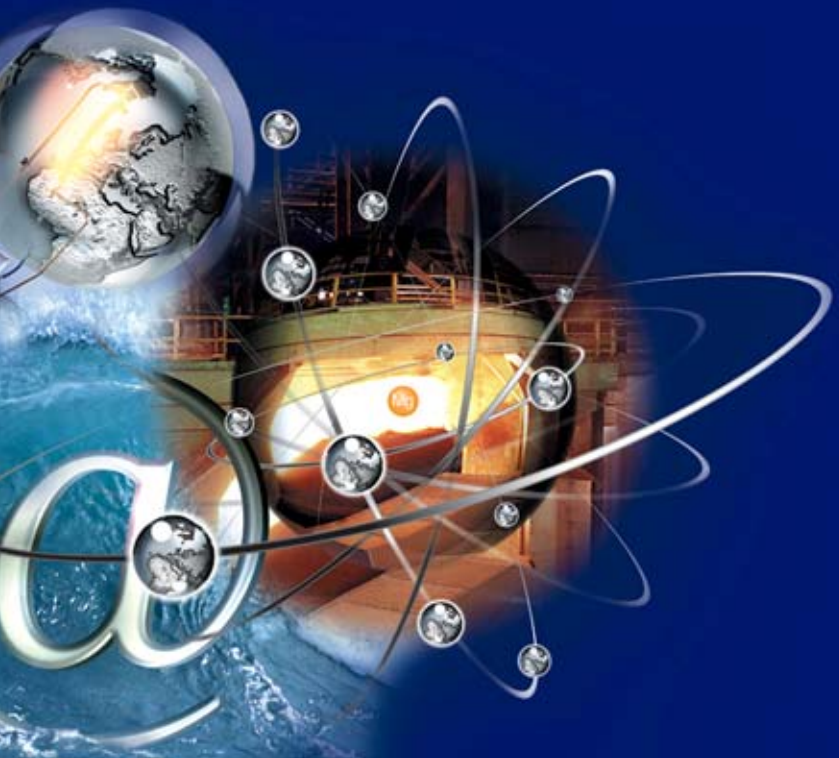
Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

Magnesium Alloys in Aerospace Applications, Past Concerns, Current Solutions



Triennial International Aircraft Fire & Cabin Safety Research Conference

October 29 - November 1, 2007

Bruce Gwynne – VP Divisional Strategic Development

Paul Lyon - Market & Materials Development Manager

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

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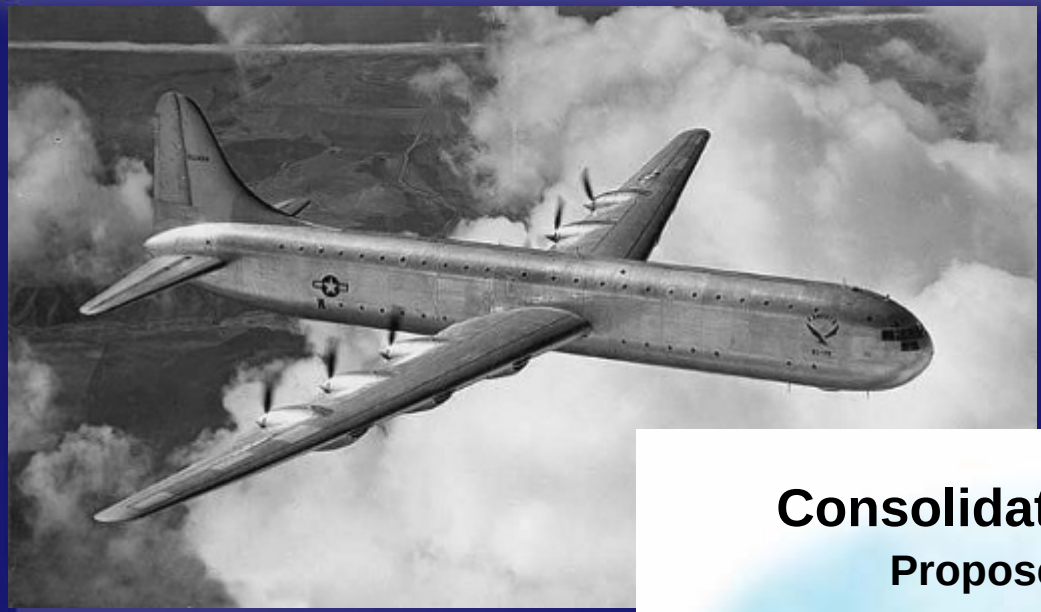
Mg Components on Aircraft - Historical

1949 - 1957 USAF Service



Convair XC - 99

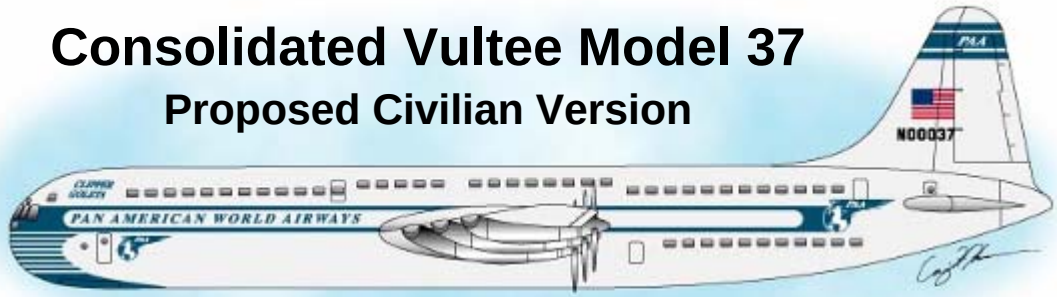
First Modern Double Deck Airliner

Capacity: 400 fully equipped troupes

Pan Am ordered 15 before program cancellation

Consolidated Vultee Model 37

Proposed Civilian Version



Magnesium Alloy Structure & Skin

Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

- 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

Al - Zn - Mn	Zn - RE - Zr	Ag - RE - Zr	Y - RE - Zr	Nd - Gd - Zn - Zr
AZ81	EZ33	QE22	WE43	Elektron 21 (EV31)
AZ91	ZE41	EQ21	WE54	
AZ92	ZE63			

Al - Zn - Mn 1930s → mid 1980s ⟶

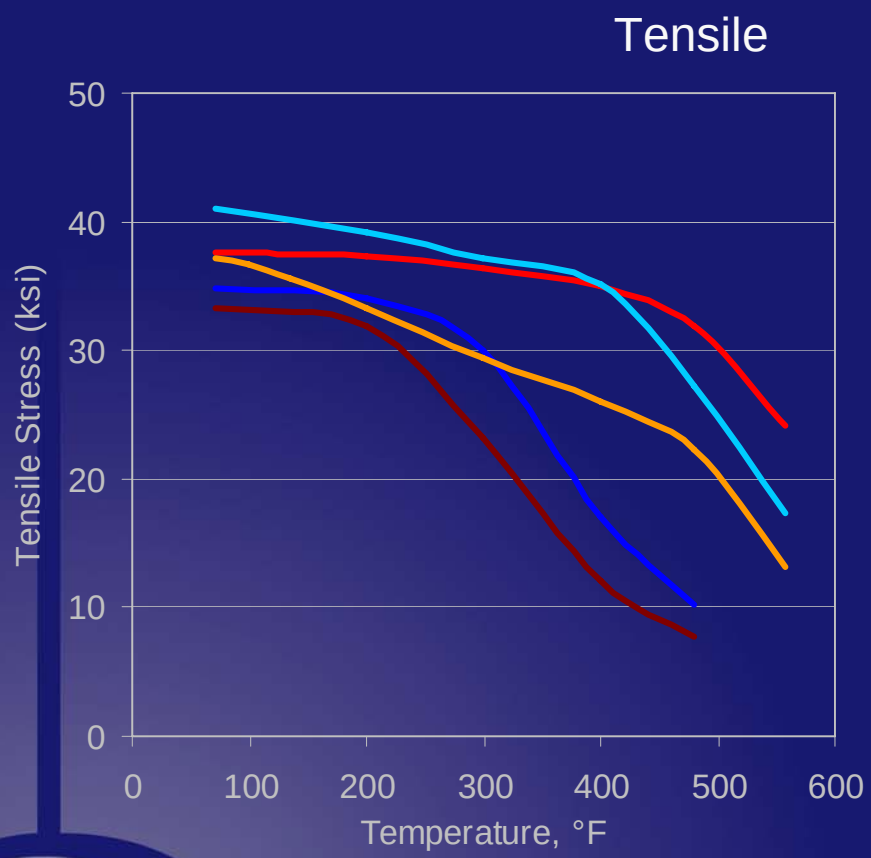
Zn - RE - Zr late 1940s → late 1960s ⟶

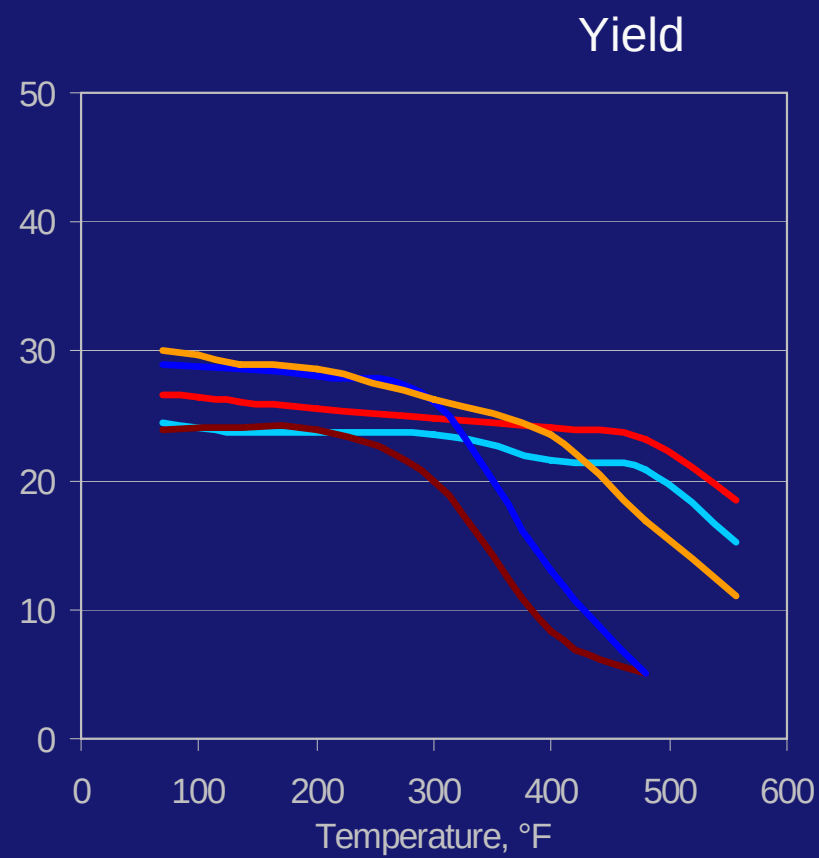
Ag - RE - Zr early 1960s →

Y - RE - Zr late 1980s →

Elektron21 late 1990s →

Elevated Temperature Exposure on the Tensile Properties of Various Magnesium & Aluminum Alloys





WE43A-T6 ELEKTRON 21 QE22A-T6 A356-T6 C355-T71

Aluminium Data from ASM Metals handbook Vol 2

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

Revised March 28, 2005

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Mg Components on Aircraft - Historical

1948 - 1954

Convair B-36 “Magnesium Overcast”

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

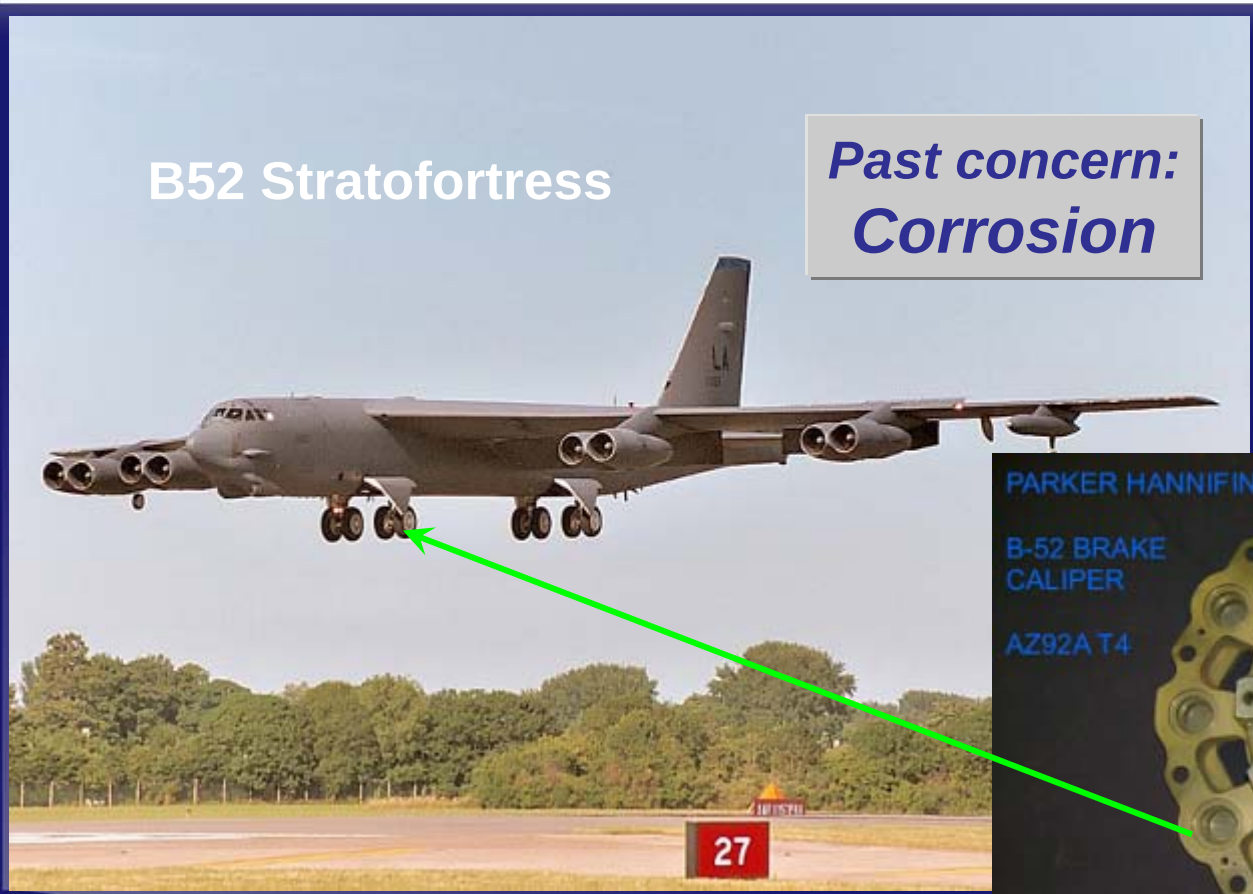
Past concern:
Corrosion

**Source: Aviation Week, 12th July 1948, P21*

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

Mg Components on Aircraft - Historical

1955 to Present



Past concern:
Corrosion

B-52s have been in service for almost 52 years, with many magnesium components lasting way beyond the initial design life.

One of many brake applications

Castings courtesy of **Lite Metal Castings**

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

AZ92/91/81 Sand & Permanent Mold 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.

No Parts Rejected for:

Fire

Boeing 727

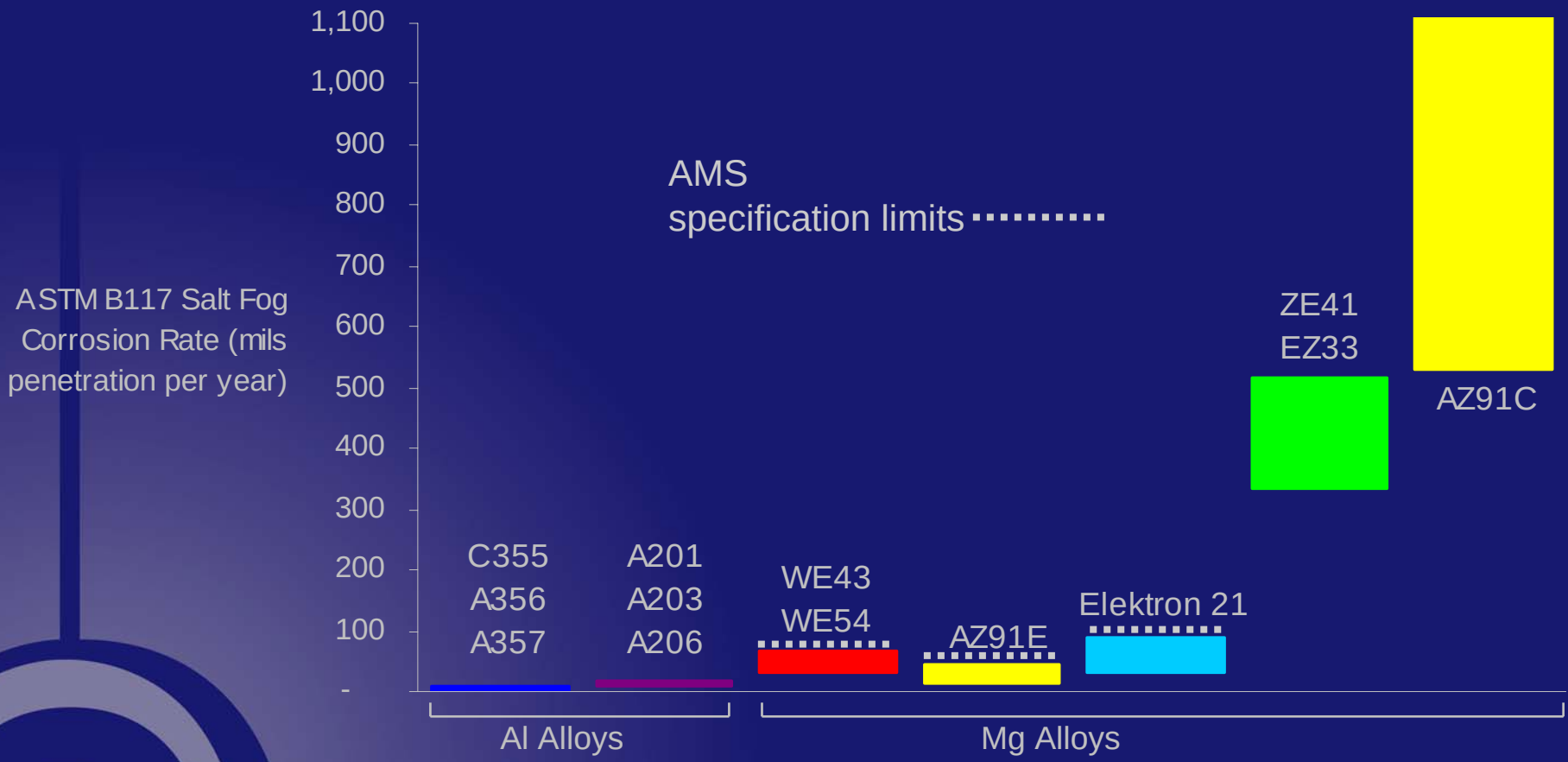
1,832 built between 1962 and 1984

Past concern: Corrosion

Krueger Flaps
AZ92 Castings

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

WITH SPEC LIMITS



Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

Corrosion Test Cylinders after ASTM B117 Salt Fog Testing

Corrosion Resistant Alloys:

WE43
AZ91E

Standard Purity Alloy:

AZ91C

Magnesium Elektron
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Salt Fog Corrosion Improvement

AZ91C vs. AZ91E

Tested 10 days
to ASTM
B117

Casting
approximately
24” x 16” x 4”

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

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AZ92A Castings

provided by Consolidated Foundries

Thrust Reverser Cascade Casting

Found on:
737
747
757
767

AZ91E Castings

Piper Comanche

Piper Chieftain

Lycoming 540 Series

Extra 300

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

Castings courtesy of Lite Metal Castings

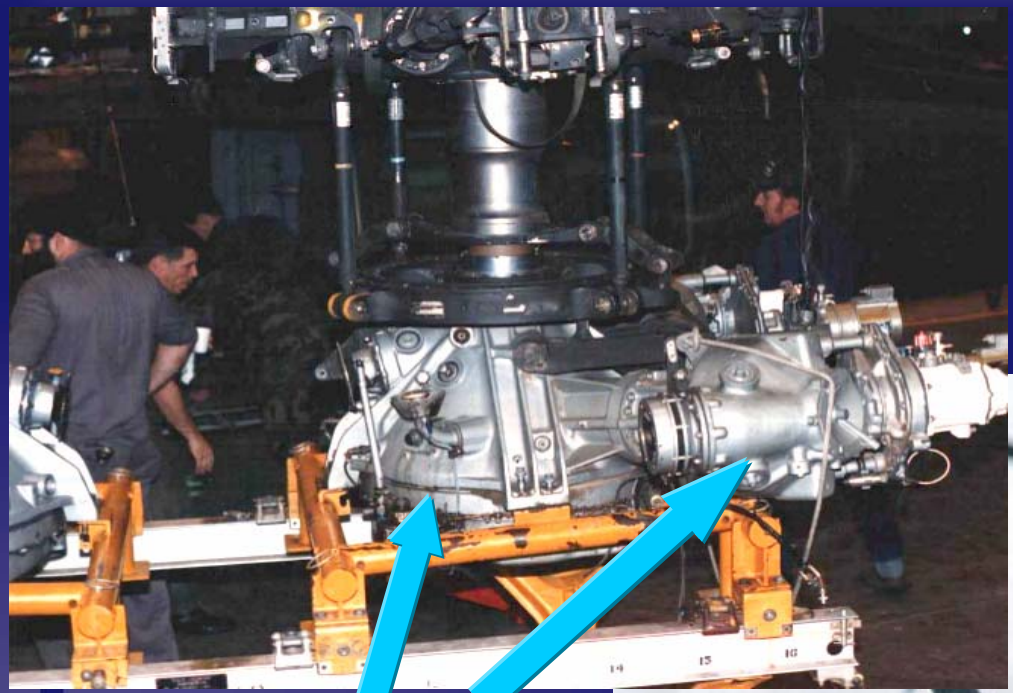
AZ91E Castings

Sikorsky CH53D
Sea Stallion

630 lbs. (285 kgs.)

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

ZE41 Castings



Sikorsky
UH60 Family (Blackhawk)

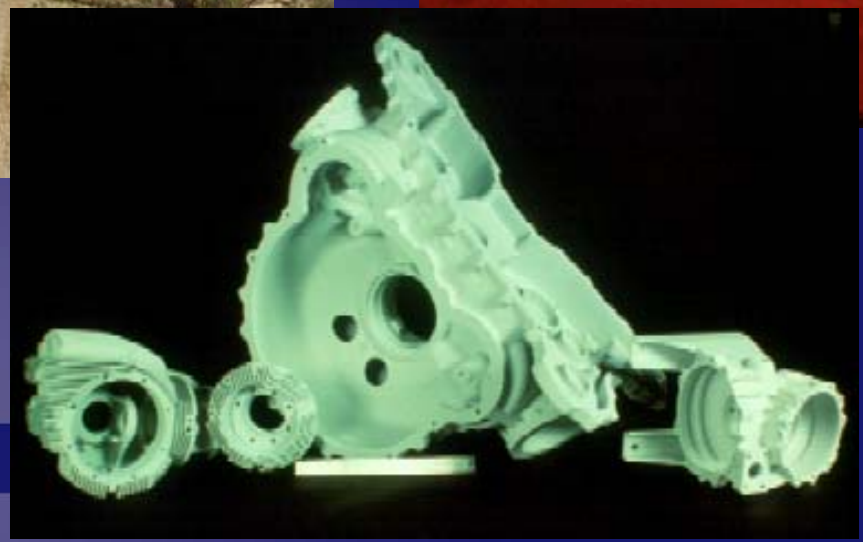
Transmission designed in ZE41 for ½ hour dry run capability

ZE41 Castings

Boeing
CH47 Chinook

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

ZE41 Castings

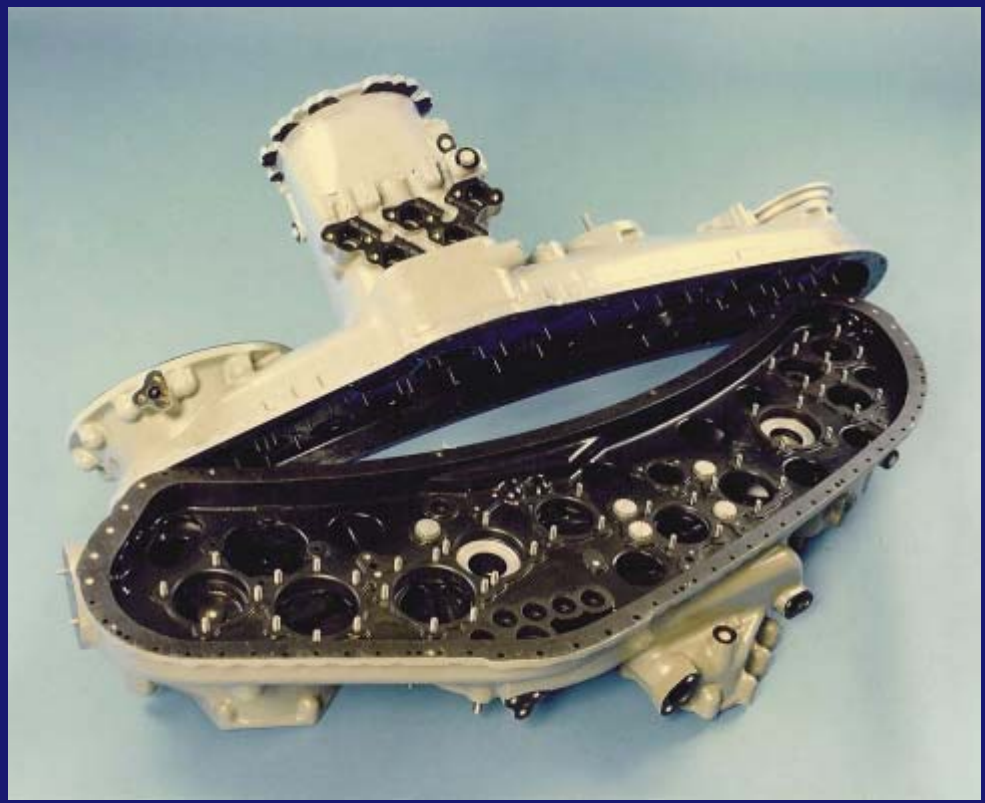


Boeing AH64
Apache

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

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

Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

ZE41 Castings

GLOBAL HAWK

EMB ERJ

Over 900 ERJ's produced since 1995

CITATION X

Rolls-Royce Allison AE- 3007

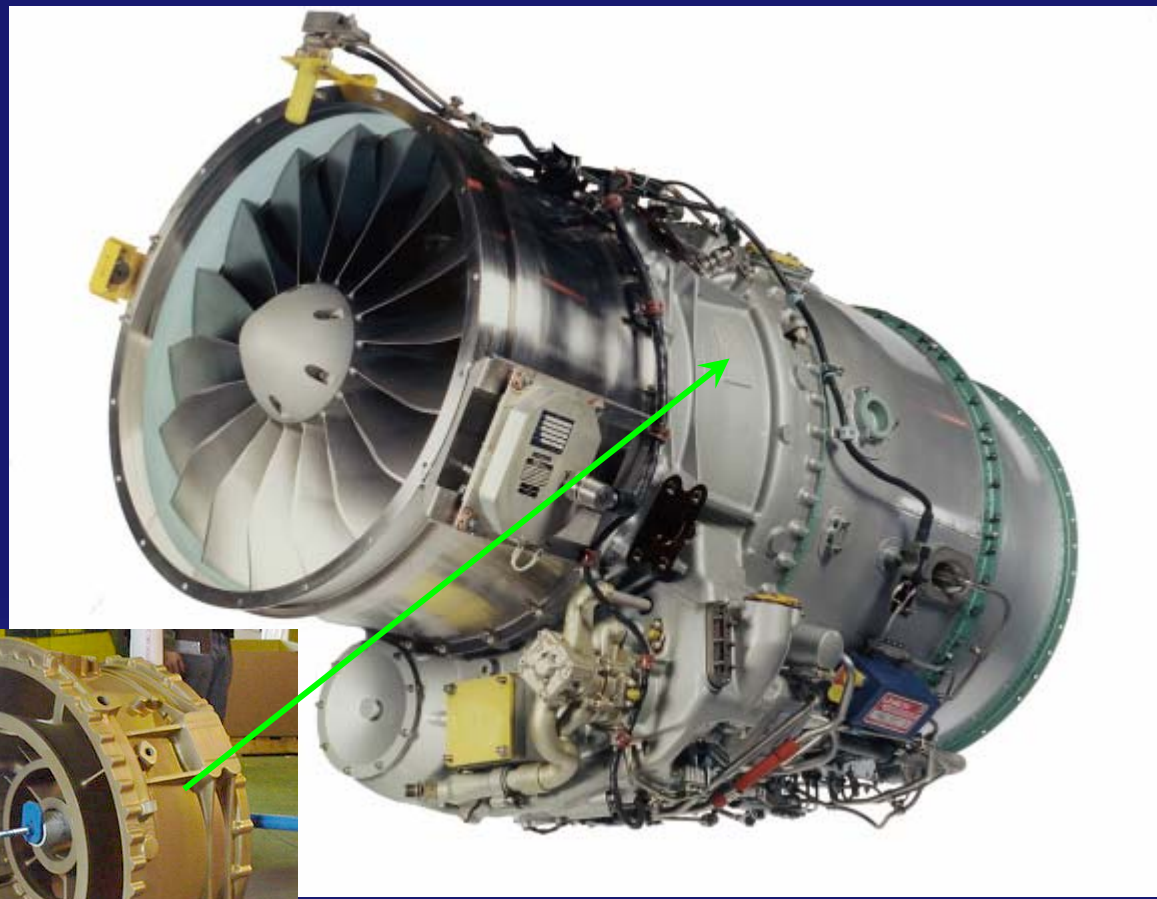
Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

ZE41 Castings

Pratt & Whitney Canada PW535 Turbofan

PW500 Family: 2,500 to 4,000 lbs Thrust

Cessna Citation Excel



Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

ZE41 Castings

Pratt & Whitney Canada PW535 Turbofan

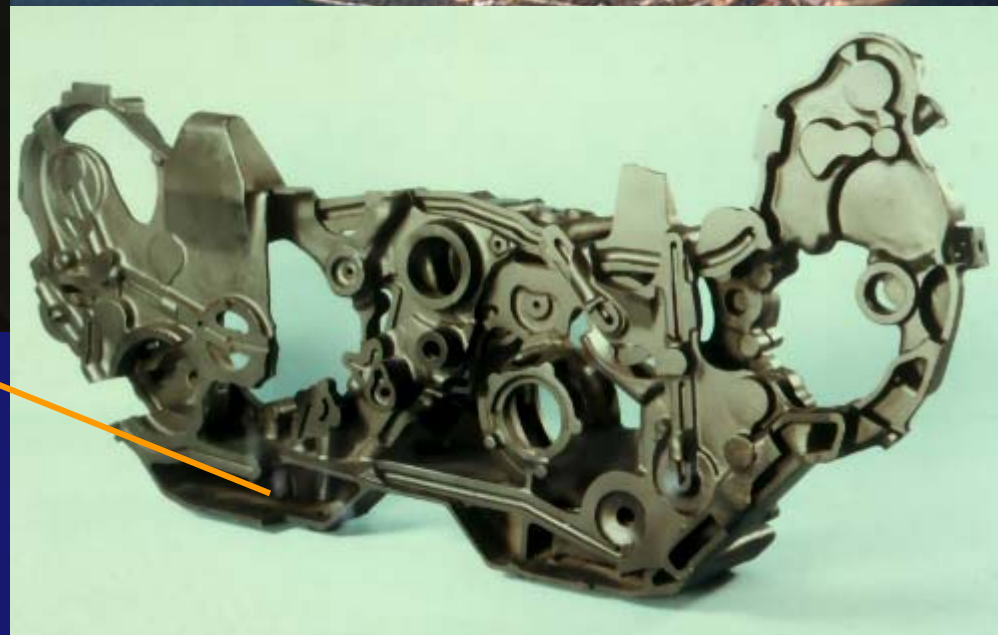
PW500 Family: 2,500 to 4,000 lbs Thrust

provided by
Fansteel
Wellman
Dynamics

ZE41 Castings

Hamilton Sundstrand
F16 AMAD

Casting mold containing
~ 100 cores



QE22 Castings

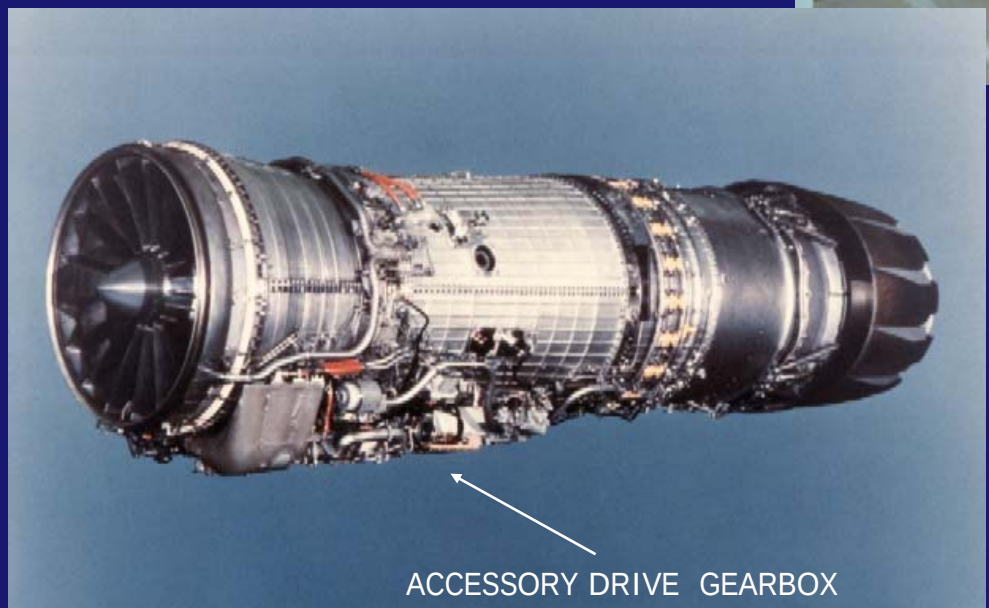
BAE 146 with
ALF 507s

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

QE22 Castings

General Dynamics F16

General Electric
F110 Engine



Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

WE43 Castings

MD500 / MD 600

MD500 Upgrade Gear Box
MD 600 Gear Box

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

WE43 Castings

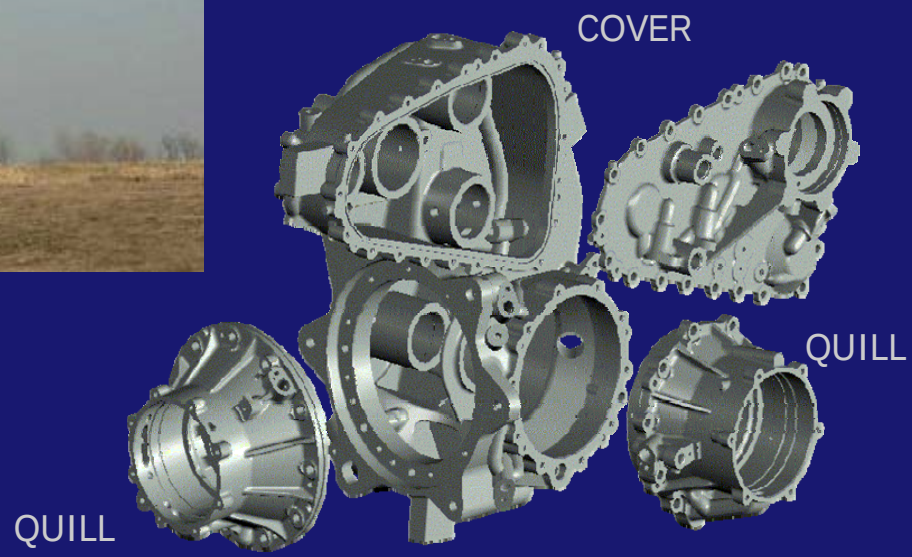
Sikorsky S92

Main transmission castings are in WE43

Believed to be 10 castings in total

WE43 Castings

Bell Agusta 609

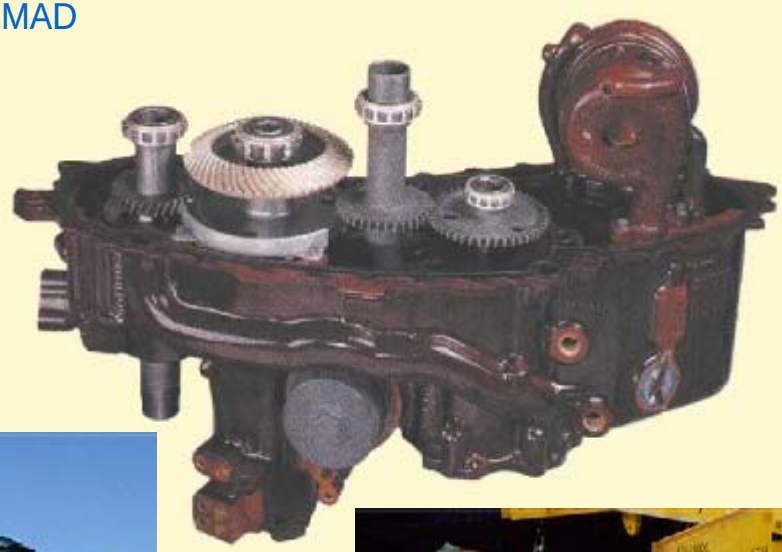


TILT-AXIS GEARBOX
(20” x 20” x 20”, 25.5#)

WE43 Castings

Pratt &
Whitney
F119

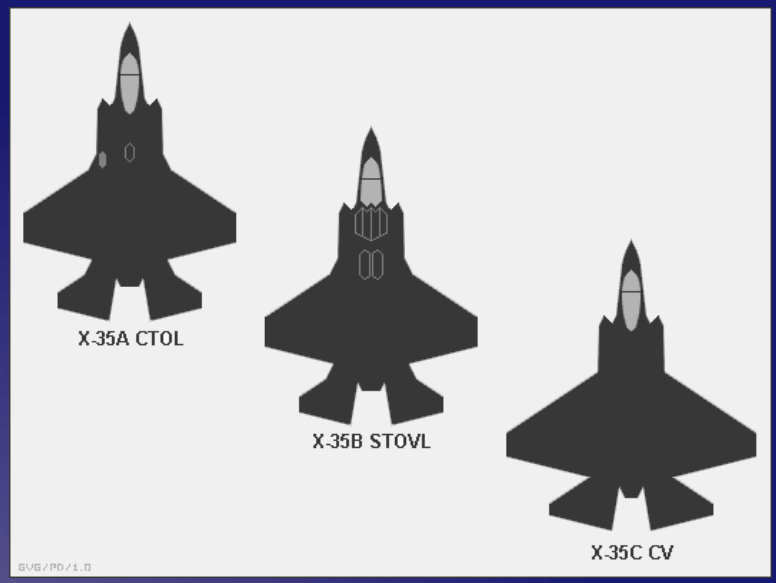
EMAD



Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

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

Military Rotary Aircraft - Attack

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

Boeing AH-64D Apache

Twin Engine Medium Attack Helicopter

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

AH-64D

Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

- Magnesium Alloys
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Expeditionary Fighting Vehicle - EFV

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.

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

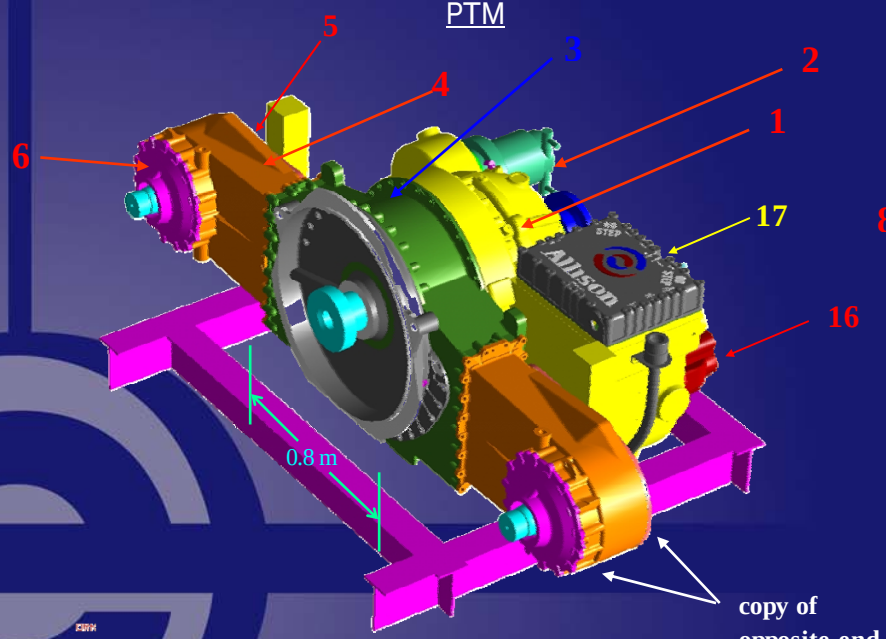
Elektron 21 Castings

EFV Transmission Castings

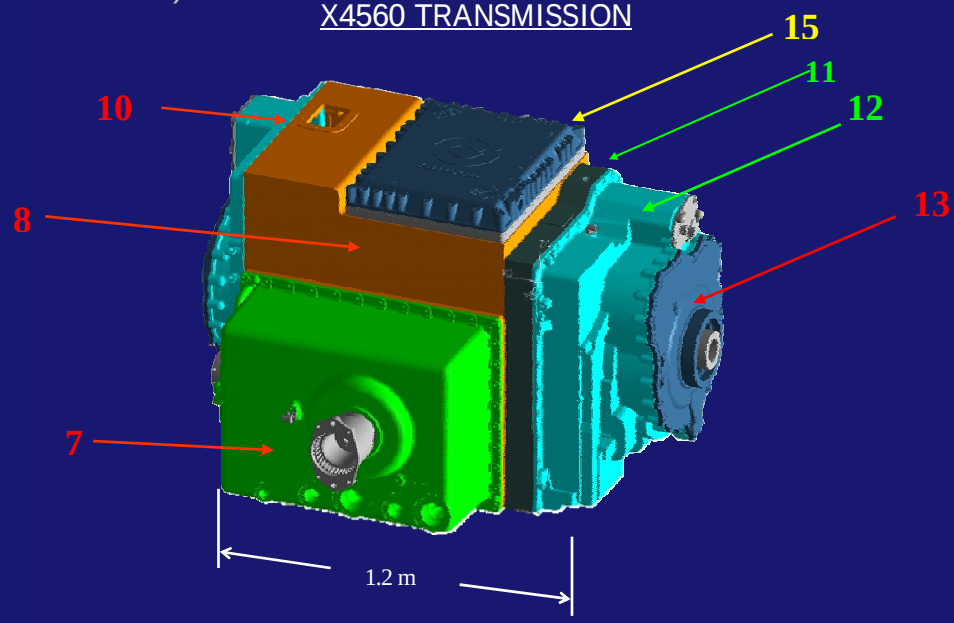
1	PTM main housing	Elektron 21
2	HYD. Output cover	Elektron 21
3	PTM center retainer	Al Alloy
4	water jet output housing	Elektron 21
5	water jet planet cover	Elektron 21
6	water jet wing cover	Elektron 21
7	main drive input housing	Elektron 21
8	main drive center housing	Elektron 21
9	right trunion cover	Elektron 21
10	right main output	Elektron 21
11	left main output adapter	ZE41
12	left main output	ZE41
13	left trunion cover	Elektron 21
15	controls cover	AZ91E
16	pump control housing	Elektron 21
17	controls cover	AZ91E

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

PTM



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

Information from Meridian Technologies

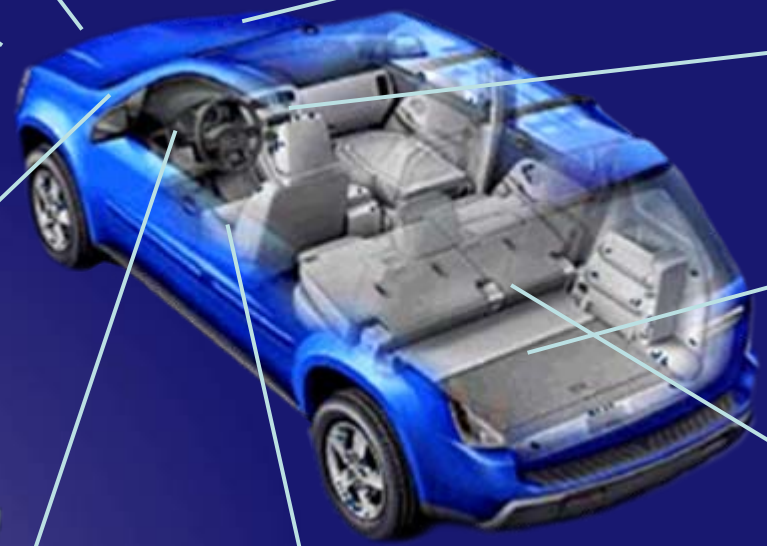
Front End Structures

Transmission Case

Cam Covers

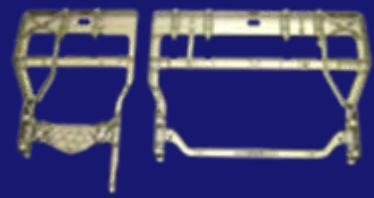
Transfer Case

Center Console



Engine Cradle

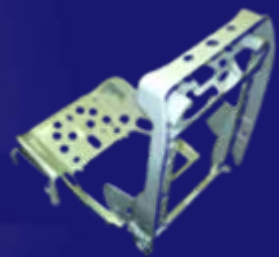
3rd Row Seat Frames



Instrument Panel

Header Bow

Bucket Seat Frames



Steering Column Brackets

Magnesium Elektron

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Magnesium Elektron

Magnesium Die Castings Alloys

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

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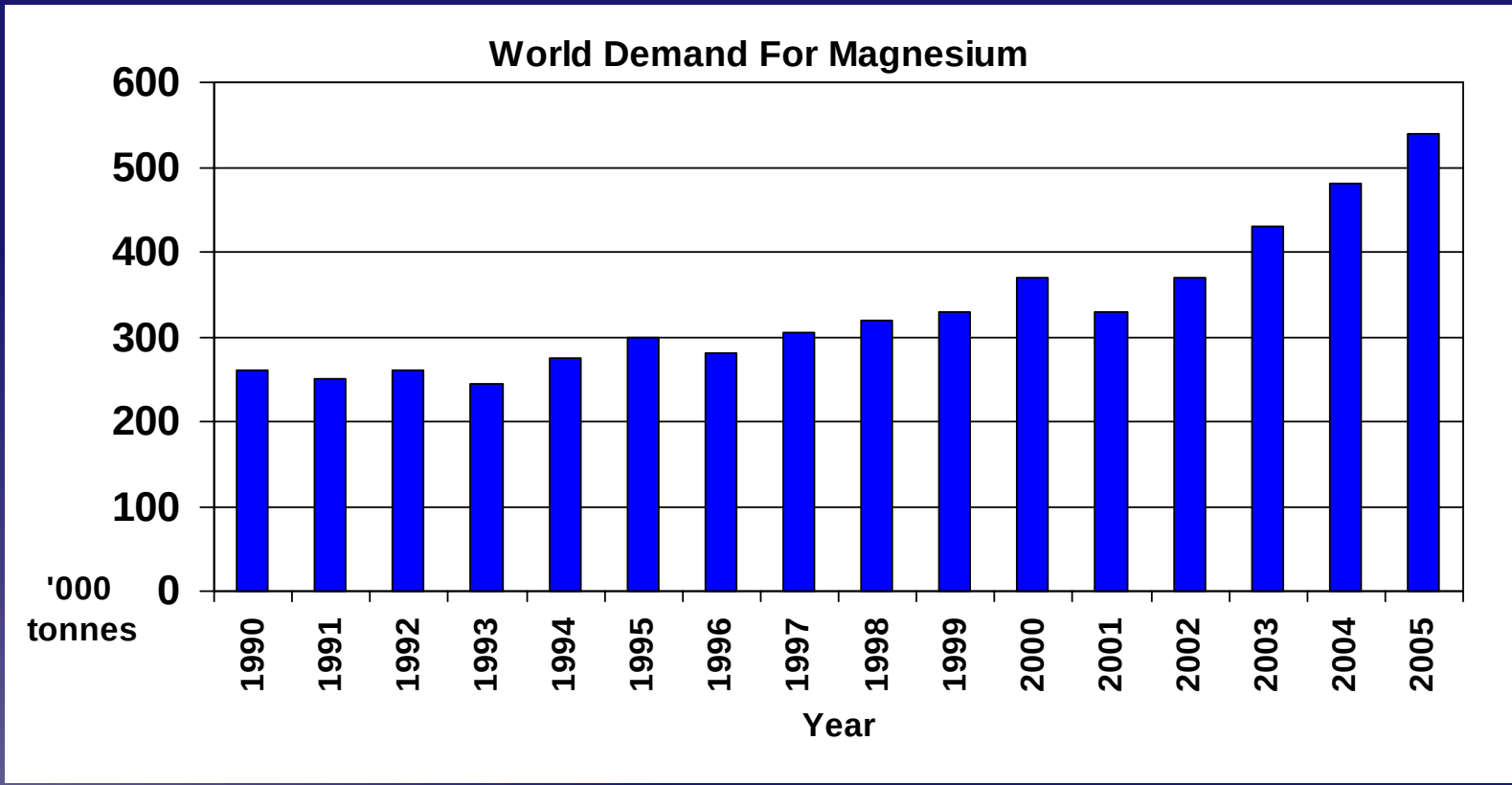
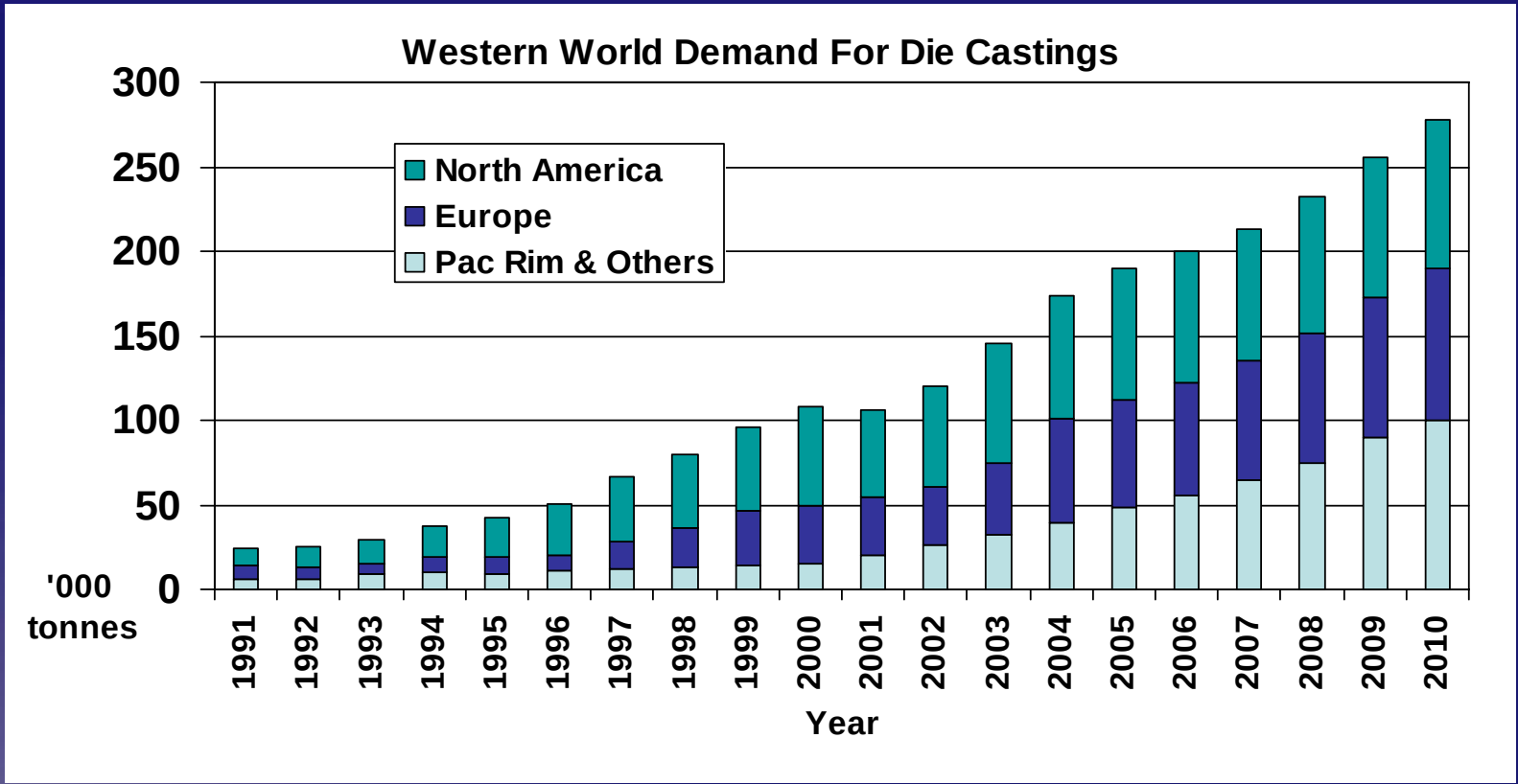
Magnesium Industry Growth

WORLD DEMAND FOR MAGNESIUM



Gain of 280,000 metric tonnes of magnesium (>600m lbs) since early 1990's

FORECAST GROWTH IN AUTOMOTIVE



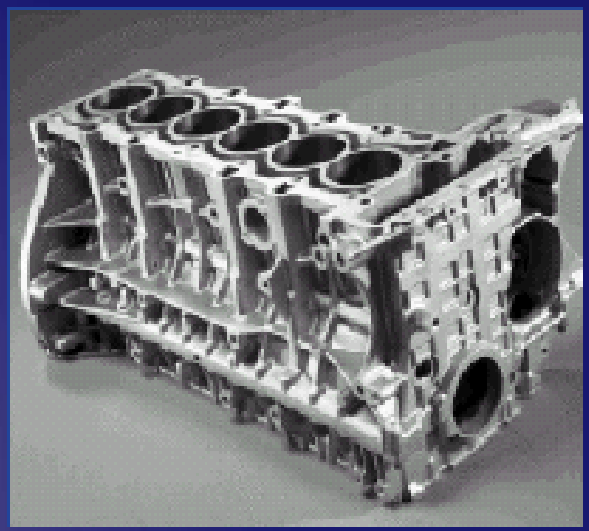
- 85% of all die castings manufactured are used for automotive components.

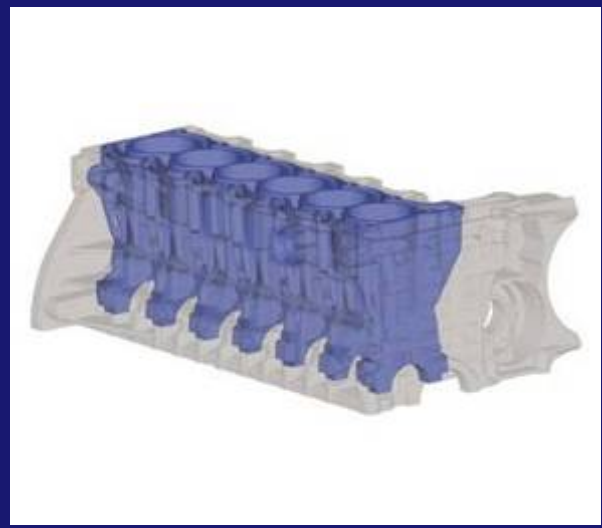
Automotive Trends

Elektron AJ62

The Ultimate Driving Machine

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





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Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

- Magnesium Alloys
- Corrosion Resistant Alloys
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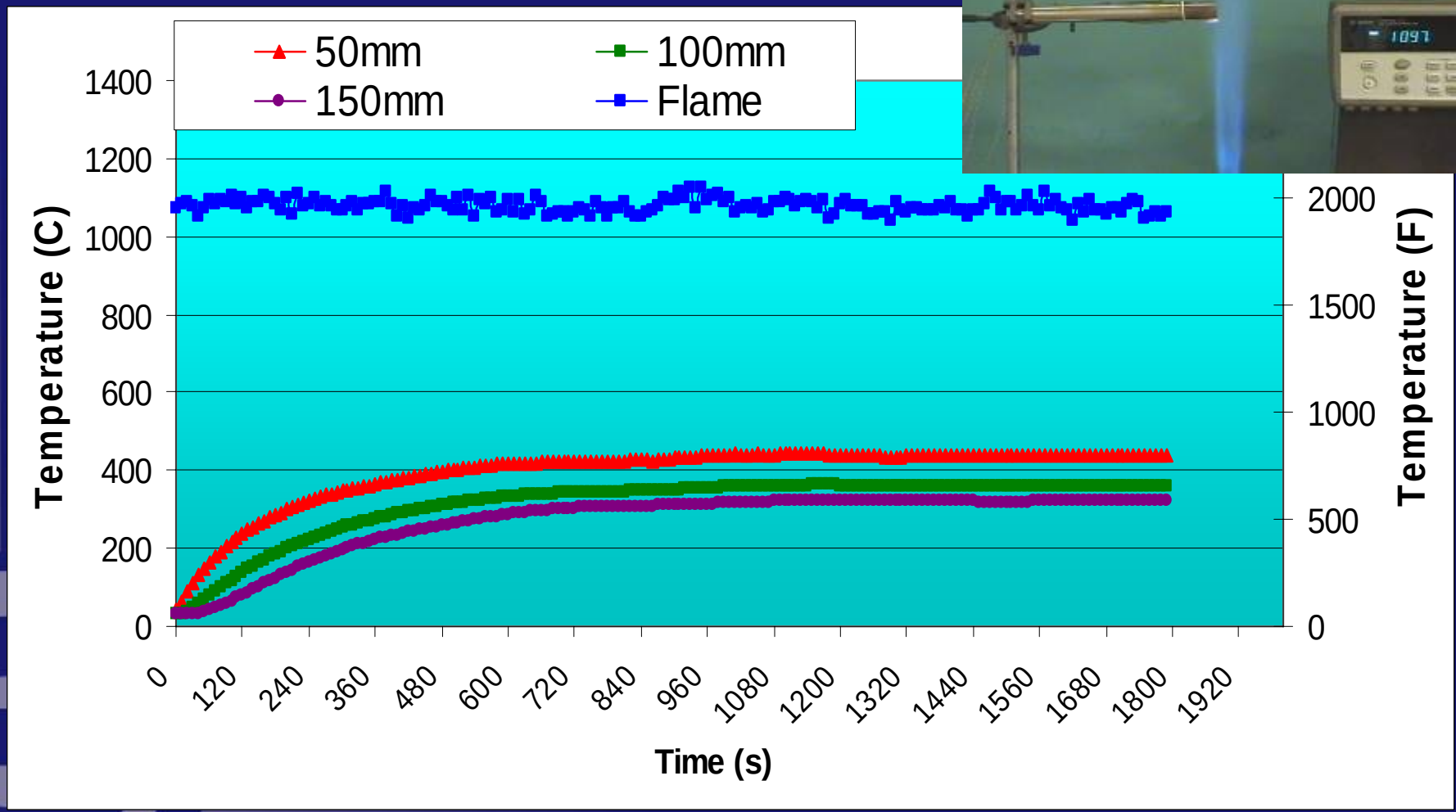
How To Start A fire !

FACTS

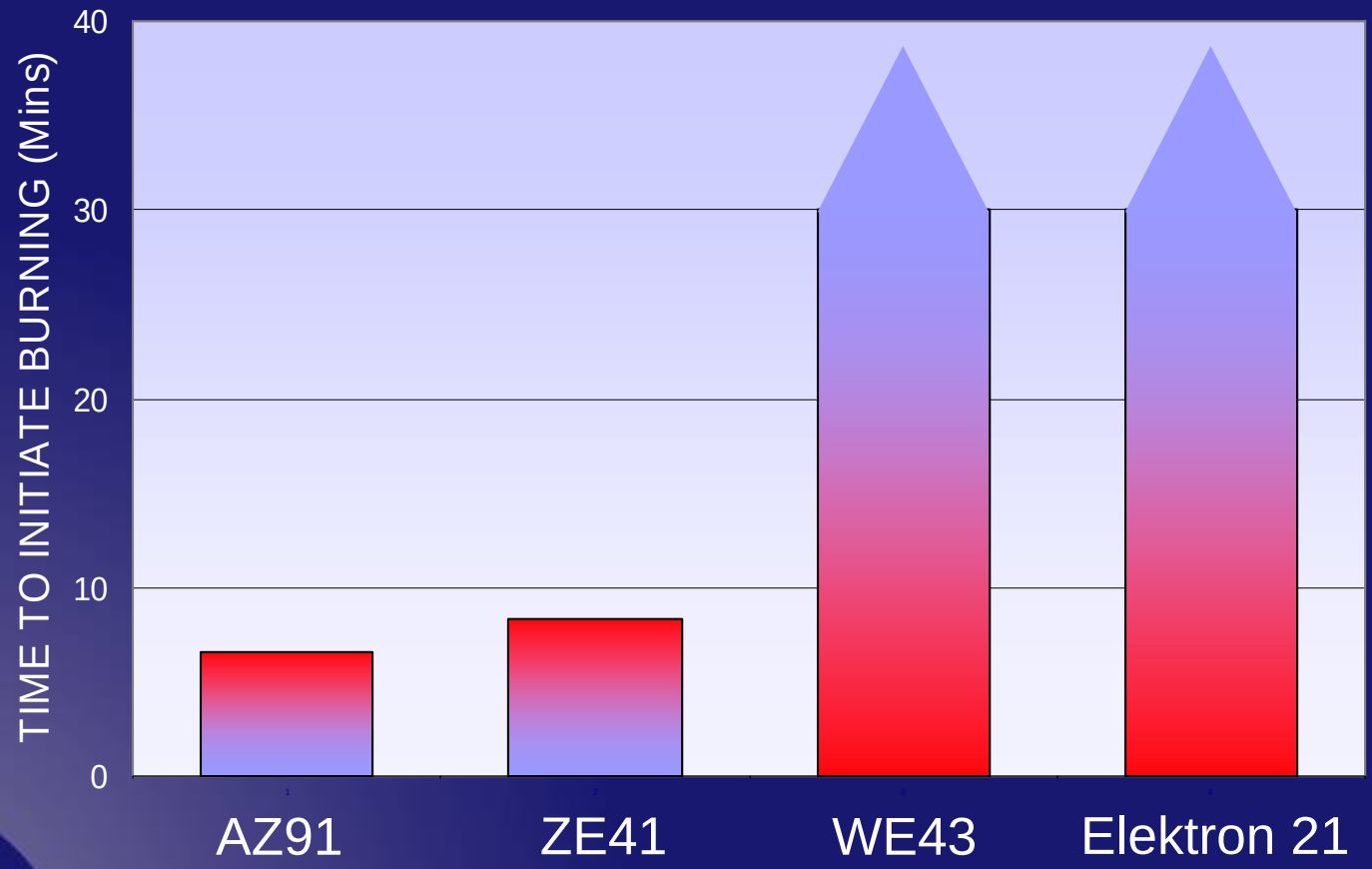
- Must Reach Melting Point
  - (Pure Magnesium = 1200^0F 650^0C)
- Must Sustain Heat Source
  - to overcome conductivity
- Must Have Oxygen
- Solid magnesium is not easy to burn

- *Magnesium powders can be designed & used in flares*
- *Aluminium powder is used in propulsion systems …*

1900^{0}F (1000^{0}C$^+$) Flame test – Elektron 21



Time to Ignition with 1900^{0}F (1000^{0}C$^+$)Flame



Magnesium Elektron
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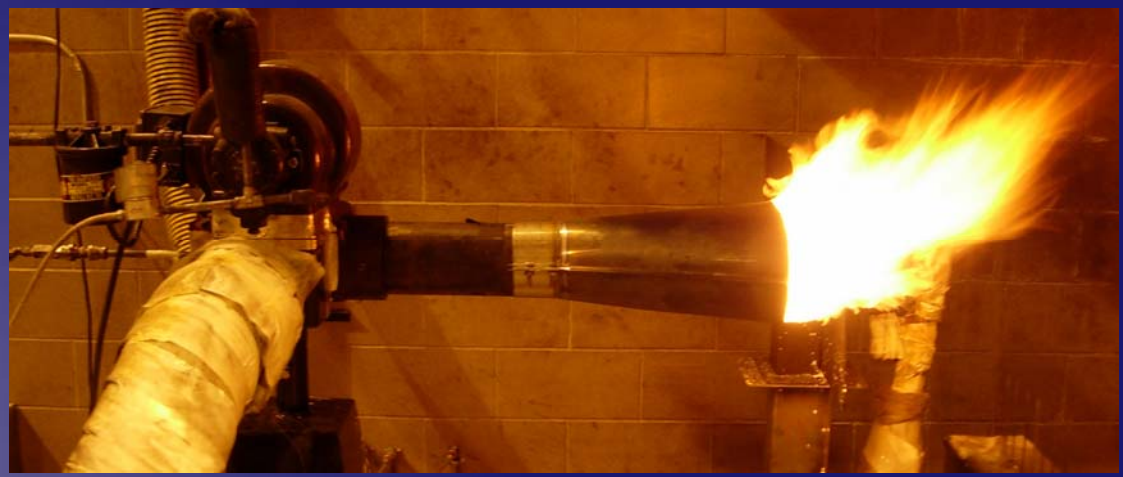
FAATC Tests - Preliminary Mg Burning Characteristics

- 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



Magnesium Elektron
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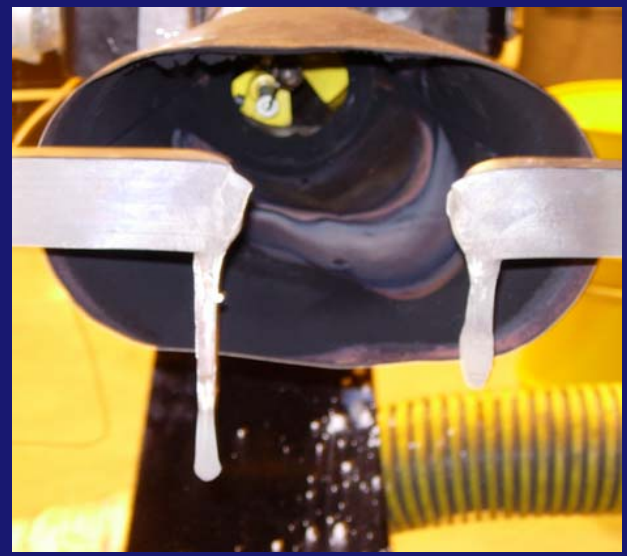
FAA Test data - FAR 25.853 Part 25, Appendix F, Part 2

Modified Seat Cushion Test

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

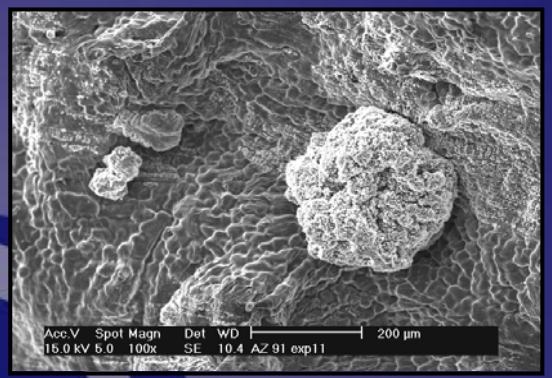
Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

Behaviour of Elektron WE43 versus AZ91*

AZ91

T ignition = 1075^0F

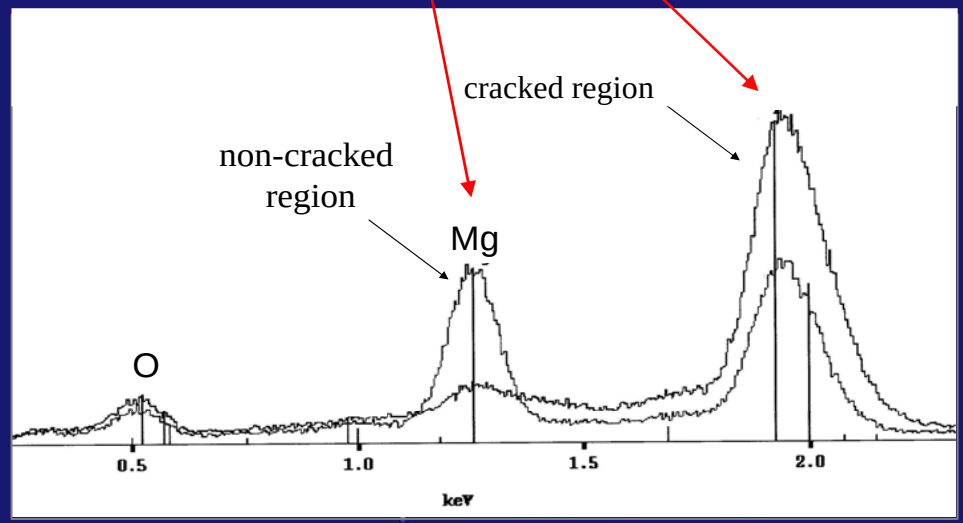


* Courtesy EADS/Grenoble University

Elektron WE43

regular surface with appearance of cracks with oxides therein

T ignition = >1275^0F

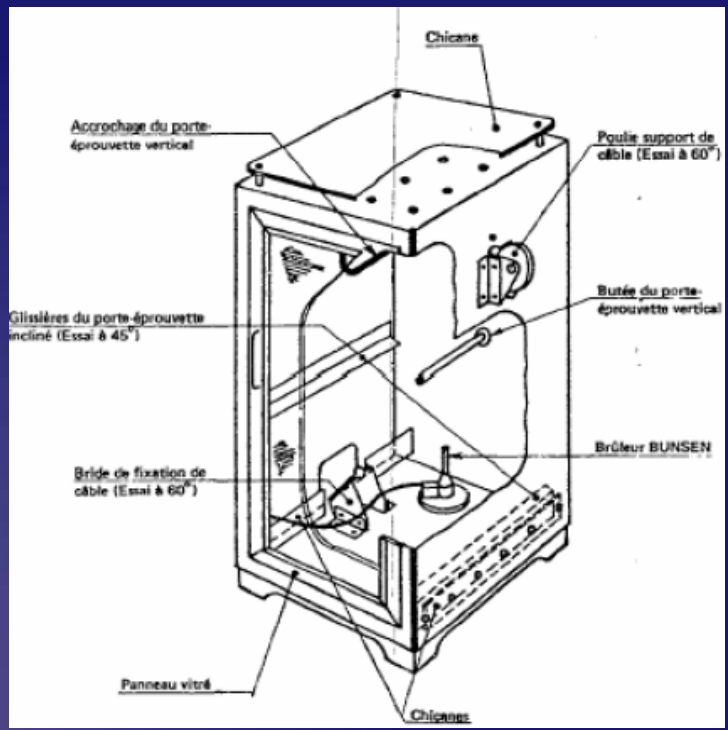


EDX analysis

Airbus Commissioned FAA Flammability Tests

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



Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

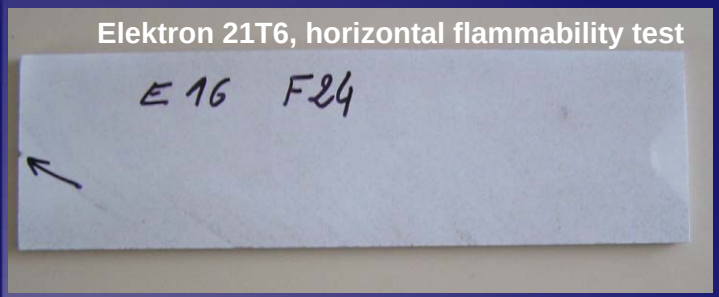
Airbus Commissioned FAA Flammability Tests

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.



Elektron 21T6, horizontal flammability test


WE43T6, vertical flammability test

All tests passed

Magnesium Elektron
SERVICE & INNOVATION IN MAGNESIUM

- Magnesium Alloys
- Corrosion Resistant Alloys
- Current Aircraft Applications
- EFV
- Automotive Growth
- Flammability
- Conclusions

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

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- **One Last Thing**

Airbus Internal Regulation Change

Airbus are evaluating Elektron 21 and Elektron WE43, both in investment cast and sand cast form, for use on their commercial aircraft.

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These alloys are no longer banned on the A380 (except for the primary structure).

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The End

Thank you for your attention