DISCOVER

what sets Signicast dramatically apart from the competition. And how those differences directly benefit you.

Welcome to Signicast, the investment casting industry leader. By working better, faster, and smarter than the competition, Signicast is able to provide you with:

1. Unprecedented Lead-Times for New Product Launches.
2. True Just-in-Time Delivery – Every Time.
3. The Highest Level of Quality.
4. Technologically-Advanced Processes and People.

Signicast is committed to satisfying customers like you. The company's progressive management team is focused on harnessing emerging technologies to provide you with the highest-quality components at a competitive cost, on time, all the time.

The information contained in this brochure is intended to be a well-grounded starting point for both buyers and designers of investment castings. Many investment castings have special requirements that fall outside the scope of this brochure, or are not discussed. Signicast's highly skilled Technical Sales and Engineering staff are available to consult with you regarding these needs and any other questions you may have.

The state-of-the-art advances rapidly in this business. And for more than half a century, Signicast has been one of the foremost companies advancing it. The experts at Signicast believe if something can be investment cast at all, they can find a way to do it. Let them prove it to you.

MADE BETTER FASTER SMARTER IN AMERICA

WELCOME

THE PROCESS ADVANTAGE

Investment casting is considered a “net shape” or “near net shape” process.

Almost any configuration can be investment cast. The key to economical use of this process is to fully utilize its flexible capabilities and incorporate as much value added into the cast piece as possible. No other metal working process provides the design freedom and variety of alloy selections available with investment casting.

A combination of Signicast’s advanced processes, extensive automation, and proprietary technologies allows Signicast to reduce a standard 12-week industry lead time to one to four weeks. The result is true Just-In-Time manufacturing capability.

PROCESS COMPARISONS

Process	Tolerance Capability	Design Freedom	Alloy Selection	Size Range	Lead Time	Volume Capability	Surface Finish	Tool Cost	Machine Cost
Investment Casting	Excellent	Excellent	Excellent	Excellent	Short	All	Good	Average	Low
Die Casting	Excellent	Excellent	Poor	Good	Long	High	Good	High	Low
Powdered Metal	Excellent	Fair	Good	Fair	Long	High	Excellent	Average	Low
Stamping	Excellent	Good	Fair	Fair	Short	High	Excellent	High	Low
Forging	Fair	Fair	Good	Fair	Long	High	Fair	High	High
Sand Casting	Fair	Good	Good	Good	Short	All	Fair	Low	High
Fabrication	Fair	Fair	Good	Good	Medium	All	Fair	Low	High

INITIALLY MACHINED

- CA-15 stainless steel
- 50% cost savings

HALF THE COST

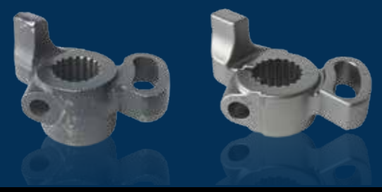
This single-piece investment casting was originally an assembly of two machined components. Eliminating almost all machining meant a 50% cost savings to the customer.

PREVIOUSLY FORGED

- CA-40 stainless steel
- 90% of forged weight was machined away

RECREATED FROM A FORGING

- 8620 alloy
- Cast internal spline
- Eliminated machining and broaching



CONVERTED FROM A FABRICATION

- 8620 alloy
- Reduced cost
- Improved quality

INITIALLY SAND CAST

- 4140 alloy
- Closer tolerances
- Eliminated machining
- Better cast finish

BETTER

INNOVATION AND FLEXIBILITY

In terms of quality, only a handful of the world's investment casters come close to Signicast.

Manufacturing throughput of less than one week is a Signicast exclusive. Continuous Flow Manufacturing – production runs non-stop, with the ultimate goal of increasing plant efficiency, utilization and speed – has revolutionized this industry, and Signicast undisputedly reinvented the process.

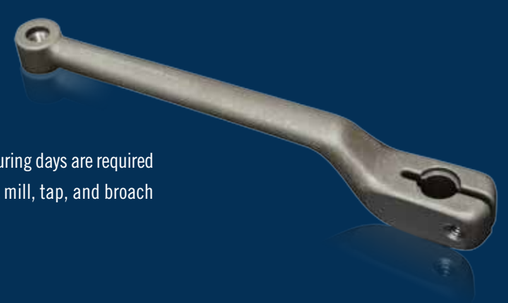
Signicast's goal is to assist customers in increasing profits, without compromising quality, speed, or value. How does Signicast do it? Through commitment to advanced Continuous Flow and complete-to-print manufacturing processes.

Rather than large batches moving from station to station, an unbroken stream of individual components flow continuously through the plant. Orders, even small ones, go from entry to shipping without interruption.

Signicast's unique proprietary software monitors and controls the process on a real-time basis – 24 hours a day, seven days a week – ensuring schedules remain 100% on time.

AUTOMATIC

Signicast's state-of-the-art manufacturing complex in Hartford, Wisconsin is the showplace for complete-to-print, Continuous Flow Manufacturing. The entire complex – from top to bottom, one end to the other – is designed to facilitate the efficient, unbroken flow of product. The total size of the facility stands at more than 650,000 square feet, with virtually every inch of it devoted to helping customers maximize their profitability.



For this shifter lever, only six manufacturing days are required to complete the cast, heat treatment, mill, tap, and broach operations.

Machined, assembled products – such as this motorcycle foot peg mount – can be supplied in two weeks or less, and may include multiple castings, purchased components, and multiple finishing operations.

Signicast's Continuous Flow Manufacturing philosophy affects every aspect of the process including production, material handling, and information processing. For example, Signicast uses an Automatic Storage/Retrieval System in an innovative way: as a material handling system. This eliminates time spent looking for and moving work pieces.

JUST-IN-TIME (JIT)

JIT manufacturing eliminates costly inventory by enabling you to receive small quantities of product, delivered frequently, according to your schedule.

INDUSTRY LEADING SPEED

At Signicast's Hartford complex, castings flow from wax patterns to metal casting in just 4.3 days, (6 if heat-treated, 8-10 if machined); tops in the industry by far.

CONTINUOUS FLOW MANUFACTURING

Continuous Flow Manufacturing production runs non-stop, increasing plant efficiency, utilization, and speed. What typically takes others up to 12 weeks to do, Signicast does with its Continuous Flow Manufacturing process in 5-10 days.

TOTAL VALUE

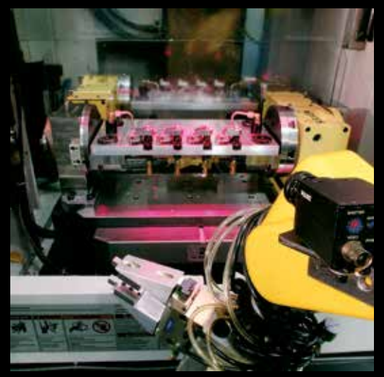
Whether you're looking for castings only, a complete-to-print product – including machining, assembly, and finishing – or other special services, Signicast offers the best total value option and will continually strive to find ways to improve processes. If there is a better way of doing things, Signicast wants to be the first to find and implement it.

At Signicast, high quality standards are met the first time. There are no rework loops. Operators are trained and empowered to identify and rectify quality problems in-process.

REDUCED LABOR COSTS

Individual parts are automatically loaded into hydraulic fixtures by robots, eliminating manual loading/unloading and reducing set-up time.

Signicast can handle all your casting requirements, from simple to complex. Large or small. Medium or high volume. Jobs you've been told "can't be done." Signicast continuously adapts to what the customer wants. It's Signicast's responsibility to make any component work within the framework of the manufacturing plants.



SIGNICAST FACILITIES

Signicast consistently demonstrates its growth philosophy. In 1972, the company moved to its current Milwaukee site and has undergone nine expansions there since that time. In 1993, Signicast continued to grow and expand in Hartford, Wisconsin and broke ground for the new corporate headquarters and additional manufacturing complexes – making the Hartford facility the most advanced of its kind in the world. Signicast utilizes digital and robotic automation designed and implemented in-house by Signicast's employees. Accelerated production and a significant increase in casting quality, are the result of unconventional thinking that has yet to be imitated by any competitor.

Automated manufacturing systems, incorporating robotics, eliminate material handling, making delivery of your job faster than any other investment caster.

Many customers simply provide their production schedules and Signicast develops a delivery program to accommodate their work flow. Flexibility is critical to success with JIT, and Signicast is equipped to handle radical shifts in output when you are faced with unexpected spikes in demand for your product.

Signicast incorporates the cellular manufacturing philosophy. Each manufacturing module operates independently, benefiting from the resources of a large company and the flexibility of small teams.

HARTFORD COMPLEX

YEAR	MODULE	SIZE OF EXPANSION (SQ. FT.)	SIZE OF PLANT (SQ. FT.)
1993	1	66,081	66,081
1995	Support	30,144	96,225
1997	2	76,372	172,597
2000	Support	21,309	193,906
2001	5	76,234	270,140
2003	3	82,654	352,794
2006	4	85,085	437,879
2012	Skywalk	9,148	447,027
2014	6	96,642	543,669
2014	7	110,890	654,559

MILWAUKEE COMPLEX

YEAR	SIZE OF EXPANSION (SQ. FT.)	SIZE OF PLANT (SQ. FT.)
1972	-	11,360
1974	12,000	23,360
1975	1,550	24,910
1978	20,885	45,795
1984	10,120	55,915
1985	13,518	69,433
1988	7,920	77,353
1989	9,572	86,925
1990	11,579	98,504

THE PROCESS

Most any configuration can be investment cast.

TOOLING

Initially, before the casting process begins, an injection die is constructed to produce precise wax patterns. All tooling is constructed of 7075 T6 aluminum at Signicast, Using CAD/CAM-driven CNC milling and EDM machines. The injection die is typically automated to produce patterns efficiently and contains numerous controls and monitoring devices to provide dimensionally consistent patterns. For many high-volume applications, multi-cavity dies are used.

WAX CELL

Signicast Time: 14 hours
Traditional Time: 96 hours

PATTERN INJECTION

A specially formulated wax is injected into a die to produce the pattern for the part. One pattern must be made for each finished part to be cast. This pattern is an exact replica of the metal part to be produced, with allowances to compensate for volumetric shrinkage during the process. The pattern also includes one or more gates to guide molten metal into the part during the solidification process.

Signicast uses a patented system that was invented and developed in-house for automatically distributing semi-solid wax to the injection presses. It is unique in the industry in its ability to control wax temperature within +/- 1 degree Fahrenheit, which is important for dimensional conformity.

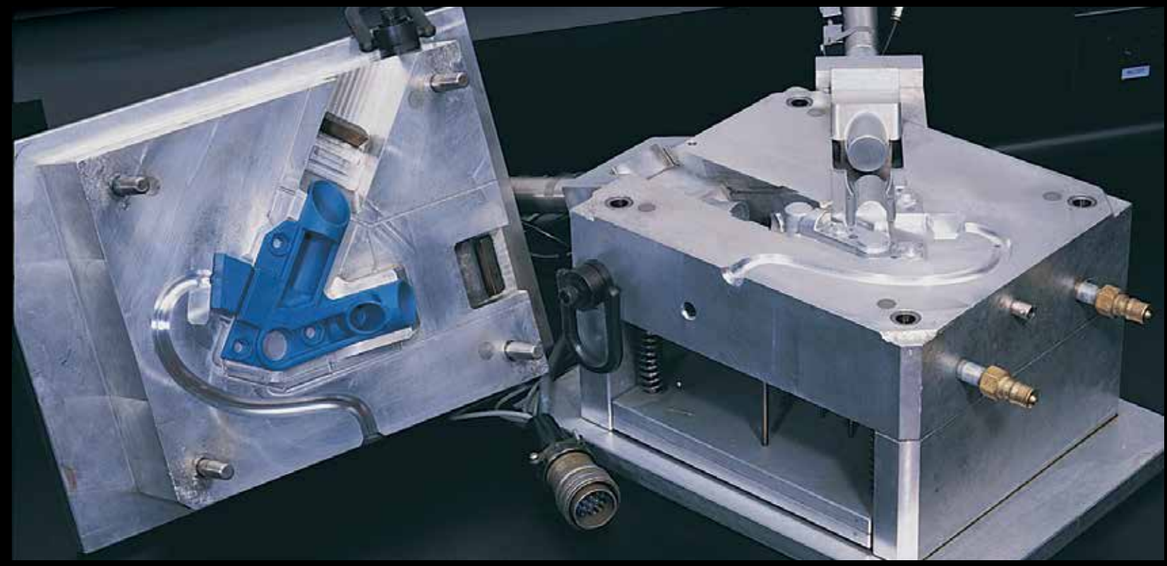
Injecting wax at this temperature gives Signicast several advantages. Since the wax is in a semi-solid state when injected, the part undergoes less shrinkage through the solidification process. In turn, the pattern possesses better dimensional stability and resists flash and cavitation (or sink) when cooling.

PATTERN ASSEMBLY

The individual wax patterns are assembled onto a wax sprue to form a mold or tree. The number of patterns assembled per mold varies, dependent upon the size, weight, and configuration of a given part.

SHELL BUILDING CELL

SHELL BUILDING
Signicast Time: 29 hours
Traditional Time: 168 hours



A ceramic mold is created by dipping or “investing” the assembled patterns in liquid ceramic slurry, draining, and then coating with a dry “stucco” sand. After drying, this process is repeated several times until a specified shell thickness results. The ceramic shell ranges in thickness from 3/16” to 1/2” depending on the size of the part being produced.

Advanced technology has allowed Signicast to incorporate robotics into this operation. Signicast utilizes sophisticated shell-drying technology to reduce the total time to build a shell to one day from the typical one-week average. Stable, economical, environmentally safe water-based slurries are used.

DEWAXING AND FIRING
Signicast Time: 5 hours
Traditional Time: 48 hours

The wax is melted out with steam heat in an autoclave and is recycled. Firing at 1800 degrees Fahrenheit fuses the ceramic particles so the mold can withstand the pressure and temperature of the molten metal. It also removes all traces of organic materials. This pre-heat improves the ability to cast fine detail. It also improves the feed of liquid metal to compensate for volumetric shrinkage.

CASTING CELL

CASTING
Signicast Time: 18 hours
Traditional Time: 72 hours

Molten metal is poured into the pre-heated molds. Typical pouring temperatures are approximately 3000 degrees Fahrenheit for steel. Before and after casting, every melt is analyzed spectrographically to assure compliance with customer specifications.

The investment casting process is unique in the broad range of alloys that can be cast. Most any alloy can be investment cast economically. Signicast specializes in ferrous, air-melted alloys. Recommendations and a guide to material properties in the Alloy Properties section of this brochure will assist you in choosing an economical alloy to meet your needs.

CLEANING
Signicast Time: 12 hours
Traditional Time: 72 hours

The ceramic shell is removed from the metal mold with high-pressure jets of water. Any ceramic material remaining in pockets or holes is dissolved away in a hot chemical bath to ensure part cleanliness.

CASTING REMOVAL
Metal castings are removed from the runner using abrasive wheel cutoff saws or a more economical proprietary process.

FINISHING CELL

GATE GRINDING
The material protrusion left from the gate, called the gate witness, is ground to print specification using a fixture for repeatability and efficiency.

FINISHED CASTINGS
Signicast Time: 20 hours
Traditional Time: 96 hours

The final cleaning operation is performed using a blast with abrasive grit or steel shot. This blasting produces a surface finish of 90-125 microinch Ra.

COMPLETE-TO-PRINT
Casting all features of a part for use in a final assembly is the optimum use of the investment casting process. However, some applications require more than can be supplied by investment casting alone.

A cost savings is generated if the casting can be used in the as-cast condition, but if premium tolerances, surface finish, or coatings are required, Signicast can supply complete-to-print components – adding only one additional day to the overall lead time. Signicast dedicates an entire facility solely to complete-to-print manufacturing. The result is a high-quality, high-value product that’s ready to ship straight from our docks in as few as 4.3 days from start to finish.

NONDESTRUCTIVE TESTING
All sample castings are nondestructively tested in order to establish first article quality. Nondestructive Testing is generally not required on production commercial castings. Listing of nondestructive tests in order of increasing costs:

- Magnetic Particle
- Fluid Penetrant
- X-Ray

CERTIFICATION

- Chemical Certification – Can be provided at an additional cost.
- Mechanical Property Certification – Adds to cost. Consider a combination of Chemistry and Hardness Certification instead. Marking each casting with a heat number adds traceability, but also adds an operation and cost.

FINAL FINISHING SERVICES INCLUDE:

- Powder Coat Painting
- Milling
- Drilling
- Tapping
- Surface Grinding
- Broaching
- Assembly
- Multi-Spindle and Turning Lathes
- Oxide coatings
- Passivation
- Painting
- Special cleaning/ packaging
- Pickling
- Special machining/ grinding
- Plating

HEAT TREATMENTS

Heat treatments are used to control hardness, mechanical properties, and corrosion resistance. Signicast can provide a wide range of heat treatment operations in-house or at highly qualified local suppliers. Unless otherwise indicated, all alloy steels are quoted with a normalize or anneal. All 300 Series stainless steels and 17-4PH are quoted with a solution anneal.

Signicast Time: 20 hours
Traditional Time: 72 hours

- Solution Anneal
- Quench and Temper
- Induction Harden
- Anneal
- Carburize
- Austemper
- Isothermal Anneal
- Nitride
- Martemper
- Spheroidize Anneal
- Carbonitride
- Meloniting
- Normalize
- Age Harden
- Nitrotec

MACHINING

Signicast has extensive machining capabilities in-house.

Signicast Time: 24 hours
Traditional Time: 336 hours

The Machining Division is utilized for major machining tasks that require CNC turning, milling, honing, or special operations. Any requirement from a simple tapping operation to complex finishing of an entire part is performed. Signicast's machining facility is used only to machine investment castings produced by Signicast. With years of experience devoted strictly to castings, Signicast's technicians have become true experts in managing all aspects of complete-to-print manufacturing.

In addition to the traditional machine shop capabilities, Signicast also provides in-line machining at the Hartford facility. Drill, tap, ream, and grind equipment have been placed directly in the casting facility – allowing final finishing to be included in the Continuous Flow Manufacturing stream, thus reducing the total time involved in producing a complete-to-print component.

ASSEMBLY/KITTING/FINAL PACKAGING

of cast component and other pieces for sale to the consumer.

Signicast Time: 12 hours
Traditional Time: 168 hours

THE TOP 5 REASONS

you should let Signicast finish your component:

1. THE HIGHEST QUALITY:
Signicast has in-cycle part checking and cutter compensation systems that verify quality through the use of contact probes and lasers.

2. THE BEST EQUIPMENT:
Signicast consistantly invests in the Finishing Division to ensure our machine tools remain top-of-the-line. All machinery receives scheduled maintenance so unexpected shutdowns won't interfere with your lead times.

3. DRAMATICALLY REDUCED LEAD TIMES:
Customers who utilize Signicast's finishing services receive completely finished components on time and enjoy the industry's shortest lead times.

4. ONE LESS SUPPLIER TO WORRY ABOUT:
Finishing your newly cast component at another facility just doubles your headaches. You already trust Signicast to provide you with the best components in the industry – why not to finish them as well?

5. BETTER COMPONENT DESIGN AND PERFORMANCE:
Since all of Signicast's modules work together seamlessly, excellent internal coordination and communications generate improved component designs, faster product launches and fewer mistakes – all with less management on your part.

The bottom line: having Signicast finish your part can save you time and money.

FASTER

GETTING TECHNICAL

Technical service is a priority at Signicast.

Early supplier involvement means Signicast's in-house technical staff and CAD capabilities are available to help you, at your site, or here at Signicast, during the formative stage of product design – improving the way your existing component is produced, even if it was previously manufactured by another cast process. Customers appreciate the advantages provided by Signicast's extensive technical capabilities.

TECHNICAL SERVICES

CAD – MAKING IT RIGHT THE FIRST TIME

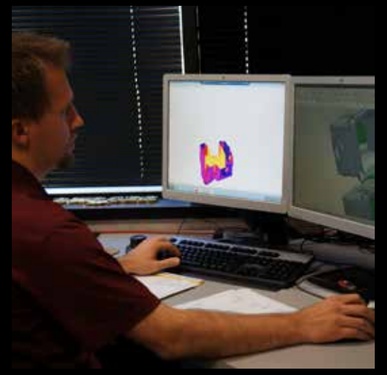
Accurate detail of design geometry can be effectively communicated through the use of three-dimensional CAD data. Signicast is able to build high-quality wax injection tooling using CAM-generated cutter paths and CNC machines. Among the many benefits of CAD tooling are:

- Reduced project time and a higher degree of interpretation using customer CAD model.
- Higher efficiency in building complex tools.

In addition to tool-making, Signicast utilizes simulation software to simulate solidification during the casting process including: part geometry, gating, sprue configuration, and temperature trials. The result is a significant time savings by eliminating multiple trials and achieving a high quality, repeatable process the first time. Signicast has the expertise to transfer data between CAD software systems.

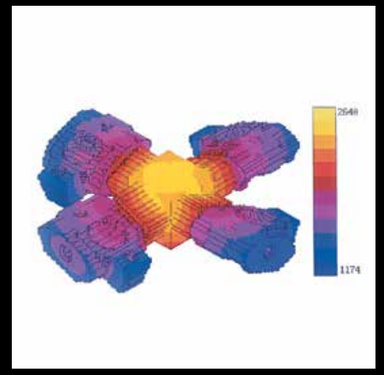
RAPID PROTOTYPING

Prototyping can be an effective way to evaluate design feasibility and productivity. However, at this stage of a product's life cycle, timing is essential. A delay of weeks can result in lost market share.



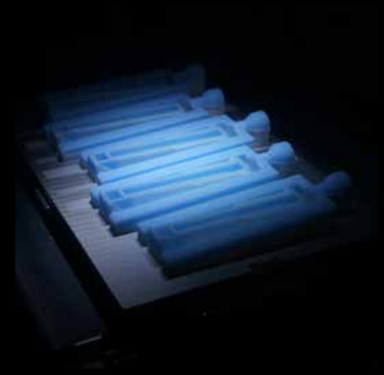
Signicast plays a major role in expediting time-to-market for new products, being well versed in utilizing prototyping to simulate a production part in a minimal time frame.

The best prototyping option to pursue is dependent on the complexity of the component, the surface quality desired, the time frame allowed, and the quantity of pieces required.



The most effective options to prototype investment castings include hard tooling, stereolithography (SLA or STL), and Multi-Jet Modeling.

Signicast prototype experts can assist you in selecting the best process for a particular situation. Cast metal prototypes can be produced in as few as five days. Consult Signicast to determine the shortest and most economical path to your rapid prototyping needs.



The technology of rapid prototyping is changing and improving continuously. Be assured, Signicast will stay on top of all new developments.

FROM 17 PIECES TO ONE

This part was originally an assembly of 17 pieces. The one-piece, 8.8 lb. investment casting – made of WCB alloy – provided a tremendous savings and eliminated dimensional variation found in the weldment. This part was the result of Concurrent Product Development between Signicast and the customer.

SMARTER

DESIGN GUIDE

DESIGN GOALS

Signicast's goal is to work in partnership with the customer to produce high quality investment cast components that will provide superior performance and durability. This requires sound mechanical design of the final component and the investment casting, reliable process controls, consideration of marketplace economic requirements, and clear communication among all parties.

In any manufacturing process, the price of a product will increase as the dimensional tolerance and inspection criteria become more stringent. Early involvement and input by Signicast's technical staff allows customers to overcome traditional casting tolerance issues. This is accomplished by innovation and technology to provide 100% conformance to specifications as-cast, delivered on time, at the lowest total cost. The most important guideline to remember is to get Signicast involved early in the design stage.

SIZE AND WEIGHT

Part size and weight are the most critical factors in determining part cost because mold capacity is limited by both size and weight. The more pieces that can run on a mold, the lower the part cost. Unnecessary mass should always be removed to reduce part weight.

NUMBER OF GATES

When possible, a part should be designed so that a single gate can feed the part. This will generally yield more pieces per mold and reduce the pour weight per mold. Single gate feeding also enhances the dimensional stability of a given part by providing a directional solidification pattern.

CASTABILITY

If a design contains features that will raise scrap or rework rates (and piece price), the Signicast Estimating Engineer will recommend design modifications to keep the piece price down.

LINEAR TOLERANCES

The investment casting process is capable of excellent repeatability. As-cast process capability of +/- three standard deviations when a single point location is repeatedly measured is typically +/- .003 to +/- .004 per inch. However, tolerance capability is largely influenced by part configuration. Symmetrical shapes with uniform wall sections will solidify with much less variation and distortion than non-symmetrical, non-uniform shapes.

NORMAL LINEAR TOLERANCES

Normal linear tolerances for normal dimensions reflect these three sources of variation:

- Prediction of Part, Shrinkage Factors (20%).
- Diemaker and Tooling, Tolerance (10%).
- Process Variation (70% of linear tolerance).

This variation is a combination of part configuration effects that result in non-uniform shrinkage, and all other process variation in producing a wax pattern, ceramic mold, and the casting.

ENGLISH (inches)		METRIC (millimeters)	
Dimension	Tolerance	Dimension	Tolerance
Up to .500"	+/- .007	Up to 15mm	+/- 0.20
Up to 1.000"	+/- .010	Up to 25mm	+/- 0.25
Up to 2.000"	+/- .013	Up to 50mm	+/- 0.35
Up to 3.000"	+/- .016	Up to 75mm	+/- 0.40
Up to 4.000"	+/- .019	Up to 100mm	+/- 0.50
Up to 5.000"	+/- .022	Up to 125mm	+/- 0.55
Up to 6.000"	+/- .025	Up to 150mm	+/- 0.65
Up to 7.000"	+/- .028	Up to 175mm	+/- 0.70
Up to 8.000"	+/- .031	Up to 200mm	+/- 0.80
Up to 9.000"	+/- .034	Up to 225mm	+/- 0.85
Up to 10.000"	+/- .037	Up to 250mm	+/- 0.95
Allow +/- .003" for each additional inch.		Allow +/- 0.1mm for each additional 25mm.	

PREMIUM LINEAR TOLERANCES

All three sources of variation can be reduced by:

- Part redesign, including addition of tie bars, ribs, and gussets to contain shapes.
- Tuning of wax injection tooling after the first sample to meet nominal dimensions.
- Straightening/coining.
- Additional inspection/gaging.
- Machining.

All of these can assist in obtaining tighter-than-normal tolerances. There are additional costs associated with the last four bullets. Signicast will work with the customer to meet the design requirements in the most economical manner.

Premium tolerance capability can be achieved, but must be considered on a part-by-part, dimension-by-dimension basis. Signicast is capable of holding +/- .002" in some features, although +/- .004" per inch is a more typical premium cast tolerance.

Premium tolerances may add secondary operations and cost to a part. It is important to designate tight tolerances that are necessary to part function and leave the rest open to normal linear tolerances.

GENERAL LINEAR TOLERANCES

What about dimensions that are on a drawing or CAD file simply to describe the shape? These dimensions can be most economically produced by applying a broader General Linear Tolerance.

ENGLISH (inches)		METRIC (millimeters)	
Dimension	Tolerance	Dimension	Tolerance
Up to 2.00"	+/- .020	Up to 50mm	+/- 0.50
Each Addtional 1.000"	+/- .010	Each Addtional 25mm	+/- 0.25

Another strategy that works well is to incorporate these types of features into a 3-D CAD file for the part, but not dimension them for inspection purposes. The feature is then tooled per the design, but valuable inspection and evaluation time is used only for features important to the customer.

TOOLING

- Signicast utilizes a system of tooling standards to ensure uniform high quality design and fabrication of wax injection dies which are generally guaranteed for the life of the part.
- Type of tooling in order of least expensive tooling, but highest piece price:
  - » MANUAL – Prototype or low volume production work.

MAXIMIZING RESULTS

Replacing machined surfaces with tightly controlled cast features provided the customer with a $500,000 annual savings. This was made possible by Signicast's "total component thinking" and a complete understanding of the component part and assembly.

- » SEMI-AUTOMATIC – Parts that are too large or fragile for fully automatic.
- » FULLY AUTOMATIC – Higher volume parts that can be ejected into a water bath. It is less labor intensive and increases productivity.

- More cavities mean higher tooling cost, but also increases productivity.
- Configurations that do not allow metal cores in tooling to be drawn due to undercuts or complicated internal shapes must be treated in one of the following ways:
  - » COLLAPSIBLE CORES – Lowest piece price, higher tooling cost.
  - » LOOSE INSERTS – Best for low volume parts, not an option for fully automatic tools.
  - » MULTI-PIECE WAX ASSEMBLIES – Best for certain configurations, tolerance control suffers along with increased part price.
  - » SOLUBLE WAX – Requires additional die for the soluble wax and increased labor for injection and removal of the soluble pattern. Provides excellent flexibility at moderate additional cost.
  - » PRE-FORMED CERAMIC CORES – High cost for specialized shapes. Used instead of soluble pattern because coring would not be properly coated during shell building process.

FLATNESS AND STRAIGHTNESS

Parts will be held flat and/or straight to .005” per inch of length. Heavy part sections may be dished, up to an additional .010”. Unless otherwise agreed, feeler gauge and surface plate (or straight edge) methods will be used to inspect flatness and straightness.

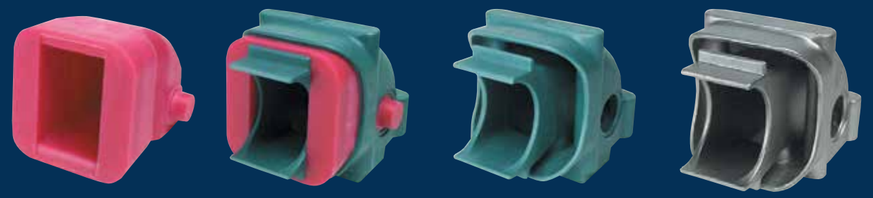
Straightening sometimes cannot be avoided and does add to costs. Do not specify tighter flatness, straightness, roundness, etc. requirements than you actually require. The actual straightening costs are often dependent on the tightness of the tolerance specified. Signicast generally straightens parts using die sets that will be included in your tooling price.

POSITION

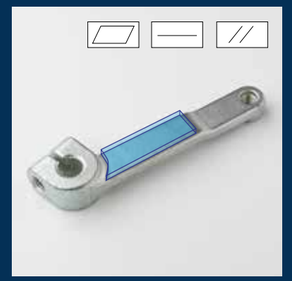
Linear tolerance of longest basic dimension. Concentricity is not a simple characteristic to measure. Consider changing the control to a runout or position notation.

CERAMIC CORING

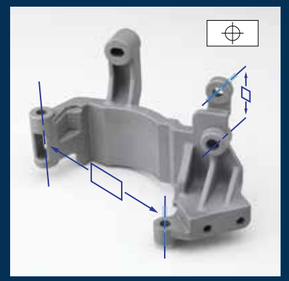
SOLUBLE WAX



FLATNESS & STRAIGHTNESS



POSITION



ORIENTATION

PROFILE

ORIENTATION

A good production tolerance is +/- 0.5 degree or +/- .008” per inch of length. This figure may vary, depending upon the shape of the piece.

PROFILE

Profile holds the same tolerances and basic principles as Flatness and Straightness except for curved surfaces.

SURFACE TEXTURE

Roughness (Ra), as measured by a stylus instrument, will be 125 microinch maximum for parts of small sections that weigh 0.5 pound or less. Larger parts may be rougher than 125 microinch. If this is important for part function, be sure to make these needs known. Secondary finishing operations can be used to improve this surface texture.

RADII

Normally, large fillet and corner radii reduces stress in the part and improves appearance. Design with the largest fillet radii that are practical. Allow .030” R minimum outside corner radii where practical. Sometimes outside corners must be tooled sharp, but this is avoided whenever possible.

GATE WITNESS

Each part is gated into one or more heavy sections. Normally, a .060” to .120” high gate witness left on the part will allow best manufacturing economy. Advise if this is objectionable.

Gates can be removed flush to the adjacent surface or ground to a specific dimension, but this often results in a higher manufacturing cost.

For accuracy, repeatability, and reduced piece cost, Signicast builds a gate grind fixture for all parts. Uncontrolled hand belting is avoided. When possible, design the part so the gate can be put on a flat surface rather than a curved surface.

Gate witness tolerances in order of increasing costs:

- Break-off witness – .060”-.120” max. depending on part size.
- Plunge Grind – .010”-.025” maximum witness.
- Flush Grind – to minus .010”.
- Swivel Grind – Grind to dimension.

BREAK-OFF WITNESS

PLUNGE GRIND

FLUSH GRIND

SWIVEL GRIND

HOLES

Through holes (round or other shape) and slots may be cast to:

SIZE	MAX DEPTH
.040" - .080"	2 x hole diameter
.081" - .200"	3 x hole diameter
.201" - .400"	4 x hole diameter
.401" +	6 x hole diameter

Preformed ceramic coring may allow hole depths up to 30 x diameter, at additional costs.

BLIND HOLES

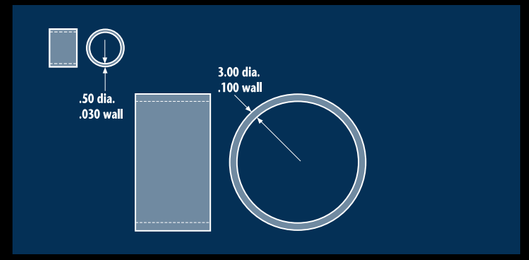
In blind hole design, large corner radii blending from the part surface to the hole are necessary to provide adequate core strength. Bottoms of blind holes should be full round or radiused as much as possible. Blind holes may be cast to:

SIZE	MAX DEPTH	BLENDING CORNER RADII
.040" - .120"	.5 x hole diameter	.5 x hole diameter
.121" - .400"	1 x hole diameter	.060" - .090"
.401" +	2 x hole diameter	.091" - .180"

- Preformed ceramic cores can be used to allow greater blind hole depths, but add significant cost to the casting.
- Incorporate countersinks and counterbores with the cast holes for improved economy.

WALL THICKNESS

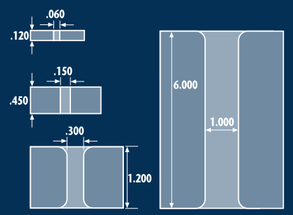
Minimum wall thickness and corner radii depend upon part configuration and size. Small investment castings may have walls cast to .030" thickness. Medium to large castings require .060"-.100" walls depending on the part geometry.



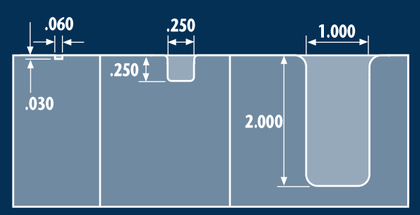
LETTERS/NUMBERS/LOGOS

Normally, raised letters or numbers in protective depressed pads are easiest to manufacture. A .020" high character on a depressed pad yields sharp, castable features. Specify exact text and dimensions of the figures. Logos can be investment cast to almost any design.

THROUGH HOLES / SLOTS



CAST FEATURES: BLIND HOLES



SPLINES/GEARS/THREADS

Gear and thread profiles can be produced with accuracies of +/- .004" per .5" of pitch. Longer lengths or larger diameters can be held to normal or premium linear tolerances as necessary.

GAGING

Signicast performs a 100% visual inspection of all parts. If dimensional verification is required, a sampling plan and process control is less expensive than 100% gaging of each part.

- Important: Whenever custom gages are used, there should be identical gages at Signicast and at the customer's facility.
- Fixed gages such as go-no-go are less expensive to use than gages with dial indicators.

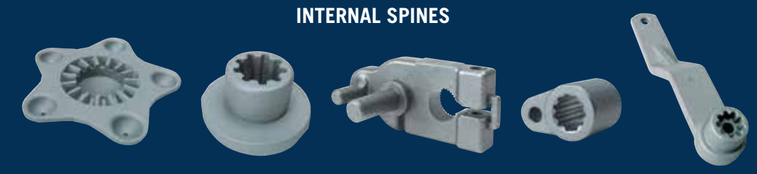
EXTERNAL SPLINES

SPLINED COUPLERS

SPUR GEARS

CAST THREADS

INTERNAL SPINES



REFERENCES:

Investment Casting Handbook, 1997 – Shows many applications, design data, alloy selection information, and quality control information.

Dimensioning and Tolerancing – ANSI Y 14.5 – An excellent engineering drawing standard published by the American Society of Mechanical Engineers. This standard defines symbols, describes tolerance and datum methods, and contains valuable information to assist design of mating components.

ALLOY PROPERTIES

Choose your material properties wisely.

ALUMINUM ALLOY

ALLOY (ANSI EQUIVALENT)	CONDITION	TENSILE STRENGTH (PSI)	0.2% YIELD STRENGTH (PSI)	% ELONGATION RANGE	HARDNESS RANGE OR MAX
A356	T6	34,000	24,000	3.5	70-105 Rb

CARBON AND LOW ALLOY STEELS

ALLOY	CONDITION	TENSILE STRENGTH (PSI)	0.2% YIELD STRENGTH (PSI)	% ELONGATION RANGE	HARDNESS RANGE OR MAX
IC 1010	Annealed	50-60,000	30-35,000	30-35	50-55 Rb
IC 1020	Annealed	60-70,000	40-45,000	25-40	80 Rb
IC 1025	Annealed	63-73,000	42-47,000	25-35	80 Rb
WCB*	Normalized	70-95,000	36-42,000	22-30	78-93 Rb
IC 1030	Annealed	65-75,000	45-50,000	20-30	75 Rb
	Hardened	85-150,000	60-150,000	0-15	20-50 Rc
IC 1035*	Annealed	70-80,000	45-55,000	20-30	80 Rb
	Hardened	90-150,000	85-150,000	0-15	25-52 Rc
IC 1045	Annealed	80-90,000	50-60,000	20-25	100 Rb
	Hardened	100-180,000	90-180,000	0-10	25-57 Rc
IC 1050	Annealed	90-110,000	50-65,000	20-25	100 Rb
	Hardened	125-180,000	100-180,000	0-10	30-60 Rc
IC 1060	Annealed	100-120,000	55-70,000	12-20	25 Rc
	Hardened	120-200,000	100-180,000	0-5	30-60 Rc
IC 4130	Annealed	-	-	-	100 Rb
	Hardened	130-170,000	100-130,000	5-20	23-49 Rc
IC 4140*	Annealed	-	-	-	100 Rb
	Hardened	130-200,000	100-155,000	5-20	29-57 Rc
IC 4150	Annealed	-	-	-	100 Rb
	Hardened	140-200,000	120-180,000	5-10	25-58 Rc
IC 4330	Annealed	-	-	-	20 Rc
	Hardened	130-190,000	100-175,000	5-20	25-48 Rc
IC 4340	Annealed	-	-	-	20 Rc
	Hardened	130-200,000	100-180,000	5-20	20-55 Rc
IC 4620	Annealed	-	-	-	100 Rb
	Hardened	110-150,000	90-130,000	10-20	20-32 Rc
IC 6150	Annealed	-	-	-	100 Rb
	Hardened	140-200,000	120-180,000	5-10	30-60 Rc
IC 8620*	Annealed	-	-	-	100 Rb
	Hardened	100-130,000	80-110,000	10-20	20-45 Rc
IC 8630	Annealed	-	-	-	100 Rb
	Hardened	120-170,000	100-130,000	7-20	25-50 Rc
IC 8640	Annealed	-	-	-	20 Rc
	Hardened	130-200,000	100-180,000	5-20	30-60 Rc
IC 52100*	Annealed	-	-	-	25 Rc
	Hardened	180-230,000	140-180,000	1-7	30-65 Rc

*Signicast recommends

ALLOY GRADE

Choice of alloy listed from least to greatest cost.

LEAST EXPENSIVE

Plain Carbon and Low Alloy Steels	8620, 4130, 4140, WCB, and 1035 are best choices due to high volume.
400 Series Stainless Steels	CA-15 (410), 440C are best choices. Specify 416 if necessary for machinability.
300 Series Stainless Steels	CF-8M (316), CF-3M (316L), CF-8 (304) are best choices. Specify CF-16F (303) if necessary for machinability.
17-4PH	Blend of corrosion resistance and strength.
Tool Steels	Costs vary widely depending on grade. S7, D2, H13 are commonly poured.
Monel	Choose based on end use.
Nickel Based Alloys	Alloy CW2M is a good choice for corrosion resistance.
Cobalt Based Alloys	All grades pour well – choice is based on end use and cost.

MOST EXPENSIVE

400 SERIES STAINLESS STEELS

ALLOY (ANSI EQUIVALENT)	CONDITION	TENSILE STRENGTH (PSI)	0.2% YIELD STRENGTH (PSI)	% ELONGATION RANGE	HARDNESS RANGE OR MAX
CA-15* (410)	Annealed	-	-	-	100 Rb
	Hardened	95-200,000	75-160,000	5-12	94 Rb-45 Rc
IC 416 (416)	Annealed	-	-	-	100 Rb
	Hardened	95-200,000	75-160,000	3-8	94 Rb-45 Rc
CA-40 (420)	Annealed	-	-	-	25 Rc
	Hardened	200-225,000	130-210,000	0-5	30-52 Rc
IC 431 (431)	Annealed	-	-	-	30 Rc
	Hardened	100-160,000	75-105,000	5-20	20-40 Rc
IC 440A (440A)	Annealed				30 Rc
	Hardened				35-56 Rc
IC 440C* (440C)	Annealed				35 Rc
	Hardened				40-60 Rc
IC 17-4 (CB7CU-1)	Annealed	-	-	-	36 Rb
	Hardened	150-190,000	140-160,000	6-20	34-44 Rc
CD-4MCu	Annealed	100-115,000	75-85,000	20-30	94-100 Rb
	Hardened	135-145,000	100-120,000	10-25	29-32 Rc

300 SERIES STAINLESS STEELS

ALLOY (ANSI EQUIVALENT)	CONDITION	TENSILE STRENGTH (PSI)	0.2% YIELD STRENGTH (PSI)	% ELONGATION RANGE	HARDNESS RB MAX
CF-3 (304L)	Annealed	70-85,000	40-50,000	35-50	90 Rb
CF-8 (304)*	Annealed	70-85,000	40-50,000	35-50	90 Rb
CH-20 (309)	Annealed	70-80,000	30-40,000	30-45	90 Rb
CK-20 (310)	Annealed	60-75,000	30-40,000	35-45	90 Rb
CF-3M (316L)*	Annealed	70-85,000	40-50,000	35-50	90 Rb
CF-8M (316)*	Annealed	70-85,000	40-50,000	35-50	90 Rb
IC 316F (316F)	Annealed	70-85,000	40-50,000	25-50	90 Rb
CF-16F (303)	Annealed	65-75,000	30-35,000	35-45	90 Rb
CF-8C (347)	Annealed	70-85,000	32-36,000	30-40	90 Rb
CN-7M (304L)	Annealed	65-75,000	25-35,000	35-45	90 Rb
HK	Annealed	65-75,000	35-45,000	10-20	100 Rb

TOOL STEELS

ALLOY	HARDNESS		
	ANNEALED WITH SLOW COOL MAX.	CYCLE ANNEAL MAX.	HARDENED RANGE
IC A-2	20 Rc	27 Rc	47-60
IC A-6	100 Rb		48-59
IC D-2		35 Rc	50-59
IC H-11	100 Rb		46-55
IC H-13	100 Rb		45-53
IC 1-M-2		30 Rc	61-63
IC M-2		30 Rc	61-63
IC O-1		100 Rb	44-57
IC S-1		100 Rb	44-57
IC S-4	100 Rb		42-53
IC S-5	100 Rb		37-59
IC S-7		100 Rb	35-57

NICKEL BASED ALLOYS

ALLOY	CONDITION	TENSILE STRENGTH (PSI)	0.2% YIELD STRENGTH (PSI)	% ELONGATION RANGE	HARDNESS RANGE OR MAX
Alloy B	Annealed	75-85,000	50-60,000	8-12	90-100 Rb
Alloy C	Annealed	75-95,000	45-55,000	8-12	90 Rb-25 Rc
CW-2M	Annealed	72-87,000	40-45,000	20-30	75-90 Rb
Alloy X	As-Cast	63-70,000	41-45,000	10-15	85-96 Rb
Monel A	As-Cast	65-75,000	32-38,000	25-35	65-75 Rb
Monel S	Annealed	100-110,000	55-65,000	5-10	20-28 Rc
	Hardened	120-140,000	85-100,000	0	32-38 Rc
Monel E	As-Cast	65-80,000	33-40,000	25-35	67-78 Rb

COBALT BASED ALLOYS

ALLOY	CONDITION	TENSILE STRENGTH (PSI)	0.2% YIELD STRENGTH (PSI)	% ELONGATION RANGE	HARDNESS RC RANGE
3	As-Cast				48-53
6	As-Cast				37-45
31	As-Cast	105-130,000	75-90,000	6-10	20-30
93	As-Cast				60-65