



# **Durability Performance of Fuel-Tank Steels in Bio-Diesel Fuels**

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# OUTLINE

- Introduction / Background
- Purpose and objective of the current study
- Experimental Procedures
  - Fuels
  - Steels/Test Cups
  - Test Method
  - Assessment criteria
- Results and Conclusions
- Value of steel for fuel tanks



# SASFT - MEMBERS

	Americas	Europe	Asia
Fuel Tank Manufacturers	Aethra Sistemas Automotivos Martinrea International Spectra Premium Ind.	Allgaier Automotive Unipart Eberspacher	Dong Hee Ind. Unipres
Equipment Suppliers		Soutec Soudronic	
Steel Suppliers	AK Steel Corporation ArcelorMittal USA No. American Stainless Nucor Corporation Severstal North America Inc. ThyssenKrupp Steel USA, LLC United States Steel Corp.		JFE Steel Nippon Steel Nisshin Steel Posco Sumitomo Metal



# INTRODUCTION

## SASFT:

- Organized by AISI to promote steel fuel tanks
- Early focus (2002-2004) – Corrosion Durability

- External Corrosion

- Salt Spray tests (ASTM B117)
- Cycle Corrosion tests (SAE J2334)

*Some corrosion occurred in some steels,  
BUT - no perforation in any steel.*

- Internal Corrosion (Fuel)

- CE10A/45 C/39weeks

*No corrosion (staining only)*

*No pitting*

**CONCLUDED: Steel systems can meet  
15-year (150,000 miles)  
requirement of CARB**



### PURPOSE and OBJECTIVES

- Driver: Growing use of alternative fuels
- Purpose: Assess the corrosion performance of 10 steel fuel tank ‘systems’ in:
  - **Alcohol-containing fuels (PHASE 1)**
    - *Completed* - *Reported at 2009 ITB Conference*
    - *Light/moderate corrosion in 2 steels for CE22A & CE85A only*
  - **Bio-diesel fuels (PHASE 2)**
    - *Completed in 4Q 2009*
    - *Subject of this report*



# EXPERIMENTAL PROCEDURE

## Fuels selected for the recent studies:

Alcohol Fuels		Bio-diesel Fuels	
CE10A (Control)	10% ethanol	B20 SME	20% Soy Methyl Ester
CE22A	22% ethanol	B90 SME	90% Soy Methyl Ester
CE85A	85% ethanol	B20 AFME	20% Animal Fat Methyl Ester
		B10 RME/SME	10% mix of: 80% RME +20% SME
<p>A = Aggressive ethanol (SAEJ1681) contains:</p> <ul style="list-style-type: none"> <li>— Water (Type II)</li> <li>— Sodium Chloride</li> <li>— Sulfuric acid</li> <li>— Acetic acid</li> </ul>		<ul style="list-style-type: none"> <li>• All fuels contained 5% water (Type II)</li> <li>• No stabilizers were present in the B100 feed-stocks</li> </ul>	



# EXPERIMENTAL PROCEDURE

## Steel Systems

- All supplied by SASFT member companies
- Commercially available for steel tank manufacturing
- Thickness: 0.8 to 1.1 mm

ID #	Base Steel	Metallic Coating	Pre-paint*
1	Low carbon steel	EG Zinc-Nickel	Magni A36
2	Low carbon steel	EG Zinc-Nickel	Magni A35
3	Low carbon steel	Hot Dip GalvAnnealed	Magni A36
4	Low carbon steel	Hot Dip GalvAnnealed	Magni A35
5	Low carbon steel	Hot Dip Tin-Zinc	None
6	Low carbon steel	Hot Dip Aluminized	None
7	Austenitic stainless (304L)	None	None
8	Ferritic stainless (443CT)	None	None
9	Ferritic stainless (430L)	None	None
10	Low carbon steel (control)	Hot Dip Lead-Tin (Ni-Terne)	None

\*Magni pre-paints (about 10 $\mu$  thickness) are proprietary epoxy coatings



# EXPERIMENTAL PROCEDURE

## ALCOHOL FUELS

## BIO-DIESEL FUELS

### Characterization of Fuels

- Oxidation stability of feed-stocks
- Reaction products (peroxides & acids) in blends

### TESTING OF STEEL CUPS/LIDS

16 hours/day at 60°C

Exposure cycle

16 hours/day at 90°C

26 weeks

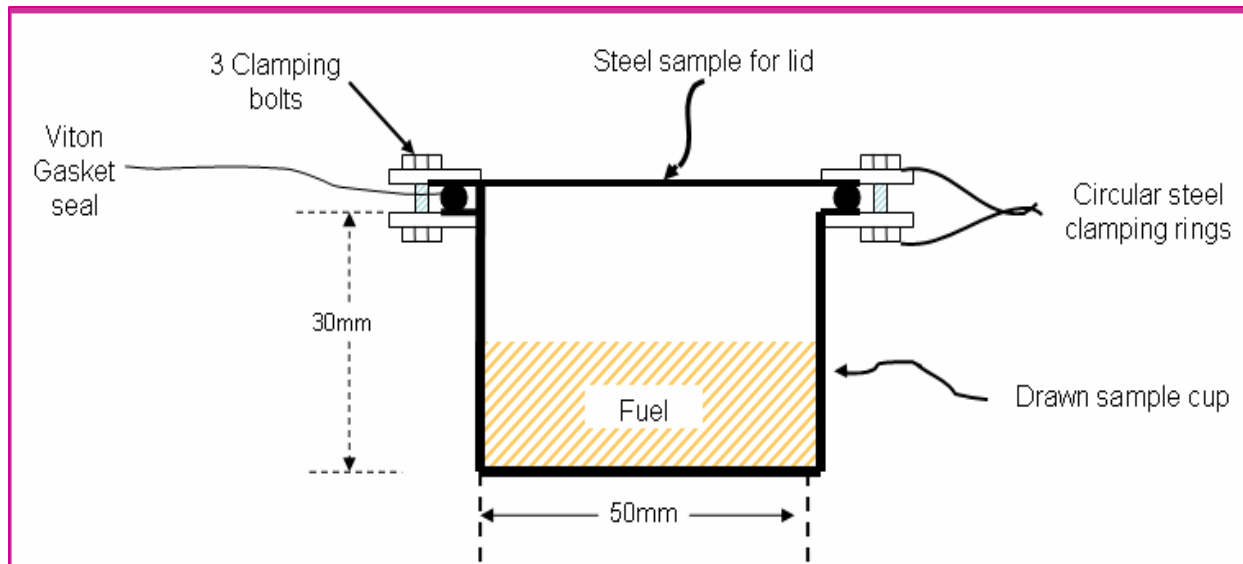
Exposure period

12 weeks



# EXPERIMENTAL PROCEDURE

## Test Method – Cups / Lids



### Set up

- Weigh cup and lid
- Add 30 ml. of fuel
- Assemble/torque to 10 pound-inch
- Shake assemblies twice/day at RT

### At completion of tests

- Clean/air dry cups/lids
- Photograph
- Weigh cup/lid
- Assess corrosion
- Assess pitting

### Each Week

- Remove fuel & shake (aerate)
- Inspect cups/lids
- **Change fuel every 4 weeks**
- Photograph/assess corrosion
  - De-lamination of coatings
  - Extent of corrosion



# EXPERIMENTAL PROCEDURE

**Assessment Criteria** – Failure is perforation  
**Corrosion Severity** – Four rating categories:

	No Corrosion	Light Corrosion	Moderate Corrosion	Pronounced Corrosion
<b>Pre-painted steel systems</b> (Steels 1-4)	<ul style="list-style-type: none"> <li>• No degradation of paint</li> </ul>	<ul style="list-style-type: none"> <li>• Softening/roughening of paint</li> </ul>	<ul style="list-style-type: none"> <li>• Lifting of paint</li> <li>• Small breaks</li> </ul>	<ul style="list-style-type: none"> <li>• Delamination</li> <li>• Significant exposure of steel substrate</li> <li>• Rust and pitting of steel substrate</li> </ul>
<b>Other steel systems</b> (Steels 5-10)	<ul style="list-style-type: none"> <li>• No corrosion product</li> <li>• No pitting</li> <li>• No weight change</li> </ul>	<ul style="list-style-type: none"> <li>• Light rust &lt; 10% area</li> <li>• Minor pitting frequency &lt; 10% area</li> <li>• Minor pit depths &lt; 10% thickness</li> <li>• Minor weight change <math>\pm 0.1\%</math></li> </ul>	<ul style="list-style-type: none"> <li>• Moderate rust 10-50% area</li> <li>• Moderate pitting frequency 10-50% area</li> <li>• Moderate pit depths &lt; 20% thickness</li> <li>• Moderate weight change <math>\pm 0.5\%</math></li> </ul>	<ul style="list-style-type: none"> <li>• Extensive rust &gt; 50% area</li> <li>• Extensive pitting frequency &gt; 50% area</li> <li>• Pronounced pit depths &gt; 20% thickness</li> <li>• Pronounced weight change - 10%</li> </ul>



# CHARACTERIZATION OF BIO-DIESEL FUELS

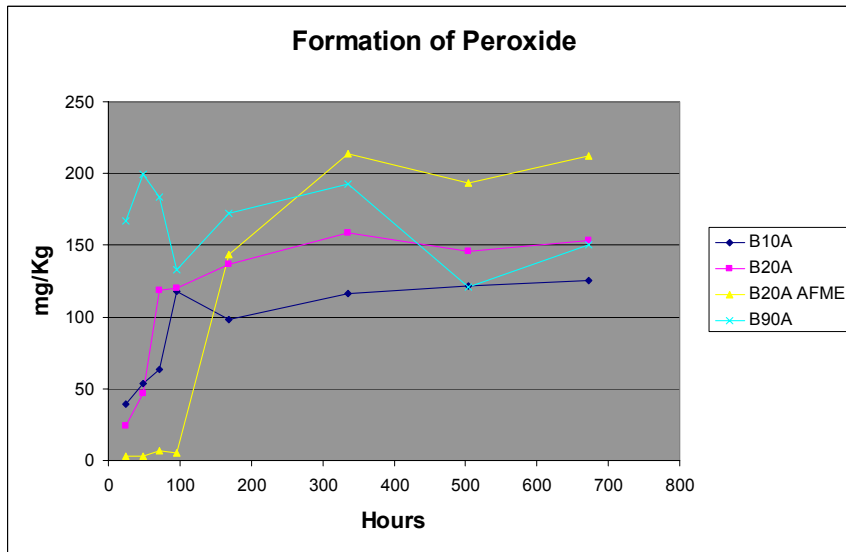
## Oxidation Stability Indexes (OSI) of Feed-stocks\*

	OSI, hours
<b>B100 SME</b>	<b>3.42</b>
<b>B100 RME</b>	<b>8.83</b>
<b>B100 AFME</b>	<b>16.85 +</b>

\* No stabilizers were present in the feed-stocks

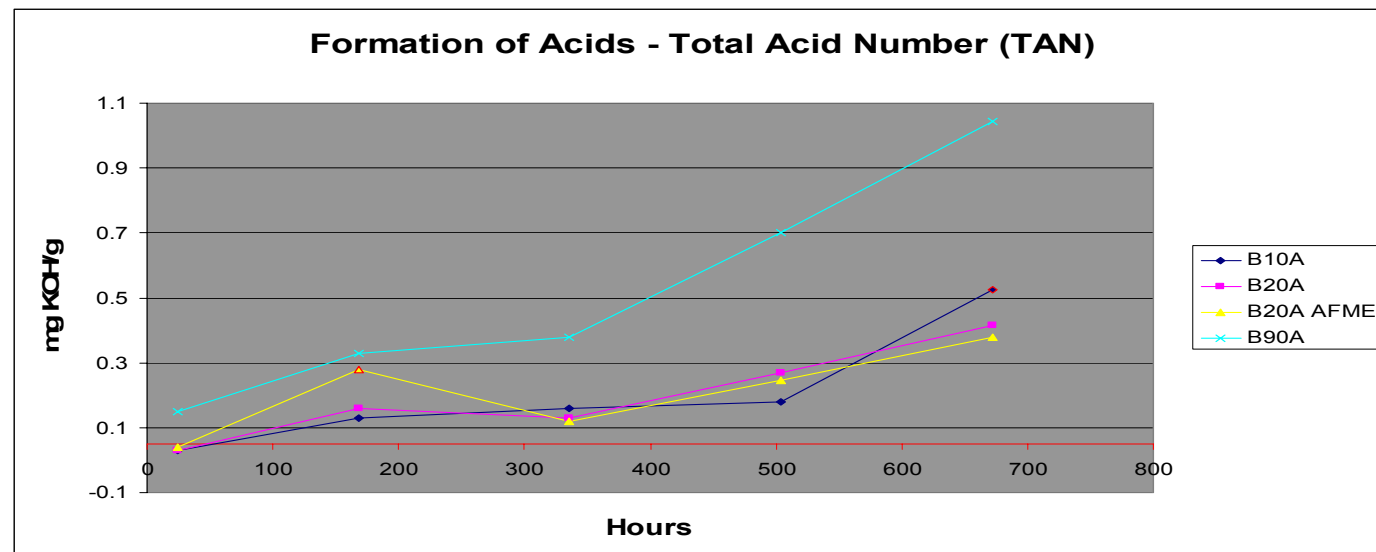


# CHARACTERIZATION OF BIO-DIESEL FUELS



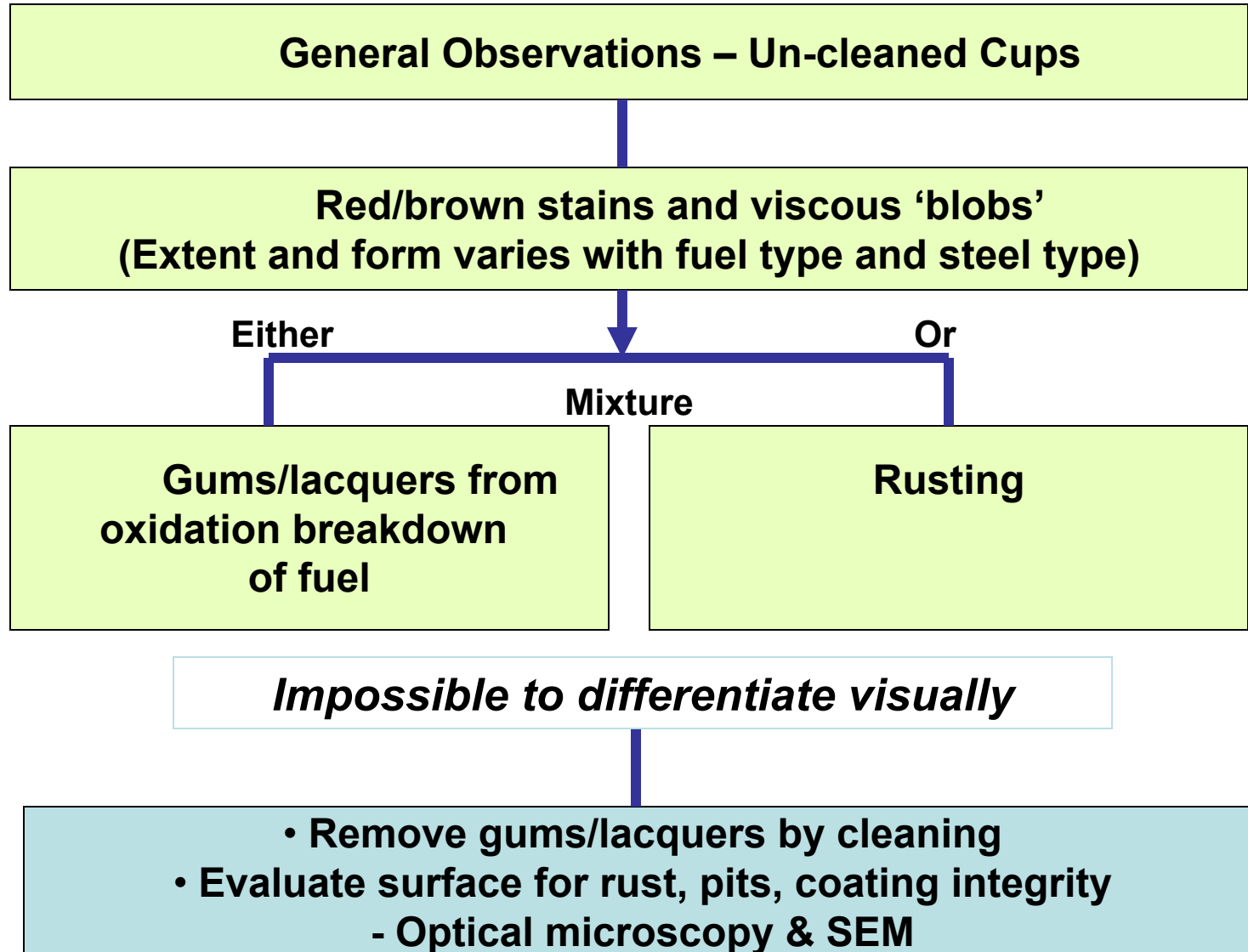
## Confirms

- Non-stabilized fuels break down to form corrosive products
- Similar to observations by a Detroit automaker in an actual diesel tank





# RESULTS – CUPS WITH BIO-DIESEL FUELS





# RESULTS – CUPS WITH BIO-DIESEL FUELS

## Visual observations (12 weeks) – Steel 1 (EG Zn-Ni Pre-painted) – Un-cleaned cups

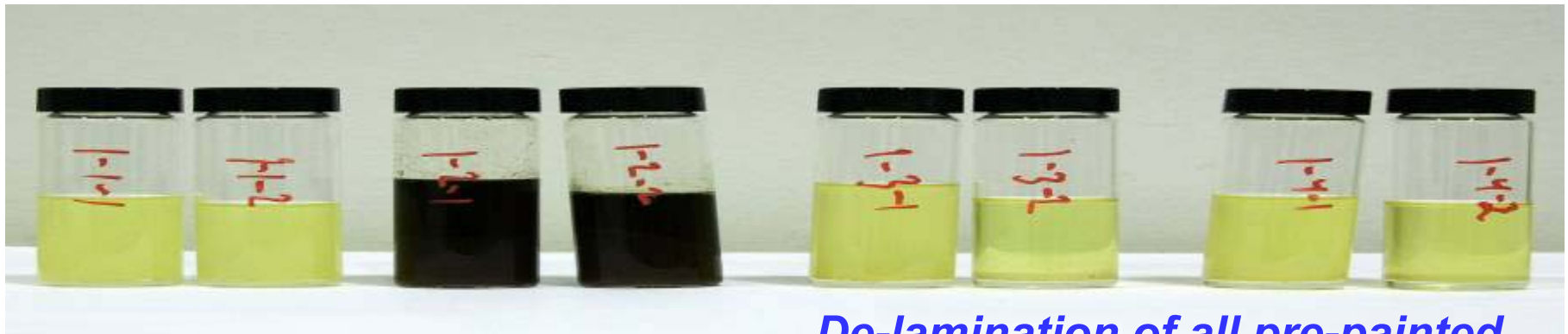


**B20 SME**

**B90 SME**

**B20 AFME**

**B10 RME + SME**



... *De-lamination of all pre-painted steels (#1-4) occurred in B90 SME*



# RESULTS – CUPS WITH BIO-DIESEL FUELS

## Visual observations (12 weeks) – Steel 7 (304L) Stainless Steel – Un-cleaned cups



**B20 SME**

**B90 SME**

**B20 AFME**

**B10 RME + SME**





# RESULTS – CUPS WITH BIO-DIESEL FUELS

Visual observations (12 weeks) - Steel 1 (EG Zn-Ni Pre-painted)  
— Un-cleaned cups/lids



**B20 SME**

**B90 SME**

**B20 AFME**

**B10 RME & SME**

— Cleaned cups (Freon cleaner)



***SEM analysis – loss of Zn-Ni coating in B90 SME***



# RESULTS – CUPS WITH BIO-DIESEL FUELS

Visual observations (12 weeks) – Steel 5 (HD Tin-Zinc)  
— Un-cleaned cups/lids



**B20 SME**

**B90 SME**

**B20 AFME**

**B10 RME & SME**

— Cleaned cups (Freon cleaner)



*SEM analysis – Sn-Zn coating intact/ Red: = Organics, Trace Fe*



# RESULTS – CUPS WITH BIO-DIESEL FUELS

Visual observations (12 weeks) – Steel 6 (HD Aluminized)  
— Un-cleaned cups/lids



**B20 SME**

**B90 SME**

**B20 AFME**

**B10 RME & SME**

— Cleaned cups (Freon cleaner)



*SEM analysis – Al-Si coating intact/Red:=Organics, Trace Fe*



# RESULTS – CUPS WITH BIO-DIESEL FUELS

Visual observations (12 weeks) – Steel 7 (430L Stainless)  
— Un-cleaned cups/lids



**B20 SME**

**B90 SME**

**B20 AFME**

**B90 RME & SME**

— Cleaned cups (Chlorinated solvent cleaner)



*Clean surfaces – all stainless steels*



# RESULTS – CUPS WITH BIO-DIESEL FUELS

Visual observations (12 weeks) – Steel 10 (Ni-Terne)  
— Un-cleaned cups/lids



**B20 SME**

**B90 SME**

**B20 AFME**

**B10 RME & SME**

— Cleaned cups (Freon cleaner)



***SEM analysis – Loss of Ni -Terne coating in patches/pits in B90 SME***





# RESULTS – BIO-DIESEL FUELS

## Pitting & Surface Assessment of Cleaned #1 Cups

ID	Steel System	Surface Stain and Pitting			
		Fuel 1 B20 SME	Fuel 2 B90 SME	Fuel 3 B20 AFME	Fuel 4 B10 Blend (80RME/20SME)
1	LCS EG Zn-Ni pre-paint (A36)				
2	LCS EG Zn-Ni pre-paint (A35)				
3	LCS HD Galvannealed pre-paint (A36)				Discolored
4	LCS HD Galvannealed pre-paint (A35)		Discolored		Discolored
5	LCS HD Sn-Zn		Discolored		Discolored
6	LCS HD Aluminized	Discolored		Discolored	Discolored
7	Austenitic Stainless (304L)				
8	Ferritic Stainless (443CT)			Discolored	
9	Ferritic Stainless (430L)			Discolored	Discolored
10	LCS Terne	Discolored	Discolored	Discolored	Discolored

 No pits

 Ext. pits (>50% area)

*Pits <0.1 mm deep*



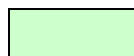
# RESULTS – BIO-DIESEL FUELS

## Metal ions in residual B90 SME fuel (ICP-MS analysis)

ID	Steel System Type	Exposure, Weeks	Concentration, ppm						
			Tin	Chromium	Zinc	Lead	Nickel	Iron	Aluminum
1	LCS-EG, Zn-Ni (A36)	4	-	-	320	-	-	7	-
		12	-	-	3,106	-	140	1,710	68
2	LCS-EG Zn-Ni (A35)	4	-	-	63	-	-	-	-
		12	-	-	1,317	-	334	975	-
3	LCS-HDGA (A36)	4	-	-	165	-	-	9	-
		12	-	-	4,578	-	140	1,734	106
4	LCS-HDGA (A35)	4	-	-	37	-	-	3	-
		12	4	-	2,662	-	-	1,547	4
5	LCS-HD Sn-Zn	4	4	-	99	-	-	-	-
		12	-	-	149	-	-	2	-
6	LCS-HD AL	4	-	-	2	-	-	26	11
		12	-	-	2	-	-	15	6
7	304L Stainless	4	-	-	4	-	-	4	2
		12	-	-	1	-	-	-	-
8	443 CT Stainless	4	-	-	3	-	-	2	-
		12	-	-	3	-	-	-	-
9	430 Stainless	4	-	-	4	-	-	-	-
		12	-	-	3	-	-	-	-
10	LCS Terne	4	5	-	-	179	-	26	-
		12	5	-	4	85	-	40	-



# SUMMARY – BIO-DIESEL FUELS



None



Light



Moderate



Pronounced

ID	Steel System	B20 SME	B90 SME	B20 AFME	B10 (80RME/20SME)
1	LCS EG Zn-Ni-pre-paint (A36)	None	Pronounced	None	Light
2	LCS EG Zn-Ni-pre-paint (A35)	None	Pronounced	None	Light
3	LCS HDGA-pre-paint (A36)	None	Pronounced	None	Light
4	LCS HDGA-pre-paint (A35)	None	Pronounced	None	Light
5	LCS HD Sn-Zn	None	None	None	None
6	LCS HD Aluminized	None	None	None	None
7	Austenitic Stainless (304L)	None	None	None	None
8	Ferritic Stainless (443 CT)	None	None	None	None
9	Ferritic Stainless (430L)	None	None	None	None
10	LCS Ni-Terne	Pronounced	Pronounced	Pronounced	Pronounced



# SUMMARY – ALTERNATIVE FUELS

## ALCOHOL FUELS

- **3 Aggressive fuels**  
[CE10A / CE22A / CE85A]
- **16 hours/day at 60°C**
- **26 weeks exposure**



- **No Corrosion for 8 steel systems**
- **Light to Moderate corrosion in CE 22A & CE 85A for:**
  - Hot-dip Aluminized
  - Terne
- **No visual indication of corrosion product contamination of fuels:**
  - Supported by zero weight loss

## BIO-DIESEL FUELS

- **4 fuels**  
[B20 SME / B90 SME / B20 AFME / B10 Blend]
- **16 hours/day at 90°C**
- **12 weeks exposure**



- **Bio-diesel fuels (without stabilizers) degrade to produce aggressive corrosion environments**
  - Extent depends on
    - Fuel type
    - Steel surface type
- **B 90SME- most aggressive**
  - De-lamination of pre-painted steels & loss of metallic coating
- **Pitting & partial loss of coating in Ni-Terne**
- **Stains but no corrosion in Sn-Zn, HDAL & stainless steels**



# STEEL FUEL TANKS = VALUE

- > **Durable steel systems proven for:**
  - Conventional fuels
  - Wide array of alcohol & bio-diesel fuels
  
- > **Additional attributes of steel tanks:**
  - Cost competitive
  - Good design flexibility
  - Impermeable (perfect for low evaporative emissions)
  - High rigidity for shape stability
  - Mass can be competitive with plastic
  - Environmentally friendly
  - Perfect for high pressure hybrid systems



# FOR MORE INFORMATION

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As gasoline (petrol) prices continue their upward spiral and geopolitical issues threaten stability of oil supplies, automakers are increasing the number of models with the capability of handling alternative fuels such as blends of gasoline and ethanol (E85 fuels) and bio-fuels. Alternative fuels can lessen North America's dependence on imported oil and the global use of oil. And that can be good for the car business.

**Technical News...**

**Benefits of Steel Fuel Tanks for Gasoline-Powered and Hybrid Vehicles**  
Presentation from Great Designs in Steel 2008 highlighting the cost competitiveness, mass fuel capacity, emissions emission, durability, design flexibility, and environmental benefits of steel fuel tanks.

**Advantages of Steel Tanks - Comparative Design Study**  
Results from a study comparing math data of a plastic fuel tank and associated engineering space was used to design a steel tank version to meet the OEM's engineering requirements.

**Steel fuel tanks - RESEARCH ANALYSIS: Fueling Opinions in the Tank Market**  
Fueled by the need to save weight and reduce evaporative emissions, a great deal of

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