Why Investment Casting & High Level Process Overview

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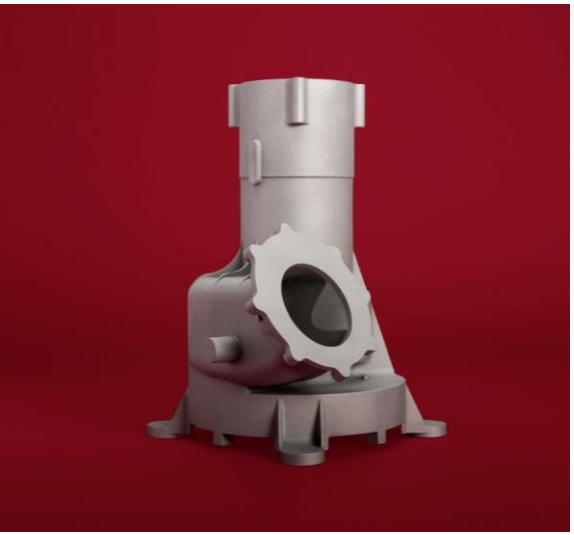
Why Investment Casting?

Some of the Benefits of Investment Casting

- Superior surface finish
- Wide range of alloys
- Manufacturing Cost Savings
- Complex, near net geometries
- Fine detail
- Operational Cost Savings

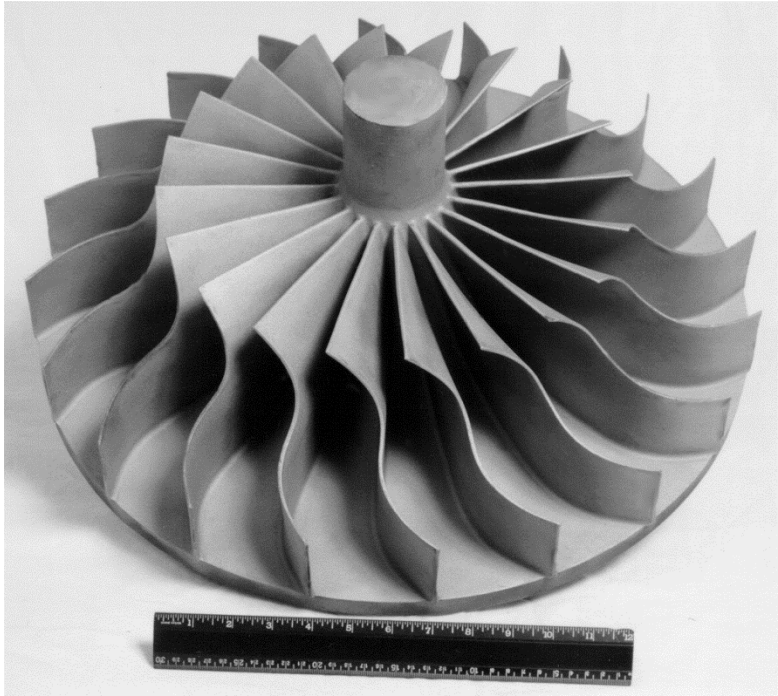


Typical Process Capabilities

- Common tolerances:
  - Linear: 1” +/- .010”, add .005” for each add’l inch
  - Flatness: depends on geometry and alloy
  - Roundness: typically, .015” on 1” diameter
  - Radii, Fillets: commonly min .010”
  - Surface roughness: 125 RMS max
  - Wall thickness depends on alloy selection

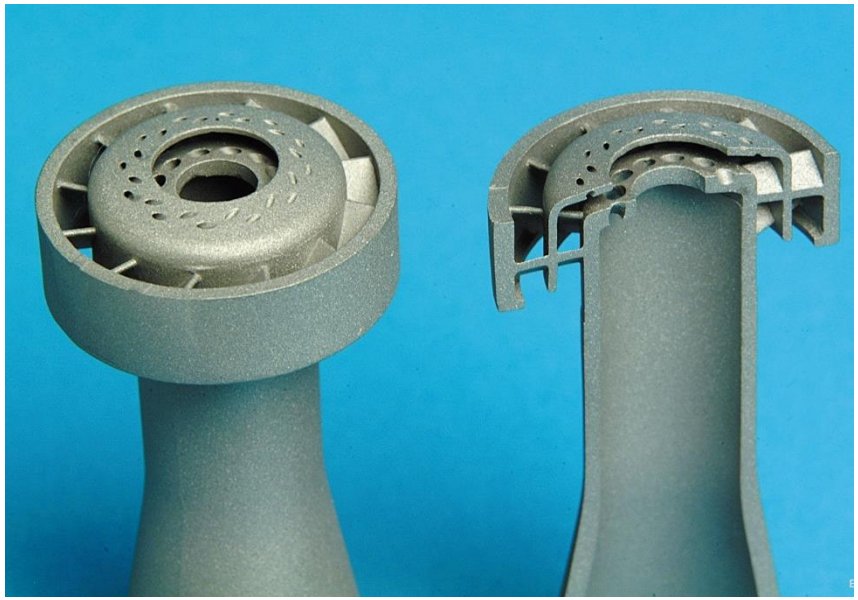
Case Study: Inconel Impeller

- Formerly machined from solid stock
- Investment casting:
  - Reduced unit cost by 45%
  - Reduced lead time by 40%



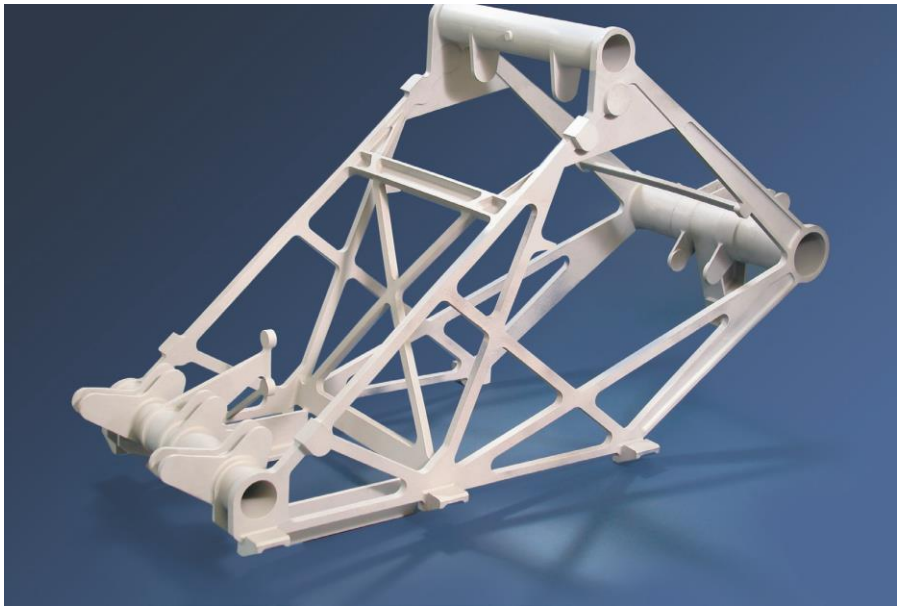
Case Study: Gas Turbine Swirler

- Formerly a 27 piece fabrication
  - High Maintenance Part
  - High Spares
- Investment casting:
  - Single Piece Casting
  - Reduced manufacturing cost by more than 50%
  - Extended unit life 600%



Case Study: Aerospace Rudder Assembly

- Formerly required 50 hours of assembly
  - 3 Aluminum castings
  - Sheet metal
  - Aluminum hog outs
  - Fastening hardware
- Investment Casting
  - Single piece casting
  - Procurement savings
  - Assembly savings
  - Inspection Savings
  - Extended unit life



Case Study – Turbocharger Assembly

- Former assembly of over 100 parts
  - Forged disks
  - Forged blades
  - Cast blades
- Investment Casting
  - Single piece casting
  - Over 75% cost savings
  - Extended Component Life

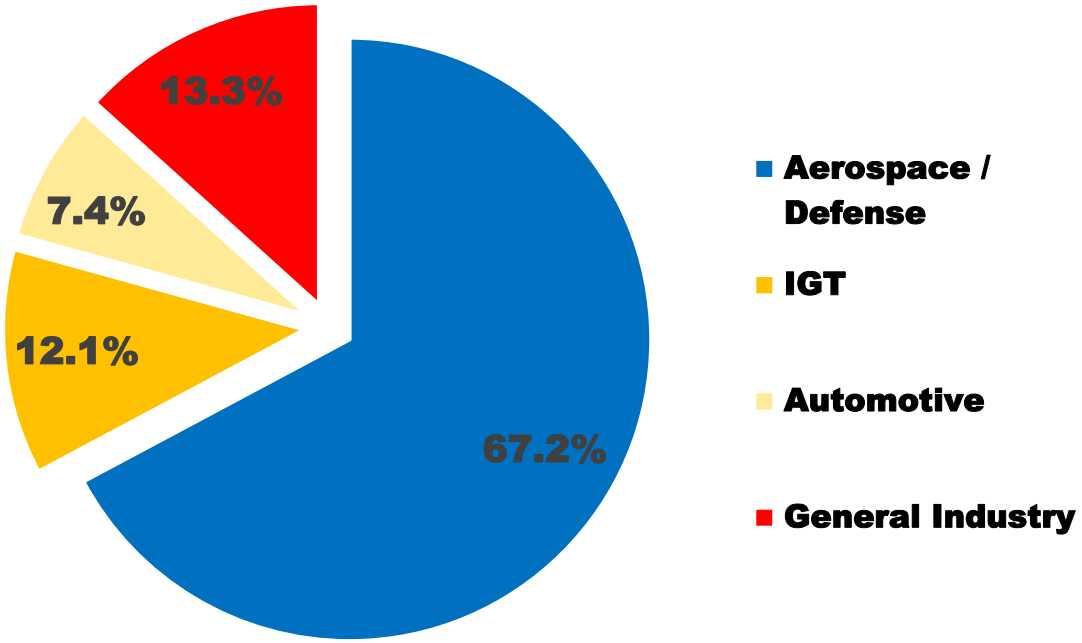
A Brief History

- Originally developed by ancient Chinese and Egyptian culture to create artwork
- Primarily used for art until development of the jet turbine engine at the end of World War II
- Since that time it has become an enabling technology in today's top industries
  - Aerospace & Defense
  - Industrial Gas Turbine (IGT)
  - Automotive
  - Oil and Gas
  - Space Exploration
  - General Industry
  - Oil and Gas
  - Medical / Orthopedics
  - Agriculture
  - Construction
  - Commercial and Consumer products

North American Investment Casting
2018 Sales by Sector ($ Billion)

Aerospace & Defense	3.90
IGT	0.70
Automotive	0.43
General Industry	0.77

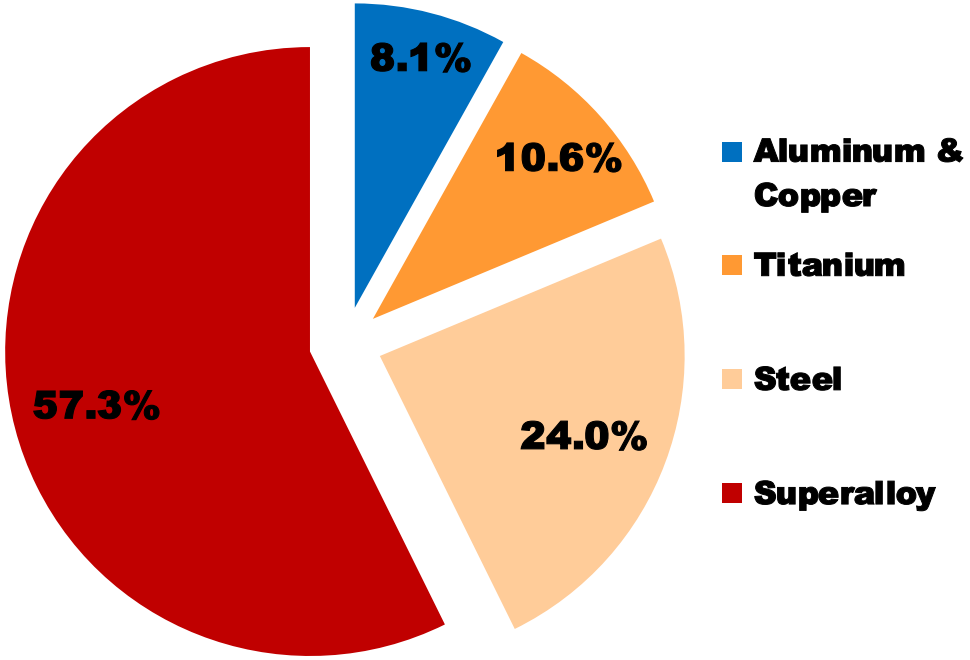
TOTAL: $ 5.80 Billion



North American Investment Casting
2018 Sales by Alloy Type ($ Billion)

Superalloy	3.32
Steel	1.39
Titanium	0.62
Aluminum & Copper	0.47

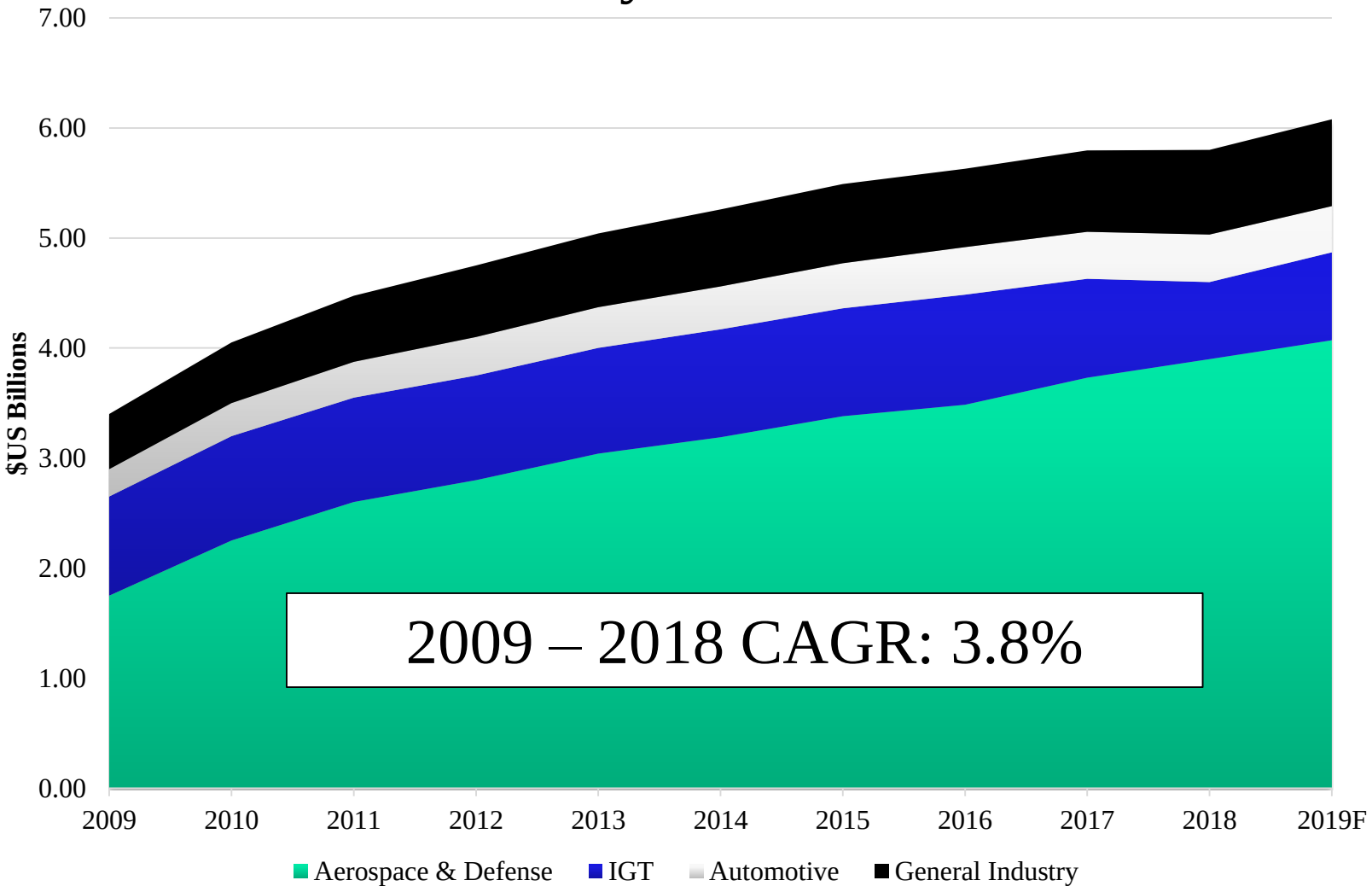
TOTAL: $ 5.8 Billion



North American Investment Casting
2018 Sales and 2019 Forecast ($ Billion)

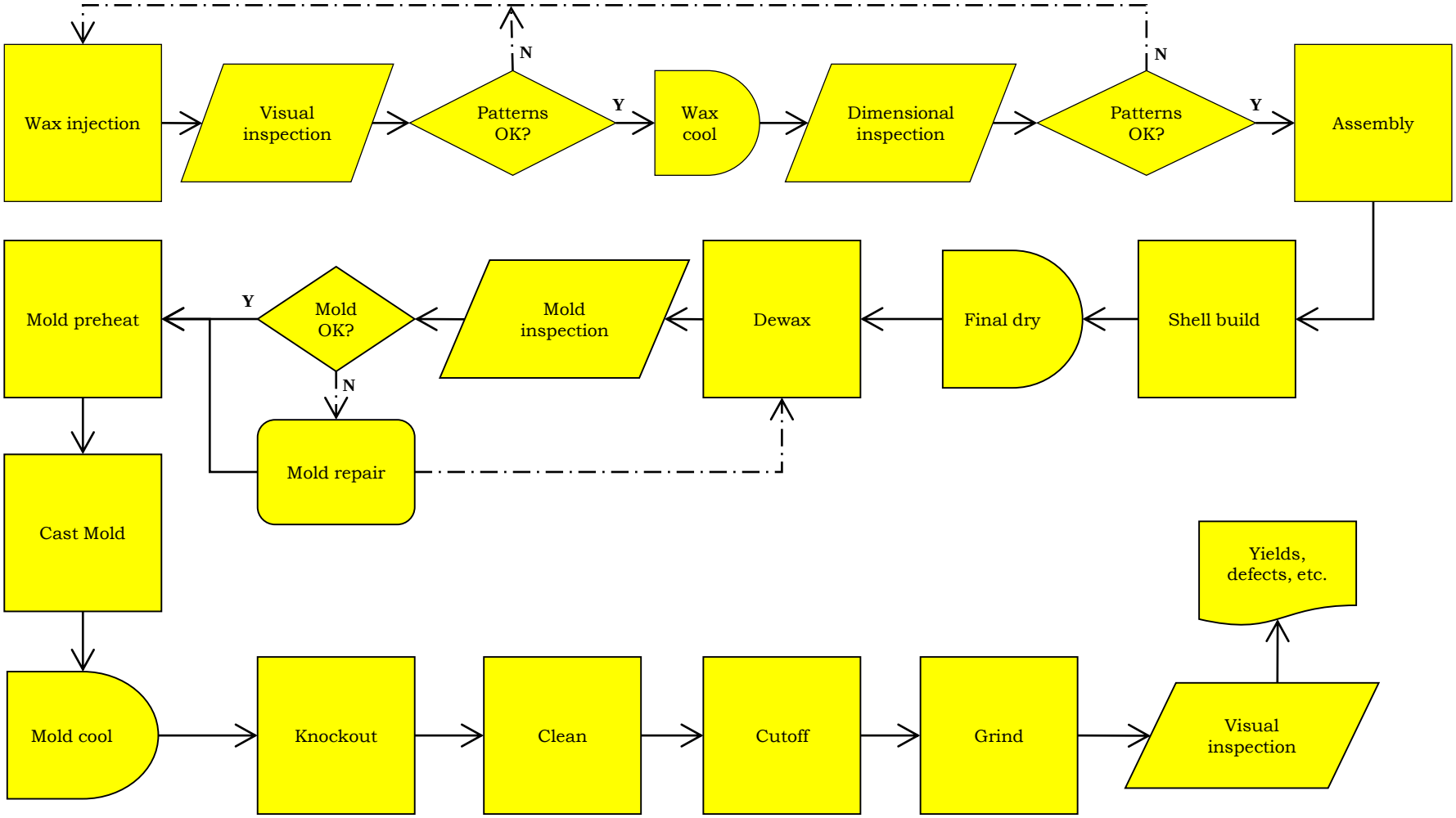
	2018	2019F	
Aerospace & Defense	**3.90**	**4.07**	
IGT	**0.70**	**0.80**	
Automotive	**0.43**	**0.42**	
General Industry	**0.77**	**0.79**	
	$ 5.80B	**$ 6.08B**	**(4.8%)**

North American Investment Casting Industry Sales Growth

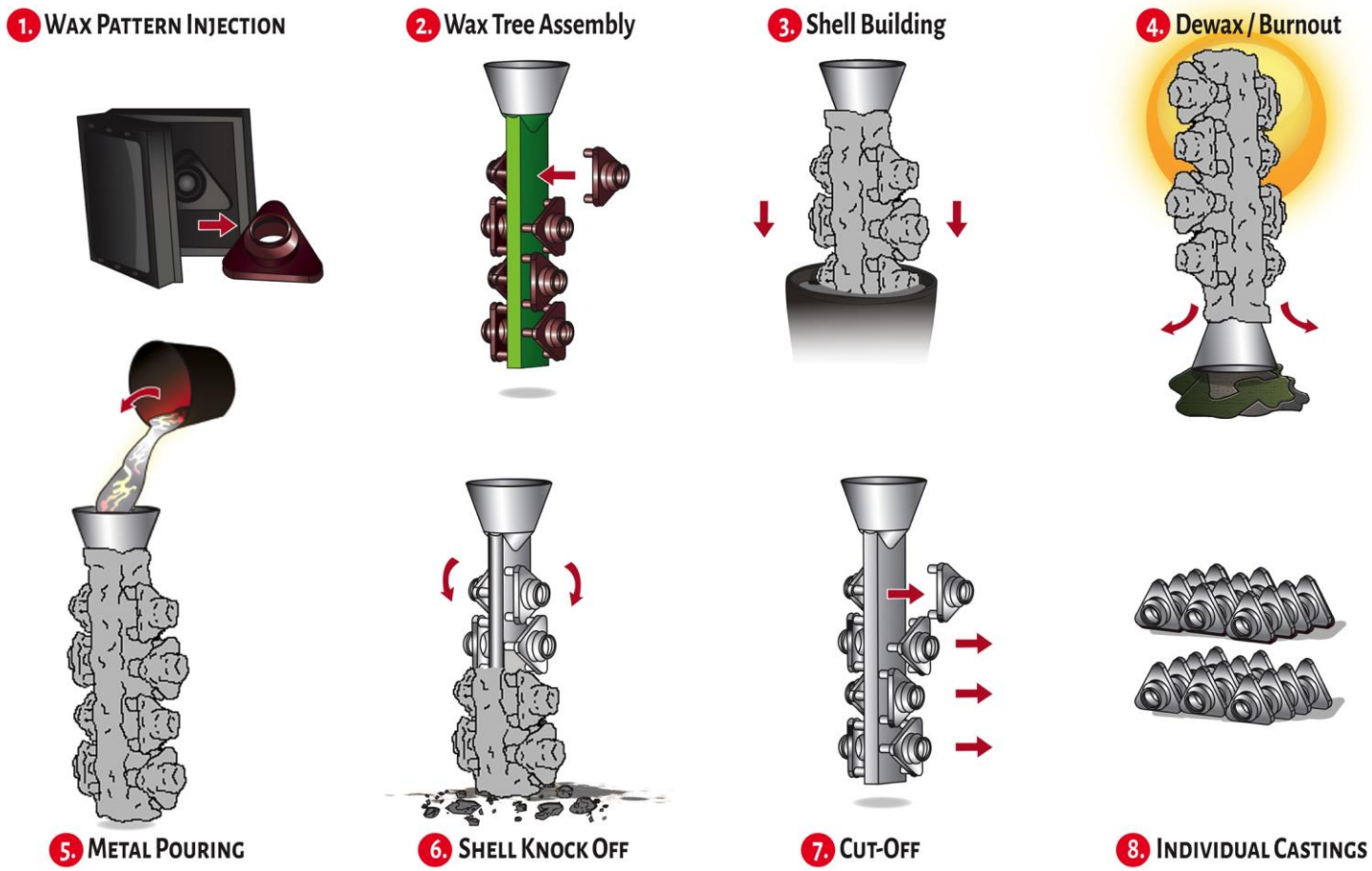


High Level Process Overview

Process Flow Chart
The Investment Casting Process



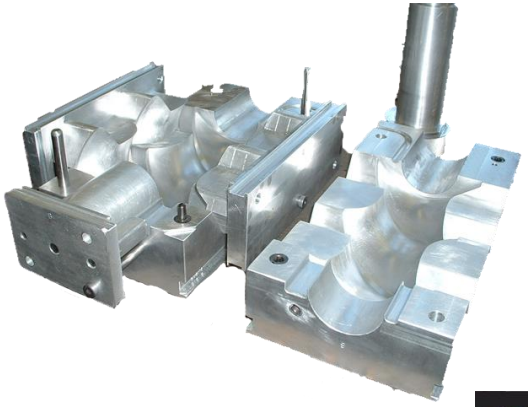
The Investment Casting Process
A Simplified View

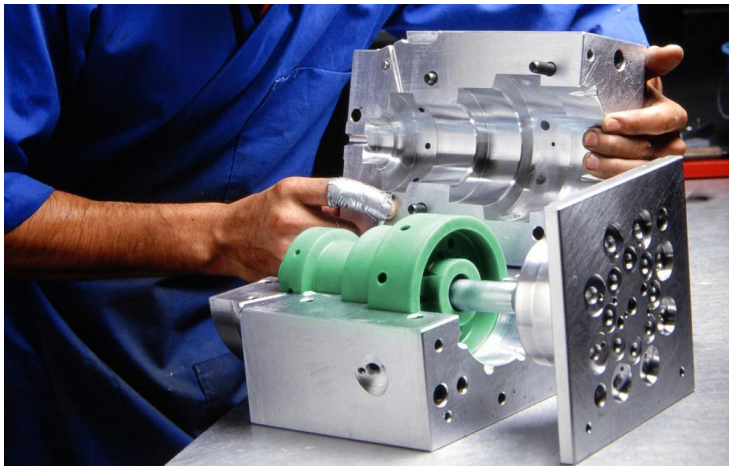


Creating a Wax Pattern

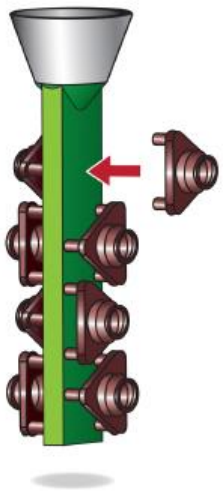
- Wax patterns are typically made by injecting wax into a metal tool or “die”
  - With the evolution of Additive Manufacturing, patterns can be printed
- In the art community, one of a kind pieces are typically carved or assembled from wax or other hydrocarbon based media
  - For multiple castings, a silicon tool is usually made from the artist’s sculpture and wax is injected or poured into the resulting cavity

Pattern Manufacture





Wax Assembly

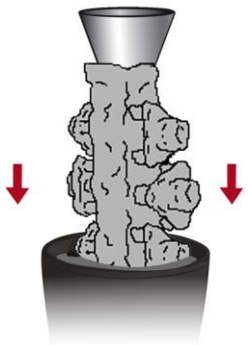


- It is uneconomical to make small parts one at a time, so wax patterns are typically attached to a wax “sprue”
- The sprue serves two purposes
  1. Provides a mounting surface to assemble multiple patterns into a single mold, which will be later filled with alloy
  2. Provides a flow path for the molten alloy into the void created by the wax pattern(s)
- The wax between the pattern(s) and the sprue are called “Gates”, because they throttle the direction and flow of the alloy into the void made by the pattern

Wax Assembly

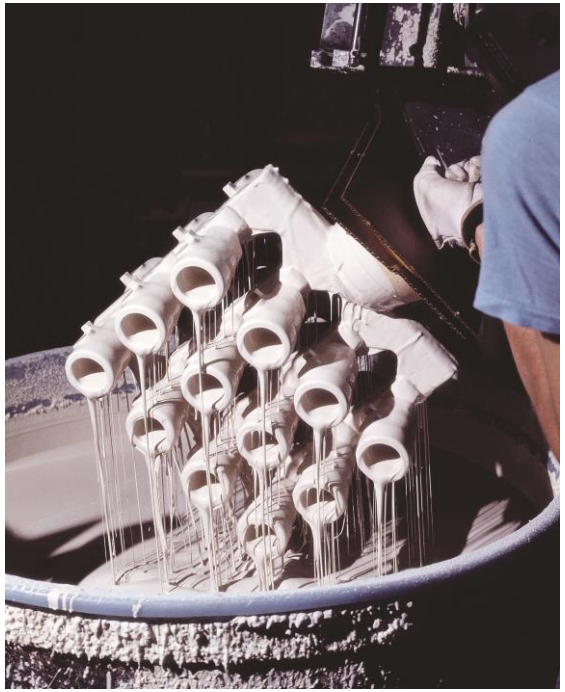
Wax Assembly

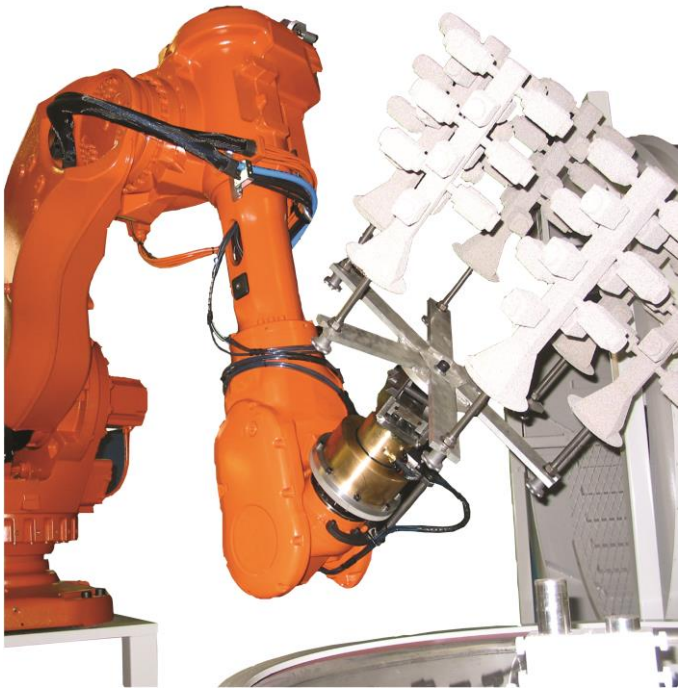
Shell Building



- The next step in the process is to build a ceramic shell around the wax tree
- This shell will eventually become the mold into which molten metal is poured
- To build the shell, the wax assembly is dipped into a ceramic slurry
- After dipping, stucco is applied to the wet surface
- The mold is allowed to dry, and the process is repeated a number of times until a laminated ceramic mold, capable of undergo the stresses of the casting process, is created

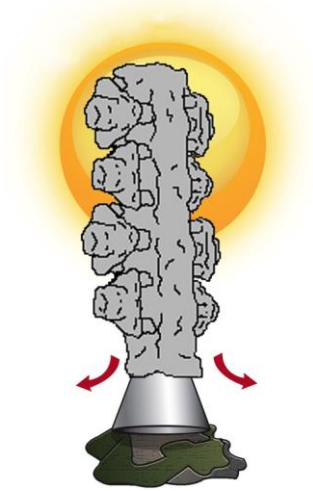
Shell Building





Shell Building

Dewax / Burnout



- Before pouring metal into the mold, the wax is removed
- This is typically done using a steam-dewax autoclave
- Another method is the use of a flash fire oven, which melts and burns off the wax
- Many foundries use both methods in concert
  - Autoclave removes the majority of the wax, which can be reconditioned and reused
  - Flash fire burns off residual wax and cures the shell, readying it for casting

Dewax / Burnout

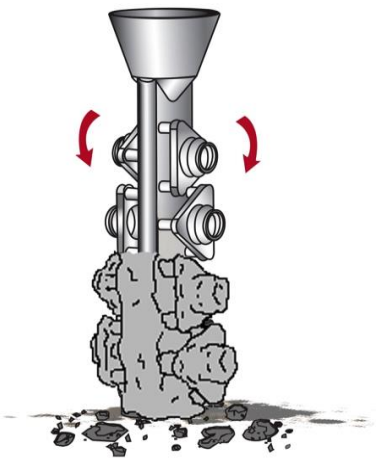
Casting

- The mold is preheated to prevent molten alloy from solidifying or “freezing off” before the entire mold is filled
- Alloy is melted in a crucible using induction melting
  - A high frequency electric current creates a magnetic field around the alloy, generating electric fields inside the metal (eddy currents)
  - The eddy currents heat the alloy due to the material’s electrical resistance
- When the alloy reaches its specified temperature, it is poured into the mold, and the mold is allowed to cool

Casting

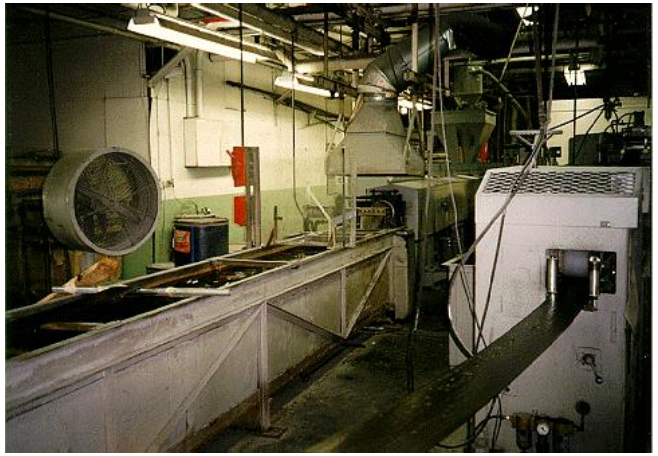
Dewax and Casting

Shell Knock Off

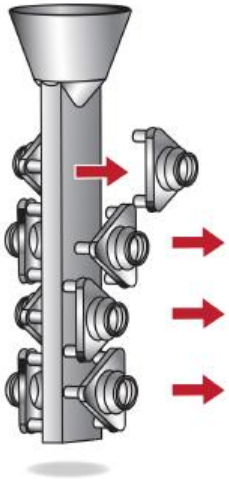


- Once cool, the shell material is removed from the metal
- This is typically done via mechanical means
  - Hammer
  - High Pressure Water Blast
  - Vibratory Table
- Shell removal can also be accomplished chemically, using a heated caustic, but this approach is being phased out due to environmental and health concerns

Shell Knock Off



Cut Off and Grind



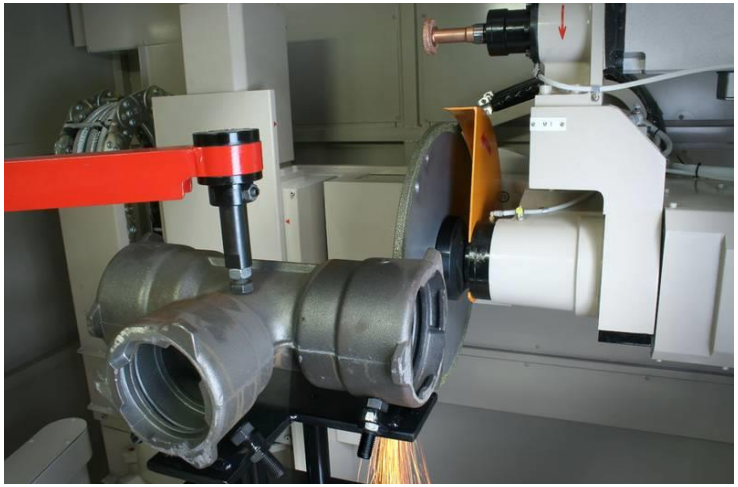
- Once the shell material has been removed, the parts are cut off the sprue
- The next step is to remove remaining portion of the gate(s) with an abrasive grinder
- Both cut off and grind can be performed manually or they may be automated

Cut Off and Grind

Finishing

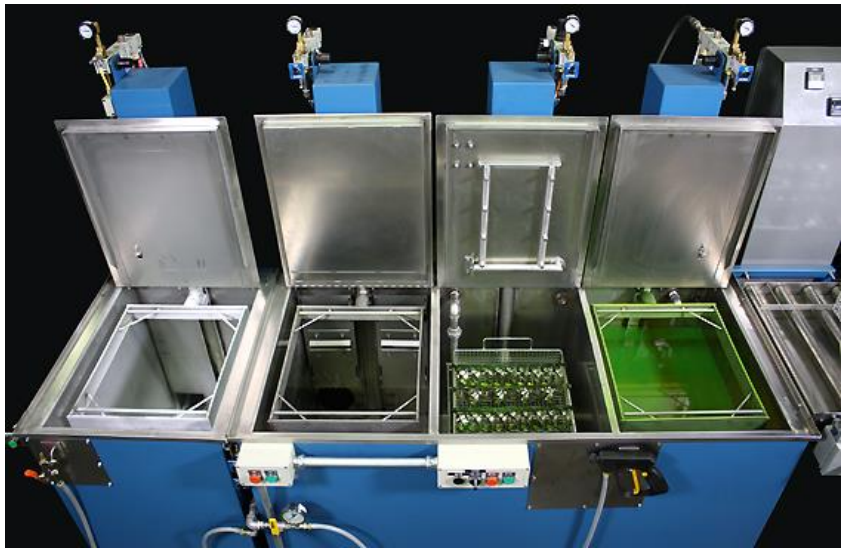
- Castings may be finished by hand, robotically or via media finishing
- Castings may undergo further metallurgical processing, such as heat treat or Hot Isostatic Pressing (HIP)
- Finished castings are inspected to customer requirement: Dimensional, FPI, X-Ray, Ultrasonic Test, etc.
- If required, castings are marked and product certifications are prepared

Finishing



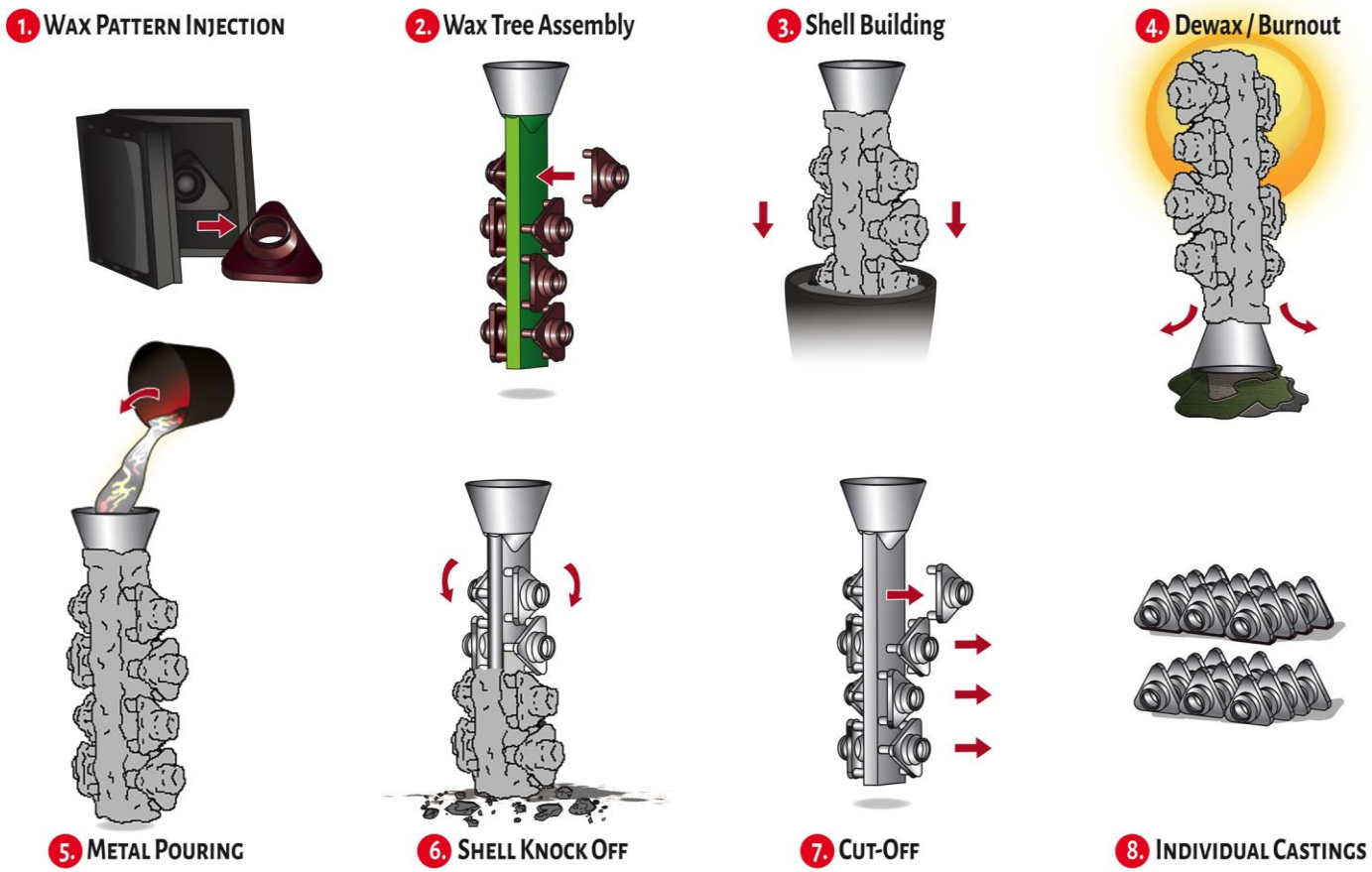
Heat Treat & HIP

Non-Destructive Testing



Post Cast Operations

The Investment Casting Process



THANK YOU

QUESTIONS?