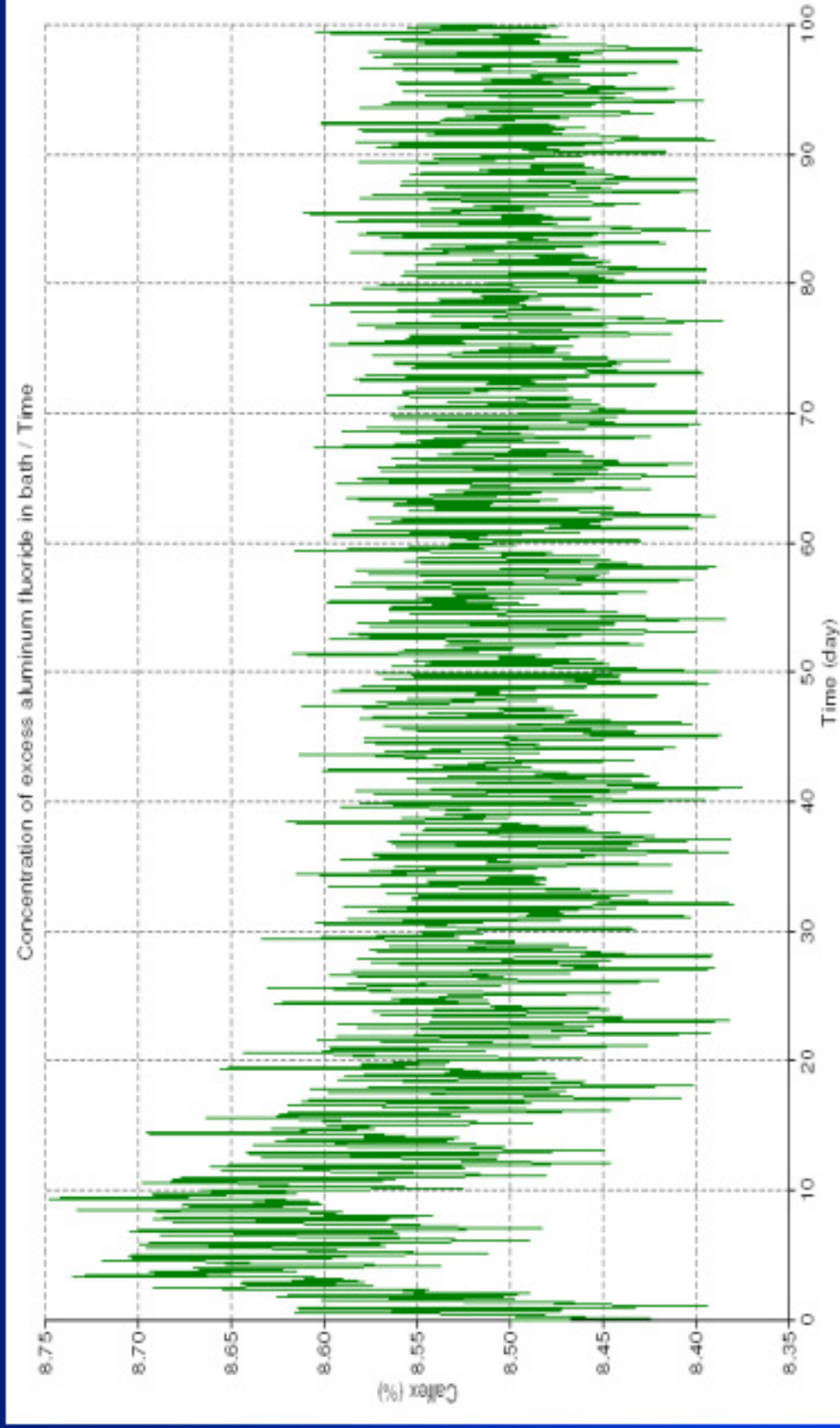
# Control logic based on bath sampling



Proportional control 1 kg/hr%, 1 sample per day, 1 day delay

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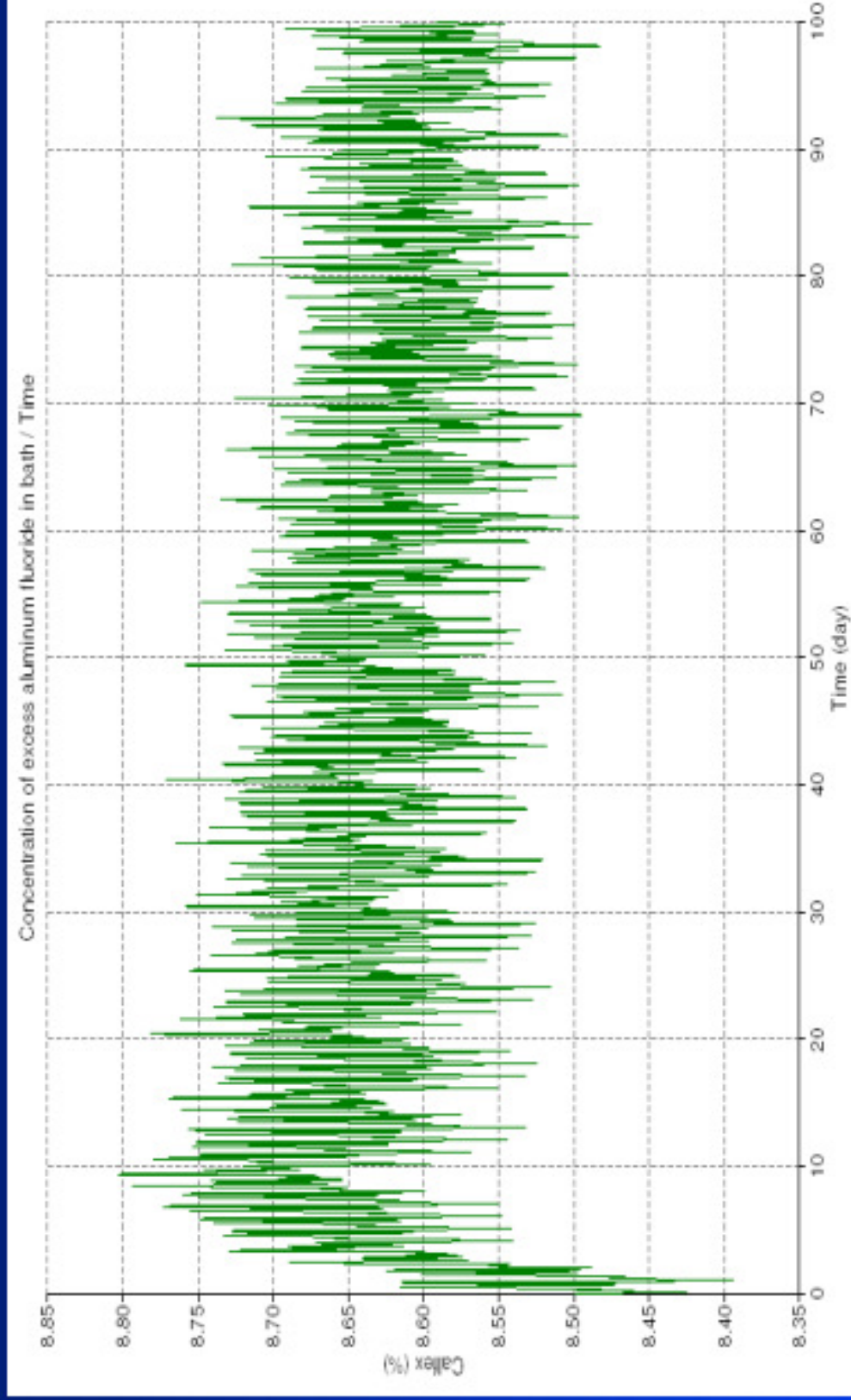
# Control logic based on bath sampling



PI control 1 kg/hr% and 10%/%, 1 sample per day, 1 day delay

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# Control logic based on bath sampling

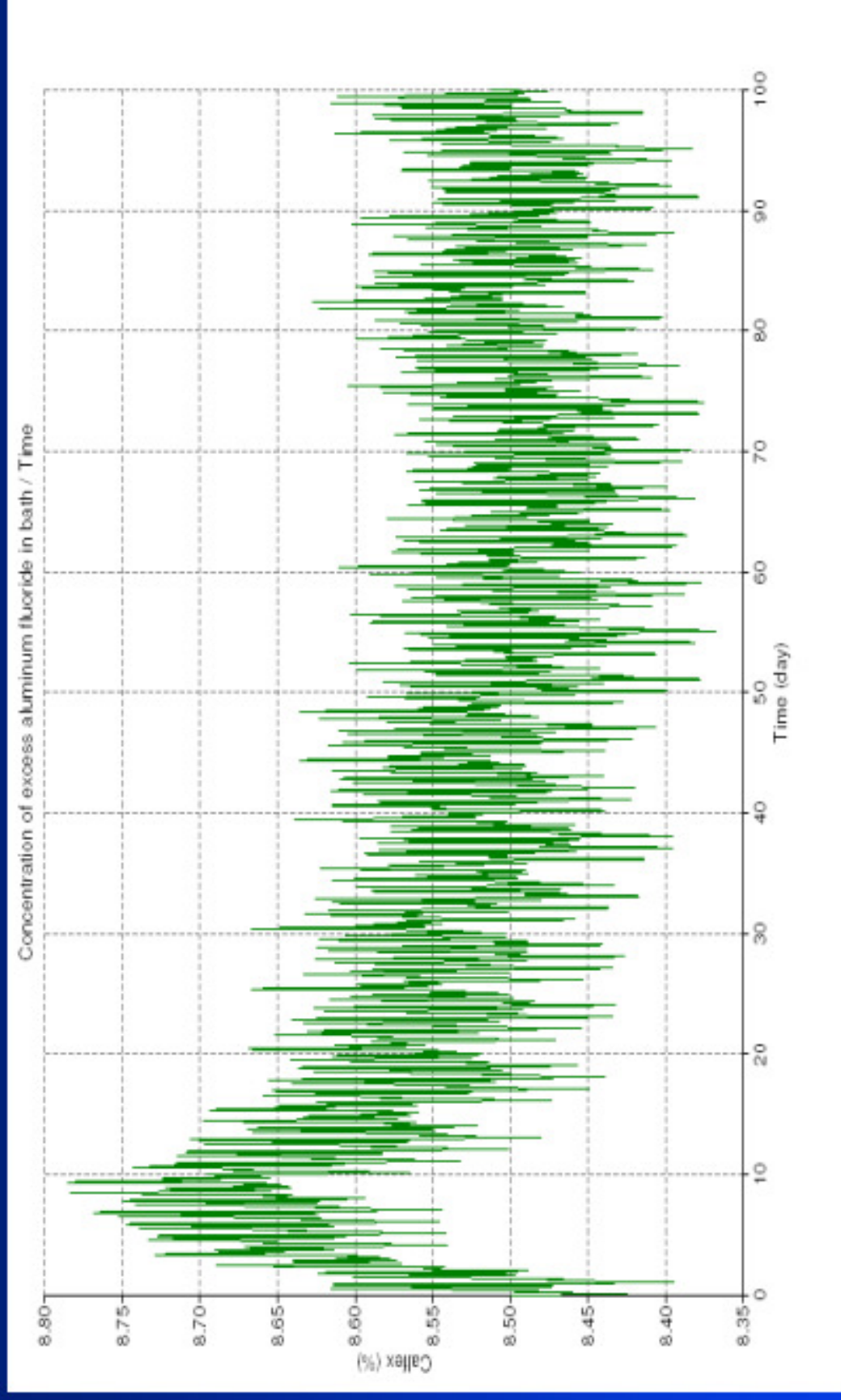


Proportional control 1 kg/hr%, 1 sample per 2 days, 2 days delay

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# Control logic based on bath sampling

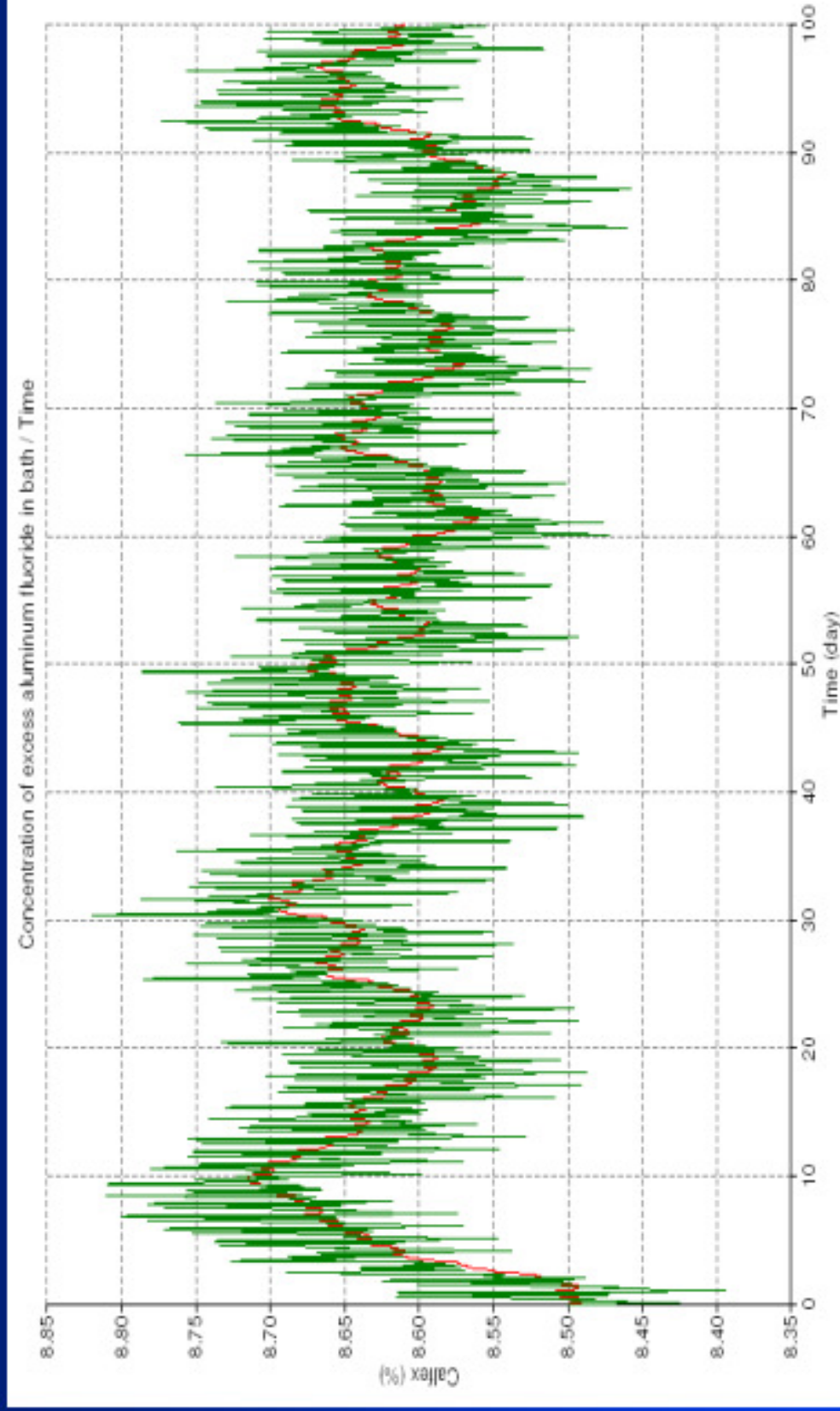


PI control 1 kg/hr% and 10%/%, 1 sample per 2 days, 2 days delay

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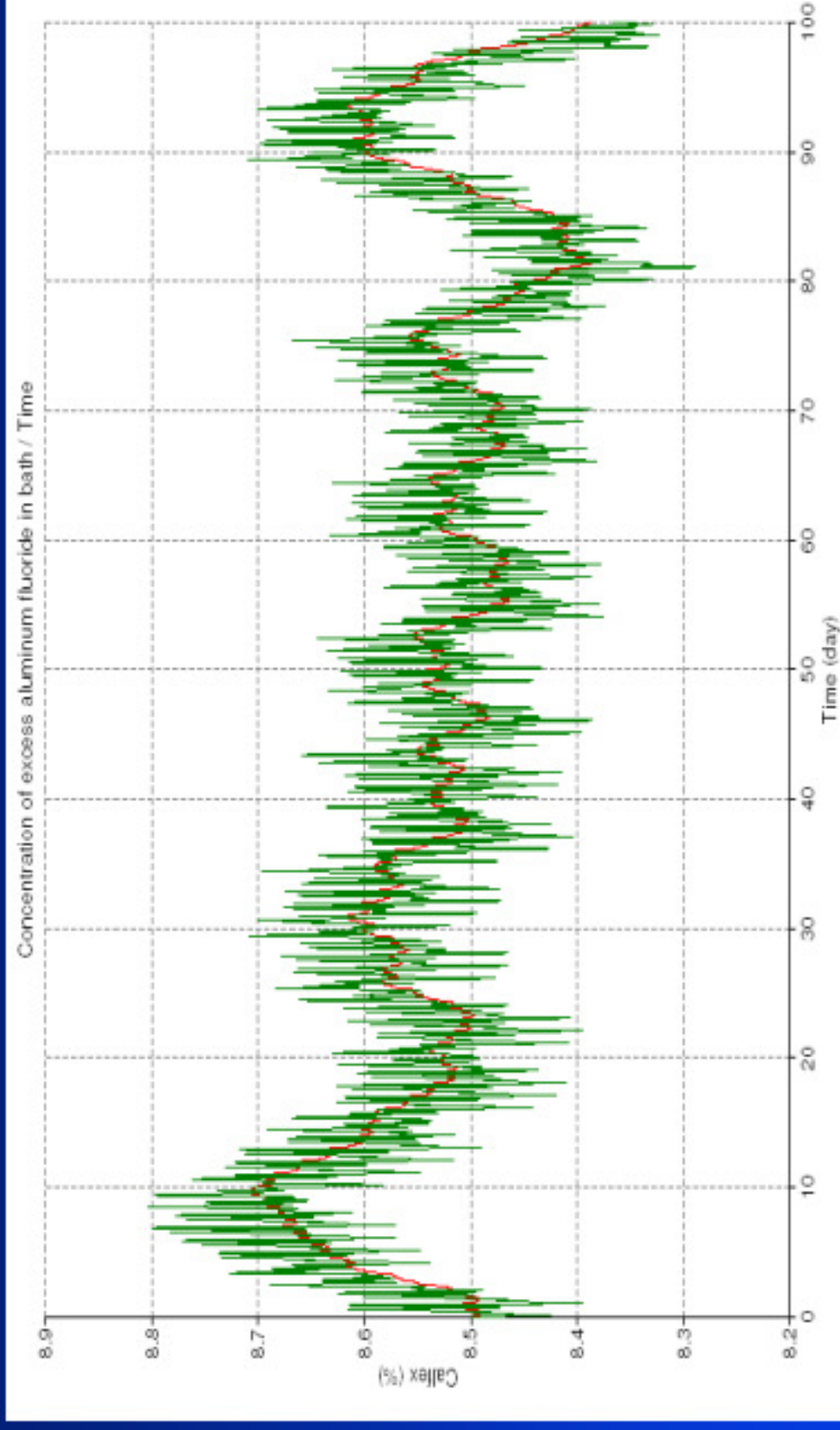
# Control logic based on bath sampling



Proportional control 1 kg/hr%, 1 sample per 3 days, 3 days delay

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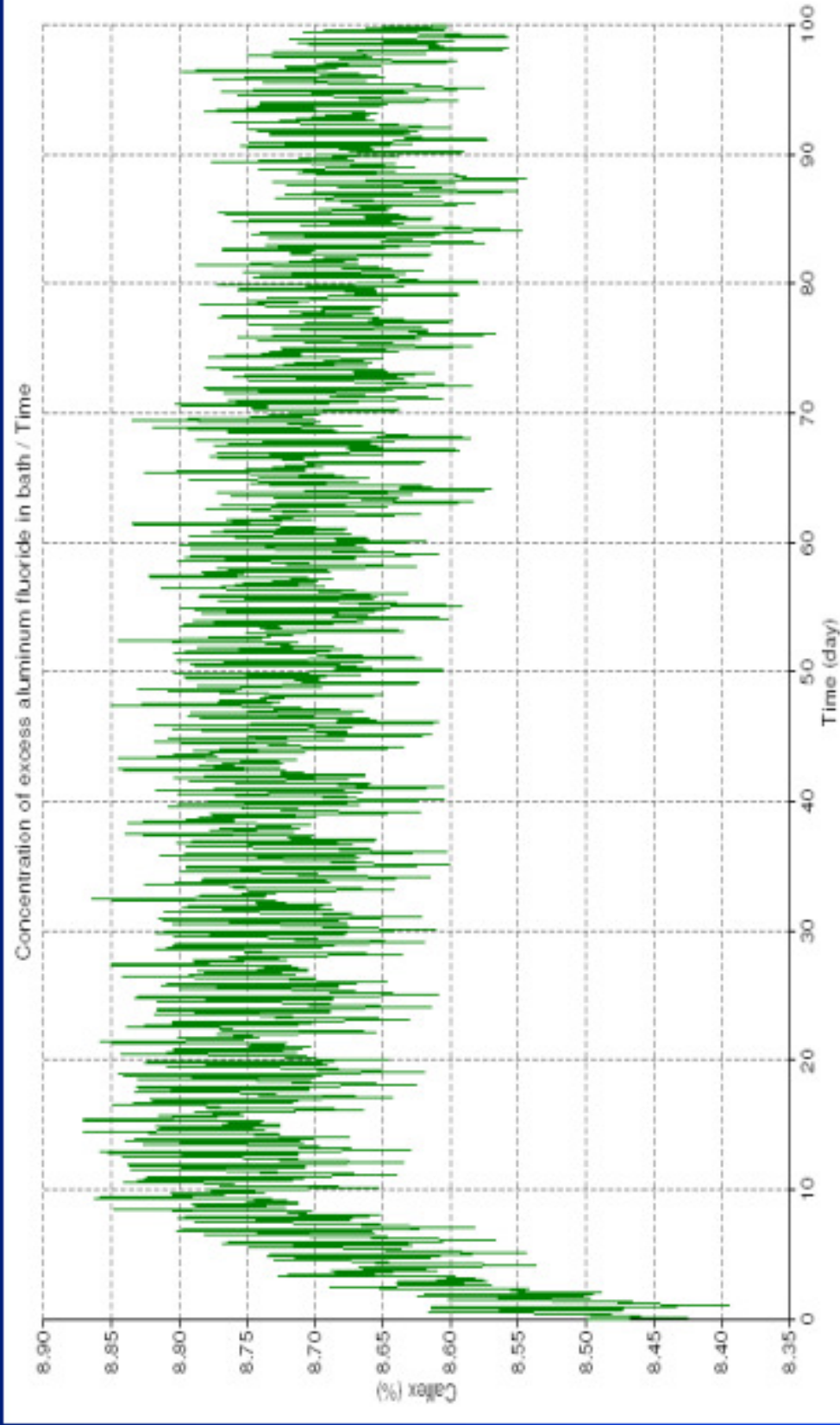
# Control logic based on bath sampling



PI control 1 kg/hr% and 10%/%, 1 sample per 3 days, 3 days delay

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# Control logic based on bath sampling

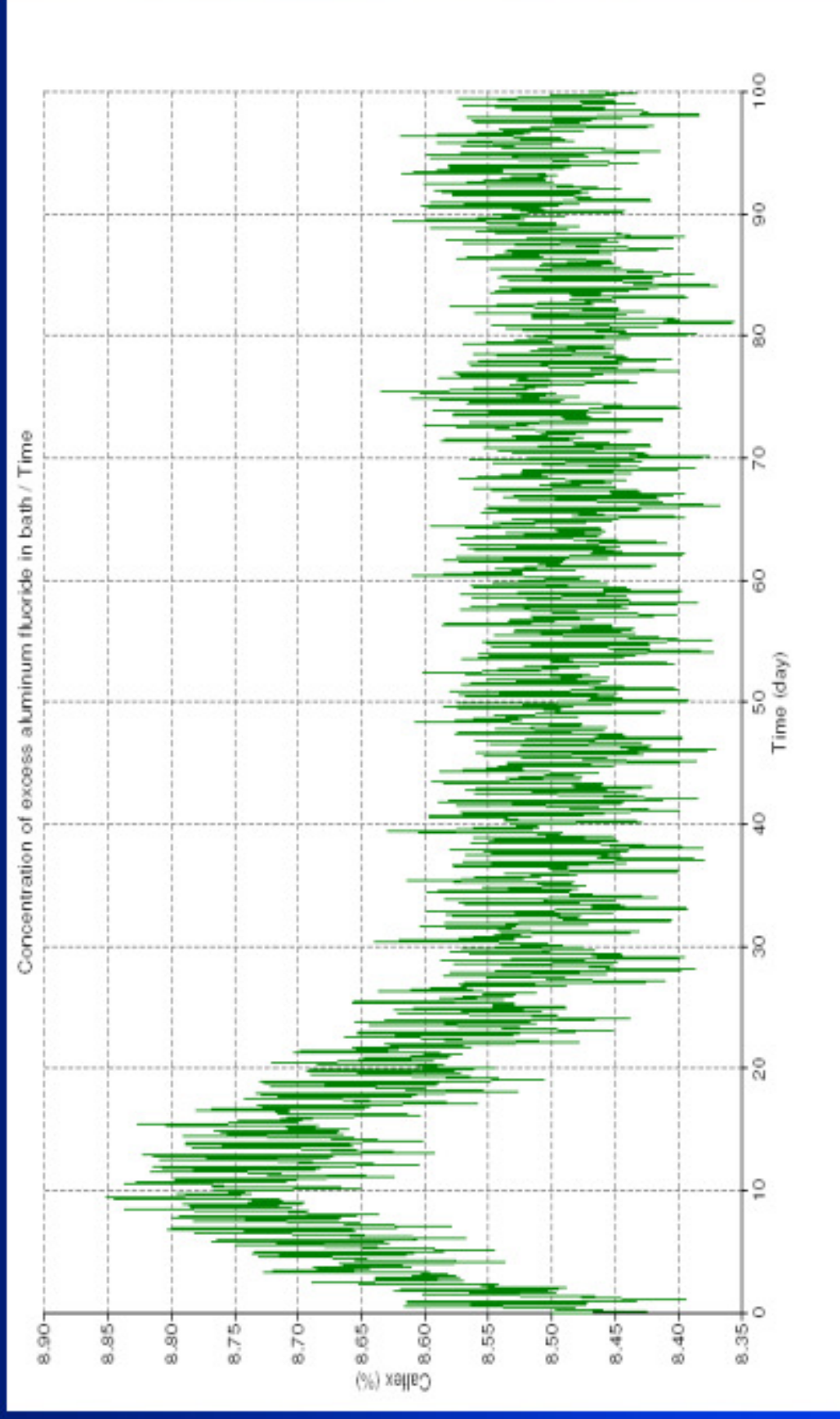


Proportional control 0.5 kg/hr%, 1 sample per 3 days, 3 days delay

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# Control logic based on bath sampling

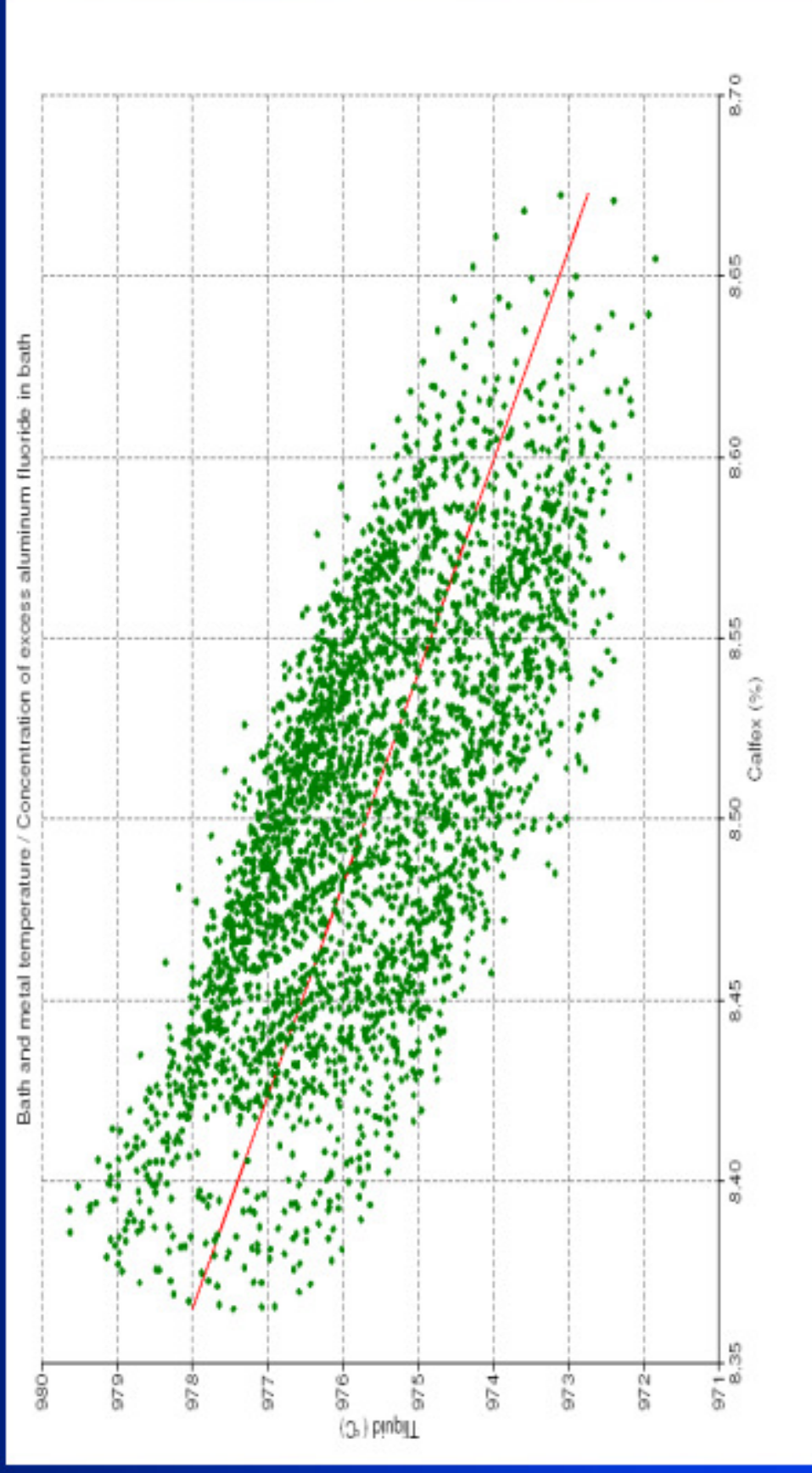


PI control 0.5 kg/hr% and 10%/%, 1 sample per 3 days, 3 days delay

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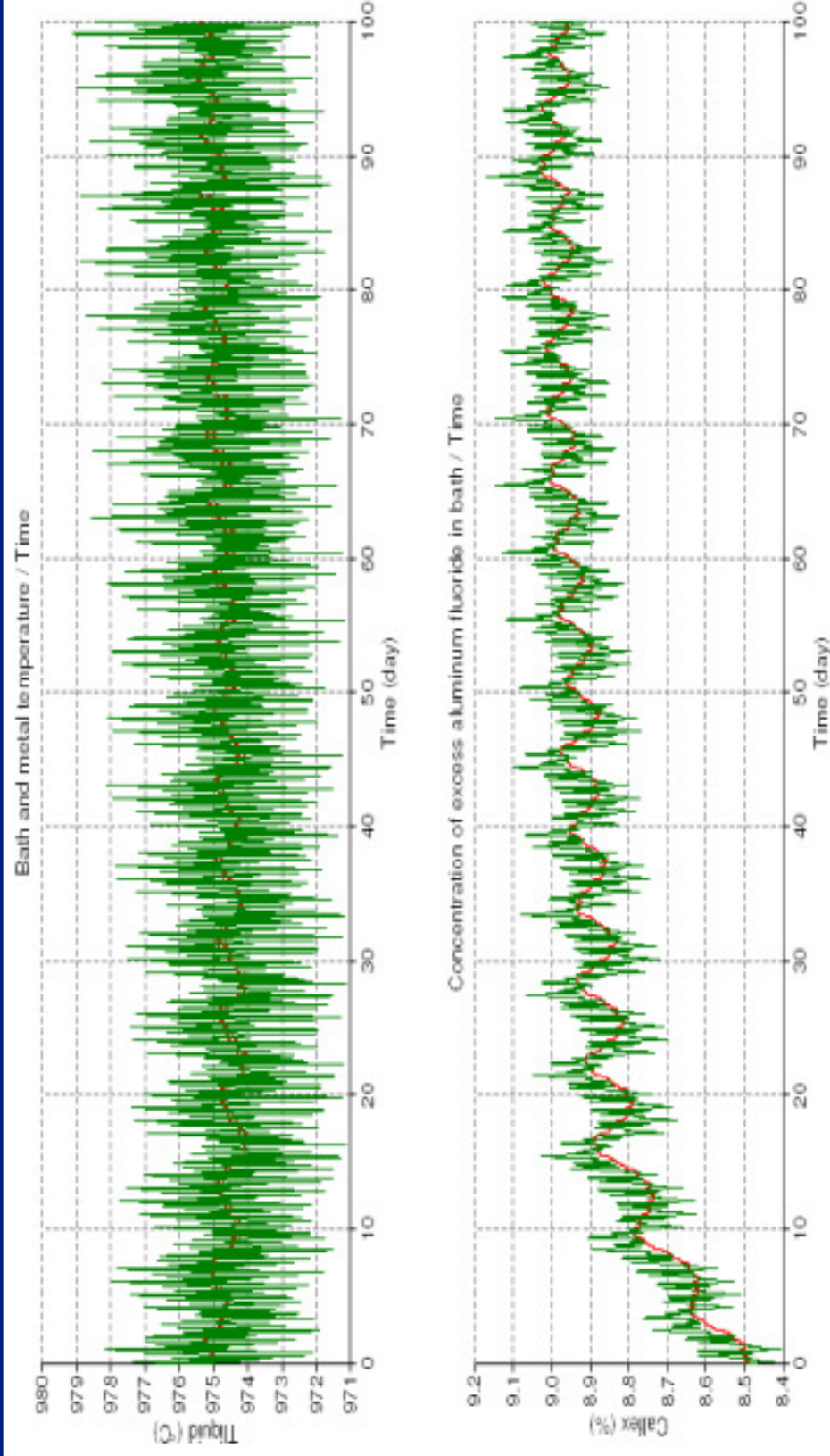


# Control Logic Based on Bath Temperature Measurement



Correlation between excess  $\text{AlF}_3$  temperature and bath temperature 3%  $\text{CaF}_2$

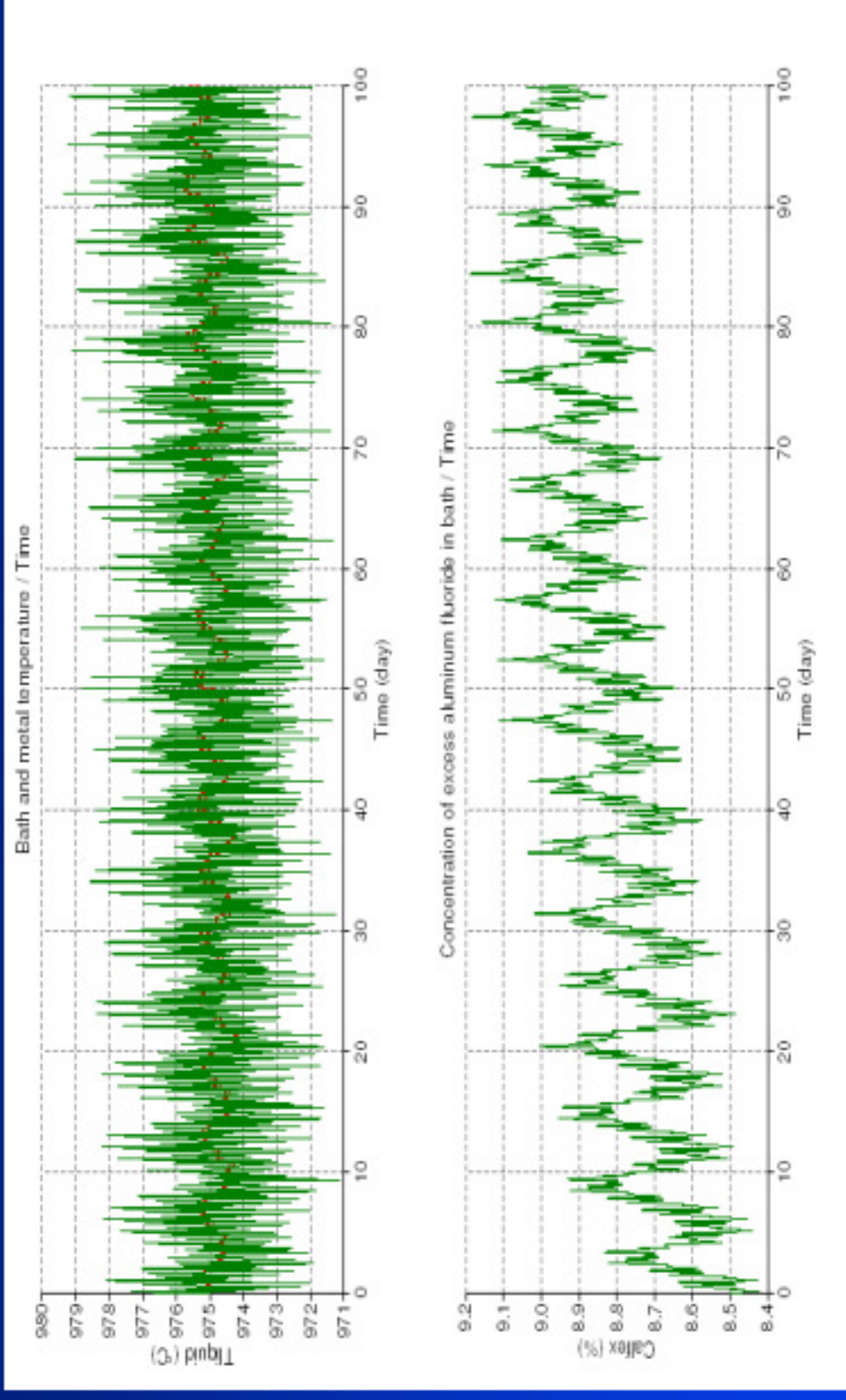
# Control Logic Based on Bath Temperature Measurement



Proportional control 0.1 kg/hr°C, 1 measure per day, no delay

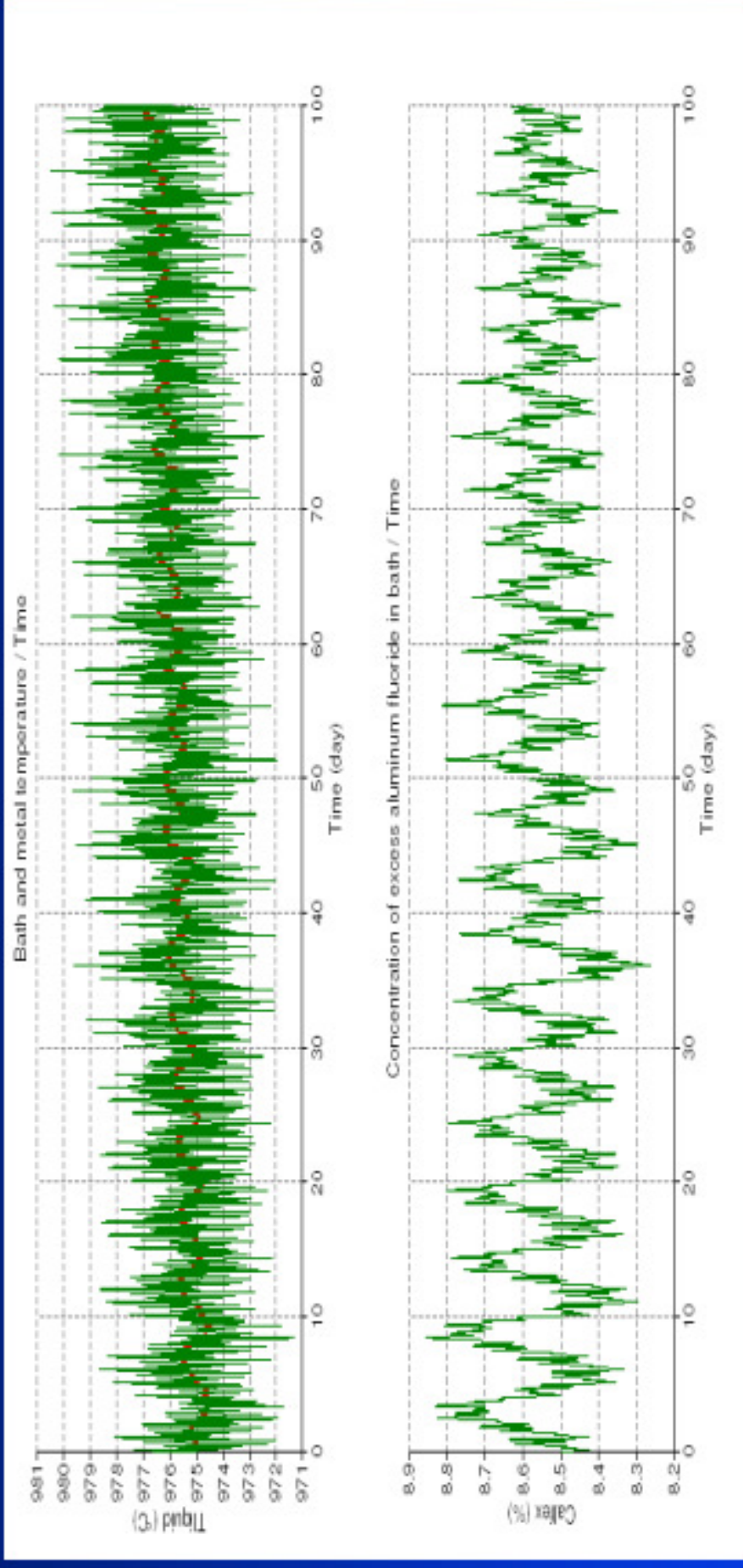


# Control Logic Based on Bath Temperature Measurement



Proportional control 0.3 kg/hr°C, 1 measure per day, no delay

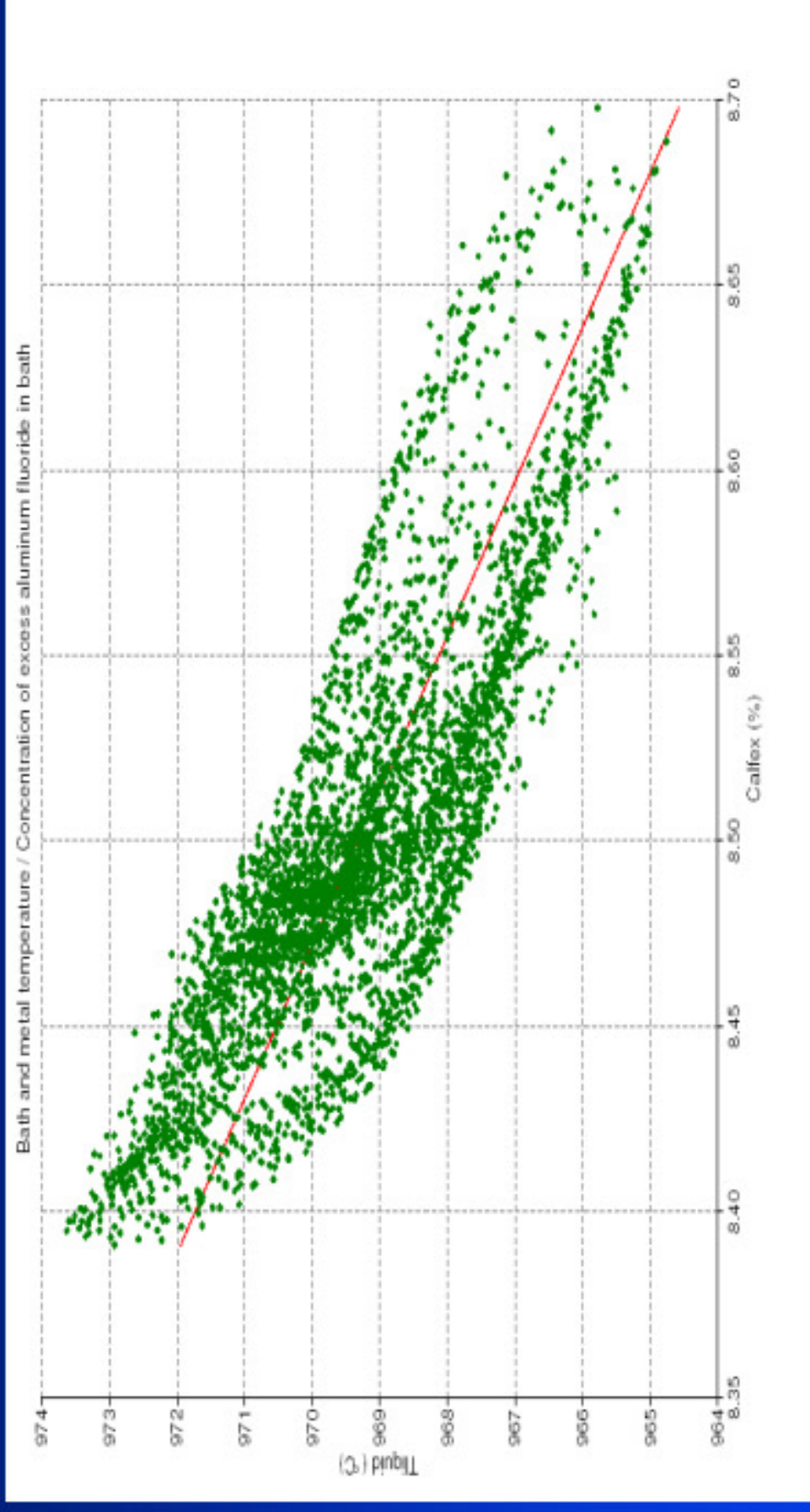
# Control logic based on both bath sampling and bath temperature measurement



PI mixed control 1 kg/hr% and 10%/%, 1 sample per day, 1 day delay,  
0.3 kg/hr°C, 1 temperature measurement per day, no delay

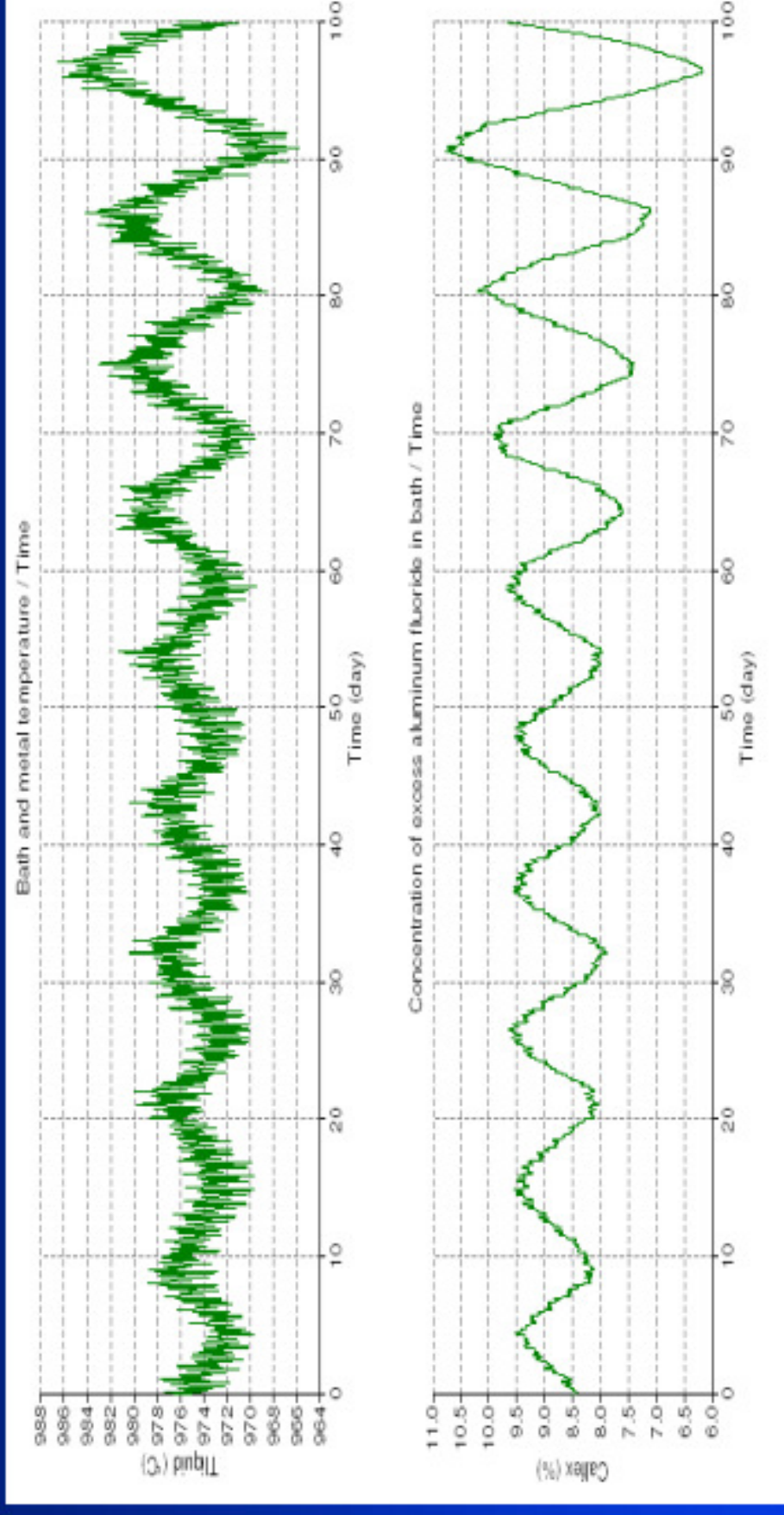


# Control logic based on both bath sampling and bath temperature measurement



Correlation between excess AlF<sub>3</sub> temperature and bath temperature 8% CaF<sub>2</sub>

# Control logic based on both bath sampling and bath temperature measurement



PI mixed control 1 kg/hr% and 10%/%, 1 sample per day, 1 day delay, 0.3 kg/hr°C, 1 temperature measurement per day, no delay, 970 °C setpoint



# Conclusions

- Clearly, using a mixed bath sample analysis and bath temperature double targets control strategy is a very bad choice of control strategy. Is there any other industrial process that is essentially using 2 controllers to control the same process variable?
- Using the cell operating temperature alone to control the excess ALF3 concentration in the bath is not very efficient either as the daily evolution of the bath temperature is much more influenced by other parameters like feeding regime than it is affected by the excess ALF3 concentration in the bath.
- Directly using the bath sample analysis results seems to be the most effective control strategy despite the fact that it involves the introduction of a time lag in the feedback loop.
- A time lag of up to 3 days between the sample collection and the report of the results is even manageable if the proportional constant is set appropriately in order to avoid overshooting.