A Review and Current Evaluation of a Decade of Concentrated PEM Fuel Cell Development at Hydrogenics 2000 to 2010

M. Kammerer

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A Review and Current Evaluation of a Decade of Concentrated PEM Fuel Cell Development at Hydrogenics 2000 to 2010

Mark Kammerer, Hydrogenics GmbH, Germany

A reality for many fuel cell systems developers in the first decade in the current millennium has been the existence of very many successful prototype projects from a technical standpoint, but relatively few commercial fuel cell product introductions. Apart from some beginnings of market volume breakthroughs in the portable fuel cell and specialized telecom back-up sectors, the same can be said about the stationary market growth. The inhibitors to commercialization have been not any one factor, but many obstacles requiring hurdling on the way to meeting the market acceptance thresholds. The list of necessary criteria to fulfill spans categories from performance and durability, to manufacturability, reliability and maintainability, to certification and safety, to cost.

Over the past decade, one by one, many of the challenges have been solved, and one-by-one, the barriers have been peeled away to a point now in 2010 one can argue, in a several early markets, there remains one barrier: price point. In some markets it can be argued that there remain no barriers except social inertia.

1 Durability and Stack Development

At the beginning of the decade many PEM developers celebrated reaching 100's of hours of operation, and by the middle of the decade, ambitious targets of 5 000 hours by 2010 necessary for the personal automotive application were set. Now in 2010 the automotive targets have been surpassed. 10 000 h is now a published expected lifetime by several stack manufacturers.

In figure 1, the progress of the H2X 500 Series (500 cm^2 nominal active area) stack is presented, showing more than 5-fold increase in power density per cell and a 500-fold increase in tested operation over the 10 year period. Currently there are no major limitations yet encountered which would prevent further durability improvements into the future.

	501 Series	505 Series	505.2 Series	506.5 Series	506.6 Series
Peak Power	3 kW	6 kW	14 kW	15 kW	20 kW
Power Density	50 W/cell	100 W/cell	233 W/cell	250 W/cell	330 W/cell
Pressure	Medium	Medium	Low	Low	Low
Temperature	80 ºC	80 ºC	65 ºC	≤ 60°C	≤ 70°C
Humidification	Full	Full	Partial	Zero	Zero
Durability	20 hrs	400 hrs	4 000 hrs	8 000 hrs	10 000 hrs

Figure 1: History of Hydrogenics FC Stack Development.

In figure 2, the improvements in durability results of the stacks in test stands running duty cycles from real world applications shows very good improvements for the stacks running on humidified (saturated) input gases towards the 5 000 h target.

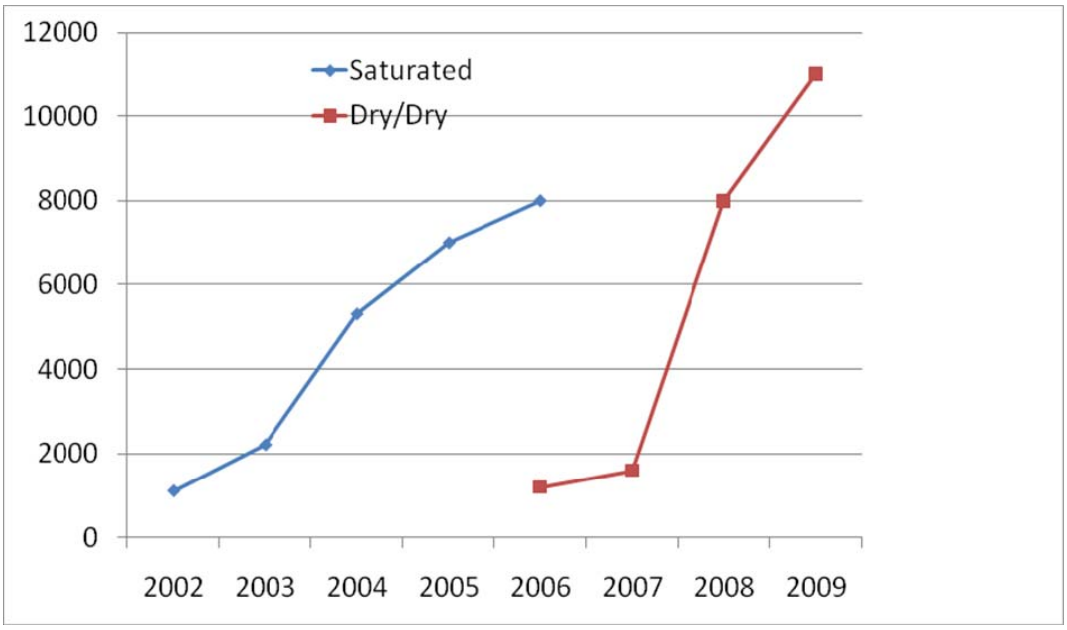
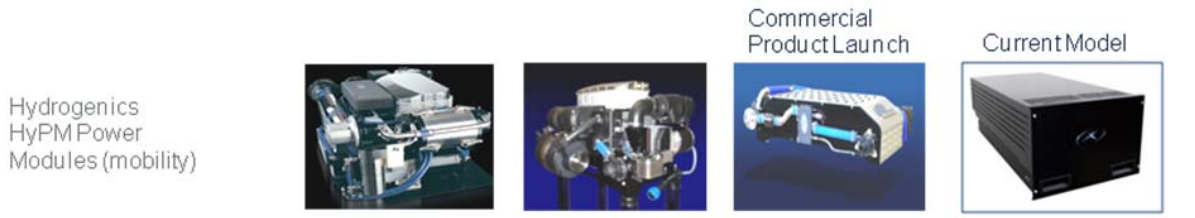


Figure 2: H2X stack lifetime – humidified vs. non-humidified.

Removing the humidifying components and running dry on the anode and cathode inlets was initially decided for back-up applications with low required run-times, but improvements in the MEA's allowed continued improvements, while simplifying the operational requirements of the stack resulting in a more simple and therefore cost-effective and reliable system. 10 000 hours is now possible.



	2001	2002	2003	2009
Stack Pressure	High	High	Low	Low
Power	25 kW	25 kW	20 kW	16.5 kW
System Mass Power Density	290 kg **86 W/kg**	200 kg **125 W/kg**	170 kg **117 W/kg**	92 kg **180 W/kg**
System Volume Power Density	365 L **68 W/L**	340 L **73 W/L**	180 L **111 W/L**	133 L **124 W/L**
System Efficiency	45…38%	45…38%	54…40%	**54…48%**
Major Components	25	19	8	6
Onboard water	Required	Required	Not required. With Ca and An saturators.	**Not required** **No saturators**

Figure 3: Fuel cell system development – Hydrogenics HyPM™ Power Module.

2 System Development

On the system level, also dramatic improvements have been made over the last decade. Power densities have doubled, both by weight and by volume, while efficiencies have increased and system complexity has decreased, by eliminating major components, resulting on a more cost-effective, compact and more reliable system.

In November 2002 the commercial product launch of the 10 kW fuel cell power module was announced, called the HyPM 10 and deliveries to customers commenced in 2003. The concept was one module – many applications, but by 2005 it was clear that the model should be split in to two versions; a version for stationary rack-mount, optimized for backup-power applications, and a version for applications requiring maximum durability, especially mobile applications. The XR (eXtended Run back-up) and HD (Heavy Duty, High Durability) family had been started. The rated power was in creased from 10 kW to 12 kW, and in 2006 further power level sizes were introduced, followed by two compact mobile versions based on the compact 200 cm^2 stack. Following is the current line-up today in 2010 (Figures 4 and 5).

	XR 4	XR 8	XR 12	XR-L 4	XR-L 8	XR-L 12
Rated Power (kW)	4.5	8.5	12.5	4.5	8.5	12.5
Peak Power (kW)	5.5	9.5	14.5	5.5	9.5	14.5
Voltage (VDC)	30-38	24-38	37-57	30-38	24-38	37-57
Dimensions (cm)	87x50x32	87x50x32	96x50x32	87x50x32	87x50x32	96x50x32
Volume (L)	139	139	154	139	139	154
Mass (kg)	80	80	90	80	80	90
Expected lifetime (h)	1 000+	1 000+	1 000+	10 000+	10 000+	10 000+

Figure 4: 2010 HyPM™ XR Stationary Power Module Family.

	HD 4-200	HD 8-200	HD 4-500	HD 8-500	HD 12-500	HD 16-500	HD 33	HD 100
Rated Power (kW)	4.5	8.5	4.5	8.5	12.5	16.5	33	100
Peak Power (kW)	5.5	9.5	5.5	9.5	14.5	18.5	37	110
Voltage (VDC)	58-79	48-79	20-40	20-40	36-57	48-76	80-160	240-480
Dimensions (cm)	85x36x25	85x36x25	79x45x30	79x45x30	94x45x30	96x51x41	115x105x45	150x115x85
Volume (L)	77	77	78	78	127	201	543	1140
Mass (kg)	75	75	105	105	78	92	325	750
Expected lifetime (h)	10 000+	10 000+	10 000+	10 000+	10 000+	10 000+	10 000+	10 000+

Figure 5: 2010 HyPM™ HD Mobile Power Module Family.

3 Reliability

Absolutely critical, besides durability is reliability. The fuel cell system must start each any every time without fail. Based on accelerated start-up/shutdown testing – the worst punishment for a PEM fuel cell – 6000 cycles were achieved, which means in practice essentially unlimited start-ups and shutdowns.

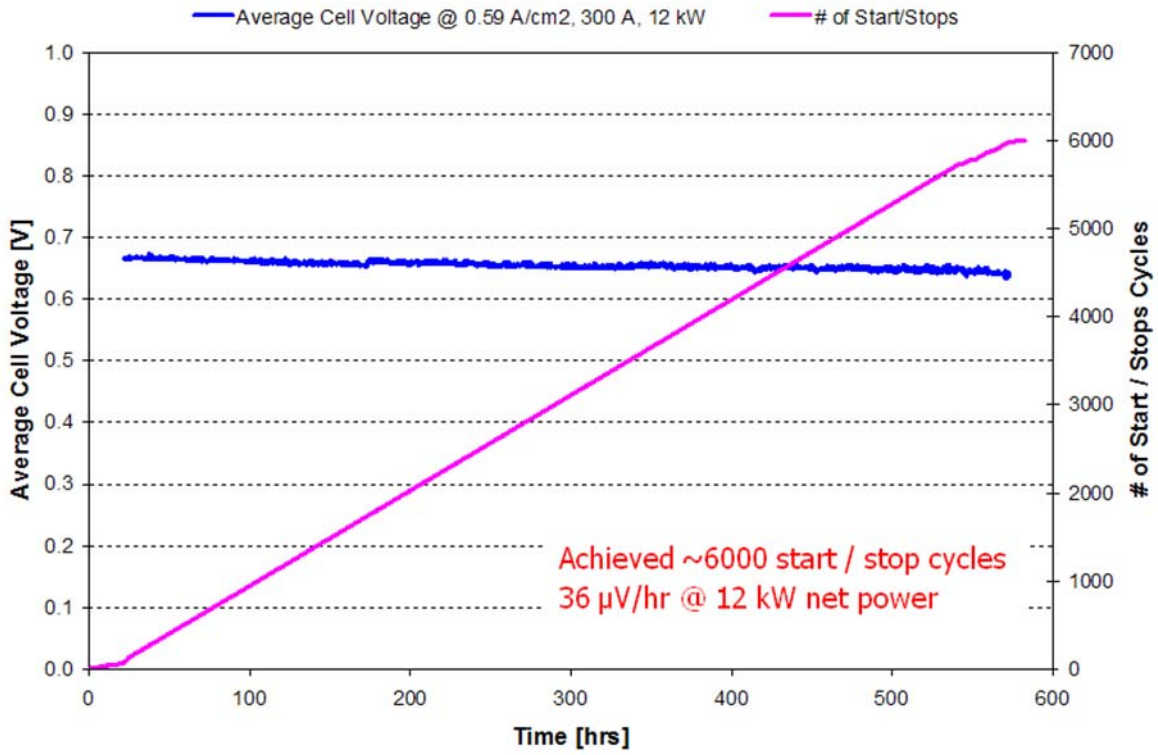


Figure 6: Accelerated Start/Stop Cycle Test results establishing unlimited start/stops.

4 Field Reliability Experience

Reliability has also been proven empirically in an extremely wide range of vehicles, applications and geographies [1]. In material handling and fleet vehicles a wide range of alpha followed by beta prototypes have been realized, which help evaluate and seed future markets, establish certification measures, validate the technology, provide maintenance data and experience and feed back into product improvements. The first alpha prototype demos from Hydrogenics were in 2005, and currently more than 60 forklifts are operating with HyPM fuel cells in real commercial service in North America and Europe [2-4].

In transit bus applications progress beyond 10 000 hours of expected stack lifetime is necessary, with cost reduction – which is largely but not entirely tied to the volume of production. Stack cost reduction, eventually leading to a tolerable frequency of stack renewal will allow feasibility of exchanging stacks in the system's lifetime to achieve the 40 000 h or 50 000 h typical of diesel engines in commercial vehicle today. Diesel-Hybrid

and CNG-Hybrid developments are paving the way for adding Fuel Cells to the Hybrids. Fuel Cell Plug-in scenarios may also play a significant role.

In stationary power Hydrogenics HyPM XR FCPM's are commercialized in the Datacenter [5] and Telecom UPS [6,7] sectors and the Data center configuration assembled with HD Long-Life stack technology is finding its place in standby prime power for renewable energy applications.

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