CO_2 Electrolysis with High Conversion Fraction for CO Utilization and Energy Efficiency

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or

5 minutes of terror!

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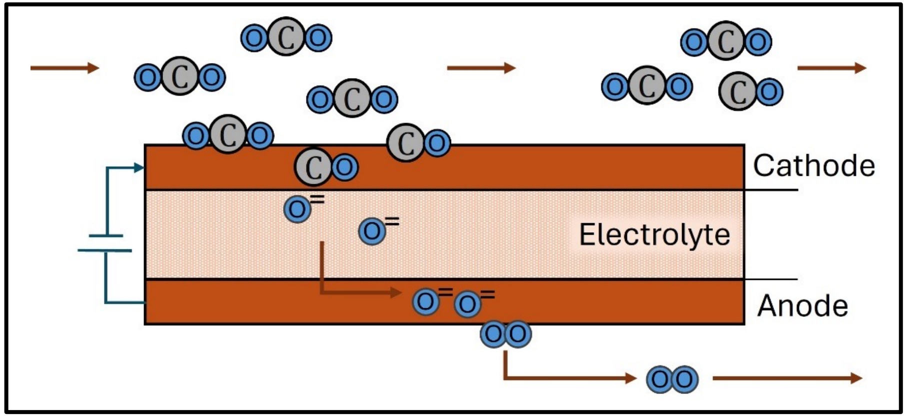
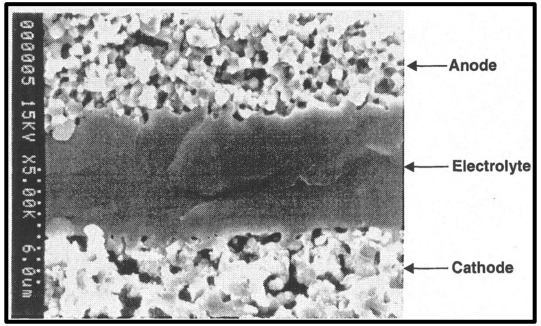
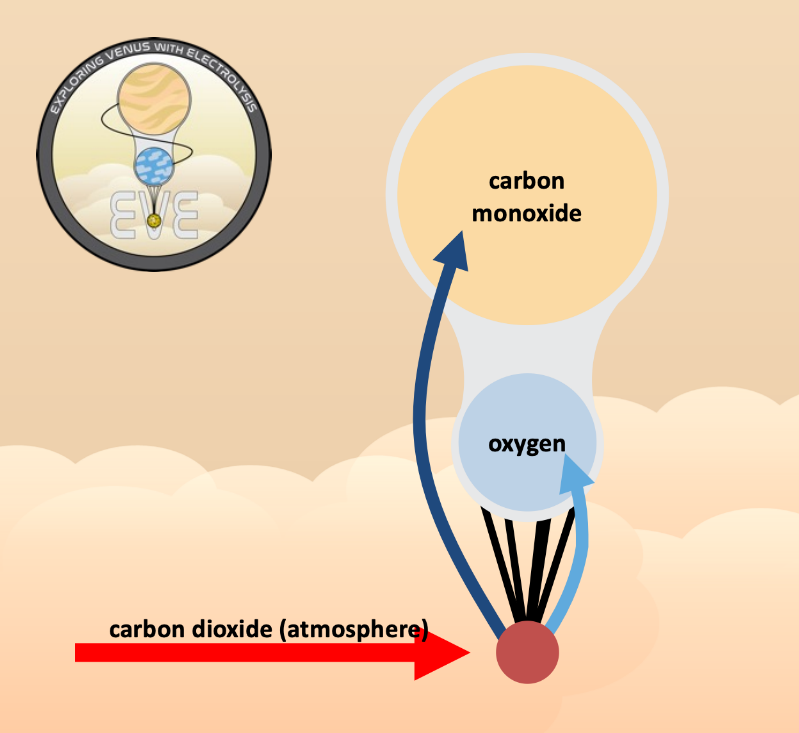
Solid oxide electrolysis for MOXIE…





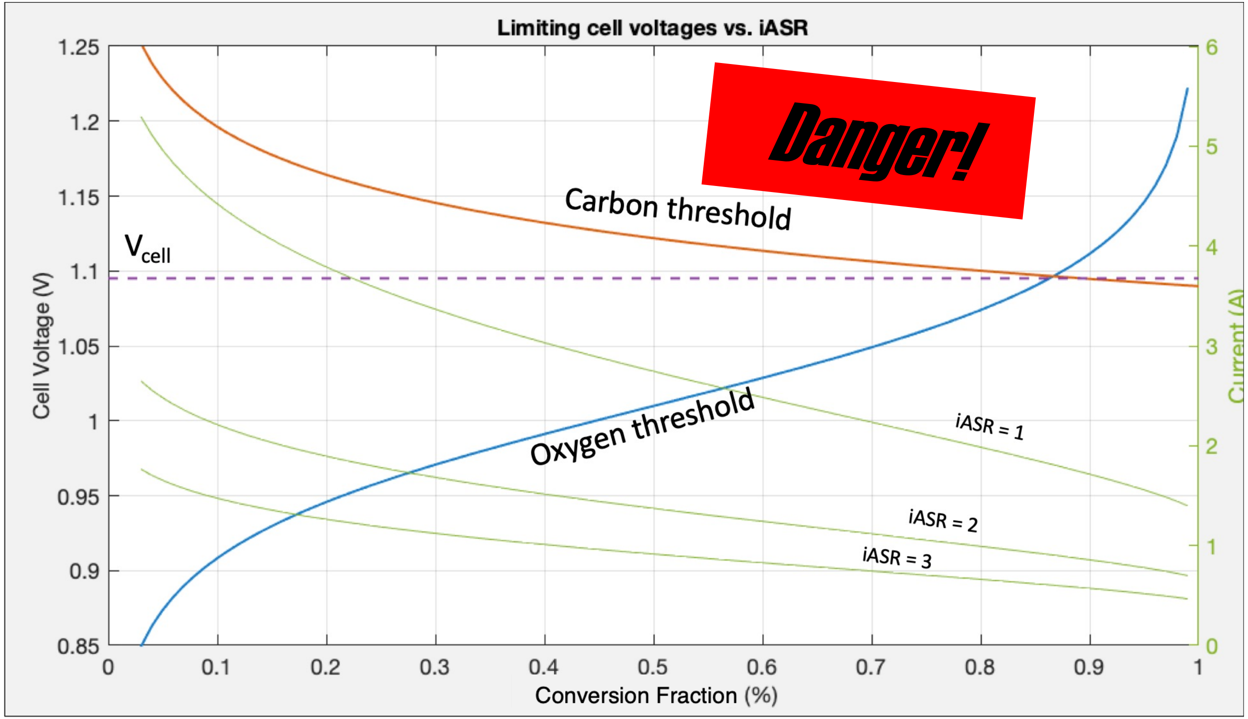
Why we want high conversion fraction (F_c)

- The MOXIE reaction is $2CO_2 \rightarrow 2CO + O_2$
  - MOXIE typically converted ~30% of the CO_2 it took in to $CO + O_2$
- The compressor uses a lot of power to collect all that CO_2!
- If we want to use the CO as fuel, or to make fuel, it needs to be purer
- For Venus balloon, we need at least 75% CO for buoyancy



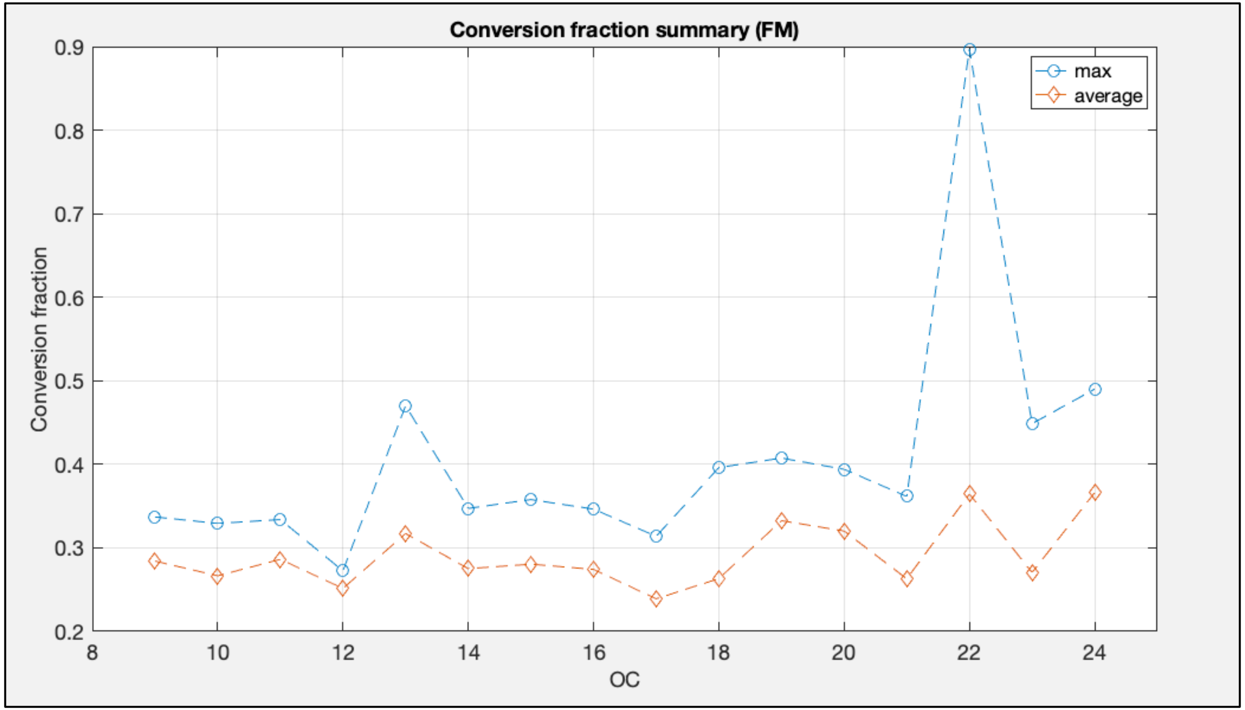
High Conversion Fraction (F_c)

- Why we didn't do it
  - Not a requirement!
  - Not a metric!
  - Not easy!
  - Not safe!
- What we can control
  - Supply voltage *or* Current (CO, O_2 rate)
  - Flow (CO_2 rate)
- What we can't control
  - Stack resistance (iASR)

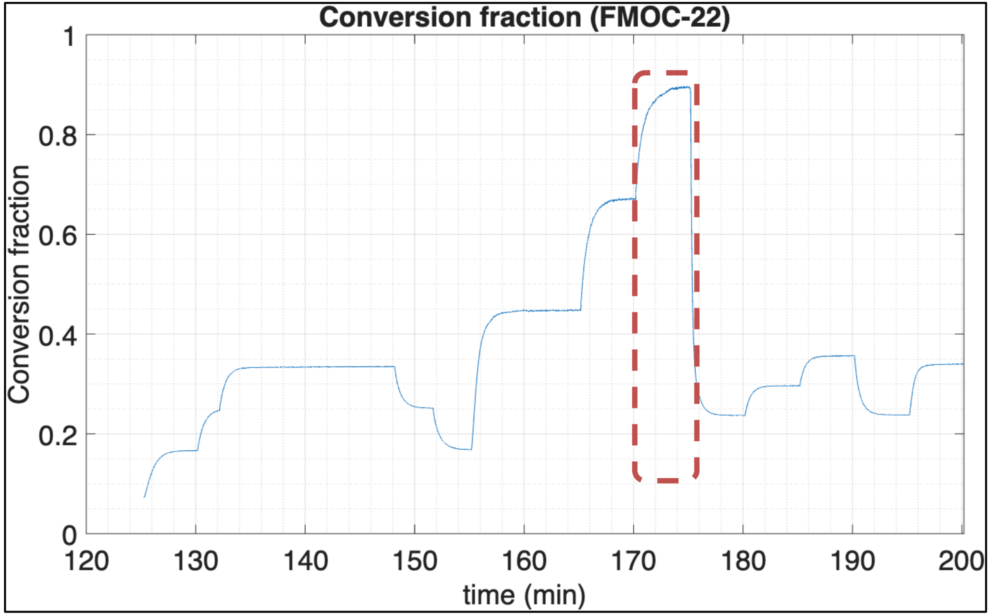


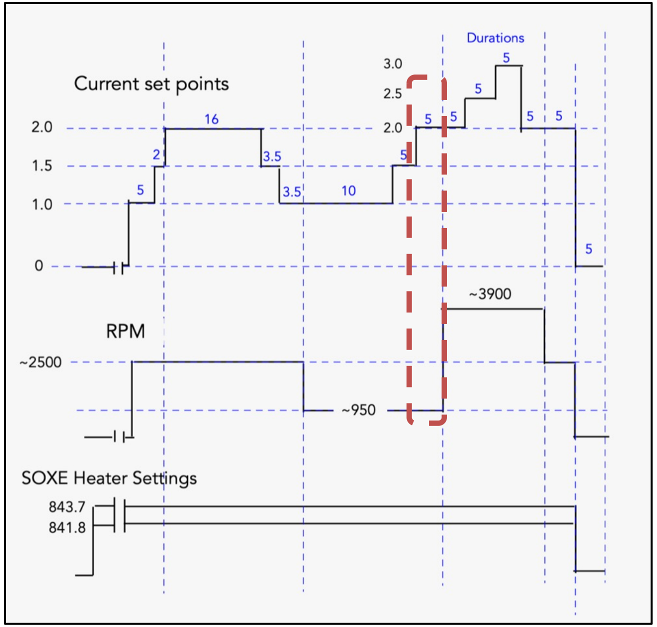
Current at fixed cell voltage vs conversion fraction

CO_2 conversion fraction (MOXIE on Mars)



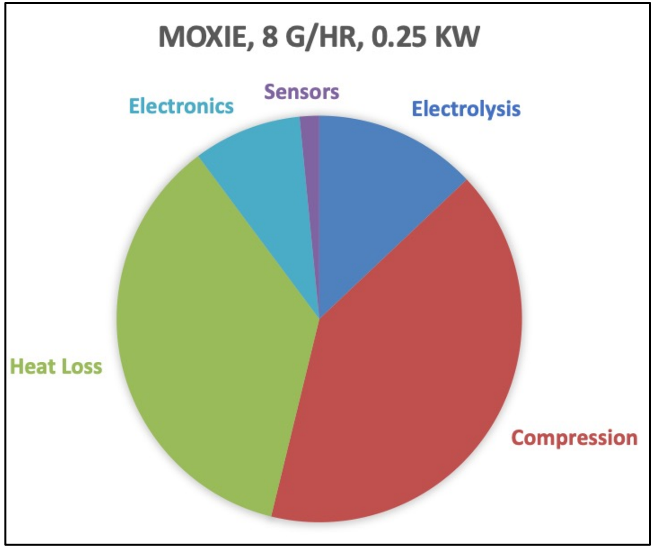
What’s going on with FMOC-22?



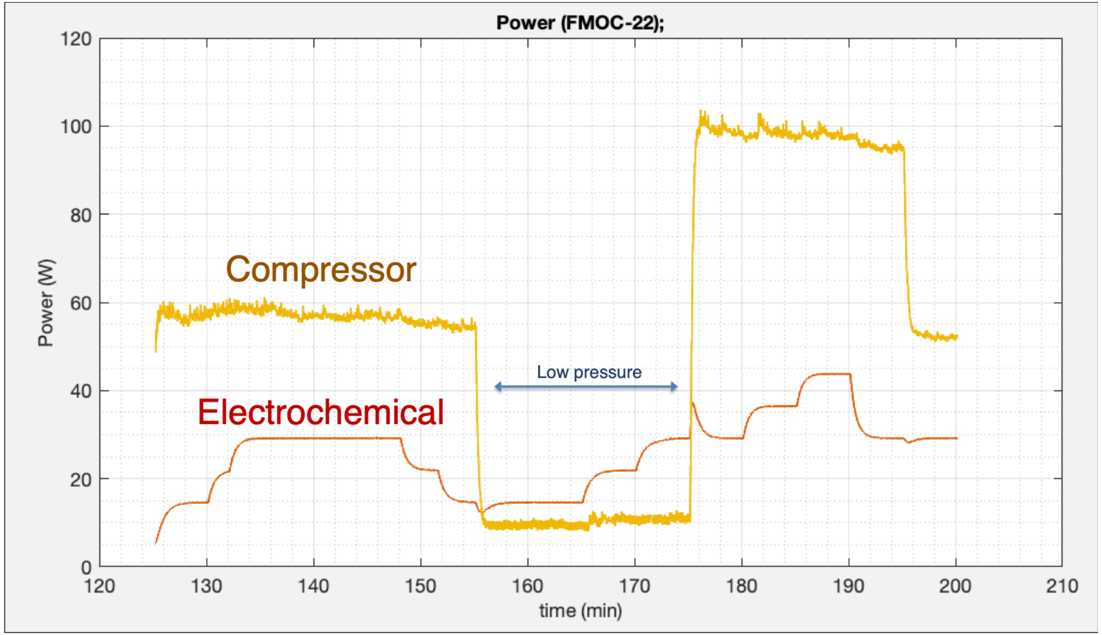


<u>Purpose: Testing low pressure SOE</u>, fixed current steps
(Also low flow, since flow and pressure are proportional on the FM)

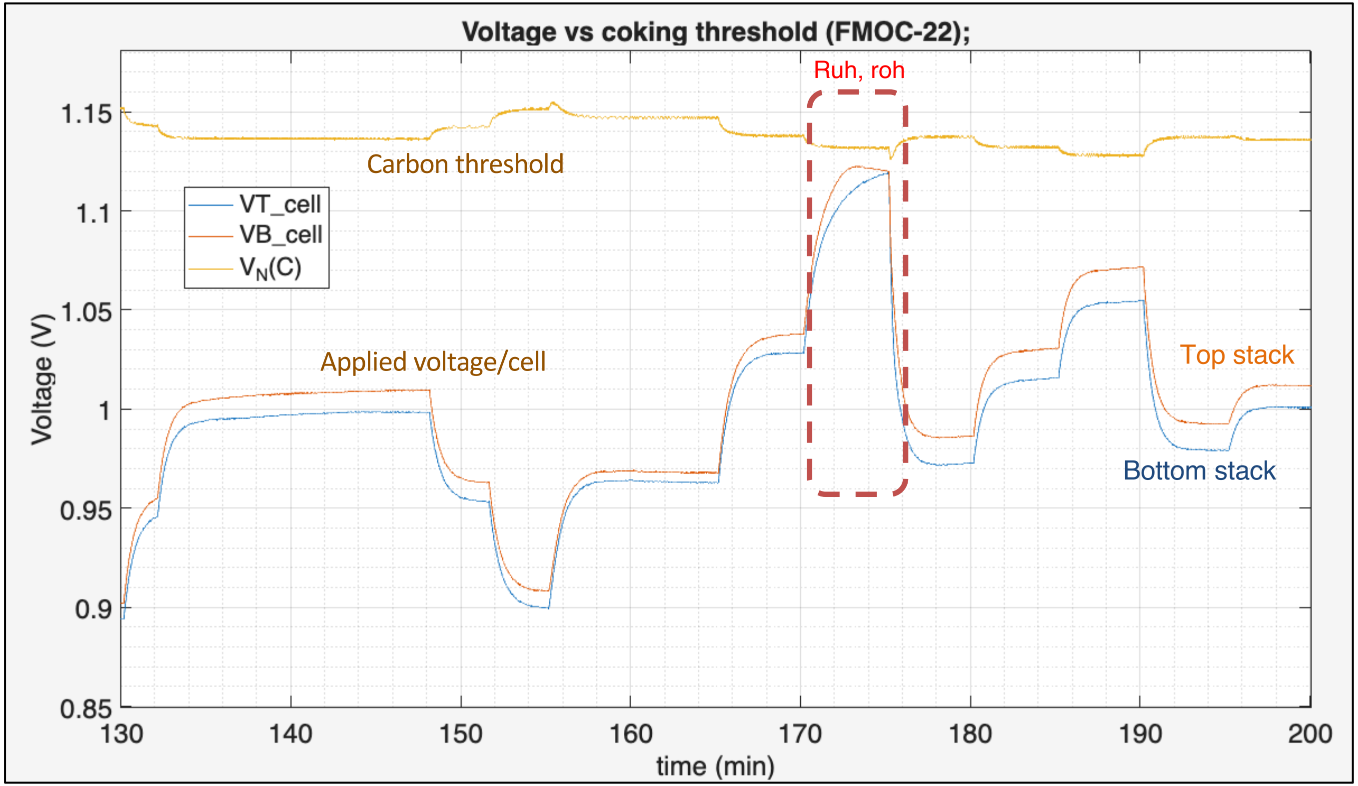
Positive impact on power usage!



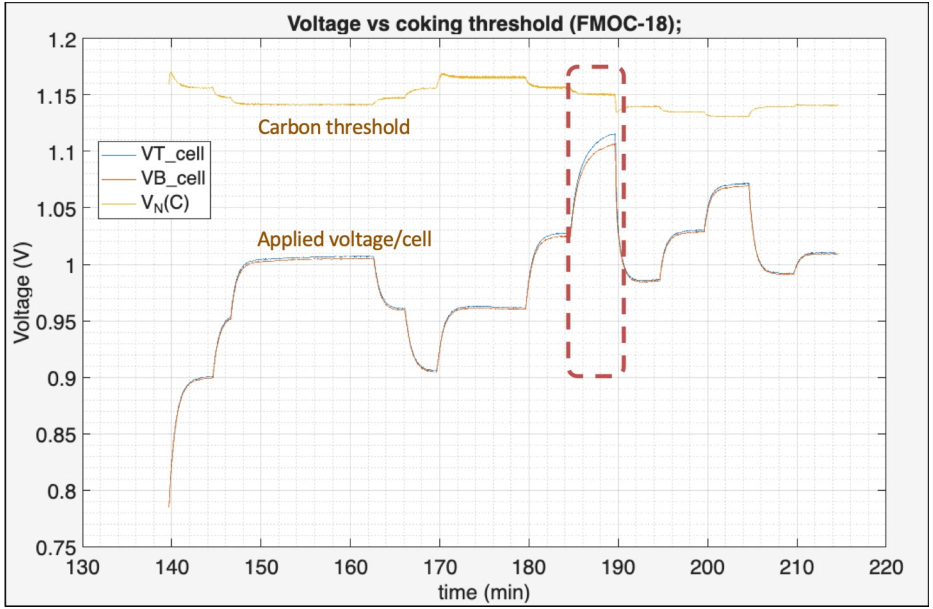
Typical power allocation for a MOXIE run.



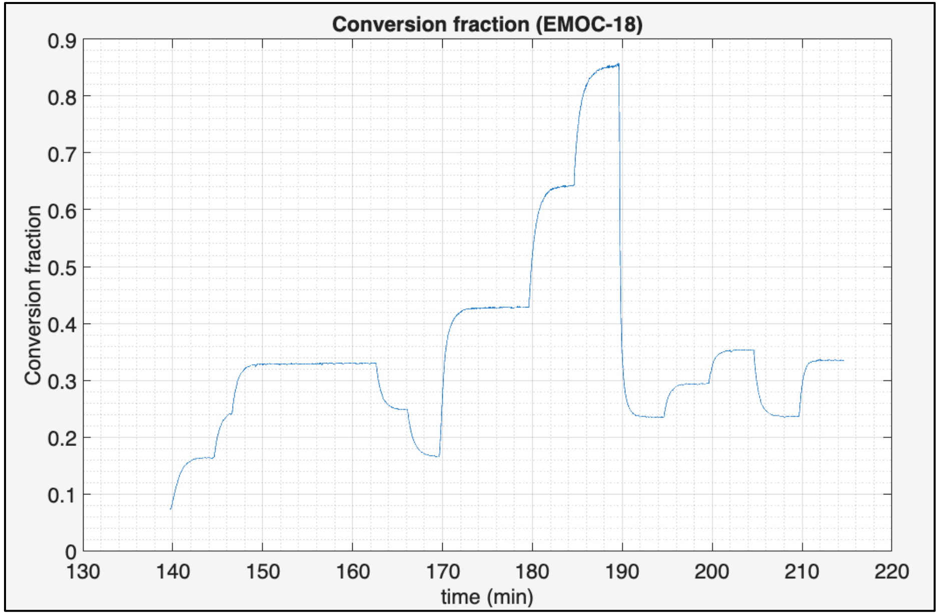
How close to V_N(C) did we come?



EMOC-18 (lab precursor) for comparison

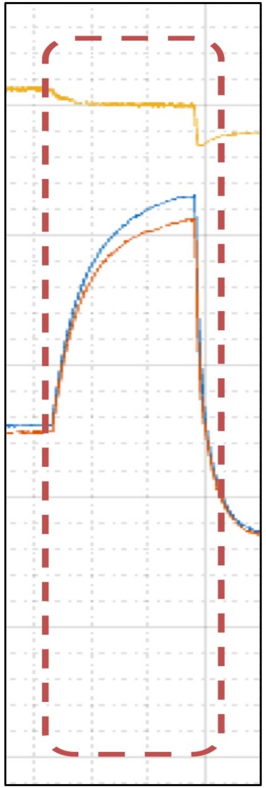


Cell Voltage

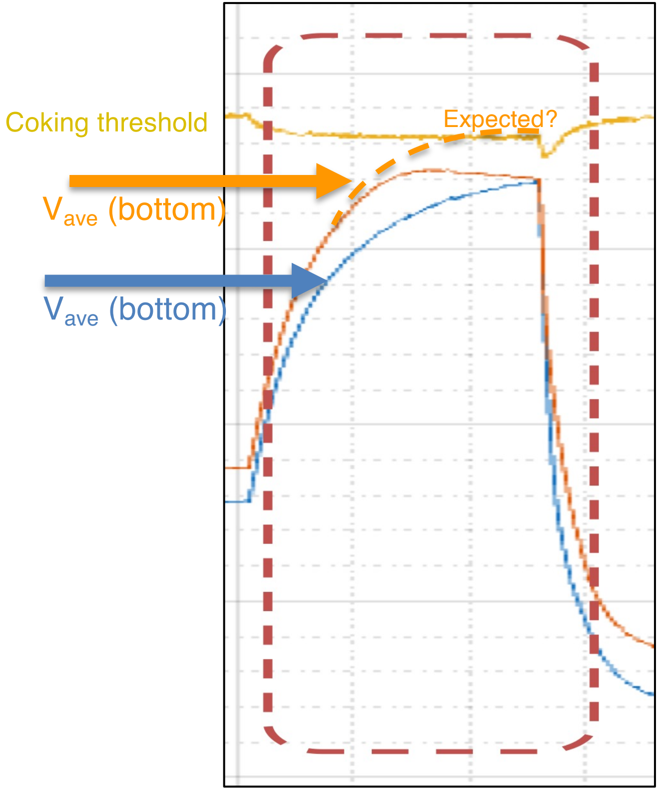


Conversion Fraction

What's going on with the bottom stack?

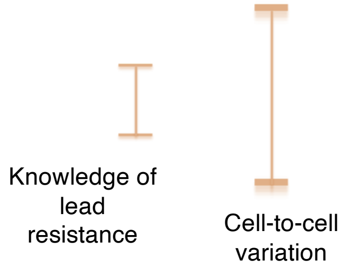


EMOC-18



FMOC-22

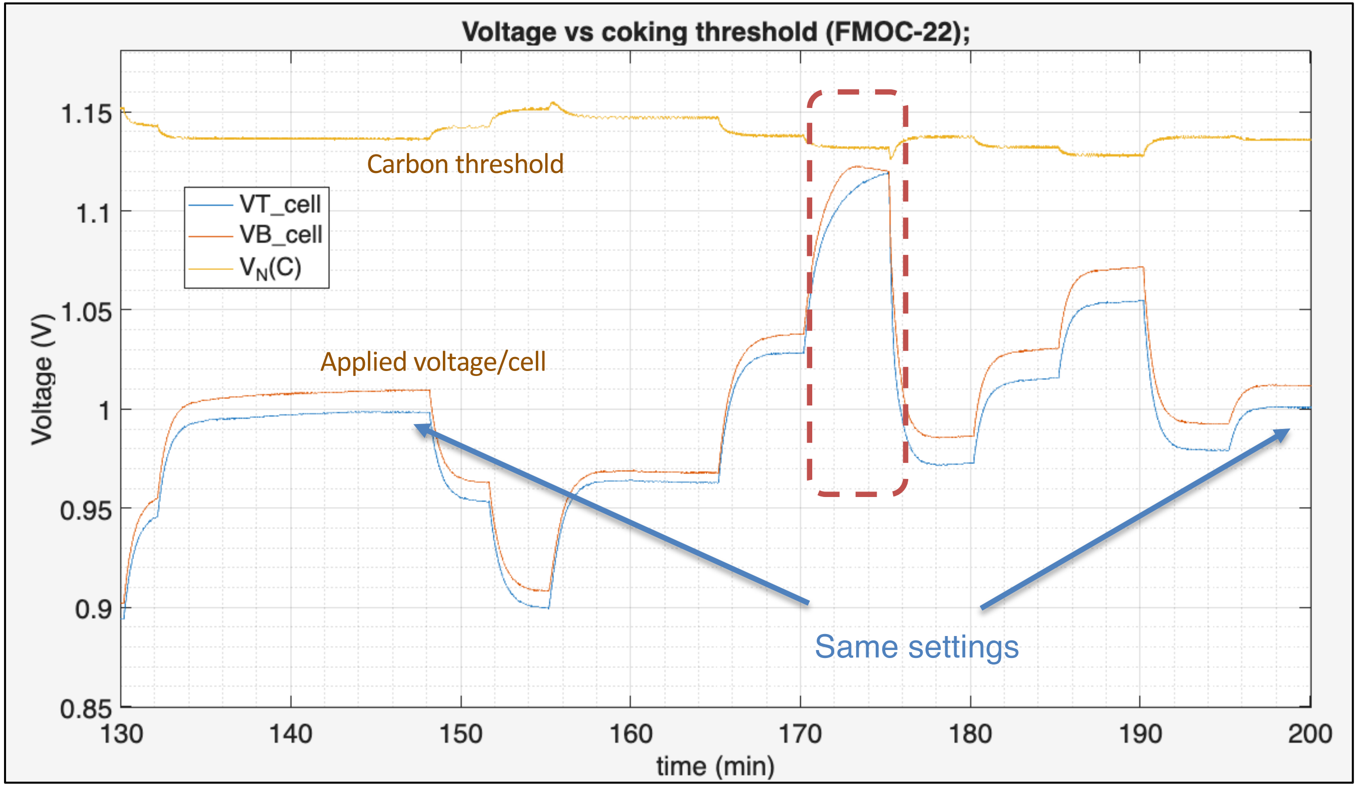
Error bars



→ There must be coking in the bottom stack!

→ But why does that make the voltage *better?*

Apparently no harm done
(it wouldn't be expected in 3 minutes)



Proposed explanation

The voltage *dropped* when carbon was being deposited. Why?

- We often see a characteristic thermal time constant of 10-15 minutes for *the stack as a whole*.
- We've seen an apparent fast response when we change flow
- We postulate a similar fast response when the *exothermic* $2CO \rightarrow 2C+O_2$ reaction kicks in!
  - Higher temperature → lower ASR → lower voltage
  - Fortuitously, this should limit the coking and prevent runaway
- Eventually, overall stack degradation from carbon deposition would take over and voltage would go up.

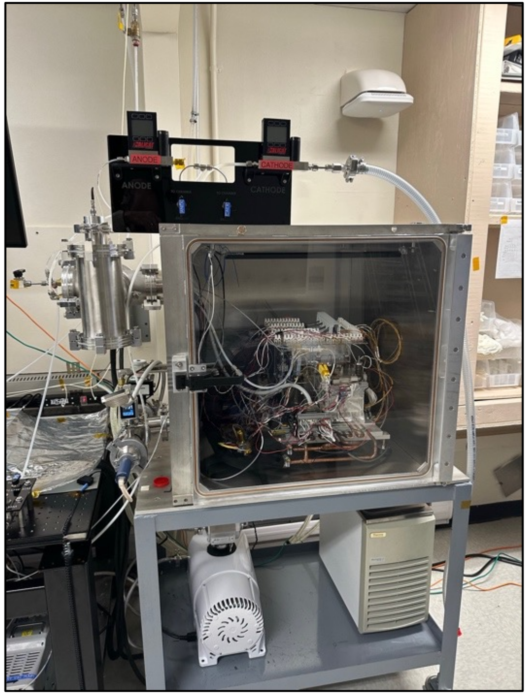
Mars Oxygen ISRU Experiment

Findings (Mars)

We demonstrated that:

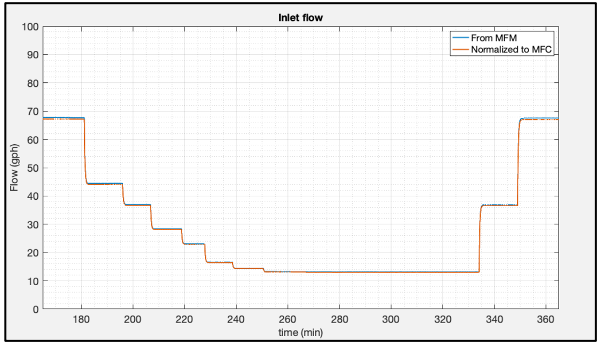
- MOXIE can operate at close to 90% conversion efficiency
- At low pressure and high efficiency the compressor power drops to a fraction of the electrochemical power
- A few minutes of carbon deposition does no significant harm, in part because it warms the cell and limits the reaction
- V_N(C) can be recognized by a characteristic signature – a substantial advantage for planning safe operations.

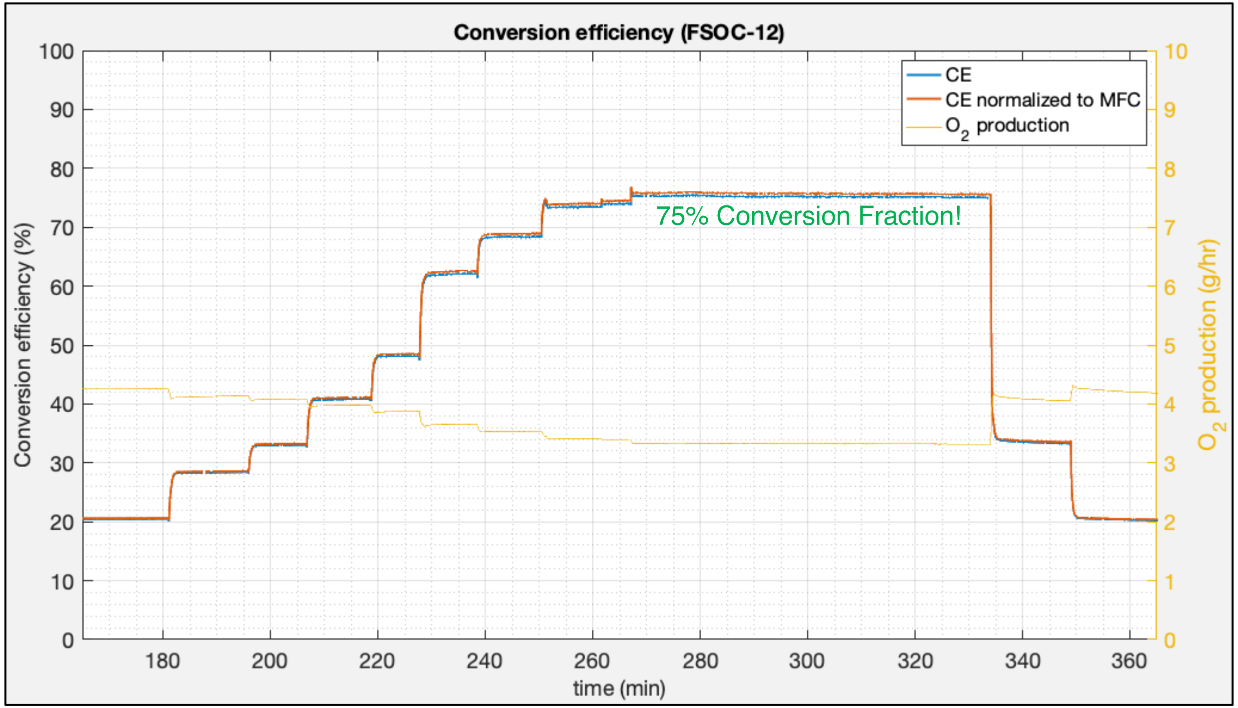
Venus: Lab experiment at 0.5 bar



At least 75% CO needed for buoyancy

We manually stepped down the flow to enhance F_c





Note ~20% drop in O2 production, from 4.2 to 3.3 g/hr

Findings (Venus)

- Under Venus conditions we sustained 75% conversion efficiency for 90 minutes on a degraded stack.
- Oxygen output drops by ~20% as inlet flow is reduced, from 4.2 to 3.3 g/hr.
  - This isn't the whole story. MOXIE has achieved 12 g/hr with much higher flow.
- Easy to compensate by adding more cell area; payoff is much better power efficiency

Thank you… NIAC NASA Innovative Advanced Concepts

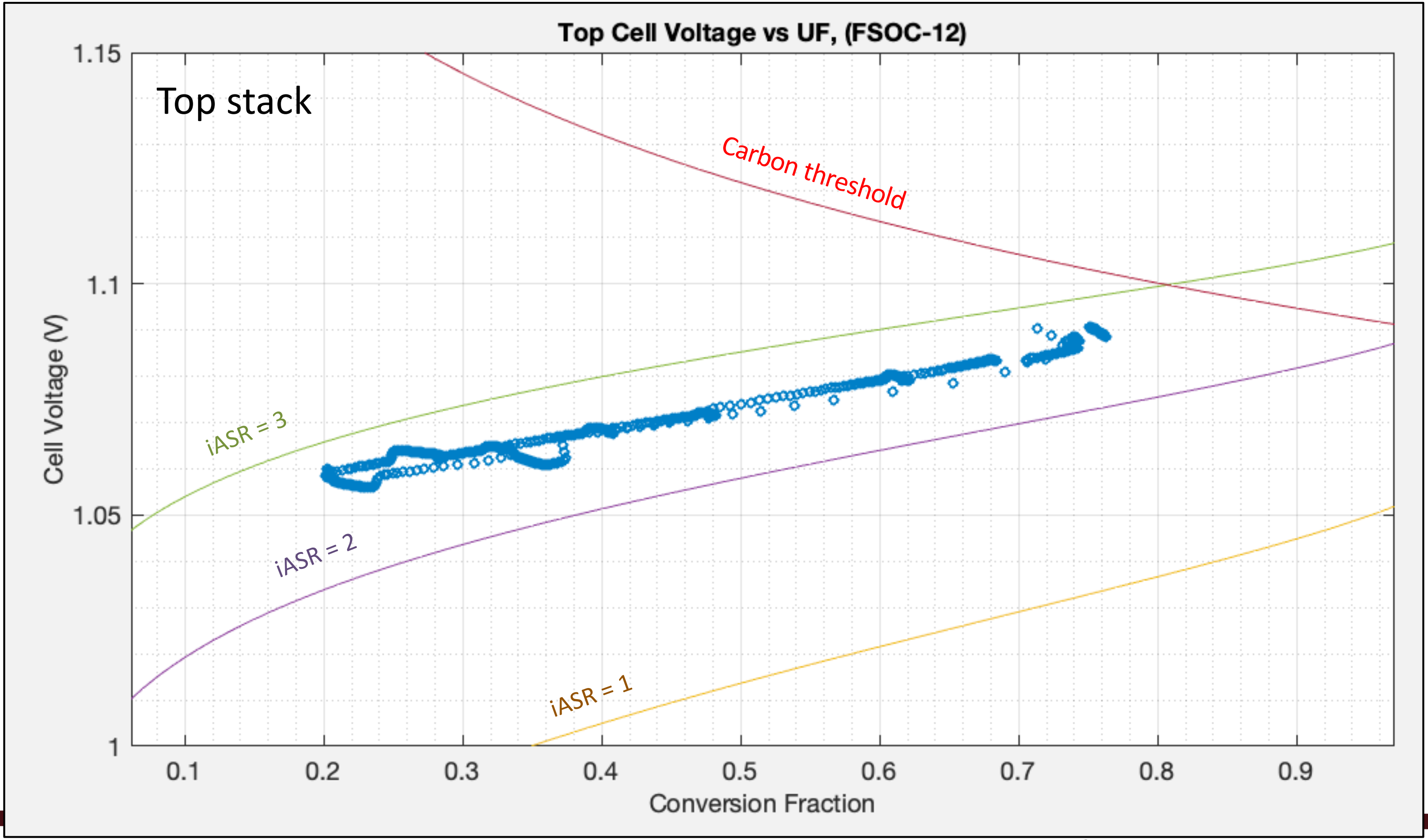
Questions?

ChatGPT Image, Inspired by https://venusroadmap.org/ ,.

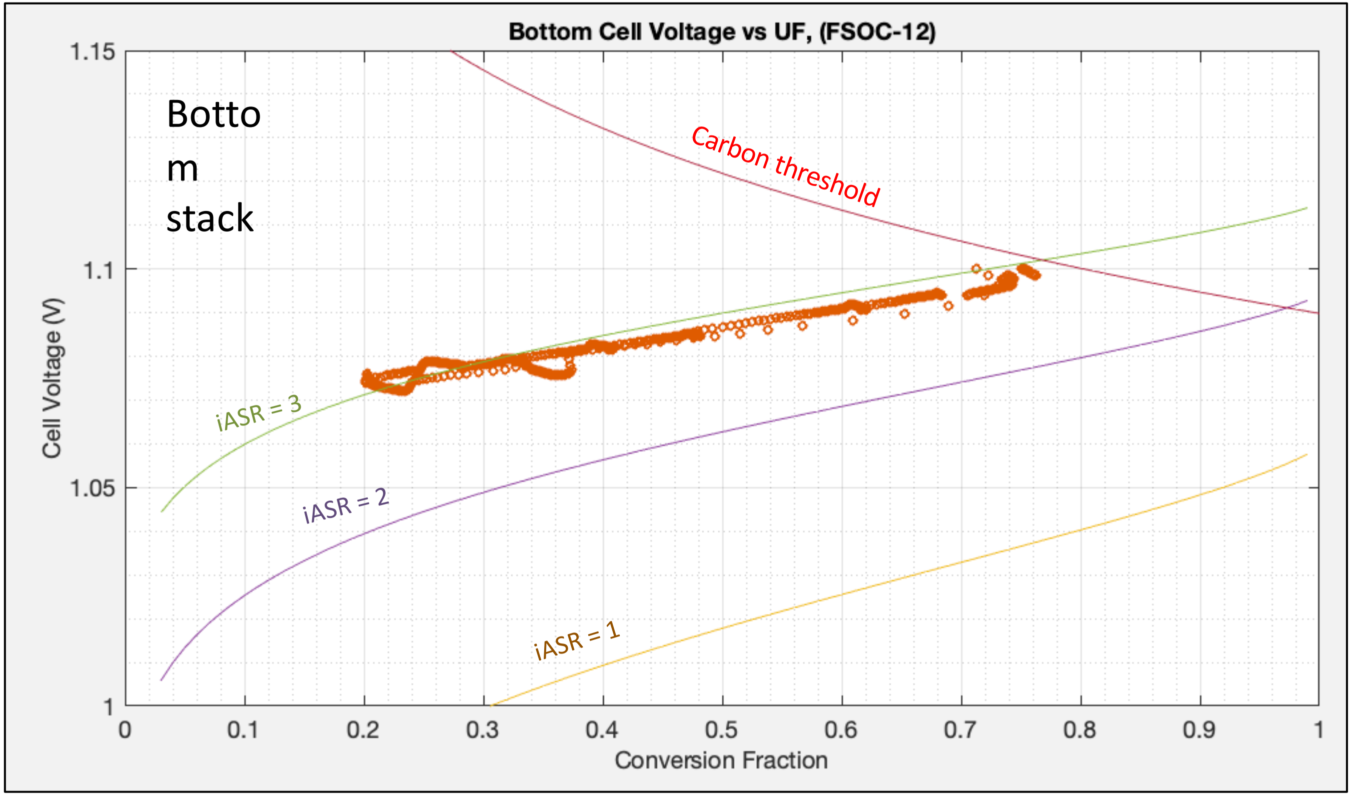
More MOXIE & EVE

BACKUP

Top stack, V_{off}=0 in model



Bottom stack, V_{off}=0 in model



MOXIE Mars Oxygen ISRU Experiment

Figure 7.2

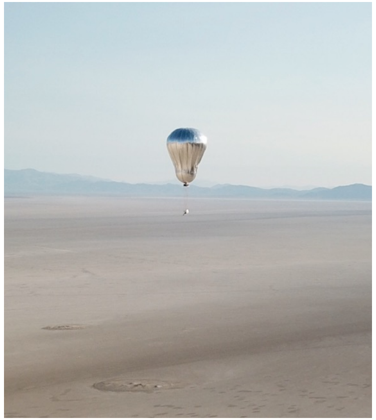


Figure A.1