SASFT
STRATEGIC ALLIANCE FOR STEEL FUEL TANKS

# Steel Fuel Tanks...
# ...Features and Attributes

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www.sasft.org

# Introduction

- For most of the history of the automobile, STEEL fuel tanks have been used
  - Effective container
  - Safe
  - Easily manufactured
  - Durable
  - Recycled
- In recent decades PLASTIC fuel tanks have emerged and grown market share
- Drivers, trends and improved features of the STEEL TANK are reviewed herein

# Outline

- Historical Perspective
  - Steel and Plastic tanks
  - Market mix
  - Misperceptions about steel tanks
- Current Market Requirements/Drivers for change
- Features and Attributes of Steel Tanks
  - Cost competitiveness and availability
  - Design flexibility
  - Fuel Capacity
  - Mass
  - Durability
    - Corrosion Requirements
      - External/road environment
      - Internal/fuels
    - Fatigue
  - Evaporative Emissions
  - Sustainability/recycling

# Historical Perspectives

- <u>Monolayer, HDPE plastic tanks</u> emerged in Europe in late 20th century
  - — Blow-molded
  - — Lower cost than steel
    - - BUT ….. *Highly permeable, allowing evaporative emissions*
      *Fluorination and sulphonation helped reduce emissions*
- <u>Multilayer HDPE plastic tanks</u> were then developed
  - — Blow-molded
  - — Favored in North America (lower emissions, slosh noise control)
    - - BUT ….. *More complex structure/molding increased costs*
      ….. *Impact of rising oil prices*
- <u>Environmental issues</u> (from 1990s)
  - — Stricter regulations on evaporative emissions (EPA, CARB, Euro V)
    - - EFFECT ….. *More complex plastics/manufacturing increases plastic tank costs*
  - — Growing requirement for recycling (especially Europe)
- <u>Advent of alternative fuels</u>
  - — Alcohol-containing fuels (E10 to E100). *Impact on emissions and driving range*
  - — Bio-diesel fuels (B10 to B90). *Impact on durability*

# Current Market Requirements (North America)

- Competitive Costs
- Low Mass
  - Driven by new fuel economy standards
- Good Design Flexibility
  - Limited engineering space requires complex shaped tanks
  - Influences fuel capacity/driving range
- Durability
  - CARB requires fully-functional fuel systems for 15 yrs
    (150,000 miles)
  - Variety of fuels

# Current Market Requirements (North America) *(Continued)*

- Strict Evaporative Emission Requirements
  - Driven by California Air Resources Board (CARB)
    - PZEV requirements (HC/24 hrs)
    - Full Vehicle: <0.35g
    - Fuel System: <0.054g
    - Fuel Tank: <0.015g (target set by OEMs)
  - Numerous USA states & Canada adopting CARB requirements
- Alternative Fuels
  - Impact on durability, evaporative emissions, driving range
- **Recycling** (important in Europe)

# Future Market Shares

- Will be determined by how STEEL and PLASTIC tanks can meet changing requirements
  - Cost and Availability
  - Lower mass
  - Stricter evaporative emissions
  - Durability/compatibility with new fuels
  - Fuel Capacity
    - Likely reduced driving range with alcohol fuels
  - Future generation vehicles e.g. Hybrids
  - Recycling (EOL vehicle accountability)

# Outdated Perceptions of Steel Fuel Tanks

- "Always more costly"
- "Less design flexibility"
- "Have higher mass"
- "Simple shapes minimize fuel capacity"
- "Steel rusts and corrodes"

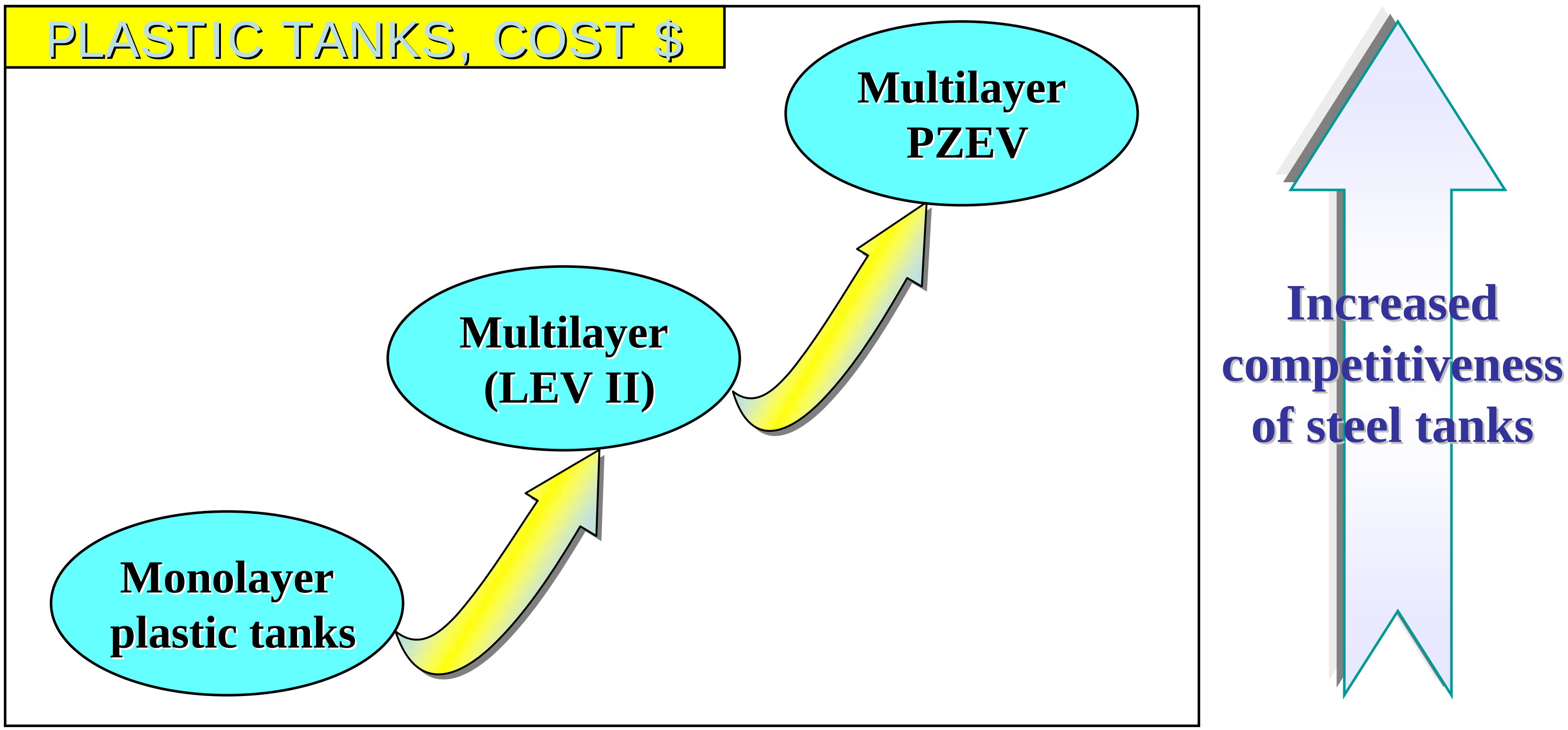
*Based on new steels and tank manufacturing processes,*
*these are MISPERCEPTIONS and…*

# Benefits of Steel Fuel Tanks

- Impermeability is ideal for meeting low evaporative emission requirements (e.g., PZEV)
- Highly formable steels & improved manufacturing allow:
  - Complex shapes
  - Increased fuel capacity
- New steel 'systems' are:
  - Resistant to external corrosion (beyond 15 yrs/150,000 miles)
  - Compatible with alternative fuels
  - Preferred for hybrid-vehicle tanks
- High rigidity for good shape stability

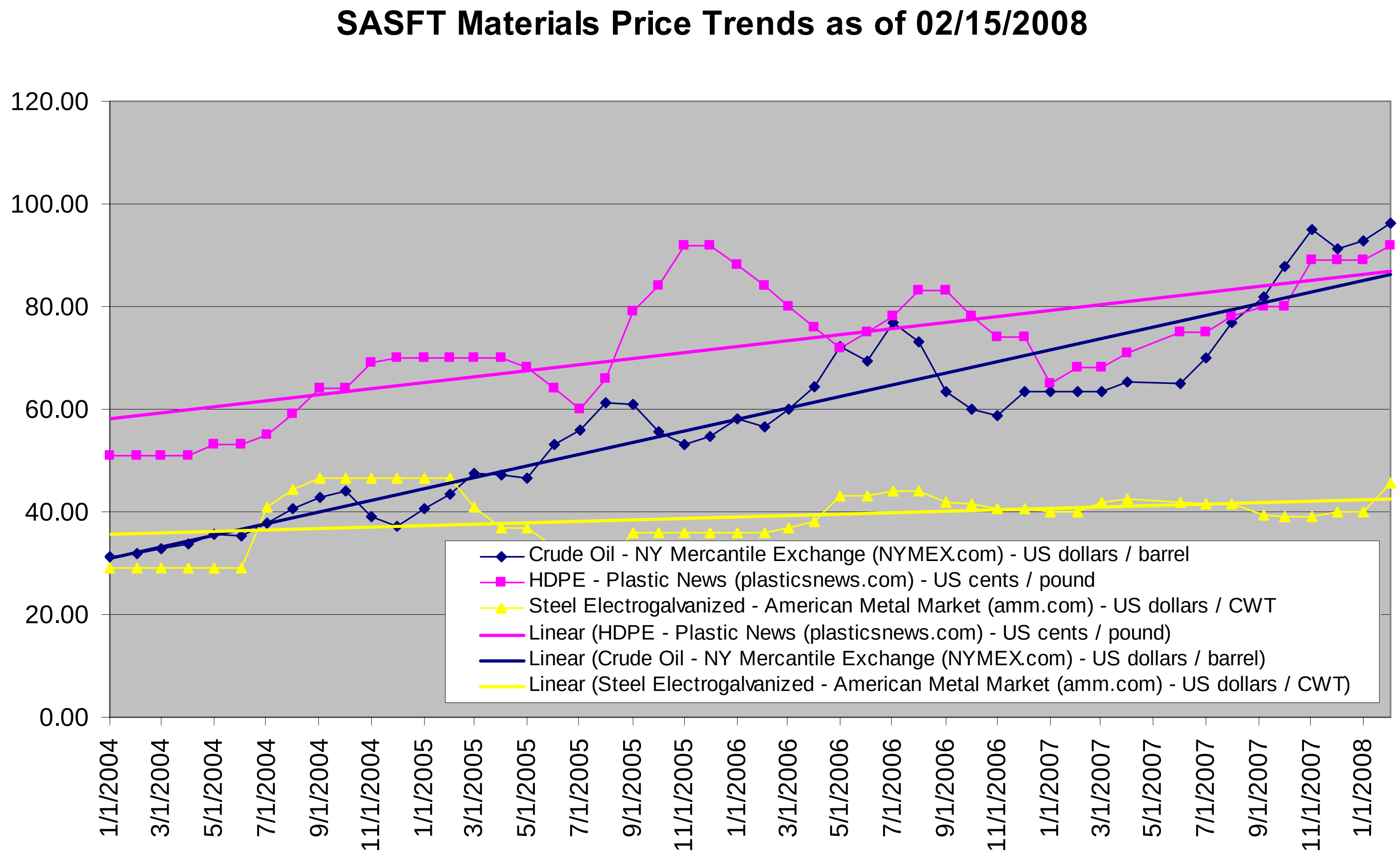
# Cost Competiveness

- As technical requirements for fuel tanks have increased, the cost competitiveness of steel tanks has increased.



# Cost Competiveness

- HDPE resin prices have been increasing much faster than steel



# Cost Competiveness

## A Purchaser's View:

"... resin price has been going up"

"... a steel fuel tank can be welded together very close to the assembly plant and now you have reduced transportation cost and that is another key driver."

Bo Anderson (GM Purchasing)
Interview with Design News, Nov. 27, 2007

## An Editor's View:

"New steels (tanks) are increasingly formable allowing more design freedom and they are 100% recyclable. And they are increasingly cost competitive. With a landed cost approach and ballooning hydrocarbon prices, they are even preferred on a cost basis."

Doug Smock (Contributing Editor)
Design News, Nov. 27, 2007

# Cost Competiveness

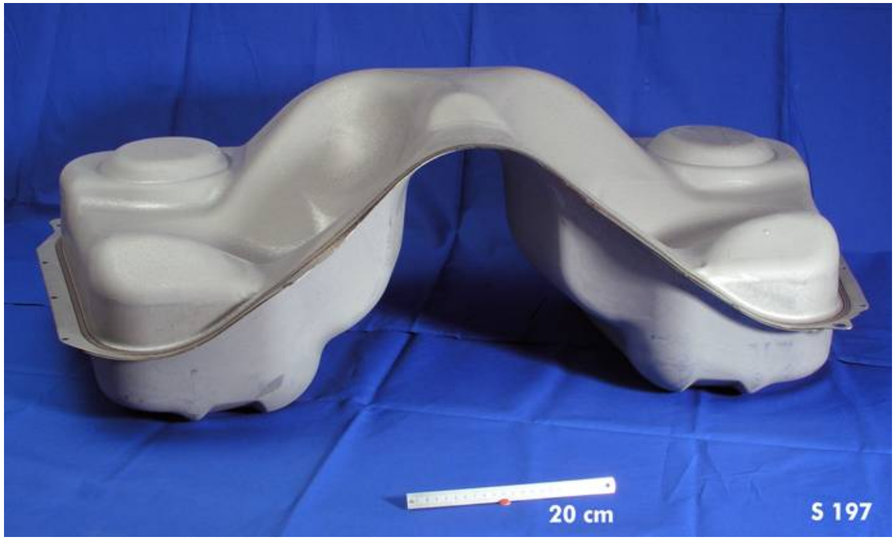
- Today steel tanks are very cost competitive
  - Especially for high technology tanks

*The PERCEPTION of higher cost steel tanks is FALSE*

- In the future
  - Geo-political uncertainty is likely to drive up oil and resin prices still further
  - Steel prices and steel's availability will be influenced much less by geo-political events

# Design Flexibility

- Today's steels are formed to highly complex shapes




Ford Mustang

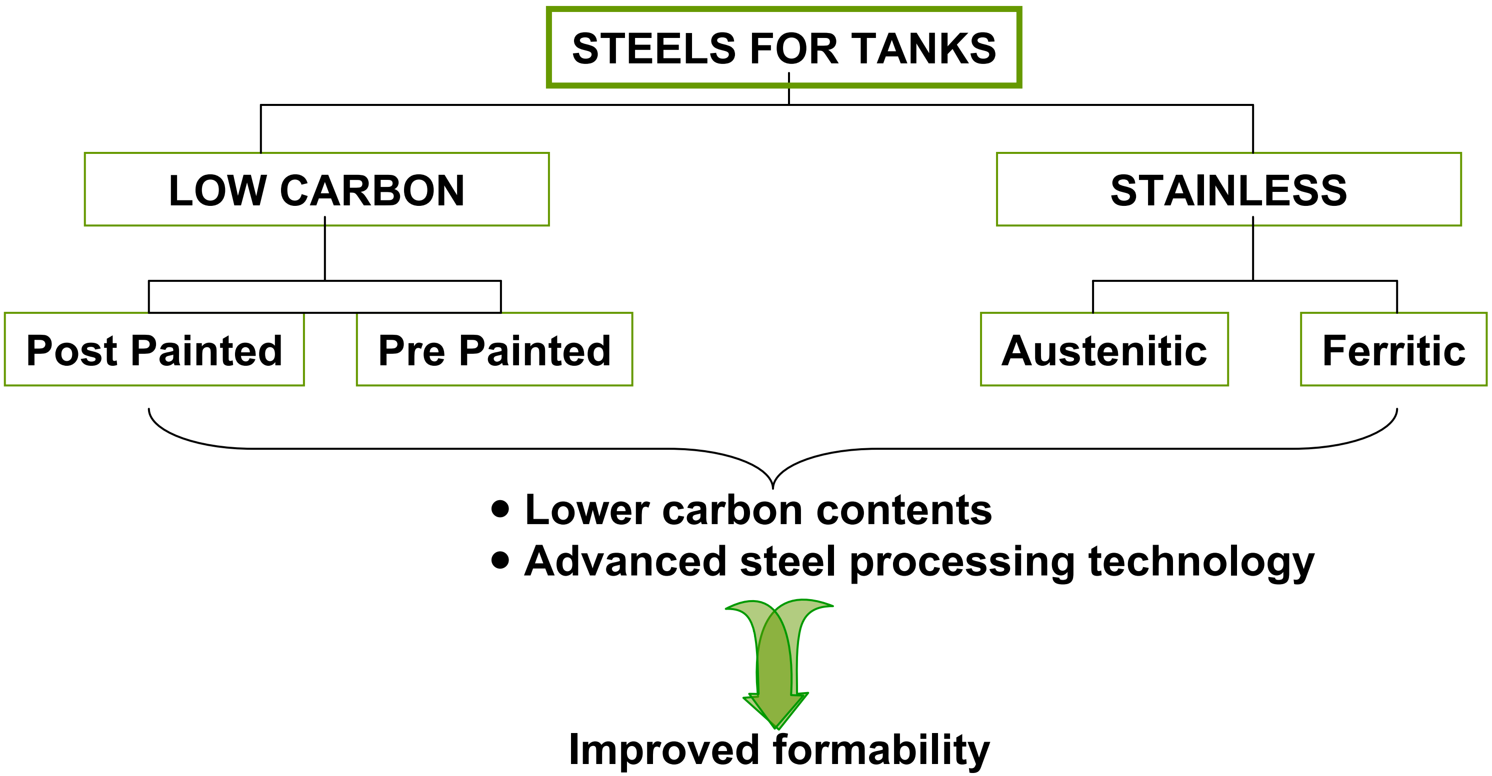
Mercedes Benz

*The PERCEPTION that only simple shapes can be made in steel is FALSE.*

***... Two principal enablers***

# Enablers for Producing Complex-Shaped Steel Tanks

- New highly formable steels
  - Interstitial-free low carbon steels
  - Improved austenitic/ferritic stainless steel
  - Improved forming lubricants (water soluble)



# Enablers for Producing Complex-Shaped Steel Tanks

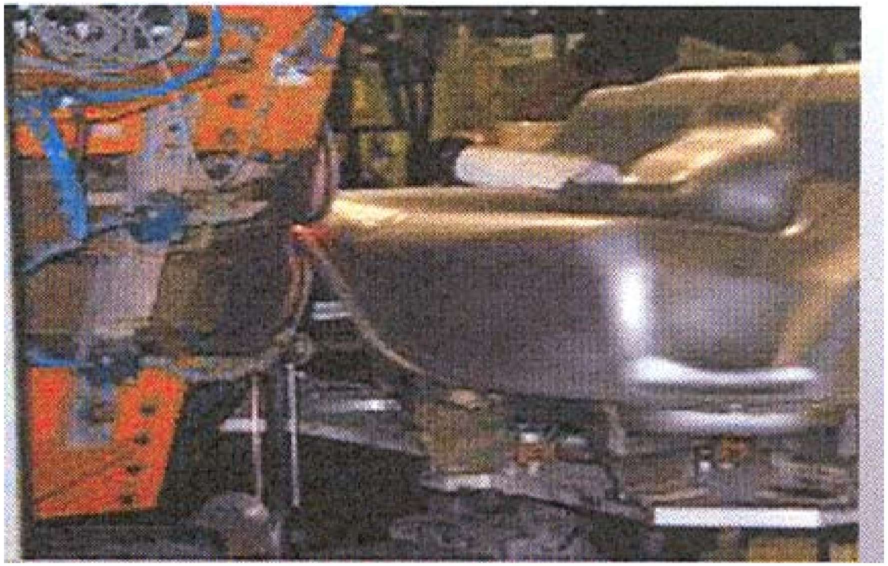
- New/improved stamping processes
  - Computer simulation techniques
  - Improved tooling materials
  - Improved stamping controls
    - Hydraulic presses
    - Variable cushion pressures
  - Dry film lubricants
- Emerging hydro-forming technology

# Enablers for Producing Complex-Shaped Steel Tanks

- Advanced welding techniques

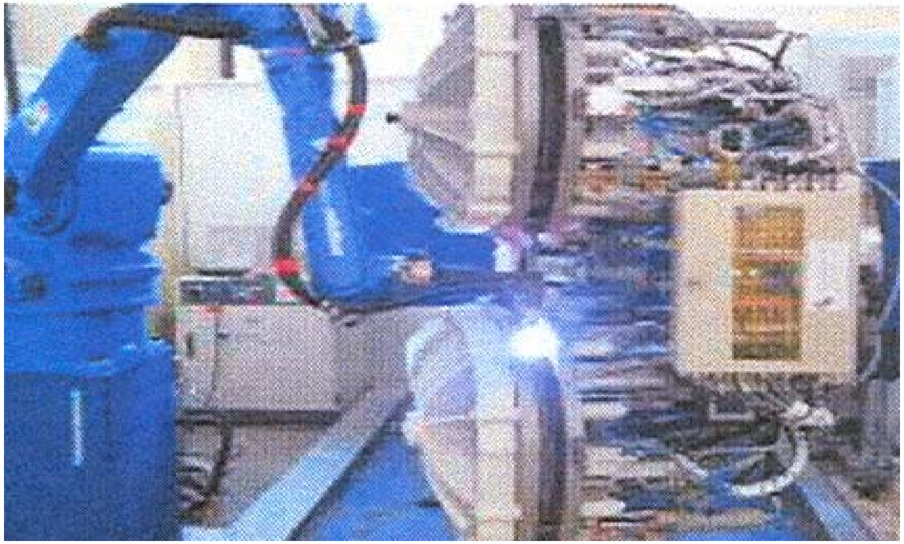
**Roll Seam Welding**

– Accommodates pre-paints
– Multi-axis 3D



**Plasma Welding**

– Multi axis 3D
– Small flanges



Photos: Courtesy of Dr. G. Pozgainer, Magna Steyr

# Mass of Steel Tanks

- **For shell structures only**
  - Mass of steel tanks is generally comparable with ‘virgin’ plastic tanks.
    - Constant steel wall thickness (typically 0.8 mm)
    - Variable plastic wall thickness (typically 5 -15 mm)
  - But fully-saturated plastic tanks absorb fuel into the shell and increase their mass
    - About 4% for Multilayer tanks
    - About 8% for Monolayer tanks

# Mass of Steel Tanks *(Continued)*

- **For tank ‘systems’**
  - A metal heat shield is often incorporated with plastic tanks
  - The heat shield is usually NOT NECESSARY for steel tanks and tank system mass can be reduced

# Lower Tank-System Mass for Steel

## EXAMPLE: Recent SASFT Feasibility Study Results

| | Steel System Steel Thickness (mm) | | Mass Kg. (lb.) | | |
|---|---|---|---|---|---|
| | **Top** | **Bottom** | **Steel System** | **Plastic System (Shell & Shield)** | **Mass Savings With Steel** |
| | | | | **Virgin Shell** | |
| **Option A** | 0.8 | 0.8 | 11.34 (25.0) | 11.84 (26.1) | 0.50 (1.1) |
| **Option B** | 0.7 | 0.8 | 10.68 (23.5) | 11.84 (26.1) | 1.16 (2.6) |
| | | | | **Saturated Shell** | |
| | | | | 12.29 (27.1) | 0.95 (2.1) |
| | | | | 12.29 (27.1) | 1.61 (3.6) |

***Because the steel tank also had higher fuel capacity***
*— Resizing the steel tank to provide the same fuel capacity as the plastic version would save additional mass.*

# Fuel Capacity

- Increased fuel capacity increases a vehicle’s driving range
  - For alcohol-containing fuels, the driving range is reduced. Hence, any means of increasing fuel capacity is desirable.
- Three enabling factors for higher fuel capacity in steel tanks
  1. Volume effects of steel versus plastic shells
  2. Rigidity effects
  3. New welding technologies for reducing steel tank flanges

# Fuel Capacity

## 1. Volume effects of steel versus plastic shells

<u>Example:</u>

- Wall thickness of 0.8 to 1.0 mm compared to a thickness of 5 to 7 mm for a plastic tank

  Average Tank Surface 1.5 $m^2$: + 7.5 liters

- Reduced clearance with surrounding parts due to the absence of swelling

  Calculated Seam length 4m: + 2.4 liters

- Optimized volume due to internal packaging of components, fuel and vapor lines

  Estimate: + 1.5 liters

- Volume loss due to packaging constraints

  Estimate: <u>- 4.0 liters</u>

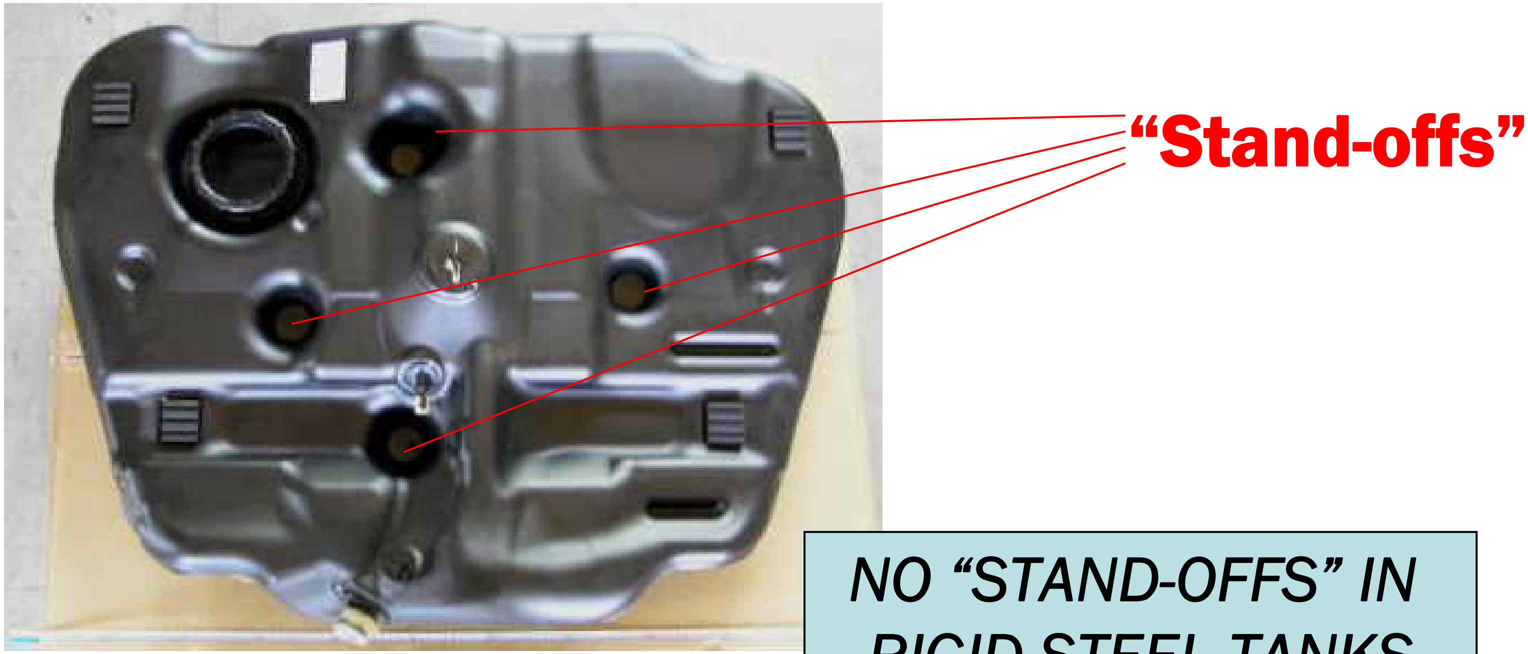
  Net Volume Advantage: 7.4 liters

A volume advantage of 7.4L (1.95 gals) for a steel tank

Source: Dr. G. Potzgainer, Magna Steyer

# 2. Volume effects related to rigidity

Plastic tanks — "stand-offs" — detract from fuel capacity




*NO "STAND-OFFS" IN RIGID STEEL TANKS - VALUABLE SPACE SAVED FOR FUEL*



# 3. Small flanges increase capacity

**Audi A8**

**BMW 3 series**

*Small flanges produced by plasma & MIG welding*

# Fuel Capacity

- A recent SASFT comparative design study
  - Steel design versus plastic design
  - Saddle tank shape
  - Steel tank met same engineering requirements

## FUEL CAPACITY RESULTS, liters (gals)

| Steel Tank | Plastic Tank | Increase |
|---|---|---|
| 85.16 (22.5) | 79.46 (21.0) | 5.7 (1.5)/7% |

*Steel tanks have a fuel capacity advantage*



- Many ‘steel systems’ are now available to suit different preferences globally

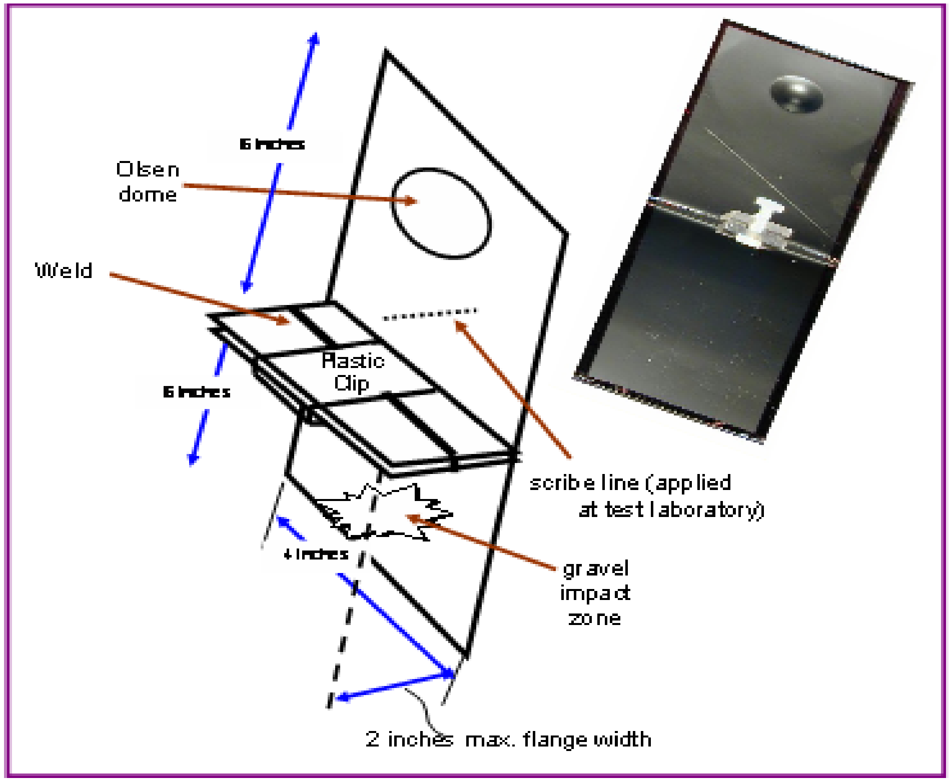
Steel Systems Selected for External and Fuel Corrosion Testing

| ID Number | Bare Steel | Metallic Coating | Surface Exposed to the Test Fuel |
|---|---|---|---|
| **Pre-painted category of steels** | | | |
| 1 | Low carbon steel | EG Zn-Ni Metallic coating | Pre-paint (with $Cr^{+6}$) |
| 2 | Low carbon steel | EG Zn-Ni Metallic coating | Pre-paint (without $Cr^{+6}$) |
| 3 | Low carbon steel | Hot dip galvannealed Metallic coating | Pre-paint (without $Cr^{+6}$) |
| 4 | Low carbon steel | Hot dip aluminized Metallic coating | Pre-paint (with $Cr^{+6}$) |
| 5 | Austenitic stainless | None | Steel + inorganic coating |
| **Post-painted category of steels** | | | |
| 6 | Low carbon steel | Hot dip terne Metallic coating | Phosphate (3mg/m2) |
| 7 | Low carbon steel | Hot dip Tin-Zinc Metallic coating | Cr-free resin (300mg/m2) |
| 8 | Low carbon steel | Hot dip Aluminized Metallic coating | Chromate |
| 9 | Ferritic stainless steel | None | Bare steel |
| **Bare steels category** | | | |
| 10 | Austenitic stainless | None | Bare steel |

*Results of <u>external</u> corrosion testing (Cyclic and Salt Spray testing) showed no perforation and durability beyond 15 years or 150,000 miles*

# Durability of Steel Systems

- External corrosion tests
  - Neutral Salt Spray (ASTM B117)
  - Cyclic Corrosion Tests (SAE J2334) – 160 cycles (~20 yrs)



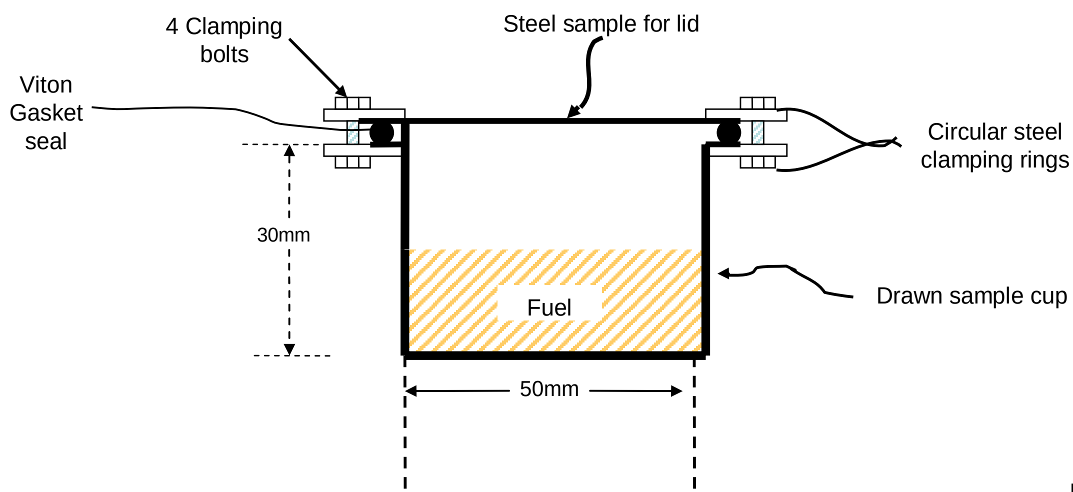

**RESULTS:**

- Some localized rusting on some steel systems
- Maximum pit depth
  - 10% one steel system
  - 10-20% two steel systems
  - 0% remaining steel systems

*Above 15 year resistance to road salt environment and gravel infringement.*

# Durability of Steel Systems

- Internal corrosion tests
  - Resistance to CE10A fuel evaluated in unique cup tests




| | | |
|---|---|---|
| Blank diameter | = | 98 mm |
| Punch diameter | = | 50 mm |
| Die radius | = | 3 mm |
| Clamping torque | = | 1.1 newton-meter (10 inch pounds) |
| Draw depth | = | 30 mm |

*All 10 steel systems showed effective corrosion resistance.*

*The perception that steel is not durable is FALSE*

# Durability of Steel Systems

- Additional studies are underway to test 10 different steel systems in alternative fuels.

  – **Alcohol fuels (with water) at 60°C**
    - E10A
    - E22A
    - E85A
  – **Bio-diesel fuels (with water) at 90°C**
    - B10 Blend of RME & SME
    - B20 SME
    - B20 AFME (Animal Fat)
    - B90 SME

*Results expected in late 2008*

# Evaporative Emissions

- Steel is impermeable to gasoline, alcohol, diesel, and bio-diesel
  - Ideal for low evaporative emission requirements

## Steel Fuel Tanks — the choice for PZEV

*Steel Fuel Tanks . . . the choice for PZEV vehicles*

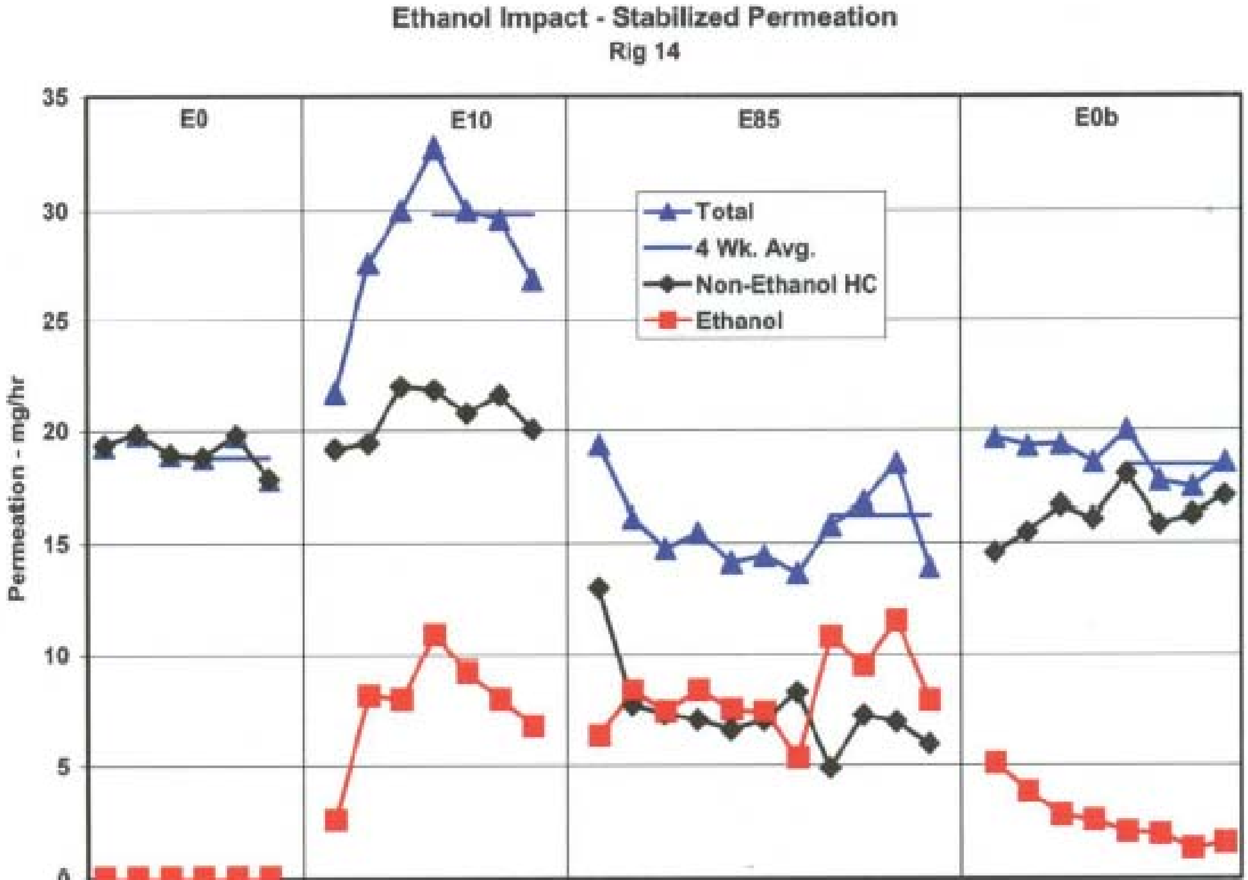
**California Air Resources Board:**

- Certified gasoline PZEV models
  - 14 in 2003
  - 23 in 2004
  - 29 in 2005
  - 40 in 2006

CARB PZEV certified vehicles for 2006

| Company | Model Year | Model Name/Type | Emission Rating | Tank Material |
|---|---|---|---|---|
| Ford | 2005 | Escape – Hybrid - 2WD, 4WD | ATPZEV | Steel |
| | 2005 | Focus – Wagon - 2X3/2X4/2X5 | PZEV | Steel |
| | 2006 | Fusion | PZEV | Steel |
| DaimlerChrysler | 2004 | Sebring – Sedan | PZEV | Steel |
| | 2004 | Stratus – Sedan | PZEV | Steel |
| BMW | 2005 | 325C1 – Coupe | PZEV | Steel |
| | 2005 | 3251 – Sedan | PZEV | Steel |
| | 2005 | 3251 – Wagon | PZEV | Steel |
| Honda | 2004 | Civic – Hybrid | ATPZEV | Steel |
| | 2004 | Accord – EX/LX Sedan | PZEV | Steel |
| Hyundai – Kia | 2005 | Elantra – GLS & GT | PZEV | Steel |
| | 2005 | Spectra – 2.0L | PZEV | Steel |
| Mazda | 2004 | Mazda 3 – 2.0L/2.3L | PZEV | Steel |
| | 2006 | Mazda 6 – 2.3L | PZEV | Steel |
| | 2006 | Tribute HEV 4WD | ATPZEV | Steel |
| Mercedes-Benz | 2005 | E350 – 3.5L | PZEV | Steel |
| Mercury | 2006 | Mariner HEV 4WD | ATPZEV | Steel |
| | 2006 | Milan | PZEV | Steel |
| Mitsubishi Motors | 2004 | Galant DE & ES2.4L | PZEV | Steel |
| Nissan | 2004 | Altima 2.5, 2.55, 2.55L | PZEV | Steel |
| | 2004 | Sentra 1.8, 1.85 | PZEV | Steel |
| Subaru | 2004 | Legacy 2.5 GT Sedan | PZEV | Steel |
| | 2004 | Legacy 2.5 GT Wagon | PZEV | Steel |
| | 2004 | Legacy L Sedan/Wagon | PZEV | Steel |
| | 2004 | Outback Ltd Sedan/Wagon | PZEV | Steel |
| Toyota | 2004 | Camry LE, SE or XLE | PZEV | Steel |
| | 2004 | Prius – Hybrid | ATPZEV | Steel/plastic bladder |
| Volvo | 2004 | S60 2.4 Sedan | PZEV | Steel |
| | 2004 | V70 2.4 Wagon | PZEV | Steel |

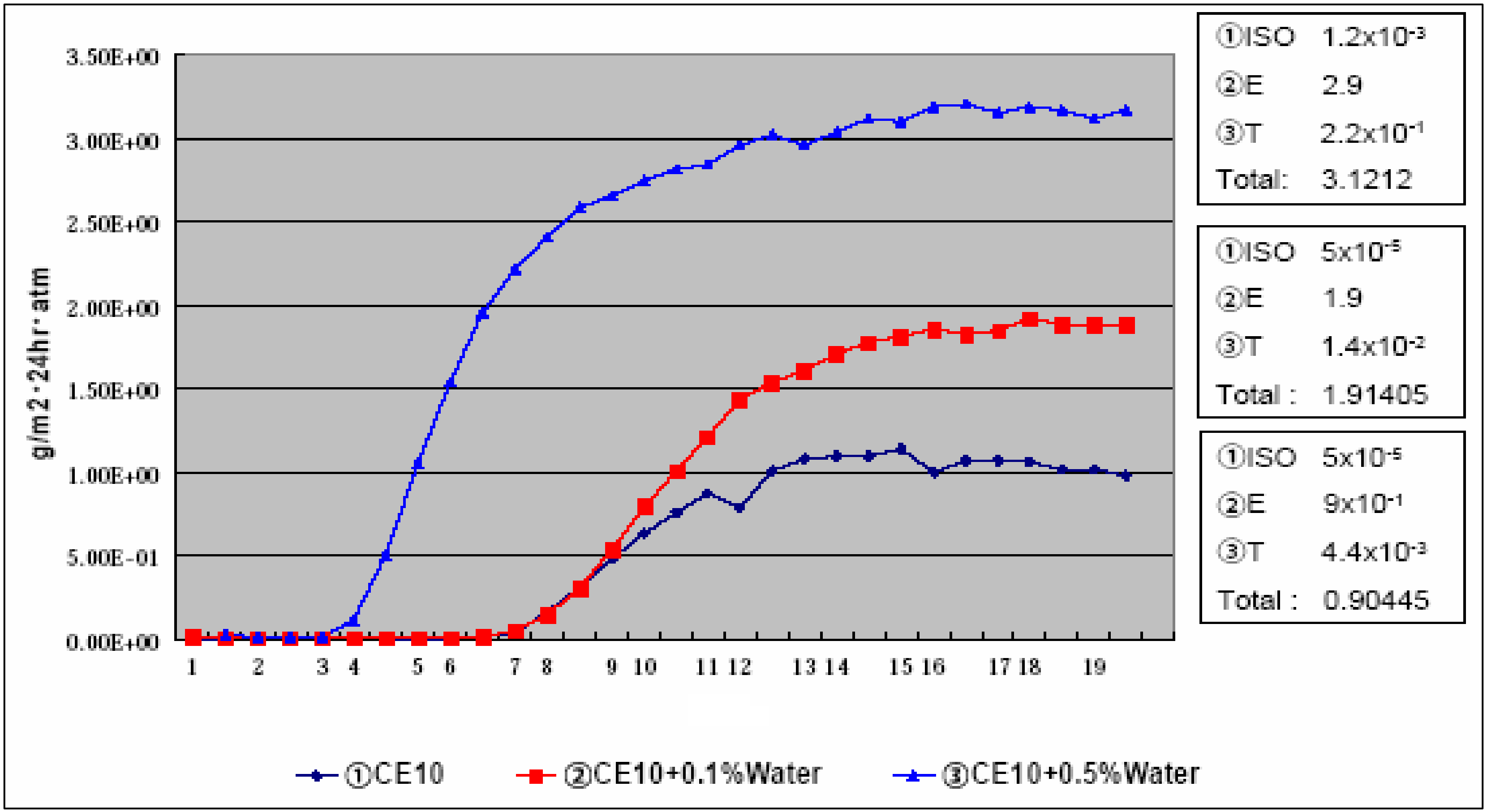
- Total permeation (HC and Ethanol) in plastic systems increases with low ethanol additions




*Source: Coleman Jones, GM presentation at ITB Conference (March 2, 2007)*



- Permeation in plastic can be exacerbated by the presence of water In alcohol-containing fuels




Source: GTR TEC, JSAE Exposition May 24, 2007

# Evaporative Emissions

- For fuels containing > 10% alcohol modifications to the <u>plastic fuel tank</u> are likely

## Necessary Modifications

(Otto Engines)

| Ethanol Content in the Fuel | Carburetor | Fuel Injection | Fuel Pump | Fuel Pressure Device | Fuel Filter | Ignition System | Evaporative System | Fuel Tank | Catalytic Converter | Basic Engine | Motor Oil | Intake Manifold | Exhaust System | Cold Start System |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ≤ 5% | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary |
| 5 ~ 10% | Probably Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary |
| 10 ~ 25% | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary | Not Necessary |
| 25 ~ 85% | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Not Necessary |
| ≥ 85% | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary | Probably Necessary |

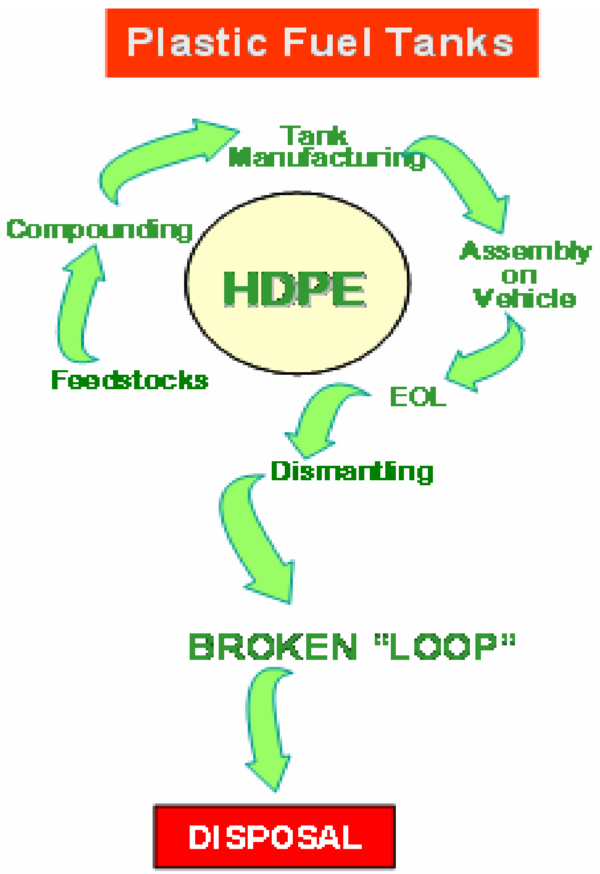
□ - Not Necessary ■ - Probably Necessary

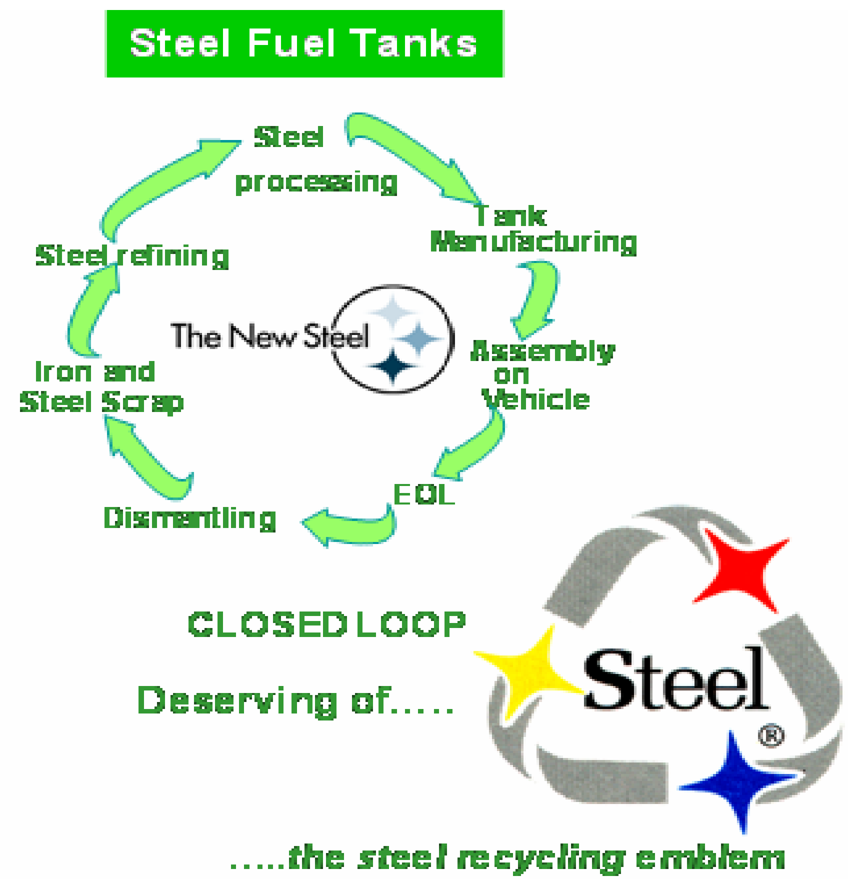
Source: Coleman Jones; Presentation to SAE (Detroit Chapter) November 16, 2007

*No modifications are necessary for <u>steel tanks.</u>*

# Sustainability/Recycling

- Steel tanks are <u>fully recycled</u> using an <u>existing infrastructure</u>.
- In North America, virtually all <u>plastic tanks are landfilled</u>.

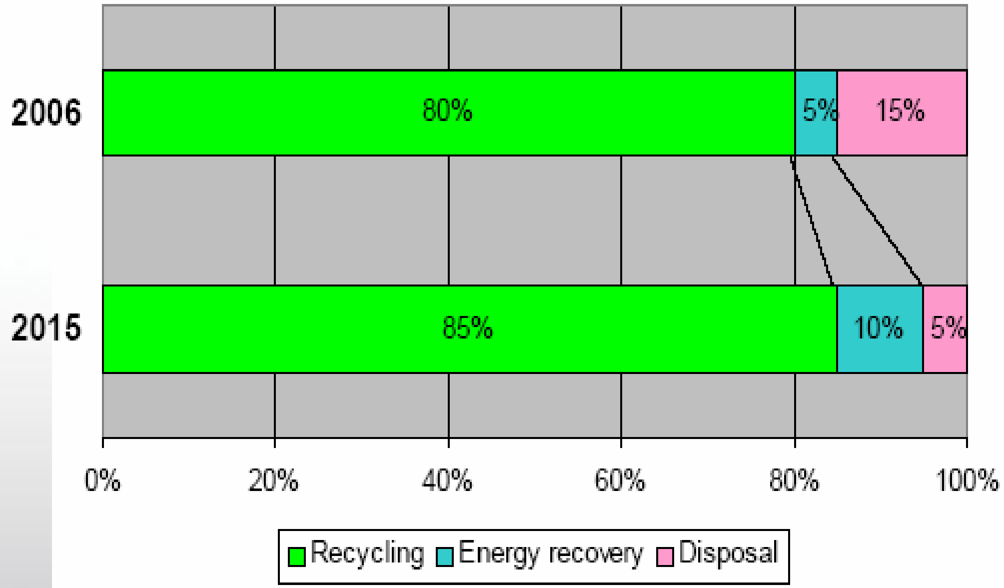


# Sustainability/Recycling

- Steel tanks allow compliance to Europe EOL regulations

The End Of Life (EOL) legislation of the European Union defines more stringent targets for recycling after utilization of the cars




Source: Dr. G. Potzgainer, Magna Steyr

| | |
|---|---|
| Recycling : | Reuse of Parts, Material or Raw Material Recycling |
| Energy Recovery : | Burning and utilizing the intrinsic energy |
| Disposal : | Landfill or Thermal Conversion |



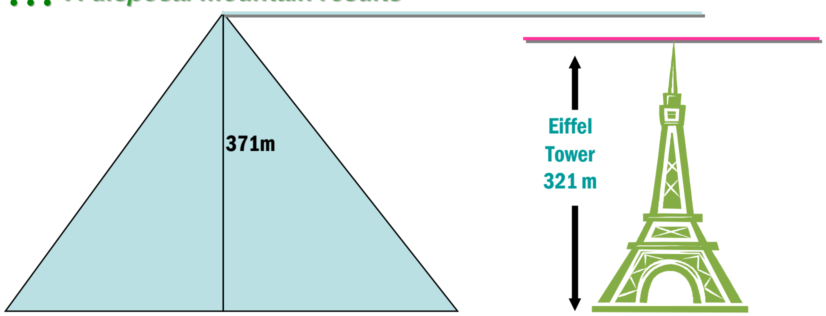
- Landfill disposal of plastic tanks depletes land resources

## Magnitude of Plastic Tank Disposal

In 2004, 303 million vehicles will be on the roads in Europe (J.D. Power PARC data)

Assuming 92% of the vehicles have plastic tanks, or at the end-of-life, they are:
- —crushed to 50% height
- —landfilled . . . .

. . . *A disposal mountain results*




SASFT —— SRI —— Stahl-Zentrum

*Steel tanks are 100% recycled —no impact on land resources*

# Magnitude of Plastic Tank Disposal

- In 2014
  - 303 million personal vehicles will be on the roads in Europe (West and East)
    (J.D. Power Vehicle PARC data)
  - Assuming 92% of these vehicles have plastic tanks
    (ITB Group - European production estimate for 2003)
  - These tanks placed end-to-end would stretch:
    - 229,000 km
    - almost 6 times around the earth

# Summary/Conclusions

- Although steel tanks have lost market share to plastics in the 1990s
  - *Steel tanks are increasingly cost competitive.*
  - *New steels/technologies allow steel tanks to meet the demanding requirements of automakers and environmental legislators.*

# Summary/Conclusions

- Key features of steel fuel tanks
  - Very cost competitive
    - Especially for high tech applications (e.g., PZEV)
    - Higher oil/resin prices in future will likely increase steel's cost competitiveness
  - High design flexibility
    - New steels/manufacturing technologies
  - Competitive in mass with plastics
    - Lower mass when heat shields are removed

# Summary/Conclusions

- Key features of steel fuel tanks
  - Durable to road environments and aggressive CE10A fuels for beyond 15 years/150,000 miles
  - Better fuel capacity for same engineering space
  - Preferred for low evaporative emissions (PZEV)
  - Sustainable
    - 100% recycled using existing infrastructure
    - Landfill resources are preserved
    - Steel – the Green material

# BACK UP SLIDES

# Strategic Alliance for Steel Fuel Tanks (SASFT)

- Global alliance for the market development of steel fuel tanks
  - Steel tank manufacturers
  - Equipment suppliers
  - Steel suppliers
- Organized by American Iron and Steel Institute (AISI)
- Cost sharing organization
- Started in 2000
- Typical projects
  - Market analysis
  - Durability optimization through corrosion studies
  - Information sharing/communications

# SASFT Members

## Steel Tank Manufacturers

| | |
|---|---|
| Aethra Componentes Automotivos | (Brazil) |
| Allgaier Automotive GmbH | (Germany) |
| Dong Hee Industrial | (So. Korea) |
| Fuel Systems LLC | (USA) |
| Harley Davidson | (USA) |
| Martinrea International | (USA) |
| Spectra Premium Industries | (Canada) |
| Unipart Eberspacher | (UK) |
| Unipres Corp. | (Japan) |

## Steel Tank Equipment Suppliers

| | |
|---|---|
| The Magni Group | (USA) |
| Soutec Soudronic | (Switzerland) |

## Steel Suppliers

| | |
|---|---|
| ArcelorMittal | JFE Steel |
| AK Steel | Material Sciences Corp. |
| Nucor | Nippon Steel Corp. |
| Severstal North America | Nisshin Steel |
| U.S, Steel Corp | North American Stainless |
| | POSCO |
| | Sumitomo Metal Industries |
| | ThyssenKrupp Steel |

# For More Information

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