Aluminum Extrusions

Designing
to the limits
of your imagination!

Brought to you by:

Aluminum Extruders Council

www.aec.org

ET Foundation

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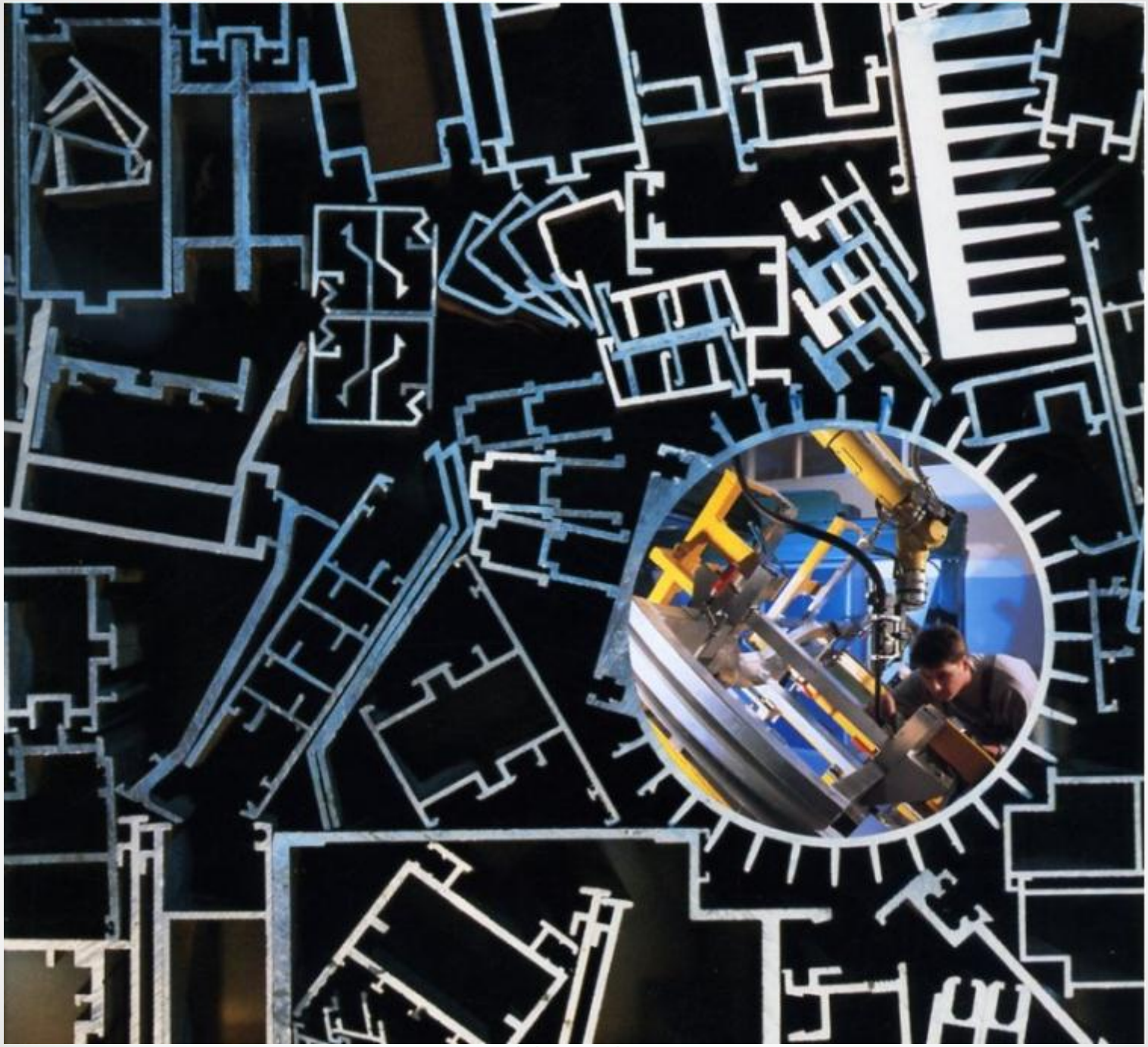
ALUMINUM

ALUMINUM EXTRUDERS COUNCIL

ET Foundation

Revised November 8, 2014



Courtesy of *Light Metal Age* magazine

Extrusion: often the most cost effective and quickest path between concept and product

- The aluminum extrusion process is incredibly versatile and capable of converting ideas to reality quickly, accurately and inexpensively

- Designers can utilize a near-net shape process to close tolerances, coupled with a list of superior physical characteristics to optimize their designs

This presentation provides both a conceptual and a practical understanding of how best to design with aluminum extrusions

Extrusion: often the quickest path between concept and product

- Aluminum extrusions offer a long list of advantages – both those inherent in aluminum as well as those gained from the extrusion process
- Combining aluminum and the extrusion process: yields results which are second-to-none regarding form, fit, function, appearance and cost, producing amazing, attractive parts and advantages
- Aluminum extrusions are green, providing strong, lightweight designs which are fully recylable

Example of Aluminum Extrusions used in Nevada Solar One Concentrated Solar Power Plant

Aluminum Extrusions are strong and efficient; creating long lasting structures, critical to our future

Photos By Gossamer Space Frames. Used By Permission of Acciona Solar Power

Aluminum Extrusion Design Competition

www.etfoundation.org

www.aec.org

Design, Architect, and Engineering Students:

Apply what you've learned about design and engineering by entering the International Aluminum Extrusion Design Competition. It's an excellent opportunity for a hands-on learning experience with the potential for professional recognition and earned scholarships.

Student Class Scholarship Awards

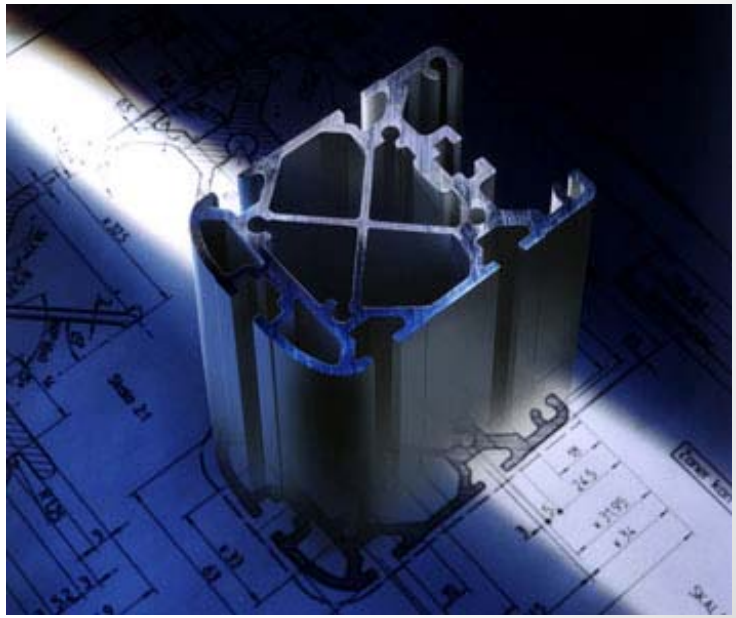
Enter the competition to receive the recognition you so richly deserve; gain pride and a sense of accomplishment. And, of course, there are the scholarships totaling **$8,500!**

Student Class Scholarships:	
1st place	$3000
2nd place	$2000
3rd place	$1000
Sapa Sustainable Design:	**$2,500**

Entry Deadline: March 30, 2015

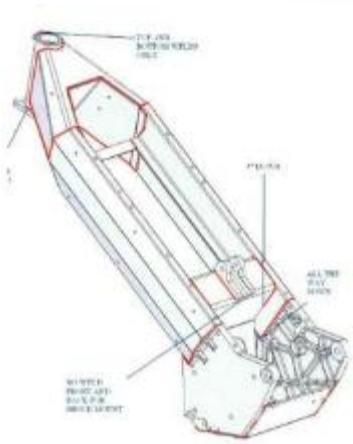
Ideas taking shape

- An idea takes shape in the designer's mind and then takes shape as a final product
- Through the flexibility of the aluminum extrusion process, profiles can be creatively fine-tuned to specifically fit the design requirements or to be specifically branded with your details
- All thanks to the amazing versatility of aluminum extrusion



The Shape is the Idea

- Almost any shape can be produced through aluminum extrusion
- The highly workable material can create a shape that can then be enhanced and perfected through additional machining, finishing and fabrication

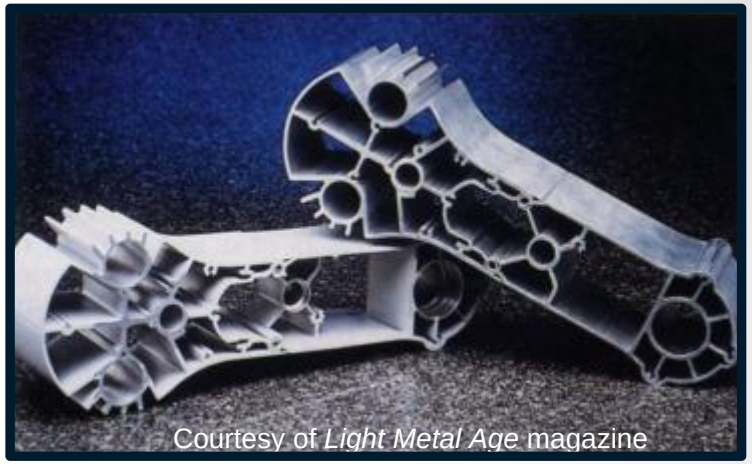


2008 Transportation Category Winner

Electric motorcycle frame

The Shape becomes more than an end in itself

- The Shape can be designed and extruded to be more than the base for a useful product.



- It can be formed to:
  - Reduce piece count / provide complex integral features
  - Facilitate manufacturing and assembly
  - Reduce costs and lead times for materials and production
  - Increase product reliability and durability
  - Simplify maintenance and repairs for the final user of the product
  - “Build in” an attractive appearance that can make the product easier to sell

Consider the Advantages:

- From simple household appliances to exotic space and electronics applications, products made from aluminum extrusions are superior in:
  - Design Flexibility
  - Performance
  - Efficiency
  - Reliability
  - Cost

Photo courtesy of NASA

Aluminum extrusions remain the best choice for many applications

- Advancing techniques in manufacturing and assembly can extend aluminum's use to even more applications, including those in which other materials have long been employed.

- The combination of the basic properties of aluminum and its alloys, plus the infinite variety of shapes possible in the extrusion process give aluminum extrusion its many advantages over other materials and methods of forming.

The aluminum extrusion process is flexible and has both extremely low tooling costs and short lead times, enabling efficient production of near net shape, complex integral parts – allowing exceptional reductions to part counts and subsequent fabrication and assembly

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient
- Corrosion-Resistant
- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
- Fully Recylcable

Courtesy of Werner Extruded Solutions LLC

Aluminum Extrusions can be produced in different *alloys* and processed to different *tempers* to achieve desired mechanical properties, corrosion resistance, machinability, formability and other attributes

Wrought Alloy Designation	Major Alloying Elements and Alloy Characteristics
1000 Series	Minimum 99% Aluminum High corrosion resistance. Excellent finishability. Easily joined by all methods. Low strength, poor machinability. Excellent workability. High electrical conductivity.
2000 Series	Copper High strength. Relatively low corrosion resistance. Excellent machinability. Heat treatable.
3000 Series	Manganese Low to medium strength. Good corrosion resistance. Poor machinability. Good workability.
4000 Series	Silicon Not available as extruded products
5000 Series	Magnesium Low to moderate strength. Excellent marine corrosion resistance. Very good weldability.
6000 Series	Magnesium & Silicon Most popular extrusion alloy class. Good strength. Good corrosion resistance. Good machinability. Good weldability. Good formability. Heat treatable.
7000 Series	Zinc Very high strength. Poor corrosion resistance. Good machinability. Heat treatable.

Typical Extrusion Tempers	Description
O	Fully annealed.
H112	Strain-hardened; used for nonheat-treatable alloys.
T1	Cooled from an elevated temperature and naturally aged.
T4	Solution heat-treated and naturally aged.
T5	Cooled from an elevated temperature and artificially aged.
T6	Solution heat-treated and artificially aged

Advantages of Aluminum

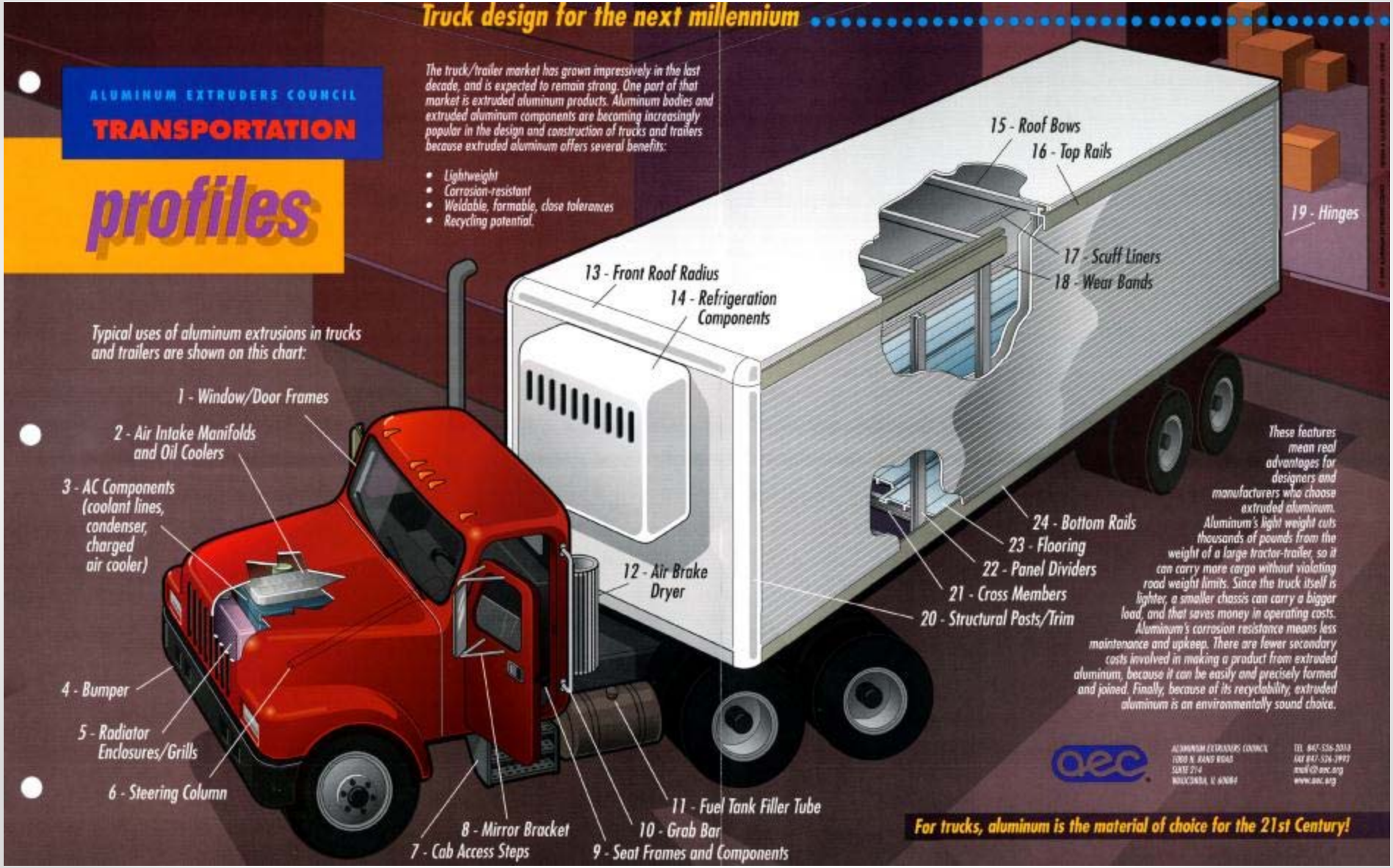
Lightweight

- Only about one-third as heavy as iron, steel, copper or brass. Thus, in applications where volume remains the same regardless of metal used, aluminum goes about three times as far as the other metals.

- Strong
- High Strength-to-Weight Ratio
- Resilient
- Corrosion-Resistant
- Heat Conductive
- Reflective
- Electrically Conducive
- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
- Fully Recyclable

Photo courtesy of Classic Trailers, Inc.

Strong, lightweight aluminum extrusions are used throughout the transportation market.



Advantages of Aluminum

- Lightweight

Strong

- Appropriately alloyed and treated, aluminum can be stronger than some steels, with ultimate tensile strengths as high as 80,000 psi to 90,000 psi or more.

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Courtesy of Werner Co.

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The modulus of elasticity (E) is the relationship of how the material deforms compared to the stress that it is under.

Material	Modulus (E) (10^6 psi)
Mild Steel	29.0
Aluminum	10.0
Brass	13.0
Zinc	13.0
Plastics:	
PS	0.51
PET	0.29
Nylon	0.42
Peek	0.56

Advantages of Aluminum

- Lightweight
- Strong

High Strength-to-Weight Ratio

- High strength plus low weight permits substantial reductions in the weight of both parts and final products

- Resilient
- Corrosion-Resistant
- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic
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Rendering and photo courtesy of Tesla Motors, Inc.

Strong, lightweight aluminum extrusions are used throughout the transportation market.

© General Motors

http://www.chevrolet.com/new-2014-corvette/?seo=goo_|_GM+Chevy+Awareness_|_GG-AWR-Corvette-Stingray-BP-SN-Exact_|_Corvette+Stingray_|_2014%20corvette

Advantages of Aluminum

- High Strength-to-Weight

Rendering and photo courtesy of Audi USA

Audi A8
Extruded Aluminum Spaceframe

Courtesy of *Light Metal Age* magazine

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio

Resilient

- Aluminum products can deflect under loads and shocks and spring right back

- Corrosion-Resistant
- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
- Fully Recyclable

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient

Corrosion-Resistant

- Excellent corrosion resistance in a wide variety of environments and contact with a myriad of substances. It develops its own inert aluminum oxide film, which is self-protective, blocking further oxidation

- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
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Photo courtesy of Aluminum Chambered Boats, Inc.

Advantages of Aluminum

- Lightweight
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Corrosion-Resistant

Courtesy of *Light Metal Age* magazine

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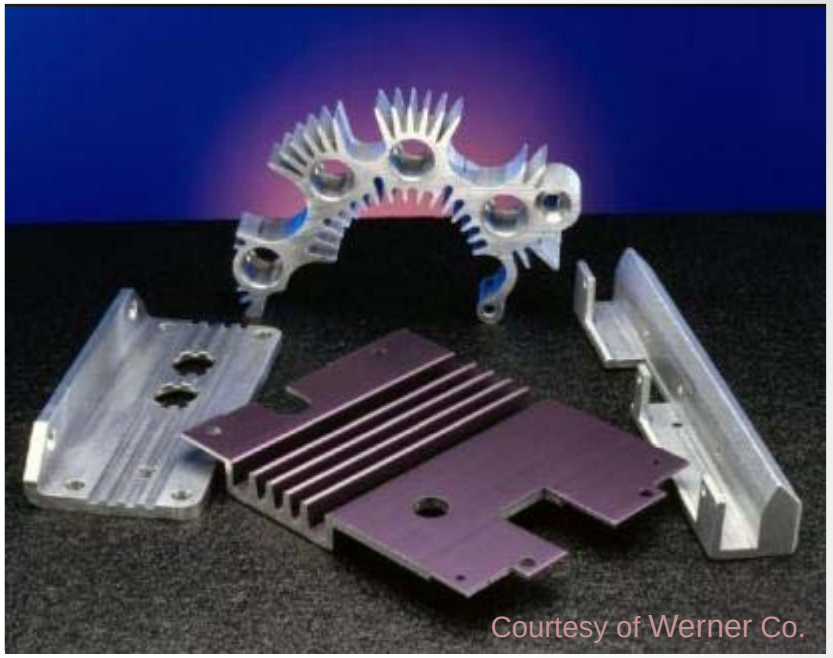

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient
- Corrosion-Resistant

Heat Conductive

- Conducts heat better than any other common metal on both a weight and cost basis.

- Reflective
- Electrically Conductive
- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
- Fully Recyclable

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient
- Corrosion-Resistant
- Heat Conductive

Reflective

- Highly reflective (more than 80 percent) of both visible light and the invisible radiation beyond both ends of the visible spectrum

- Electrically Conductive
- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
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Advantages of Aluminum

- Lightweight
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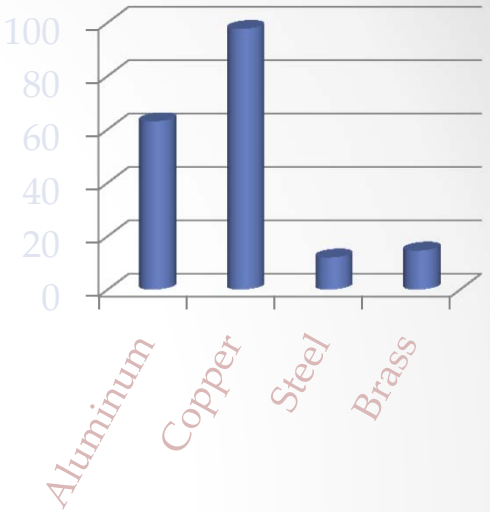
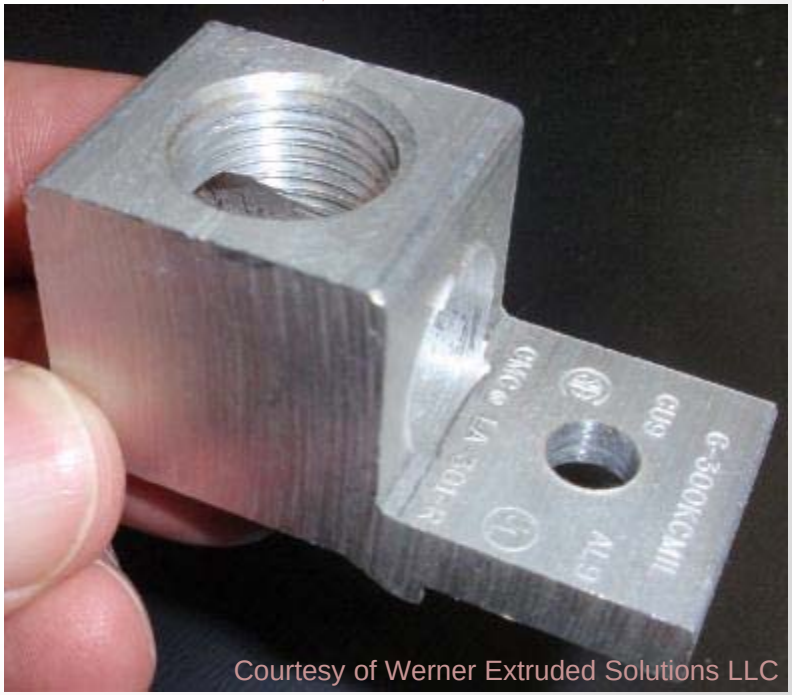
- Heat Conductive
- Reflective



Electrically Conductive

- Volume for volume, aluminum carries electricity about 62% as well as copper. On an equal weight basis, aluminum can be twice as conductive as copper, and aluminum is often the most economical choice.


Courtesy of Werner Extruded Solutions LLC

- Non-Magnetic
- Non-Sparking
- Non-Combustible
- Cold Strength
- Fully Recyclable

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient
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- Heat Conductive
- Reflective
- Electrically Conductive

2008 Honorable Mention-Engineer Products Category

Non-Magnetic

- The non-magnetic character of aluminum makes it particularly useful for a variety of electrical and electronic applications

- Non-Sparking
- Non-Combustible
- Cold Strength
- Fully Recyclable

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient
- Corrosion-Resistant
- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic

Non-Sparking

- Even though it is an excellent electrical conductor, aluminum does not produce sparks. This is an essential property for products used with highly flammable or explosive materials and atmospheres

- Non-Combustible
- Cold Strength
- Fully Recyclable

Advantages of Aluminum

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- Strong
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- Resilient
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- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic
- Non-Sparking

Courtesy of Werner Extruded Solutions LLC

- **Non-Combustible**
  - Solid aluminum does not burn or generate hazardous emissions, making it safer in applications where fire is a potential hazard
- Cold Strength
- Fully Recyclable

Advantages of Aluminum

- Lightweight
- Strong
- High Strength-to-Weight Ratio
- Resilient
- Corrosion-Resistant
- Heat Conductive
- Reflective
- Electrically Conductive
- Non-Magnetic
- Non-Sparking
- Non-Combustible

- Cold Strength
  - Aluminum's many advantages are not impaired by exposure to cold. In fact, aluminum gains strength and ductility as temperatures are reduced, making it a preferred metal for cryogenic (low-temperature) applications.
  - Steel and plastics get brittle when the temperature drops... Aluminum gets stronger and tougher!
- Fully Recyclable

Advantages of Aluminum

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Mt. Everest Climb Photo courtesy of Werner Co.

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- Cold Strength

Courtesy of *Light Metal Age* magazine

- Fully Recyclable
  - Aluminum is fully, and repeatedly, recyclable, able to be recycled over and over without degradation or loss of its innate characteristics.
  - For products with a limited life (such as consumer durables and transportation products), aluminum's recyclability coupled with its other outstanding attributes make it a superior material choice.
  - Aluminum has significant scrap value and is particularly environmentally friendly because recycling requires only 5% of the energy necessary to produce virgin aluminum.

Advantages of Aluminum

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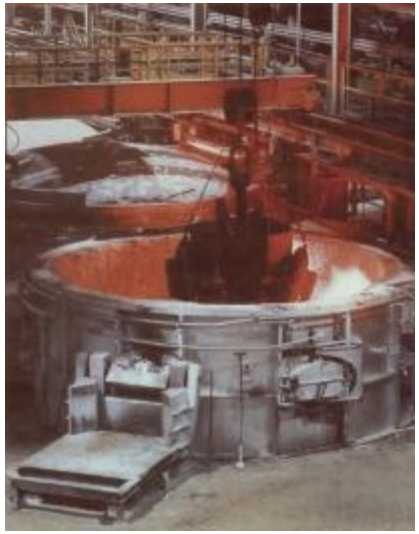

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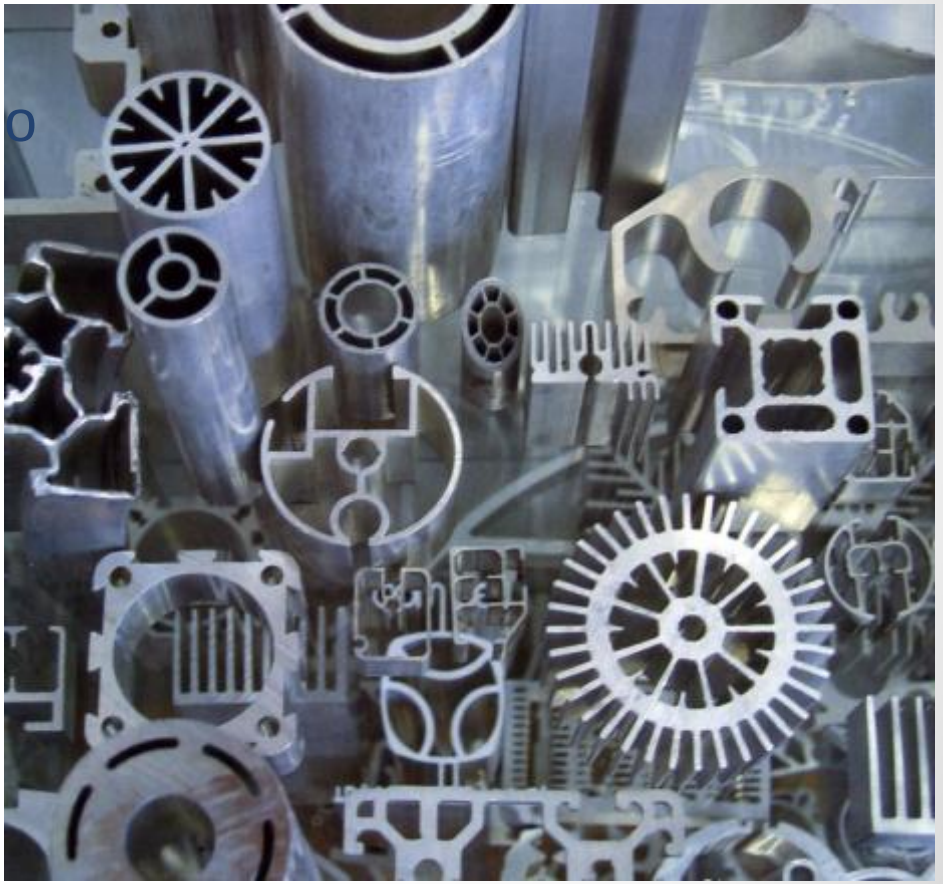
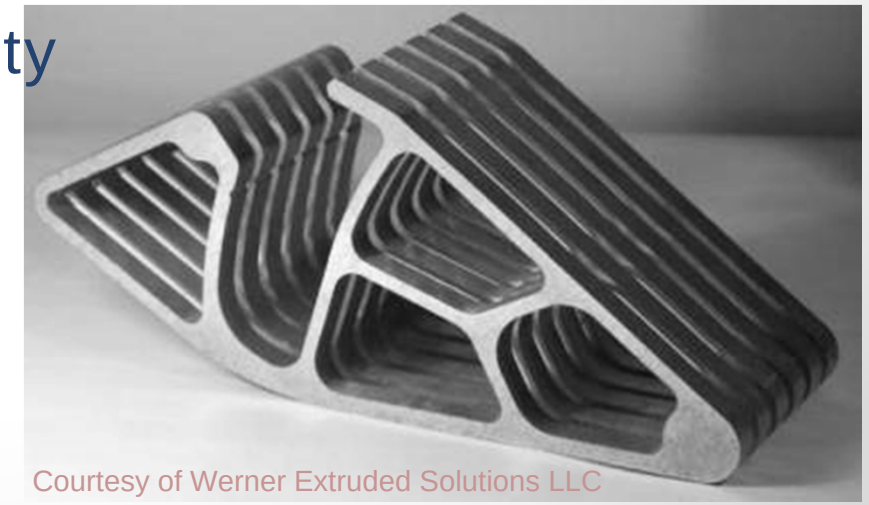


Courtesy of *Light Metal Age* magazine

Advantages of Aluminum Extrusions

- Attractive
- Suitable for a wide range of finishes
- Virtually seamless
- Easy to fabricate
- Joinable by various methods
- Suitable for easy-assembly designs
- Suitable for complex, integral shapes
- Produced to close tolerances
- Produced with uniform quality
- Cost-effective
- Short production lead times



Courtesy of Werner Extruded Solutions LLC

Advantages of Aluminum Extrusions

Attractive

- Aluminum's natural metallic surface is aesthetically pleasing. The natural protective oxide coating can be thickened by anodizing for extra protection, painted or powder coated for additional appearance benefits.

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Advantages of Aluminum Extrusions

- Attractive

Suitable for a wide range of finishes

- Aluminum accepts a great variety of finishes, colors and textures

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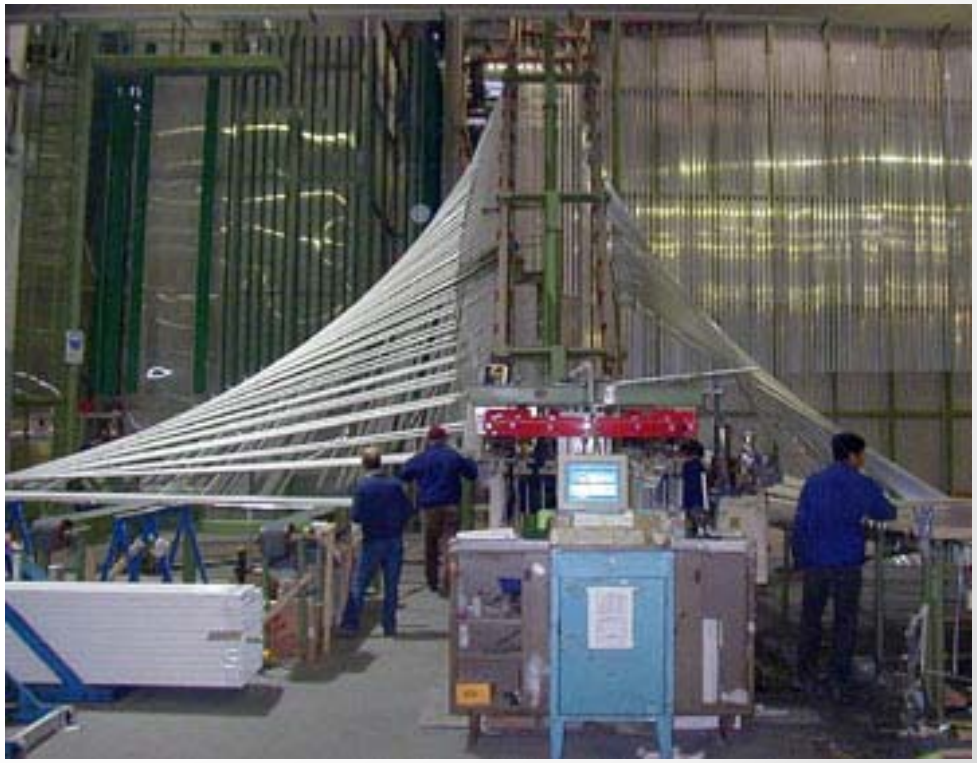

Advantages of Aluminum Extrusions

- Attractive
- Suitable for a wide range of finishes

Virtually seamless

- Aluminum extrusions, even tubes and other hollow shapes, have no mechanically joined seams which could loosen, leak, mar appearance or reduce strength. They are one-piece products, both visually and functionally

- Easy to fabricate
- Joinable by various methods
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- Suitable for a wide range of finishes
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Easy to fabricate

- Often, designing with aluminum extrusions can eliminate many fabrication and assembly steps
- Aluminum extrusions can be made with almost any cross-sectional shape. Parts can be easily cut, machines, finished, fabricated and assembled.

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Courtesy of Alexandria Extrusion

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- Attractive
- Suitable for a wide range of finishes
- Virtually seamless
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Joinable by various methods

- Aluminum extrusions can be joined to other aluminum products or to different materials by all major methods, including welding, soldering, brazing, bolts, rivets, chips, adhesives, clinching and slide-on, snap-together or interlocking joints.

- Suitable for easy-assembly designs
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Advantages of Aluminum Extrusions

- Attractive
- Suitable for a wide range of finishes
- Virtually seamless
- Easy to fabricate
- Joinable by various methods

Photo courtesy of Classic Exhibits, Inc.

Suitable for easy-assembly designs

- Aluminum extrusions can be designed for easy assembly with other parts including mating surfaces or shapes that match up for easy joining.

- Suitable for complex, integral shapes
- Produced to close tolerances
- Produced with uniform quality
- Cost-effective
- Short production lead times

By using aluminum extrusion's ability to easily and cost effectively produce complex, integral profiles, designers can often accomplish tremendous part-count reductions!

Advantages of Aluminum Extrusions

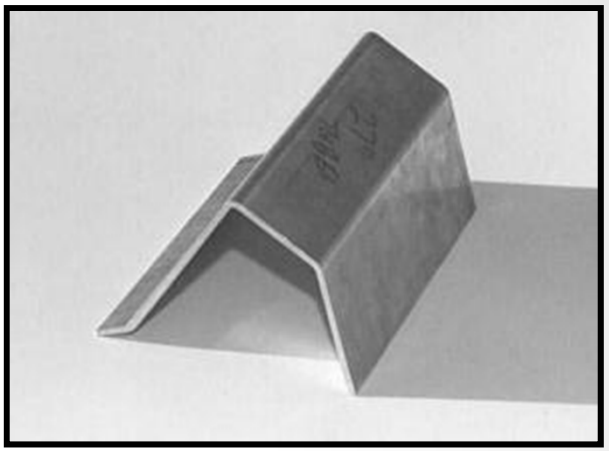
- Suitable for easy-assembly designs

Advantages of Aluminum Extrusions

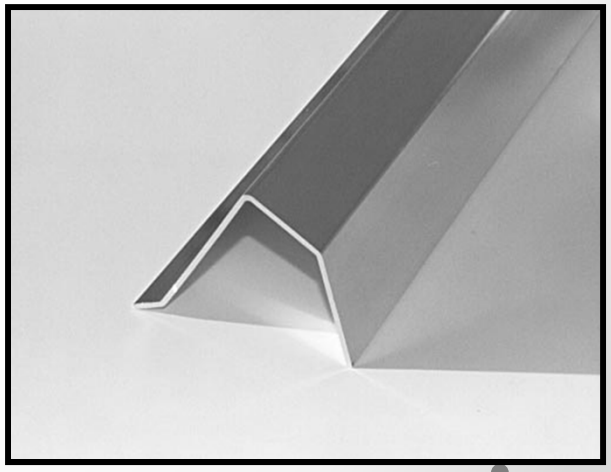
USING THE EXTRUSION PROCESS FOR NET SHAPE:

- **Reduce the number of operations required**
- **Reduce the corner stress from bending**
- **Cosmetically more attractive**

Aluminum sheet stock = 3 operations



Extrusion = 1 operation



Photos courtesy of Alexandria Extrusion Company

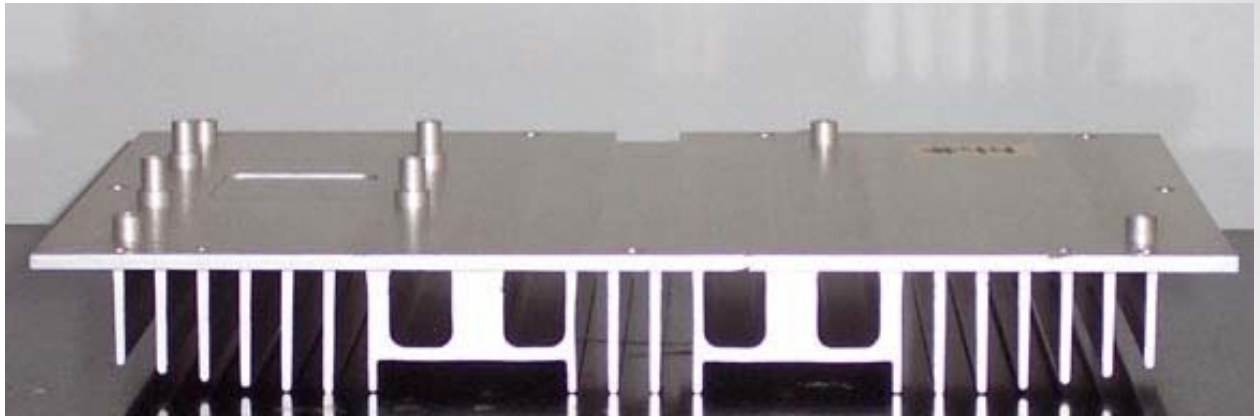
Advantages of Aluminum Extrusions

ALUMINUM EXTRUSIONS REPLACE CASTINGS

- Significantly lower tooling cost
- Improved strength
- No porosity
- Cosmetically more attractive
- Shorter lead time

Photo courtesy of Alexandria Extrusion Company

Advantages of Aluminum Extrusions



2005 Commercial/Industrial/Consumer Winner

- Attractive
- Suitable for a wide range of finishes
- Virtually seamless
- Easy to fabricate
- Joinable by various methods
- Suitable for easy-assembly designs

- **Suitable for complex, integral shapes**
  - Shapes can combine functions that would otherwise require the production and joining of several different parts.
- Produced to close tolerances
- Produced with uniform quality
- Cost-effective
- Short production lead times

Advantages of Aluminum Extrusions

Courtesy of Werner Extrusion Solutions LLC

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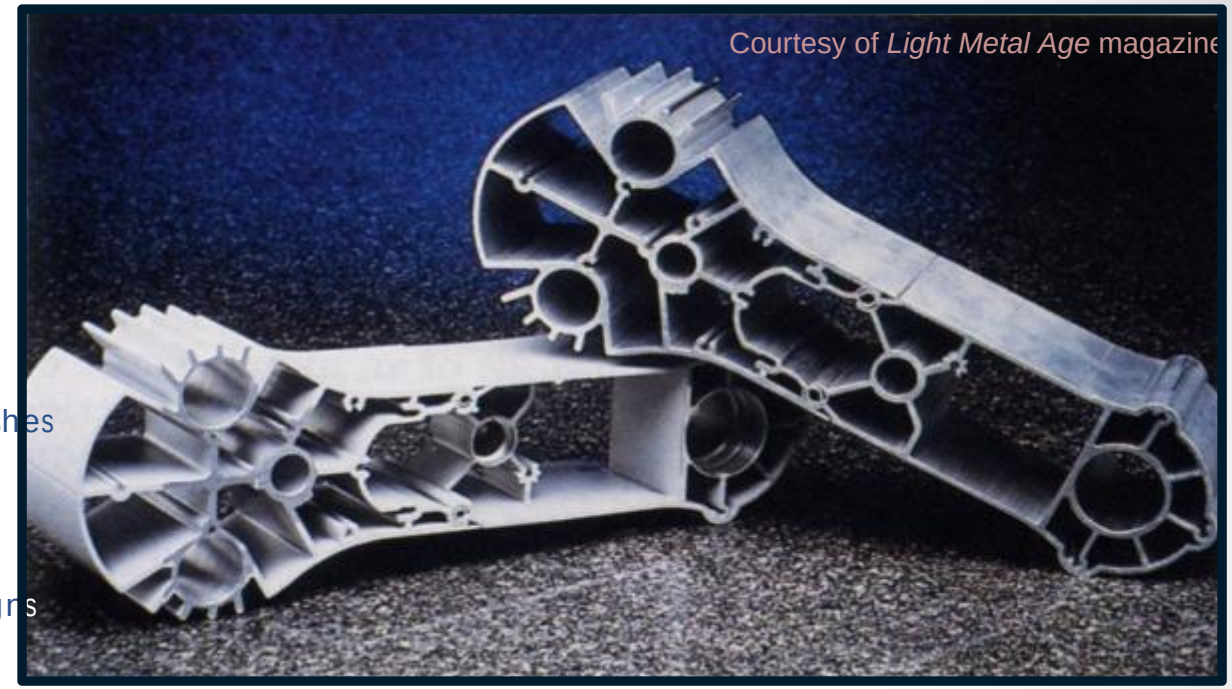
Courtesy of Tolomatic, Inc.

- Suitable for complex, integral shapes
  - Shapes can combine functions that would otherwise require the production and joining of several different parts.
- Produced to close tolerances
- Produced with uniform quality
- Cost-effective
- Short production lead times

Advantages of Aluminum Extrusions



- Attractive
- Suitable for a wide range of finishes
- Virtually seamless
- Easy to fabricate
- Joinable by various methods
- Suitable for easy-assembly designs

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- Joinable by various methods
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- Produced to close tolerances
  - Every process has its deviation from nominal
    - For castings, for example, it's shrinkage and draft
  - For the aluminum extrusion process, dimensional tolerances are more an evolution than they are fixed
    - Improvements in die construction and press practices can provide for even tighter dimensional tolerances than standard on aluminum profiles
    - For many applications, standard aluminum extrusion dimensional tolerances have proven to be more precise than those for most competing processes

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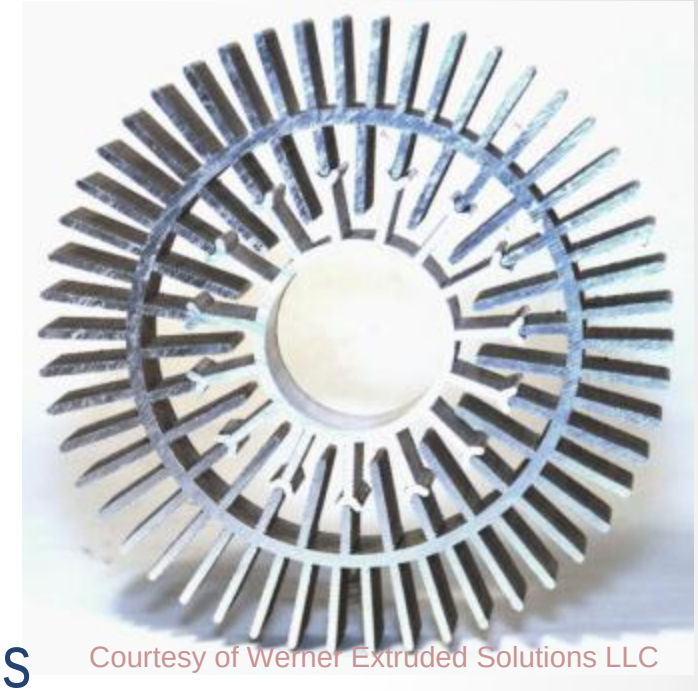

Courtesy of Werner Extruded Solutions LLC

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Courtesy of Werner Extruded Solutions LLC

- **Produced with uniform quality**
  - This reliability reduces customer costs by minimizing rejections rate, corrective fabrication and production slowdown – particularly important to the manufacturer who depends upon just-in-time (JIT) delivery.
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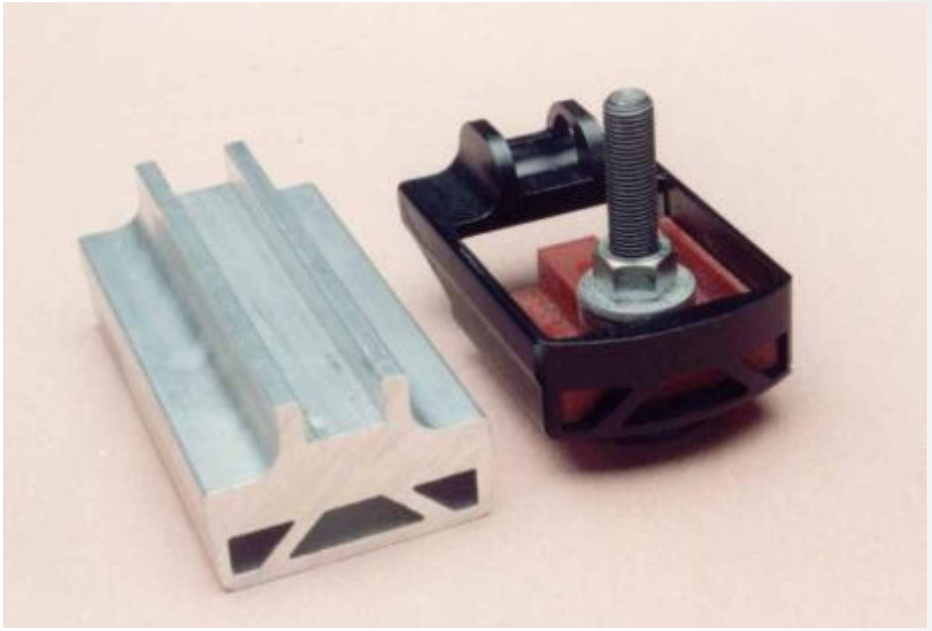

Cost-effective

- The boundless diversity of shapes permitted by the extrusion process cuts down or eliminates many machining—as well as joining—operations. Also, the tools required for aluminum extruding, such as dies and related items, are relatively inexpensive.

- Short production lead times

Advantages of Aluminum Extrusions

- Ski-doo snowmobile circa 2001
  - Fabricated, welded ski mount

- Ski-doo snowmobile circa 2005
  - Extruded aluminum ski mount

Courtesy of Werner Extrusion Solutions LLC

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- Suitable for easy-assembly designs
- Suitable for complex, integral shapes
- Produced to close tolerances
- Produced with uniform quality

Process	Typical Tooling Cost ($)
Vinyl Extrusion	$1,500 and up
Injection Molding	$25,000 and up
Die Castings	$25,000 and up
Roll Forming	$30,000 and up
Stampings	$5,000 and up
Aluminum Extrusions	$500 to $5,000

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Examples of Value Added Operations for aluminum extrusions:

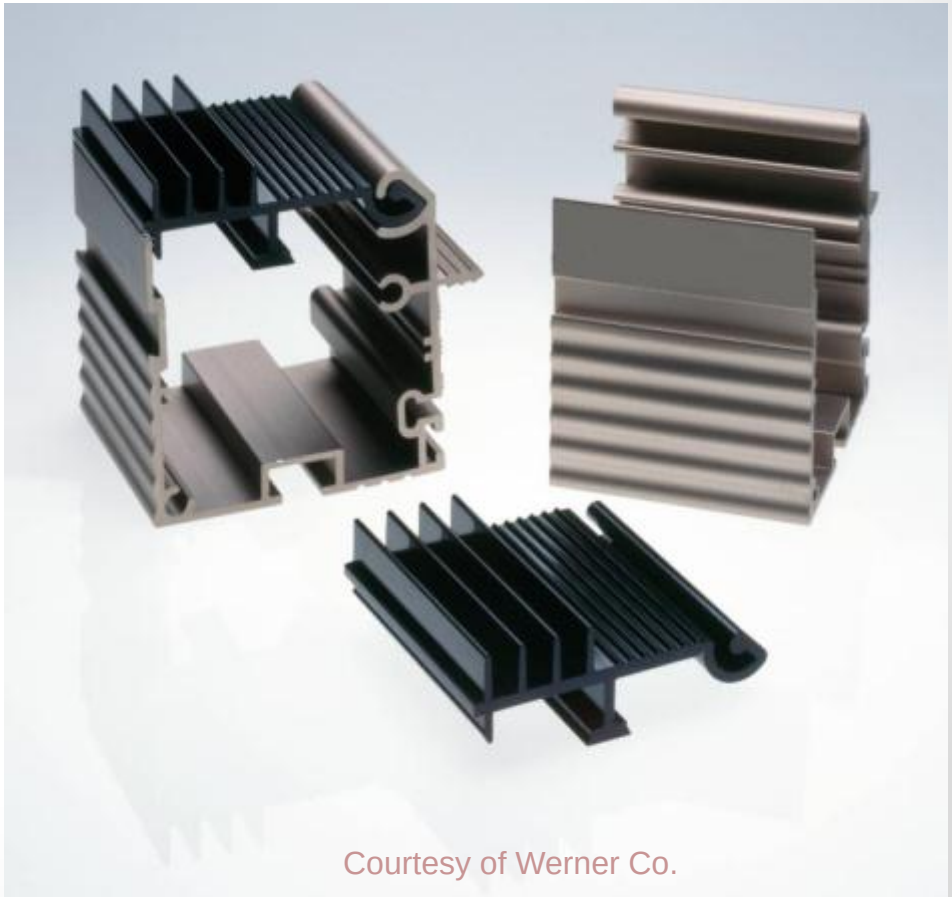
- Finishing
  - Painting (wet and powder)
  - Polish, bright dip & anodize
  - Mechanical Finishes
  - Silk screening
- Fabrication
  - Sawing
  - Punching/piercing/drilling
  - Machining
  - Bending
  - Welding
  - Milling
  - Tumbling

Courtesy of Werner Co.

The Possibilities are Boundless, Limited only by the Imagination

- The extrusion pictured is a theoretical shape created to illustrate some of the range of possibilities provided by aluminum extrusions

- How can YOU use this flexibility to:
  - Spark your imagination?
  - Create new product concepts?
  - Develop improved manufacturing efficiencies?



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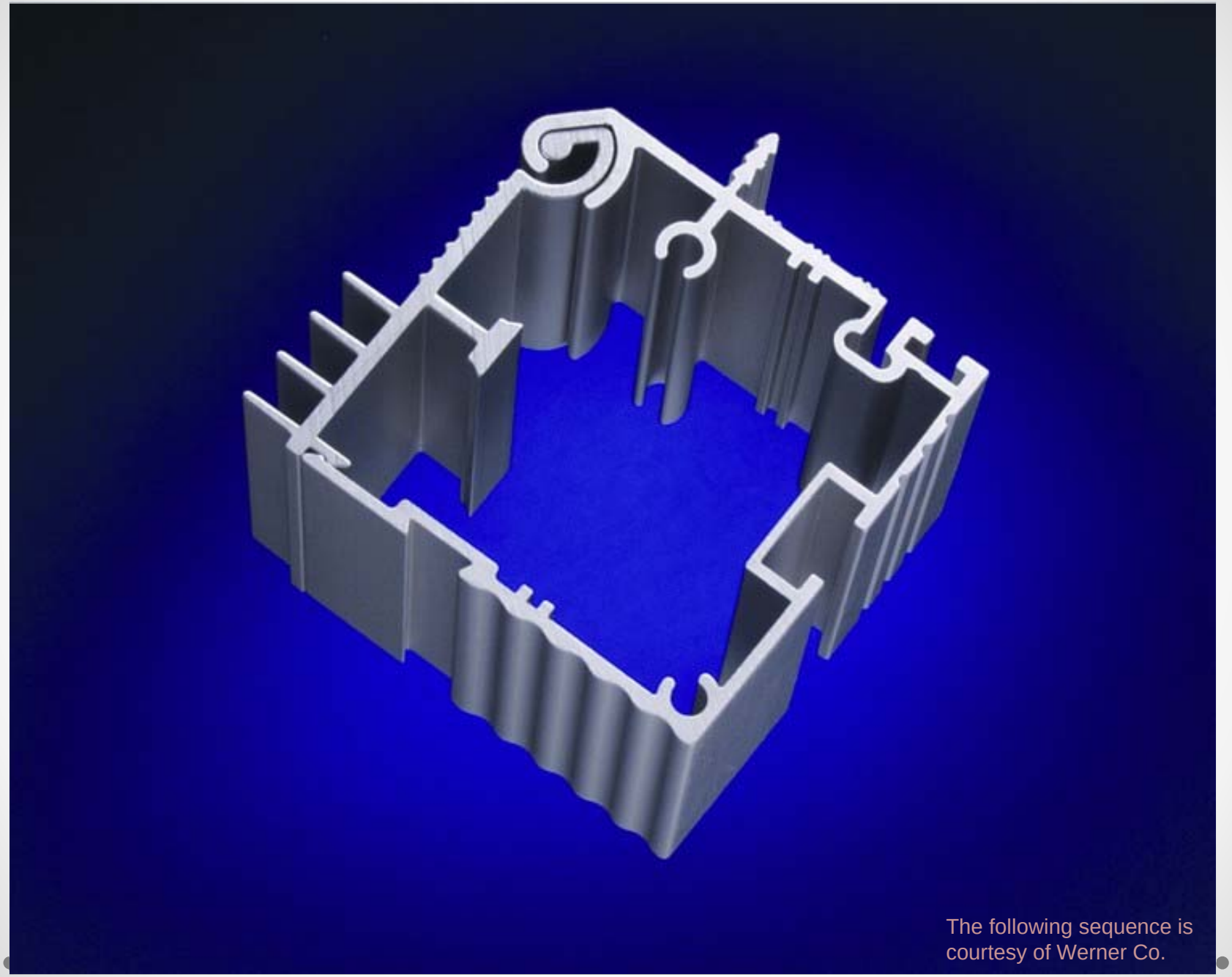
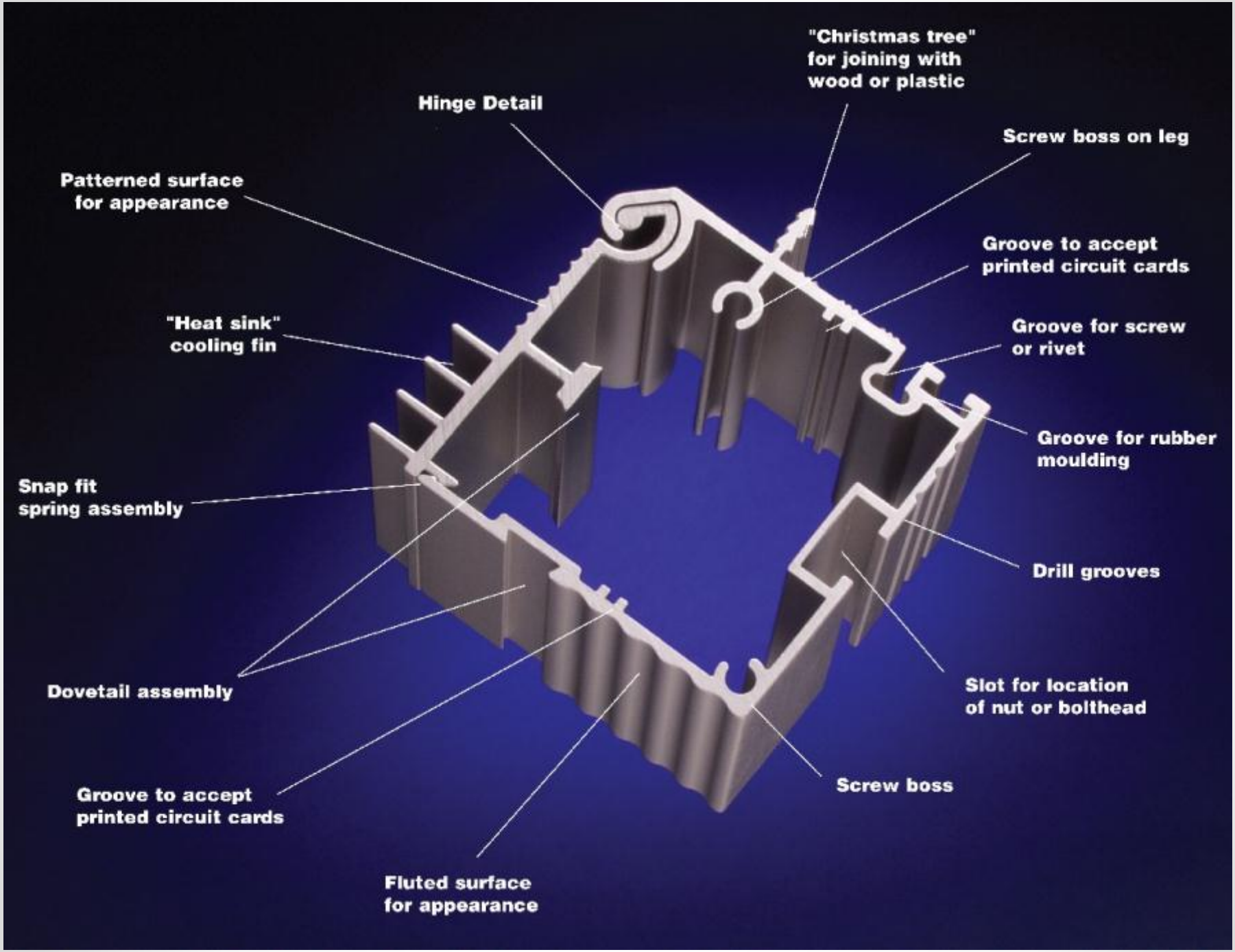
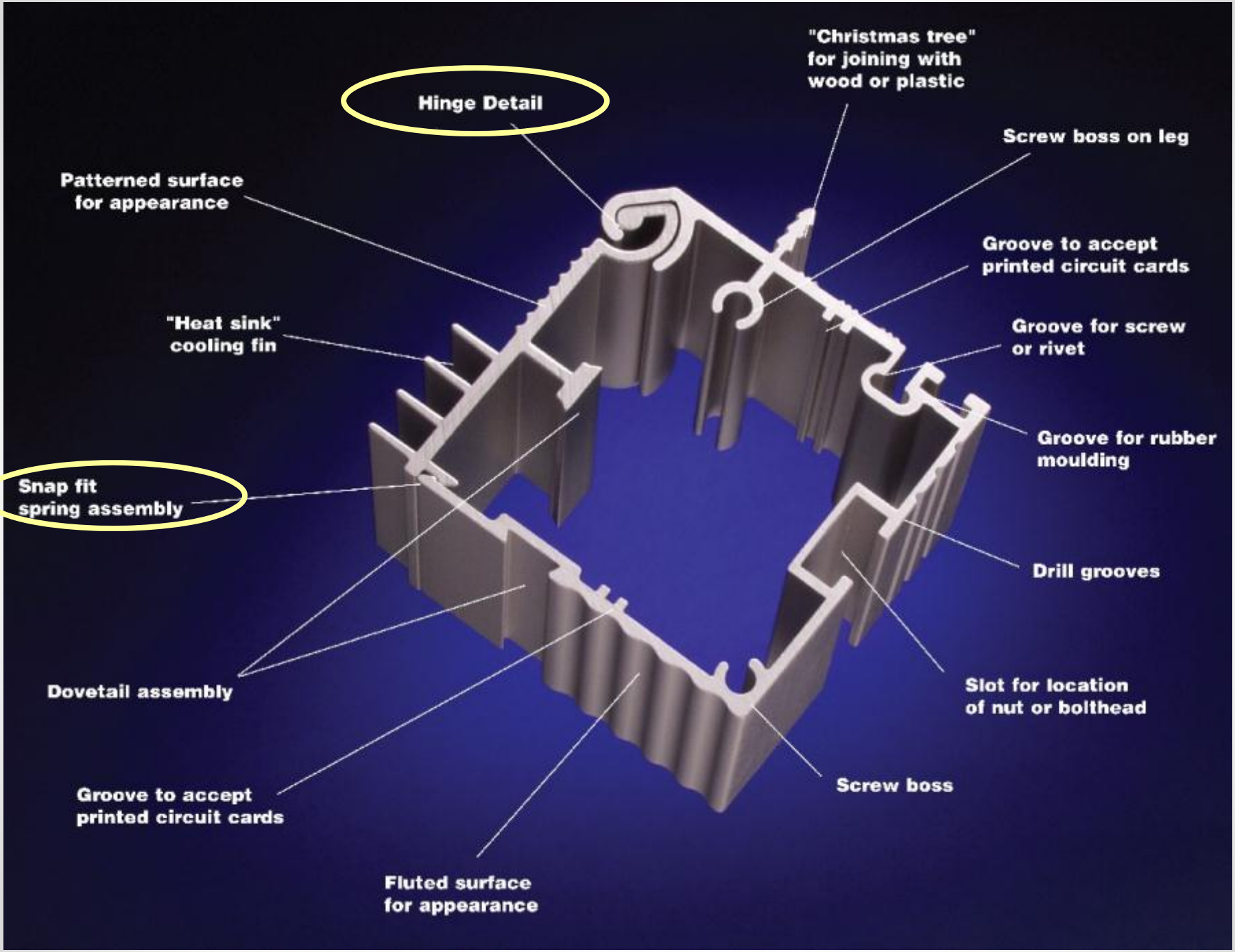


The following sequence is courtesy of Werner Co.


"Christmas tree" for joining with wood or plastic
Hinge Detail
Screw boss on leg
Patterned surface for appearance
Groove to accept printed circuit cards
"Heat sink" cooling fin
Groove for screw or rivet
Groove for rubber moulding
Snap fit spring assembly
Drill grooves
Dovetail assembly
Slot for location of nut or bolthead
Screw boss
Groove to accept printed circuit cards
Fluted surface for appearance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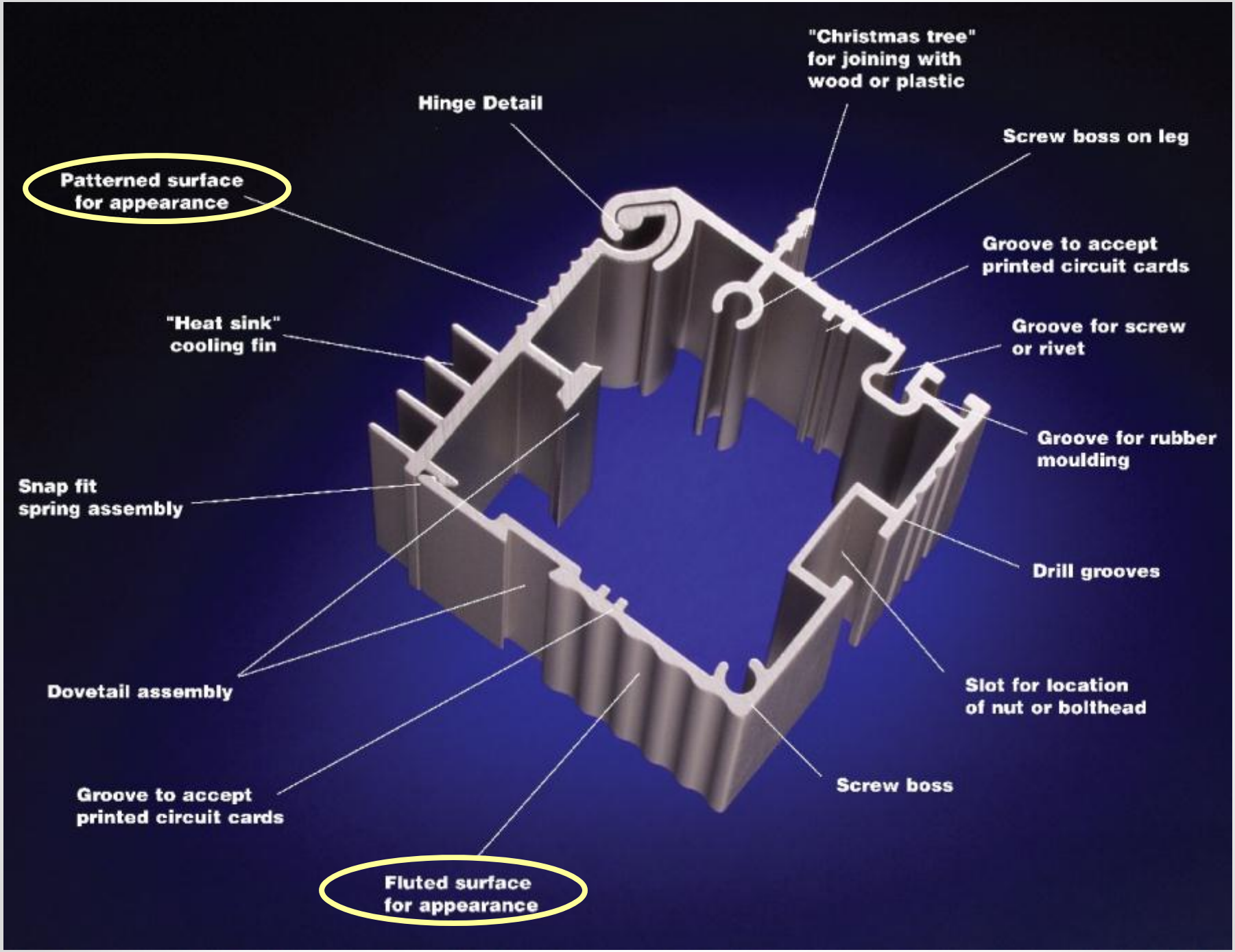
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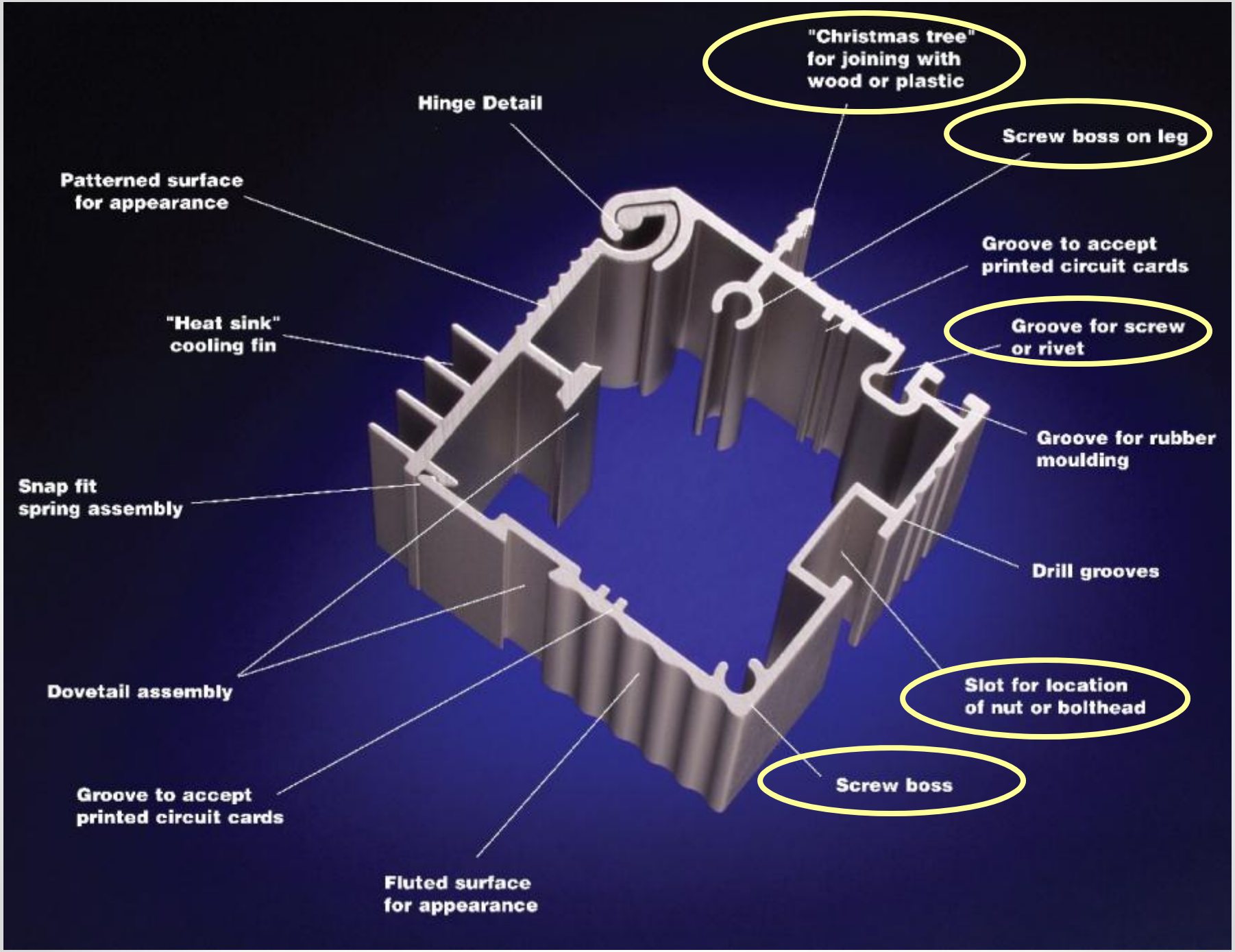
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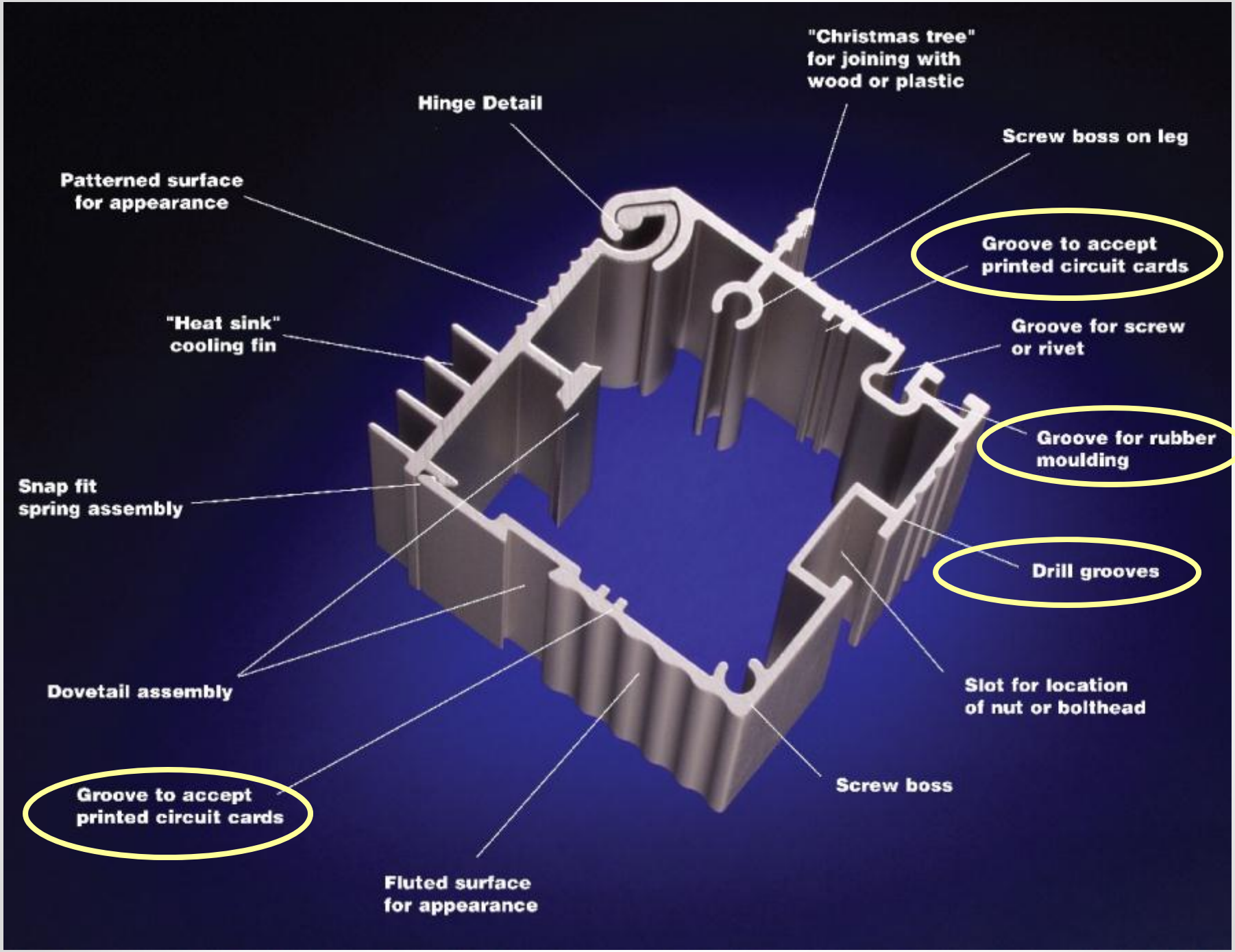
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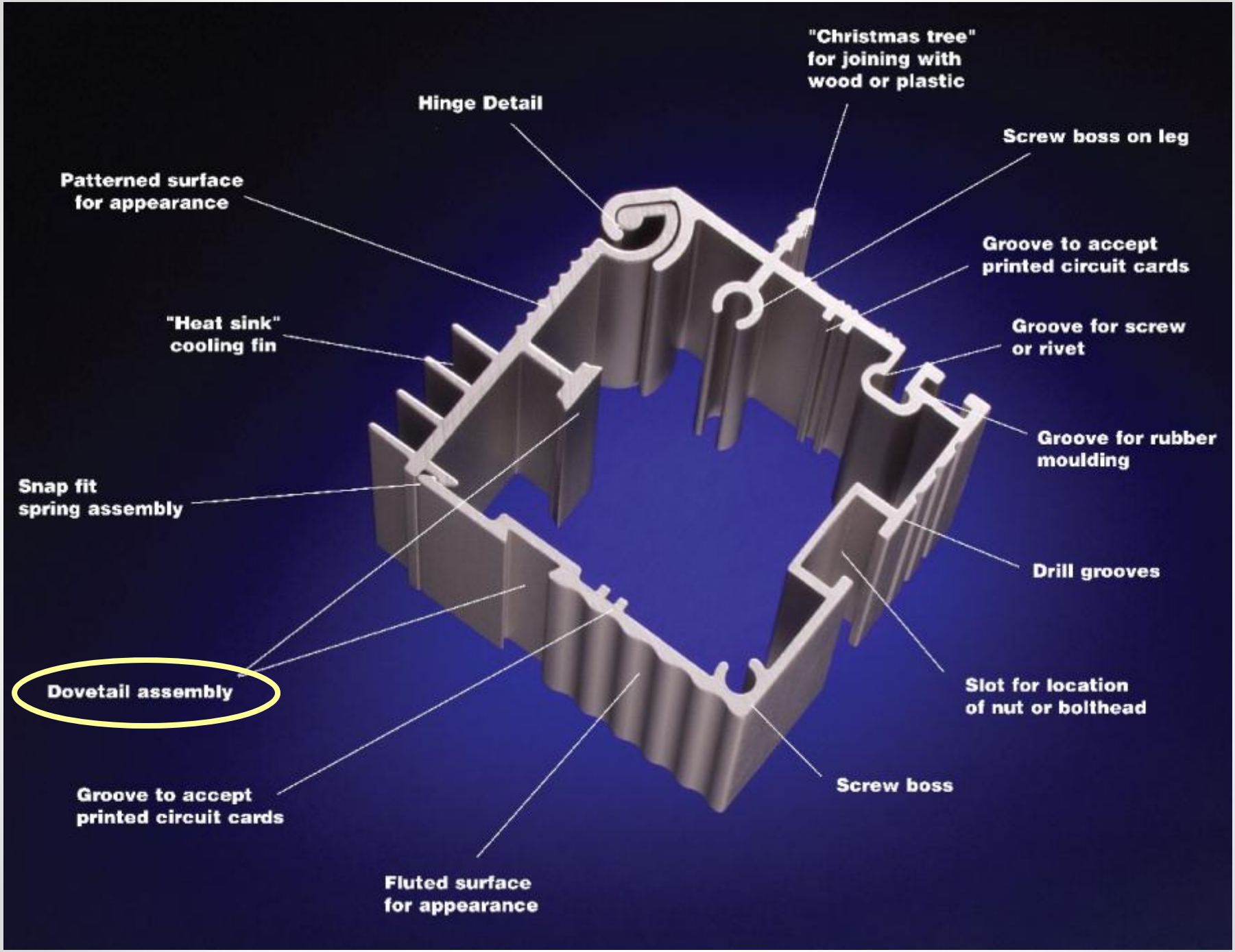
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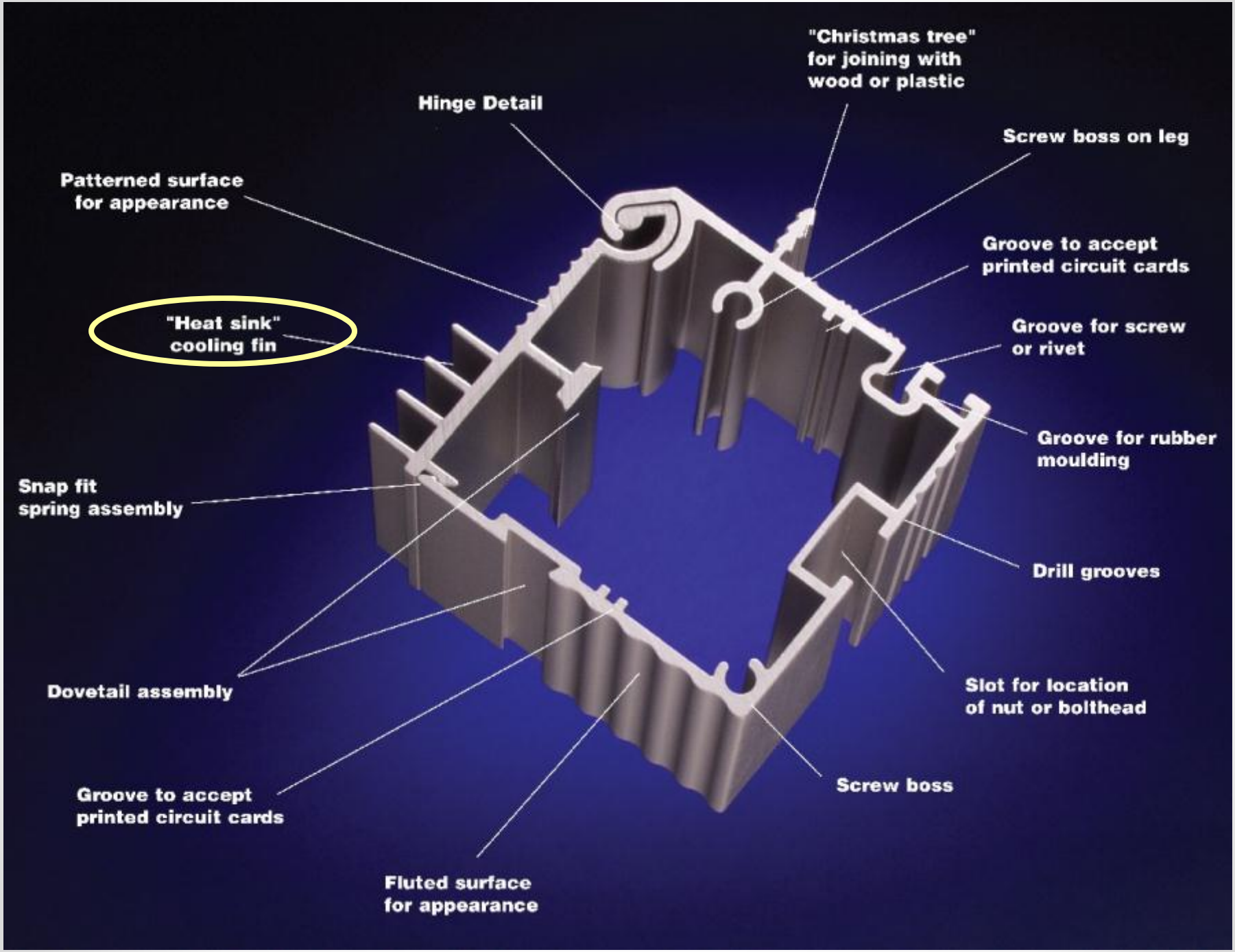
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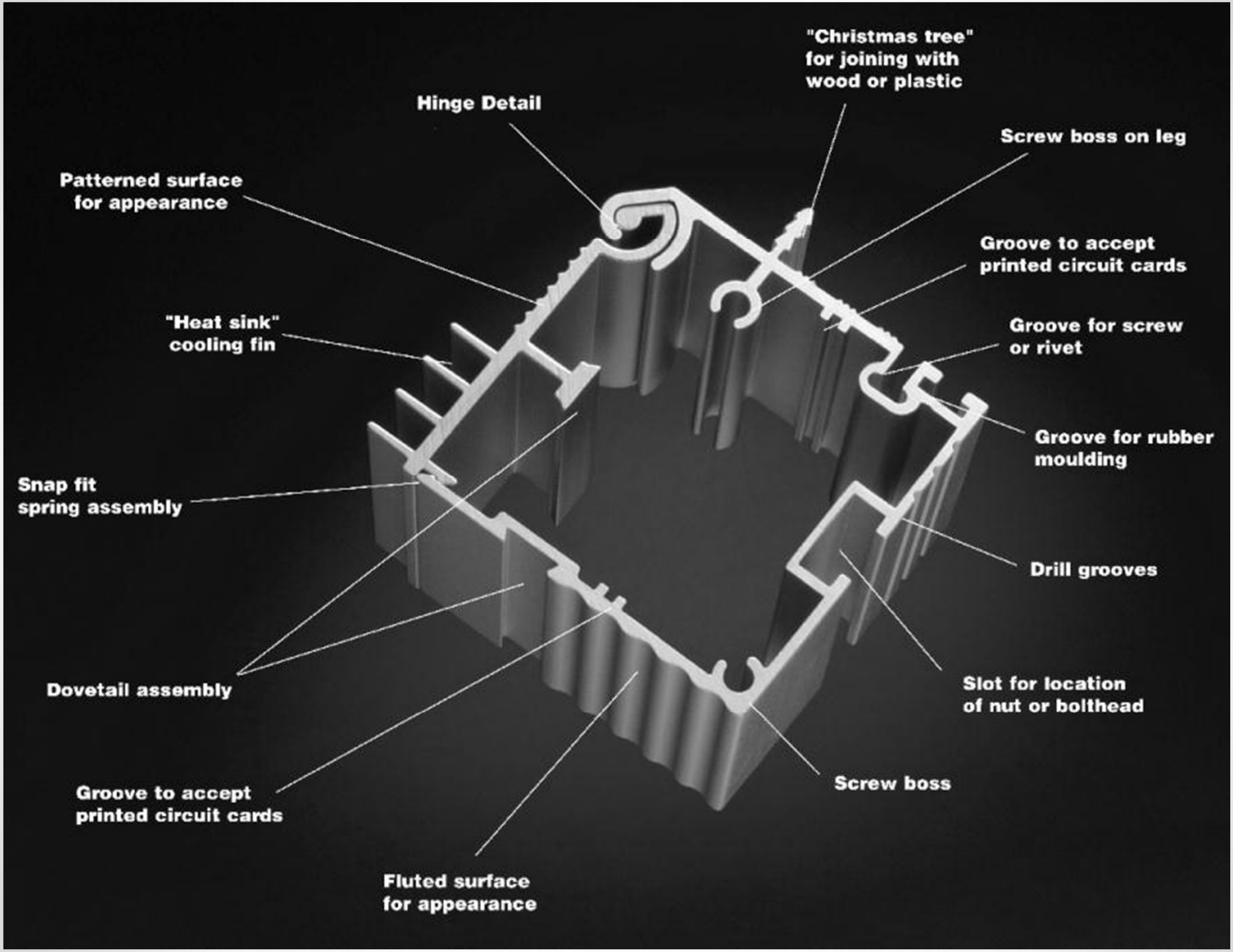
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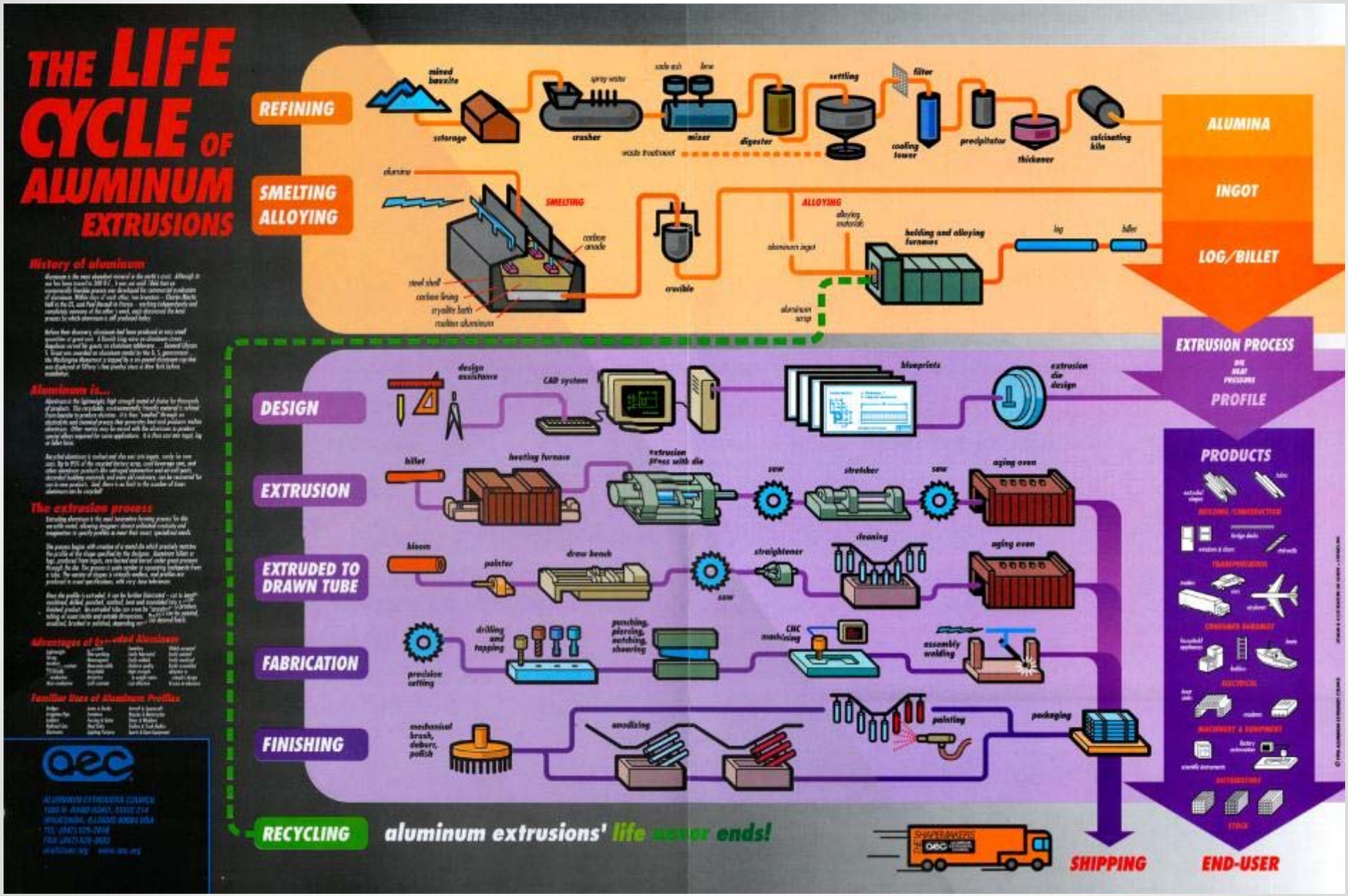
Aluminum starts as a very abundant substance, aluminum oxide. It is converted to aluminum and used in various forms throughout the world.



The Extrusion Process

- Tooling
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- Handling Equipment
- Finish Saw
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- Fabrication & Finishing

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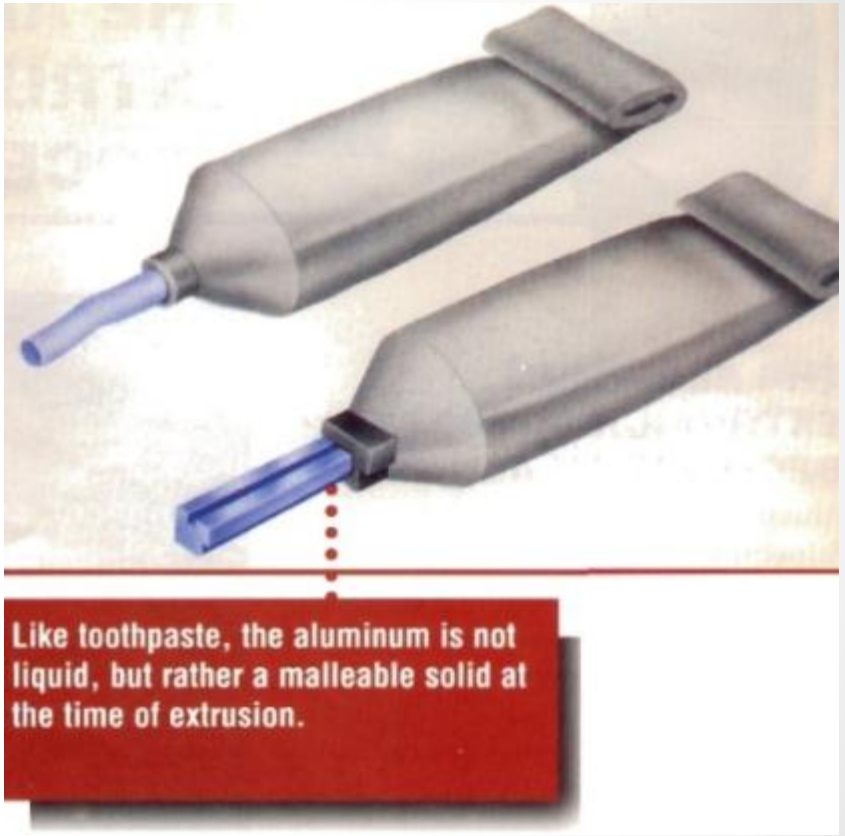
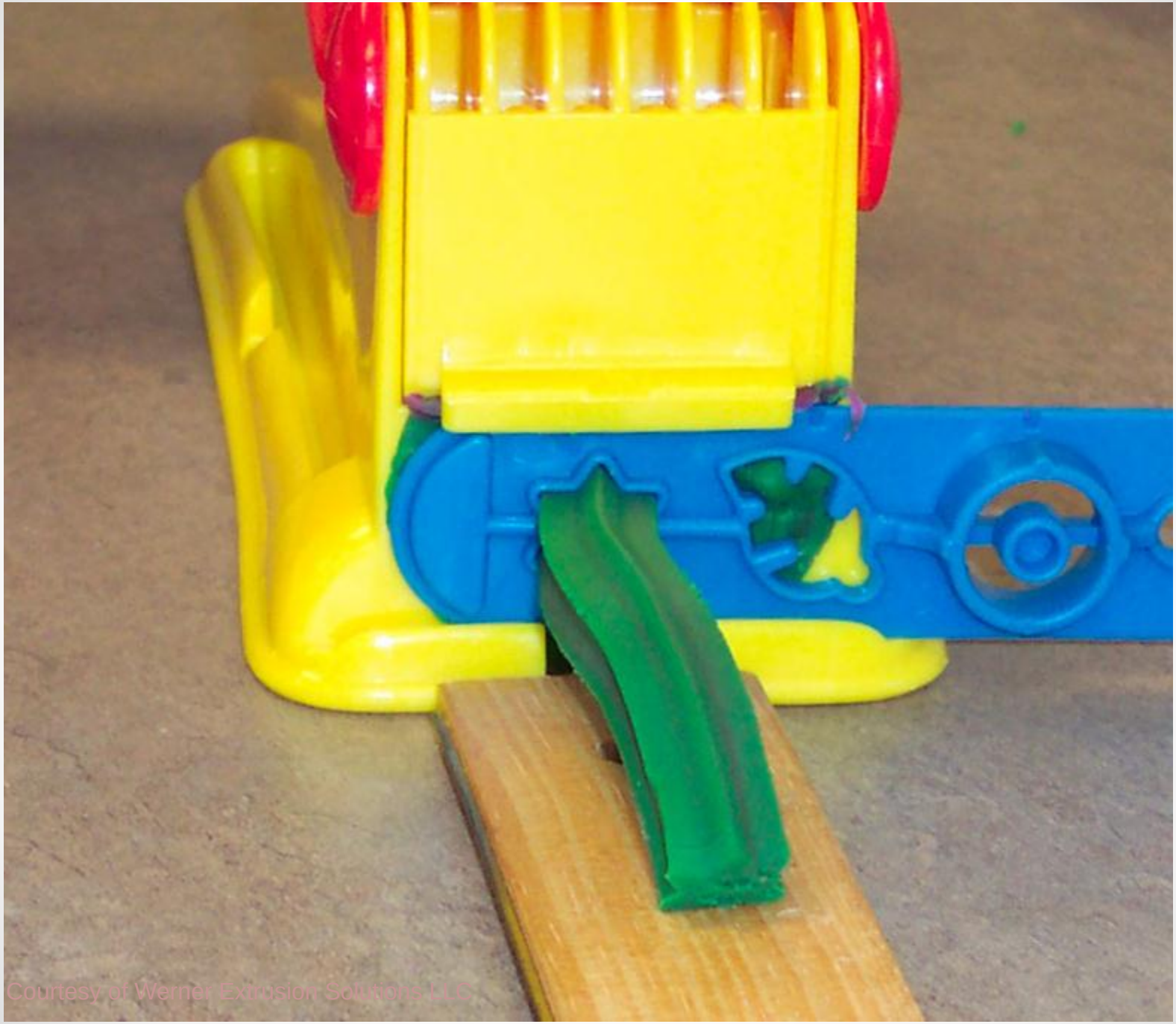
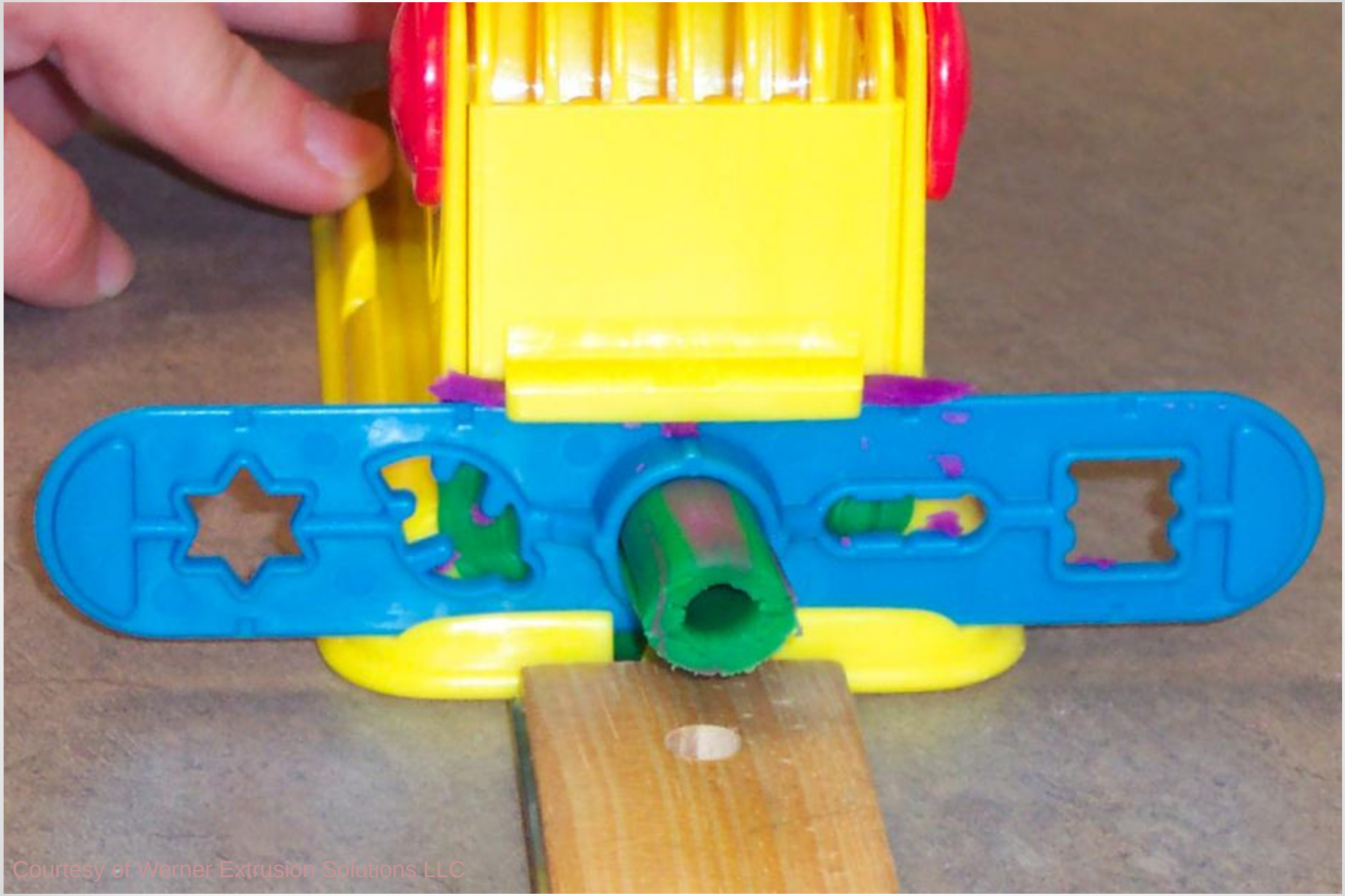
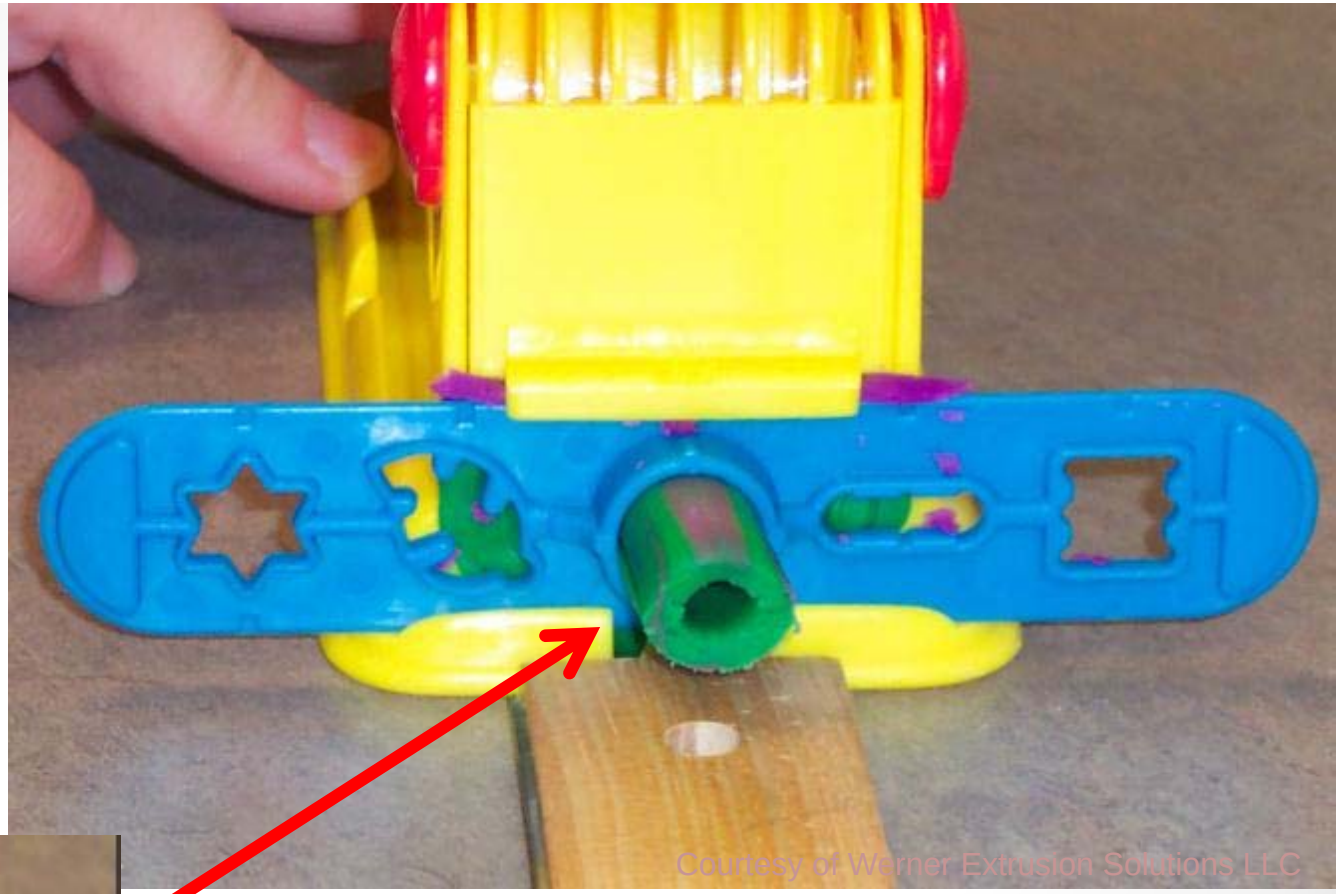


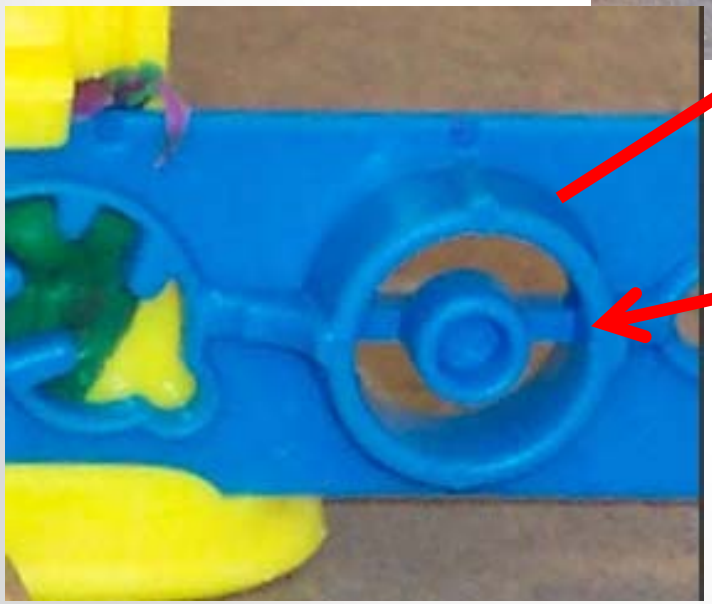


Courtesy of Werner Extrusion Solutions LLC


Courtesy of Werner Extrusion Solutions LLC

HOW ARE HOLLOW SHAPES EXTRUDED ??

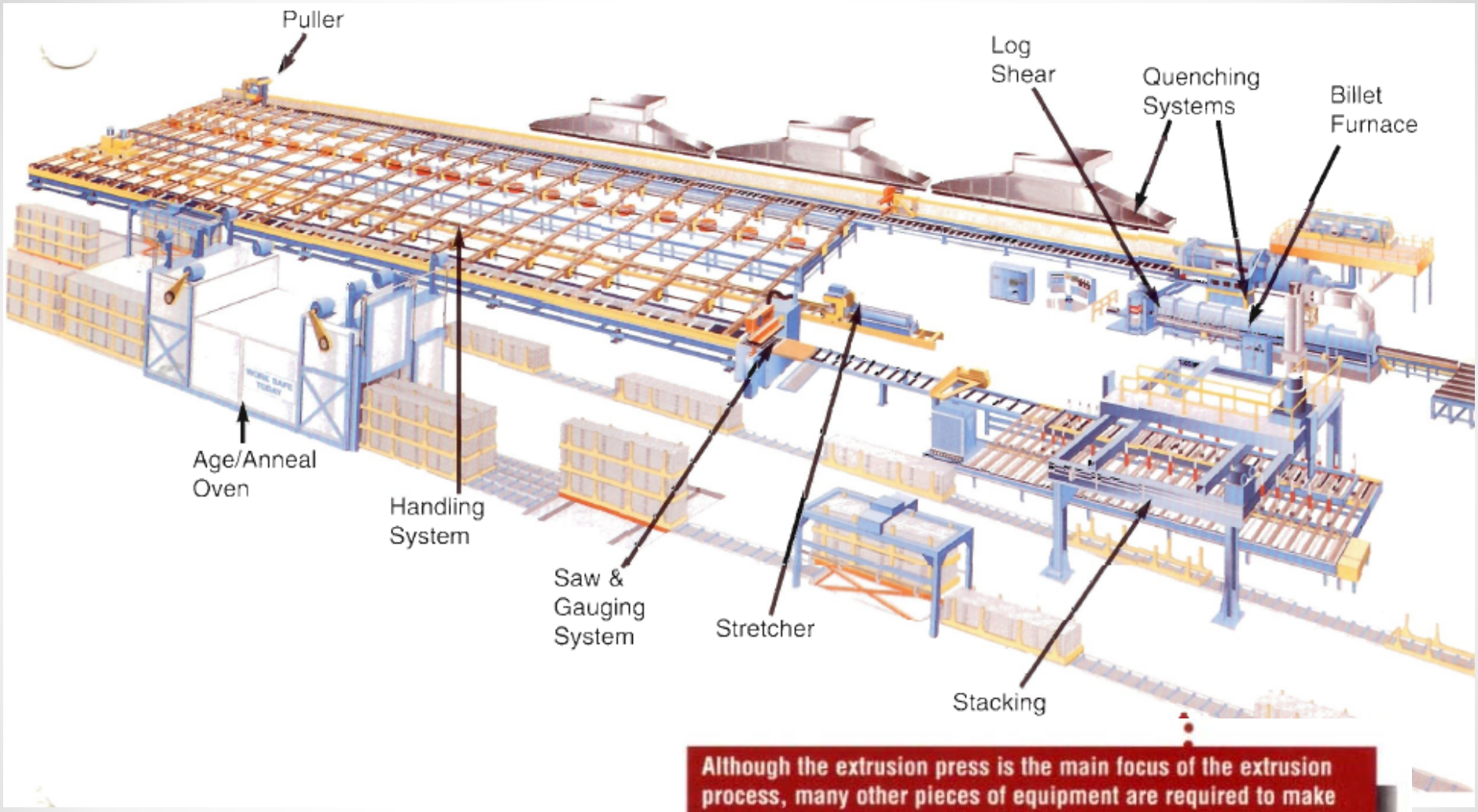




The PlayDoh flows through the opening between the part of the die that forms the outside diameter and the inside “mandrel” supported by two horizontal supports.

The PlayDoh SEPARATES into two tube halves and “welds” back together due to the pressure needed to make it flow through the annular opening into a tube shape.

The Extrusion Process – Equipment overview

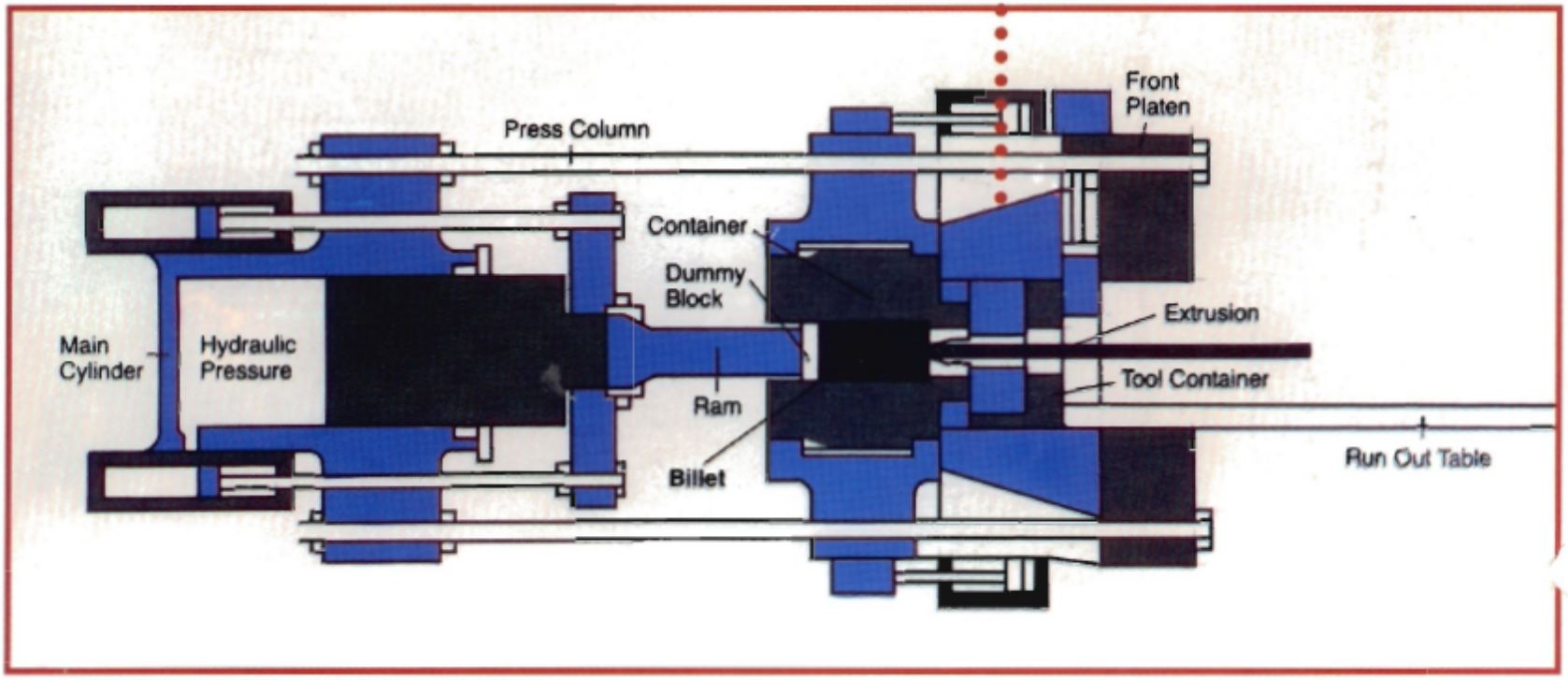


Although the extrusion press is the main focus of the extrusion process, many other pieces of equipment are required to make an aluminum extrusion. In addition to the press, the illustration depicts a billet furnace, quenching systems, log shear, puller, age/anneal oven, handling equipment, saw and gauging system, stretcher, and stacking system.

The Extrusion Process

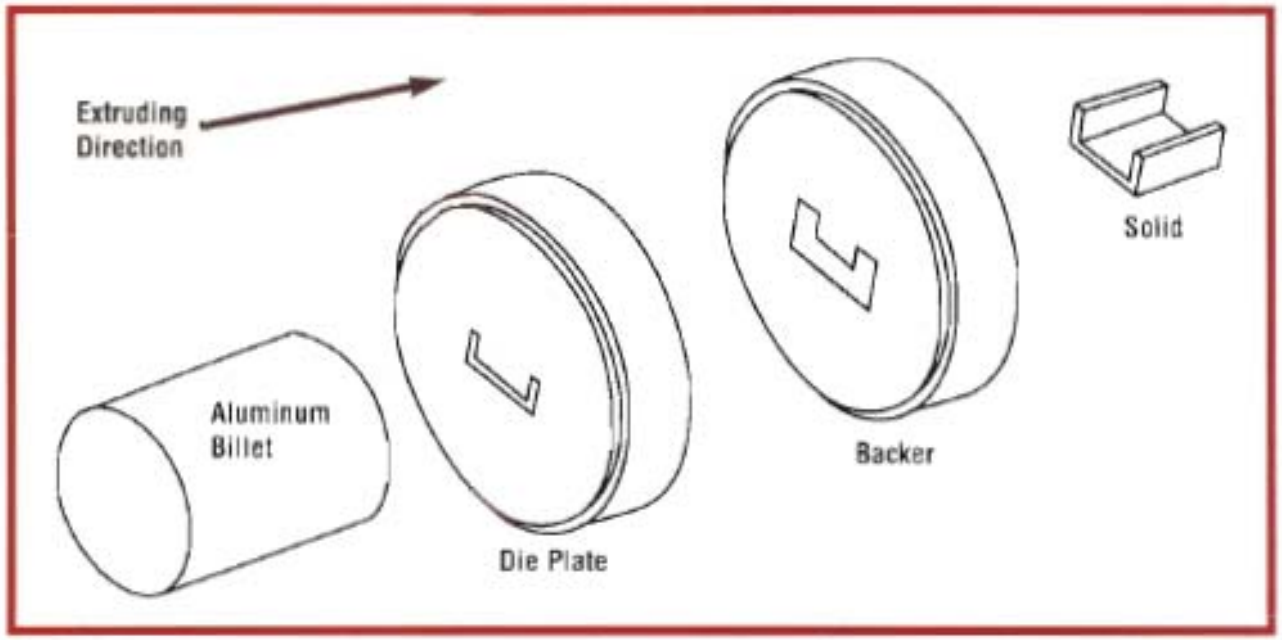
Aluminum extrusion is the most innovative forming process for this versatile metal, allowing designers to exercise their creativity and stretch their imaginations to design profiles that meet their exact, specialized needs.

Unlike a simple tube of toothpaste, an aluminum extrusion press is comprised of many different parts which function together.



The Extrusion Process

- Tooling
  - Hollow Dies
  - Solid Dies
  - Multiple hole dies
- Billet Furnace
- Extrusion Press
- Handling Equipment
- Finish Saw
- Aging System
- Fabrication & Finishing



Solid dies have one or more openings, and produce extrusions without any enclosed internal voids. The opening in a solid die has the exact cross-sectional profile of the extruded shape. Solid dies are used primarily in the production of bars, channels and angles, as well as many custom shapes.

The Extrusion Process

- Tooling
  - Hollow Dies
  - Solid Dies
  - Multiple hole dies
- Billet Furnace
- Extrusion Press
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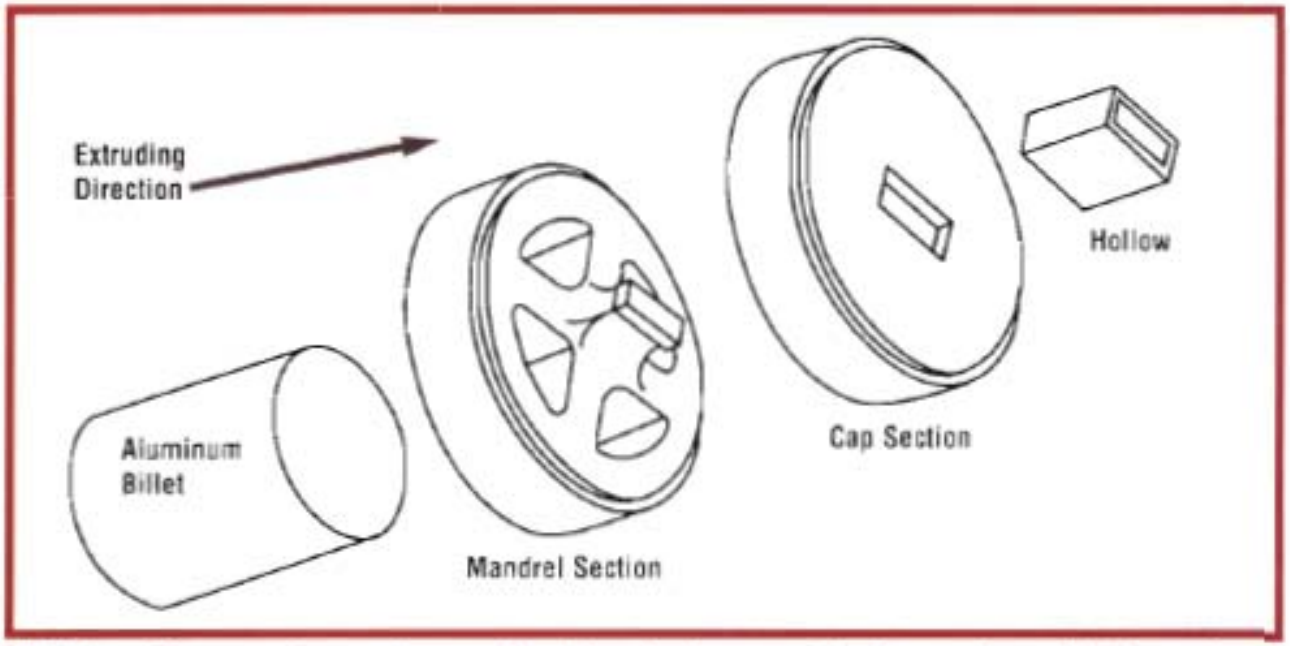
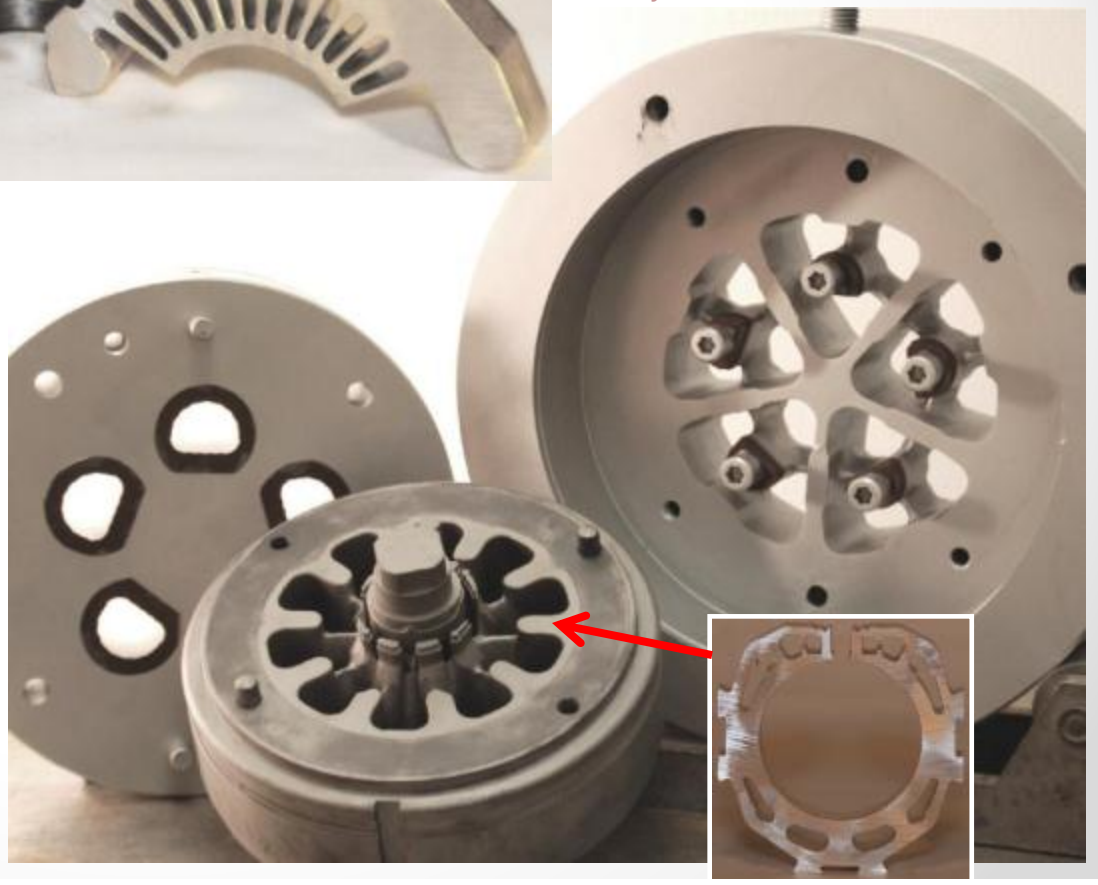


Hollow dies produce shapes that include an entirely enclosed internal void and have "closed" profiles. Hollow dies require two components, a die cap and a mandrel section, in order to produce required shapes. Hollow dies produce tubes and many custom hollow shapes.

The Extrusion Process

- Tooling
  - Hollow Dies
  - Solid Dies
  - Multiple hole dies
- Billet Furnace
- Extrusion Press
- Handling Equipment
- Finish Saw
- Aging System
- Fabrication & Finishing

Courtesy of Werner Extrusion Solutions LLC



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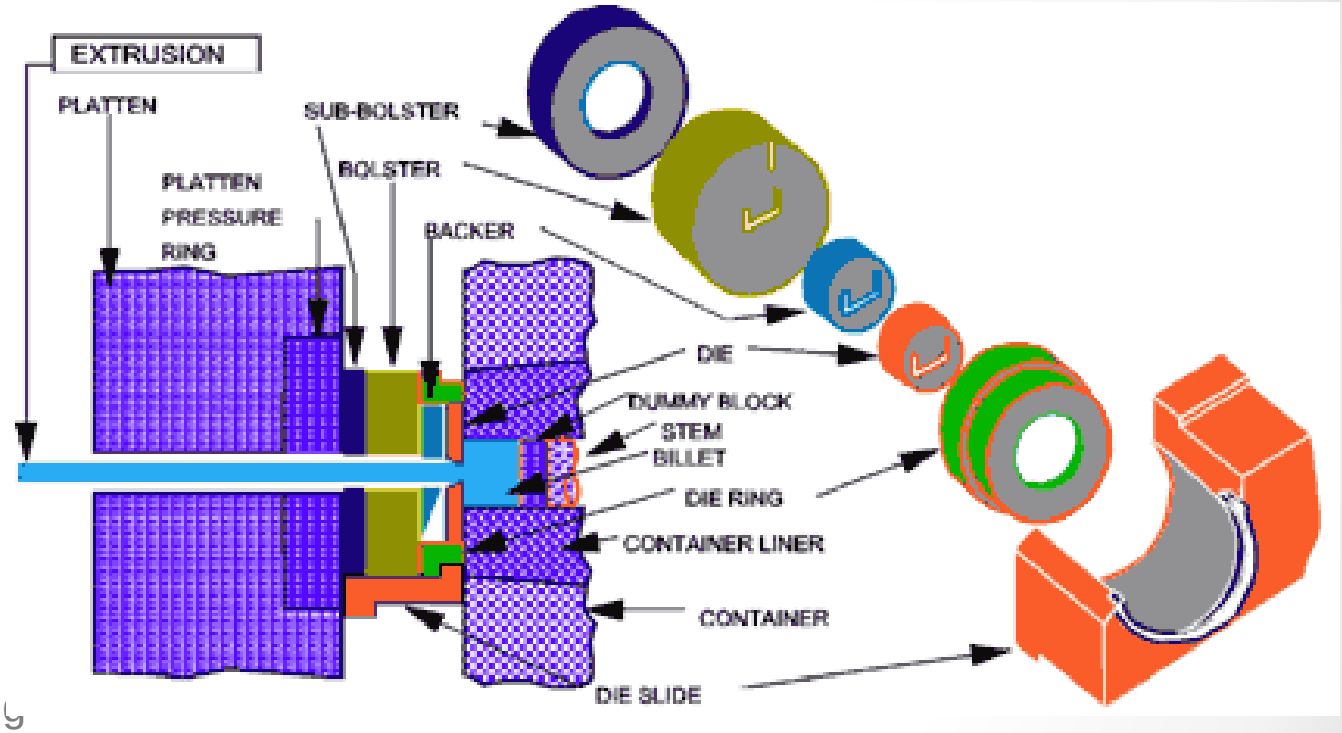

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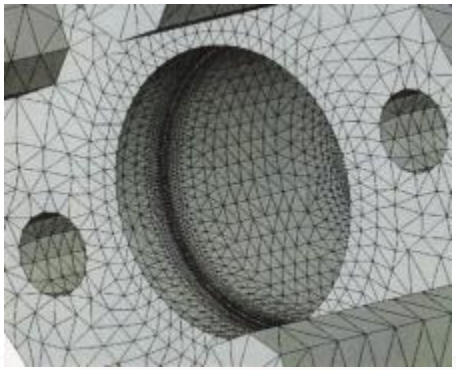

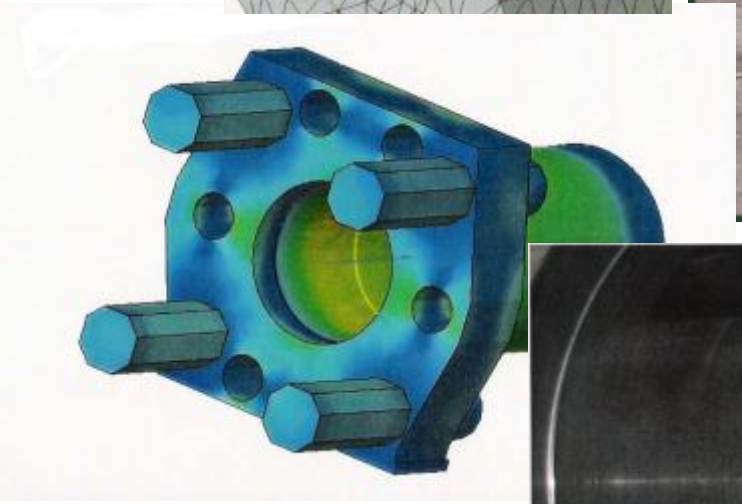

Courtesy of Extrusion Press Maintenance Manual

The Extrusion Process

- Tooling
  - Hollow Dies
  - Solid Dies
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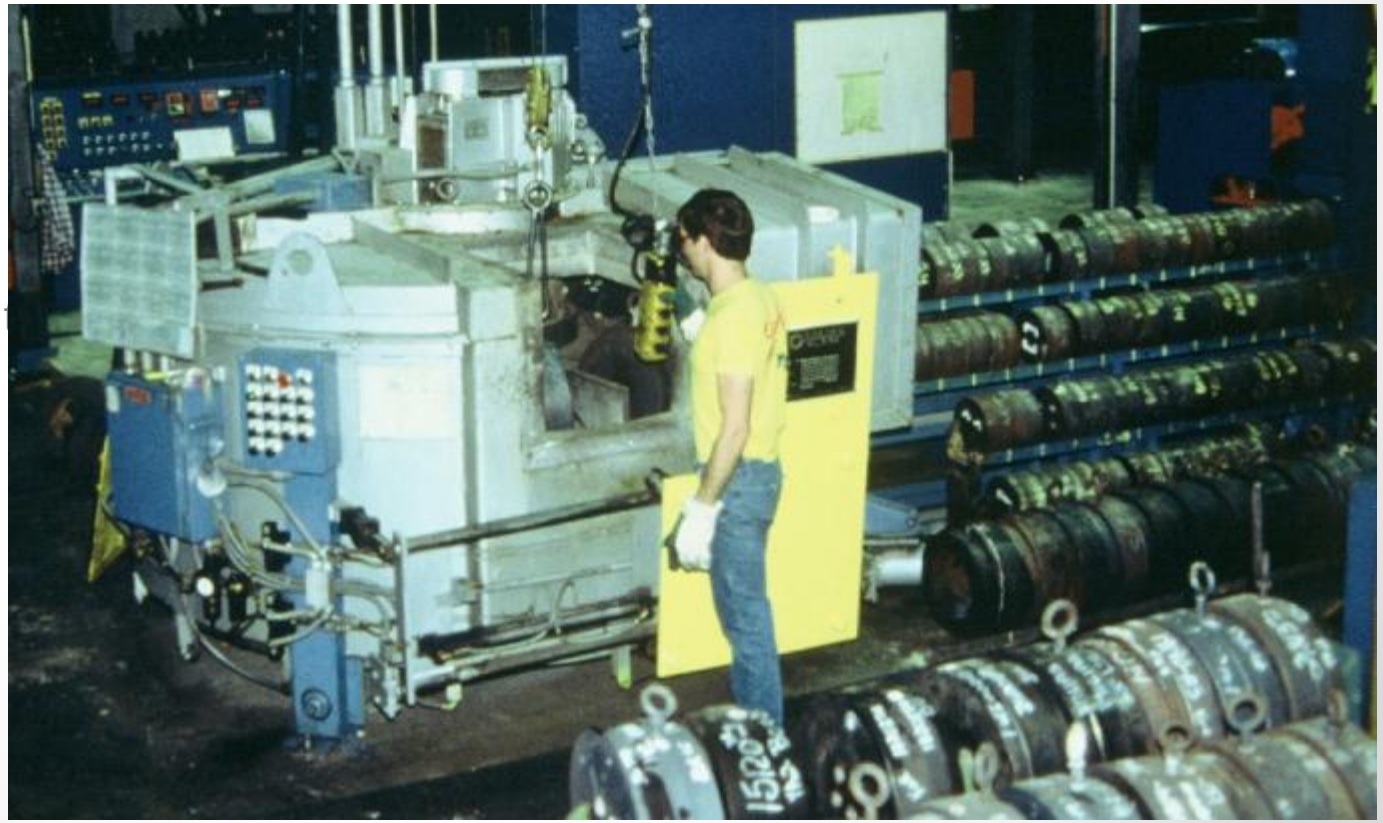
Courtesy of Werner Extrusion Solutions LLC



The Extrusion Process

- Tooling
  - Die Ovens

- Billet Furnace
- Extrusion Press
- Handling Equipment
- Finish Saw
- Aging System
- Fabrication & Finishing

Courtesy of Omav, Castool and Extrusion Pres Maintenance Manual

The Extrusion Process

- Tooling
- Billet Furnace
- Extrusion Press
- Handling Equip.
- Finish Saw
- Aging System
- Fabrication & Finishing

Courtesy of *Omav and Extrusion Press Maintenance Manual*

Courtesy of Werner Extrusion Solutions LLC

The Extrusion Process

- Tooling
- Billet Furnace
  - Cutting & Shearing Logs into Billets
- Extrusion Press
- Handling Equip.
- Finish Saw
- Aging System
- Fabrication & Finishing

Log Shear Photo Courtesy of *Omav and Extrusion Press Maintenance Manual*

Billet Saw Photo Courtesy of *B&O and Extrusion Press Maintenance Manual*

The Extrusion Process

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- Extrusion Press

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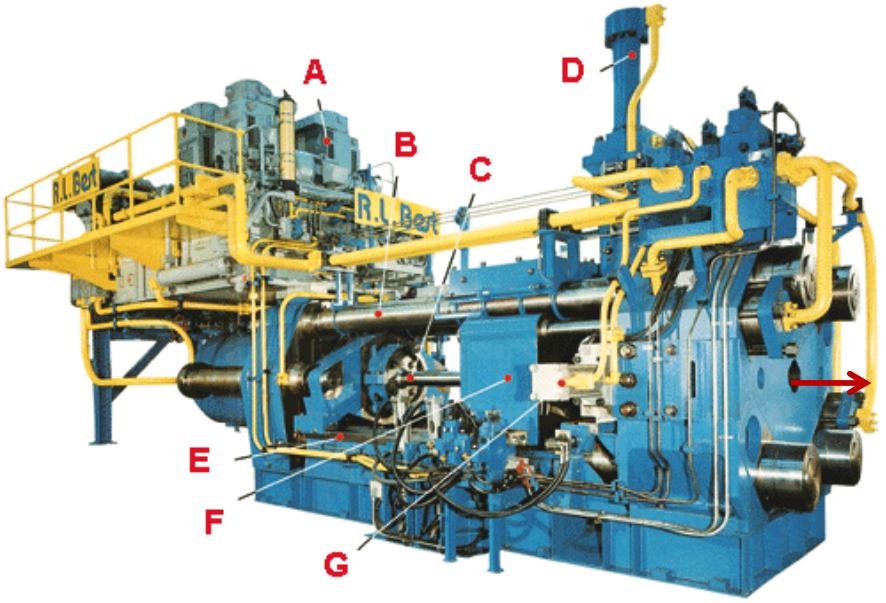
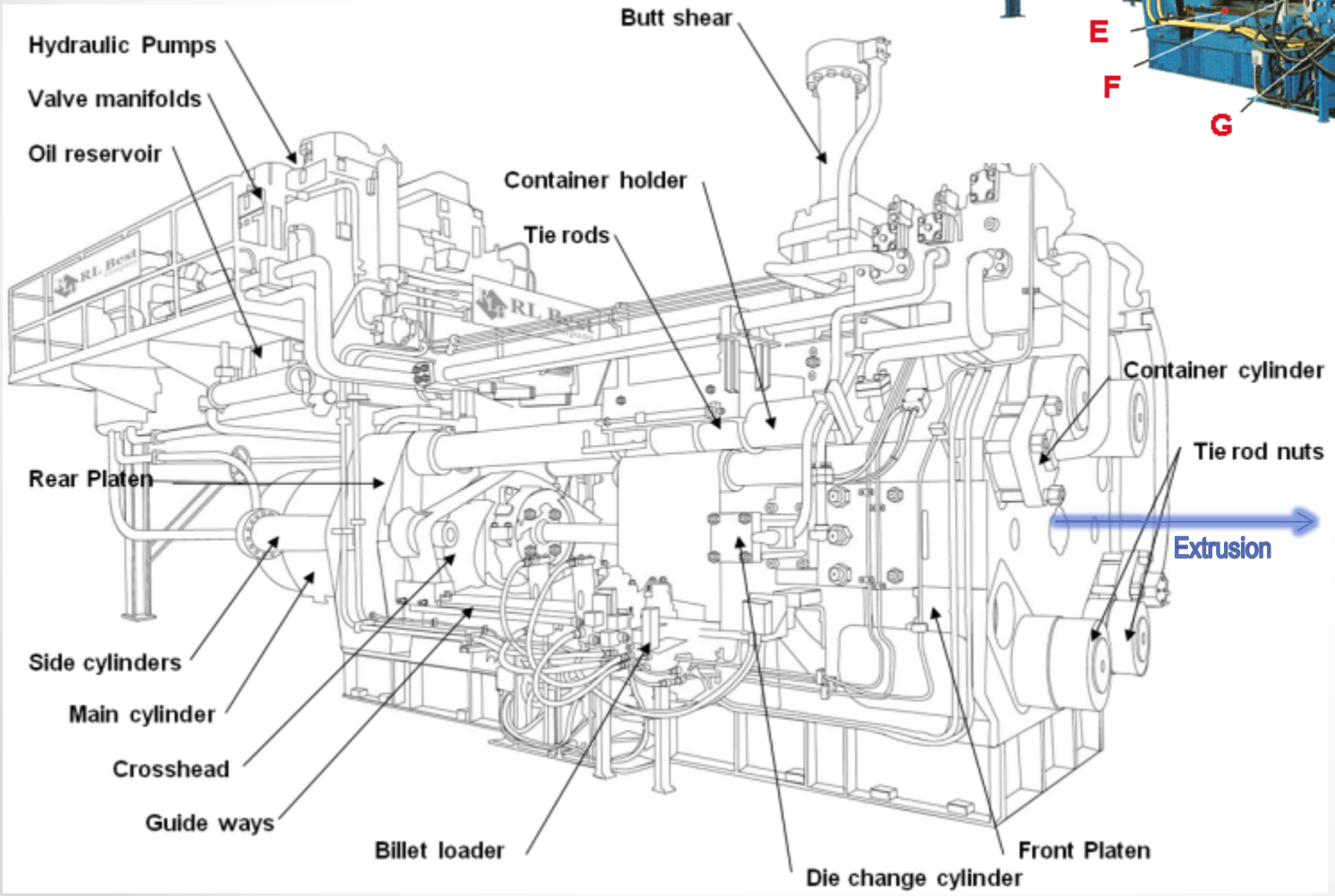


Courtesy of *Extrusion Press Maintenance Manual and RL Best*

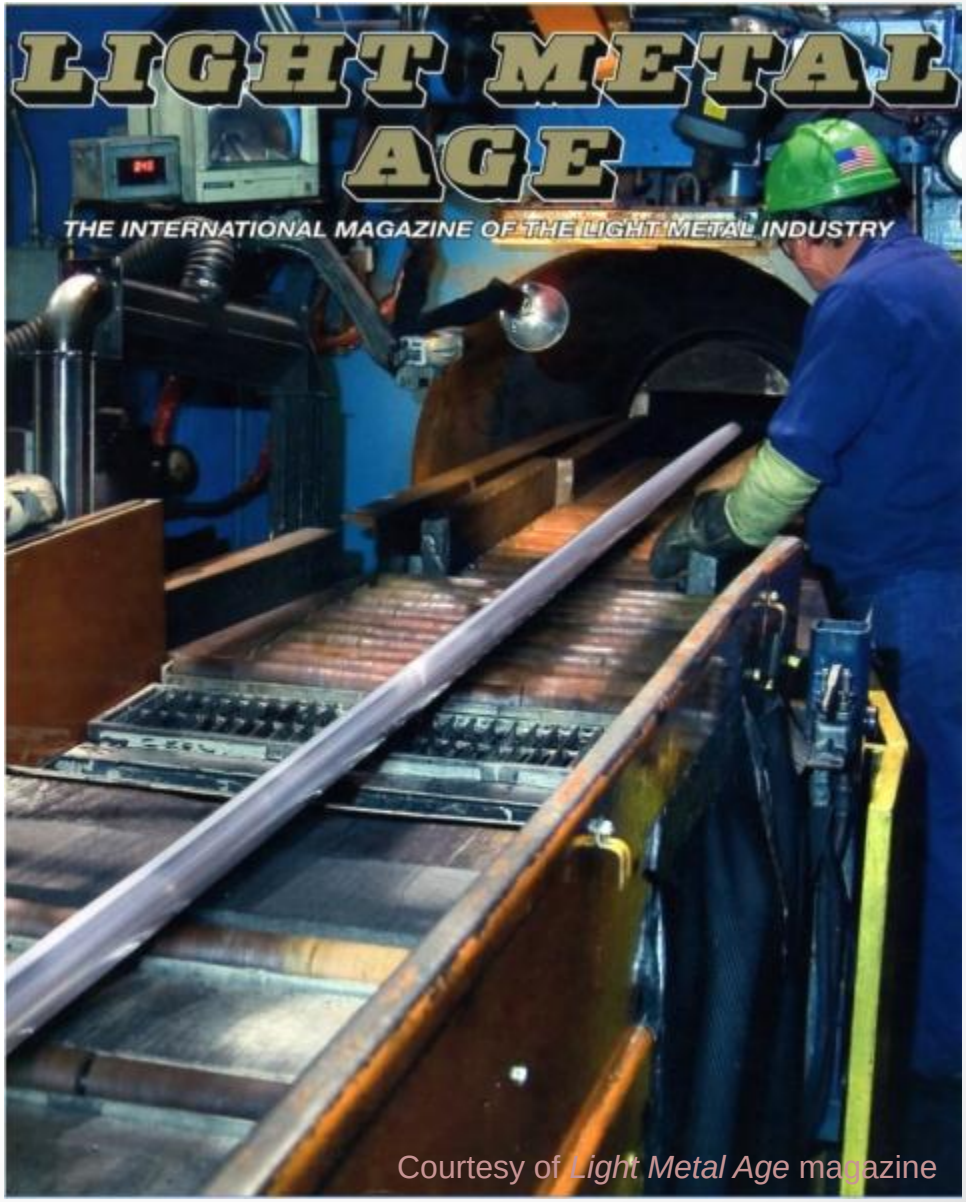


The Extrusion Process

- Tooling
- Billet Furnace

- **Extrusion Press**

- Handling Equipment
- Finish Saw
- Aging System
- Fabrication & Finishing



Courtesy of *Light Metal Age* magazine

The Actual Extrusion Process

- Tooling
- Billet Furnace
- Extrusion Press
- **Handling Equipment**
- Finish Saw
- Aging System
- Fabrication & Finishing

Courtesy of *Light Metal Age* magazine

The Actual Extrusion Process

- Tooling
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Courtesy of Werner Extrusion Solutions LLC

The Actual Extrusion Process

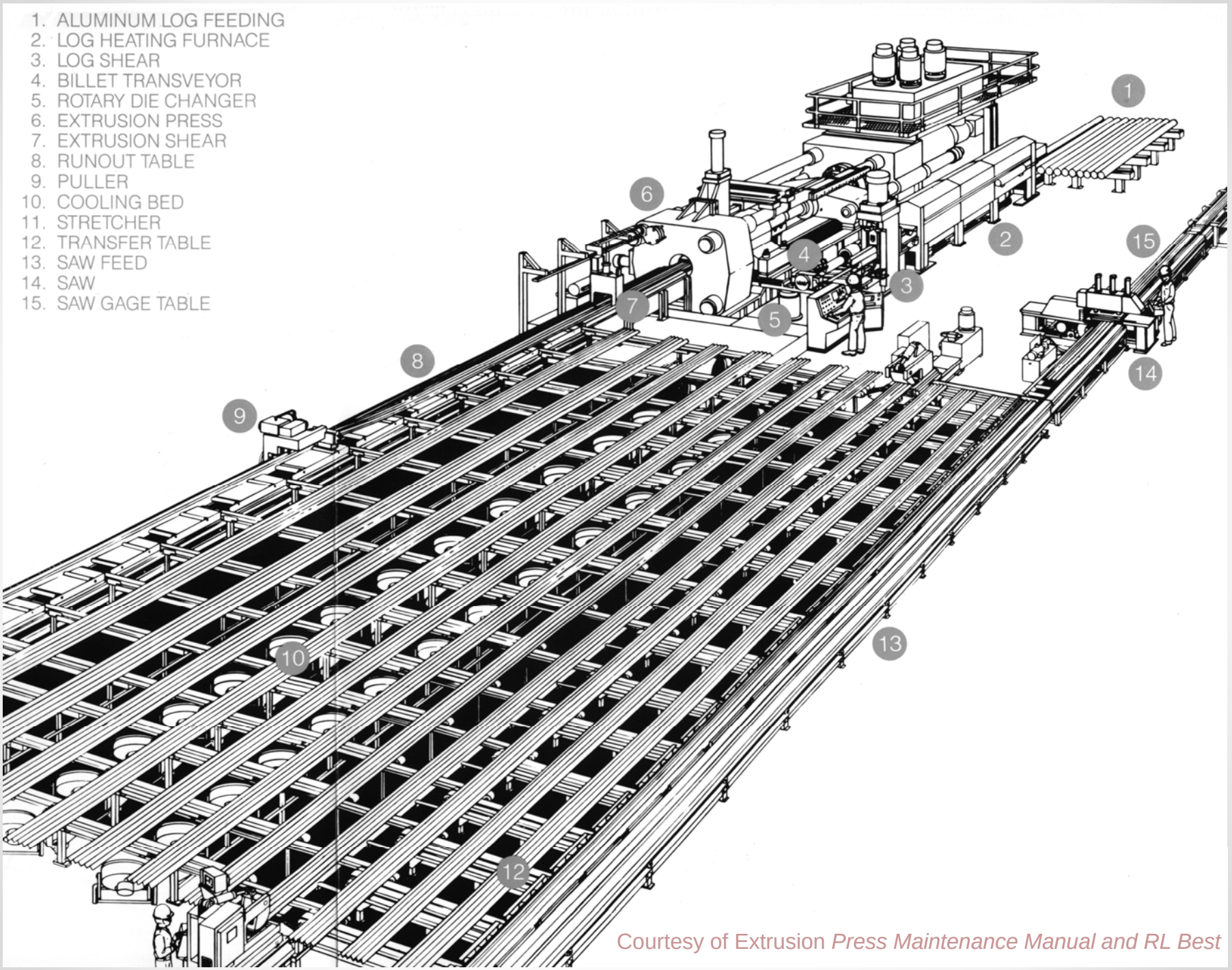
- Tooling
- Billet Furnace
- Extrusion Press

- Handling Equipment

- Finish Saw
- Aging System
- Fabrication & Finishing

Courtesy of Wemer Extrusion Solutions LLC

1. ALUMINUM LOG FEEDING
2. LOG HEATING FURNACE
3. LOG SHEAR
4. BILLET TRANSVEYOR
5. ROTARY DIE CHANGER
6. EXTRUSION PRESS
7. EXTRUSION SHEAR
8. RUNOUT TABLE
9. PULLER
10. COOLING BED
11. STRETCHER
12. TRANSFER TABLE
13. SAW FEED
14. SAW
15. SAW GAGE TABLE



Courtesy of Extrusion *Press Maintenance Manual and RL Best*

The Actual Extrusion Process

- Tooling
- Billet Furnace
- Extrusion Press
- Handling Equip.
- Finish Saw
- Aging System
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Courtesy of Werner Extrusion Solutions LLC

The Actual Extrusion Process

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Courtesy of Werner Extrusion Solutions LLC

The Actual Extrusion Process

- Tooling
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- Extrusion Press
- Handling Equip.
- **Finish Saw**
- Aging System
- Fabrication & Finishing

Courtesy of Werner Extrusion Solutions LLC

The Actual Extrusion Process

- Tooling
- Billet Furnace
- Extrusion Press
- Handling Equip.
- Finish Saw

- Aging System

- Fabrication & Finishing

The Actual Extrusion Process

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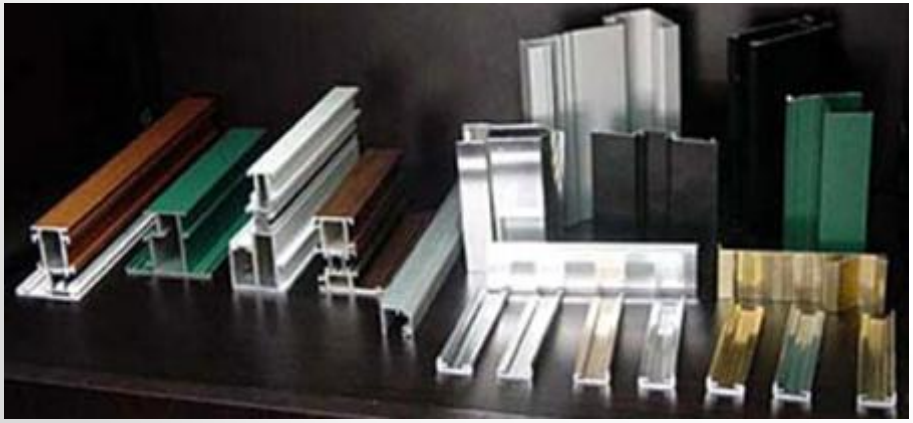


Courtesy of Werner Extrusion Solutions LLC

The Actual Extrusion Process

- Fabrication & Finishing: Anodizing

Extrusions are racked either horizontally or vertically.

Electrical contact with profiles is critical.

The Actual Extrusion Process

- Fabrication & Finishing: Anodizing

Courtesy Mid-States Aluminum Corp.

Racked extrusions are moved into a series of etching, anodizing and other tanks by crane.

The Actual Extrusion Process

- Fabrication & Finishing: Anodizing

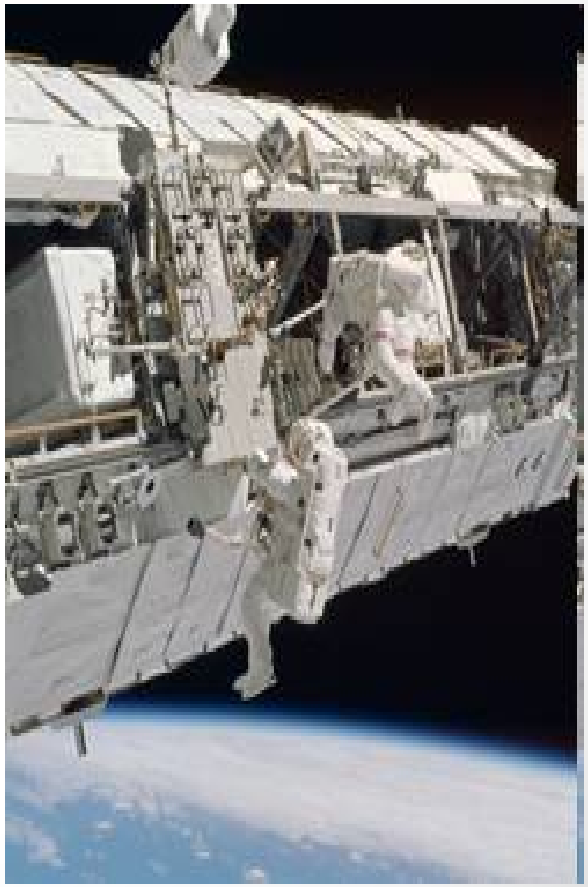
What Is Anodizing?

- Anodizing is an electrochemical process that converts the aluminum surface into a decorative, durable, corrosion-resistant, anodic aluminum oxide finish.

Courtesy of PFOnline.com

What Can Anodizing Do for Aluminum?

- The Anodic Oxide Finish Enhances:
  - Wear resistance
  - Lubricity
  - Electrical properties
  - Heat management
  - Corrosion resistance
  - Aesthetics
  - Bonding



What Can Anodizing Do for Aluminum?

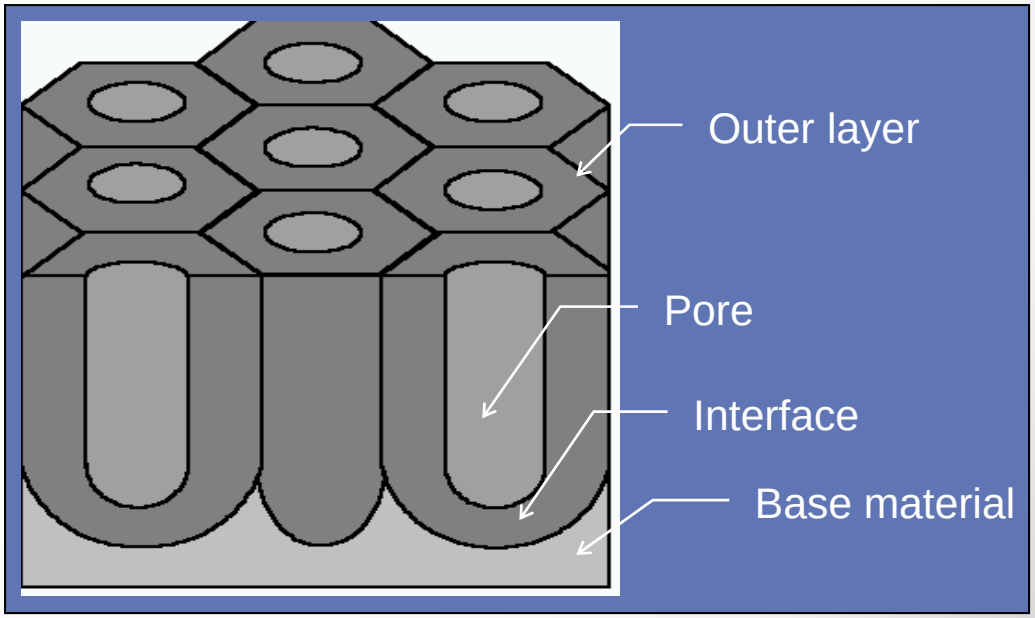
- It provides attractive, minimum-maintenance, highly durable exteriors, roofs, curtain walls, ceilings, floors, escalators, lobbies, and staircases in skyscrapers and commercial buildings throughout the world.
- It has revolutionized the construction of computer hardware, exhibit displays for trade shows, scientific instruments, and a constantly expanding array of home appliances, consumer products, and building materials.
- It is environmentally safe, producing few, if any, harmful effects on land, air or water.

The Anodic Oxide

- The anodic oxide structure originates from the aluminum substrate and is composed only of aluminum oxide.

- Total finish thickness, pore diameter and cell wall thickness range in size depending upon process parameters.

- The anodic oxide is integrated with the underlying aluminum for total bonding resulting in a finish with no filiform corrosion and unmatched adhesion.



The Anodic Oxide

- The anodic oxide is integrated with the aluminum substrate, and has a highly ordered, porous structure that allows for secondary processes, e.g., organic and inorganic coloring, and a variety of seals that enhance its end use.

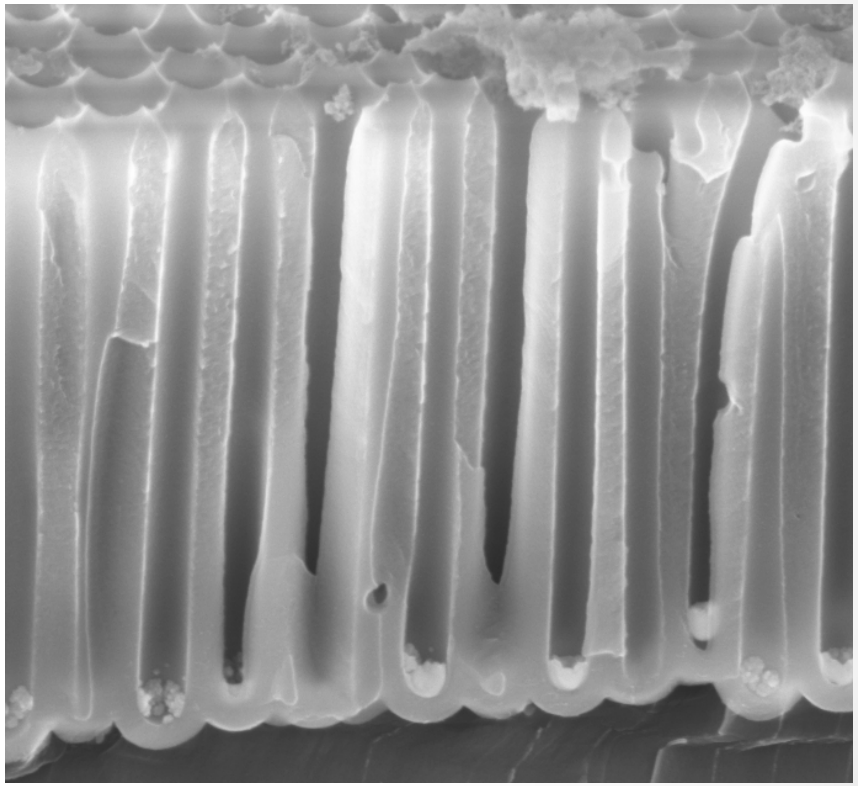
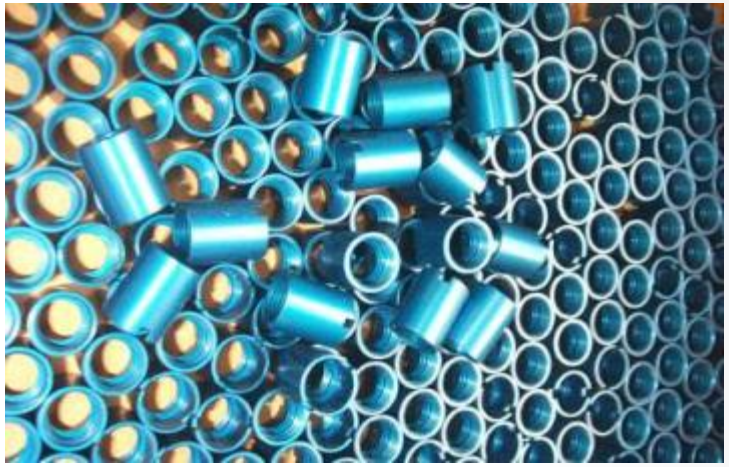


Photo courtesy of FEM, Schwäbisch Gmünd, Germany

Benefits of the Anodic Oxide

- **Durability.** Most anodized products have an extremely long life span and offer significant economic advantages through maintenance and operating savings.
- **Color Stability.** Exterior anodic coatings provide good stability to ultraviolet rays, do not chip or peel, and are easily repeatable.
- The unique dielectric properties of an anodized finish offer many opportunities for electrical applications.



Photos courtesy of the Aluminum Anodizers Council

Benefits of Anodizing

- **Ease of Maintenance.** Scars and wear from general use (fabrication, handling, installation, frequent surface cleaning) are virtually nonexistent. Rinsing or mild soap-and-water cleaning usually will restore an anodized surface to its original appearance. Mild abrasive cleaners can be used for more difficult deposits.

- **Aesthetics.** Anodizing offers a large and increasing number of gloss and color alternatives, and minimizes or eliminates color variations. Unlike other finishes, anodizing allows the aluminum to maintain its metallic appearance.

Benefits of Anodizing

- **Cost**. A lower initial finishing cost combines with lower maintenance costs for greater long-term value.
- **Health and Safety:**
  - Anodizing is a safe process that is not harmful to human health. An anodized finish is chemically stable, will not decompose, is nontoxic, and is heat-resistant to the melting point of aluminum (1,221°F).
  - Since the anodizing process is an enhancement of a naturally occurring oxidation process, it is non-hazardous and produces no harmful or dangerous by-products.
  - The anodic oxide is recyclable with the aluminum substrate.

Common Anodic Oxide Types

- Hard Anodizing (or Type III anodizing) is a term used to describe the production of anodic oxides characterized by high hardness and abrasion resistance. They are produced using special anodizing conditions (very low temperature, high current density).
- Conventional Anodizing (or Type II anodizing) increases the decorative corrosion resistance of the aluminum component. It can be dyed to produce many beautiful colors and printed with graphics and photo images. They are produced at room temperature and lower current density.

Common Applications for Anodizing

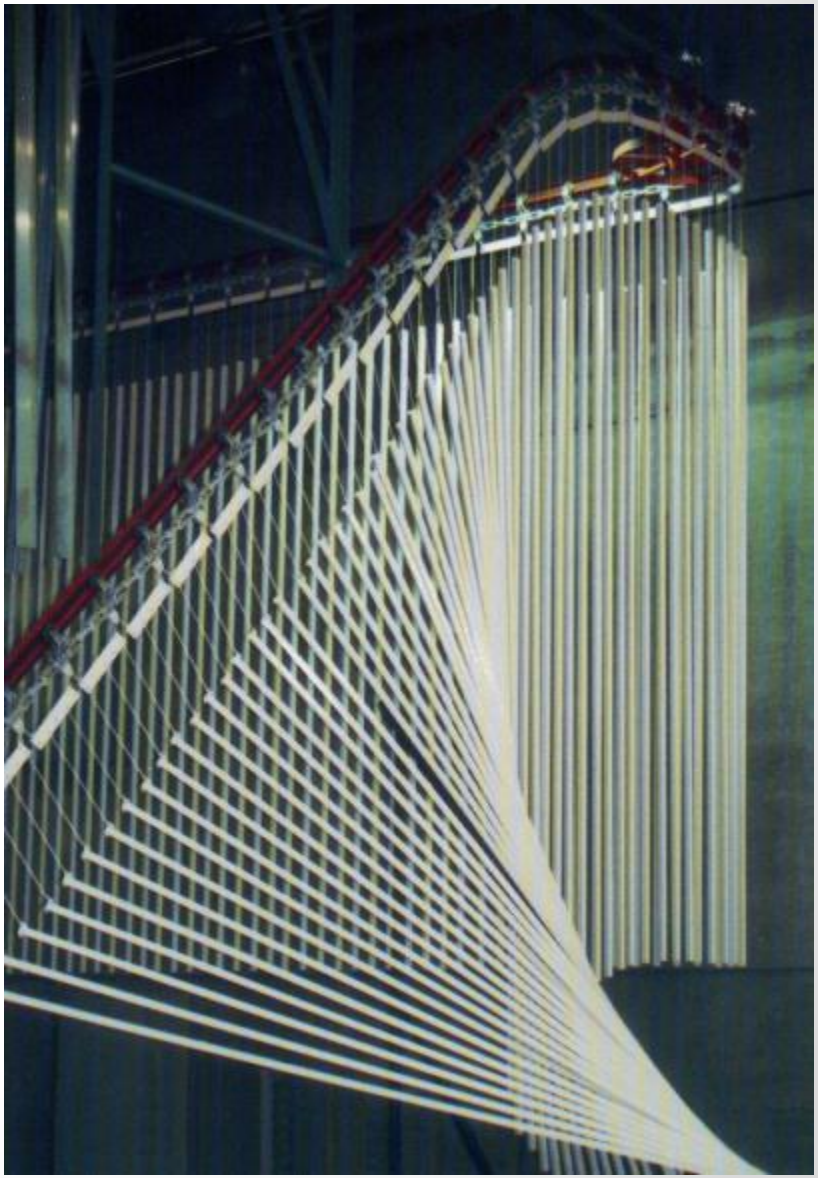
- Structures and architectural categories of all types
- Commercial and residential building products
- Motor vehicle components

Common Applications for Anodizing

- Appliances
- Food preparation equipment
- Furniture
- Sporting goods and boats

Fabrication & Finishing: Painting

Extrusions are typically painted in either horizontal or vertical paint lines, using either liquid paint or powder coat.



Why Coat Extruded Aluminum?

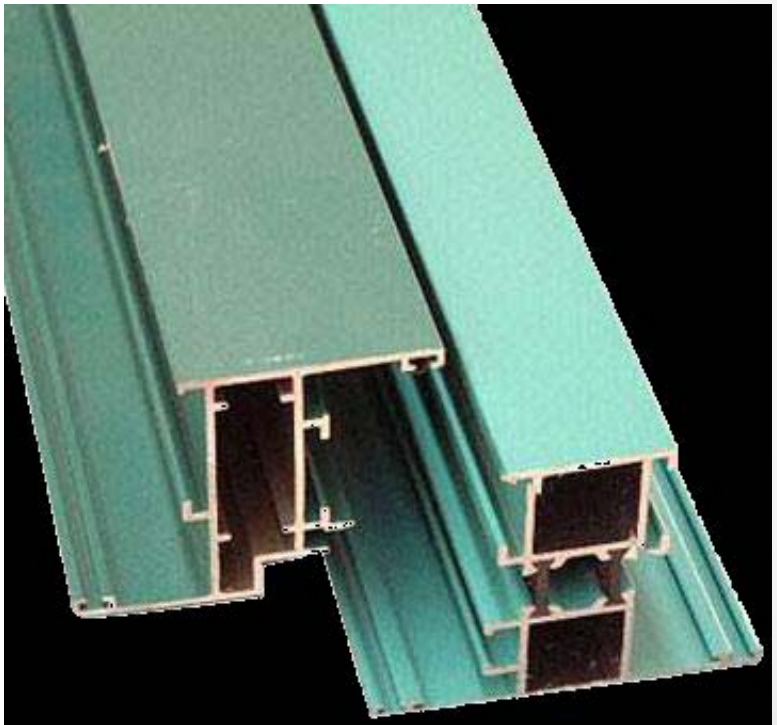
- Cosmetic Function:
  Control the Appearance
  - o Color Coordination
  - o Visual Uniformity

- Protective Function:
  Guard the Substrate
  - o from Environmental Damage
    - Acid Rain, other Pollutants
    - Salt Spray
  - o from Excess Oxidation

Photos courtesy of Bill Hanusik/Akso Nobel

Why Coat Extruded Aluminum?

- Coated Aluminum Extrusions are used in a variety of end uses
  - Building Products
    - Commercial Windows
    - Curtain Wall
    - Column covers
    - Residential Windows
  - Transportation
    - RV and Bus windows
    - Windshield frames
  - Specialty
    - Sports Equipment
    - Solar Panels



Courtesy of PPG Coil & Extrusion Coatings

Versatility of Coatings

Courtesy of Bill Hanusik and Akzo Nobel

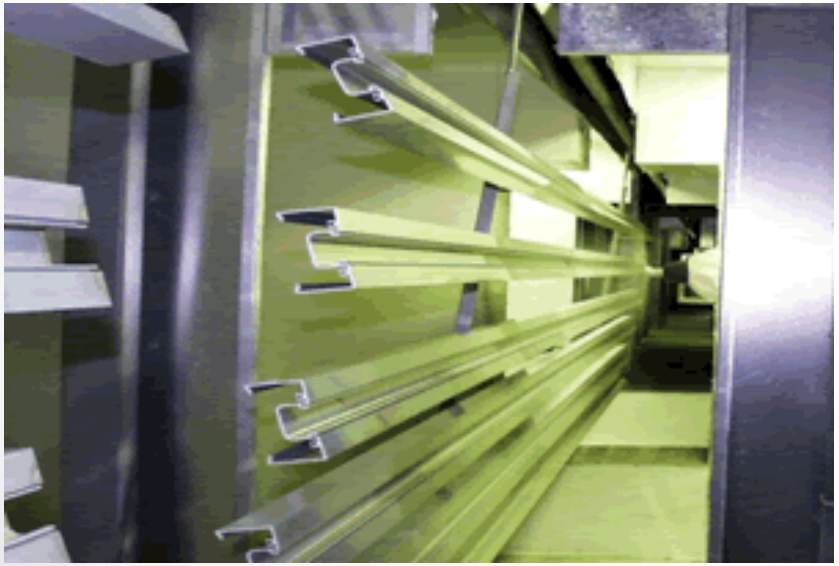
- Range of Resin Chemistries
- Grades of Performance Properties *(fading/warranty)*
- Visual Finishes
- Costs

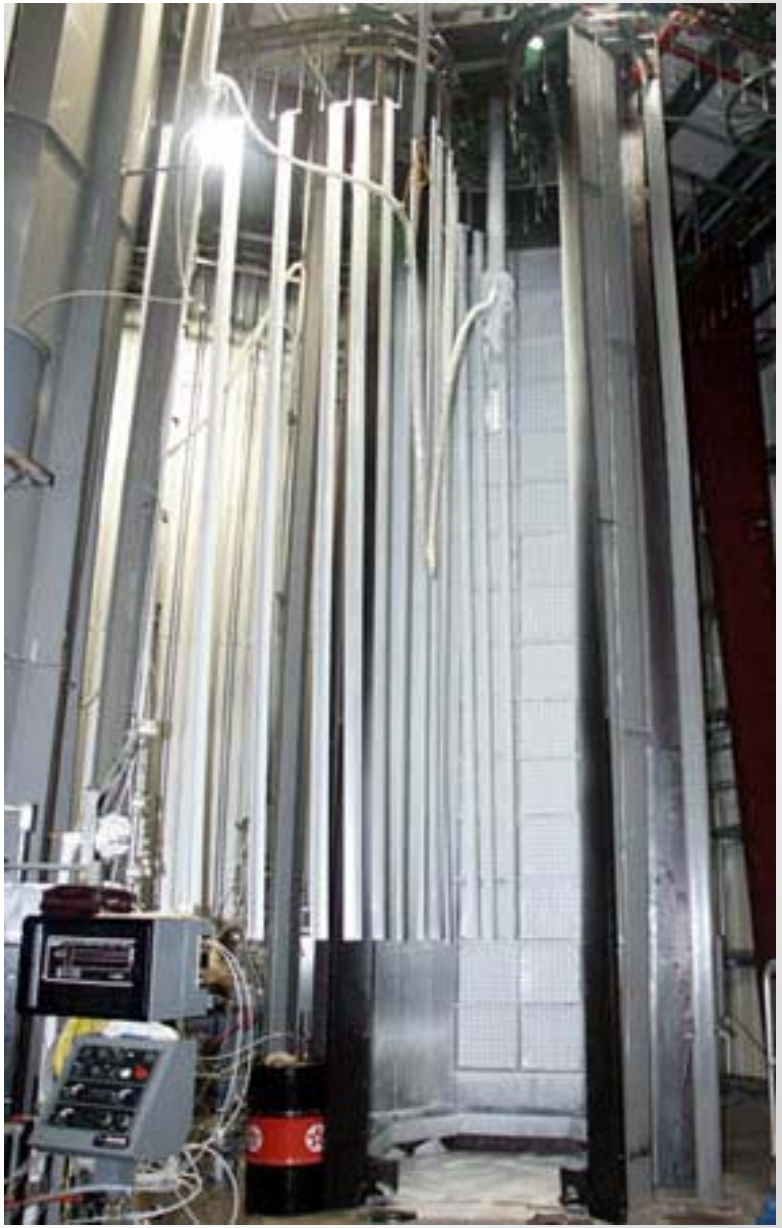
Fabrication & Finishing: Painting

A wide variety of colors are possible.

Liquid Paint and Powder Coat

- Cleaning and Pretreatment
- Electrostatic Spray Application
- Cure





Formulations Based on Resin Type

- Polyester
- Acrylic
- Modified Polyester
- Fluoropolymer

Resin Type	VOC [1]	Color Range	# of Coats	Performance[2]	Properties	Applications
Polyester	low	wide selection	1	AAMA 2603	good film integrity, good color retention, good exterior durability, wide gloss range	primary & replacement windows, light fixtures, miscellaneous extruded aluminum profiles
Acrylic	high	wide selection	1	AAMA 2603	good film integrity, good color retention, good exterior durability, wide gloss range	primary & replacement windows, light fixtures, miscellaneous extruded aluminum profiles
Siliconized Polyester	medium	wide selection	1 or 2	AAMA 2603	better than pure polyester; improved durability	same as polyester; light commercial applications
Fluoropolymer	high	somewhat limited	2 (3-4) (color depndt.)	AAMA 2604 and 2605	best overall weather-ability, longest color life and gloss retention, best flexibility and chemical resistance	spandrel panels, curtainwall, store fronts, windows, column covers, louvers, mullions, high exposure areas

1. Relative level of VOCs (as shown here) applies only to liquid coatings; powder coatings contain little or no VOCs.
2. Not all coatings will meet these performance characteristics.

Comparing Liquid and Powder Coatings

LIQUID

- Brighter "Metallic" Colors
- Smoother Finish
- Salt-Spray Resistance (e.g., Seacoast)
- Proven History (mature technology)

POWDER

- No Volatile Organic Compounds (VOCs)
- Harder Finish
- Fabrication might require less Touch-up
- Overspray can be Reclaimed

Comparing Liquid and Powder Coatings

- Liquid Coatings offer more metallic choices than powder
- Powder coatings are available in a wide range of solid and mica pigment effects.
- Silver metallic finishes are the preferred choice for curtainwall applications.
- Silver mica's are a good design choice in powder
- Powder Coatings exhibit superior hardness in use. They have long been used for applications like motor cycle frames, lawn mowers, mountain bikes and appliances for a hard finish
- Powder Coatings show an advantage in use in areas where architectural metal is exposed to abrasion like storefronts and entry doors.

Comparing Liquid and Powder Coatings

	Liquid Coating	Powder Coating	Comments
Emissions	–	+	Powder coatings have no VOC. (~1% volatiles, ½ H_2O)
Waste	–	+	Powder coatings produce less waste during application.
Energy Use	–	+	Can be 30% less than liquid
Film Builds	+/–	+/–	Powder can be applied at higher film builds than liquid. Although this is a benefit from a surface protection standpoint, it needs to be considered in engineering and fabrication process.
Appearance	+	–	Liquid coatings can be smoother than powder coatings, which exhibit some fine 'orange peel' effect. Although orange peel has been minimized in modern formulations, liquid can still achieve a smoother finish. Slight textures can minimize surface imperfections.
Material Transfer/Use	–	+	Both technologies use electrostatic application techniques. Powder coatings have no solvents that evaporate during application like liquid coatings. Powder use can offer over 95% transfer efficiency when powder overspray is recovered for re-use on large runs with standard colors.
Metallic Colors	++	–	Bright metallic color based on aluminum flake is better in liquid technology. Powder metallic looks are available using mica effect pigments.
Corrosion Resistance (seacoast environments)	+	–	Single coat powders on aluminum are susceptible to filiform corrosion in industrial or marine environments. Multi-coat powder or combination systems show promise, but need a track record as technology develops.

Courtesy of AIA

Environmental Considerations

- Powder Coatings contain no VOC's
- VOC's can be burned with liquid coatings, but require energy and emit CO2.
- Powder Coatings use less energyin transportation
- Liquid Coatings may be advantageous from an environmental perspective in certain environments.

Although environmentally preferable factory applied coatings contribute to the sustainability of a project, they do not contribute to the attainment of LEED points on a project.

AAMA Market Segments

Monumental Buildings

AAMA 2605

Liquid in US Powder in Europe.

Most are Mettalics or Micas

Specification Driven

Light Commercial Institutional/ Education/ Small Office Buildings

AAMA 2605. 2604

Specification Driven

Liquid in US, Powder in Europe Today

Mix of Mettalics, Micas and Solid Colors

Commercial Window/ Storefront

- AAMA 2605, 2604
- Manufacturer and Architect Driven

Residential Windows

- AAMA 2604, 2603
- Manufacturer Driven

Other Applications

- Fencing, Hand Rails, Accents
- AAMA 2605, 2604, 2603

Courtesy of AIA

Examples of Coatings

34 Story, Midtown Towers IV Lofts, Miami, FL. Windows, Sliding Glass Doors and Railings.

Liquid Paint

Ritz Carlton, Grand Cayman, extruded railings, awnings, windows and doors.

Powder Coat

Courtesy of AIA

Examples of Coatings

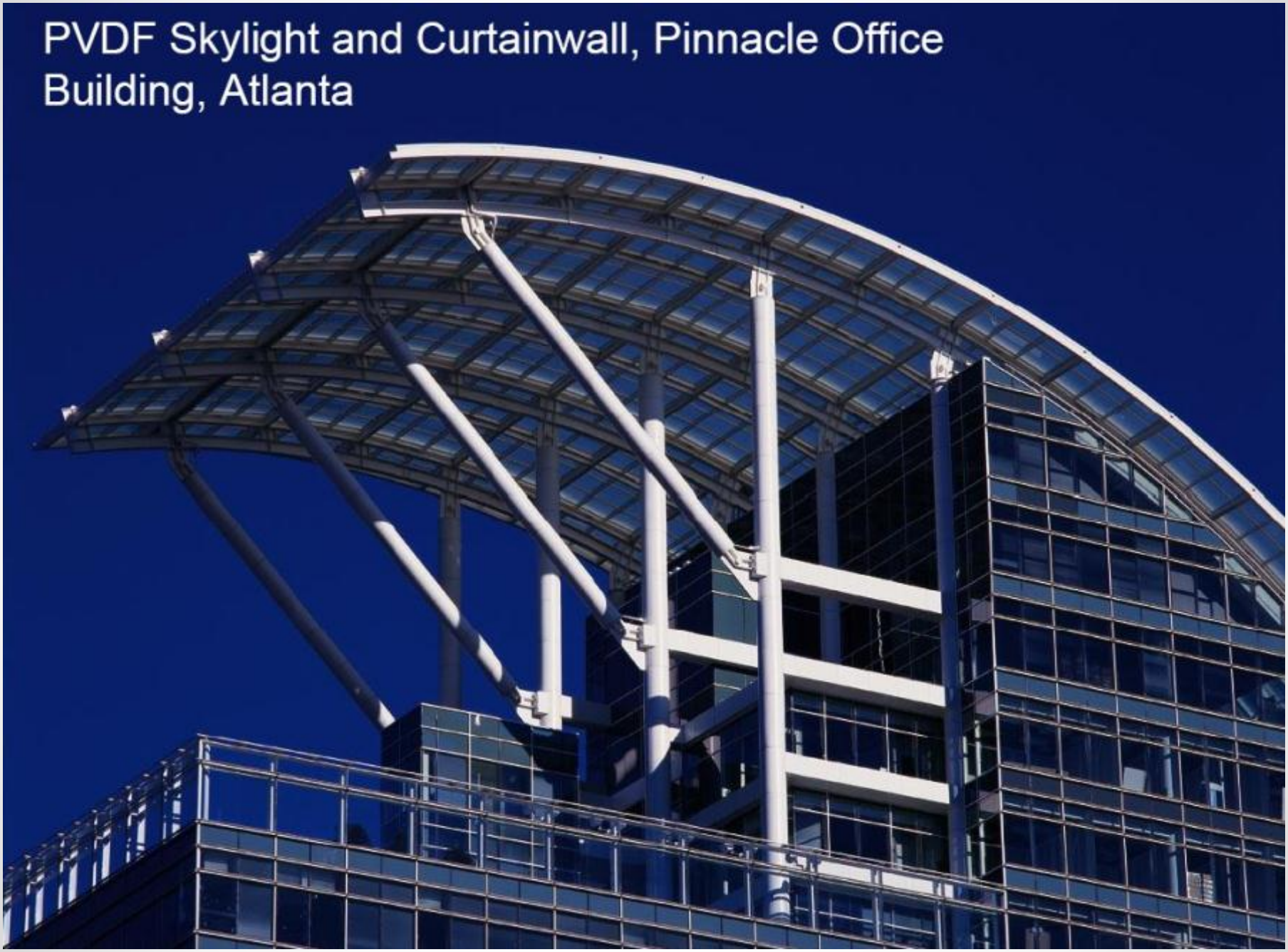
Courtesy of AIA

Naples Florida Municipal Parking Garage,
Extruded aluminum sun screens
and decorative railings.

Powder Coat

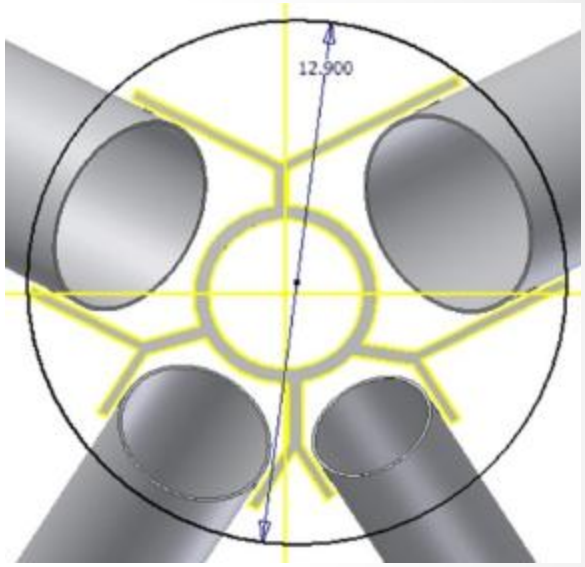
AOL Timer Warner Building,
Manhattan, New York,
Extruded aluminum louvers,
windows and doors.

Powder Coat


PVDF Skylight and Curtainwall, Pinnacle Office Building, Atlanta

Some Limitations of the Aluminum Extrusion Process

- Circle Size
  - The circumscribing circle that the profile could fit through
- Wt/Ft
  - Too heavy? Too light?
- Shape Constraints
  - High tongue ratios
  - Somewhat balanced wall thicknesses
  - Other



Some Limitations of the Aluminum Extrusion Process

Cross Section Area in sq inches	Circumscribed Circle Size in inches					Corresponding Profile weight (lbs/ft)	
	<1	1 to 7	7 to 10	10 to 14	>14	Min	Max
<.050	L	x	x	x	x	-	0.06
.050 to .100	G	G	L	x	x	0.06	0.12
.100 to 1.0	**W**	**W**	L	x	x	0.12	1.18
1.0 to 2.5	x	**W**	**W**	L	x	1.18	2.94
2.5 to 10	x	**W**	**W**	G	L	2.94	11.76
>10	x	x	**W**	G	L	11.76	-

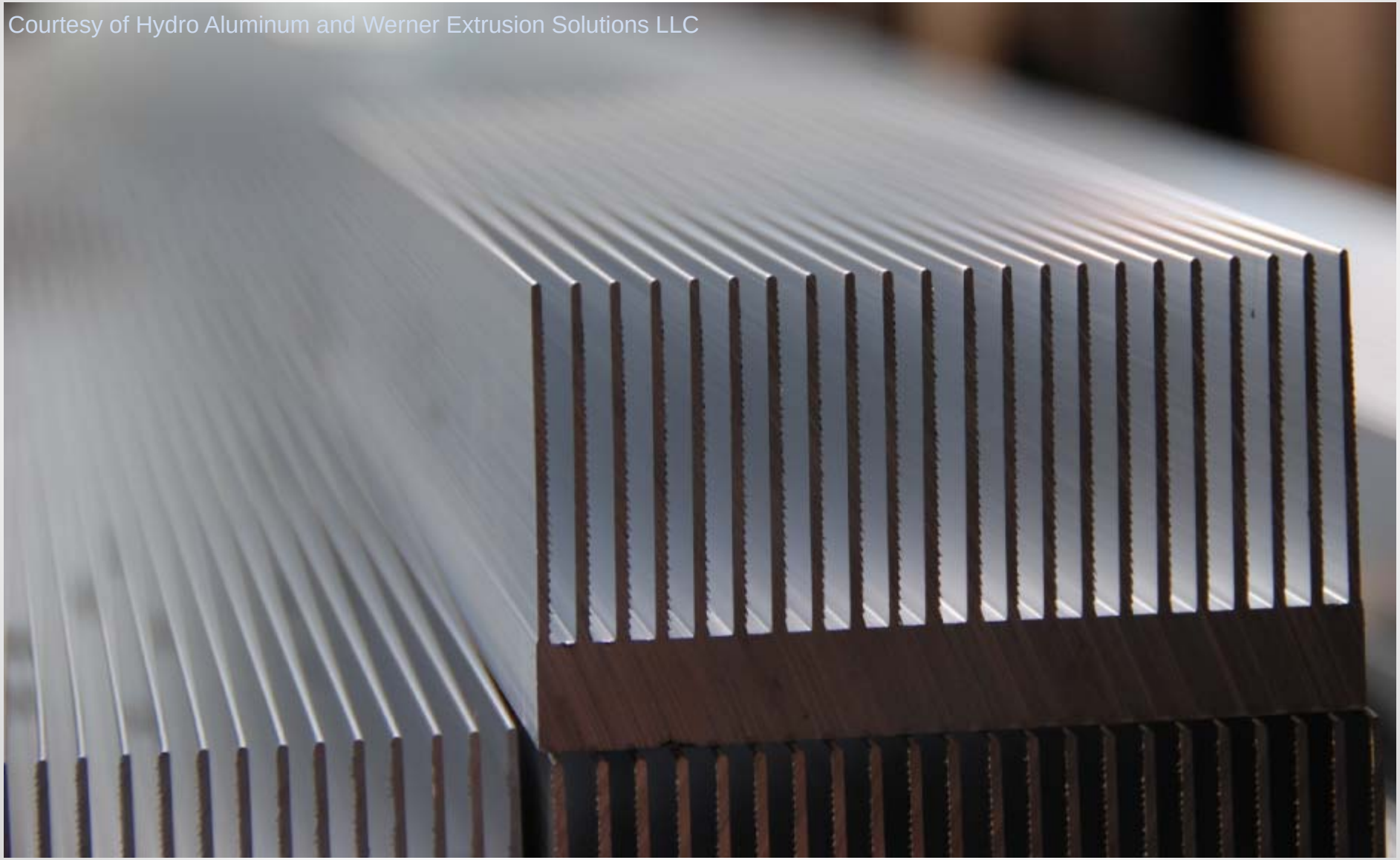
x	Not available
L	Limited Availability
G	Generally Available
W	**Widely Available**

NOTE:

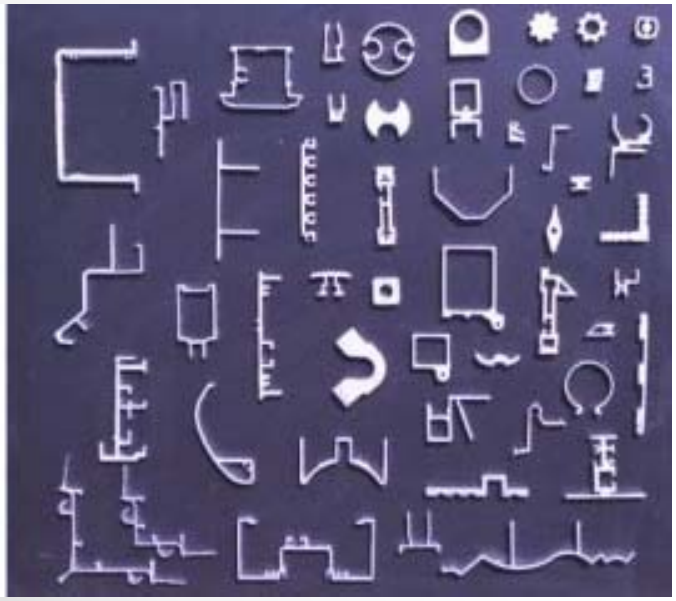
There are many presses available with up to 7" diameter containers
There are fewer presses available with 7" to 10" diameter containers
There are even fewer presses available with 10" to 14" diameter containers
There are very few presses available with greater than 14" diameter containers

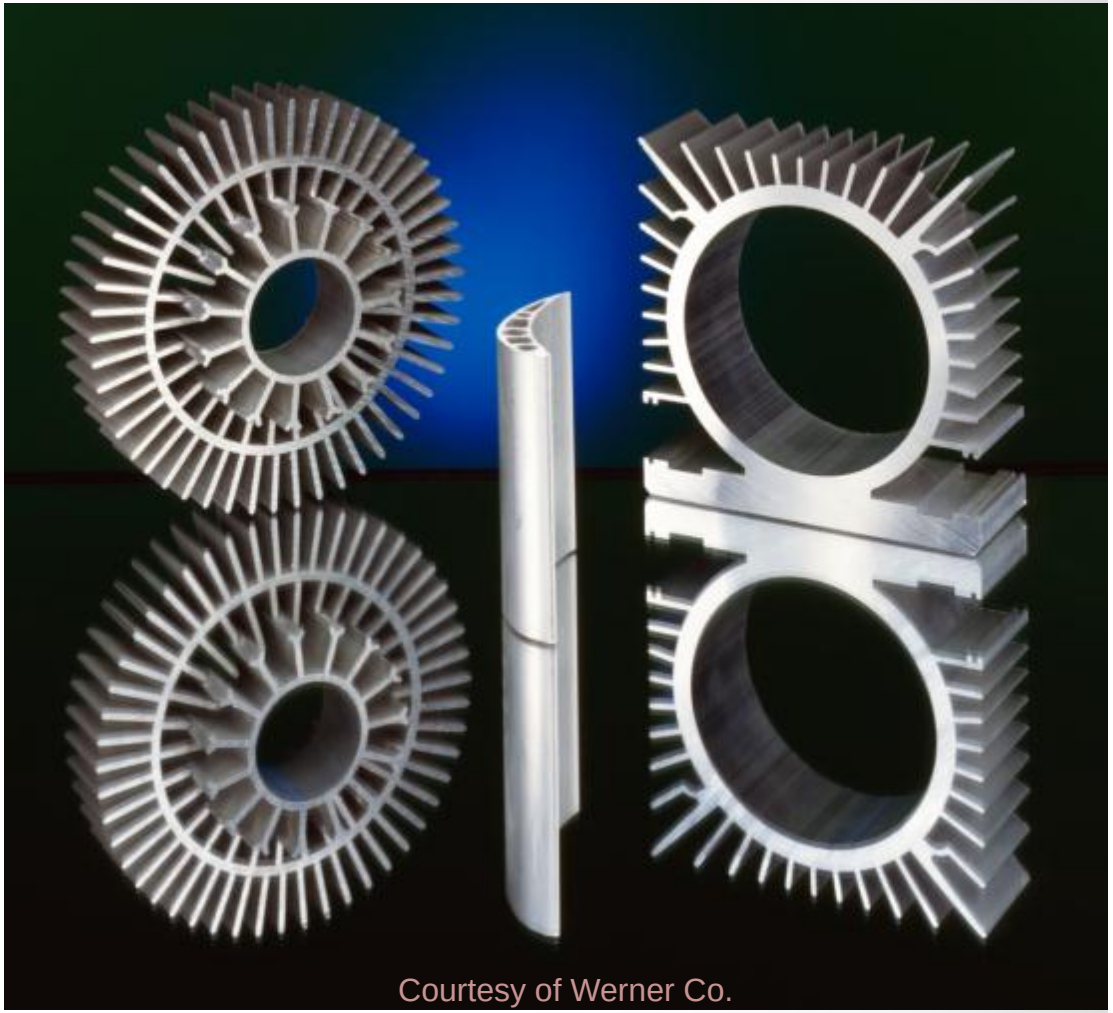
Examples of Aluminum Extrusions

Difficult Tongue Ratio



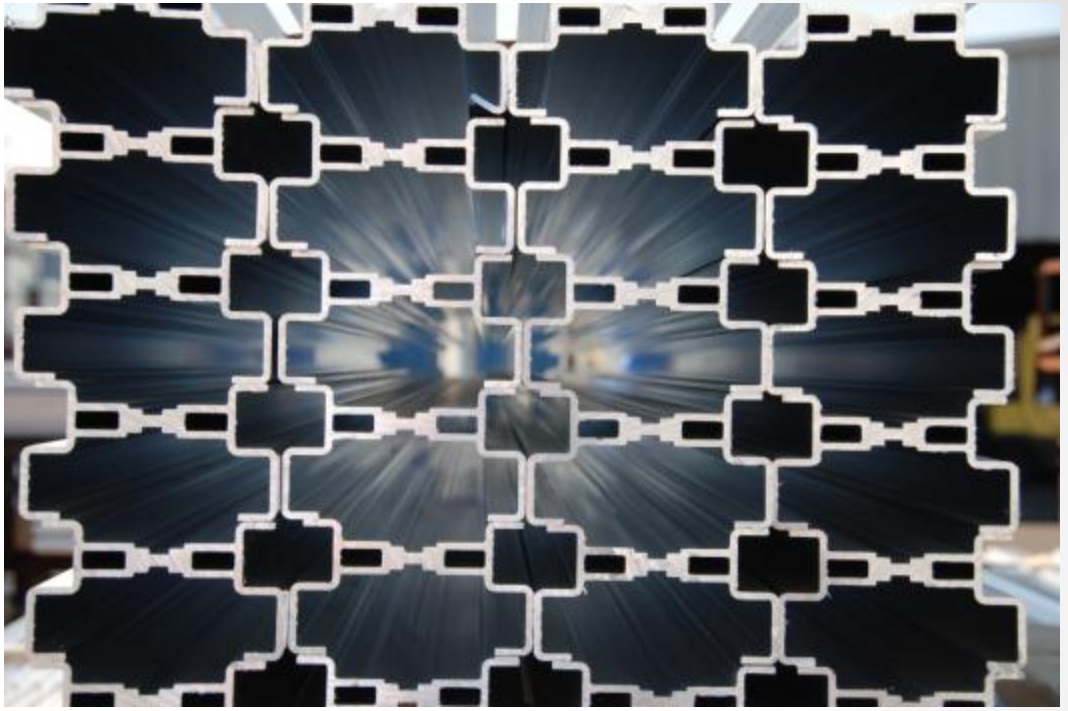
Examples of Aluminum Extrusions

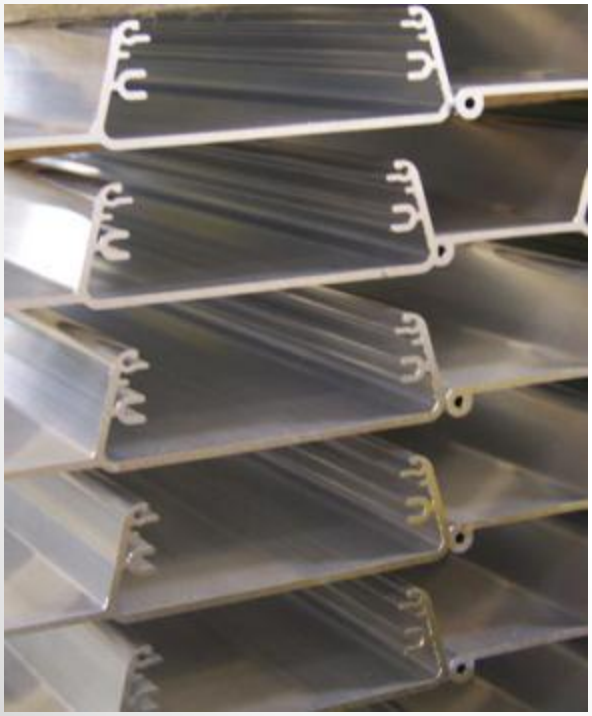




Courtesy of Werner Co.

Examples of Aluminum Extrusions





Courtesy of Hydro Aluminum and Werner Extrusion Solutions LLC

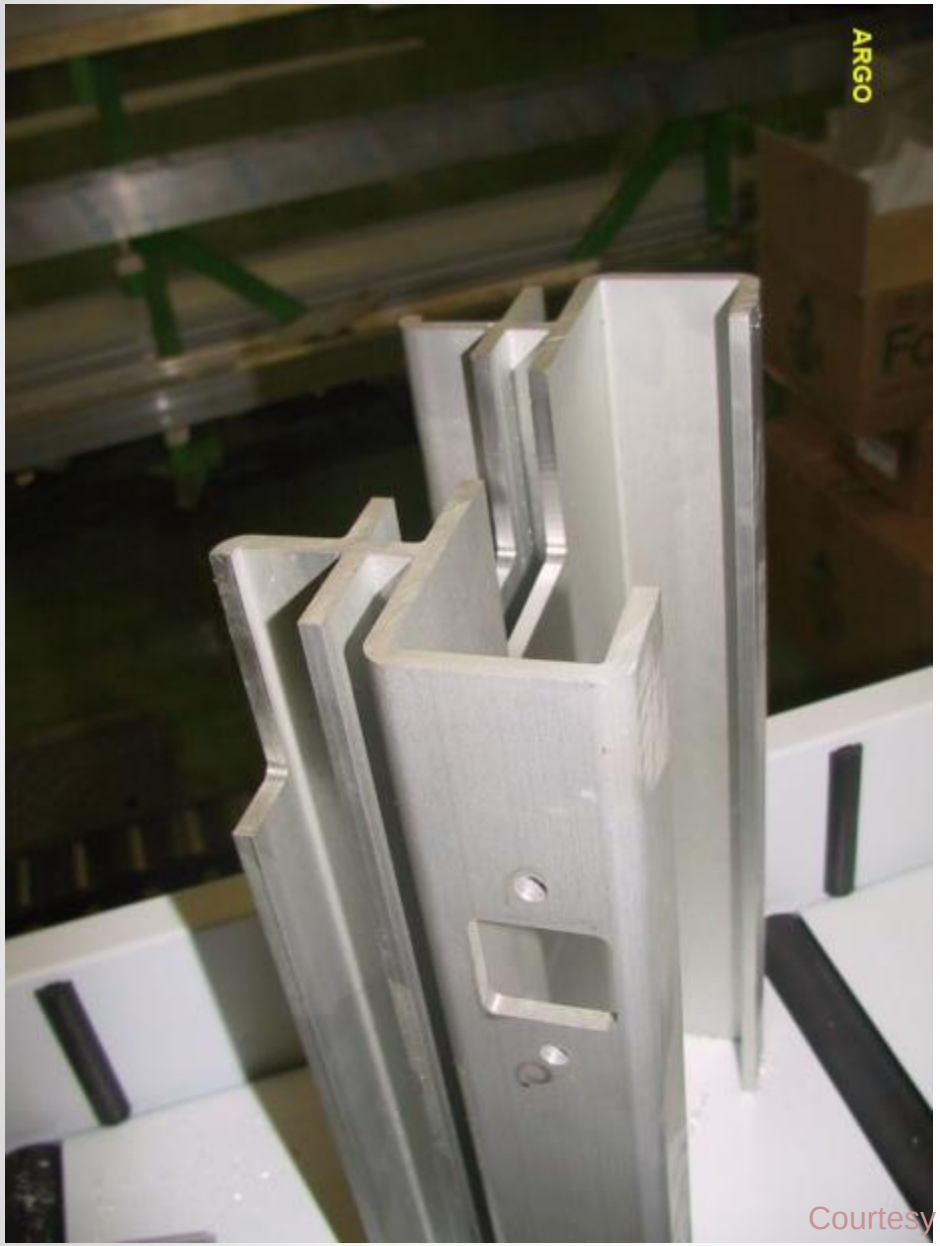
Fabrication of Aluminum Extrusions

While standard cutting, drilling, tapping, milling and other machining operations can be done effectively on aluminum extrusions, there are custom machines designed to optimally fabricate both large and small shapes, in both short and long sizes

Fabrication of Aluminum Extrusions

Courtesy of FOM USA

Fabrication of Aluminum Extrusions



Courtesy of FOM USA

Fabrication of Aluminum Extrusions

Courtesy of FOM USA

Examples of Aluminum Extrusions

Modular assembly

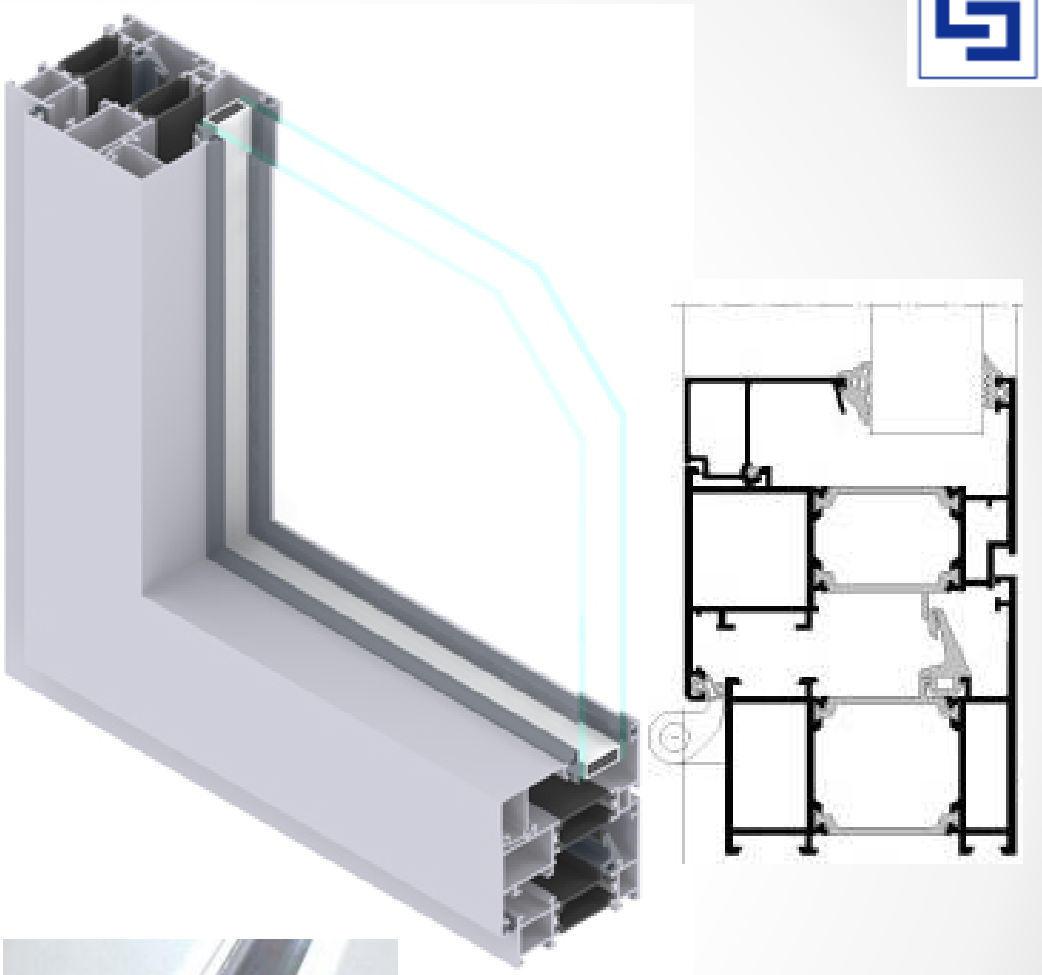
TECHNOFORM **BAUTEC**

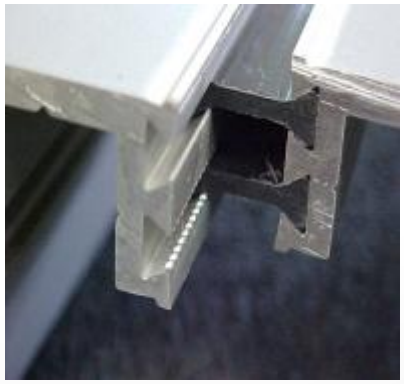
Polyamide
Insulating Struts

- 30 year old method of thermally breaking aluminum fenestration products.

- Allows for separating an aluminum profile into two parts to reduce thermal conductivity within a window or door system.

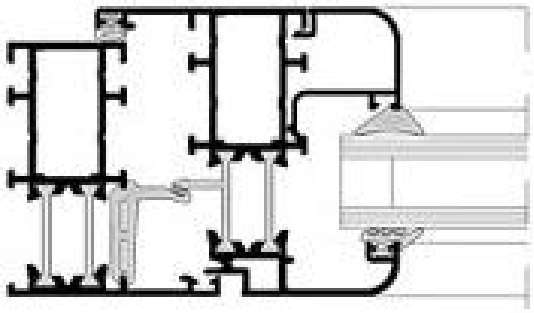
- The three step assembly process includes knurling of the aluminum pocket, insertion of the strut, and crimping the assembly to create a structural, mechanical bond.

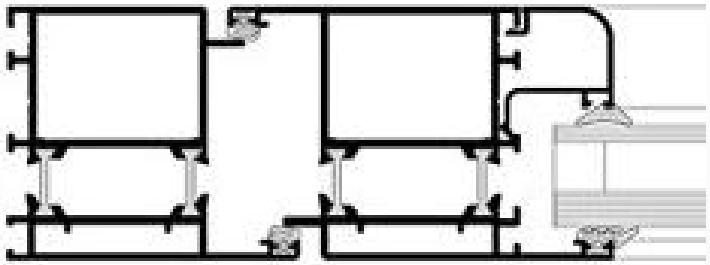




Design/drawing courtesy of Gastadello Sistemi

TECHNOFORM **BAUTEC**

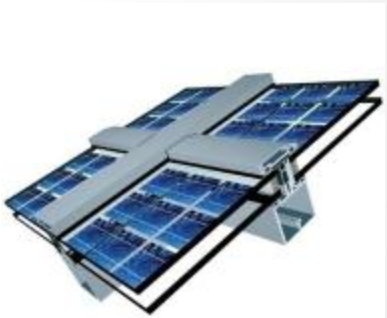




Design/drawing courtesy of
www.gastadellosistemi.it

Examples of Aluminum Extrusions

Building-Integrated Photovoltaic insulating glass modules framed in extruded aluminum



Photos courtesy of Schüco International KG

Examples of Aluminum Extrusions

Courtesy of *Light Metal Age* magazine

Examples of Aluminum Extrusions

Courtesy of *Light Metal Age* magazine

Examples of Aluminum Extrusions

Telecommunications Industry

- Extruded from 6061 alloy
- Machined in a 5 axis CNC fixture
- Straightlined mechanical finish applied
- No anodic coating applied

Examples of Aluminum Extrusions

Electronics Industry

- Extruded from 6063
- T5 Temper
- Heat dissipation enclosure – transferring thermal energy from a high temperature object to a 2nd object of a lower temperature
- Machined in a multi-axis CNC machining center
- Clear sulfuric anodize finish

Courtesy of Alexandria Extrusion

Examples of Aluminum Extrusions

Defense Industry

- Extruded from 6061 alloy
- T6 Temper
- Machined in a 4th-axis CNC fixture
- ExtremEtch™ matte finish – minimal reflectivity in comparison to Alkaline etch
- Mil Spec Type III hardcoat – black

2014 International Aluminum Extrusion Design Competition

www.etfoundation.org

www.aec.org

Design, Architect, and Engineering Students:

Apply what you've learned about design and engineering by entering the International Aluminum Extrusion Design Competition. It's an excellent opportunity for a hands-on learning experience with the potential for professional recognition and earned scholarships.

Student Class Scholarship Awards

Enter the competition to receive the recognition you so richly deserve; gain pride and a sense of accomplishment. And, of course, there are the scholarships totaling **$8,500!**

Student Class Scholarships:	
1st place	$3000
2nd place	$2000
3rd place	$1000
Sapa Sustainable Design:	**$2,500**

Sapa Extrusions North America is the Exclusive Platinum sponsor of the 2014 Design Competition

Sustainable Design Award

- **Promotes aluminum's "green" advantages**
  - Will be presented to the student entry that
  - Meets the four basic judging criteria: creativity, practicality, process improvement, and market potential
  - Best addresses societal and/or environmental concerns
  - Is a viable extrusion-based product that meets the demands of the environment while contributing to the quality of life for its intended users.
- **Examples :**
  - A device that helps a third world farmer increase crop yields with less labor
  - An item that facilitates daily living for the handicapped or elderly

Past Design Competition Winners and Honorable Mentions

ET Foundation DESIGN COMPETITION BOARDSLIDE DESCRIPTIVE

THE BOARDSLIDE PROJECT STARTED OUT
WITH THE REALIZATION THAT THERE ARE VIRTUALLY
NO PROPER BRACKETS FOR HANGING
SKATEBOARDS ONTO A WALL.

ALSO, RESEARCH SHOWED THAT
OVER 2 MILLION SKATEBOARD DECKS
END UP IN LANDFILLS EACH YEAR.

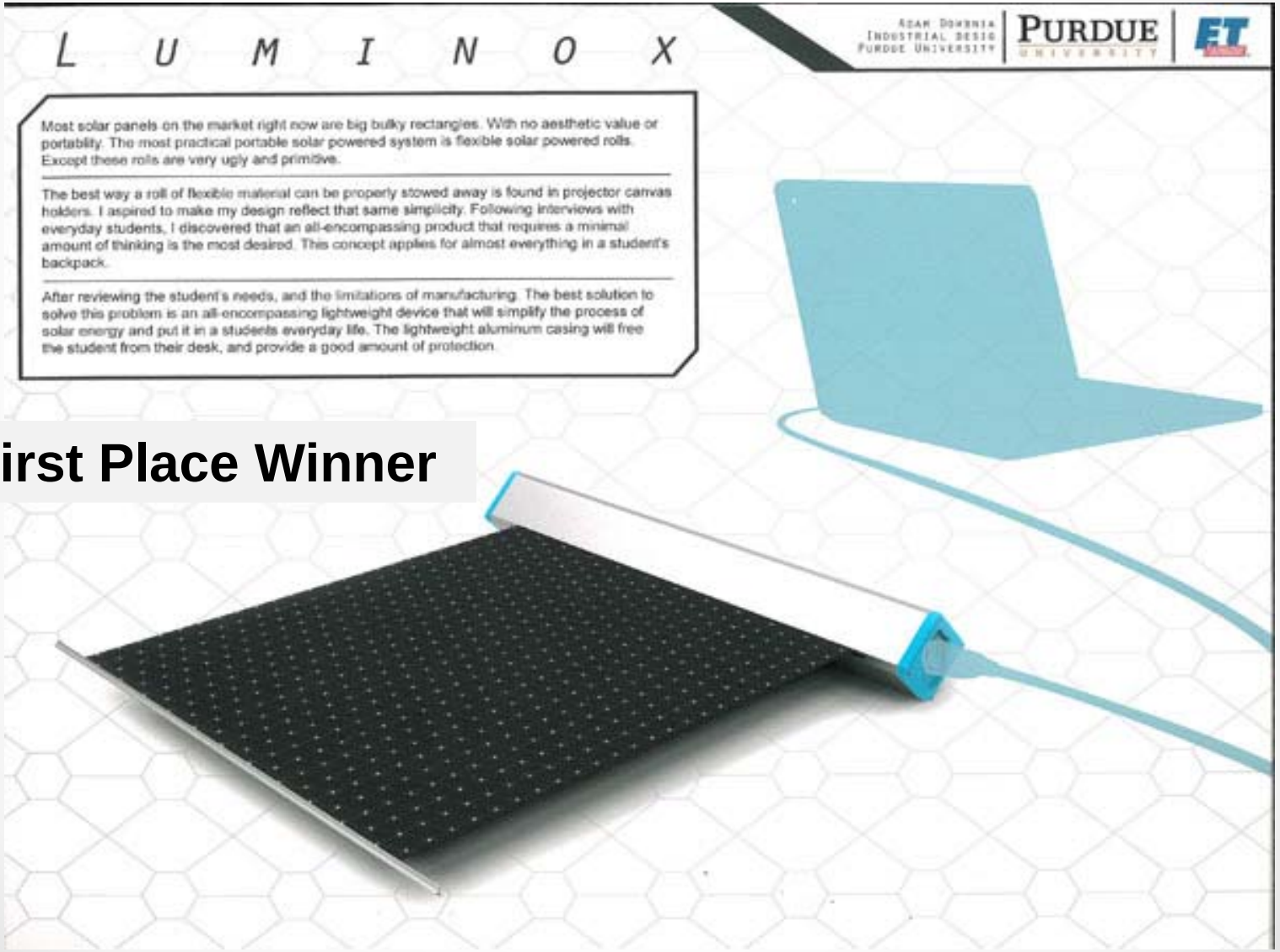
SO THE INNEVITABLE HAPPENED:
DESIGN A BRACKET
THAT WILL PERMIT
FIXING BOARDS
TO A WALL,
EITHER AS A HOLDER
FOR SKATEBOARDS
OR AS A BRACKET TO MAKE
A SHELF, REUSING OLD DECKS.

BECAUSE OF ITS ENCAPSULABLE PROFILE
PRINCIPLE, THE ALUMINUM EXTRUSION PROCESS
WAS SELECTED FOR THE MAIN
COMPONENTS OF THIS PRODUCT.

2014 Sustainable Design Winner

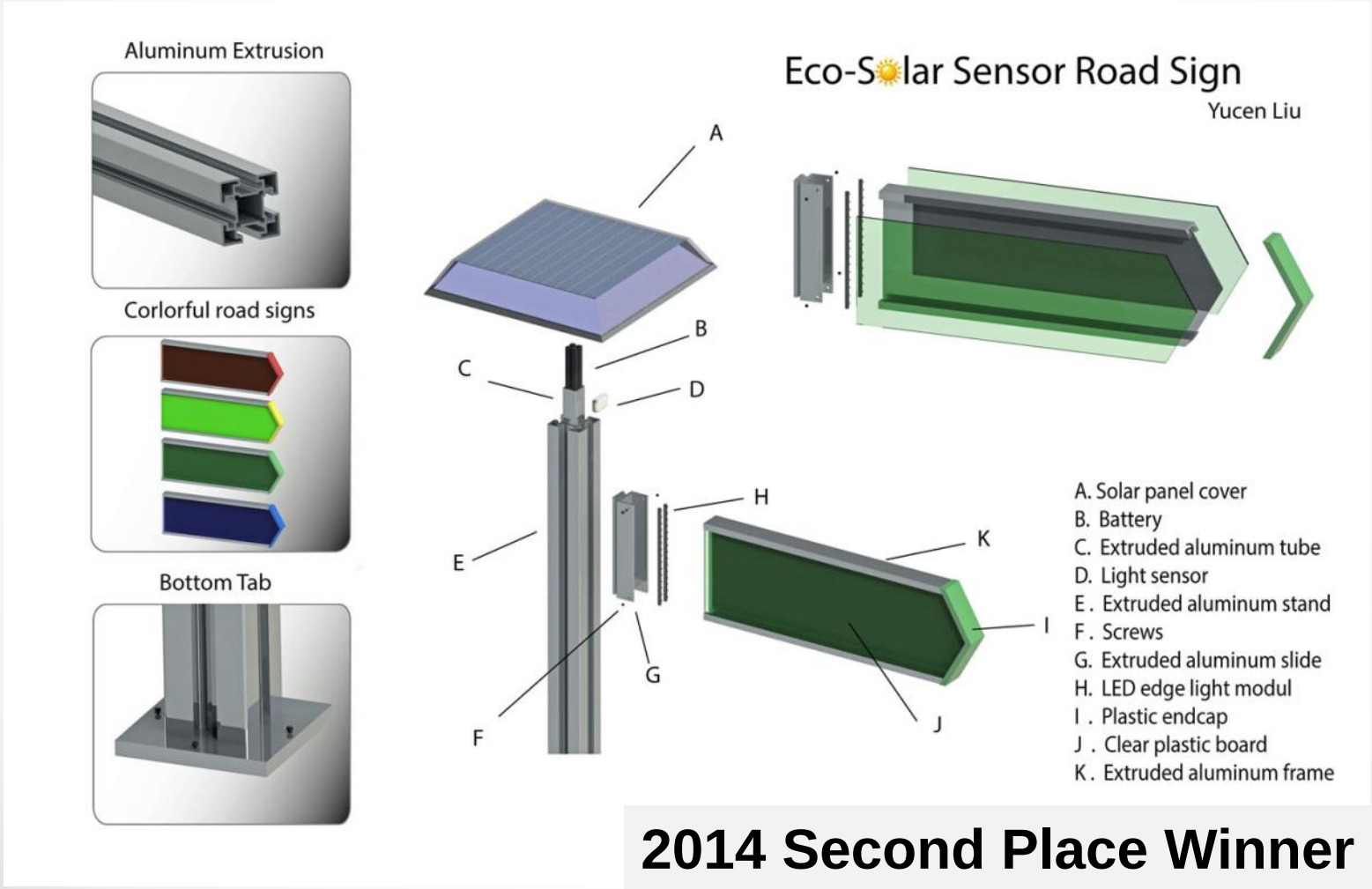
02/14/14 NICHOLAS PARENT DAWSON COLLEGE

Past Design Competition Winners and Honorable Mentions



2014 First Place Winner

Past Design Competition Winners and Honorable Mentions



2014 Second Place Winner

Past Design Competition Winners and Honorable Mentions

2013 First Place Winner

Past Design Competition Winners and Honorable Mentions

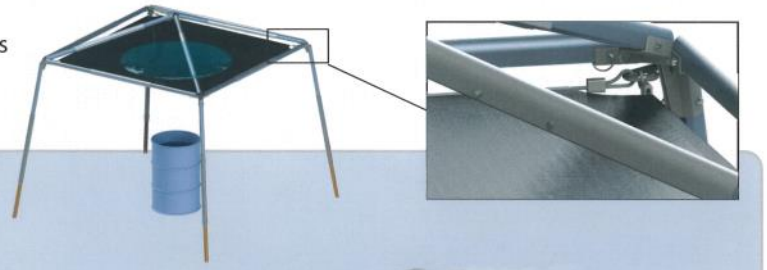
2013 Sustainable Design Award

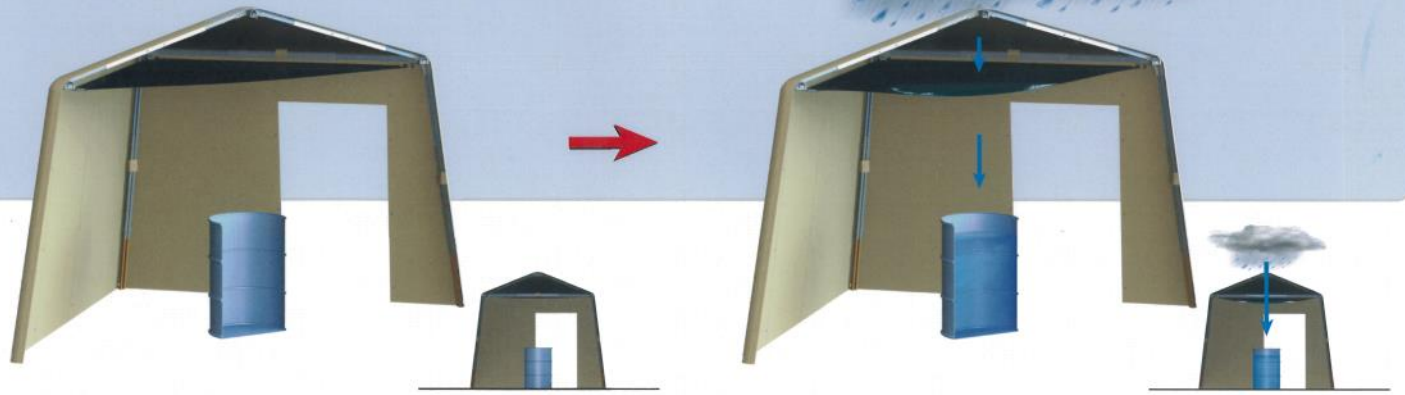
Refugee Tent

Water Collection & Filtration

The Easily removable Carbon Cloth is attached to the corner connectors with the use of simple hooks. This Component allows the tent to filter rain water and allow it to be collected in the water barrel.

When it rains, the water goes through the top mesh and then proceeds to collect into the active carbon cloth which filters it and allows the water to drip and collect in the 55 gallon barrel. The active carbon cloth filter can easily be removed and place over the barrel to filter water from other sources.





ET Foundation

February 15th 2013

Past Design Competition Winners and Honorable Mentions

2012 First Place Winner

This extruded aluminum stretcher is designed to transport injury victims.

The MedStretch extruded aluminum stretcher is lightweight and mobile for transporting injury victims. The compact stretcher design unfolds, sets up quickly and stores easily.

Past Design Competition Winners and Honorable Mentions

Past Design Competition Winners and Honorable Mentions

2011 Sustainable Design Award
Co-winner
Evaporative Cooling Device

VAPOR is a portable cooling canister based on the pot-in-pot system commonly used in Northern Africa. The VAPOR is an elegantly simple device that keeps food items cool by using evaporative cooling.

Past Design Competition Winners and Honorable Mentions

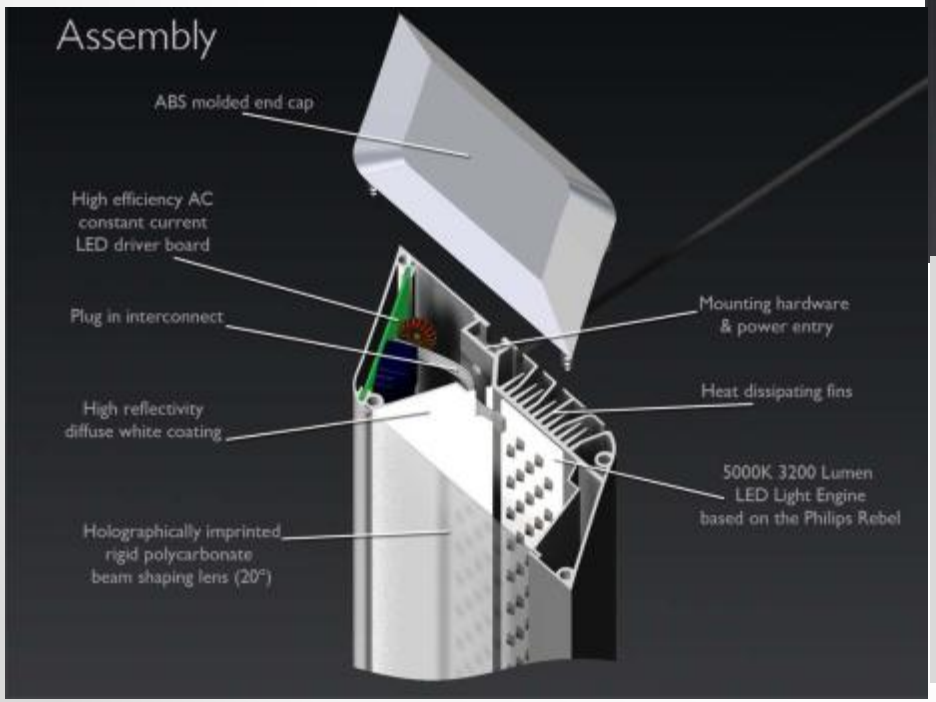
2011 Sustainable Design Award
Co-winner
Hydroponic Gardening System

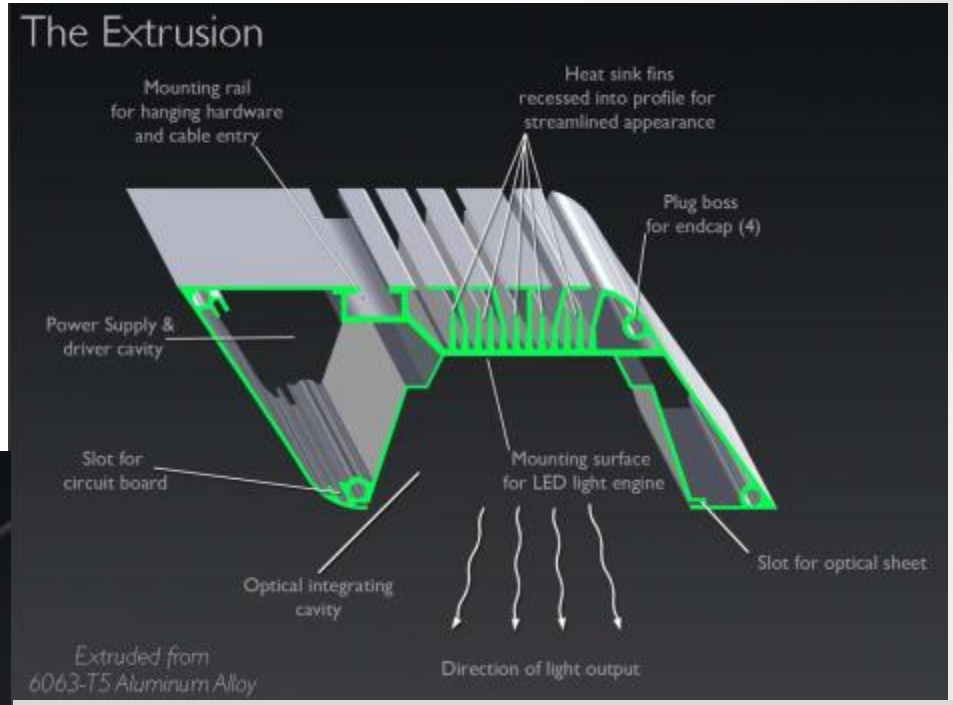
This urban gardening solution provides a cost-effective method for growing fresh vegetables in areas where land for traditional gardens is not available, such as driveways, rooftops, porches, and basements. The single–extrusion design accommodates cavities for water, sand, nutrient solution, filter media, and a heating element and takes full advantage of the ability to build in functionality and even takes advantage of aluminum's heat transfer capabilities.

Past Design Competition Winners and Honorable Mentions

2010 Grand Prize
Hanging LED Light Fixture

EXCELLENT STUDENT ENTRY EXAMPLE
The 2010 Grand Prize was awarded to a student entry. The Grand Prize is only awarded in combined Student & Professional competition years.

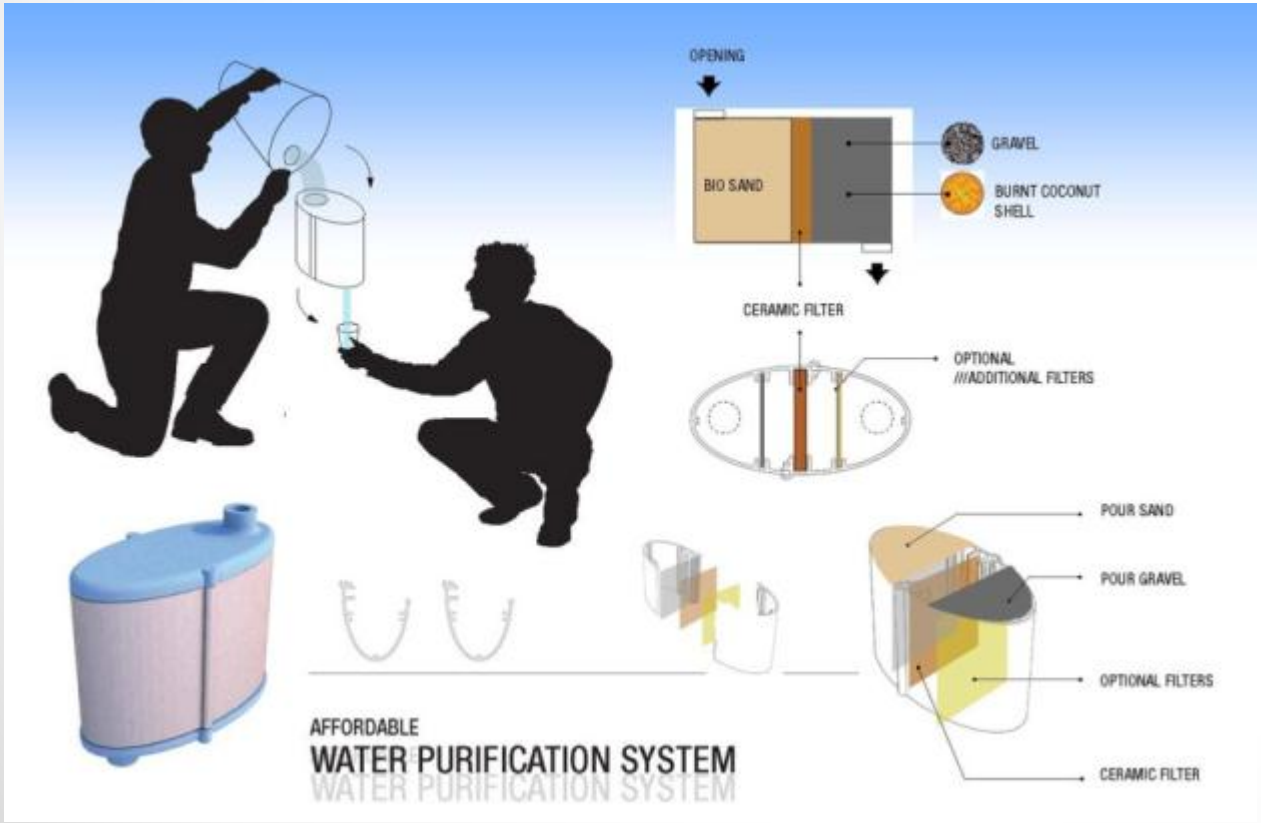




"LED light fixtures must properly dissipate heat generated by LEDs to ensure high efficiency and long life. "Integrated designs can include heatsink fins, slots, optical cavities, mounting rails, screw bosses—all necessary for LED fixtures. Increased design integration reduces part count and cost," noted the designer. "Also, smooth extrusions need little to no finishing to make thermal interfaces, unlike die casting which must be machined and results in a higher cost."

Past Design Competition Winners and Honorable Mentions

2010 Sustainable Design Award



Innovative water filtration/purification system uses extruded aluminum to exploit many of the design possibilities that the aluminum extrusion process provides. A single profile is used to form both halves of the main compartment and integrates filter guides in the extrusion design so that minimal post-extrusion fabrication is needed.

Aluminum Extrusion Design Competition

www.ETFdesign.org

- Website contains contest information, design resources, and more.
- Download the Call for Entries, including Entry Form from the website
- Entries are due **March 30, 2015**
  - (see Entry Form for details)

General Aluminum Extrusion information and resources:

www.AEC.org

ALUMINUM EXTRUDERS COUNCIL

List of LINKS

- Aluminum Association – www.aluminum.org
- The European Aluminium Association – www.eaa.net
- The International Aluminium Institute – www.world-aluminium.org
- German Aluminium Association (GDA) - www.aluinfo.de/
- The Aluminum Anodizer's Council – www.anodizing.org
- The *American Architectural Manufacturers Assoc.* –www.aamanet.org

- **Other Useful Publications from the Aluminum Association**
  - **Aluminum standards and data**
    - This reference contains: nominal and specified chemical compositions of alloys; typical mechanical and physical properties of commonly used commercial alloys; mechanical property limits; information on comparative characteristics and applications; definitions, and dimensional tolerances for semi-fabricated products. The new 2009 edition contains the latest information from the 2009 American National Standards for wrought aluminum and aluminum alloys. In addition, the Terminology Section has been reorganized and harmonized with international definitions. All of this is included in a convenient format, in either print or CD versions. The publication is available in both metric and US customary units.
      - Available at: http://www.aluminum.org/Content/NavigationMenu/BookStore/WhatsNew1/default.htm (also available by calling 301-645-0756).
  - **Teal Sheets - International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys**

    Revised for 2009, with information on 23 new alloy designations, their associated chemical composition limits and nominal densities. This registration record is the defining source for the designations and chemical composition limits for wrought aluminum and wrought aluminum alloys referenced in a number of standards and specifications worldwide. It contains close to 500 designations, chemical composition limits and nominal densities for wrought aluminum and wrought aluminum alloys registered with The Aluminum Association internationally. Other information includes a list of previously registered - but currently inactive - alloy designations, the Declaration of Accord on an International Designation System for Wrought Aluminum and Wrought Aluminum Alloys and a list of the Signatories to the Accord.
      - Available on line at: www.aluminum.org/tealsheets

- **Other Useful Publications from the Aluminum Association**
  - **Yellow Sheets - Tempers for Aluminum and Aluminum Alloy Products**
    - This publication provides a listing of the alloy/temper products that are not included in the AA publication Aluminum standards and data, which is described above. It also contains a listing of deactivated alloy/temper products and provides information on the procedures for registering new alloy/product tempers. There is also a metric companion document known as the "Tan Sheets".
      - Available at the Bookstore at: www.aluminum.org or a direct link at: http://www.aluminum.org/source/Orders/index.cfm?section=BookStore&ETask=1&Task=1&SEARCH_TYPE=FIND&FindIn=0&FindSpec=Yellow&x=17&y=10 (also available by calling 301-645-0756)
  - **Guidelines for Minimizing Water Staining of Aluminum**
    - This publication is available from the Aluminum Association's Sheet & Plate Division as a free download at: http://www.aluminum.org/Content/NavigationMenu/TheIndustry/SheetPlate/GuidelinesforMinimizingWaterStainingofAluminum2009/TR309.pdf
  - **Aluminum Applications in the Rail Industry**
    - **http://www.aluminum.org/Content/NavigationMenu/TheIndustry/SheetPlate/AluminumApplicationsintheRailIndustry/Aluminum_Applications_in_the_Rail_Industry.pdf**
  - The article above is available as free download at: http://www.aluminum.org/Content/NavigationMenu/TheIndustry/SheetPlate/default.htm

Courtesy of *Light Metal Age* magazine
More Info @ AEC.ORG

Sample Quiz Q&A's

QUESTION	ANSWER	QUESTION	ANSWER
Are aluminum extrusions limited to simple standard shapes or are complex integral shapes possible?	Complex shapes are possible and easily done	It is necessary to chemically treat aluminum to create a protective oxide coating?	No
As aluminum is subjected to colder temperature it gets (circle those that apply):	Tougher, brittle, stronger, more ductile, smaller	Hollows can only be created in aluminum extrusions by subsequently drilling or otherwise creating the voids?	No
It is always easier to extrude simple shapes and then subsequently fabricate and assembly complex features than to incorporate this into the extrusion design?	No	Can aluminum be welded or brazed?	Yes
Are aluminum extrusion tooling costs generally lower than competitive manufacturing processes?	Yes	Lead times for aluminum extrusion tooling is often in excess of 5 weeks?	No
What is the most common alloy series used for aluminum extrusions?	6xxx series (Mg-Si-based)	Is anodizing applied like liquid paint?	No
Aluminum is about _ % as heavy as iron, steel, copper and brass?	33%	Can aluminum be powder painted?	Yes
What types of ultimate tensile stresses are possible for appropriately alloyed and heat treated aluminum?	80,000 – 90,000 psi	Aluminum extrusions can only be generally made in small sizes that would fit within a 5 inch circumscribing circle?	No
Is aluminum generally corrosion resistant?	Yes	On an equal weight basis, can aluminum be twice as conductive as copper?	Yes
Does aluminum conduct heat better than other common metals on both a weight and cost basis?	Yes	Aluminum is magnetic?	No
Properly produced and treated, what % reflectivity is possible with aluminum?	80%	Aluminum by nature is non-sparking?	Yes
Volume for volume, aluminum is less than 50% as electrically conductive as copper?	No – it is 62%!	Will solid aluminum support combustion?	No