Magnesium Alloys in Aerospace Applications, Past Concerns, Current Solutions

Triennial International Aircraft Fire & Cabin Safety Research Conference
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Bruce Gwynne – VP Divisional Strategic Development
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Mg Components on Aircraft - Historical 1943 - 1944 (prototypes)

Northrop XP-56 Black Bullet
Experimental Flying Wing Fighter

The All Magnesium Aircraft
- Magnesium Alloy Airframe & Skin
- Heliarc welded structure

Magnesium Elektron
Service & Innovation in Magnesium
Convair XC-99
First Modern Double Deck Airliner
Capacity: 400 fully equipped troupes

Consolidated Vultee Model 37
Proposed Civilian Version

Pan Am ordered 15 before program cancellation

Magnesium Alloy Structure & Skin
Magnesium Elektron

• Magnesium Alloys
• Corrosion Resistant Alloys
• Current Aircraft Applications
• EFV
• Automotive Growth
• Flammability
• Conclusions
# Magnesium Casting Alloys

Magnesium Casting Alloy Families – Commonly used alloy systems employed today

<table>
<thead>
<tr>
<th>Alloy System</th>
<th>Alloys</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al - Zn - Mn</td>
<td>AZ81, AZ91, AZ92</td>
<td>1930s → mid 1980s</td>
</tr>
<tr>
<td>Zn - RE - Zr</td>
<td>EZ33, ZE41, ZE63</td>
<td>late 1940s → late 1960s</td>
</tr>
<tr>
<td>Ag - RE - Zr</td>
<td>QE22, EQ21</td>
<td>early 1960s →</td>
</tr>
<tr>
<td>Y - RE - Zr</td>
<td>WE43, WE54</td>
<td>late 1980s → Elektron 21 (EV31)</td>
</tr>
<tr>
<td>Nd - Gd - Zn - Zr</td>
<td></td>
<td>late 1990s →</td>
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Elevated Temperature Exposure on the Tensile Properties of Various Magnesium & Aluminum Alloys

Aluminium Data from ASM Metals handbook Vol 2

Revised March 28, 2005
Magnesium Elektron

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Mg in Aerospace
Mg Components on Aircraft - Historical

Convair B-36 “Magnesium Overcast”

- 4 tonnes of magnesium alloy - 10% of structural weight*
- 1,900 lbs weight saving - Range extended by 190 miles*

Past concern: Corrosion

*Source: Aviation Week, 12th July 1948, P21
B-52s have been in service for almost 52 years, with many magnesium components lasting way beyond the initial design life.

Past concern: Corrosion

One of many brake applications

Castings courtesy of Lite Metal Castings
Boeing 727 had 1200 magnesium part nos. including leading & trailing edge flaps, control surfaces, actuators, door frames, wheels, engine gear boxes, power generation components, structural items (not primary), and others.

Past concern: Corrosion

No Parts Rejected for:

Boeing 727
1,832 built between 1962 and 1984

Krueger Flaps
AZ92 Castings
Corrosion Comparison of Some Magnesium & Aluminum Castings Alloys-Test Coupons

ASTM B117 Salt Fog Corrosion Rate (mils penetration per year)

Al Alloys
- C355
- A356
- A357
- A201
- A203
- A206

Mg Alloys
- WE43
- WE54
- AZ91E
- Elektron 21
- ZE41
- EZ33
- AZ91C

AMS specification limits

WITH SPEC LIMITS
Corrosion Test Cylinders after ASTM B117 Salt Fog Testing

Corrosion Resistant Alloys:
- WE43
- AZ91E

Standard Purity Alloy:
- AZ91C

WE43  AZ91E  AZ91C

10 Days Exposure

20 Days Exposure
Salt Fog Corrosion Improvement

AZ91C vs. AZ91E

Tested 10 days to ASTM B117

Casting approximately 24” x 16” x 4”
Magnesium Elektron

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AZ92A Castings

Thrust Reverser Cascade Casting

Found on:
- 737
- 747
- 757
- 767

provided by Consolidated Foundries
AZ91E Castings

Piper Comanche

Lycoming 540 Series

Extra 300

Piper Chieftain

TEXTRON LYCOMING
6 CYLINDER SUMP
AZ91E T6

Castings courtesy of Lite Metal Castings
AZ91E Castings

Sikorsky CH53D Sea Stallion

630 lbs. (285 kgs.)
ZE41 Castings

Sikorsky
UH60 Family (Blackhawk)

Transmission designed in ZE41 for ½ hour dry run capability
ZE41 Castings

Boeing AH64 Apache

AH-64C
EZ33A Castings

Rolls Royce
RB211 gearbox
ZE41 Castings

Bombardier Q Series Dash 8

PW150 Series – 7000 shp class

Pratt & Whitney Canada
PWC 100 Series Turboprop
Operating on >1900 aircraft

BAe ATP
ZE41 Castings

GLOBAL HAWK

EMB ERJ

Over 900 ERJ’s produced since 1995

CITATION X

Rolls-Royce Allison AE-3007
ZE41 Castings

Pratt & Whitney Canada PW535 Turbofan
PW500 Family: 2,500 to 4,000 lbs Thrust

Cessna Citation Excel
ZE41 Castings

Pratt & Whitney Canada PW535 Turbofan
PW500 Family: 2,500 to 4,000 lbs Thrust

provided by
Fansteel
Wellman
Dynamics
ZE41 Castings

Hamilton Sundstrand
F16 AMAD

Casting mold containing ~100 cores
QE22 Castings

BAE 146 with ALF 507s
QE22 Castings

General Electric
F110 Engine

General Dynamics F16

F-16C/D

ACCESSORY DRIVE GEARBOX
WE43 Castings

MD500 / MD 600

MD500 Upgrade Gear Box
MD 600 Gear Box
Main transmission castings are in WE43

Believed to be 10 castings in total
WE43 Castings

Bell Agusta 609

First flight March 7, 2003

TILT-AXIS GEARBOX
(20” x 20” x 20”, 25.5#)
WE43 Castings

Pratt & Whitney F119

EMAD

F-22A
WE43 Castings

Lockheed Martin
Single Engine Joint Strike Fighter

planned production ranges from 3,000 to 6,000 aircraft
	numerous participating countries
Elektron 21 Castings

Boeing Mesa has selected Northstar Aerospace as the source for the Block III transmission.

**Elektron 21** has been selected for use on seven drive train castings including the main transmission housing.

**Boeing AH-64D**
Apache
Twin Engine Medium Attack Helicopter

AH-64D
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The EFV will be capable of transporting 18 Marines and a crew of three over water at speeds of 29 miles an hour; the design uses a planing hull propelled by two water jets. On land, it will achieve speeds of 45 miles an hour, with cross-country mobility equal to an M1 Abrams tank.
Elektron 21 Castings

EFV Transmission Castings

PTM=power transfer module (converts from driving water jets to tracks)

X4560 TRANSMISSION
1st EFV SDD Transmission Completion
July 24th, 2002
Magnesium Alloys
Corrosion Resistant Alloys
Current Aircraft Applications
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Flammability
Conclusions
Major Magnesium Based Auto Products

- Front End Structures
- Transmission Case
- Cam Covers
- Center Console
- 3rd Row Seat Frames
- Header Bow
- Engine Cradle
- Instrument Panel
- Bucket Seat Frames
- Steering Column Brackets

Information from Meridian Technologies
**Major Platforms Using Magnesium**

- GM Full Sized Vans - Savana & Express - up to 26.3 kg
- Audi A6-2.8 Multitronic - up to 20.31 kg
- GM Minivans - Safari & Astro - up to 16.7 kg
- Ford F-150 Truck - 14.9 kg
- VW Passat, Audi A4 & A6 - from 13.6 to 14.5 kg
- Audi TT - from 11.48 to 12.51 kg
- Porsche Boxster Roadster - 9.9 kg
- Buick Park Avenue - 9.5 kg
- Alfa Romeo 156 - 9.3 kg
- Jaguar XJ - 8.7 kg
- Golf & Polo - from 8.16 to 9.19 kg
- DaimlerChrysler SLK Roadster - 7.7 kg
Gain of 280,000 metric tonnes of magnesium (>600m lbs) since early 1990's
• 85% of all die castings manufactured are used for automotive components.
Automotive Trends

Elektron AJ62

- Mg/Al Composite Engine Block
- 10 kg weight saving.
- Now in full production - 450,000 units per annum.

A Division of Luxfer Group
Magnesium Elektron

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How To Start A Fire!

FACTS

• Must Reach Melting Point
  – (Pure Magnesium = 1200°F 650°C)
• Must Sustain Heat Source
  – to overcome conductivity
• Must Have Oxygen
• Solid magnesium is not easy to burn
  
  • Magnesium powders can be designed & used in flares
  • Aluminium powder is used in propulsion systems …
1900°F (1000°C) Flame test – Elektron 21
Time to Ignition with 1900°F (1000°C+) Flame

- AZ91
- ZE41
- WE43
- Elektron 21

TIME TO INITIATE BURNING (Mins)
FAATC Tests - Preliminary Mg Burning Characteristics

- **FAR 25.853 Appendix F Part 2 – Seat Cushion test**
  - 1900F flame with heat flux of 10.5 Btu/ft$^2$/sec
  - 2 minute exposure plus 5 minute dwell time
- Tests on Magnesium exceeded 2 minutes – flame on 4 - 5 minutes, until melted & beyond
WE43, Elektron 21 - Did not burn when melted or self extinguished

Part 2 seat cushion test used as severe condition for preliminary Mg alloy data.

AZ31 - Burned when melted
Behaviour of Elektron WE43 versus AZ91*

AZ91

regular surface with appearance of cracks with oxides therein

Elektron WE43

T ignition = >1275°F

EDX analysis

T ignition = 1075°F

* Courtesy EADS/Grenoble University
Airbus commissioned tests at an FAA approved laboratory.

Industrial flame test according to IGC 04.24.106, corresponding to US FAA, CS25 / JAR 25 / FAR 25§25-853
Both Elektron WE43 and Elektron 21 tested,

2mm and 6mm (0.08 inch & 0.25 inch) thick cast sheets.

With and without HAE surface treatment.

0°, 45° and 90° angle flame impingement.

All tests passed
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Conclusions

• Many successful past & present aircraft applications of Magnesium
• Past concerns were mainly corrosion, few for Fire
• Solid Magnesium requires significant heat to melt
• Melting point is the same as Aluminium
• Melting must occur before opportunity to burn
• Newer alloys (WE43, Elektron 21) are more “flame resistant” than older alloys
• Magnesium used in Aircraft Engines. More recently, resurgence of interest in Magnesium for interior applications to save weight
Magnesium Alloys
Corrosion Resistant Alloys
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One Last Thing
Airbus are evaluating Elektron 21 and Elektron WE43, both in investment cast and sand cast form, for use on their commercial aircraft.
These alloys are no longer banned on the A380 (except for the primary structure).
The End

Thank you for your attention