



DOE Hydrogen Program

2012 DOE Hydrogen Program Review

Corrugated Membrane Fuel Cell Structures

Stephen Grot

Ion Power, Inc (Prime)

GM & GrafTech (Sub-Contractors)

May 18, 2012

Project ID #
FC090

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Start: Sept 1, 2010
- End: Sept 30, 2013
- 25% Complete

Budget

- Total project funding
 - DOE share \$1,651,616
 - Contractor share \$507,096
- Funding received in FY11: \$400,000
- Planned Funding for FY12: \$300,000

Barriers

B: Costs

- Lower Metal GDL cost
- Lower Plate/GDL manufacturing costs

C: Performance

- High power density with low Pt loaded MEAs

Partners

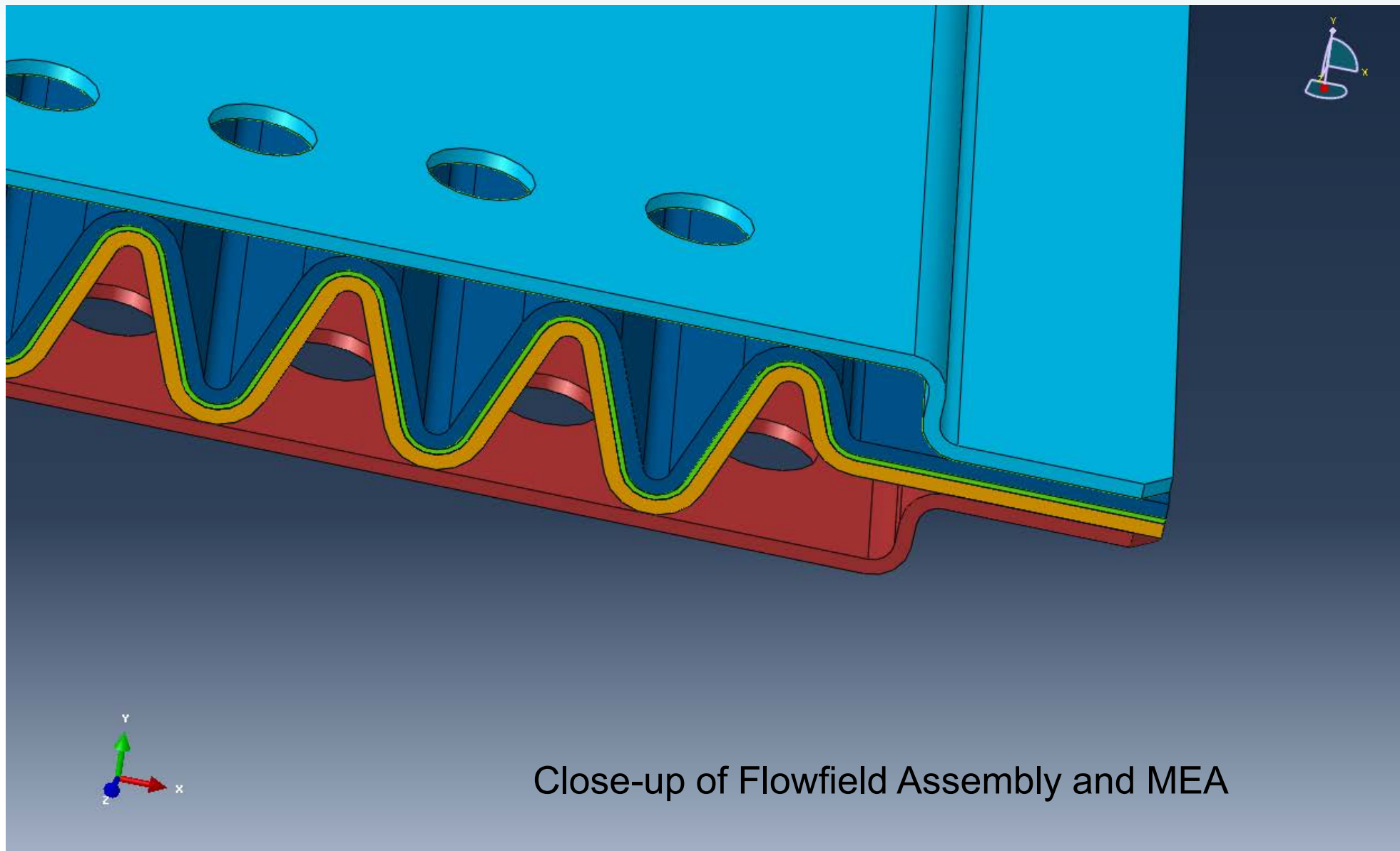
- Project lead
 - Ion Power
- Interactions/ collaborations
 - General Motors
 - Testing and Modeling
 - GrafTech
 - Graphite components
 - GKD/Dexmet
 - Metal screens

Objectives

To pack more membrane active area into a given geometric plate area, thereby allowing both targets of power density and platinum utilization to be achieved

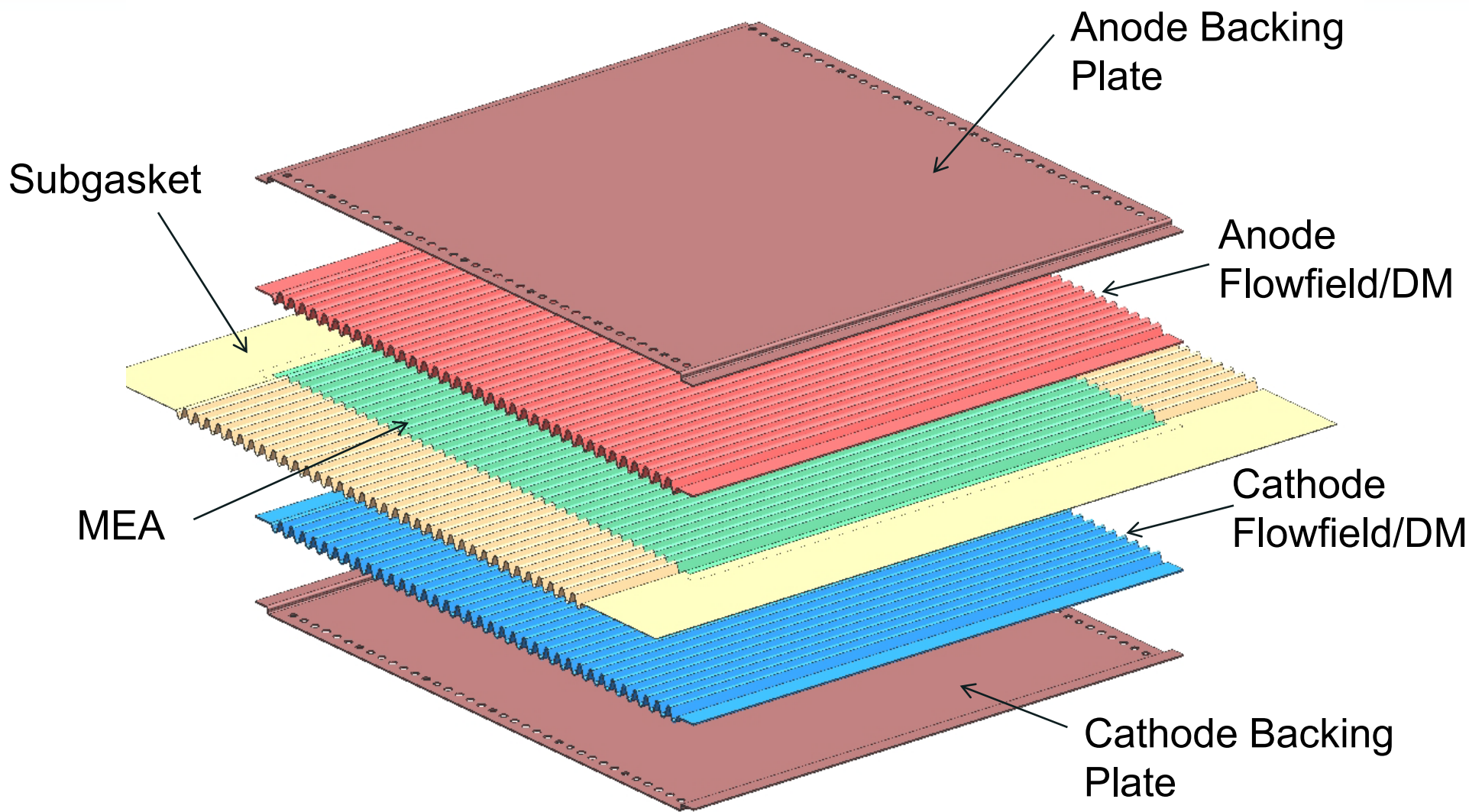
- To demonstrate a fuel cell single cell (50 cm²) with a 2-fold increase in the membrane active area over the geometric area of the cell by corrugating the MEA structure
- Incorporation of an ultra-low Pt loaded corrugated MEA structure in a 50 cm² single cell that achieves the DOE 2015 target of 0.2 gram Pt/kW, while simultaneously reaching the power density targets:
 - 1 W/cm² at full power
 - 0.25 W/cm² at ¼ power

Objectives

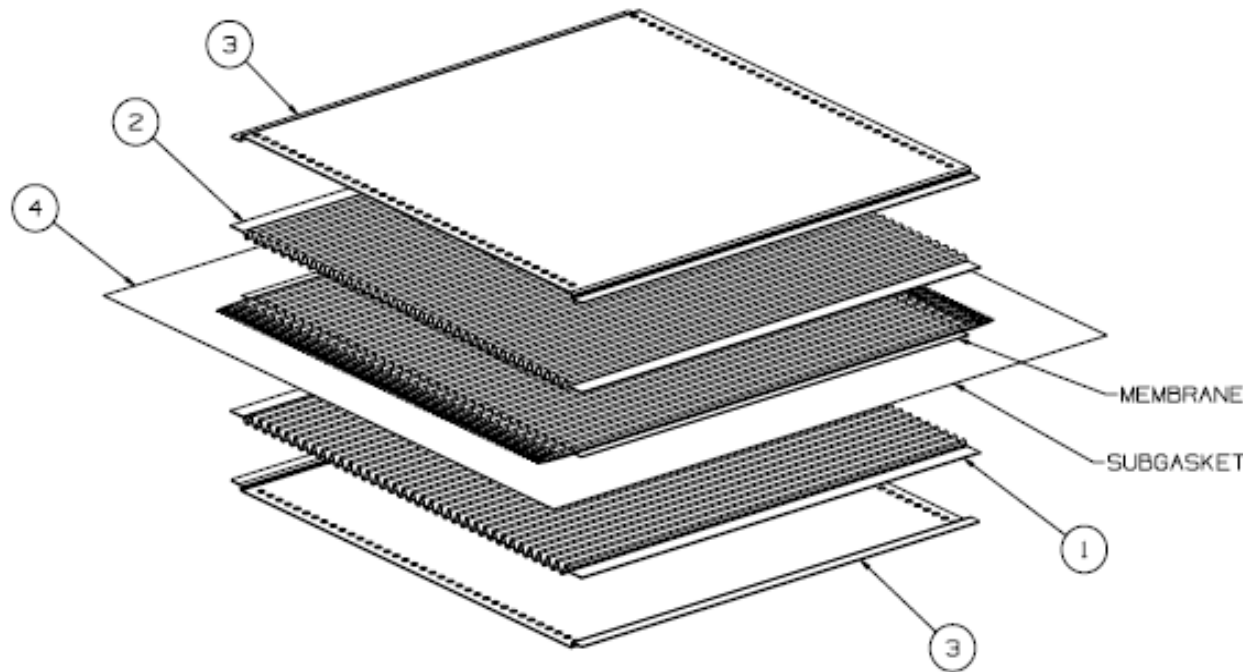


SINGLE CELL HARDWARE

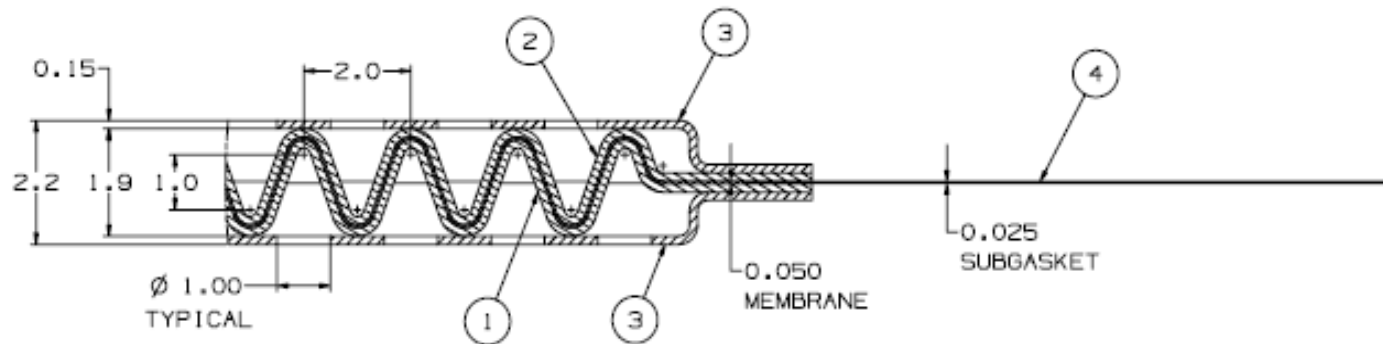
Original Cell Design Requiring Convoluted Seals



Redesigned Cell with Molded Subgasket to Eliminate Need for Convoluted Seal

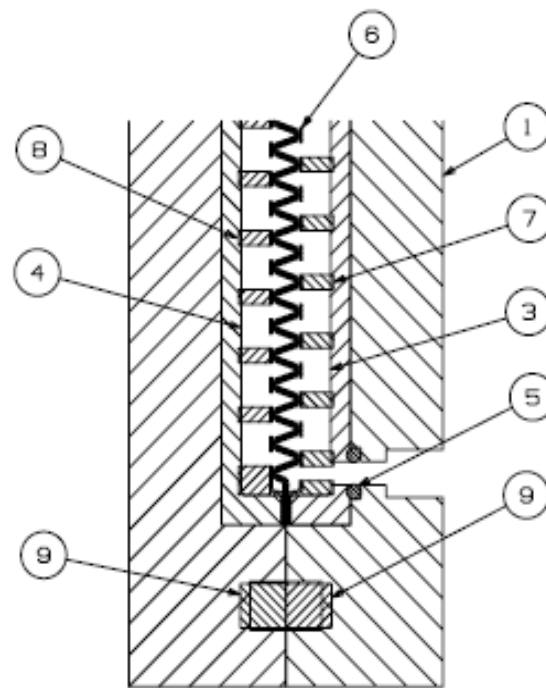
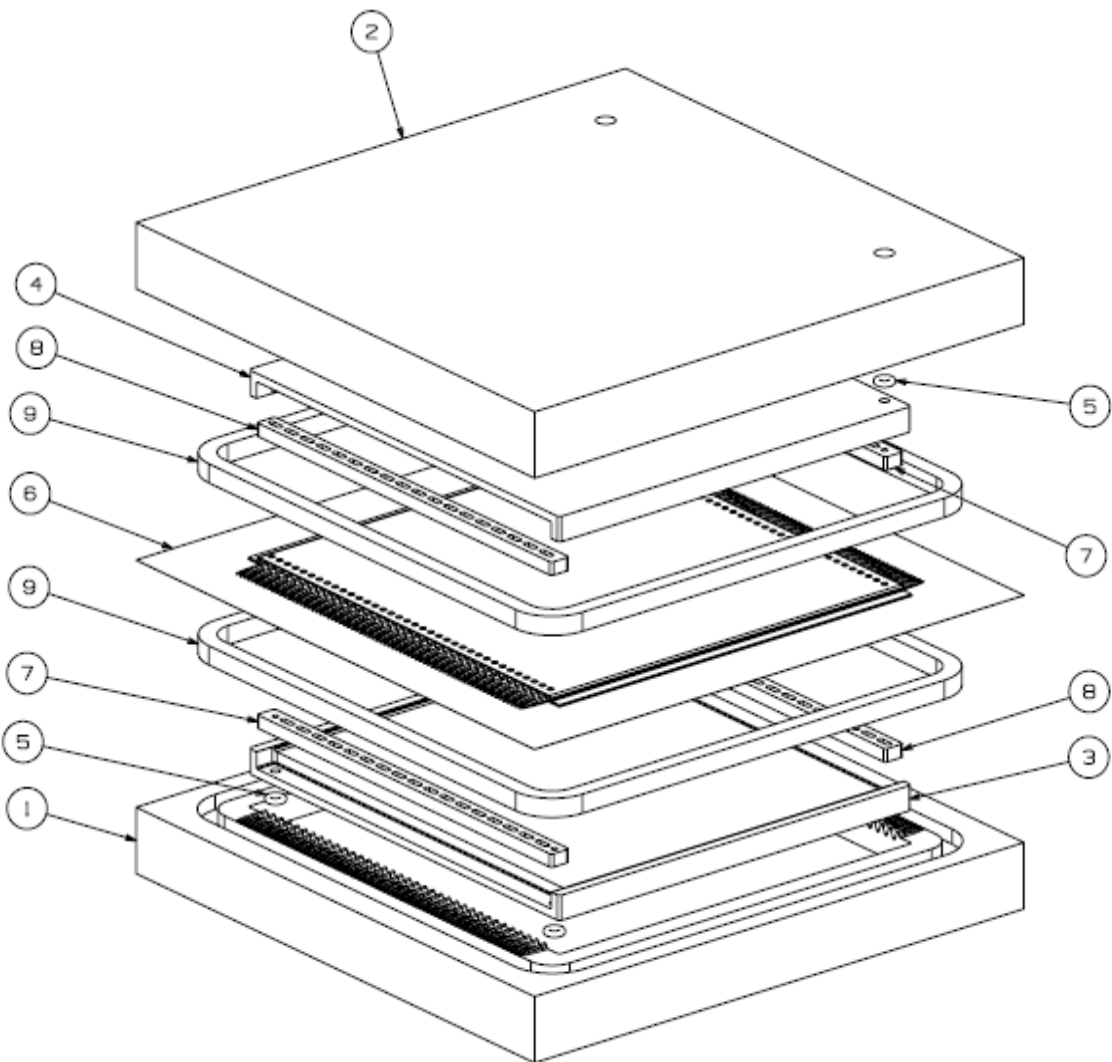


1. Anode corrugated GDL – Plate subassembly
2. Cathode corrugated GDL – Plate subassembly
3. Flowfield Backing Plates
4. Membrane Electrode Assembly with Molded Subgasket

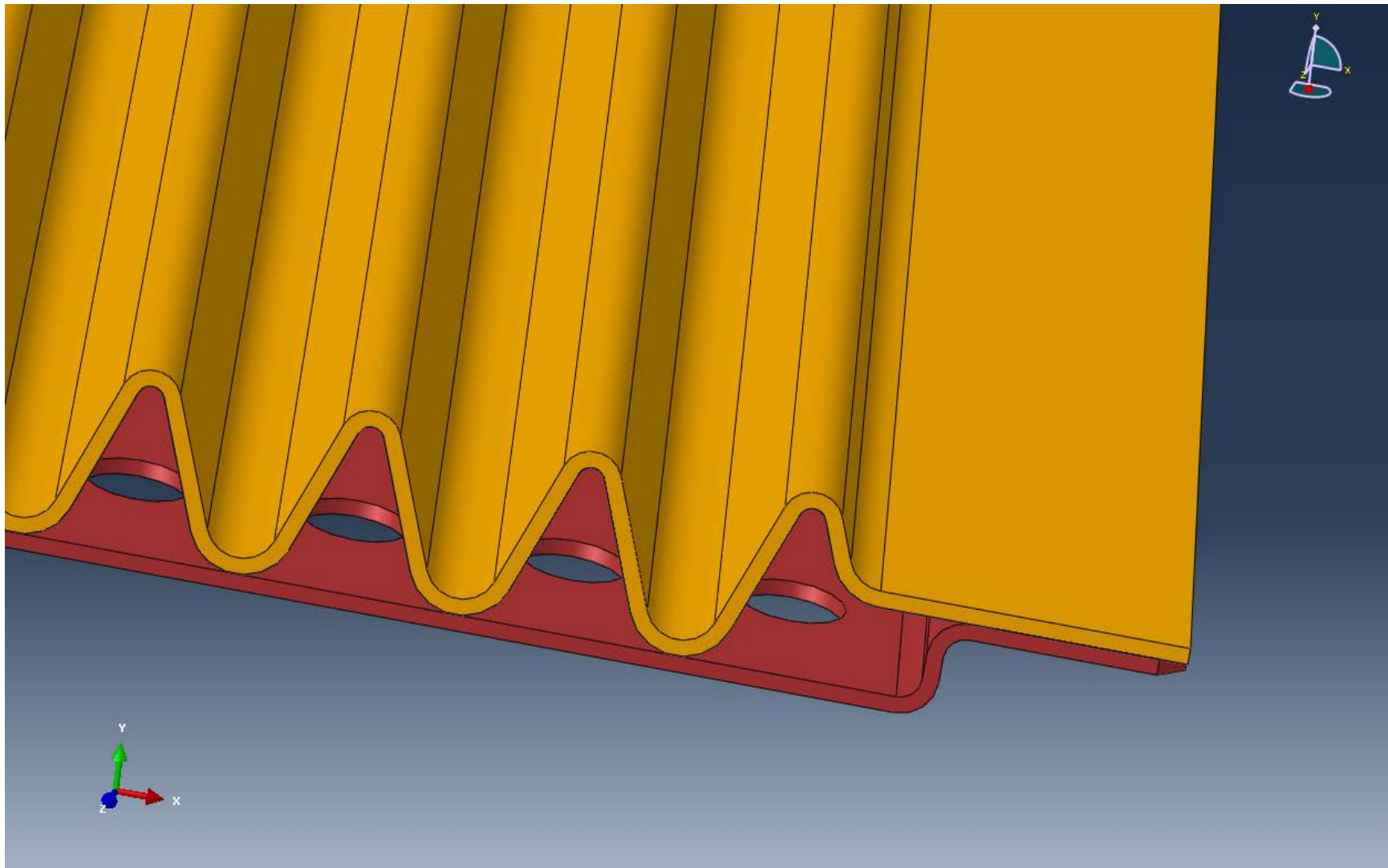


Redesigned Cell Layout with Die Cut Seals

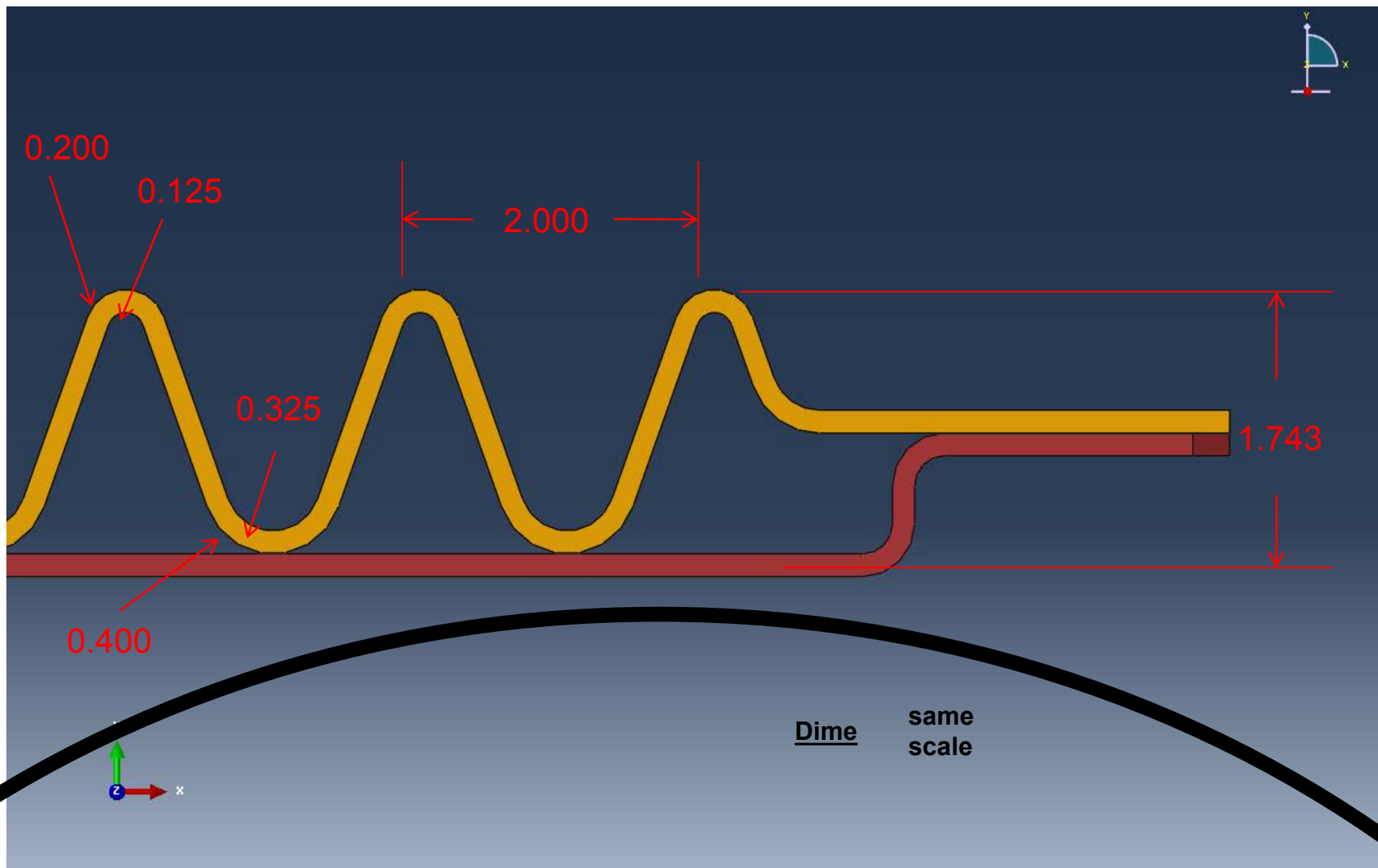
1. Anode Plate
2. Cathode Plate
3. Anode Spacer
4. Cathode Spacer
5. Plate to Spacer O-Ring
6. Cell Assembly
7. Anode Flow Directors
8. Cathode Flow Directors
9. Die Cut Membrane Seals



Anode Corrugated GDL-Plate Subassembly Isometric View



Corrugated GDL-Plate Subassembly Profile View



Status of Single Cell Hardware

- Cell fixture is complete.
- Subgasket forming tools are complete.
- Seals and flow distributors are being fabricated.
- Checkout of fixture and testing can begin as soon as Corrugated GDL-Plate Subassembly becomes available.

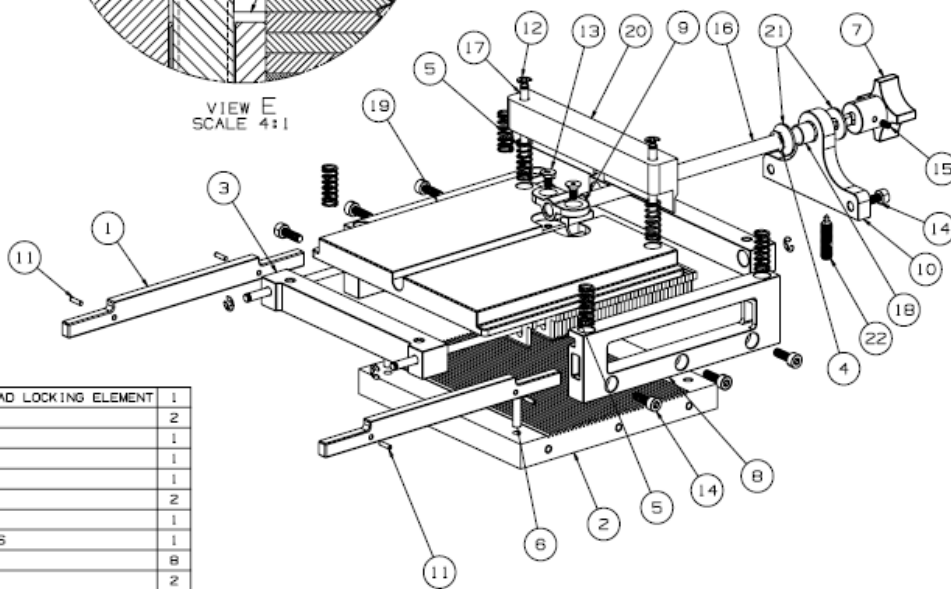
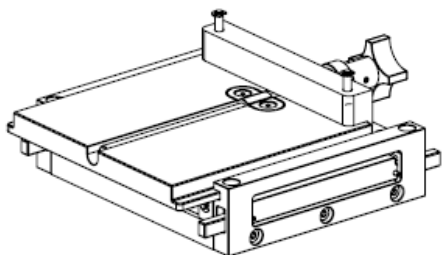
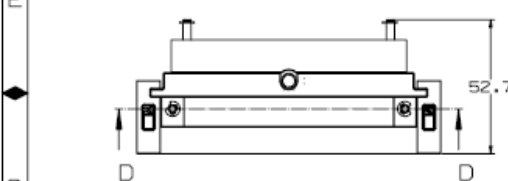
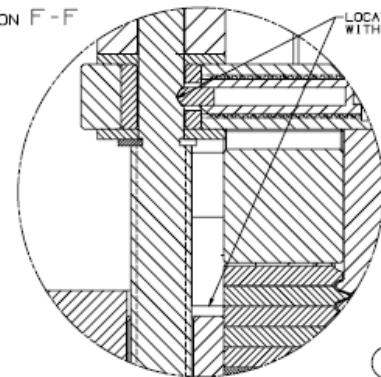
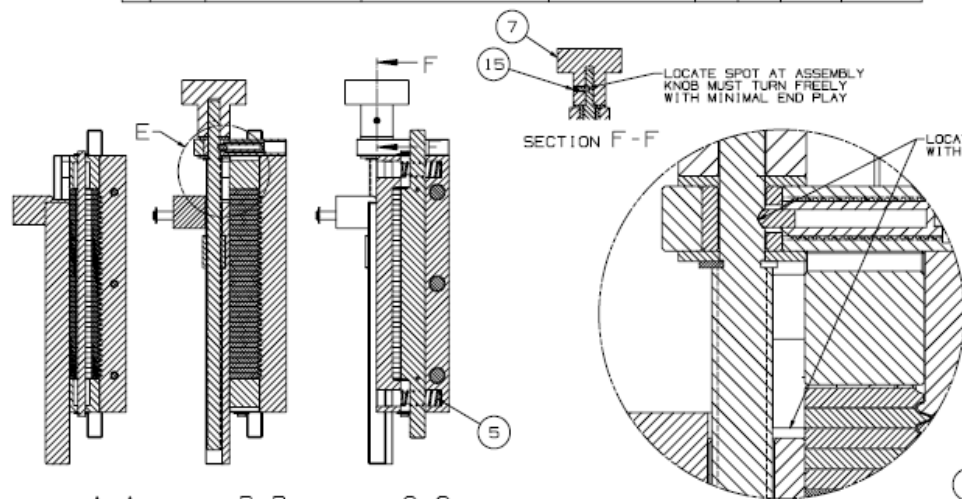
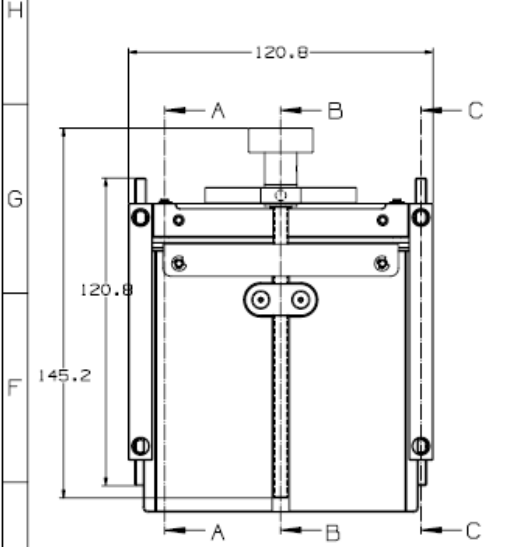
CORRUGATED GDL-PLATE SUBASSEMBLY FORMING TOOL

Technical Accomplishments



KEY PRODUCT CHARACTERISTICS									
⊕ SAFETY/COMPLIANCE	◇ FIT/FUNCTION	TOTAL ON DRAWING							
⊕ S/C CHECKPOINTS	◇ F/F CHECKPOINTS	LAST NO. USED							
NO	TYPE	DRAWING ITEMS	DESCRIPTION	RATIONALE	PTS	ZONE	ASM/MAN	CRITERIA	

DWG STATUS					REVISION HISTORY					AUTH		DR		CK		END	
ZONE	DATE	STG	REL	CHK/PDI													
13FE12	U	001	A		DRAWING CREATED					ESR-12	TM						



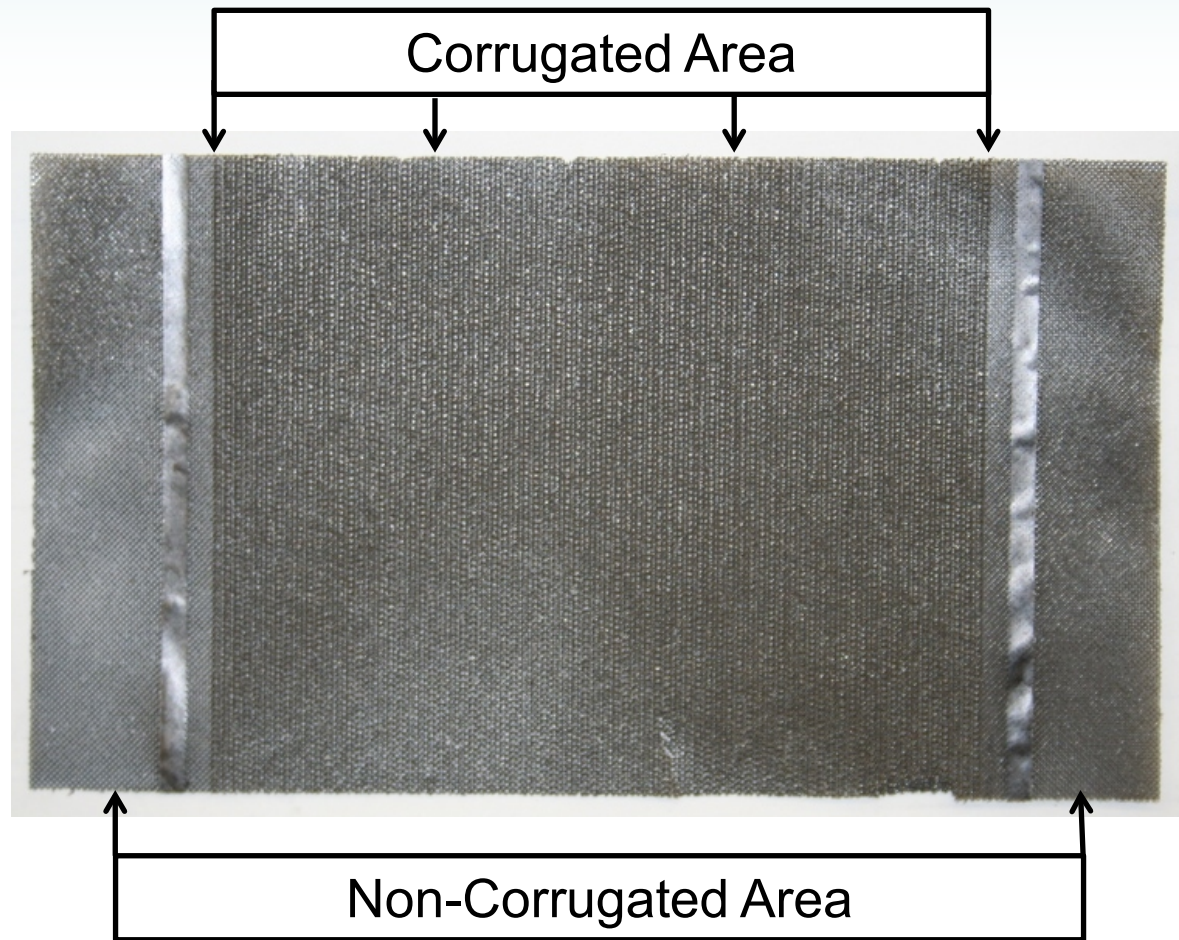
22	AYB00598	SPRING PLUNGER-MC#B476A34 W/NYLON THREAD LOCKING ELEMENT	1
21	AYB00461	WASHER-MC #95830A238 PTFE	2
20	AYB00422	SLIDE-FORM BLADE COMPRESSION	1
19	AYB02012	SLIDE PLATE-CF FORM TOOL	1
18	AYB00466	SLEEVE BEARING-MC #2639T3 PTFE	1
17	AYB00425	SHAFT-GUIDE	2
16	AYB00459	SHAFT-CM FORM TOOL	1
15	AYB00464	SCREW-CUP POINT SOCKET #2-56 X 3/16" SS	1
14	AKF14879	SCREW, SOCHD CAP, M3X10	8
13	AKF22551	SCREW, FLATHEAD, #4-40 X 0.250	2
12	AKF37390	RING - RETAINING, E-STYLE 1/8"	2
11	AKF47112	PIN, DOWEL .0625 DIA X .25 LG	4
10	AYB00457	PILLOW BLOCK-CM FORM TOOL	1
9	AYB00456	NUT-SLIDE	1
8	AKF47089	MOUNTING BAR-FORM BLADE LIFTING	2
7	AYB00458	KNOB-MC #B1135K11 ALUMINUM	1
6	AKF41961	DOWEL PIN-1/8 X 1/2 STEEL	4
5	AKF47102	COMPRESSION SPRING-.24"OD MCB435K39	6
4	AYB00460	CLIP-MC #9B40BA126 SS	1
3	AYB02002	BLADE ASM-CF FORMING	1
2	AYB02001	BASE-CF FORM TOOL	1
1	AKF47090	BAR-FORM BLADE LIFTING	2
ITEM	PART NO.	DESCRIPTION	QTY

	THIS DOCUMENT IS IN ACCORDANCE WITH ASME Y14.5M-1994 AS AMENDED BY THE GM GLOBAL DIMENSIONING AND TOLERANCING ADDENDUM-2004.			DATE
	REFERENCE	DRAWER T. MIGLIORE	13FE12	
	AKF47090	APVD1	6. FLY	
		APVD2		
		APVD3		
		APVD4		
		APVD5		
DO NOT SCALE	METRIC	FORM TOOL ASM-CONVULATED FLOWFIELD		
SIZE	DRAWING NUMBER	DWG STATUS	SHEET NUMBER	
A1	AYB02000	U 001	1 of 1	

HIERARCHY QUANTITY	DWG ITM	ZONE	DWG RELTN SHIP	PART NUMBER	P-A ITM	DES SLS	REL LVL	POI	NMC1	MASS (kg)	PART NAME	OBJECT	SH1	ITM	WF1	CLASS	SEC NO	DWG COLLECTOR	
PARTS SHOWN ON DRAWING												FILES TO BUILD DRAWING							

GENERAL MOTORS

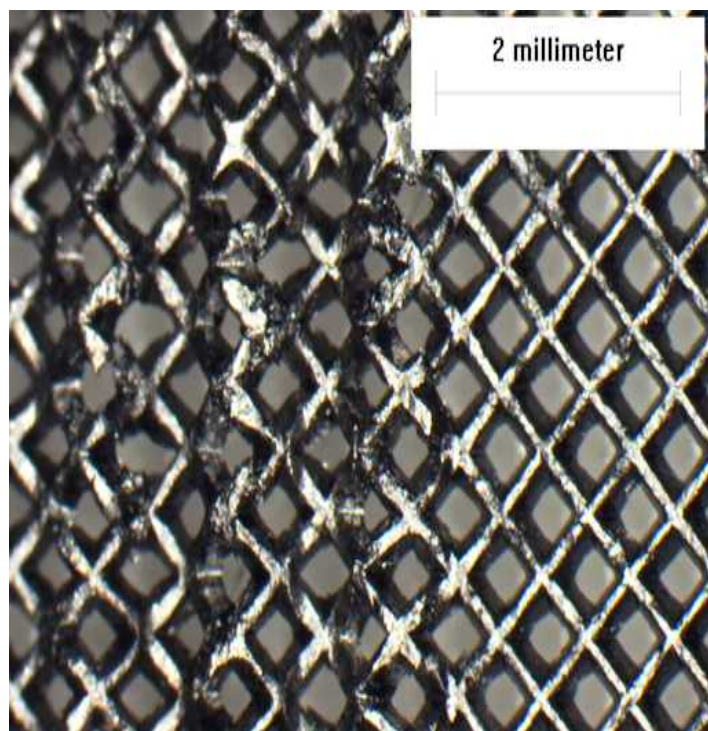
Formed GrafTech Perforated GDL Substrate



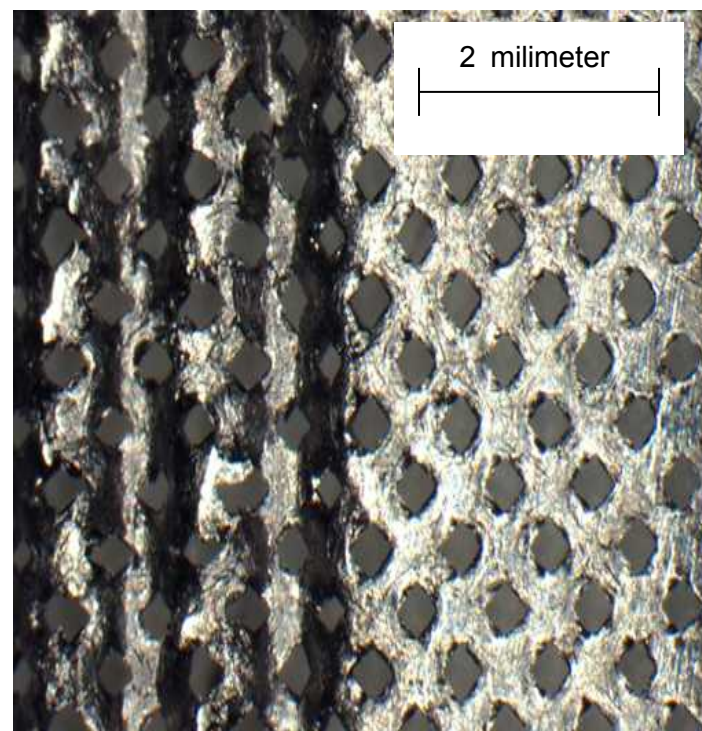
Perforated GDL substrate has been compression molded to corrugated geometry. The forming tool previously described will be used to make the corrugations instead of compression molding.

Formed GrafTech Perforated GDL Substrate

Rough side of the perforated material.
Notice the transition from flat material
into the corrugations.



Smooth side of the perforated material.
Notice the transition from flat material
into the corrugations.



The flat edges of the part will allow the outside gasket to seal the perforated material
in the fixture. (300 openings / cm²)

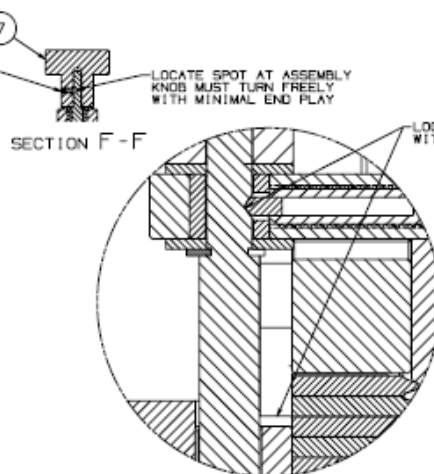
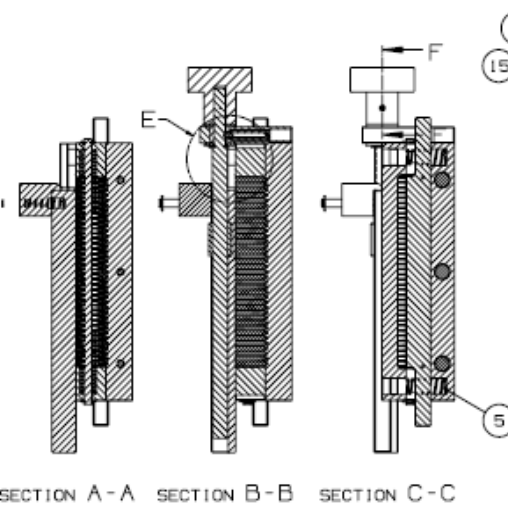
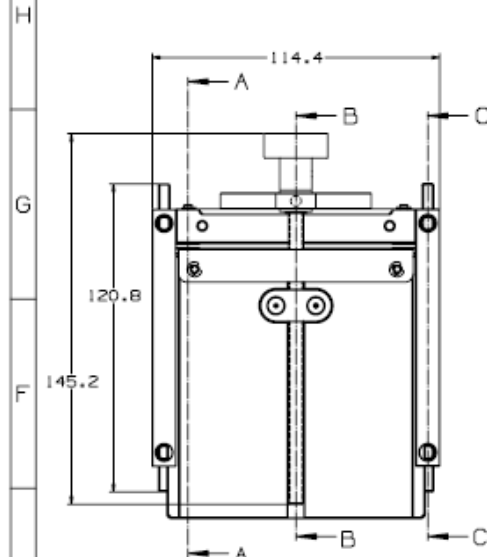
CORRUGATED MEMBRANE FORMING TOOL

Technical Accomplishments



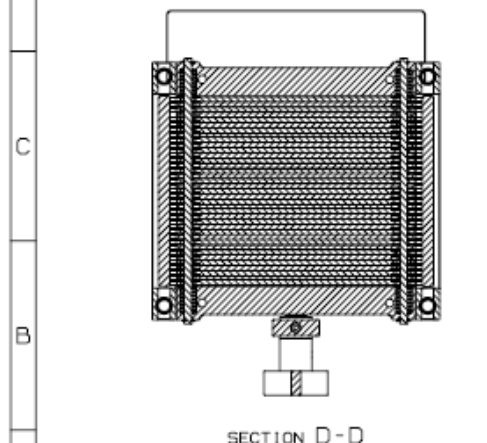
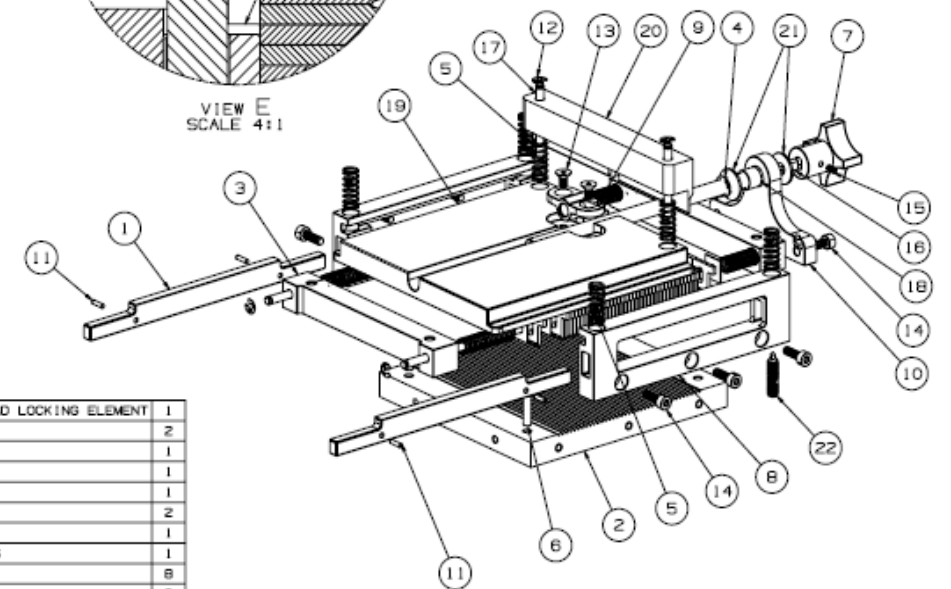
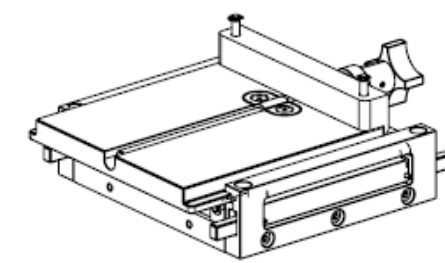
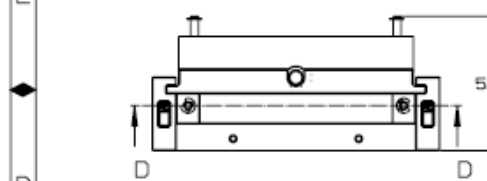
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ZONE	DWG STATUS				REVISION HISTORY				AUTH	DR	CK	END
	DATE	STG	REL	CHK/PDI								
295E11	U	001	A		DRAWING CREATED				ESR-11	TM		9F



LOCATE SPOT AT ASSEMBLY
KNOB MUST TURN FREELY
WITH MINIMAL END PLAY

LOCATE SPOT FOR SHAFT DETENT AT ASSEMBLY
WITH FORM BLADE SLIDE LOCATED AS SHOWN



22	AYB00599	SPRING PLUNGER-MC#8476A34 W/NYLON THREAD LOCKING ELEMENT	1
21	AYB00461	WASHER-MC #05630A238 PTFE	2
20	AYB00422	SLIDE-FORM BLADE COMPRESSION	1
19	AKF47097	SLIDE PLATE-CM FORM TOOL	1
18	AYB00488	SLEEVE BEARING-MC #2639T3 PTFE	1
17	AYB00425	SHAFT-GUIDE	2
16	AYB00459	SHAFT-CM FORM TOOL	1
15	AYB00464	SCREW-CUP POINT SOCKET #2-58 X 3/16" SS	1
14	AKF14878	SCREW, SOCHD CAP, M3X10	8
13	AKF22551	SCREW, FLATHEAD, #4-40 X 0.250	2
12	AKF37390	RING - RETAINING, E-STYLE 1/8"	2
11	AKF47112	PIN, DOWEL .0825 DIA X .25 LG	4
10	AYB00457	PILLOW BLOCK-CM FORM TOOL	1
9	AYB00458	NUT-SLIDE	1
8	AKF47099	MOUNTING BAR-FORM BLADE LIFTING	2
7	AYB00456	KNOB-MC #81135K11 ALUMINUM	1
6	AKF41981	DOWEL PIN-1/8 X 1/2 STEEL	2
5	AKF47102	COMPRESSION SPRING-.24"OD MCG435K39	8
4	AYB00460	CLIP-MC #8840BA126 SS	1
3	AKF47082	BLADE ASM-CM FORMING	1
2	AKF47081	BASE-CM FORM TOOL	1
1	AKF47090	BAR-FORM BLADE LIFTING	2
ITEM	PART NO	DESCRIPTION	QTY

GM THIS DOCUMENT IS IN ACCORDANCE WITH ASME Y14.5M-1994 AS AMENDED BY THE GM GLOBAL DIMENSIONING AND TOLERANCING ACQUAINTANCE-2004.

LG CHANGE RESTRICTED NO MANUAL CHANGES

DO NOT SCALE

METRIC DIMENSIONS SHOWN IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

SIZE: DRAWING NUMBER: **A1 AKF47080**

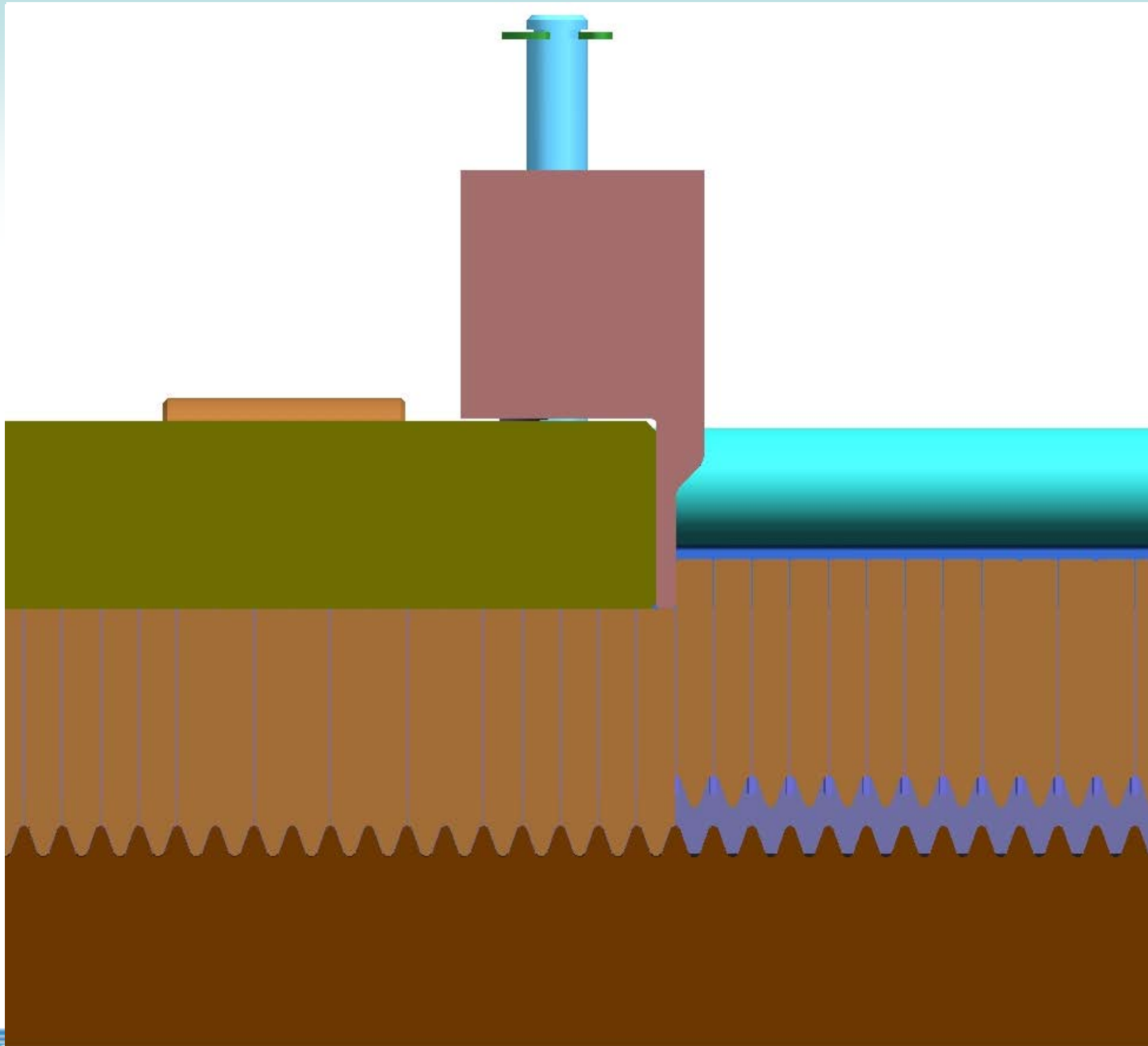
FORM TOOL ASM-CONVULATED MEMBRANE

DATE	BY	CHK	APP
295E11	T. WIGMORE		
295E11	G. FLY		
	APV2		
	APV3		
	APV4		
	APV5		

ZONE	STG	REL	PDI	SHEET NUMBER
U	001			1 of 1

HIERARCHY QUANTITY	DWG	ZONE	DWG REL. TO SHIP	PART NUMBER	P-A	QLS	DES	REL	PDI	NMC1	MASS (kg)	PART NAME	OBJECT	SH	ITM	MFI	CLASS	SEC	NO	DWG COLLECTOR
PARTS SHOWN ON DRAWING													FILES TO BUILD DRAWING							

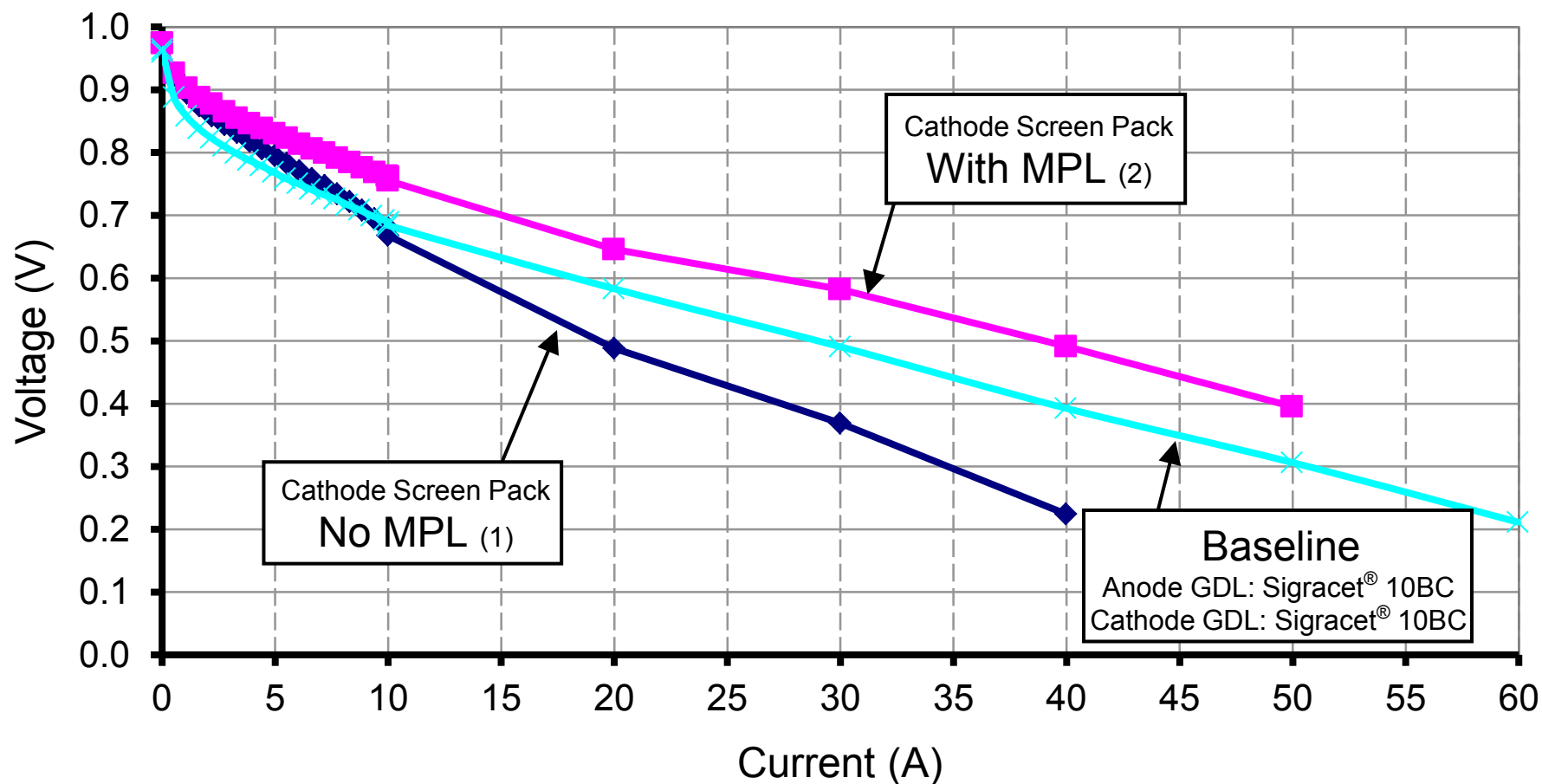
GENERAL MOTORS



GDL DEVELOPMENT

Demonstration of Microporous Layer's (MPL) Effect Utilizing a Flat Cell Configuration:

- (1) Cathode: Expanded Ti Metal Screen Pack (6 layers of 2 mil, ~2500 openings/cm² screen)
- (2) Cathode: Expanded Ti Metal Screen Pack with graphite microporous layer*



*US Patent #7063913

GKD Stainless Steel Woven Mesh Specifications

Volumetric 3 wire mesh

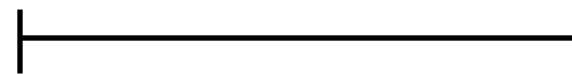
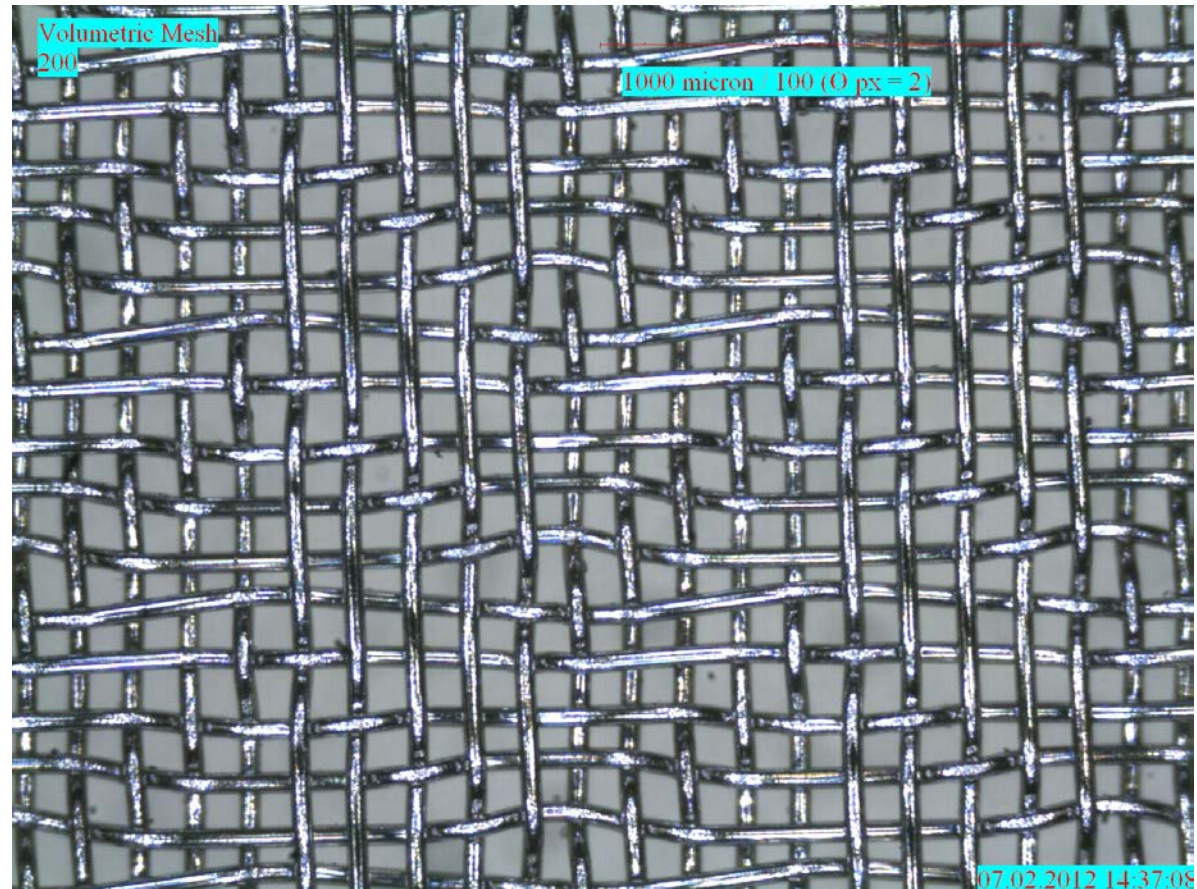
Opening: 0.077 mm

10,000 openings/cm²

Wire Diameter: 0.050mm

SS 316L (.0019")

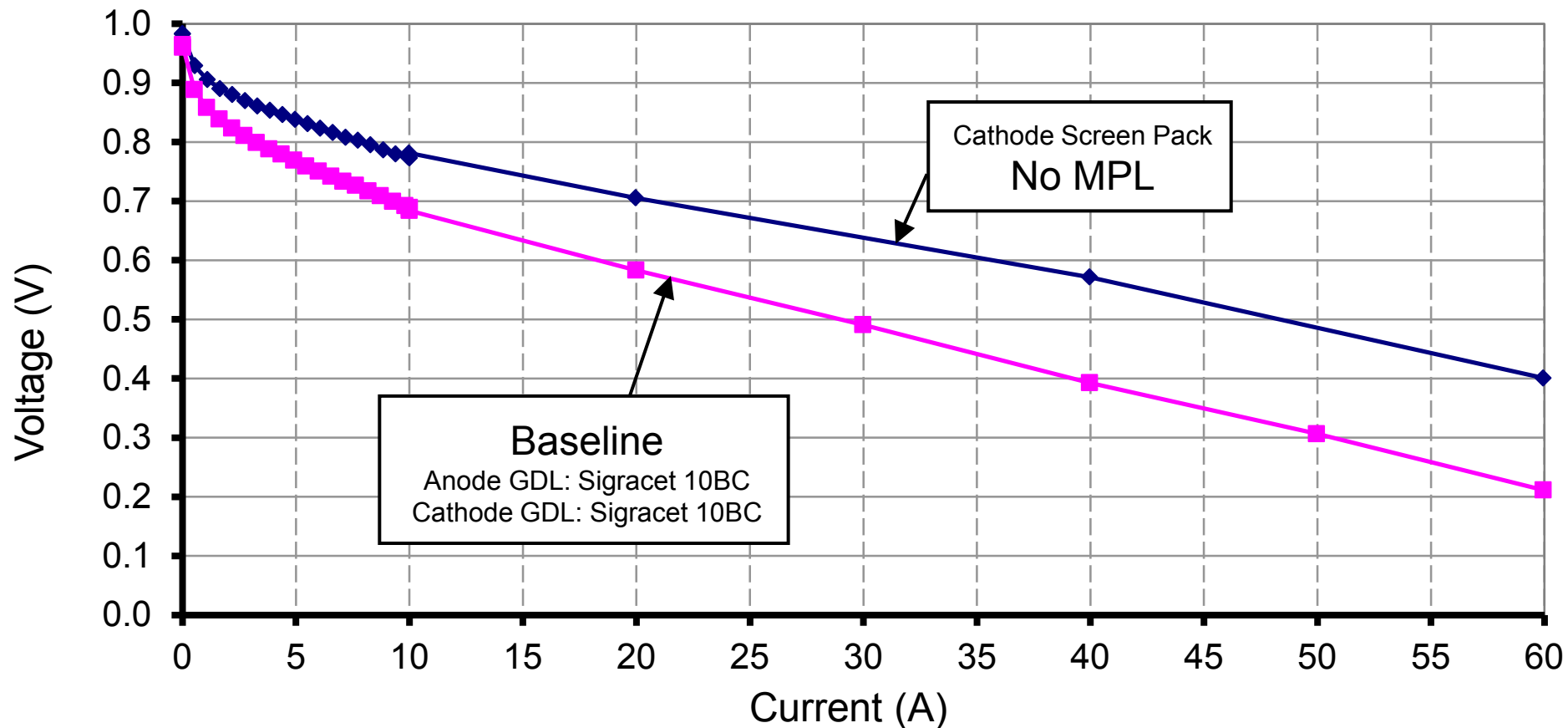
- Coated in 500nm Au
- Final gold-coated screen will be convoluted using the flowfield forming fixture previously described.
- Convoluted gold-coated screen will be brazed to gold-coated flowfield backing plate
- Gold becomes brazing flux



1mm

Demonstration of metal screen with no MPL in a flat cell configuration

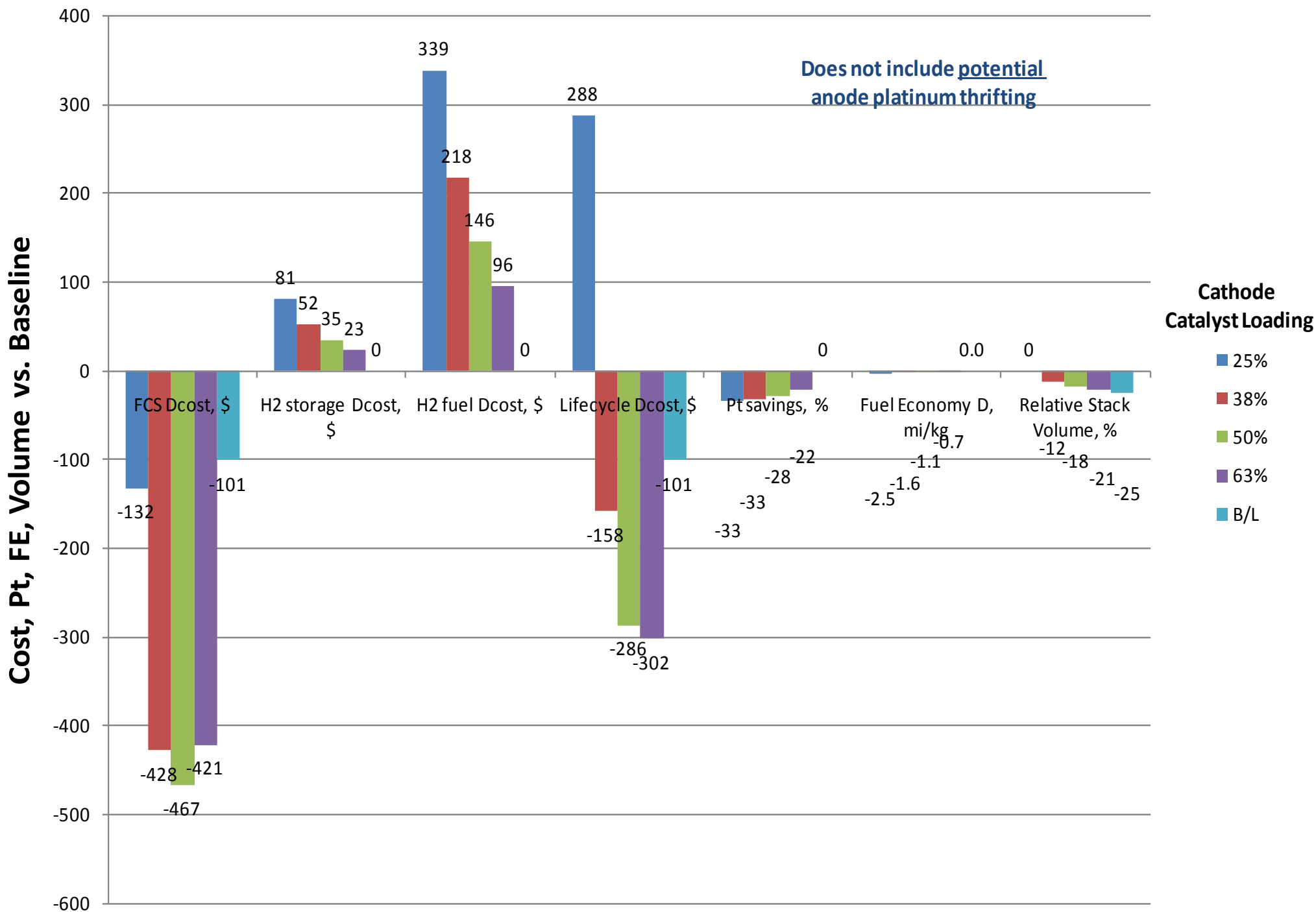
Cathode: 1 layer of gold-coated SS screen with no microporous layer



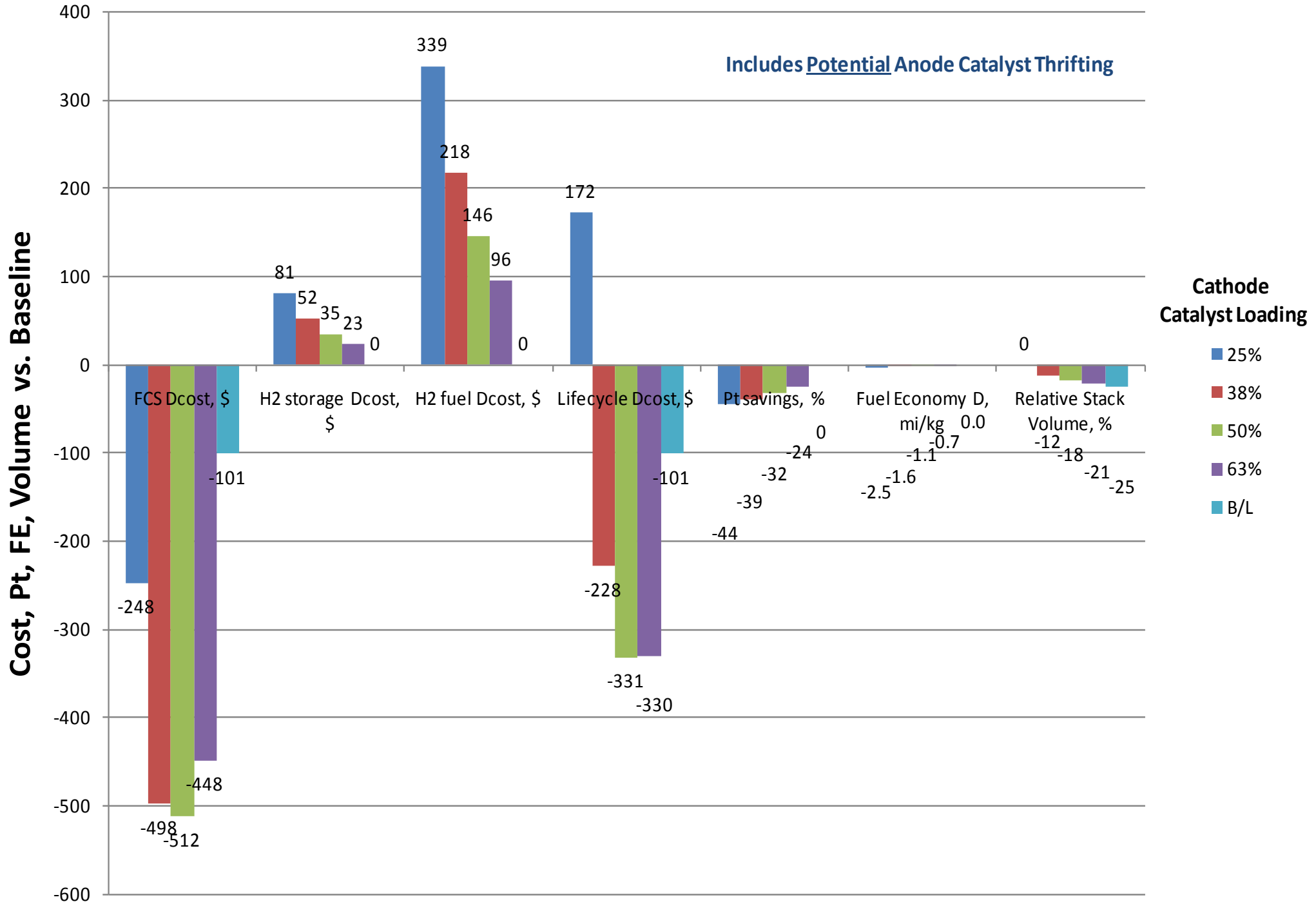
Assumptions and Definitions for GM Cost Analysis of Corrugated Fuel Cell Stack

- Fuel Cell Stack Delta cost reflects changes in membrane area, platinum loading, and bipolar plate cost
- Hydrogen Fuel Delta cost reflects additional hydrogen cost over life of vehicle due to increased hydrogen crossover from the increased membrane area
- Hydrogen Storage Delta cost reflects the cost of additional onboard storage required to maintain the same range as the baseline case.
- Lifecycle Delta cost is the Fuel Cell Stack Delta cost plus the Hydrogen Fuel Delta cost plus the Hydrogen Storage Delta cost.
- First slide reflects maintaining the same areal Pt loading on the anode while second slide reflects reducing the areal Pt loading to maintain the same total Pt loading on the anode.

Delta Cost, Pt, Fuel Economy, Stack Volume vs. Pt loading (corrugated stack)



Delta Cost, Pt, Fuel Economy, Stack Volume vs. Pt loading (corrugated stack)



Collaborations

Subcontractor

- **General Motors:** Modeling, Testing, and Jig Design

Subcontractor

- **GrafTech:** Graphite-based GDL - Plate Subassembly Development

Suppliers

- **Dexmet:** Expanded Ti metal screens and plates, in different shapes
- **GKD:** Woven SS metal screens

Vendors

- **Precious Plate, Inc.:** gold coating of metal GDL
- **Vac-Met:** metal brazing

Project Summary

- Detailed GM Lifecycle Analysis shows significant Life Cycle cost savings at a mid Pt loading and not at ultra low or not as much at baseline Pt loadings
- Small corrugation feature size requires fixturing to prototype
- Candidate GDL metal material have been found that have superior fuel cell performance and can be formed into the desired structures

Proposed Future Work

- Work with fixture to form corrugated GDL-Plate subassemblies, both in GrafTech graphite and brazed GKD SS
- Incorporate into single cell for first fuel cell testing