DOE Hydrogen and Fuel Cells Program Record	
Record #: 9018	**Date:** March 23, 2010
Title: Platinum Group Metal Loading	
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Approved by: Sunita Satyapal	**Date:** June 1, 2010

Item:

Total content of platinum group metals (PGMs) in state-of-the-art polymer electrolyte membrane fuel cell stacks has decreased by more than 80% since 2005. Improvement in performance and durability at low catalyst loading has allowed fuel cell developers to produce stacks with PGM content lower than the DOE 2010 target. DOE is on track to meet the 2015 PGM total content target on schedule.

Supporting Information:

DOE regularly determines fuel cell technology status using results reported by fuel cell developers. The results are reviewed in consultation with the FreedomCAR & Fuel Partnership's Fuel Cell Technical Team (the Tech Team), and quantitative status reports are documented by DOE. Status of PGM total content in fuel cell stacks from 2005 to 2009 is depicted in Figure 1.

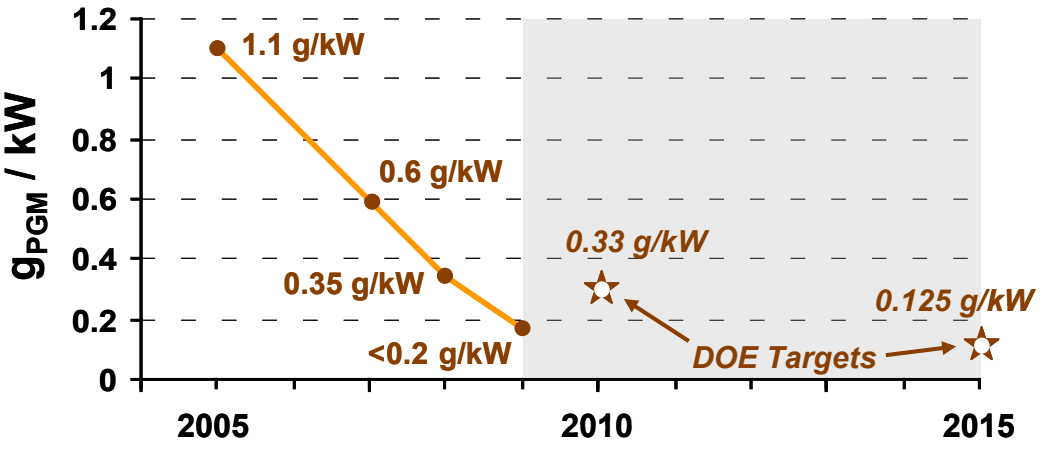

Figure 1. Status of PGM total content in fuel cell stacks[1] from 2005 to 2009 compared to DOE targets.

The state-of-the-art in PGM total content for 2005 was drawn from results reported by General Motors (GM) and De Nora. A 2005 publication by GM reported a power density of 0.7 W/cm^2 at 0.65 V with a total PGM loading of 0.8 mg/cm^2 (0.4 mg/cm^2 on both

[1] Each status number represents an estimate of loading in state-of-the-art fuel cell stacks. Estimates are based on data reported from stack and single-cell testing. See text for full details of the status determination.

cathode and anode) [1]. The publication noted that anode PGM loadings as low as 0.05 mg/cm^2 could be used with minimal impact on performance, leading to PGM total content in the range of 0.6 – 1.1 g_{PGM}/kW. The quoted range corresponds to single cell testing only. A 2005 Annual Progress Report submitted to DOE by De Nora (E-Tek Division) also indicated PGM total content as low as 0.6 g_{PGM}/kW in single cell testing, and 1.5 g_{PGM}/kW in stack testing [2]. Based on these results, DOE concluded that **the FY 2005 stack-level PGM total content status was 1.1 g_{PGM}/kW**. Results from 3M, which showed even lower PGM total content with Nanostructured Thin-Film (NSTF) catalysts in single cell testing [3], were not included because of issues with electrode flooding during operation under non-ideal conditions.

The FY 2007 status was based on results reported in 2006 and 2007 by three suppliers. Stacks containing 3M materials achieved PGM total content as low as 0.47 g_{PGM}/kW in 2007 [4]. Based on progress made in addressing water management issues, these 3M results were included in the 2007 analysis of PGM total content. By 2007, Cabot Superior MicroPowders achieved 0.3-0.4 g_{PGM}/kW in single cell testing [5] and 0.6 g_{PGM}/kW in stack testing [6]. Earlier results reported by PEMEAS (E-Tek Division) demonstrated PGM total content as low as 0.6 g_{PGM}/kW in single-cell testing and 0.7 g_{PGM}/kW in stack testing [7]. Based on these results, DOE concluded that **the FY 2007 PGM total content status was 0.6 g_{PGM}/kW.**

In 2008, DOE commissioned Directed Technologies, Inc. (DTI) to prepare an estimate of fuel cell system cost based on a model fuel cell system [8,9]. This system had a PGM loading of 0.25 mg/cm^2 (achieved by 3M in single cell testing) and a stack power density of 715 mW/cm^2. The Tech Team concurred that the PGM loading of 0.25 mg/cm^2 and corresponding stack power density of 715 mW/cm^2 are representative of 2008 state-of-the-art automotive technology. Based on DTI's analysis**,** DOE concluded that **the FY 2008 PGM total content status was 0.35 g_{PGM}/kW**.

In 2009, continued improvements in NSTF technology at 3M led to single cell PGM total content of less than 0.18 g_{PGM}/kW. In late FY 2009, 3M reported PGM total content in a 400 cm^2 short stack as low as 0.19 g_{PGM}/kW [10]. Based on these results, DOE concluded that **the 2009 PGM total content status was less than 0.2 g_{PGM}/kW** (or, on a specific power basis, greater than 5 kW/g_{PGM}).

To avoid placing excessive emphasis on any one technology, DOE maintains a portfolio of catalyst technologies, including novel PGM catalysts dispersed on carbon and non-carbon supports. Efforts to decrease PGM total content of non-NSTF catalyst technologies toward 2010 and 2015 target levels are ongoing. Work also continues to optimize NSTF catalysts, which have yet to meet 2015 PGM total content targets, and which have yet to demonstrate simultaneous achievement of all 2010 technical targets.

[1] Hubert A. Gasteiger, Shyam S. Kocha, Bhaskar Sompalli, Frederick T. Wagner, Applied Catalysis B: Environmental 56 (2005) 9.

[2] Emory S. De Castro et al., “Integrated Manufacturing for Advanced Membrane Electrode Assemblies,” in: *FY 2005 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2005, pp. 723.

[3] Mark K. Debe et al., “Advanced MEAs for Enhanced Operating Conditions,” in: *FY 2005 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2005, pp. 730.

[4] Mark K. Debe et al., “Advanced Cathode Catalysts and Supports for PEM Fuel Cells,” in: *FY 2007 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2007, pp. 833.

[5] Paolina Atannasova et al., “Development of High-Performance, Low-Pt Cathodes Containing New Catalysts and Layer Structure,” in: *FY 2006 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2006, pp. 787.

[6] Paolina Atannasova et al., “Development of High-Performance, Low-Pt Cathodes Containing New Catalysts and Layer Structure,” DE-FC0402AL67620, Final Technical Report.

[7] Emory S. De Castro et al., “Integrated Manufacturing for Advanced Membrane Electrode Assemblies,” in: *FY 2006 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2006, pp. 687.

[8] Brian D. James and Jeffrey A. Kalinoski, “Mass Production Cost Estimation for Direct H2 PEM Fuel Cell Systems for Automotive Applications,” in *FY 2009 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2009, pp. 925-930.

[9] DOE Hydrogen Program Record #8019, "Fuel Cell System Cost - 2008," http://www.hydrogen.energy.gov/pdfs/8019_fuel_cell_system_cost.pdf.

[10] Mark K. Debe et al., “Advanced Cathode Catalysts and Supports for PEM Fuel Cells,” in *FY 2009 Progress Report for the DOE Hydrogen Program*, U.S. Department of Energy, Washington, DC, 2009, pp. 1065.