Automotive Magnesium Applications and Life Cycle Environmental Assessment

Naiyi Li

Ford Motor Company

Dearborn, Michigan USA

3rd International Conference on SF_6 and the environment

Scottsdale, AZ

Dec 1-3, 2004

Presentation Outline

- Mg applications
- Life Cycle Assessment – E and CO_2
- FMC's perspective and programs

Why Magnesium?

- **Reduce output of greenhouse gases**
- **Reduce dependence on imported oil**
- **Improve driving affordability**

Fuel Economy

- Federal & State Requirements
- Corporate Mandates
- Competitive Pressure

Emission Standards

- Federal & State Requirement

Safety

- Reduce Cg
- Brakes, Airbags
- Crash Structures

NVH

- Stiffness
- Insulation

Performance

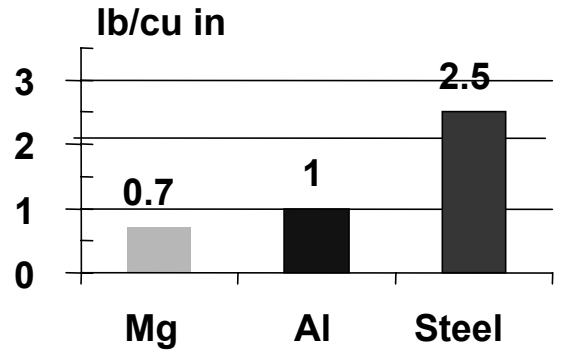
- 4W Drive
- Traction Control
- Powertrain Features

Heavy Extras

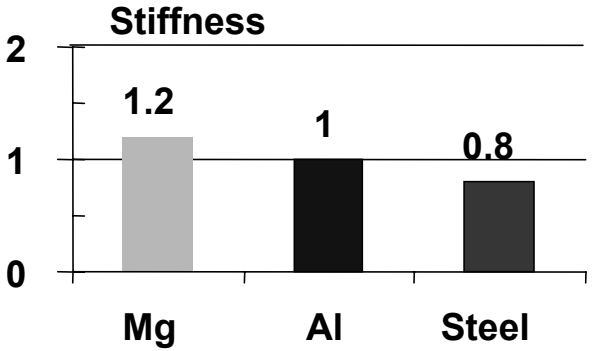
- Convertibles
- Power Accessories
- Electronic Devices

Material Comparison

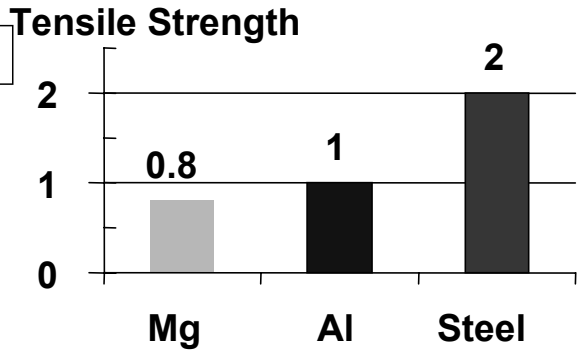
Light



Stiff



Strong



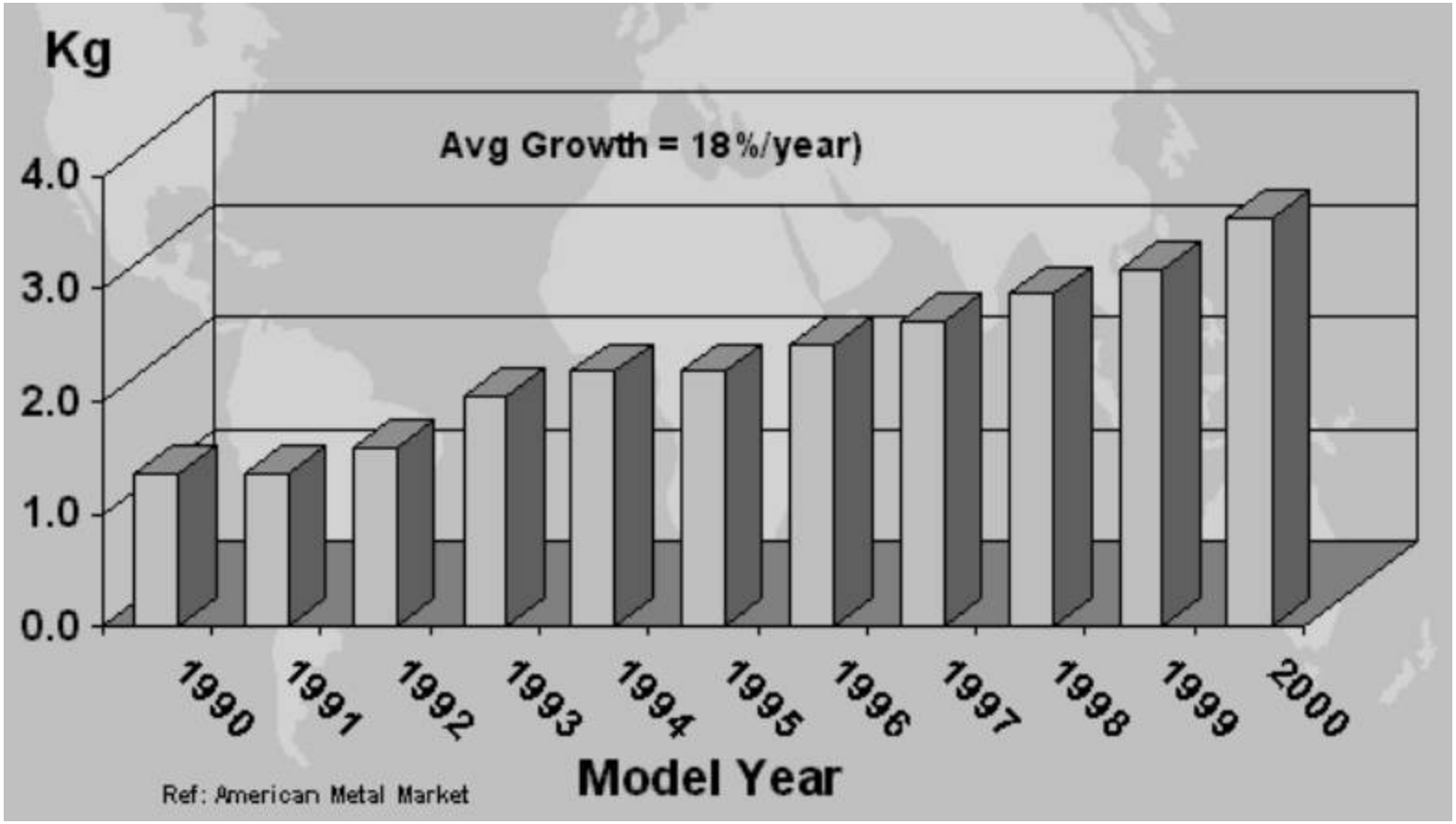
Magnesium Supply Base

- **Norsk Hydro**
- **US Magnesium**
- **Timminco**
- **Pechiney**
- **RIMA & Brasiliera de Magnesio**
- **Dead Sea Magnesium**
- **Solikamsk & Avisma**
- **PRC, China (356,000 tonnes, yr 2003)**

Total world wide volume 2003 < 600,000 tonnes

Average Magnesium Usage per Vehicle NA (Kilograms)

2000 MY (Kg)
Mg = 3.6
(Al = 111.6)

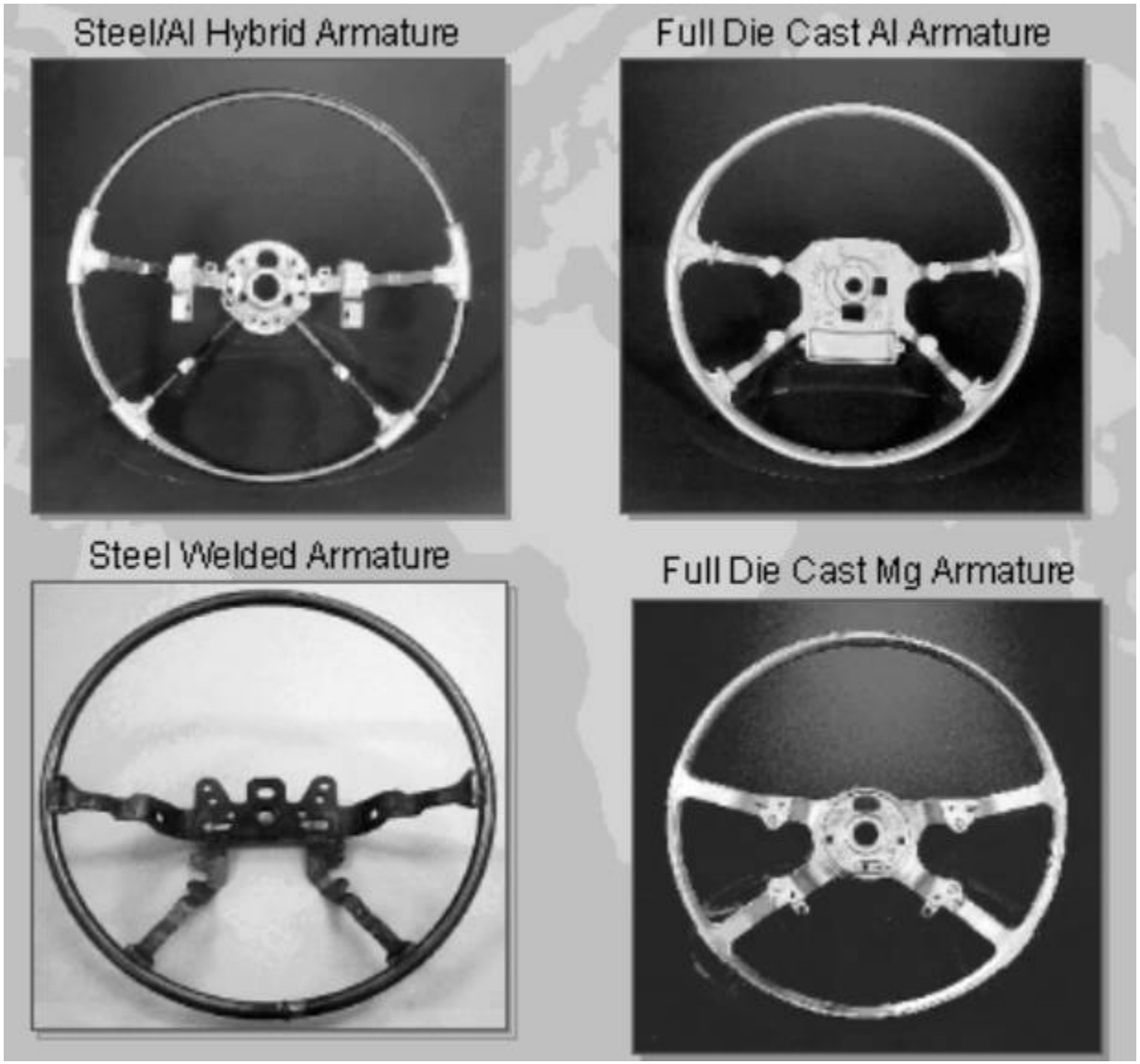


Potential Mass Reduction Opportunities with Magnesium

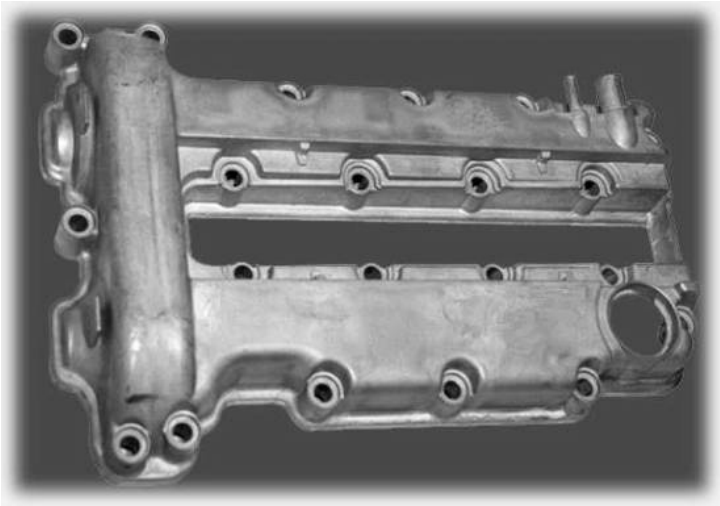
Subsystem	Potential replacement	Mass in Mg	Mass saved
Powertrain	88	58	30
Chassis	80	35	45
Body	12	5	7
Interior	31	21	10
Total (Kg)	211	119	92

•Based on P2000 Ford

Current Steering Wheel Armature



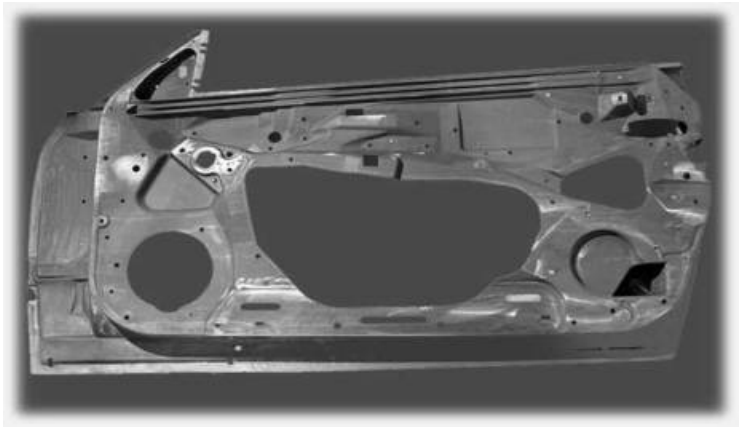
Light weight solutions



Cam cover, AZ91D
1.15 Kg

Transmission housing
AZ91D, 9.10 Kg

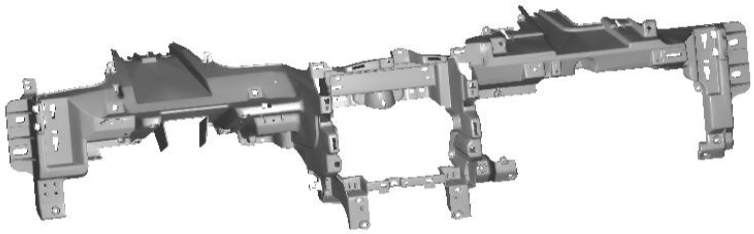
Light weight solutions

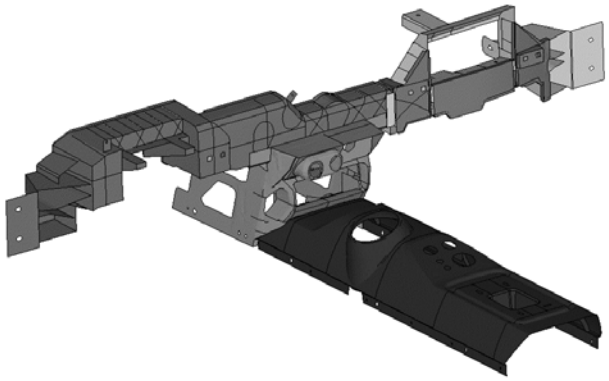


door inner, AM50, 4.5kg
weight save 45 %
over steel-version

tailgate, AM 50, 2.7kg
weight save 40 %
over steel-version

Light weight solutions

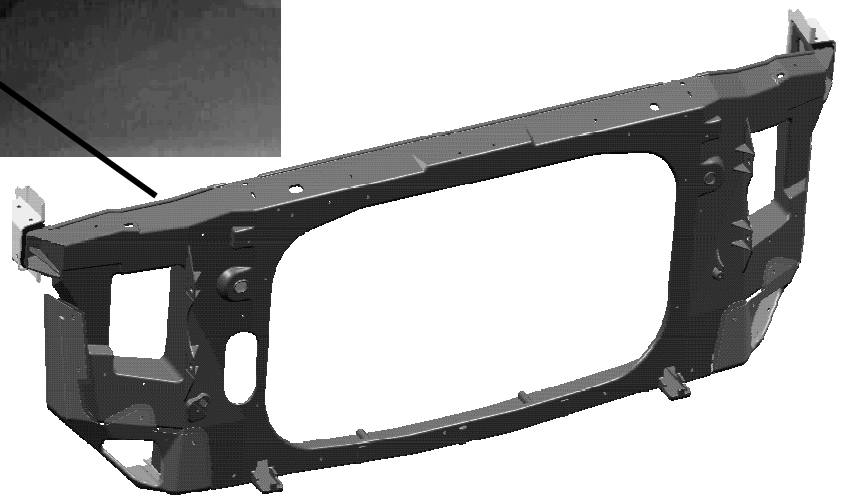




IP cross members (Jaguar & Ford GT)

Light weight solutions

Radiator Support



Life Cycle Assessment

Definition -

Life Cycle Assessment (LCA), a tool to support product and process development as part of the Design for Environment efforts on a strategic or operational level

Goal -

- Perform external/internal LCA study fully meeting ISO 14040-x and review requirements.
- Identify environmental hot-spots along the life cycle

Life Cycle Assessment

System Boundaries -

Include the whole life cycle (from resource depletion to material production, part(s) production, assembly, use and end-of-life treatment including transports).

Data Quality Requirements -

- time-related, geographical, & technology coverage
- precision, completeness and representativeness
- consistency and reproducibility of the methods used
- sources and representativeness
- uncertainty of the information

Life Cycle Assessment

Minimum Data Required -

a) process flow diagram

b) electricity (in kWh/kg process product), electricity source (% hard coal, % natural gas, % nuclear, etc.)

c) steam and heat (in MJ/kg process product), energy source (hard coal, natural gas, etc.)

d) yield (kg input/ kg process product)

e) CO_2, CH_4, SF_6, HFC and any other emissions leading to global warming (kg/kg process product)

f) SO_2 emissions and any other emissions leading to acidification (kg/kg process product; specify)

g) Non-methane Votile organic Carbons (NMVOC) emissions and NOx emissions (kg/kg process product)

Life Cycle Assessment

Life Cycle Impact Analysis Categories include –

- Global Warming (in CO_2 equivalency) using IPCC data for **CO_2**, CH_4, N_2O, HFCs, CFCs, PFCs, **SF_6**

  (IPCC – Intergovernmental Panel on Climate Change)
- Acidification Potential (kg SO_2 equivalency)
- Summer Smog Potential (kg Ethene equivalency)
- Winter Smog Potential (kg SO_2 + kg dust)
- Ozone depletion (in kg R11 equivalency)
- Emissions effecting health of Fauna/Flora
- Nutrification Potential (in kg Phosphate equivalency)

Life Cycle Assessment

In general, the environmental Burdens can be itemized by life cycle stage,

$$\{B\} = \{B\}_{MP} + \{B\}_{ASSM} + \{B\}_{OP} + \{B\}_{MN} + \{B\}_{SHP} + \{B\}_{EOL}$$

MP – material production

ASSM – part manufacture & vehicle assembly

OP – vehicle operation & use

MN – vehicle maintenance & repair

SHP – shipment to market

EOL – vehicle end of life

Life Cycle Assessment

vehicle weight reduction vs. Life Cycle Energy (LCE) and Life Cycle CO_2 emissions

Various Warming Gases & Production Energy Rates per unit pound of material (Ford LCI database)

	Steel	Al (virgin)	Mg
CO_2 lb/lb	3.5	8.14	6.0
Fluorocarbons, lb/lb CF_4 (6500 GWP) & C_2F_6 (9200 GWP)		4.8 ~ 5.9 E-4	
SF_6 lb/lb (IPCC 23900 GWP)			5.0 E-4
Total CO_2 equivalency, lb/lb	3.5	11.3 ~ 12.1	18
Production Energy, BTU/lb	21400	87100	64500
Production efficiency	98 %	98 %	98 %
Substitution factor	100 %	55 %	33 %

Life Cycle Assessment

vehicle weight reduction vs. Life Cycle Energy (LCE) and Life Cycle CO_2 emissions

Vehicle Operational Parameters per unit weight reduction

	Taurus	Expedition
Production Energy, BTU/lb	103300	93500
Total CO_2 equivalency, lb/lb	16.1	14.6
Baseline Mass, lb	3076	5300

Baseline Values of LCE and CO_2 in its Life Cycle (10 yrs)

	Taurus	Expedition
Metro Hwy, MPG	28.3	15.5
LCE, BTU E+6	758	1381
CO_2 equivalency, lb	115500	208000

Life Cycle Assessment

vehicle weight reduction vs. Life Cycle Energy (LCE) and Life Cycle CO_2 emissions

Impact of weight reduction 500 lbs on LCE reduction

	Taurus	Expedition
Al for Steel	3.5 %	1.6 %
Mg for Iron/Steel	**7.5 %**	**3.8 %**

Impact of weight reduction 500 lbs on CO_2 reduction

	Taurus	Expedition
Al for Steel	4.5 %	2.1 %
Mg for Iron/Steel	**6.0 %**	**3.0 %**

FMC's Policy Letter No. 17
Protecting Health and the Environment

- Engineering Material Specification for RESTRICTED SUBSTANCE MANAGEMENT STANDARD, WSS-M99P9999-A1

- The requirements established by this Standard apply to all products supplied to Ford. They apply equally to Full Service Suppliers, proprietary, and Ford specified items.

SF6 prohibited at Ford starting 1/31/2004

Ford Motor Company

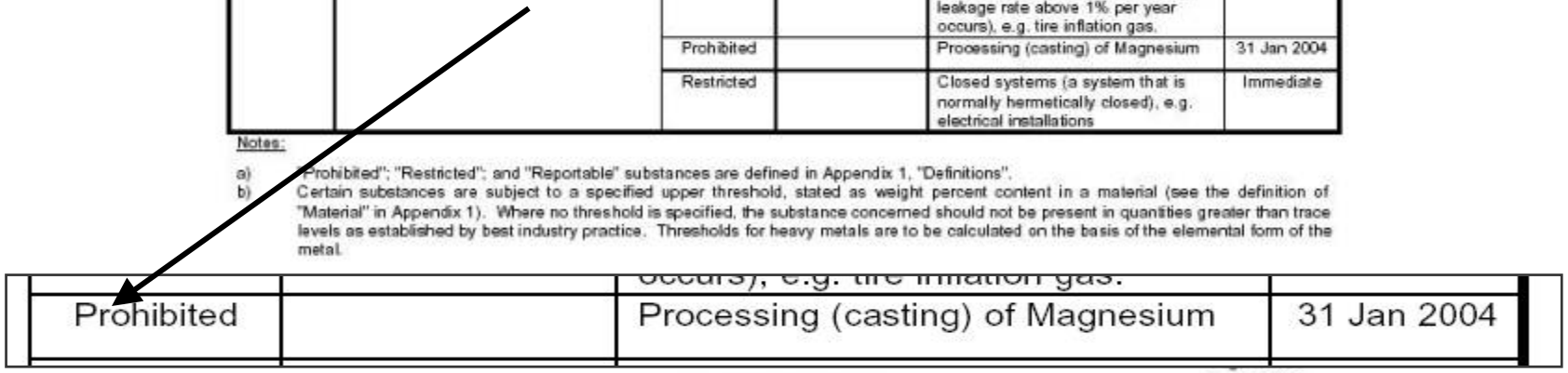
ENGINEERING MATERIAL SPECIFICATION WSS-M99P9999-A1

TABLE 1 (Cont'd)
SUBSTANCE RESTRICTIONS

Row Number	Substance	Type of Restriction (a)	Threshold (not to be exceeded) (b)	Applications affected / Comments	Effective date
58	Polybrominated diphenylethers (PBDEs)	Prohibited		All products except those containing Decabromodiphenyloxide	Immediate
		Restricted		Products containing Decabromodiphenyloxide	Immediate
59	Polychlorinated biphenyls (PCBs)	Prohibited	0.001%	All Products	Immediate
60	Polychlorinated terphenyls (PCTs)	Prohibited	0.001%	All Products	Immediate
61	Polyvinylchloride (PVC)	Reportable		All Products	Immediate
62	Products of endangered species	Prohibited		All Products	Immediate
63	Radioactive substances	Restricted		All Products.	Immediate
64	Reproductive toxicants	Restricted		All Products	Immediate
65	Sensitizing substances	Restricted		All Products	Immediate
66	Sulfur hexafluoride	Prohibited		Open systems (a system where under normal working conditions a leakage rate above 1% per year occurs), e.g. tire inflation gas.	Immediate
		Prohibited		Processing (casting) of Magnesium	31 Jan 2004
		Restricted		Closed systems (a system that is normally hermetically closed), e.g. electrical installations	Immediate

Notes:

a) "Prohibited"; "Restricted"; and "Reportable" substances are defined in Appendix 1, "Definitions".
b) Certain substances are subject to a specified upper threshold, stated as weight percent content in a material (see the definition of "Material" in Appendix 1). Where no threshold is specified, the substance concerned should not be present in quantities greater than trace levels as established by best industry practice. Thresholds for heavy metals are to be calculated on the basis of the elemental form of the metal.



ENGINEERING MATERIAL SPECIFICATION
RESTRICTED SUBSTANCE MANAGEMENT STANDARD **WSS-M99P9999-A1**

Current Advanced Programs

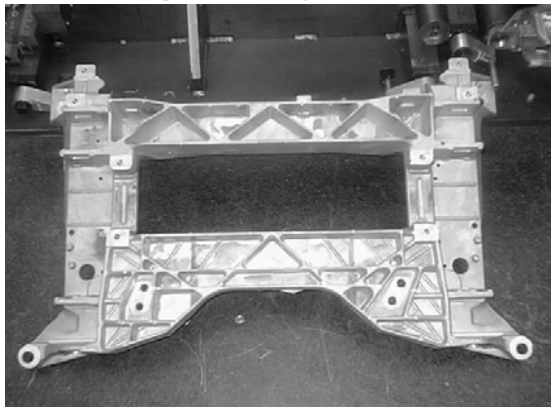
UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

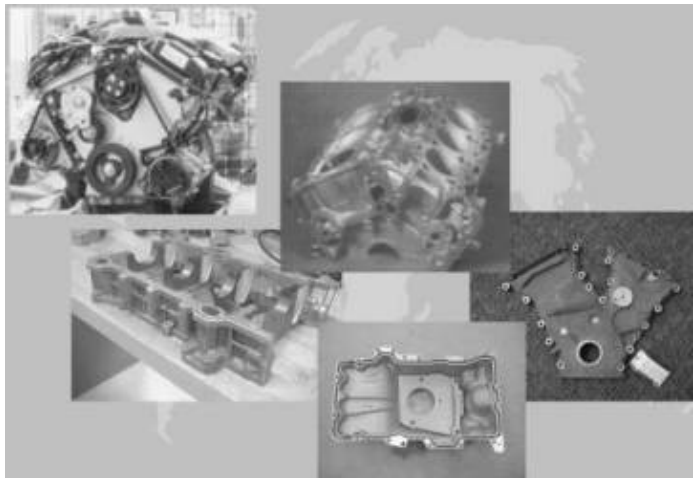
Powertrain program (USCAR consortium)

- **Engine Block, Bedplate, Oil Pan & Front Cover - Ford**
- **Newly developed high temp Mg alloys**

Chassis program (USCAR consortium)

- **Engine Cradle - GM Corvette '06**
- **Commercial Mg alloys** (34 -> 22#)





Current Advanced Programs (cont.)

Cost-Reduced Magnesium Die Castings Using Heated Runners (CORMAG) –

Mg Casting Lab at Ford

- cold chamber (400 ton)

- hot chamber (300 ton)

Issues with Using Large Quantities of Magnesium in Auto Industry

The magnesium "industry" is unlike the polymer, aluminum, and steel industries:

- **significant R&D**
- **full technical and commercial support**

  alloy development, design & modeling, casting, manufacturing, failure analysis, corrosion, quality, training, etc.

Summary

- **Introduce Mg automotive applications**
- **Life Cycle Assessment confirms the environmental performance gains (E & CO_2) resulted from Mg on cars and SUVs**
- **Abandon SF_6 at Ford and need to use alternative cover gases**
- **Conduct R&D programs with leverage and develop Mg supplier basis**