Investment Casting



Process Benefits

Lower cost
Shorter lead times
Wide alloy choice
Process consistency
As-cast surface finish
Less machining
Reduced assembly

Design Flexibility

Wide size range
Near-net shapes
Intricate geometries
Accurate dimensions
Thin walls
Cored internal passageways
Rapid prototyping compatibility



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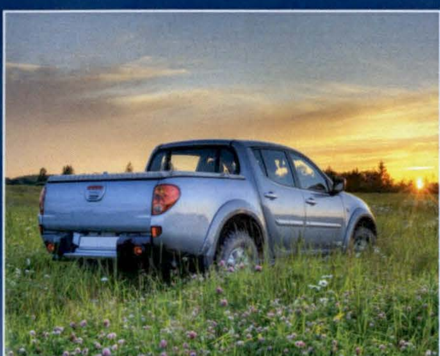
Investment Casting Case Studies & Applications



Everyone... Everywhere... is Touched by Investment Castings



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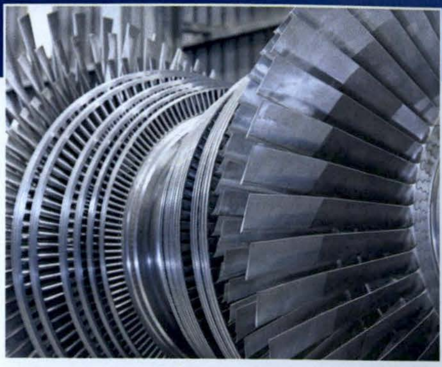

Explore the Potential of Investment Castings

Virtually every industry from A to Z uses investment castings. This booklet provides a sampling of investment casting applications and case histories to provide an overview of how investment castings have been used to reduce or eliminate assembly, machining, welding, and thus save time and money.

Investment castings are available in unlimited alloy choices, and because of the design flexibility offered by the process, near-net-shape investment castings are available in a wide range of sizes, with intricate geometries, accurate dimensions, thin walls, and cored internal passageways. The investment casting process is especially adapted to rapid prototyping technology.

The Investment Casting Institute is represented by casters from all over the world. Information on the capabilities of Investment Casting Institute members follows this supplement; also available on the Institute's website at: www.investmentcasting.org.

Acknowledgments

The Investment Casting Institute wishes to thank all the Members of the Institute and others who provided case studies, photographs or information for this booklet.

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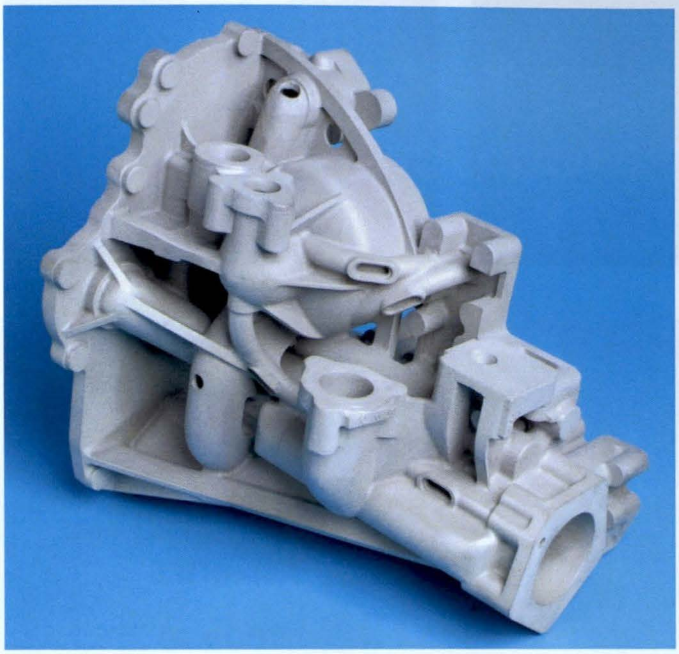


Complex Lubrication Pump Features Curved Passage 0.23" Diameter & 11 Long

Complexity both inside and out characterize this investment-cast main lubrication pump. The 12" x 9" x 13" aluminum casting, used in a commercial aircraft turbine engine, features superior surface finish and contains numerous internal passages which could not be machined.

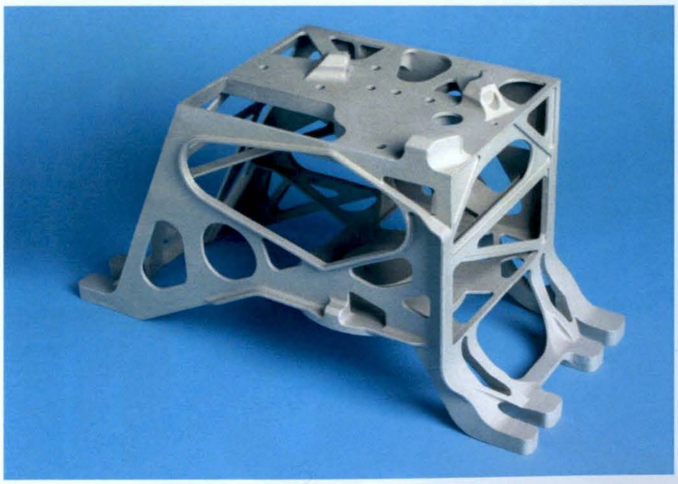
The casting is manufactured with 15 individual soluble wax cores. The most difficult curved internal passage is 0.230" diameter and 11" long. Additionally, extensive grade B areas require stringent x-ray inspection. Castings must pass internal pressure testing of 800 psi.

Form and Function Critical in Investment Cast Component

Both form and function are critical in this investment cast component. The complex aluminum casting is both a reminder of the critical role investment castings play, and of the flexibility of the investment casting process itself.

The casting is a key component in the mechanism which controls the pitch rotation of a regional jet plane. The very intricate shape and size of the 15" chassis, plus the necessity of thick and thin sections, make it a great example of investment casting.

While it is theoretically possible to create the component using other processes, this would require assembly of multiple parts which would be much more costly than the single investment cast part. The single investment casting also provides additional fatigue and strength benefits.

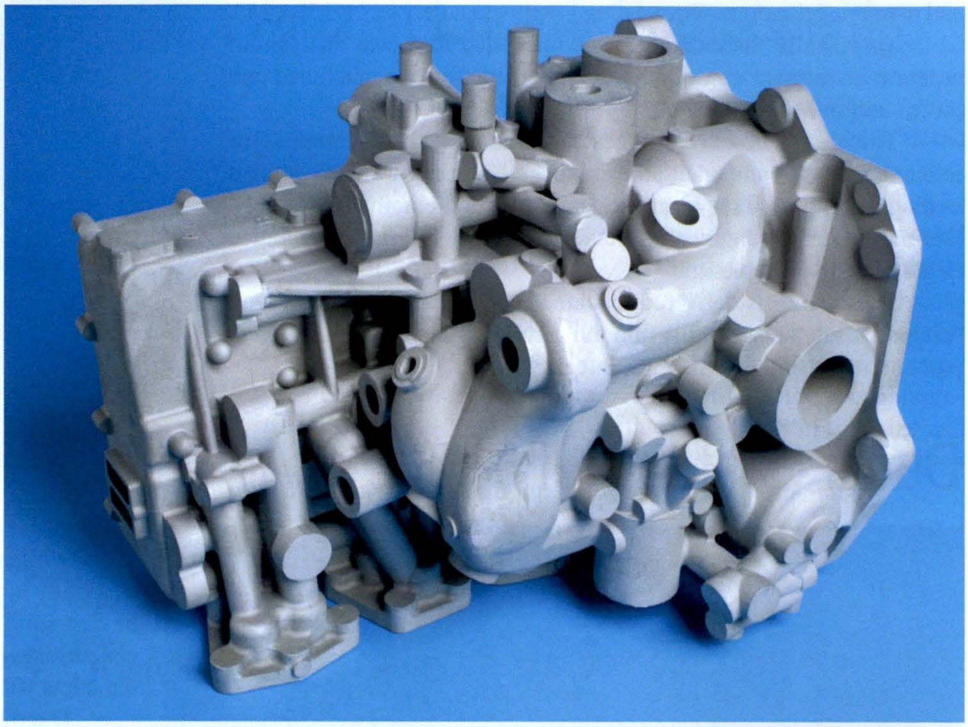


The caster worked closely with the customer to achieve the most effective tooling and casting design without compromising the part's function. Tooling design allowed wax build without soluble wax or assembly.

Helicopter Part Features Thin Walls and 180 Narrow Holes

This aluminum strut used in a helicopter engine was designed as an investment casting. The 19" diameter x 12" part has .060" cast walls with soluble core passage and 180 holes .080" in diameter.

Investment Casting "Wow Factor" Illustrated in Aerospace Components



Just one look at the complex exterior of this casting is enough to elicit a "Wow!" but the casting also includes multiple complex internal passages.

The 12" x 11.5" x 16" component controls fuel flow in a commercial aircraft jet engine. The Aluminum C355 casting is as impressive on the inside as it is on the outside. It features 11 intricate internal passages, which were formed by proprietary shellbuilding techniques without the use of ceramic coring.

The part was designed as an investment casting, which was considered the only viable manufacturing method to effectively achieve low cost and low weight requirements.

Extraordinary Complexity Underscores Flexibility of Investment Casting

The complexity which can be achieved with the investment casting process is underscored in this award-winning. casting. It has six intricate complex cores ranging from 3" to 12" in length, with .600" to 1.5" diameters. Cast in aluminum, the fuel metering unit for an aircraft engine measures approximately 11" x 10" x 8". It was designed as an investment casting.

Titanium Investment Casting Replaces 8-Piece Fabrication

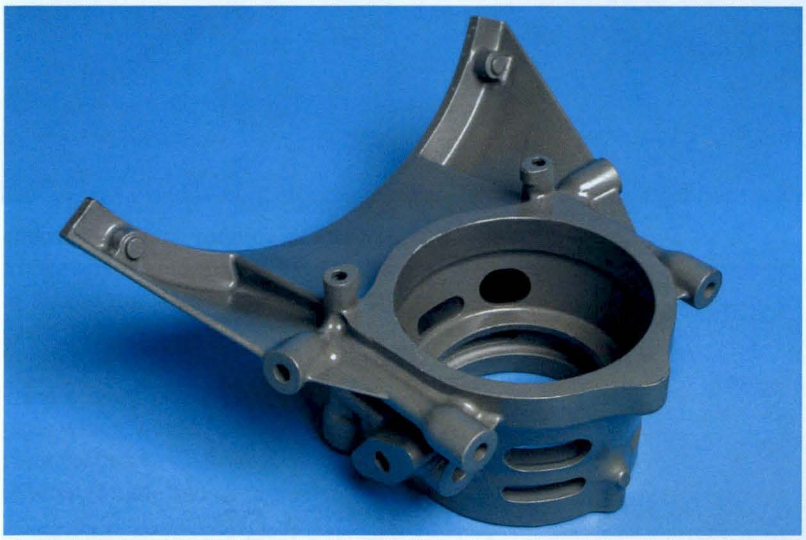
This aircraft engine lower strut casting combines into one casting what was originally eight separate part numbers of sheet fabricated and machined titanium. The casting is approximately 22" x 15" x 18".

Specifically the customer was interested in a cost analysis of separate investment cast titanium components for two machined end pieces and five sheet metal parts.

The caster, however suggested combining these components into one integral component, thus taking advantage of the investment casting's ability to form complex geometries and eliminate assembly. During concurrent engineering reviews, another fitting was included in the overall piece design.

The casting is delivered machined, finished and prefitted with fasteners ready for assembly into the aircraft. Benefits include lower part count and higher structural integrity.

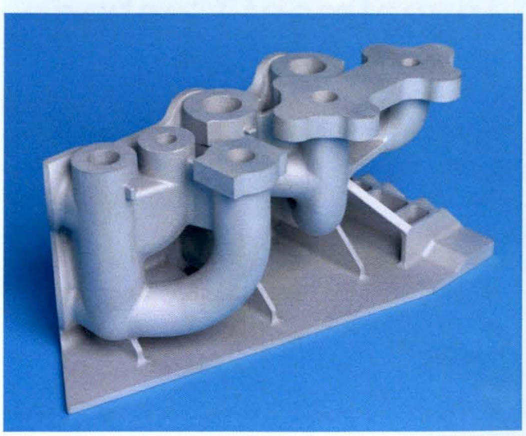
Ducts Cast to Net Shape in Aerospace Inlet Gear Box



While this aerospace inlet gearbox casing was originally made with all the ducts and small holes to be cast solid and machined to size by the customer, concurrent engineering enabled the caster to modify the ducts while still in the design stage.

The ducts– three vertical, two horizontal and one long diagonal– ranging in diameter from 1.0 mm to 1.9 mm, were cast to net shape. All ducts are interconnected and produced using a proprietary shell process.

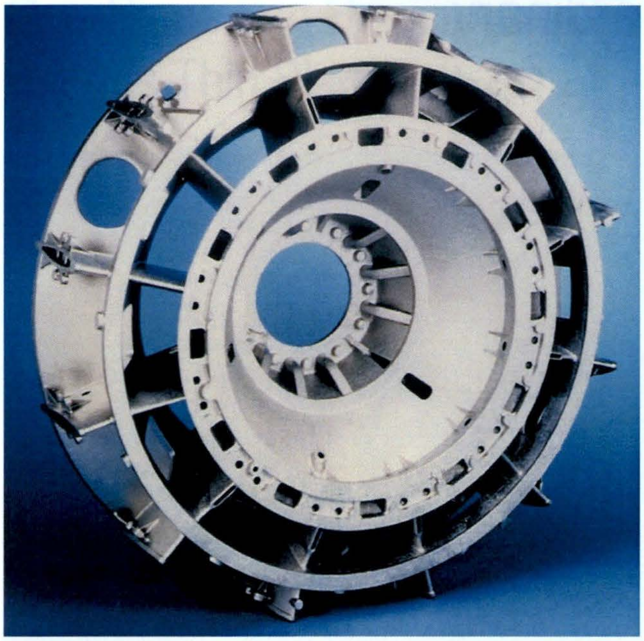
The component is cast in 17-4 PH stainless steel and measures approximately 11" wide x 9" high. Secondary operations include heat treat and HIP. Benefits include elimination of several machining operations, thus reducing time and costs significantly.



Multiple Features Combined in Near Net Shape

The design complexity of this aluminum casting is the result of the melding of features such as pressure vessel, manifolding, and flanges for sealing mechanical mounts.

Producing all of these features in a single cast piece eliminates costly fitting and welding of separate details and the structural consequences of added weld joints. The design flexibility offered by the investment casting process allowed the customer to sculpture a near net shape which minimized material content, fit within the available envelope, and met the seven prescribed interfaces of the aircraft. The part is approximately 9.5" x 4.5" x 4.5".



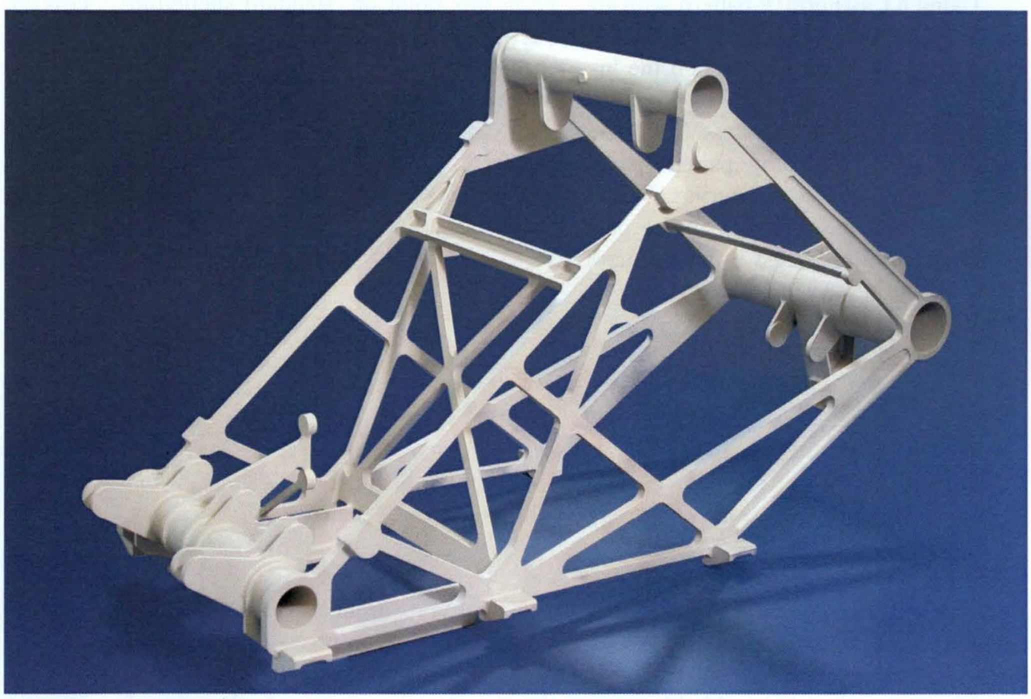
Large Titanium Investment Casting Replaces 88 Smaller Aircraft Engine Components

What was once 88 smaller stainless steel (17-4PH) castings, machined and welded together, was ultimately produced as a single 52" (132cm) titanium investment casting with improved strength and dimensional control, and also substantially reduced weight (about 55% the weight of steel with comparable strength).

The part is a fan frame hub used in an aircraft engine. It supports the front (fan section) of the engine and ties it to the compressor section.

The technology gained by the production of this part led to the design and manufacture of many castings, which means time and money savings for aircraft engine manufacturers. When this casting was first produced, nothing of this size and complexity had ever before been attempted in titanium.

Investment Cast Component Eliminates Multliple Processes, 50 Man-hours of Assembly



An investment cast rudder assembly for an aerospace application was previously composed of three aluminum castings, sheet metal assemblies, aluminum hog-outs and associated aircraft fastening hardware.

The previous design required 50 man hours to assemble. In addition, the one-piece casting limits procurement, inspection and administrative costs to a single part rather than the multitude required of the previous assembly.

The one-piece casting has provided consistent, dimensionally accurate design which requires minimal inspection and greatly reduced rejection rates compared to the previous design.

Measuring 36" x 24" x 14", the component is cast in A 357 with mechanical properties of 41,000T, 31,000Y, 2.5% E. Mechanical properties are derived from five different locations on the casting.

The dual "bicycle" frame design is unique. The part is light weight with wall thickness less than .095".

Investment Casting Meets Extraordinary Challenges for Complex Aerospace Part

The investment casting process is known for its design freedom, but this investment caster took the flexibility of the process one step further with the manufacture of an aluminum center body with complex internal passages.

At first glance, the order for aerospace prototypes did not seem to present a difficult casting design, but further examination revealed some extraordinary challenges.

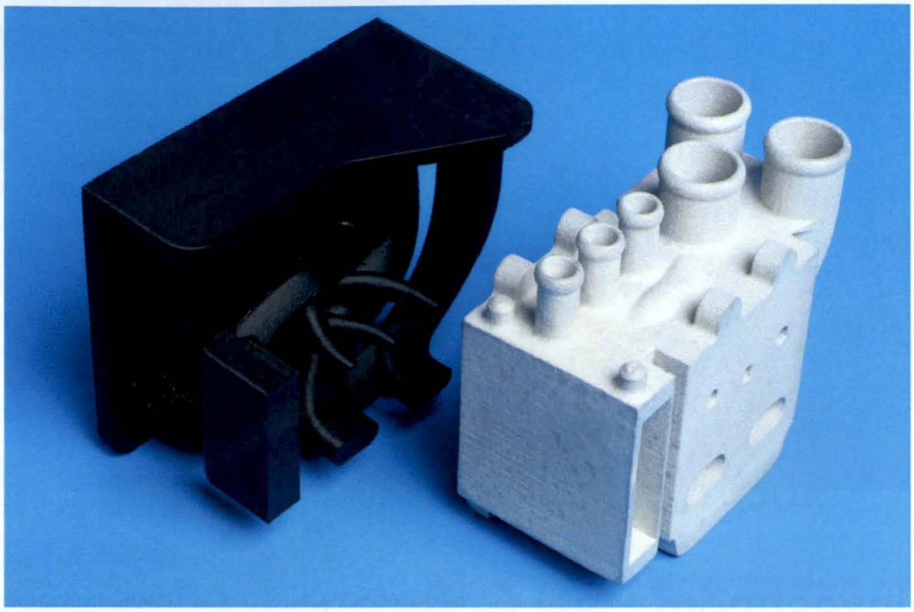
As engineers began the process of designing gating and establishing the total casting process, it became apparent that coring would require the most engineering. Due to the size and complexity of the internal holes and passageways, the logical approach would have been to use preformed ceramic cores, but the budget established by the customer and time constraints simply would not allow this option.

Using a CastForm™ pattern with all the holes and passageways in place, the investment caster set out to shell the internal passages rather than use ceramic cores or inserts. (CastForm patterns are plastic rapid prototyping patterns produced by selective laser sintering.)

Holes and passageways in the patterns were first inspected by flow check and bore scope to ensure that all passages were clear.

"Utmost care" were the key words during the shelling process. Failure of a single internal passage would render the casting unusable and place the overall project in jeopardy.

Using a proprietary ceramic material, shellbuilding personnel began the process with a first and second coat. After each coat, the holes were inspected to make sure they remained open. At this point, the holes were filled with the same ceramic material. A hand-held semi-pneumatic device was used to force the material through the passages, thereby assuring that no air pockets were present.



Internal passages in the casting on the right were shelled, not cored. The black figure on the left is a plastic representation to illustrate the complexity of the internal passages.

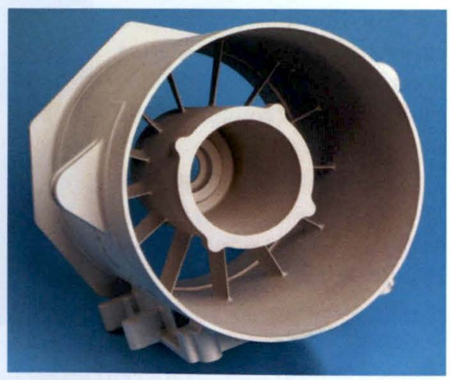
From this point on, standard shellbuilding parameters applied.

After casting, another challenge remained–how to remove the internal ceramic material without destroying the castings. The exterior was water blasted to remove the ceramic shell, but this process could not dwell on the holes without damaging the soft aluminum. A proprietary caustic leaching process designed for aluminum completed the operation.

After cleaning, inspection and heat treat, the parts were ready to ship to the customer in 28 calendar days.

Adapter Housing Features Six Internal Passages 3" to 13" long

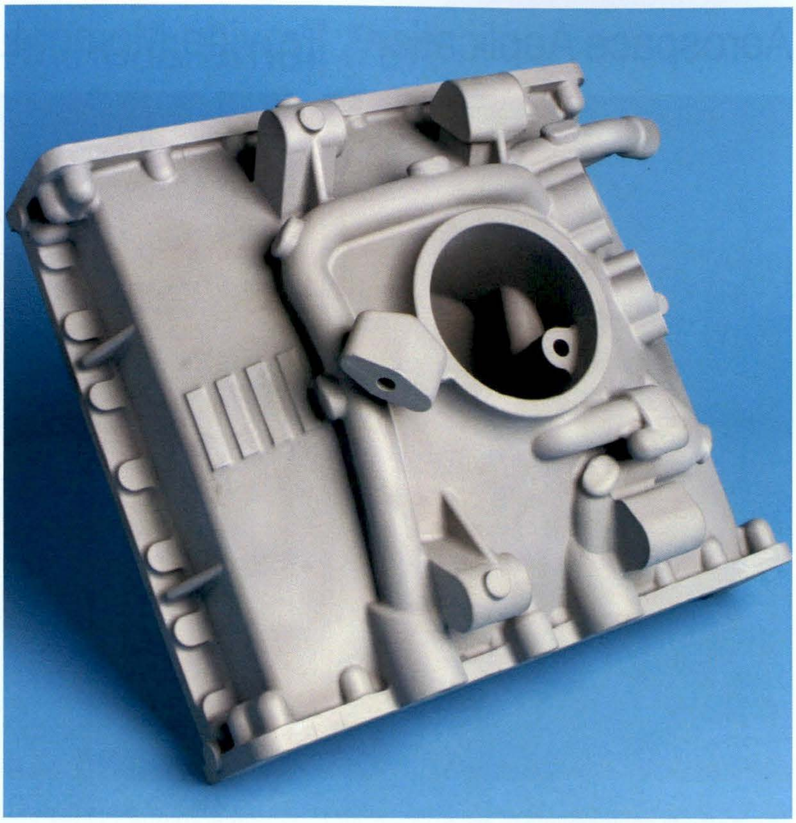
This adapter housing for a turbine engine, cast in aluminum, was designed an as an investment casting. It features six complex cores from 3" to 13" long with .312 to .600 diameters.



The part is used in auxiliary power units, gas turbine engines used primarily during aircraft ground operation to provide electricity, compressed air and shaft power for main engine start, air conditioning, electric power and other aircraft systems.

Cast in aluminum, the part measures approximately 14" x 12" x 8".

One-Piece Fan Housing Bridges Thin Blades, Thick Interior Section

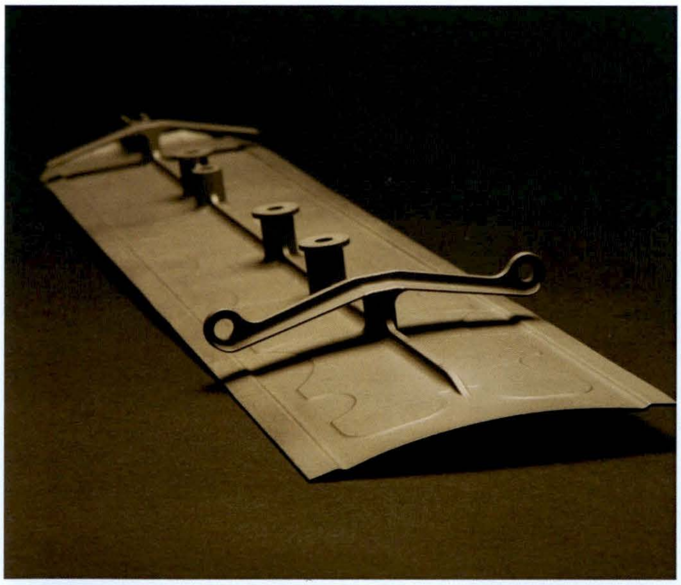


This one-piece investment cast fan housing for a commercial helicopter combines several functionalities into a single unit. Within the interior of the casting is a circular housing for mounting a fan motor and impeller. Thirteen very thin blades are attached to motor housing to the main case. Externally there is a mounting platform for a motor drive, and an inlet flange for attachment to a condenser.

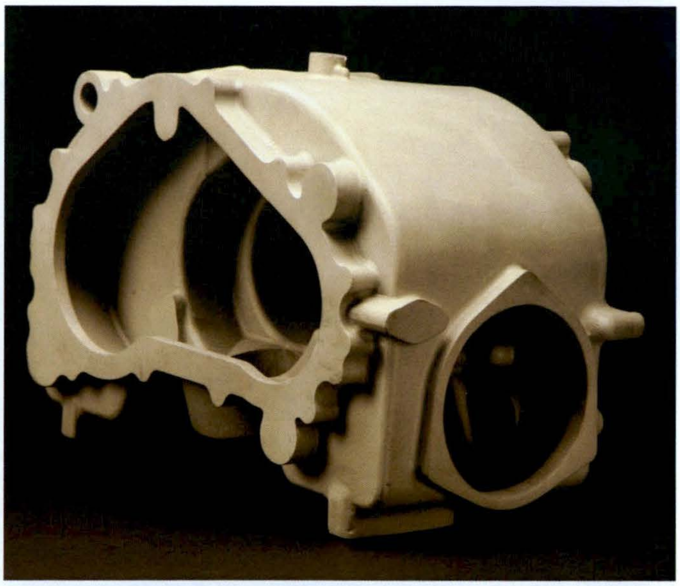
The customer chose investment casting over other methods because it provided a cost-effective solution for manufacturer of a complex part. Investment casting allowed the internal configuration of the casting to be undercut, and accommodate the shape, orientation, and aerodynamics of the radial blades.

The fan housing, cast in aluminum, encompasses a mix of very thin blades (.070" - .030") bridging the relatively heavy interior motor housing (.300") and exterior case (.200" - .100"). The part measures approximately 9.5" x 8" x 8".

Thin Walls, Complexity Often Dictate Investment Casting Choice

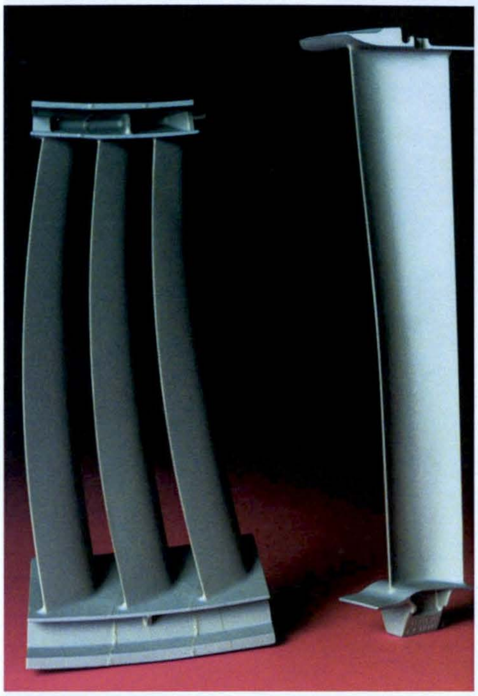


This aerospace afterburner flap was converted from a brazed sheet metal assembly into a vacuum-cast component in nickel, and features a long, thin wall. The conversion resulted in significant cost savings for the customer as it reduced the labor hours required for machining.



Thin-walled with hollow configurations, this complex aero engine gearbox is cast in aluminum and was formerly produced as a machined hogout.

Aerospace Applications Provide Momentum for Technology Advances



The constant improvement of aerospace blades and vanes has provided the momentum for many technology advances in the investment casting industry.

Turbine engine blades and vanes for both aerospace and industrial gas turbine applications exemplify many of the benefits of the investment casting process, including high strength corrosion resistant alloys, internal cored passages, and the ready-to-use supply chain management offerings provided by many investment casting professionals today.

Concurrent Engineering Used to Develop Castable Design for Aero, Land-based Turbines

This interturbine vane directs high-pressure air flow in aerospace or land-based turbine engines. The component was created using concurrent engineering practices to develop a castable design that would eliminate the need for welding in a high-strength alloy.

Swirler for Gas Turbine Engine is Small Part which Replaced 27-piece Fabrication

A single-piece swirler for a gas turbine engine replaced a fabrication consisting of 27 pieces. This investment casting is approximately 1.5" in diameter by 3.6" in length.

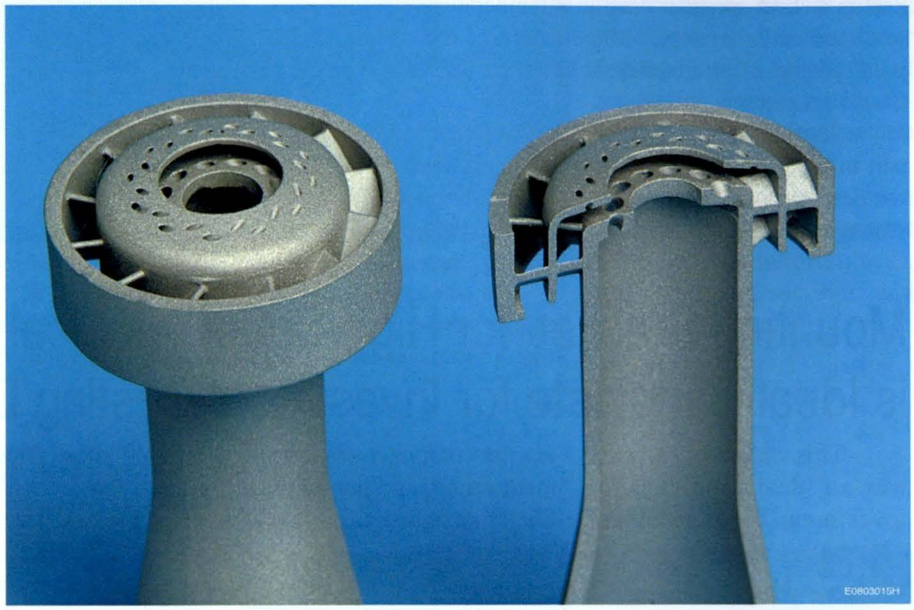
The fabrication experienced durability problems, often needing to be replaced prior to the warranty period. Parts produced through investment casting have overcome these issues, resulting in extended life.

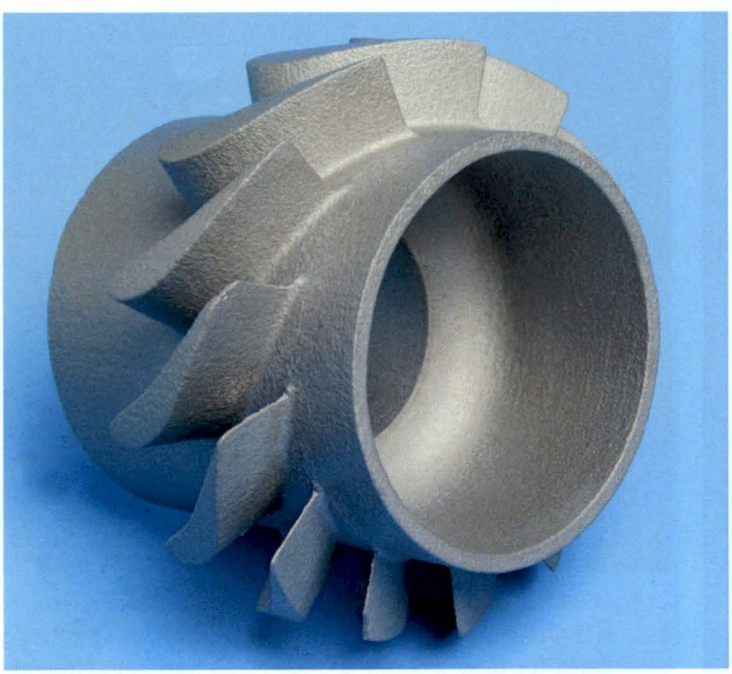
The original fabrication was flow tested as a result of variations in the fabrication process. However, the casting has proved so repeatable that the flow requirement has been eliminated on the cast part.

There is a series of .070" diameter holes located on the inner cap surface, as well as .030" holes on the outer cam. These holes are cast in, not machined. Tight spacing between the inner and outer cap surfaces makes traditional shelling techniques impossible. A new shell system was added to handle the complex components. A special dip technique was developed to properly build shell layers in critical areas of the part.

This part is produced using soluble wax and individually injected caps that come together in the final wax injection.

The success of this part has opened the door for more opportunities to convert from a fabrication to a casting with this customer.





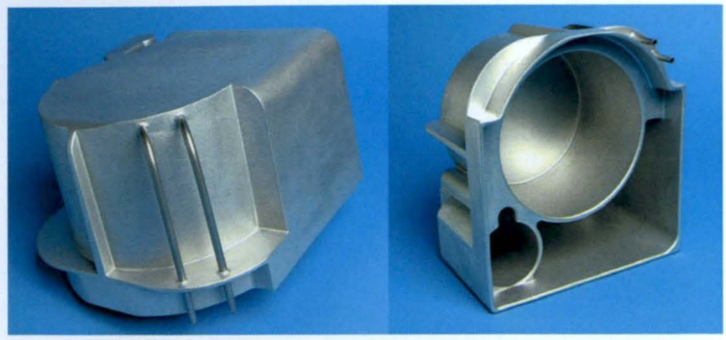
Investment Cast Turbine Replaces Fabrication and 13 Welded Fins

Before its rebirth as an investment casting, this part was a fabrication of a tube and 13 welded fins.

Rapid prototyping allowed minor design changes along the way and eliminated tooling altogether. The investment casting process saved the customer hundreds of dollars per part in fabrication time and resulted in a better looking more structurally sound part in a single casting. He found he could create one shape and machine it to many different variations of parts.

The seven-stage turbine rotor is cast in Cobalt 6 and measures 3.25" diameter x 2.55" length.

Stainless Steel Tubing Incorporated in Aluminum Casting, Part Delivered in Two Weeks



Not only is approximately 40" of stainless steel tubing integrally cast in this aluminum casting, but heat transfer was significantly improved and the first sample was delivered in less than two weeks.

The 13.74" x 13.75" x 5.75" aluminum (A356) component is a heat spreader used in a temperature-control vessel in a medical laboratory. Manufacture of the casting was a joint project of an investment caster and a supplier of SLA Quickcast patterns.

Starting from a CAD model, the caster redesigned the part to incorporate integrally cast stainless steel tubing. The customer was able to save the expense of making two separate castings and then welding them together to incorporate the tubing.

Internal solidity of the casting promotes even heat transfer. This includes the post-cast welding to fill core support holes. Section thickness ranges from .250" to more than 1.5". Secondary operations include nickel plating.

Mounting Bracket for High-Speed Medical Centrifuge is Ideal Candidate for Investment Casting Design

This mounting bracket was an ideal candidate for investment casting design. Although it could have been produced as a hog out, this was prohibitively expensive. Previous attempts at producing the component as a weldment failed, and the part was finally designed as an investment casting.

A critical support for a high-speed medical centrifuge, the component is cast in 304L stainless steel. The part measures 17" x 14" x 5".

Flatness had to be held within 0.20 TIR, and the two upright arms parallel to within .020."

Nondestructive testing included fluorescent particle inspection and X-ray (class 2, Grade B). Secondary operations were machining and passivation.

Orthopedic implants for the hip, knee and shoulder are investment cast in cobalt-chrome alloy and are ideal investment casting candidates for their smooth surface finish and high-strength, nonreactive alloy composition.

Alloy Choice Plays Major Role in Conversion from Die Casting to Investment Casting

Alloy choice for strength played a major role in this conversion from an aluminum die casting to a stainless steel investment casting.

The component, which measures .75 x 1.75 x 3.75" is used in a high-performance knee brace. It provides lateral support and forward movement simulating the motion range of the human knee.

The original die-cast parts were not strong enough and bent during use. By the time this was discovered, the customer was in full production and could not take the time required to have investment casting tooling produced.

An investment caster, using the die cast tooling, produced parts to verify that 304 stainless steel hinges would perform under heavy use. The die cast tooling was then modified for the investment casting process, with the customer experiencing a minimum of production disruption. The entire transition time was within three weeks.

Typical of investment cast parts, this component includes cosmetic features, thin walls and sections, and contoured surfaces.

Investment Casting Design Reduces Cost, Adds Enhancements for Dental Tool

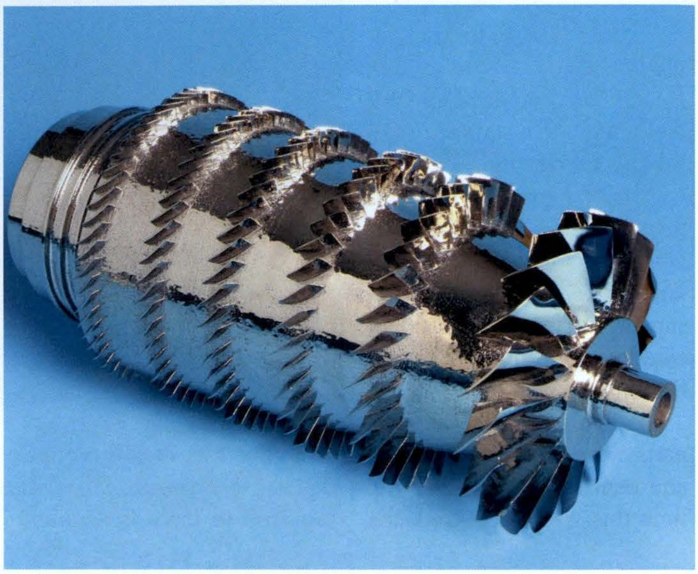
The end user was looking for a light-weight ergonomically correct handle body for a device used to cure dental fittings. This design accomplished that goal.

The component is 356 aluminum measuring approximately 5.5" long with .75" oval taper. By casting the interior with a core, a slot used to mount the circuit board eliminates any use of fasteners. Machining of the inside bore features would have been cost prohibitive. These features reduced the cost of the system while adding enhancements not available from the competition. Walls are as thin as .050".

Consistency in casting the outside contour of the handle eliminates unnecessary machining; gate placement was done so the final machining would remove it from the part.

Many investment casting houses can supply fully finished, painted and ready-to-assemble components like the handle body and front cap of these dental tools. Cast in aluminum, the part also features contoured edges, thin walls and cast-in interior holes.

Hundreds of Pieces Combined Into One Investment Cast Component



Literally hundreds of pieces were combined into a single investment cast component featuring integrally bladed rotors for a turbocharger. The rotor provides compression and expansion for a diesel engine, small power generator or a small jet engine.

Cast in MAR-M2-47 superalloy, the part measures 8.5" x 3.7" x 4.1".

Traditionally, these integral rotors would be comprised of forged disks that are machined, as well as either forged or cast individual blades, which also required machining. By replacing a fabricated rotor assembly with an integrally cast rotor, costs were reduced by more than 75%. This is because machining operations are nearly eliminated.

The product design has been greatly simplified by taking advantage of this integral casting. This project opens the door for opportunities to change the way these parts are designed and manufactured.

Investment Casting Flexibility Important in Automotive Component

The flexibility of the investment casting process is reflected in this casting designed with the customer to meet critical performance criteria in a fully variable valve train for an automotive gasoline engine.

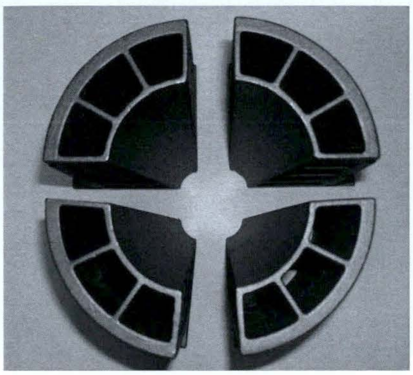
The levers are located between the camshaft and the inlet valves and impart the movement of the cams into a lesser or greater valve stroke, resulting in improved emissions and a drop in fuel consumption of between six and 16%.

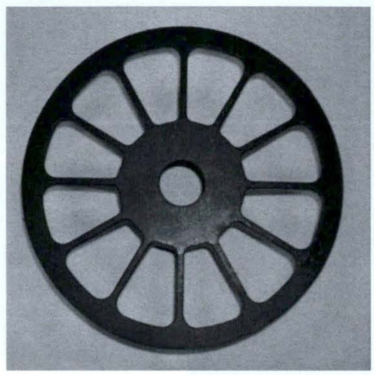
The original concept called for castings in 8640 alloy, hardened and tempered to a hardness of Rockwell C 47 to 53. The actual developed engine performance resulted in an unforeseen wear condition, which required a change in alloy, heat treat, and surface treatment.

In order to meet the new operating characteristics, the alloy was changed to 30CrMoV9. The castings are heat treated to a Rockwell C 37; after several finishing steps, the castings are subjected to a proprietary plasma nitriding treatment that leaves the parts with a surface hardness of Rockwell C 72.

The part is a good example of the flexibility offered by the investment casting process. The final casting geometry provides the necessary cross section mass in high stress areas while offering the weight savings of thinner sections in low stress areas, thereby providing an optimal weight-to-performance ratio.

Decreasing Weight of Assembly by More than 50% Makes for Good Investment Casting Application... But One with Challenges





Since the original method of manufacture was completely machined from bar stock, there was no economical method to reduce weight for this hand tool. The structurally hollow investment cast component reduced weight by more than 50%.

A request from one of its customers put an investment caster in the position once again of demonstrating the benefits of the investment casting process. The customer requested assistance in designing an assembly of six individual parts that would be used to remove a worn out cylinder liner in a diesel engine. The assembly design created a lot of challenges. Since the completed tool would be hand held, weight would be a critical factor but the cast design could not sacrifice the required strength.

The original method of manufacture was completely machined from solid bar stock with no economical method to reduce weight. Working with the customers engineers, the caster came up with a structurally hollow design that reduced the weight from 31.88 lbs as the bar stock design to 14.91 lbs as the cast design, a total reduction of 16.97 lbs.

Before the final design could be approved, sample castings were required for test. The investment caster made the 4130 casting by using prototype wax patterns produced one of their three 3D wax imaging machines. Two of the components required a .750 acme inside diameter thread that would mate up with a .75 acme shaft. The original prototypes required that the thread be machined but was found to be extremely difficult and very costly to produce. Thus, machining the acme thread was out of the question. They must be cast to size – but how?

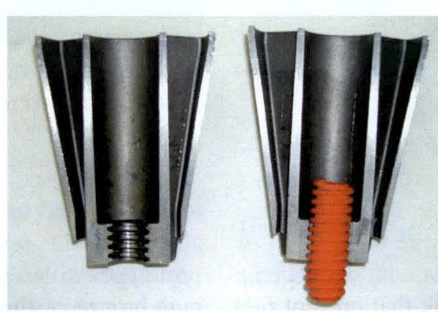
Some of the problems to consider were diameter and length shrink factor in production, and the effect of heat treating the final casting as far as metal shrinkage, and cleanliness of initial castings (bubbles and thread imperfections).

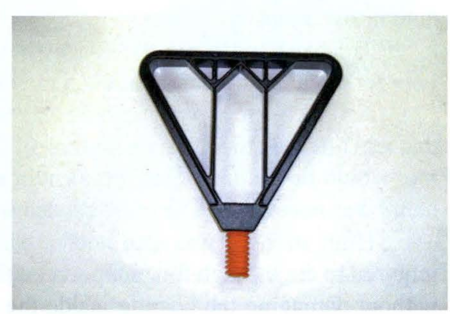
After testing the prototypes, the customer found no strength loss, mechanics were very satisfied with the weight of the tool, and the investment caster was approved to build production tooling. The complexity of the tooling is quite apparent as the photos illustrate, but not as difficult as designing a tool that would produce the acme thread, to gage fit, without machining.

Once the tooling was completed on the two details, interchangeable cores with variable shrink factors could be used to produce the acme thread. The problem with the interchangeable cores were time, the large number of cores required and the high cost of machined cores.

The team came up with a very practical solution to solve the problem. They would build the cores on a FDM (fused deposition modeling) machine. The build time was quick and the cost was relatively low. The variable size cores were built and used in the production to produce sample parts for size check. When the proper size was determined more cores were produced by the FDM method that would suffice for the production run of castings.

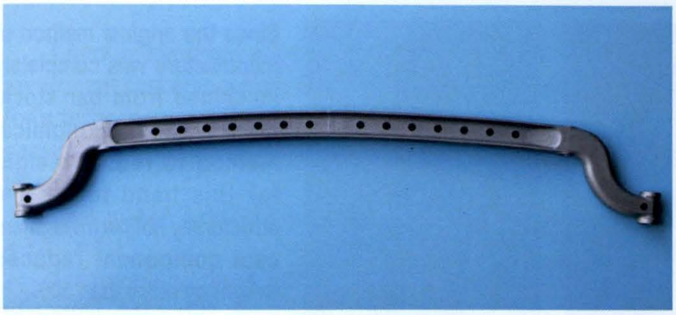
The solution to this manufacturing problem was not accomplished by any one idea, but a combination of team work, ingenuity and technology.





Casting the threads was accomplished with cores built on a fused deposition modeling machine.

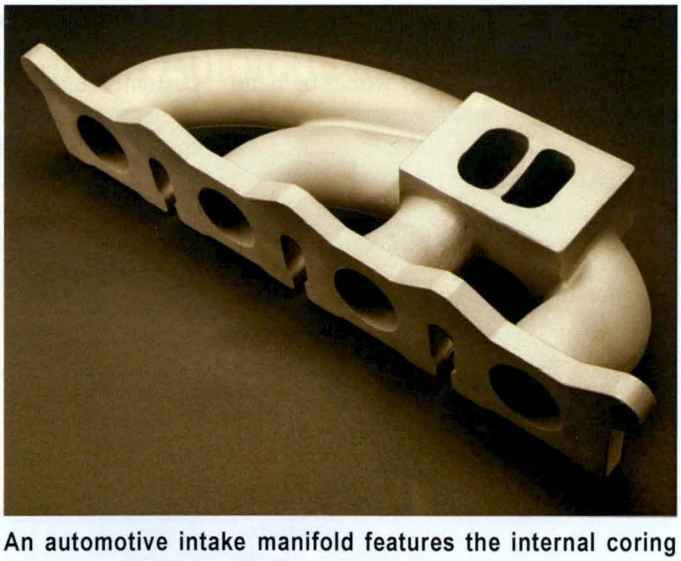
Investment Casting Provides Replacement Parts for Vintage Cars



This investment cast I-beam axle for 1928-1934 Ford is made for Ford Hot Rod cars. Since parts are unavailable at automotive stores, the component is produced in limited quantities. Although the part can be produced by forging, the customer indicated the cast component is about half the cost of the forged part. The stainless steel component is approximately 48" long.

This windshield bracket assembly was investment cast for the restoration of a 1932 Rolls Royce Ghost. With reverse engineering and the help of rapid prototyping technology, the component was completed in three weeks. The bronze assembly 17" x 12" x 1".

Alloy Choice and Quick Turnaround Point to Investment Casting



An automotive intake manifold features the internal coring capability of the investment casting process.

Alloy choice, overall configuration and rapid turnaround were major considerations when choosing the investment casting process to manufacture a fuel pump removal tool for the automotive industry.

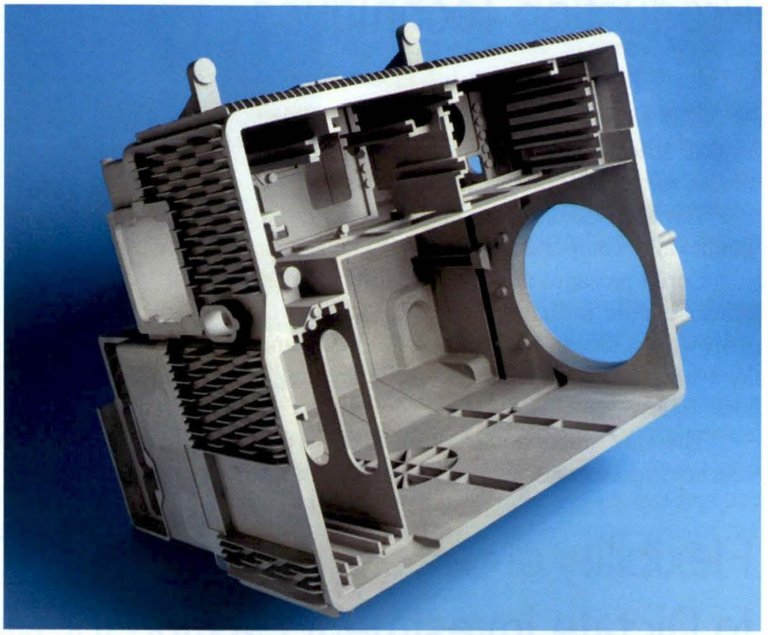
The fuel pump removal tool was designed as a joint project between an investment caster and a major auto maker.

An emergency recall required the removal of the fuel pump that was attached to the inside bottom of the fuel tank. Since the tool would be used in a gas fume environment, a non sparking metal was necessary. The alloy chosen was aluminum bronze.

High strength was also needed since the tool would be required to cut through four supports on the bottom of the pump without damaging the coating inside the tank that prevent fuel from seeping.

The customer in this case had an idea of what the tool should do, but not a complete design. Using rapid prototyping technology and its casting expertise, the investment caster was able to provide several design iterations in the form of plastic prototypes within a 48-hour period, and produced 17,100 aluminum bronze castings in seven weeks from final design concept including packaging, assembly and shipping of the complete product to auto dealers throughout the world.

Single Investment Casting Replaces Numerous Machined Components



This complex electronic housing sensor for military application, was designed as an investment casting because it is less costly than a fabricated assembly of numerous machined components.

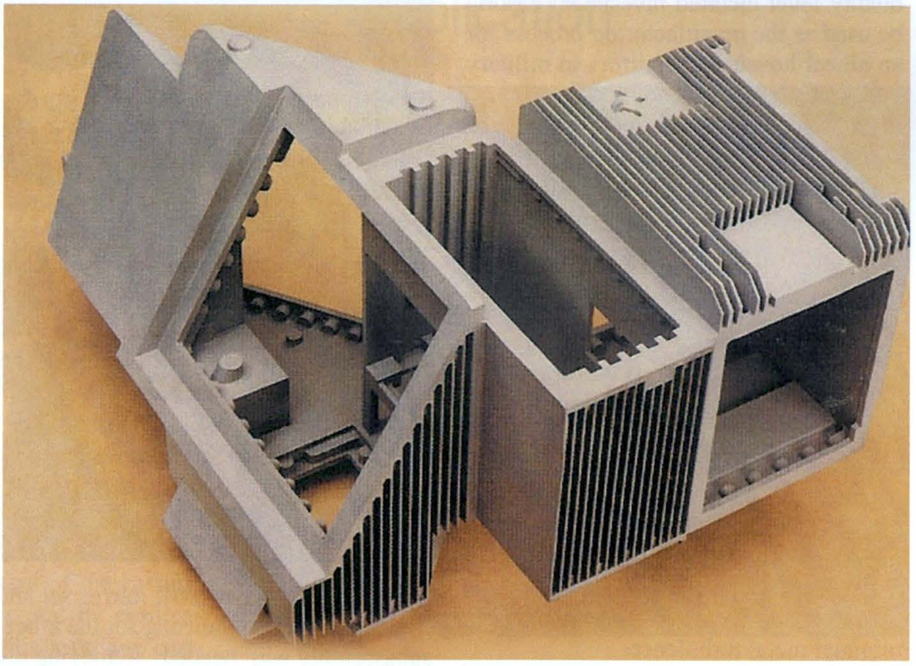
The near net shape configuration minimizes machining requirements; the thin-walled construction with finned walls assure superior heat dissipation.

The one-piece thin-wall construction features three integral net shape card guide bays. The staggered fin design allows for taller fins spaced closer together for increased heat transfer.

With challenging profile tolerances required throughout, an elaborate inspection fixture was necessary to inspect critical features. Minimum mechanical requirements of 41 Ksi and 2% are determined from integrally cast prolongations attached to the casting in critical areas.

The aluminum casting measures approximately 24" x 22" x 16".

Investment-cast Abrams Tank Part Replaces Two Sand Castings



Quality and complexity characterize this investment-cast commander's integrated display chassis used in the M1A2 Abrams Tank. This critical application exemplifies how investment casting technology can be used to manufacture net and near net shapes in extremely complex configurations.

Designed as a one-piece investment casting, the part replaced two sand castings and reduced the amount of machining and assembly previously required. One-piece construction also enhanced reliability and performance.

The alloy used is A356-T6. Minimum mechanical properties of 33,000 tensile, 27,000 yield and 3% elongation were determined from integrally cast specimens. Metallurgical quality requirements include a combination of grade C and D areas IAW MIL-STD-2175, of which the grade C areas are subjected to radiographic examination. Penetrant inspection is performed IAW MIL-STD-6866, Type 1, Method A on every part. There were 1191 dimensions or features requiring inspection for first-article approval. Due to the near net shape of the casting, significant weight reduction, a major consideration, was attainable.

Inner Passages of Pump Valve Component Require Special Production Techniques

This casting features a single-piece design that allows the customer to take advantage of a small part footprint that gives maximum performance for a high-pressure application.

The stainless steel casting is an a military aircraft main hydraulic pump valve component with cast attenuator chamber sphere.

Cored passages are accomplished by using soluble cores which require ceramic formation inside by straight-dipping procedures though narrow inlet areas. Inner chamber coating and drying are accomplished by a unique combination of ceramic layering and moisture management techniques.

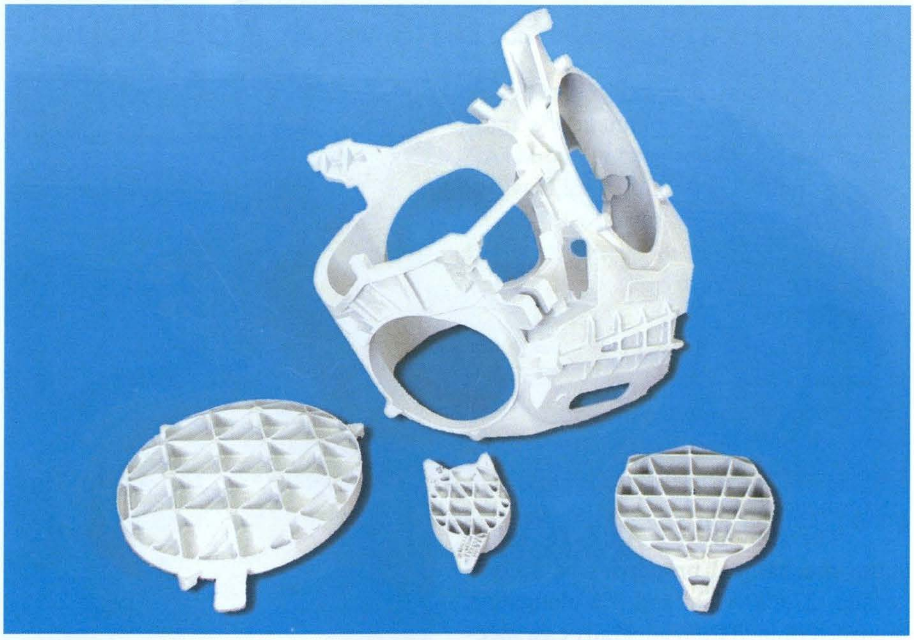
The cast sphere wall is inspected via ultrasonic techniques. Post-cast cooling controls, as well as HIPping assure high part density.

Flexibility of Casting Material, and Complexity Combine to Dictate Investment Casting for Military Mirror Housing

Flexibility of casting material, complex configuration, thin walls, and a high quality level dictated investment casting be used as the manufacturing process for an afocal housing for mirrors in military helicopter.

This silicon carbine/aluminum metal matrix composite (SiC/MMC) component was designed as an investment casting. The lightweight investment casting houses three SiC/MMC mirrors. Size of the housing is 14" x 14" x 17".

Three factors make the part unique. First, the casting is being produced from SLA (stereolithography) patterns; second, the material is an aluminum-based silicon carbide metal matrix composite; and third, it is being cast using a unique, patented version of the investment casting process. This process excels in casting highly viscous alloys such as SiC/MMC in concentrations up to 40%. The process provides a well-controlled method with minimal metal turbulence.



In order to push the state-of-the-art stand-off ranges and perform under extreme temperatures encountered by the modern war fighter on it's targeting system, an extremely stiff mirror set and thermally matched housing for the afocal subassembly was needed. Achieving the near perfect optical wavefront error meant aluminum mirrors were too flimsy, sagging under their own weight. Beryllium would have provided the required stiffness, but thermally matching the housing meant a beryllium afocal housing hogout, which would have been cost prohibitive, if it could be done at all in the large complex housing geometry. The SiC/MMC mirrors and housings provide the stiffness, thermal match and castability.

Buffer Yoke is Part of Military Effort to Improve Lightweight Ground Combat System

A buffer yoke casting, which is a structural component for the redesigned M777 155mm Lightweight Towed Howitzer, is part of an effort using titanium investment castings to improve the Howitzer system for ground military combat.

This 10" x 12" x 30" component clearly exemplifies the benefits of the investment casting process, including speed of manufacture, affordability and design freedom. Previously produced as a fabrication, this casting is one of a suite of 19 parts. This application represents the first time investment cast titanium was selected for a land-based armament system. The new 155 mm Lightweight Towed Howitzer is 42% lighter than its predecessor and has a 25% smaller footprint. The radical redesign was possible in large part by a reliance on titanium structural castings.

The work that has been done in developing the specifications and manufacturing processes for titanium castings is paving the way for systems like the Future Combat System. With the successful manufacture of the M777 Lightweight Howitzer, the industry has demonstrated its ability to produce the lightweight, rugged components necessary to meet the ambitious requirements flowed down from war-fighters to design engineers.

The suite of 19 structural castings has significantly fewer parts and welds, as well as greatly reduced length of welds, when compared to the original prototype fabrications. Reduced raw material inputs, shorter manufacturing cycle times and significantly broader design freedom are also important positive outcomes of the investment casting process.

Economics Makes Investment Casting the Manufacturing Process Choice for Hi-Tech Energy Application

While investment casting was not the only option available to manufacture a critical component in the high-tech Z-machine at Sandia National Laboratory, it was by far the most economical way to go.

The investment cast anode is one of several castings that are part of an assembly that creates the water convolute for the Z machine, which was being upgraded at Sandia National Laboratories.

The machine's immediate purpose is to provide data to feed into supercomputers that simulate nuclear weapon explosions and to test materials under extreme conditions.

The customer had several options in the fabrication of the design, but chose investment casting due to the cost of tooling and piece price, as well as confidence in maintaining profile requirements in a cast shape. A fabrication of this shape was projected to cost six to eight times the casting cost and the customer did not believe a fabrication could maintain the profile requirements due to the weld movement and distortion of internal structure.

The size of the casting, its contours and its application make this a unique casting. Cast in stainless steel (304L), the casting is roughly 27" x 26" x 17". Its contour is designed to minimize the electric field over the surface of the part to help increase the performance of the pulse energy machine.

Alloy Choice is Major Factor in Choosing Investment Casting for Military Application

Because investment casting allows almost unlimited alloy choice, manufacturers can shop around for the properties they need or most desire. This is especially important for military applications where performance and weight are of prime importance.

The investment casting process was used to produce a proprietary part for a day/night multifunctional targeting pod for a fighter aircraft. Cast in an investment castable beryllium aluminum metal matrix composite material (Beralcast 363), the part measures about 5.25" x 3.5" x 5" and weighs about half a pound as cast.

The primary benefit of using this part is its high stiffness, low density and its ability to be cast to near net shape. Be-Al alloys are very attractive options for aerospace engineers because of their high stiffness (equivalent to steel) and low density (typically 20% less than cast aluminum alloys).

In this application, the high stiffness allowed the targeting pod to reach its full designed performance rating while still meeting its target weight.

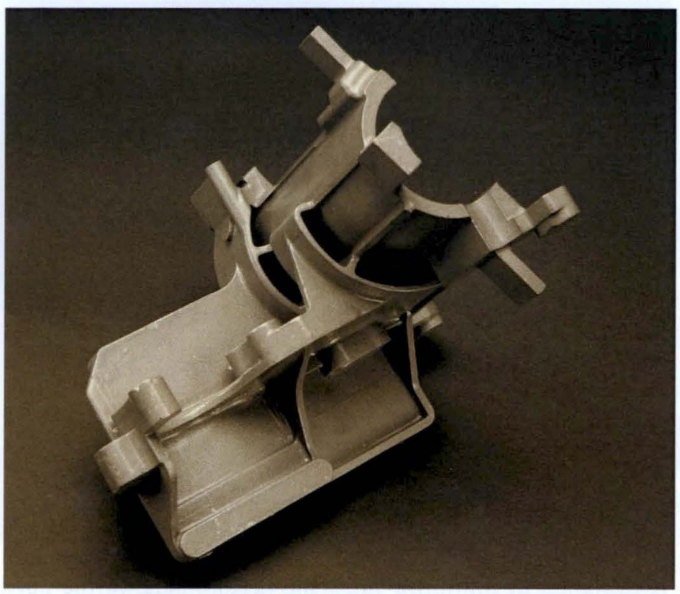
Since this was the first time this part was fabricated by any method, investment casting was selected in competition with a fully machined option for a similar material.

> "The ability to investment cast a part to near net shape reduced the material usage by up to 80% when compared with a fully machined part."

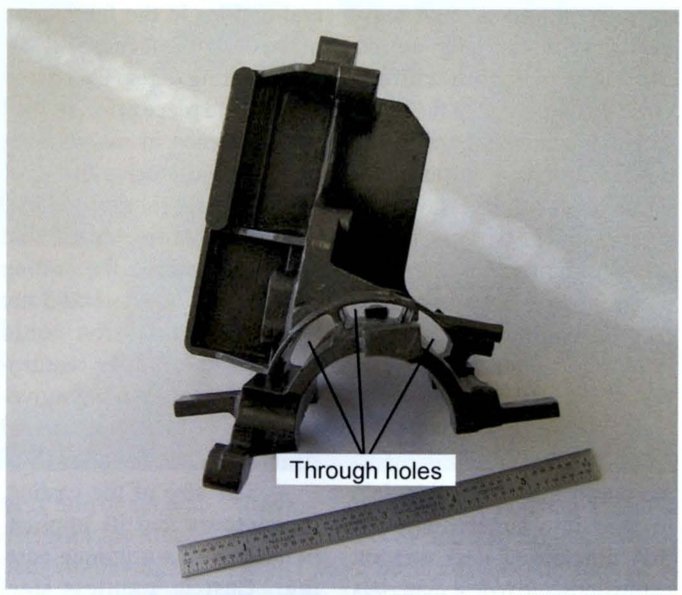
The ability to investment cast a part to near net shape reduced the material usage by up to 80% when compared with a fully machined part, which is a significant cost savings considering the cost of Be-containing metals. The reduced machining time required by the near net shape casting lowered cost, improved cycle time and cut back on occupational exposure to beryllium.

Yet another benefit of the investment casting process is illustrated in the narrow through-hold cavities in the central region of the casting. The customer wanted to cast these holes to dimension and not perform any machining on them. Due to the reactive nature of molten Be-Al, there was no suitable ceramic core technology to help form these features. Thus, the decision was made to shell these regions along with the rest of the part. In order to achieve this objective, an alternative shell system was developed.

This application was the first use of investment cast Be-Al metal matrix composites by a European defense contractor (which requested its name be withheld for proprietary reasons). A total of five investment cast Be-Al components are used in this targeting pod.

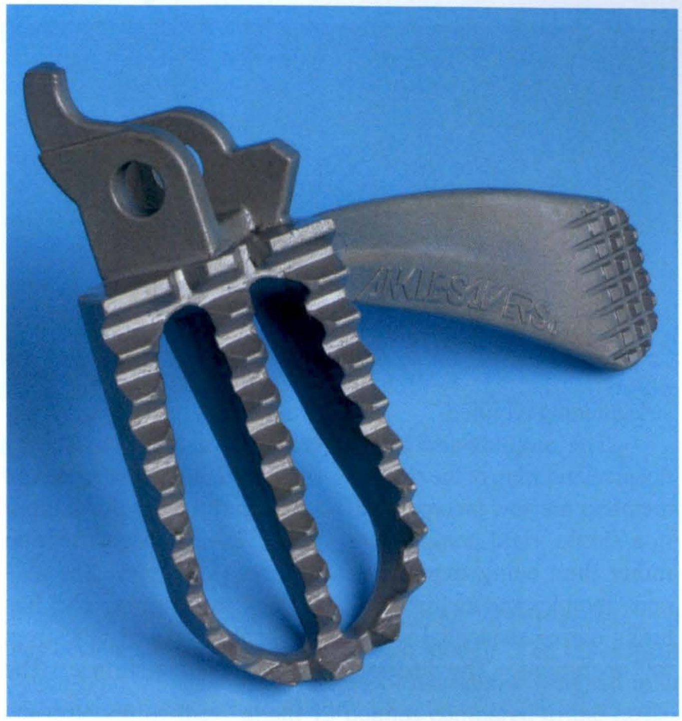


The metal matrix composite used to cast this component provided light weight, high stiffness, and low density. The near net shape eliminated significant machining.



A finer grade stucco and revised application technique were needed to cast through holes. Ceramic cores could not be used because of the reactive nature of the alloy.

Design Freedom of Investment Casting Improves Form and Function of Motorcycle Part



The design freedom afforded by the investment casting process made the Ankle-Savers® Foot Peg a stronger, more reliable, more aesthetically pleasing product for motor cycle enthusiasts.

Several design changes improved both function and appearance of the former weldment. Investment casting design flexibility allowed for large sweeping radii to be added to the part design. Part numbers and company logo were also cast into each part. Other changes included thicker walls where more strength was needed, and cast in functionality with teeth and knurlig.

Lisa Davis, head of operations/media and rider support for Moto Innovations LLC noted, "The one-piece investment cast product has improved product reliability with zero warranty replacements required to date as a result of broken or bent pegs. These pegs take quite a bit of abuse on any given weekend. The off-road enthusiast is putting their motorcycle in extreme conditions and running the bike at top speeds."

"The part mixes a combination of good looks and robust functionality," she said. "In the world of MotoCross, the part obviously has to perform, and in a very reliable way. However, the riders take their bikes and appearance of their bikes very seriously."

The Ankle-Savers are cast in precipitation hardening stainless steel and measure approximately 6" x 5" x 1.5".

Magnesium Driver Offers Lower Cost Alternative to Titanium

When you combine light-weight magnesium with thin walls, and a hollow interior, the result is super light weight. That's music to the ears of avid golfers, especially those who like the performance of titanium, but not the price tag.

An investment caster specializing in magnesium has produced a new golf club head, which represents a 50% savings over the current oversize titanium drivers. The very thin walls (0.75 mm in most areas) allows for an enhanced sweet spot on the face of the driver. The very light weight allows high club head speed.

An added feature is an eccentric weight of stainless steel in the bottom of the driver than can be adjusted to move the center of gravity left or right to compensate a hook or slice.

The pattern for the casting was produced using thermojet solid object modeling technology. Custom design changes were easily accomplished by modifying the CAD.

A beta version of this club was tested by a semi pro golfer; astounding drives in excess of 300 yards were common.

Single Investment Casting Replaces 13 Pieces in Steering Head of Motorcycle Chassis

This single-piece investment cast steering head for a motorcycle chassis replaced 13 individual pieces and greatly reduced the amount of welding needed to perform the same functions in previous chassis assemblies.

The precision and accuracy of the casting eased the assembly operation and reduced the amount of rework and straightening required.

The angular and positional relationship of the chassis members are now incorporated in a single, rigid component, rather than being dependent upon complex and multiple fixturing during sequential welding operations. The steering stop-boss, fuel tank mount and a mounting hole for an optional engine guard accessory are included in the casting. Precision investment casting allowed the inclusion of a steering fork lock whose cylinder operates in a cast-to-size socket and requires only the tapping of a cast-to-size cross hole for a set screw to hold it in place.

Another feature made available by the ability of investment casting to reproduce small details and achieve fine surface finish is the tamper proof Vehicle Identification Number (VIN) pad. The $2^3/_4$" x $^{13}/_{32}$" rectangular pad has diagonal ribs raised .008" from the surrounding surface. The

VIN is roll stamped into this ribbed surface as the final step of chassis fabrication. Any attempt to alter the VIN would be apparent by the inability to recreate the raised ribs.

Investment Casting Achieves Contours, Aesthetic Qualities Not Practical by Machining

This shotgun receiver and tang is used in a well-known brand of shotgun. The assembly, made of chrome hardenable stainless steel (alloy 410), was designed as an investment casting. Machining is limited, and the pleasing contours would have been impractical if produced in any other way.

Manufacturers knew from the beginning that the investment casting process would be used on the receiver and tang. With this in mind, it was possible to incorporate superior features in the design of the firearm. The tang is cast in one piece, avoiding the more costly assemblies of less modern designs. Dimensional controls are built into the process at all stages of production. Hot straightening is used to improve final dimensional conformity. Two castings are machined prior to joining by TIG welding.

Investment Cast Diving Helmet Combines Security of Metal with Light-weight Efficiency of Plastic

Deep sea diving helmets have been traditionally heavy and made of corrosion-resistent metal. They are also a bit cumbersome. While plastic (carbon fiber) helmets offer a light-weight alternative, many divers have an inherent dislike of plastics and opt for the security of more traditional metal helmets.

So how do you get the best of both worlds? How do you get a lighter weight, corrosion-resistent metal helmet that will withstand great pressures, provide a great surface finish and feature lot of fine detail for attaching such in-helmet necessities as valves, radio communication, light intensification and more?

The answer is simple: investment casting and rapid prototyping technology.

A QuickCast pattern was created using stereolithography (SLA) technology. Since no tooling is involved, there were no restrictions on design changes; several versions of the pattern could produced before castings were made.

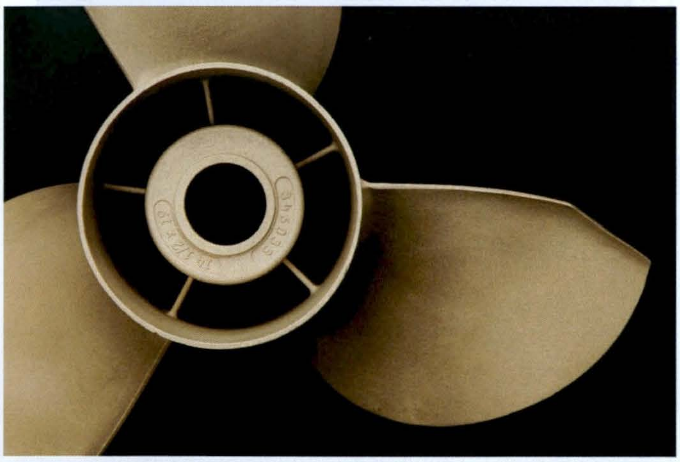
The helmet manufacturer decided on a thin-wall diving helmet of 316 Stainless Steel. They wanted a lot of detail that had previously been machined. A locking device that had previously been machined is now being cast.

The one-piece construction of the helmet featured tolerances of less than ±0.005", wall thicknesses ranging from 0.10" to just under 1.0", and a surface finish roughness of 125 RMS at most. Investment casting eliminated the need for a lot of machining, which was required of the sand cast model. The investment cast version of the helmet weighed in at about 13 pounds compared to the earlier 45-pound sand casting model.

The fine cosmetic appearance was also a winner to the customer, as was the significant reduction in labor to manufacture the new helmet.

Investment cast diving helmet has cast-in features which were previously machined.

Fully assembled helmet.



Propellers are just one of many marine applications of investment casting. Typical features include thin walls and clean surface finish.

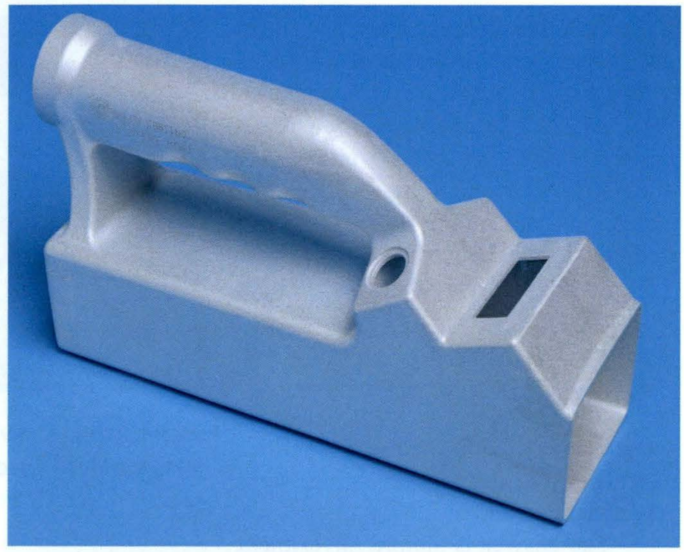
Functional External Appearance Conceals Internal Detail of Investment Cast Component

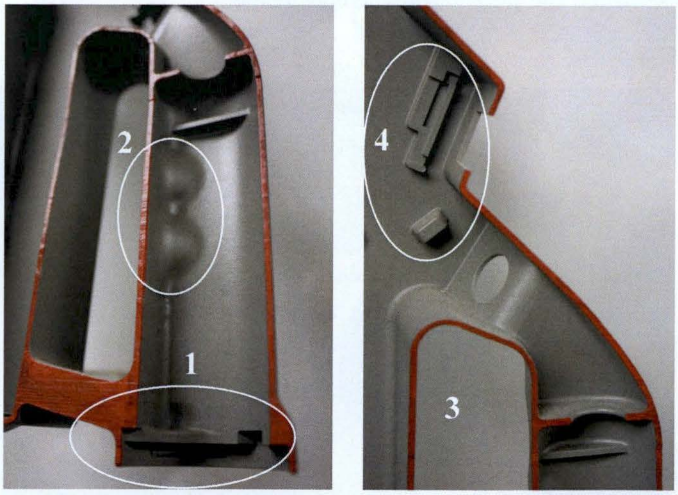
This hand-held electronic housing is functional in appearance at first glance, but the unassuming exterior conceals several fine cast details in a one-piece design which illustrate a number of investment casting advantages.

The aluminum (A356-T6), casting measures approximately 10" x 6" x 3" and maintains a constant 2mm wall thickness, so all external sculpting is replicated inside as well. Additional interior features include cast slots and pads for mounting electronics, as well as cast slots and holes for mounting switches and a display. The handle portion is hollow with an internal barrier wall that divides the handle into two discreet chambers, each of which is undercut from the outside. At the rear of the handle are three locating reliefs and a raised snap ring for holding the backing cover in place.

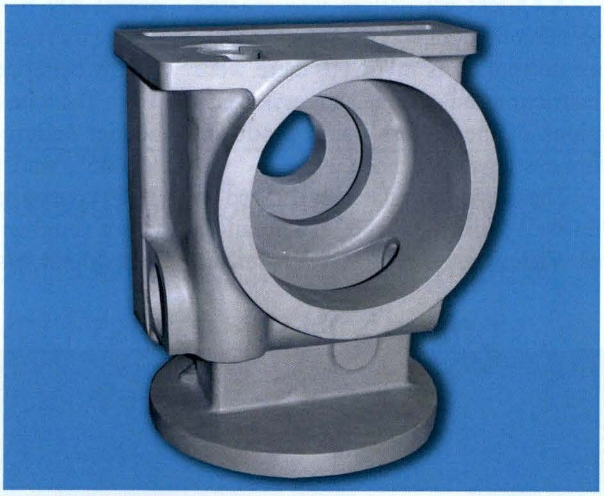
Since the housing was for a handheld device, weight and durability were considerations. Despite its overall size, the thin-wall casting weighs only 20 ounces, and provides a contoured handle with a comfortable center of gravity. The near net shape of this configuration enhances the structural integrity of the unit by combining its multiple features into a single cast piece. The dimensional precision improves affordability by reducing the need for secondary operations.

Minimal secondary machining includes three holes and the facing of two surfaces.





Internal detail of casting: (1) orientation slots and snap ring; (2) finger relief maintaining constant wall thickness; (3) wall partition and half wall dividing handle into two separate chambers, (4) slots and partitions.



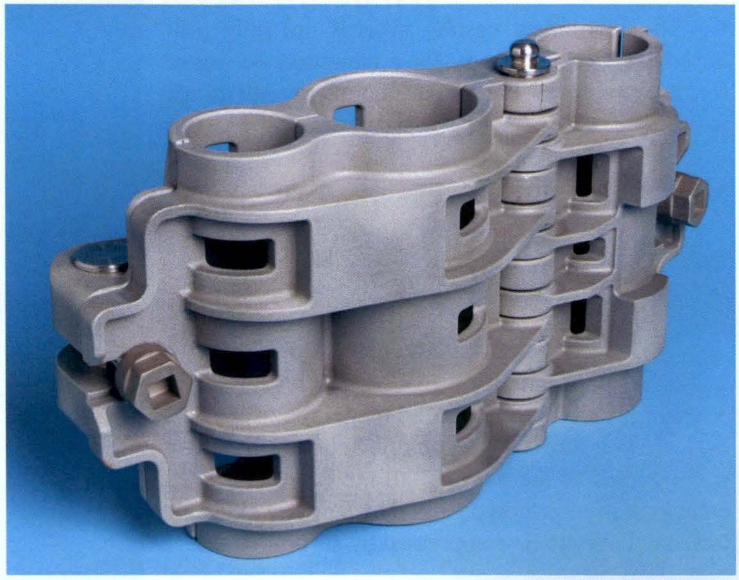
Four Part Numbers Combine in One Investment Casting

This large stainless steel housing used by the nuclear industry, replaces four earlier part numbers and occupies less space in the final gear assembly.

The component measures 13" x 14" x 16" and weighs about 190 pounds. The customer demands a class 1 grade B NDT requirement throughout the castings.

The preproduction castings were manufactured using SLA patterns and were supplied just in time for the completion of a test installation.

Investment Casting Conversion Saves $600 per Assembly



Conversion to investment casting saved $600 per assembly, reduced the number of parts to assemble, and incorporated value-added features.

The riser clamp assembly functions as a clamp for pipes and cables. It is cast in stainless steel and measures about 8" x 8' x 14". The original 65-pound design proved to be too heavy for the assemblers. A collaborative effort with the customer resulted in finding a number of ways to reduce wall thickness where allowed and add many lightening pockets throughout the part. This resulted in a final weight reduction of 20 pounds.

Ultimately, the success of the project stemmed from a relationship with the customer very early in the design effort, which took full advantage of the investment casting process and added value to the final product.

New Single-piece Investment Casting Replaces 7-part Fabrication

When you can combine a seven-piece fabrication into a single casting and have a new component which is stronger, more dimensionally consistent, and more attractive yet at lower cost, the decision is a no brainer.

That was exactly the situation for Tait Towers, a leader in the design and quality staging for the touring entertainment industry as it commissioned an investment casting firm to cast a part for their staging equipment.

The investment foundry's sales engineer noted the part is used in the assembly of large sound stages and platforms. "They came to us with a casting design for a part they called a K-nut. This part is used just above the wheel on a 4-wheel platform. These platforms are rolled in and locked together to form the base of the stage. The K-nut casting is part of the locking mechanism," he said. "In this industry, the stages need to be quick and easy to assemble and disassemble; they need to be light weight; and they must fold into a small package for transport to the next show."

"Tait was fabricating this part from seven pieces, which was costly and time consuming. By combining the seven pieces together, they created a casting design that would replace the fabrication," he continued. "The end product is stronger due to the elimination of all the welds, it is dimensionally more consistent, it is more attractive, and it has the company logo on it in four places– and all at a lower price."

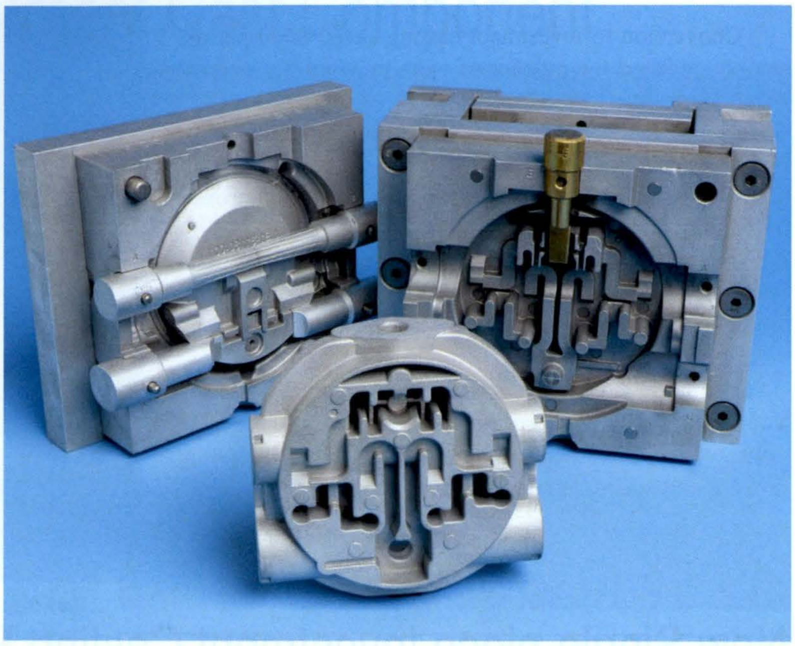
The 6" x 6" x 2.5" new component is cast in ASTM A216, grade WCB.

The original component was a fabrication of seven separate pieces welded together.

The new single-piece investment casting costs less, is stronger and more dimensionally consistent, more attractive, and includes the Tait logo as cast-in feature.

The new investment cast component is shown on a section of a portable stage.

Both Part and Tooling Turn to Investment Casting



The investment casting process not only produced a main valve body for a two-stage converter for LP-gas engines, but also the tooling needed to cast the complex component.

The final aluminum casting measures 4.7" x 4.5" x 1.25". Designed as an investment casting, the part is not only a unique design, but also a very complex casting. The myriad of cast-in features eliminated any extra machining operations, resulting in huge cost savings.

A timing crunch required creative thinking regarding tooling. The investment caster reverse engineered the part to create a solid model file of the tool design using rapid prototyping technology to create wax patterns of the tool and all the core pins. The combination of prototype and tool-building skills allowed delivery to be compressed by several weeks.

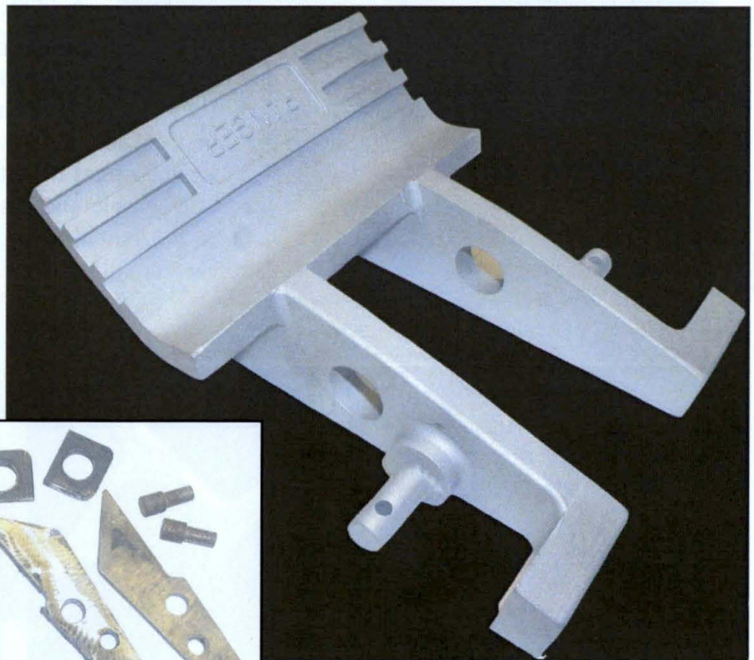
12-piece Fabrication Converted to Single-piece Investment Casting

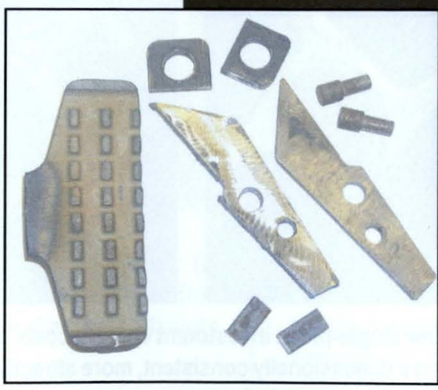
While there are many good reasons to convert to investment casting from other processes, one of the most graphic is combining a multiple-part fabrication into a single investment casting. This single-piece investment casting has replaced a 12-piece assembly.

Cast in a low alloy steel (4140), the 5" x 6" x 1 ½" pedal is used in offshore oil drilling.

The single casting is part of a mechanism used to release piping into the hole as drilling progresses. The pedal casting has helped to reduce the total assembly time from more than eight hours to less than one hour, thus improving the productivity at the customer's operation. The customer has the added benefit of having its company name cast in the part and clearly displayed. Two other castings in the assembly were also fabrications.

The cast parts used in the assembly allow a smoother and more reliable action. The castings also incorporate a more reliable safety catch on the pedal that prevents the piping from lifting during a gas blowback. If the piping lifts, several hundred feet of piping can be lost down the hole.





The single-piece investment casting above replaced a 12-piece assembly. Nine of the 12 pieces are shown at left.

Conversion from Machining to Investment Casting Eliminates Scrap, Decreases Weight, Saves Time and Money

Eliminating scrap and decreasing the weight of the part by two pounds were the result of converting a split coupling used for a valve application from machining to investment casting.

The original two-piece component weighed in at seven pounds. It was machined from bar and took 18 hours to complete each piece. The new investment casting not only significantly reduced the weight, but also eliminated all but 25 minutes of machining (surface machining and two holes drilled and tapped).

The new two-part component is cast in WCB (1025), CA-15 (410) and brass, measures about 3" x 3" x 4". It is used in the oil industry to join a shaft and piston for protection valves.

A representative of the investment casting company producing the component indicated the most beneficial advantage was time and money saved due to the extensive machining cost that was eliminated from the original design.

This investment cast coupling, is turnkey and can be used right out of the box.

The cast and assembled part at left, weighs 40% less than previously machined component, right.

"The new component weighs 40% less than the original bulky, fully machined version, which makes for easier handling and assembly. Scrap has been eliminated, and the overall appearance of the new part is vastly improved," he said.

The new design spawned a revamping of part design and manufacturing processes for the customer.

"They were so happy with this part that we were given the opportunity to quote many other parts for them. Sand castings are being converted to investment castings, as well as other formerly machined-from-stock parts– with very similar results," he said. "We've been able to do about 20 new parts for this customer alone. Once we proved the process, the customer was in a hurry to find other part we could convert. It was like opening a flood gate; the process sold itself."

Part Within a Part Highlights Complexity, Design Flexibility

The complexity involved in casting a part within a part dictated investment casting as the most logical manufacturing method for making an intricate stainless steel body casting/roll seal valve. A family of the casting design is manufactured in various sizes for marine, industrial, waterworks and ground fueling.

Cast in 316L stainless steel or monel, depending on the application, the investment casting replaces a welded assembly of castings and machined parts. Investment casting offered a more consistent, cost-effective manner in which to manufacture. Overall production yield and field performance was greatly improved and both manufacturing and operating expense were reduced.

The part has a complex internal "grid" used as cast, which enables the end item to function as designed. The grid feature is uniform around the internal diameter, is very difficult to access, and the rework in this area can be prohibitive.

During conversion from welded assembly to casting, special attention was focused on wall thickness, grid design, and "mating" of the two structures.

This casting is the second largest in a family of five identical designed parts. External an internal configuration is basically the same, with overall size being the major difference. A number of special problem-solving techniques, including propriety drying techniques were required to successfully produce the part.