Agenda

• Aluminum is used in most cars and trucks (where and what extent)
• Fuel economy legislation (NA and Global)
• Technologies available to reach fuel economy improvements
• What has changed in the last 3 years
• Impact of aluminum use
• Questions
Historic Aluminum use in NA Auto (and future projections)

Executive Summary

Fifty years of uninterrupted aluminum growth for North American manufactured light vehicles is essentially guaranteed. There is nothing on the horizon that would tell us that this burst in aluminum growth can be significantly slowed over the next ten years.
Universal Aluminum Use (or at least very common)
Closures and Body in White
### Current Applications Produced Using Arconic Material

- **Ford**
  - F150 BIW and closures
  - F250, F350, F450 BIW and closures
  - Navigator
  - Expedition
  - Mustang hood and fenders

- **GM**
  - Chevy Malibu
  - Cadillac CTS, CTS-V hood and doors
  - Cadillac XTS
  - Cadillac ATS
  - Cadillac CT6, doors, BIW parts
  - Buick LaCrosse
  - Camaro

- **FCA**
  - 300
  - 200
  - Charger
  - Challenger
  - SRT-8 Charger
  - Liberty
  - SRT-8 Grand Cherokee
  - Cherokee
  - Pacifica Hood and Doors

- **Honda**
  - Acura MDX

- **Tesla**
  - BIW and closure panels

- **Nissan**
  - Altima
  - Maxima
  - Infiniti JX
  - Pathfinder
  - Rogue
  - Murano

- **Subaru**
  - Tribeca
  - Legacy
  - Outback hood, liftgate

- **Daimler Truck**
  - Cab outer
  - Inner panels, reinforcements

- **Toyota**
  - Lexus RX, hood and liftgate

- **PACCAR Truck**
  - Cab outer
  - Inner panels, reinforcements
Fuel Economy Legislation
Size and Weight Change in North America – Over time

Charting the Bloat
Ford F-150: 1984–2010

- **1984**
  - Length: 192" (w/o mirrors)
  - Width: 79" (w/o mirrors)
  - Weight: 3,891 pounds

- **1990**
  - Length: 197.1" (w/o mirrors)
  - Width: 79" (w/o mirrors)
  - Weight: 3,886 pounds

- **2000**
  - Length: 202.2" (w/o mirrors)
  - Width: 78.3" (w/o mirrors)
  - Weight: 3,923 pounds

- **2010**
  - Length: 211.2"
  - Width: 78.9" (w/o mirrors)
  - Weight: 4,823 pounds
Fuel Economy Regulations

Regulations only get tougher moving forward

Passenger Vehicle Fuel Economy Fleet Average

Solid Lines = Actual Std.
Dotted Lines = Estimated Std.

Passenger Vehicle GHG Emissions Fleet Average

Solid Lines = Actual Std.
Dotted Lines = Estimated Std.

Conversion factor between fuel economy and CO₂ emissions:
• 8887 g CO₂ per gallon of gasoline
• 10180 g CO₂ per gallon of diesel
US Corporate Average Fuel Economy (CAFE) standards are size based, so each vehicle has a fuel economy target based upon its wheelbase and track.
Truck Targets – What is a truck?

Truck CAFE targets

Footprint (sq ft) vs. Target mpg

2012 Truck target
2016 truck target
2017 Truck target
2018 Truck Target
2019 truck target
2020 truck target
2025 truck target

Models:
F150
Durango
Grand Cherokee
Example: Chrysler 300

Chrysler 300 Model Introduced in 2011

Wheelbase: 120.2 inches
Ave. track: 63.6 inches
Footprint = wheelbase x track/144
  = 53 sq ft.

<table>
<thead>
<tr>
<th>Year</th>
<th>Target (mpg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>29.2</td>
</tr>
<tr>
<td>2016</td>
<td>32.6</td>
</tr>
<tr>
<td>2020</td>
<td>37.6</td>
</tr>
<tr>
<td>2025</td>
<td>46.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Engine</th>
<th>transmission</th>
<th>Café mpg</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.7 L (8 cyl)</td>
<td>Auto 5 speed</td>
<td>24.1</td>
</tr>
<tr>
<td>3.6 L (6 cyl)</td>
<td>Auto 5 speed</td>
<td>27.2</td>
</tr>
<tr>
<td>3.6 L (6 cyl)</td>
<td>Auto 8 speed</td>
<td>30</td>
</tr>
</tbody>
</table>

11% improvement by reducing engine size
21% improvement by adding 8 speed transmission

Next launch --- 2018 !!!
Low Friction Lubricants
Engine Friction Reduction
VVT - Dual Cam Phasing (DCP)
Discrete Variable Valve Lift (DVVL) on OHV
Stoichiometric Gasoline Direct Injection (GDI)
Combustion Restart
Turbocharging and Downsizing
Exhaust Gas Recirculation (EGR) Boost
6/7/8-Speed Auto. Trans with Improved Internals
Dual Clutch or Automated Manual Transmission
Electric Power Steering
Improved Accessories
Belt mounted Integrated Starter Generator
Mass Reduction (3.5 to 8.5% of Curb Weight)
Mass Reduction (1.5% of Curb Weight)
Low Rolling Resistance Tires
Low Drag Brakes
Aero Drag Reduction

% Improvement in Fuel Economy

Dramatic Weight Reduction Across All Applications

Potential Weight savings with aluminum – D-class vehicle

<table>
<thead>
<tr>
<th>Component</th>
<th>Steel (kg)</th>
<th>Aluminum (kg)</th>
<th>Typical Wt. Saving (kg)</th>
<th>% saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hood</td>
<td>16</td>
<td>8</td>
<td>8</td>
<td>50</td>
</tr>
<tr>
<td>Fenders</td>
<td>7</td>
<td>3.5</td>
<td>3.5</td>
<td>50</td>
</tr>
<tr>
<td>Decklid</td>
<td>17</td>
<td>9</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>Doors</td>
<td>73</td>
<td>43</td>
<td>30</td>
<td>41</td>
</tr>
<tr>
<td>BIW</td>
<td>328</td>
<td>209</td>
<td>119</td>
<td>36</td>
</tr>
<tr>
<td>Total</td>
<td>441</td>
<td>273</td>
<td>169</td>
<td>38</td>
</tr>
</tbody>
</table>

50 kg saved

Source: Alcoa Technical Center

(1) Current BIW using AHSS

Potential Weight savings with aluminum – D-class vehicle
Primary and Secondary Weight Savings

Primary weight savings is the actual savings associated with changes to the Body and closures via material changes, design optimization and thickness reductions.

In all cases, a primary weight savings leads to a secondary weight savings:

- A lighter vehicle allows for smaller suspension components, brakes, engine, etc. with comparable performance of the base vehicle
- Typically, 30% of the primary savings can be obtained as secondary savings in cars.¹
- In light trucks, 10-15% of the primary savings is achievable (because of towing and cargo requirements).

At the specification stage, the weight target for the secondary systems must be reduced to reflect the primary weight savings.

A 10% REDUCTION IN CURB WEIGHT RESULTS IN A 6 TO 7% FUEL ECONOMY IMPROVEMENT (INCLUDING ENGINE DOWNSIZING)

¹ AZT reference
Aluminum Auto Applications – Current and Previous
High volume auto body evolution

Evolution of auto design scenarios

MPG Requirements

Aluminum Intensive Vehicle
(Strength & ductility for safety, Robust joining)

Multi-Material

Tailoring Products

Steel & Aluminum Hybrid
(High scrap utilization, Steel to aluminum joining)

Aluminum Closures
(Increased formability for design/styling)
Review of 3 Production Aluminum Doors

**Audi A8**  
(same Concept as A6)

- Front Driver door (DIW)
- Wt = 25 lb (11.4 kg)
- Max Depth = 145 mm
- Joining methods: laser, SPR
- Number of parts = 14 (incl 1 extrusion)
- Alum extruded door guard beam
- Vehicle production volume:  
  - A8 - 23,000
  - A6 – 220,000

**Infiniti M56**

- Front Driver door (DIW)
- Wt = 25 lb (11.4 kg)
- Max Depth = 130 mm
- Joining methods: MIG, SPR
- Number of parts = 16 (incl 5 extrusions)
- Alum extruded door guard beam
- Vehicle production volume = 15,000

**BMW 7 Series**  
(same Concept as 5 Series)

- Front Driver door (DIW)
- Wt = 25 lb (11.4 kg)
- Max Depth = 156 mm
- Joining methods: laser, SPR, clinch
- Steel door guard beam
- Number of parts = 11
- Vehicle production volume:  
  - 7 series - 65,000
  - 5 series – 210,000
Audi Aluminum Vehicles

2013 Audi A8
Aluminum since 1994

2006 Audi TT
Aluminum since 2008 (hybrid steel/alum)

2016 Audi Q7

2013 Audi R8
Aluminum since 2006
Jaguar/Land Rover Aluminum Vehicles

2013 Jaguar XJ
Aluminum since 2003

2013 Jaguar XE

2013 Range Rover

2013 Jaguar F Type

2016 Jaguar XF

2017 Jaguar F Pace
Ferrari 430
Aluminum since 1998

Ferrari 599
Aluminum since 2003

Lamborghini Gallardo
Corvette – GM Aluminum Vehicles

Corvette Z06
Aluminum Frame since 2006

New Model C07 and Z07 launched in 2013
All models will have an aluminum frame
Mercedes Benz Aluminum Vehicles

2013 Mercedes Benz SL Roadster

110 kg lighter than steel body

2011 Mercedes Benz AMG SLS Coupe
Mercedes Benz Steel/Aluminum Hybrid Vehicles

2014 Mercedes Benz S Class

Aluminum roof, doors, hood, decklid, rear package shelf, frontend, front subframe

Saved 50 kg using aluminum over the steel body
2015 F150 Introduction – 2014 Detroit Auto Show
Ford F-150 facts

Best in class gasoline fuel economy (19/26 mpg)

Best in class towing performance

700 - 890 lb lighter than 2014 steel model

America’s best selling vehicle for over 30 years

Contributes to CAFE improvement for the first time
Aluminum improves fuel economy across Ford’s entire vehicle line

THE NEW 3.5L V6
3.5L ECOBOOST®
5.0L V8 FFV

"THE NEXT GENERATION"
2.7L ECOBOOST®

2.7 L EcoBoost engine has higher cargo capacity than steel truck with 5L and 6.2L V8 engines

Vehicle weight savings enabled engine downsizing
# Curb Weight Comparison between steel and aluminum F150

<table>
<thead>
<tr>
<th></th>
<th>Regular Cab</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Aluminum Ford F150 - 2015 Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5.5-ft. Styleside</td>
<td>6.5-ft. Styleside</td>
<td>8.0-ft. Styleside</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Steel Ford F150 - 2014 engine</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5L V6 EcoBoost</td>
<td>4x2</td>
<td>905</td>
<td>950</td>
<td>678</td>
<td>720</td>
<td>2.7L EcoBoost® V6</td>
</tr>
<tr>
<td>3.5L V6 EcoBoost</td>
<td>4x4</td>
<td>-</td>
<td>-</td>
<td>516</td>
<td>552</td>
<td>3.5L EcoBoost® V6</td>
</tr>
<tr>
<td>Base Curb Weight - 3.7L V6</td>
<td></td>
<td>635</td>
<td>616</td>
<td>610</td>
<td>608</td>
<td>3.5L Ti-VCT V6</td>
</tr>
<tr>
<td>5.0L V8 (lbs)</td>
<td></td>
<td>568</td>
<td>546</td>
<td>557</td>
<td>534</td>
<td>5.0L Ti-VCT V8</td>
</tr>
<tr>
<td>6.2L V8</td>
<td></td>
<td>740</td>
<td>773</td>
<td>778</td>
<td>-</td>
<td>5.0L Ti-VCT V8</td>
</tr>
</tbody>
</table>

|                     | SuperCab |                 |                 |                 |                 |                                  |
|---------------------|----------|----------------|----------------|----------------|----------------|                                  |
|                     | 5.5-ft. Styleside | 6.5-ft. Styleside | 8.0-ft. Styleside |                 |                 |                                  |
| **Steel Ford F150 - 2014 engine** |             |                 |                 |                 |                 |                                  |
| 3.5L V6 EcoBoost    | 4x2       | 740            | 773            | 778            | -              | 2.7L EcoBoost® V6                |
| 3.5L V6 EcoBoost    | 4x4       | 632            | 654            | 614            | 640            | 3.5L EcoBoost® V6                |
| Base Curb Weight - 3.7L V6 |             | 798            | 874            | -              | -              | 3.5L Ti-VCT V6                   |
| 5.0L V8 (lbs)       |             | 648            | 691            | 691            | 733            | 5.0L Ti-VCT V8                   |
| 6.2L V8             |             | 913            | 919            | -              | -              | 5.0L Ti-VCT V8                   |
# Curb Weight Comparison between steel and aluminum F150

<table>
<thead>
<tr>
<th></th>
<th>5.5-ft. Styleside</th>
<th>6.5-ft. Styleside</th>
<th>8.0-ft. Styleside</th>
</tr>
</thead>
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<tr>
<td><strong>Steel Ford F150 - 2014 engine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5L V6 EcoBoost</td>
<td>733</td>
<td>809</td>
<td>778</td>
</tr>
<tr>
<td>3.5L V6 EcoBoost</td>
<td>617</td>
<td>690</td>
<td>658</td>
</tr>
<tr>
<td><strong>Base Curb Weight - 3.7L V6</strong></td>
<td>657</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5.0L V8 (lbs)</td>
<td>632</td>
<td>715</td>
<td>681</td>
</tr>
<tr>
<td>6.2L V8</td>
<td>908</td>
<td>903</td>
<td>943</td>
</tr>
<tr>
<td><strong>Aluminum Ford F150 - 2015 Engine</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.7L EcoBoost® V6</td>
<td>747</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5L EcoBoost® V6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5L Ti-VCT V6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0L Ti-VCT V8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: ARCONIC*
CAFE comparison – Smallest engine option available in 4WD
Cargo Capacity Comparison

Cargo Capacity
3.0 L V6 Ecoboost

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Cargo Capacity (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5 ft bed 4 x 2</td>
<td>1500</td>
</tr>
<tr>
<td>5.5 ft bed - 4 x 4</td>
<td>2000</td>
</tr>
<tr>
<td>6.5 ft bed - 4 x 2</td>
<td>2500</td>
</tr>
<tr>
<td>6.5 ft bed - 4 x 4</td>
<td>2000</td>
</tr>
</tbody>
</table>

2014 F150 (Steel)  2015 F150 (Aluminum)
2017 Ford Super Duty – Also all aluminum
CAFÉ standards for Trucks – Why not go smaller?

2013 GMC Canyon, Chevy Colorado

<table>
<thead>
<tr>
<th></th>
<th>2.5L I4</th>
<th>3.6 L V6 VVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x2</td>
<td>20/27</td>
<td>18/26</td>
</tr>
<tr>
<td>4x4</td>
<td>19/26</td>
<td>17/24</td>
</tr>
</tbody>
</table>

2015 F150 Fuel Economy – Yellow Stickers

<table>
<thead>
<tr>
<th></th>
<th>2.7L EcoBoost® V6</th>
<th>3.5L Ti-VCT V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x2</td>
<td>19/26/22</td>
<td>18/25/20</td>
</tr>
<tr>
<td>4x4</td>
<td>18/23/20</td>
<td>17/23/19</td>
</tr>
</tbody>
</table>
CAFE standards for Trucks – Why not go smaller?
Conclusions

• Some technologies such as low friction lubes, aero improvements, electric power steering will be used in nearly all vehicles

• Engine and transmission improvements are critical to reaching Café targets, but can’t do it all

• Weight reduction without significant vehicle downsizing allows for additional engine downsizing (along with turbos) to improve fuel economy without reducing performance.

• Aluminum hoods are common place and are continuing to grow, more closures will become aluminum.

• Body applications are the next area for aluminum implementation after closures – typically only on the larger vehicles. Look for applications on the D, E class and pickup trucks.

• Some OEMs will focus on all aluminum and others will use a hybrid material (steel/aluminum) approach.
ARCONIC
Innovation, engineered.
New Alloy Development Targeting Body Structure Applications

Applications

- Closure panels
- Crash critical
- High form
- High strength

Automotive growth projects
Component Analysis

- The number of vehicles with aluminum closures and complete body structures will increase by significant proportions over the next ten years
  - The chart does not include the numerous vehicles that will also have partial body structures, vacuum die cast shock towers and other VD cast body parts
Truck CAFE targets

- Ford F150
- 2.7 L EcoBoost 2WD
- 3.5L EcoBoost 2WD
- 3.5L EcoBoost 4WD
- Grand Cherokee
- Durang

Footprint (sq ft)
Truck CAFE targets

Footprint (sq ft)

- 2016 truck target
- 2020 truck target
- 2025 truck target

2.7 L EcoBoost 2WD

2.7 L EcoBoost 4WD

CAFE standards for Trucks – Ford F150 2.7 L EcoBoost 4WD