The Influence of Disruptive Innovation on Today's Aluminum Products

Product - Alloy - Process

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Disruptive Technology
– a look back

- Which developments had the greatest impact on the shape of the industry after 100 years?
- Aluminum mill products only
  – Ignored refining, smelting developments
- What other innovations were spun off as a result of these developments?

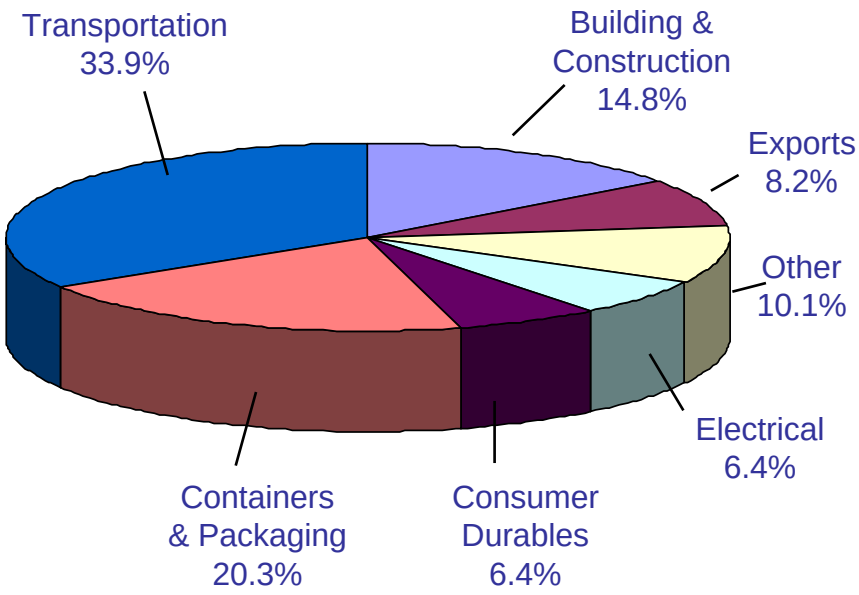
The Panel – An Alcoa Perspective

- Harold Hunsicker, 1936-1979
- John Hatch, 1940-1973
- Ron Bachowski, 1959-1996
- Paul Lyle, 1952-1985
- John Jacoby, 1955-1994
- special assistance from
  - Don Stewart, Jim Staley, Dave Smucker

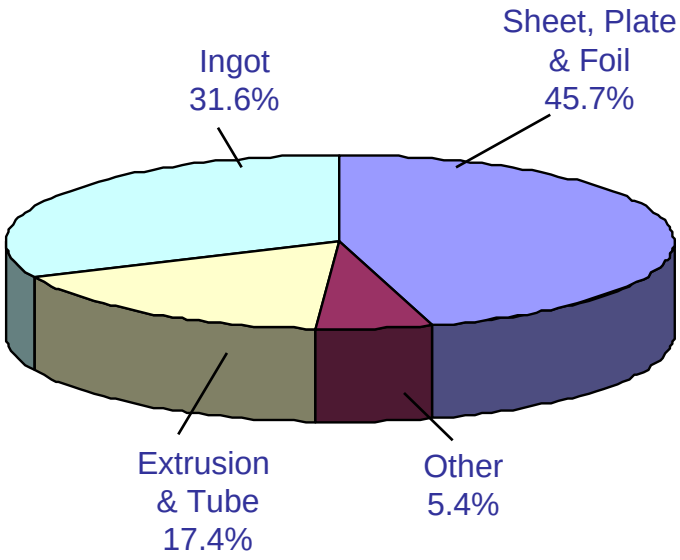
Aluminum Shipments by Major Market (2004 A. A. Statistical Review)

United States and Canada

Major Market

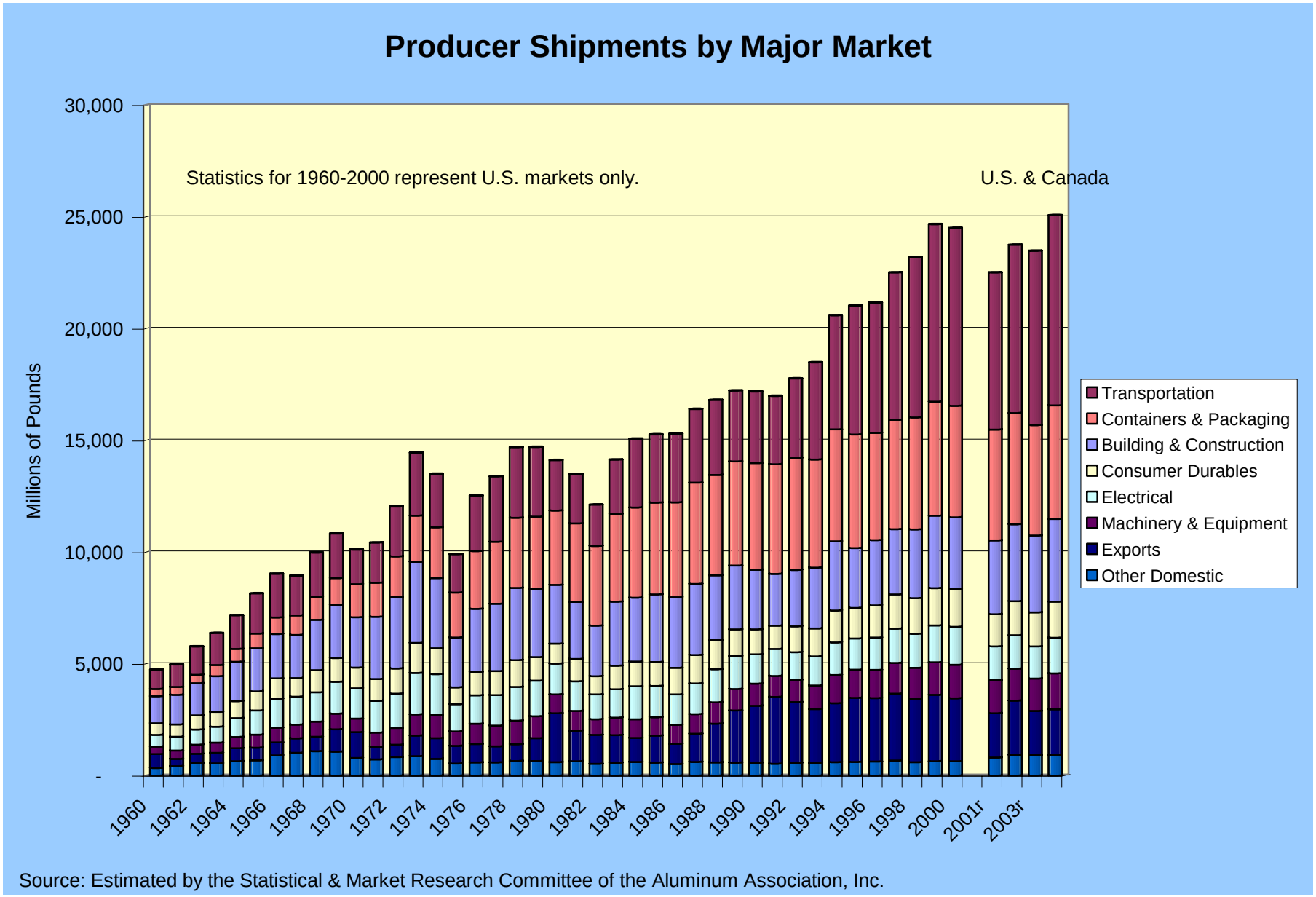


Product Form



11,372 M tonnes (25.1 billion lbs)

North American Al Shipments AA Data - 2004



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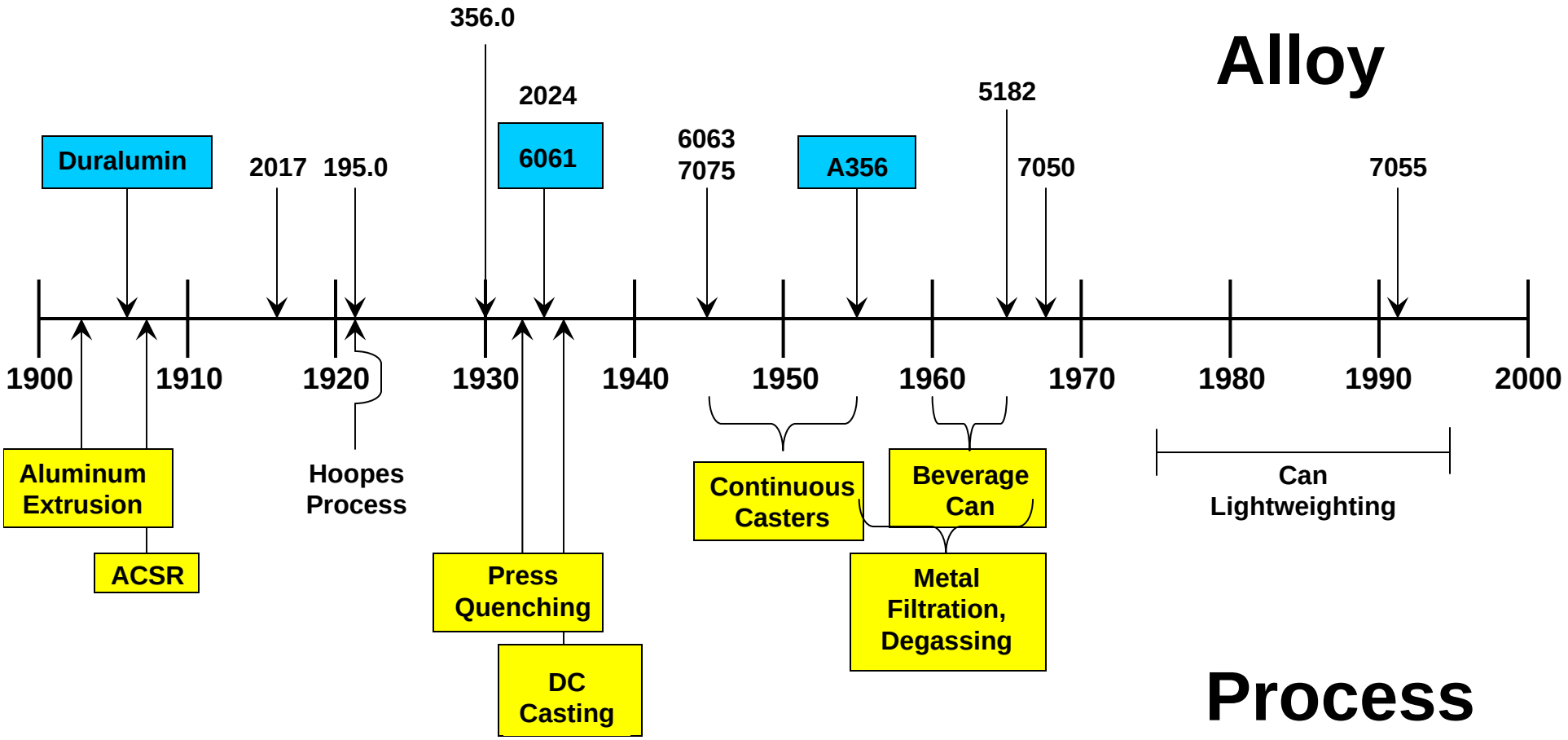
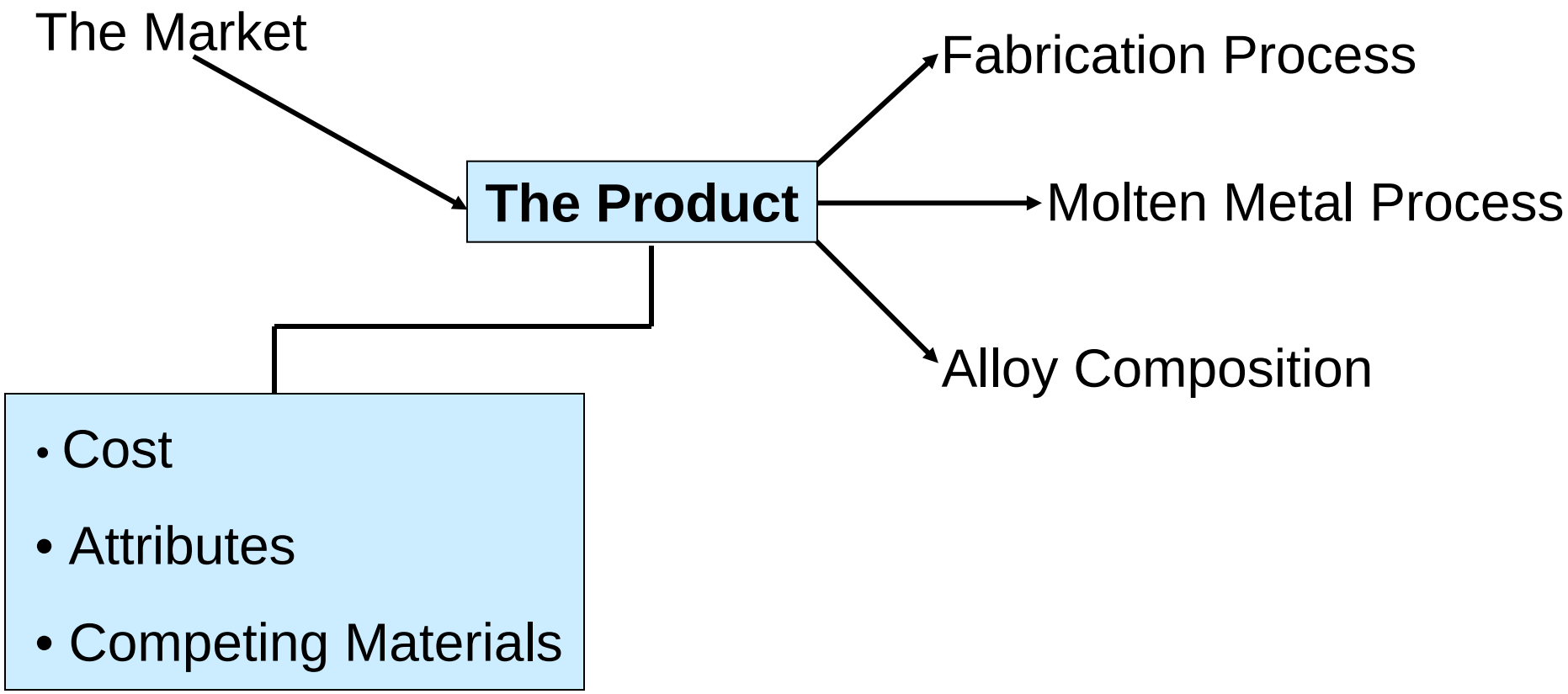
20th Century "Top 10"

1.	DC Casting	Alcoa, 1930's
2.	Discovery of Age Hardening	Germany, 1908
3.	Two-Piece Beverage Can	Reynolds, Coors
4.	Aluminum Extrusion Process	Alcoa, 1905
5.	Continuous Molten Metal Treatment	Alcoa, 1950's
6.	Alloy 6061	Alcoa, 1930's
7.	Electrical Conductors	Alcoa, 1908
8.	Continuous Casting	Hunter, Properzi, Hazelett
9.	Shape Casting Alloy (A356)	Alcoa, 1960's
10.	Extrusion Press Quenching	Alcoa, 1930's

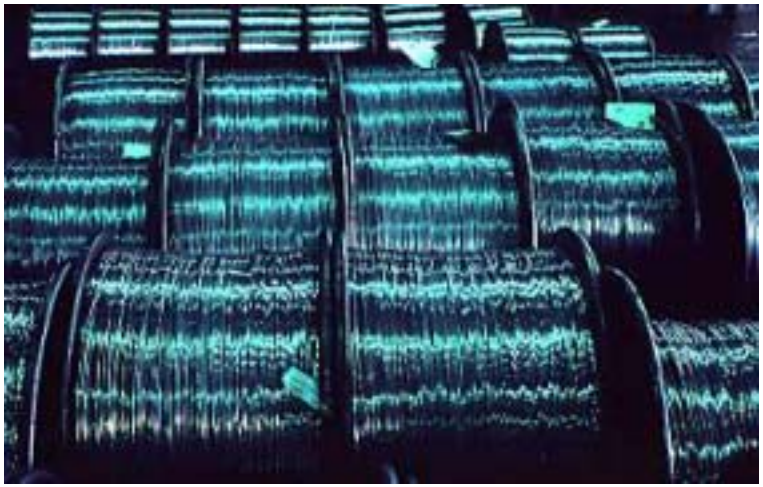
Timeline for Aluminum Product Development



Market Needs Drove Innovation
Everything else flows from there



Electrical Conductors: 1908



2004 Production in North America
~350,000 Tonnes

Market Needs

- Lighter and cheaper conductor vs copper

Direct benefit

- First high volume application for aluminum

Side benefits

- Economical fab methods
- Quality control established
- Hoopes process for high purity

Discovery of Age Hardening: 1908

Market Needs

Stronger product (they didn't know what other properties they needed).

Direct Benefits

First applications of Aluminum to aircraft – arguably made possible today's aircraft industry.

Spin Offs

Began a continuous series of alloy improvements – 2xxx, then 6xxx, then 7xxx alloys with more desirable (and targeted) properties for specific aerospace (and other) applications.

Age-Hardened Alloy Development

Alloy and Year of Registration

6xxx

- 6151 - 1928
- 6061 - 1933
- 6063 - 1944
- 6351 - 1958
- 6262 - 1960
- 6005 - 1962
- 6060 - 1972
- 6082 - 1972

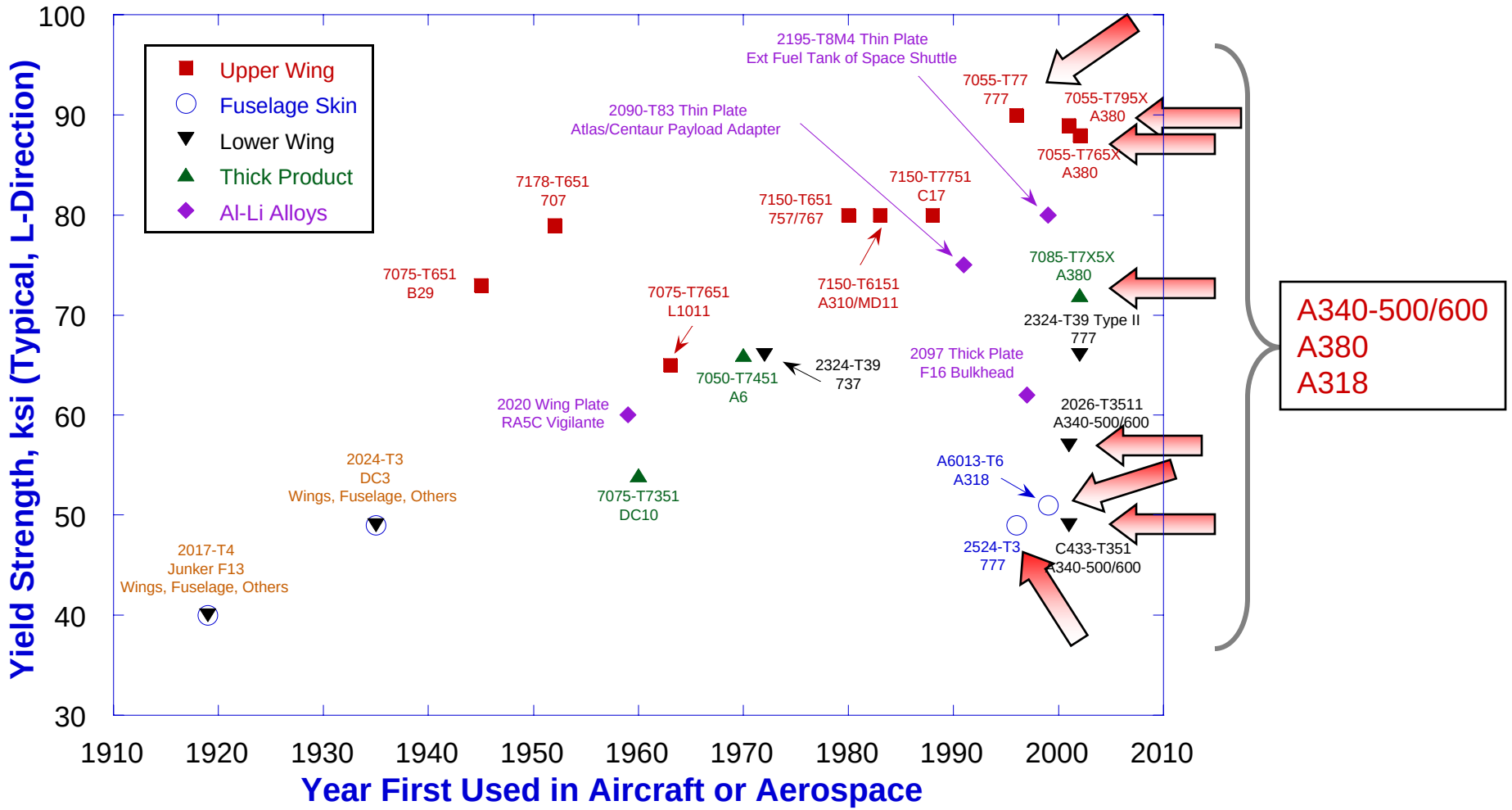
2xxx

- 2017 - 1916
- 2014 - 1928
- 2024 - 1932
- 2011 - 1934
- 2219 - 1954
- 2124 - 1970
- 2324 - 1978
- 2524 - 1995

7xxx

- 7075 - 1943
- 7178 - 1950
- 7475 - 1969
- 7039 - 1962
- 7050 - 1971
- 7150 - 1978
- 7055 - 1991
- 7085 - 2002

Aerospace Alloys –
Strength Vs. Year First Introduced



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High-Strength 7xxx Alloys

Alloys 7150, 7085 Aircraft (Upper Wings)

Alloys 7175/7050/7085 Forgings

Alloys 7050/7055 Sports Equipment

Alloys 7150/7055 Extrusions

Direct Chill (DC) Casting: *1935*

Market Needs

Larger aluminum wrought products: sheet, plate, extrusions

Direct Benefits

Bigger coils and parts
Higher recovery
Better ingot quality

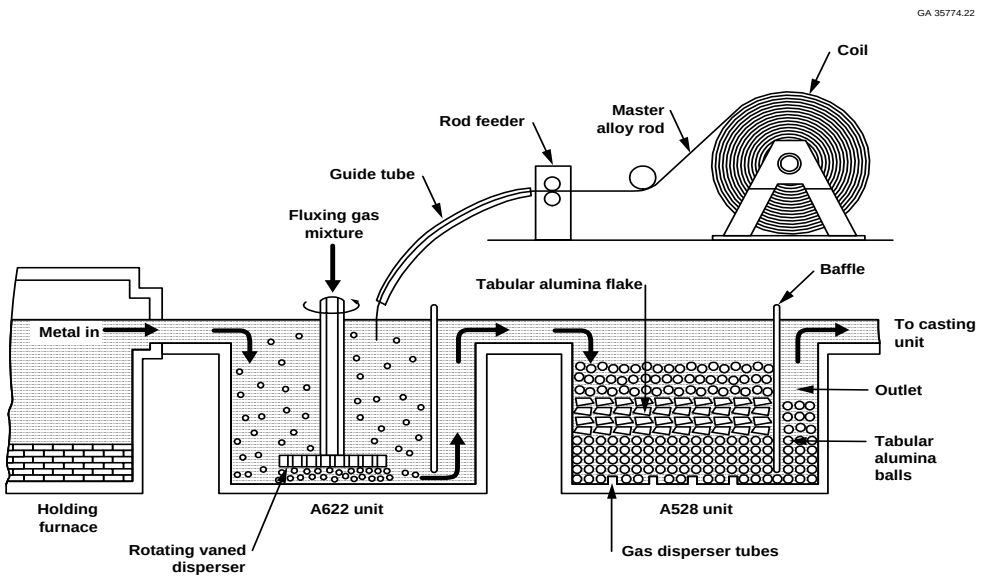
Spin Offs

Higher performance (fatigue, ductility)
New alloy compositions (5xxx, 7xxx)

Continuous Molten Metal Treatment:

1950's-1960's

De-gassing and Filtration



<u>Market Needs</u>

Better **quality**
wrought products
sheet, plate, extrusions

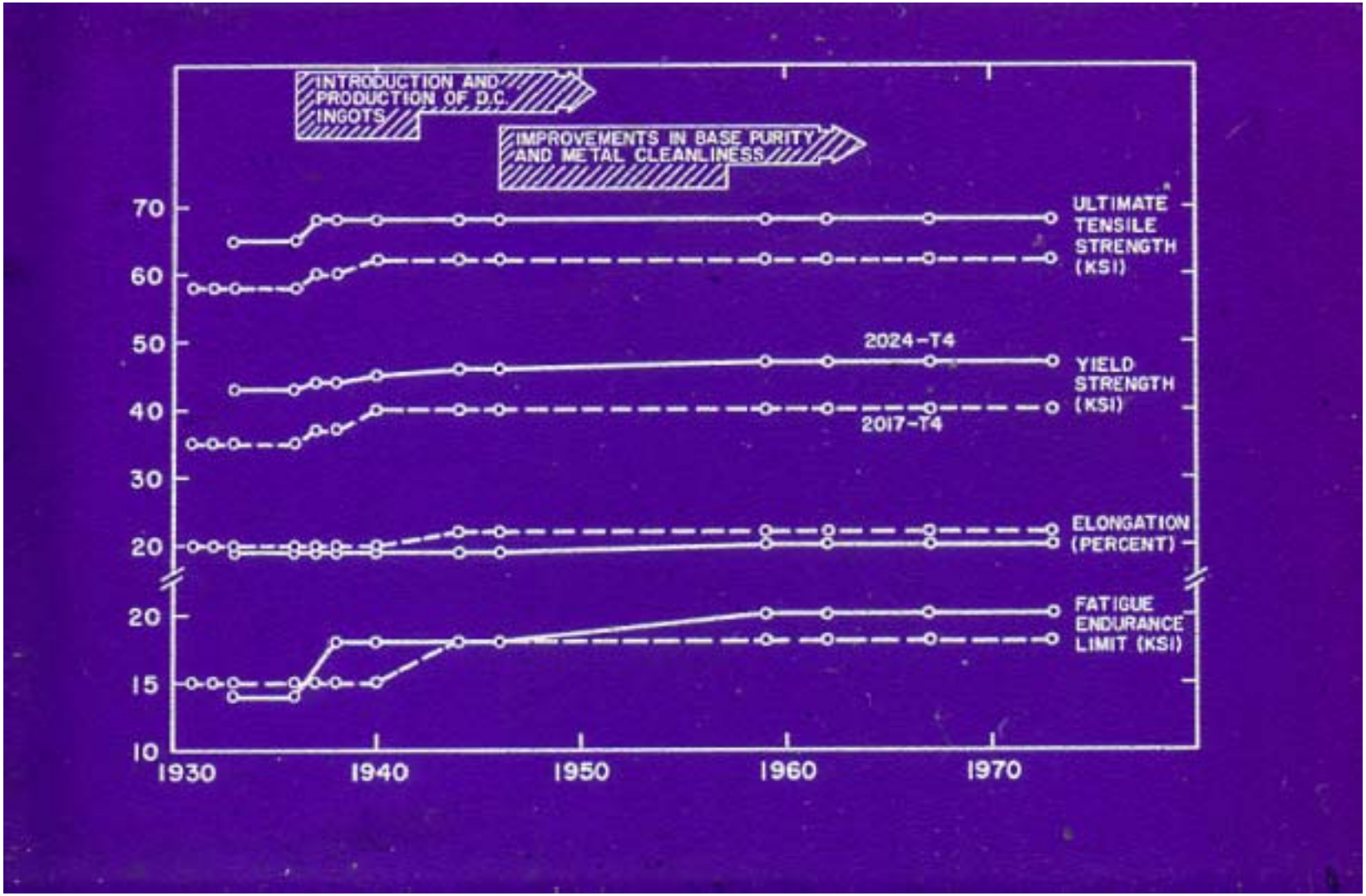
<u>Direct Benefits</u>

Higher performance
(fatigue, ductility)
Wire, can sheet, aerospace, LNG
Better fabricability, recovery

<u>Spin Offs</u>

Larger ingot
In-line grain refining
(better castability)
Higher solute alloys

Property Improvements due to Casting and Metal Treatment



Two Piece Beverage Can: 1960's

40% of North American market for FRP

Market Needs

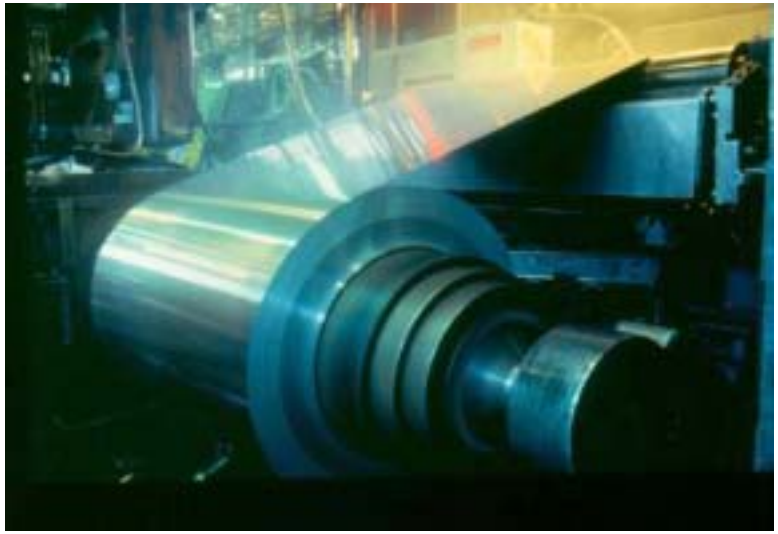
- Low cost, user friendly beverage container
- Easy opening, quick chill
- No effect on flavor
- Manufactured by high-speed processes

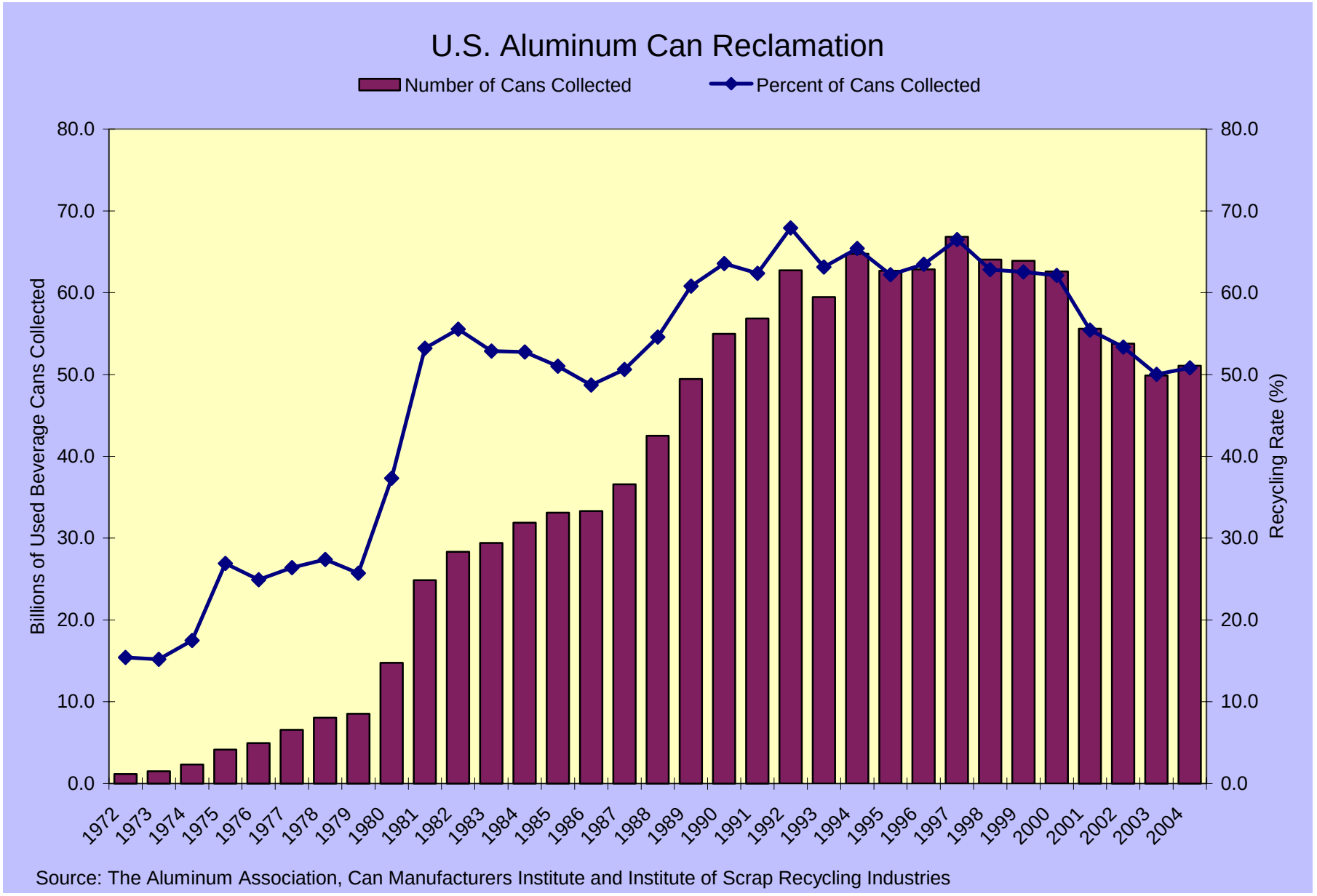
Direct Benefits

- 200 billion can/year market
- Largest single market for aluminum

Spin Off Benefits from RCS Technology

- Rolling Technology
  - Multi-stand mills
  - Gauge control systems
  - Lubrication
- New Alloys
- Draw and Iron Technology
- Recycling Technology
  - Delacquering and melting





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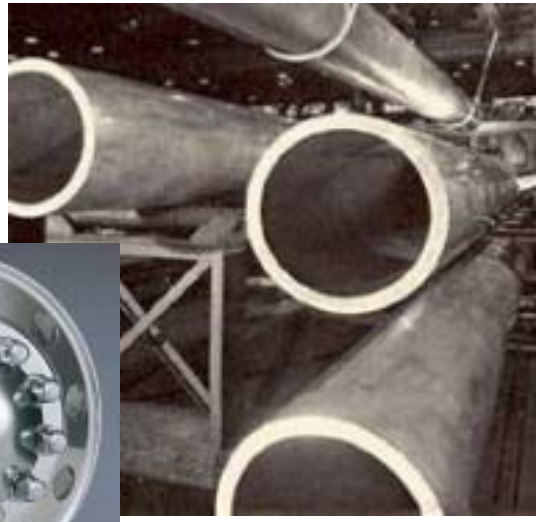
Alloy 6061: 1933

Market Needs

- Al product with mech. properties = mild steel
- Weldable
- Corrosion resistant
- Good finishing

Process Requirements

- Robust alloy: Rolled, forged, extruded at low pressures
- Can be quenched slowly

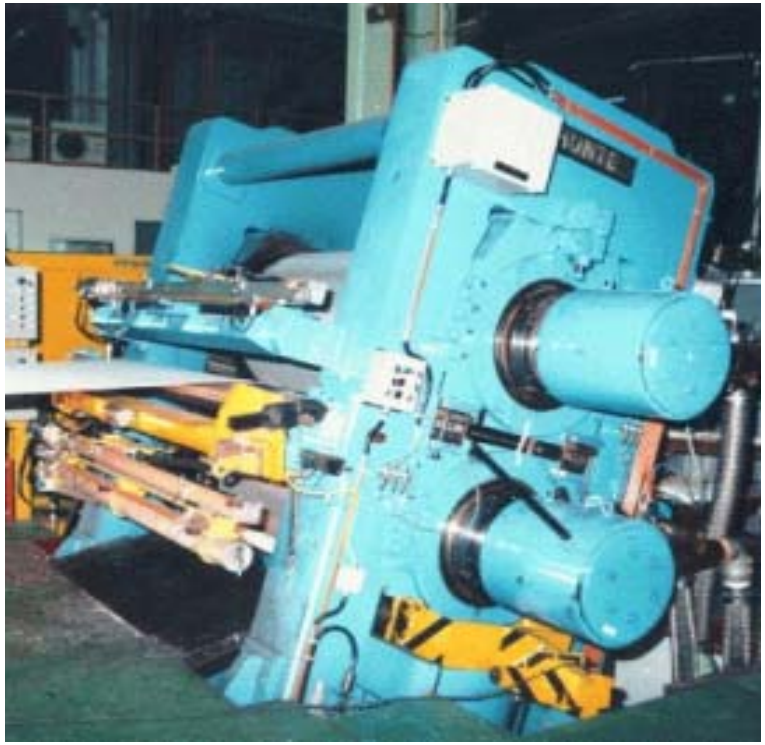


Continuous Casting: 1940's-1950's

25% of US FRP is continuously cast

<u>Market Needs</u>

- Reduce cost of commodity products



<u>Direct Benefits/Side Effects</u>

Low capital

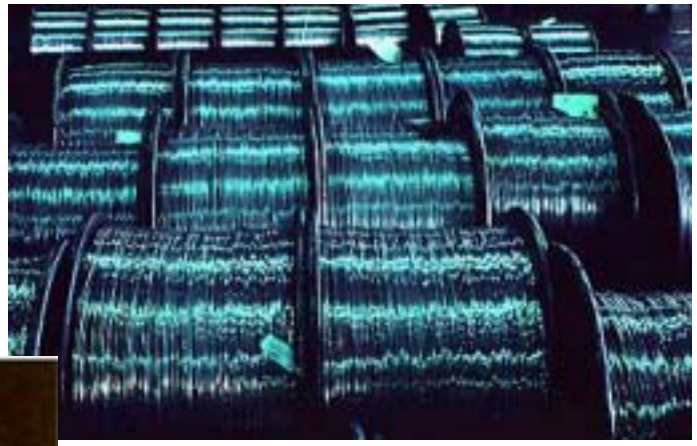
- More producers can compete

Lower conversion costs

- Cost sensitive products have moved to continuous casters
- Foil, wire, building products

Continuous Cast Product Examples

Lidding



Wire

Impact Extrusions

Fin stock

Formed containers

Structural Castings

A356 patented in 1960's

Market Needs

Low cost structural products – early castings had low ductility and fatigue resistance

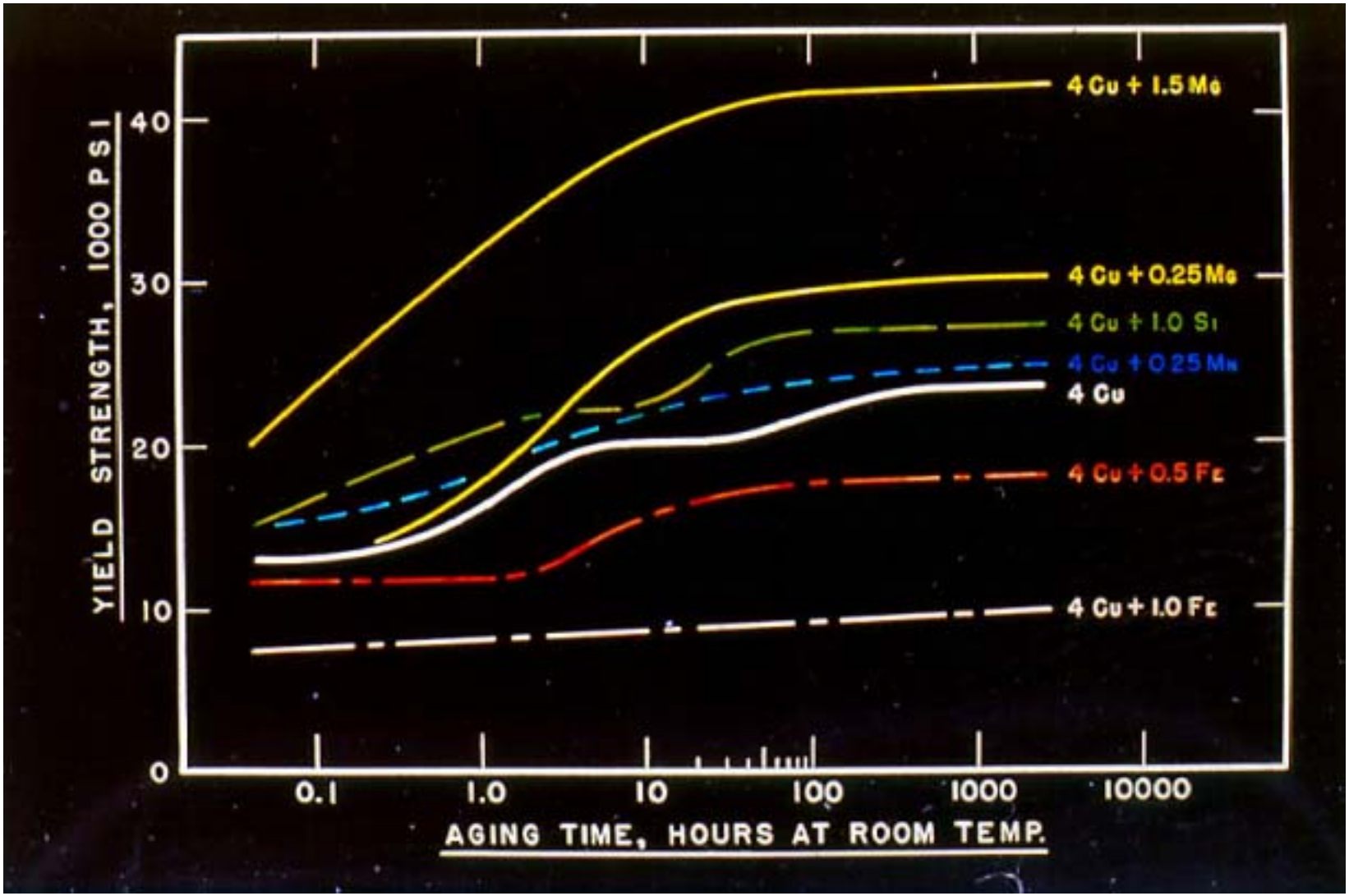
Direct Benefits

Improved mechanical properties opened markets for aluminum wheels and other structural components

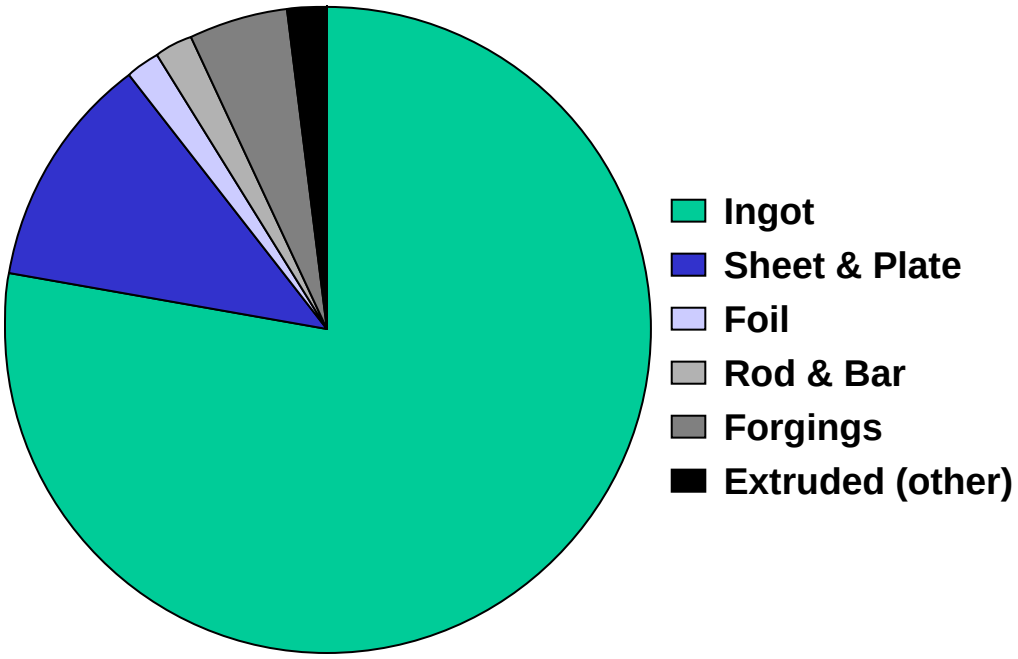
Spin Offs

- New casting technologies
- Higher solute alloys

Influence of Metal Purity on Alloy Properties – circa 1937



Automotive Usage of Aluminum Cast and Wrought Products: 2.56 Million MT

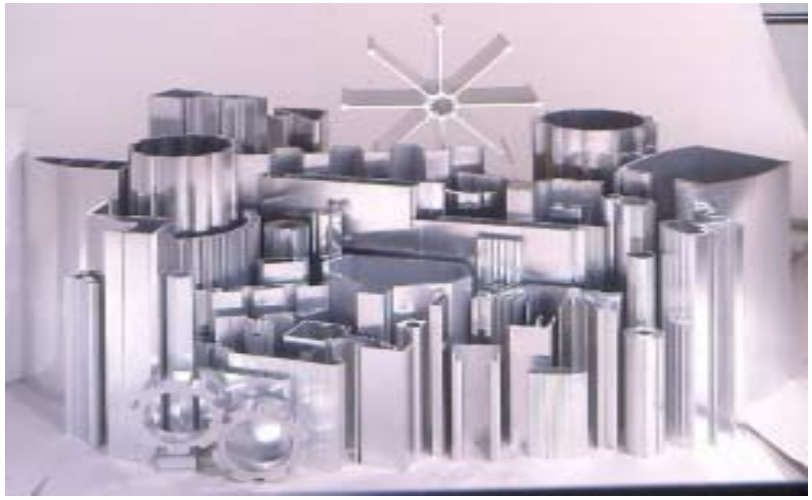


2.00 Million MT of Castings

- Auto total 5,655 B lbs
- Ingot 4,400
- Sheet and Plate 655
- Foil 104
- Rod & Bar 96
- Forgings 103
- Extruded (other) 297

Extrusion Press Quenching

6063 patented in 1940's



Market Needs

Low cost shaped product to construct windows, doors for post-WW2 building boom.

Direct Benefits

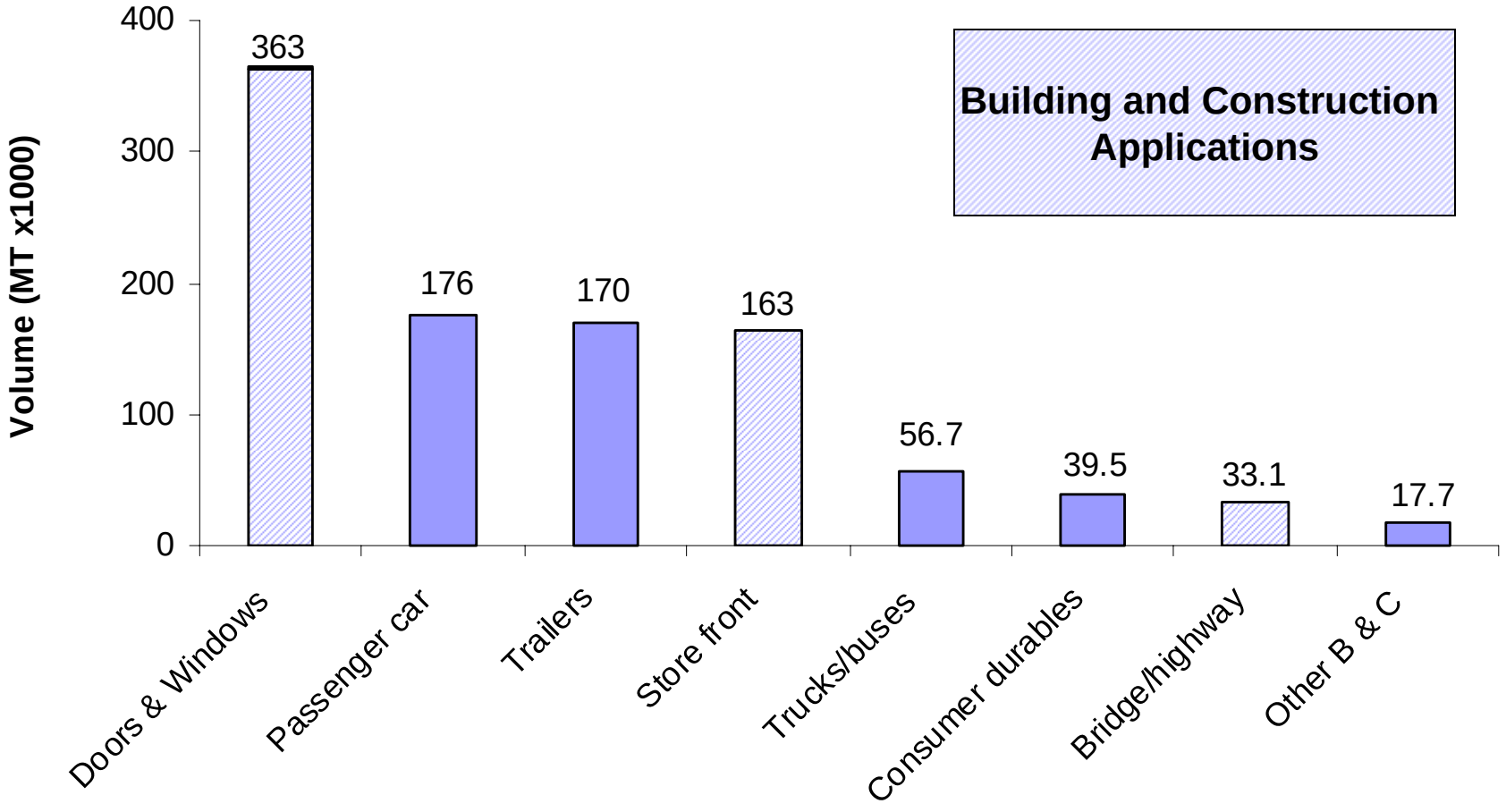
Opened markets for aluminum extruded shapes to compete in building product market. (by far largest market for extrusions.)

Spin-offs/Process Impacts

- Developed specific 6xxx alloys to optimize speed and properties w/o HT
- Allows low capital entry into the market.

Extrusion Usage By Market

2004 Aluminum Association Data



Summary

- Today's market for aluminum products was shaped by disruptive process innovations during the 20th century
  - DC casting and melting treatment allowed for improved quality, bigger parts and new alloys to be produced.
  - Continuous casting and extrusion press quenching enabled aluminum to be competitive with other materials.
- Age hardening Al alloys were a key factor in the development of today's modern aircraft. Alloy development based on the precipitation hardening concept continues to the present time.
- The 2-piece beverage can grew into aluminum's largest market and greatly influenced rolling and recycling technologies.
- The use of aluminum for EC applications highlighted the need for quality control and consistency in composition and properties.
- The development of robust alloys (A356, 6061) was crucial in establishing aluminum's role in structural applications.

Implications for Future Product Innovation
What is the next aluminum can?

- In any large volume market, aluminum will compete with steel, plastic or wood
  - Low cost is key - drives alloy and process choices
  - Exploit functionality of product forms
  - Look for light weight and durability advantages
- Processes to reduce the cost of base metal will help our competitive position vs other materials
- Understand the real needs of the customer:
  - Understand his value proposition
  - Exploit forming, joining, finishing savings
  - Look at total life cycle including recycling

Implications for Alloy Development

- Where material cost is not the driver, exotic (and profitable) alloy and processes are viable…. properties which reduce customer's cost or greatly improve performance must justify the price.
  - Aircraft, space, sports equipment
  - Composite materials which combine Al properties with other materials
- For commodity markets (transportation), alloys will become more standardized and competition will be based on process consistency
- It may be hard to recognize a breakthrough until years after it happens….Lessons learned from MMC, powder metallurgy, Al-Lithium

Implications for Process Development

- Low cost traditional processes
  - Extend continuous casting to higher solute alloys, higher performance products
  - Eliminate unneeded processes via better process control (Anneals, SHT, side trims, cleaning)
- Low cost manufacture of composite materials
  - Combine Al with other materials to improve functionality (Forming, service temperature, specialized corrosion characteristics, wear, ….?)