amber_kinetics:

The Future of Energy Storage

Dr. Seth R. Sanders, CTO

ssanders@amberkinetics.com

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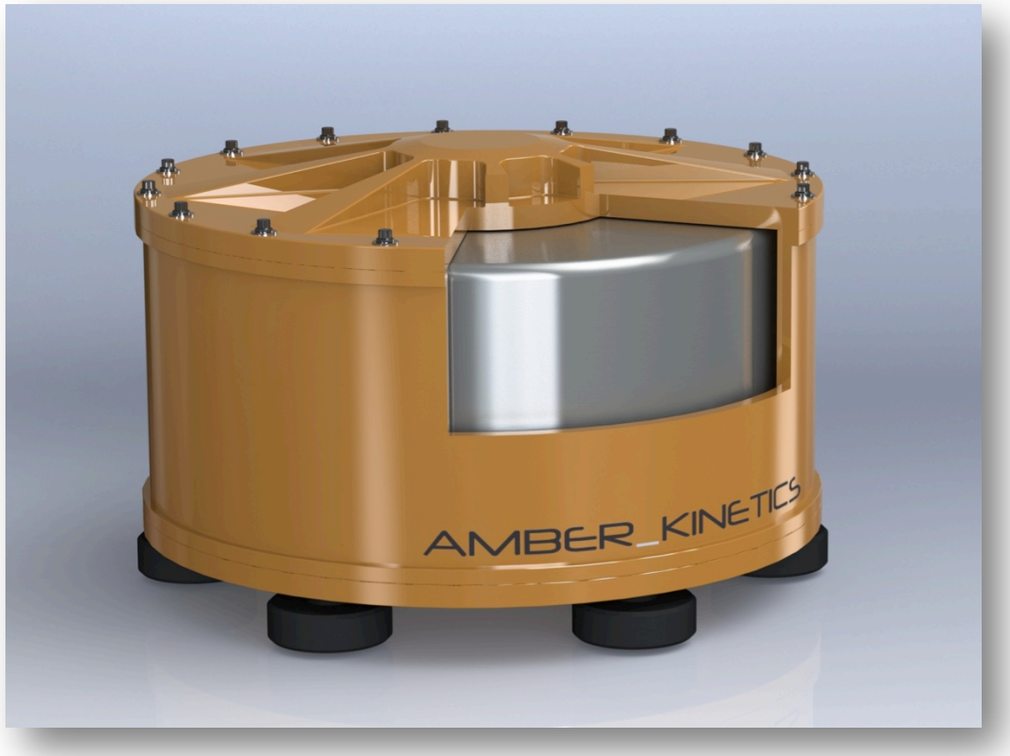
Amber Kinetics Flywheel

GEN-2 Flywheel	
Features	
Power	6.25 kW
Energy	25 kWh
Duration	4.0 hr
Cooling	Passive Convection
Round-trip Efficiency	90%
Cycle Life	> 30,000
Calendar Life	> 30 years
Electrical	
Input / Output Voltage	750 Vdc
Full Power Response Time	< 1 sec
Average Coasting Loss	< 200 watts



Flywheel Basics

$$\Delta E = \Delta\sigma \bullet k_s \bullet V$$

- **Rotor Design**
  - **Energy extracted is proportional to stress swing, shape factor, and volume**
Material	Strength	Density	Strength/Density	Cost	Strength/Cost	Comments
	MPa	kg/m^3	$MPa/(kg/m^3)$	$/kg	Mpa/$	
Steel	1400	7780	0.2	1	1400	Conventional metal working
Carbon fiber composite	4000	1750	2.3	20	200	Processing slow and expensive (?)
Glass fiber	1200	2100	0.6	3	400	As above
Kevlar fiber	3500	1200	2.9	12	292	As above

- **Steel Considerations**
  - **Yield stress, fracture toughness, defect / inclusion dimension**

Installation at Amber Alameda Test Site

- Below grade installation
- Detailed safety study informs trench plate surface re-enforcements
- Off-grid testing with 208 Vac 3-phase service for Gen 2 alpha and beta units

Gen 2 Beta Testing at Amber Alameda Test Site

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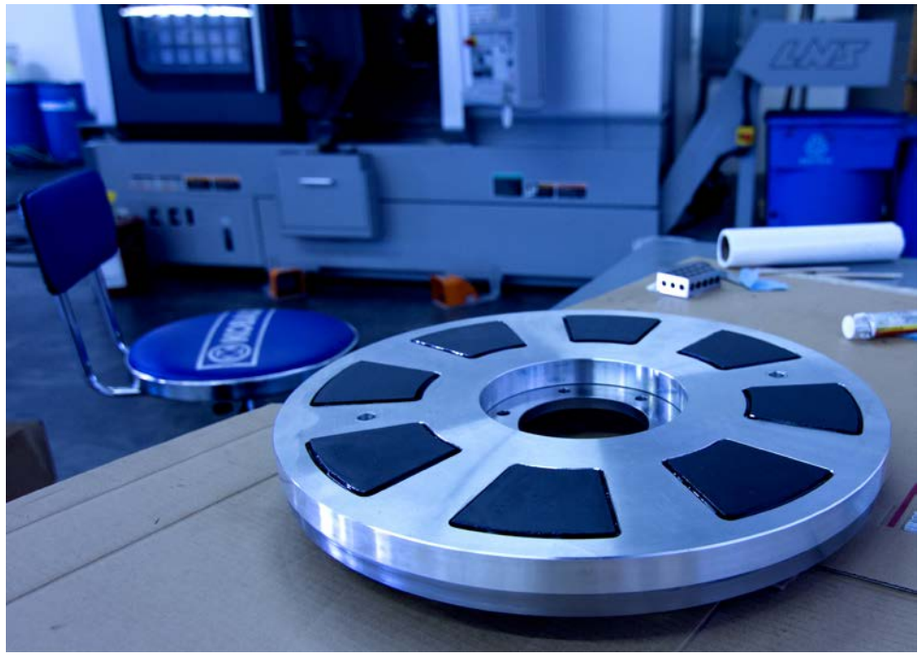
- Observations:
  - Fully tested over speed range.
  - 25 kWh extractable energy at full speed of 8500 rpm
  - Resonances all below speed range, as designed
  - Critical resonance at 2500 **rpm**, is well damped via internal damping
  - Residual unbalance and suspension result in imperceptible vibration of 0.01 **G** over speed range
  - Operating temperature of all components as designed. No significant temperature rises.

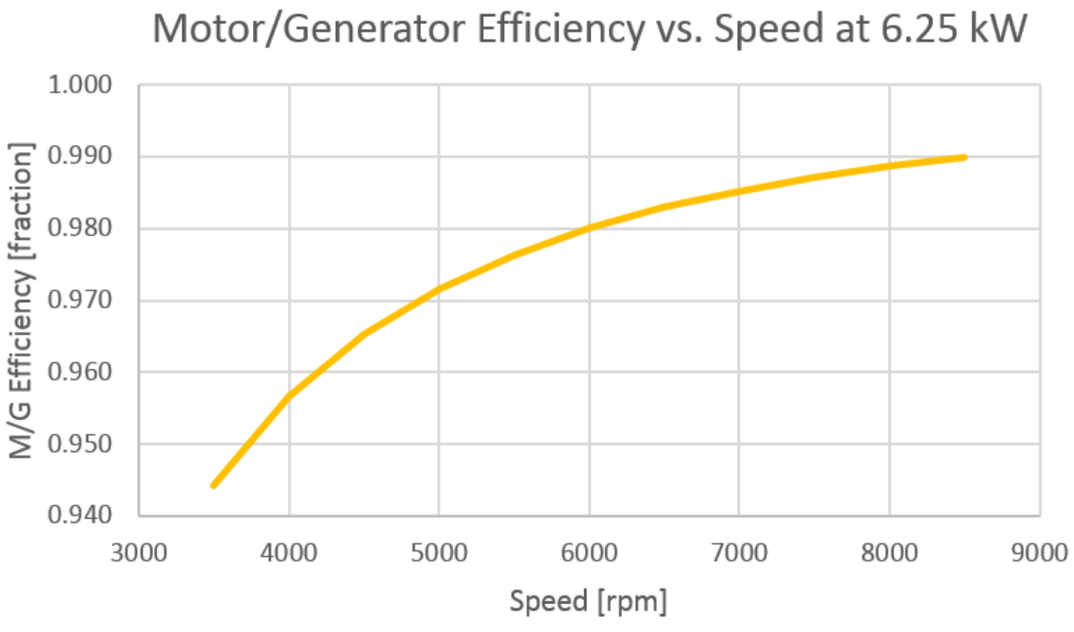
Gen 2 Beta Coasting Loss Data

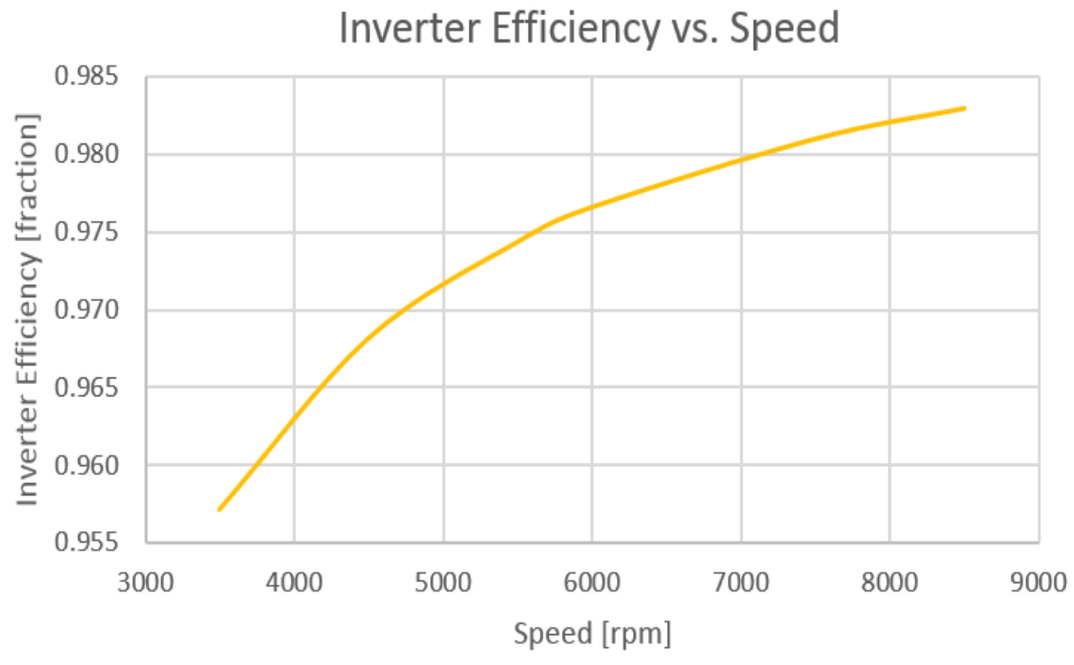
- Residual bearing torque and windage are main contributors

DC-to-Mechanical Roundtrip Efficiency >90%

Parameter	ms/Hz







Next Steps

- Testing of containerized energy blocks
- Design upgrades reduce cost and reduce losses

Summary

- Potential for very low system costs (measured on a $/kWh basis)
- High round trip efficiency
- 30-year calendar life
- >30,000 full depth of discharge cycles
- Low self-discharge losses
- No energy or power capacity degradation over life
- Full power capacity in charge and discharge at *any* state of charge
- No discernible vibration response over speed range
- No water or active cooling required