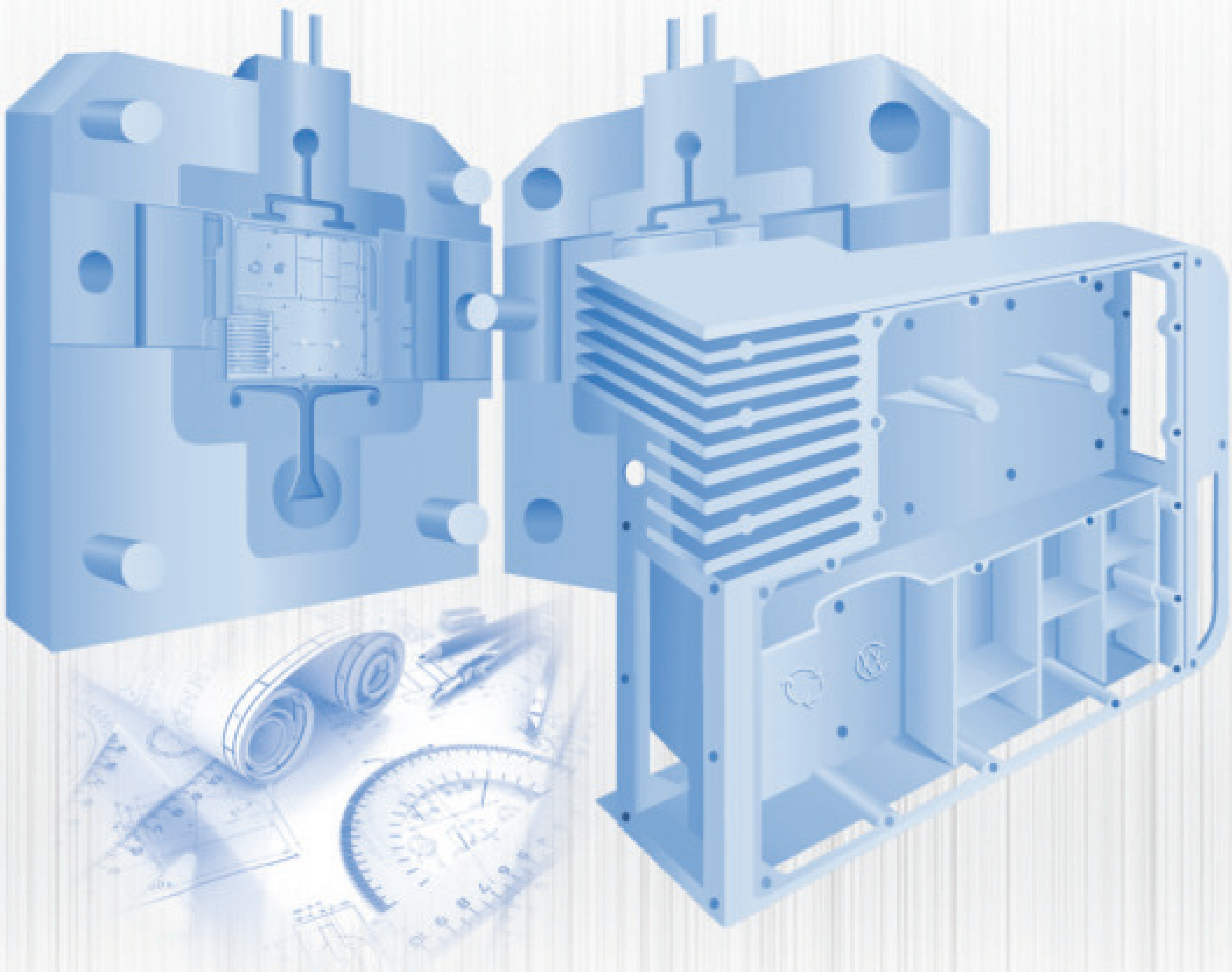
The CWM Die Casting Design and Specification Guide

for Custom Al, Mg, & Zn Components



A Condensed Resource for OEM Designers and Engineers

Comprehensive guidelines for cost-effective die casting production. Written for OEM product designers and engineers to aid in optimizing their part designs and specifications for production in Aluminum, Magnesium, and Zinc die casting alloys.

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Contents

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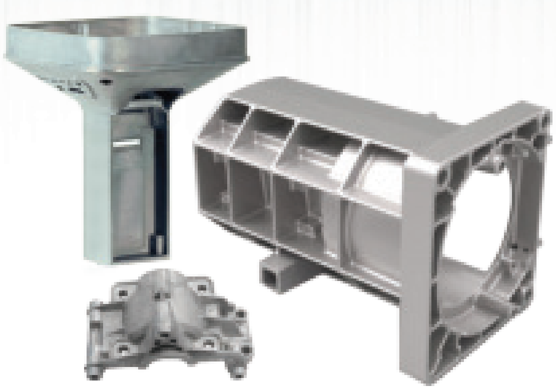

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Over 90 die casting design guides & resources are available to OEM product designers and engineers for download.

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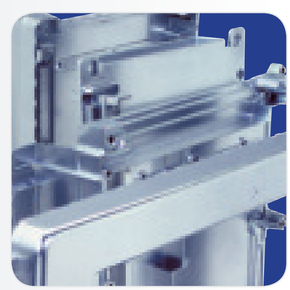


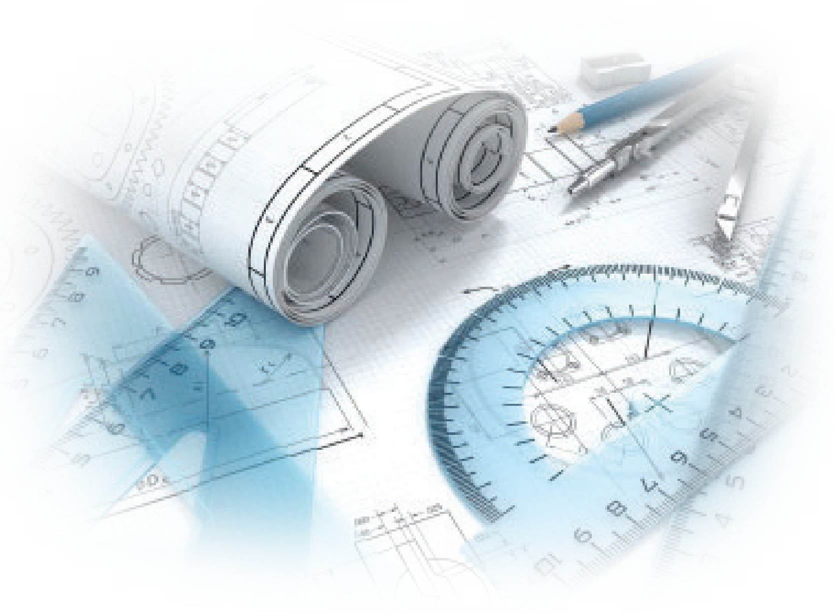
Design & Specification Guide Introduction

The guidelines presented in this publication are intended to aid OEM product design engineers in designing and specifying parts for cost-effective die casting production—in aluminum, magnesium, zinc and ZA-8 alloys.

These guidelines were researched and compiled by Chicago White Metal Casting from over 80 years of industry experience and the latest design and production resource data, relying primarily on NADCA Product Specification Standards for Die Casting. These design-for-die-casting guidelines are intended to be a concise and easily-referenced initial source for the key specifications that drive the cost and performance of components die cast in Al, Mg and Zn alloys.

Many of the Standards and Guidelines presented require further detailed qualifications, dependent on the specific design, configuration, and performance requirements of a proposed part. In such cases, the detailed NADCA Standards and other sources are referenced. The CWM engineering department should always be consulted early in the product concept stage, before irrevocable design-for-manufacturing decisions are made.

Selected design data, including sections of the NADCA Product Specification Standards manual, are available to download from the CWM Die Cast Design Center at dc2.cwmdiecast.com. The full version of this valuable reference can also be purchased from CWM at a special discount, using the special discount order form in the Resource Center's Reference Manuals section.



Recyclable Die Castings and Environmental Practices

All of the metal alloys used by CWM are produced from recycled raw materials. For example, all of the aluminum parts are die cast from post-consumer recycled aluminum, which meets the requirements of high-performance applications. The die casting alloy recycling stream, illustrated in Figure 1, is based on the existing worldwide infrastructure that has been operative for over 70 years. This basic flowchart, with varying amounts of reclaimed alloy going to secondary and primary producers, applies to the majority of all metal cast by Chicago White Metal Casting.

The environmental management systems of CWM and their divisions are ISO 14001 registered. The company was a charter member of the U.S. EPA's Environmental Performance Track Program and has been named by the EPA as a Green Biz Leader company.

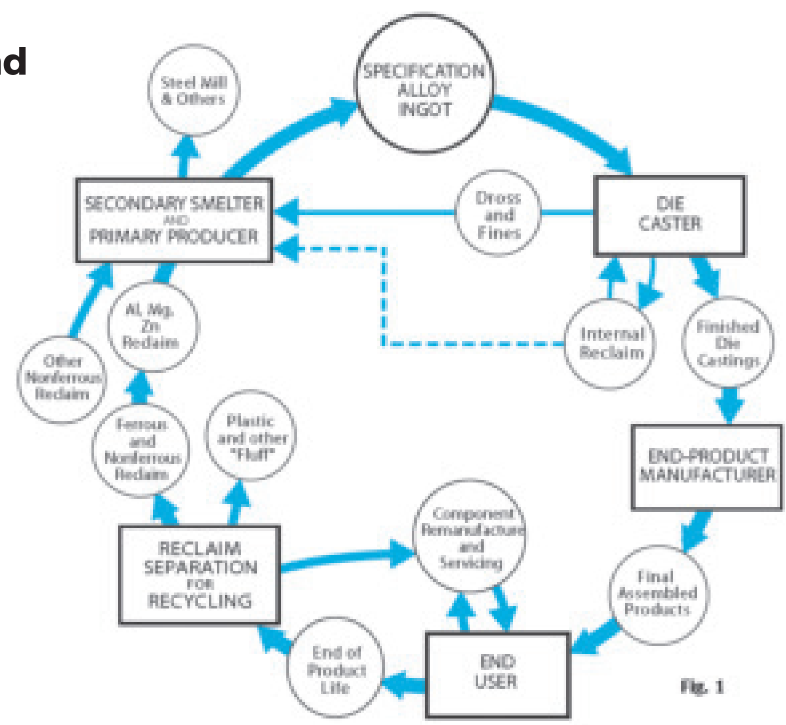


Fig. 1

Anatomy of a CWM Die Set and Die Cast Part

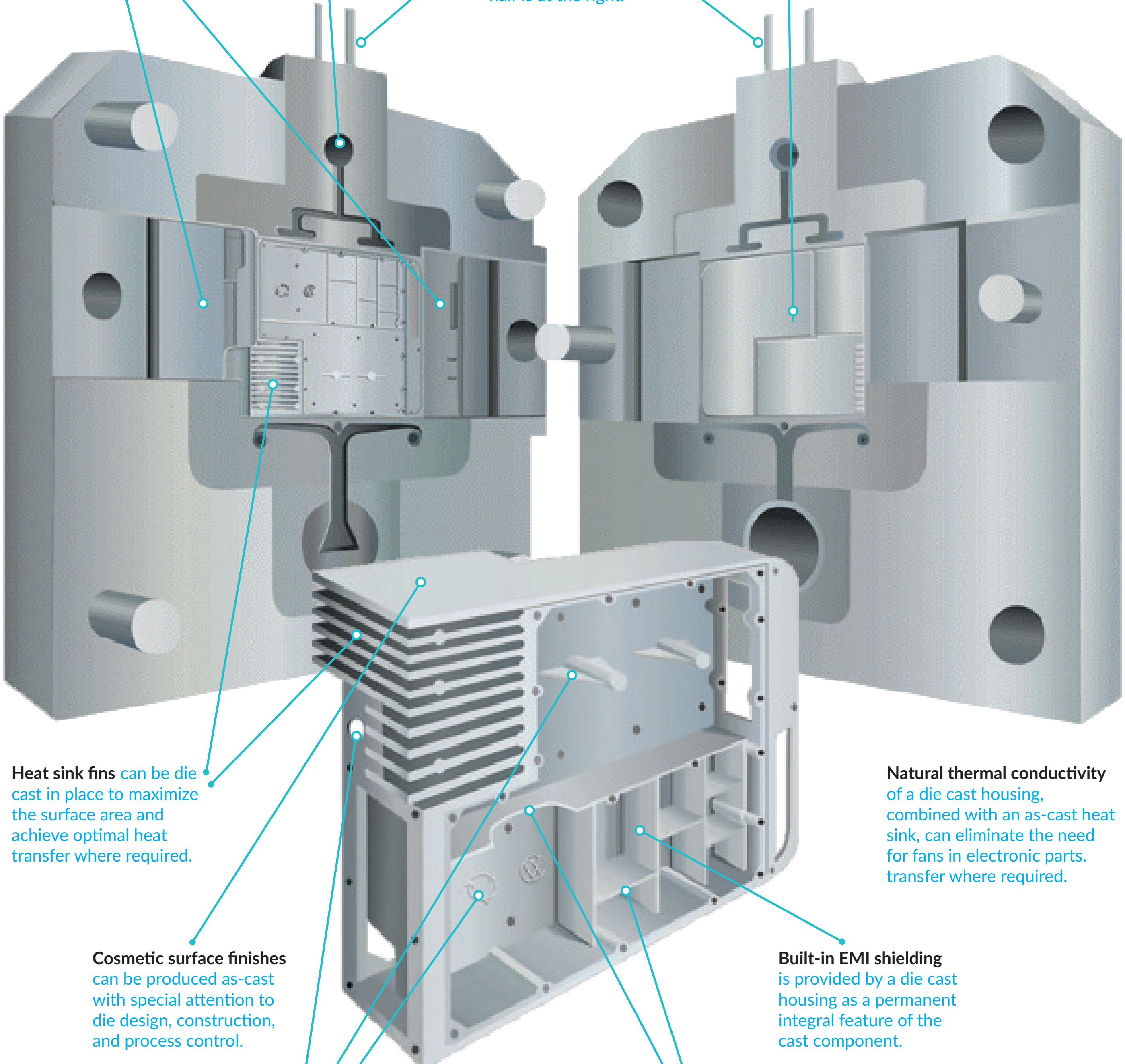
Automatic moveable slides can produce all holes and features as-cast. The ejector half of this die casting die set is at left.

Precision shut-offs, vacuum systems, as well as advanced runner and overflow design, help minimize any porosity in the final cast part.

Oil heating & cooling lines are used in both halves of the die set for precise temperature control during very rapid casting cycles. The cover, or stationary, half is at the right.

Special surface treatment is used on all CWM die cavities to help prevent premature die wear, improve casting surface finish, minimize distortion, etc.

Premium tool steel, used to build all CWM die cavities, assures maximum die life and performance.



Heat sink fins can be die cast in place to maximize the surface area and achieve optimal heat transfer where required.

Natural thermal conductivity of a die cast housing, combined with an as-cast heat sink, can eliminate the need for fans in electronic parts. transfer where required.

Cosmetic surface finishes can be produced as-cast with special attention to die design, construction, and process control.

Built-in EMI shielding is provided by a die cast housing as a permanent integral feature of the cast component.

Intricate features, cored holes, and bosses can be cast in place – including logotypes or other designations, and even external threads – often eliminating all machining.

Thin, rigid walls can be die cast to minimize package size – an advantage matched by no other high-speed production process.

1 Matching Material Properties

Die casting alloys are generally several times as strong as and many times more rigid than plastics, and their mechanical properties compare favorably with powdered iron, brass, and screw-machined steel.

Designing for proper strength in a product depends on two main factors: strength of the material selected and configuration of the part.

Die casting alloys offer a wide range of as-cast material strengths, ranging as high as 54 psi (372 MPa) ultimate tensile. The designer can usually develop sufficient strength in critical features simply by providing adequate wall thickness. Where additional strength is required, reinforcing features (such as ribs, flanges and locally thickened sections) can be accurately computed and precisely cast. (See Guidelines G-6-2-2015 and G-6-3-2015 in *NADCA Standards*.)

The die casting process allows the product designer freedom to create extremely intricate geometries. CWM offers the designer material choices in all of the major non-ferrous alloy categories: aluminum, magnesium and zinc.

Aluminum 380 Alloy

Die casting alloy A380 is the most widely used aluminum alloy, offering the best combination of properties and ease of production. It is specified for nearly every product type where the properties of aluminum are desirable.

Magnesium AZ91D Alloy

Magnesium is the lightest commonly used structural metal. Its use in die cast parts has grown dramatically with no weight penalty.

AZ91D is the most widely used magnesium die casting alloy, offering high purity with excellent corrosion resistance, strength, and castability.

Zinc (ZAMAK) No. 3 Alloy

Zinc No. 3 offers the best combination of mechanical properties, castability, and economics and is the most widely used zinc alloy in North America. It can produce castings with intricate detail and excellent surface finish at high production rates. Zinc can be cast thinner than any other die casting alloy.

Table 3a **CWM PART PRODUCTION & DIE LIFE, BY ALLOY**

Conventional Alloys	Aluminum	Magnesium	Zinc	Miniature Zinc
Alloy	**A380**	**Mg AZ91D**	**Zn No. 3**	**Zn 2, 3, 5, 7, ZA-8**
Part Size Range	.75" x .75" to 18" x 18"	.75" x .75" to 18" x 18"	.75" x .75" to 18" x 18"	Minuscule to 4" x 4" x 1"
Part Weight Range	.5 oz. to 10 lbs.	.25 oz. to 10 lbs.	.5 oz. to 8 lbs.	1/14 oz. (2g) to 3/4 lb. (337g)
Machine Tonnage Range	200-800 tons	80-650 tons	80-500 tons	4-Slide Miniature
Vacuum-Assist Availability	Yes	Yes	Yes	No
Expected Die Life	1X	3X to 5X	Life of Part	Life of Part

Table values are approximations. Part sizes shown, in some cases, will require center gating of a part, not always practical with particular part designs.

ZA-8 (Zinc-Aluminum) Alloy

ZA-8, with a nominal aluminum content of 8.4%, has the highest tensile strength and the highest creep strength of any zinc alloy. ZA-8 offers excellent bearing properties, with lighter weight and greater strength than iron and bronze. It is being used by CWM to produce net-shape die cast parts to replace more costly machined components.

For a discussion of the hot and cold chamber die casting processes, consult the Product Design for Die Casting Manual, published by NADCA and available from CWM Die Cast Design Center (DC²) at no cost.

See Table 3a for approximate production part size and weight ranges, and machine tonnages, offered by CWM for each alloy category.

MATERIAL PROPERTIES & NOMINAL CHEMISTRY

Table 1 Typical Material Properties: Die Casting Alloys & Selected Plastics

Typical alloy values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings. (2015 NADCA Standards. Sec. 3)

Commercial Designation	Die Casting Alloys				Plastic	
	Al 380	Mg AZ91D	Zamak 3	ZA-8	ABS	Nylon 6 (30% Glass Filled)
MECHANICAL PROPERTIES						
Ultimate Tensile						
psi x 10^3	47	34	41	54	8	22
(MPa)	(324)	(234)	(283)	(374)	(55)	(151)
Yield Strength						
psi x 10^3	24	23	32	42	6.5	19
(MPa)	(165)	(159)	(221)	(290)	(48)	(131)
Elongation						
% in 2 in.	3	3	10	8	--	7
Young's Modulus						
psi x 10^6	10.3	6.5	≥12.4	12.4	1.0	1.5
(MPa x 10^3)	(71.0)	(44.8)	(≥85.5)	(85.5)		
Torsional Modulus						
psi x 10^6	3.9	2.4	≥4.8	4.8	--	--
(MPa x 10^3)	(26.9)	(16.5)	(≥33.1)	(33.1)		
Shear Strength						
psi x 10^3	27	20	31	40	--	--
(MPa)	(186)	(138)	(214)	(275)		
Hardness						
(Brinell)	80	63	82	103	--	--
Impact Strength						
ft-lb	3	2.7	43	31	--	--
(J)	(4)	(3.7)	(58)	(42)		
Fatigue Strength Rotary Bend (5 x 10^6 cycles)						
psi x 10^3	20	14	6.9	15	0.15	0.3
(MPa)	(138)	(97)	(47.6)	(103)		
Compressive Yield Strength 0.1% Offset						
psi x 10^3	n/a	23	60	37		
(MPa)	n/a	(159)	(414)	(252)	--	--
PHYSICAL PROPERTIES						
Density						
lb/in^3	0.098	0.066	0.240	0.227	0.0376	0.048
(g/cm^3)	(2.7)	(1.8)	(6.6)	(6.3)	(1.0)	(1.4)
Melting Range						
°F	1000-1100	875-1105	718-728	707-759	221	431
(°C)	(538-593)	(468-596)	(381-387)	(375-404)	(105)	(221)
Electrical Conductivity						
% IACS	27.0	11.5	27.0	27.7	--	--
Thermal Conductivity						
BTU/ft hr °F	55.6	41.8	65.3	66.3	--	--
(W/m°K)	(96.2)	(72.3)	(113.0)	(114.7)		
Coefficient of Thermal Expansion						
1/°F x 10^{-6}	11.8	14	15.2	12.9	--	--
(1/°C x 10^{-6})	(21.2)	(25.2)	(27.4)	(23.3)		
Pattern Shrinkage						
in/in or mm/mm	0.006	N/A	0.006	0.007	--	--

2 Die Construction

The two die halves shown on page 2 are an example of a single cavity die with both fixed cores and moving core slides, which produce additional as-cast features in the part. The use of core slides can totally eliminate or significantly reduce secondary machining requirements.

Multiple-cavity dies can be used to increase production rates substantially, and lower piece costs.

CWM unit dies employ standardized unit die holders into which replaceable die cavity “units” can be inserted. These replaceable units can be removed from or placed into a unit die holder without removing the unit frame from the die casting machine. CWM unit dies can significantly reduce die construction costs. They are available in single and double unit holders.

Unit dies have some limitations. They generally can only accommodate the production of smaller-sized parts, and they restrict the use of moving core slides, water cooling, and gating. Therefore, unit dies are most appropriate for less complex product designs and for products with lower annual volumes.

Moving Core Slide Options

Fixed cores and core slides (or pulls) can be designed into the die casting die to form selected features, as cast.

Core slides, also called moving die components, can be activated in various ways. Two of the most common are angle pins and hydraulic cylinders.

The angle pin is a mechanical source of motion that is activated by the opening and closing of the die. Its advantages are that it does not require hydraulics or limit switches, and is generally more economical to manufacture. Its limitations are that it can be used only for short slide travel, and there is no control over the cycle of the slide pull.

The hydraulic method of slide motion permits a choice of cycles, allows the placement of slides on any side of the die, and avoids interference when removing the casting from the die.

The choice is dependent upon factors such as production volume, the size of die, the length of travel of the slide, the size of area being cored out, and the specific configuration of the part.

CWM will always make the most cost-effective recommendation for the particular core slide to achieve the desired result.

Importance of a Casting’s Parting Line

The parting line is the perimeter of the casting formed by the separation line along the two halves of the die casting die. This line affects which half will be the “cover” die half and which will be the “ejector” half.

This magnesium die cast part prominently displays a parting line.

This line also influences any tolerances that must be held in this area of the cast part. Tolerancing standards are specific to part characteristics at the parting line and are presented in more detail on page 9 and in the Coordinate Dimensioning section of the *NADCA Standards*.

Designation of a parting line on a casting drawing is an important decision, and is rarely obvious to a designer not familiar with the die casting production process. Placement of the parting line must always be the final decision of the die casting engineer, since its location is essential for the casting to meet desired specifications.

If there is no cosmetic surface requirement, the casting can be oriented in the two die halves to suit the most favorable overall casting conditions.

In the case of a part that must have a cosmetic surface finish, the cover die half will generally be used to produce a specified cosmetic surface. This permits the ejector die half to contain the required ejector pins—which assist in ejecting the part cleanly from the die after each casting shot— as well as any engraved lettering or identification to be cast into the part.

With parts requiring a cosmetic surface, it is critical that this be discussed in detail during the earliest review meeting. Location of the casting’s parting line, as well as the gate, overflows, and vents, must not affect any of the part’s designated cosmetic surfaces.

Assuring Longer Die Life

The number of parts that can be produced from a die casting die is dependent on factors such as the quality of the die steel, the alloy specified, the specific design of part features, the cosmetic surface requirements for the part, and the number of die setups over the life of the tool.

While CWM utilizes the highest quality premium tool steel in all of its die casting die construction, as well as a proven die surface treatment to optimize die life, design features that can drastically shorten die life must be taken into consideration.

Sharp internal or external corners should be avoided. Specifying highly cosmetic as-cast surfaces can result in shorter die life and greater tool maintenance costs.

A comparison of CWM die life by alloy category appears in Table 3a.

Die Casting Die Specification Checklist

CWM makes available a Die Casting Die Specification Checklist which should be consulted during the design of any new die casting component.

3 Minimizing Part Porosity

The high metal velocities and pressures used to achieve the fine product detail, cosmetic surfaces, and high cycle rates unique to the die casting process normally result in some internal porosity, below the “skin” of the die cast part (Fig. 3).

Porosity levels in a cast part can be detected by “X-ray” or “sectioning” procedures. CWM utilizes real-time automated X-ray imaging to accurately document the presence of internal porosity, and can provide a recording of all radiographic images for customer review.

Minimizing porosity begins with early planning in the design of the die cast part and communication with CWM engineering. If porosity in specific areas will be detrimental to product function, this should be clearly outlined before die design and construction begins, since zero porosity is virtually impossible to achieve in a die casting.

Acceptable modifications in part designs can often be suggested that will greatly reduce potential porosity problems. Once this important step has been taken, CWM can utilize mold flow simulation, optimized gating and overflow design, die design, special management of the heating and cooling lines in the die, vacuum systems, and sophisticated process control and monitoring to limit porosity to non-critical areas of the part.

When 100% pressure tightness is essential in a die cast part, early CWM consultation becomes even more important. If the specific configuration of a component dictates that it cannot be cast pressure-tight, impregnation may be required. (Refer to Pressure Tightness, Sec. 6, NADCA Standards).

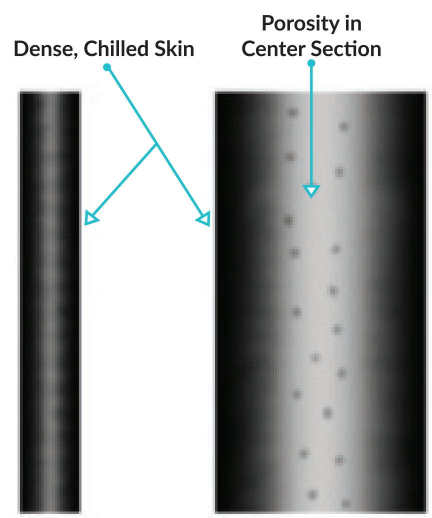


Fig. 3 In a thin-walled die casting, the finegrained dense “skin” is a large percentage of the section, as in the section above, left, which would contain virtually no porosity. The dense “skin” in a thick section (right) represents a small percentage of the wall.

4 Optimizing Part Heat Transfer

Designers of electronic and related devices must allow for thermal energy to be dissipated efficiently in their housing designs. Heat sinks produced as either die castings or extrusions have proven most effective in these applications.

The die casting process offers the product engineer the added advantage of great flexibility in housing and heat transfer design. An optimized heat sink can be incorporated into virtually any die cast housing design.

Unlike a plastic molded housing and extruded heat sink combination, EMI/RFI shielding is a built-in function of a thermally optimized die cast housing.


diecast solutions

Find this download in CWM Die Cast Design Center for download: “Superior EMI Shielding with Die Cast Housings.

All forms of extended surfaces for heat transfer can be die cast: straight fins, “S” shapes and round pins etc. in all diameters, are easily optimized for width, length and thickness in a die cast design and readily cast in place with the rest of a housing design.

As with any special part feature, consultation with CWM engineering is urged well before final product designs are agreed upon.

5 Pre-Planning Post-Cast Machining

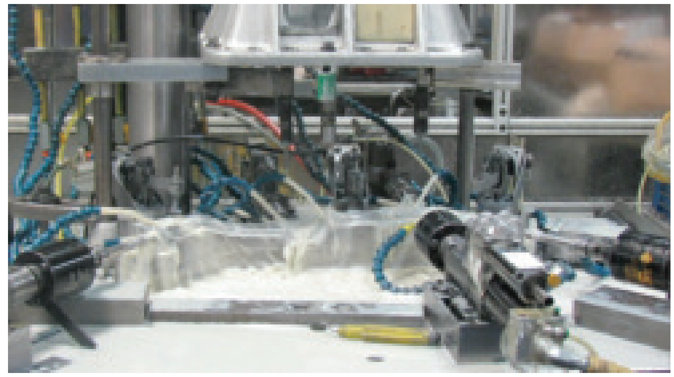
When machining is to be performed on a die casting, a minimum amount of material should be removed so as to avoid penetrating the less dense portion below the “skin” (see Fig. 3).

To assure clean-up, an allowance must be provided for both the machining variables and the casting variables. These allowances are a function of specified linear dimension tolerances and parting line tolerances (refer to tolerancing guidelines on next section).

The best post-casting (secondary) machining results are attained if the die casting is located from datum points that are in the same die half as the feature to be machined.

It is important to discuss any and all secondary machining requirements with CWM prior to die design. If consultation occurs early in the design of the part itself, CWM engineers can often minimize the effect of tolerance accumulation and unnecessary machining. Most importantly, with a combination of minor part design revisions and special considerations in the design of the die, higher density areas can be assured in regions of critical secondary machining.

A complete presentation of machining stock allowances is given in the *NADCA Standards*, Sec. 4, Coordinate Dimensioning. Included are examples for stock allowances, machining allowances, linear casting allowances, across parting line allowances, maximum stock, and casting dimensions—based on datum points in either the same die half or the opposite die half.



Standard & Precision Dimensional Tolerances (Table 3b)

QUICK GUIDE TO COORDINATE DIMENSIONING

Die Casting Alloy:	Aluminum	Magnesium	Zinc/ZA-8

WALL THICKNESSES

Nominal wall thicknesses that can be die cast are heavily dependent on part geometry. With small castings, wall thicknesses of 0.030 in. (.762 mm) may be attained with an optimized part design and alloy selection.

LINEAR DIMENSION TOLERANCES

Length of Dimension in same die half

	Aluminum	Magnesium	Zinc/ZA-8
Up to 1" (25.4 mm)			
Standard Tolerance	**±0.010** (±0.25 mm)	**±0.010** (±0.25 mm)	**±0.010** (±0.25 mm)
Precision Tolerance	**±0.002** (±0.05 mm)	**±0.002** (±0.05 mm)	**±0.002** (±0.05 mm)
for each additional in. >1" (25.4 mm)			
Add'l Standard Tolerance	**±0.001** (±0.025 mm)	**±0.001** (±0.025 mm)	**±0.001** (±0.025 mm)
Add'l Precision Tolerance	**±0.001** (±0.025 mm)	**±0.001** (±0.025 mm)	**±0.001** (±0.025 mm)

PARTING LINE TOLERANCES—added to Linear Tolerances

Projected Area of Die Casting: inches^2 (cm^2)—Tolerances are "plus" values only

	Aluminum	Magnesium	Zinc/ZA-8
up to 10 in^2 (64.5 cm^2)			
Standard Tolerance	**+0.0055** (+0.14 mm)	**+0.0055** (+0.14 mm)	**+0.0045** (+0.114 mm)
Precision Tolerance	**+0.0035** (+0.089 mm)	**+0.0035** (+0.089 mm)	**+0.003** (+0.076 mm)
for each additional 10 in^2 (64.5 cm^2)			
Standard Tolerance	**+0.0075** (+0.19 mm)	**+0.0075** (+0.19 mm)	**+0.0050** (+0.13 mm)
Precision Tolerance	**+0.0050** (+0.153 mm)	**+0.0050** (+0.153 mm)	**+0.0045** (+0.114 mm)

For projected area of die casting over 300 in^2 (1935.5 cm^2), consult CWM.

MOVING DIE COMPONENT TOLERANCES—added to Linear Tolerances

Projected Area of Die Casting Component: inches^2 (cm^2)—Tolerances are "plus" values only

	Aluminum	Magnesium	Zinc/ZA-8
up to 10 in^2 (64.5 cm^2)			
Standard Tolerance	**+0.008** (+0.20 mm)	**+0.008** (+0.20 mm)	**+0.006** (+0.15 mm)
Precision Tolerance	**+0.006** (+0.152 mm)	**+0.005** (+0.127 mm)	**+0.005** (+0.127 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)			
Standard Tolerance	**+0.013** (+0.33 mm)	**+0.013** (+0.33 mm)	**+0.009** (+0.23 mm)
Precision Tolerance	**+0.010** (+0.254 mm)	**+0.007** (+0.178 mm)	**+0.007** (+0.178 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)			
Standard Tolerance	**+0.019** (+0.48 mm)	**+0.019** (+0.48 mm)	**+0.013** (+0.33 mm)
Precision Tolerance	**+0.014** (+0.356 mm)	**+0.010** (+0.254 mm)	**+0.010** (+0.254 mm)

For projected area of a moving die casting component over 100 in^2 (645.2 cm^2), consult CWM.

FLATNESS TOLERANCES: inches (mm)

Maximum Dimension of Die Cast Surface

	Aluminum	Magnesium	Zinc/ZA-8
up to 3.00 in. (76.20 mm)			
Standard Tolerance	**+0.008** (+0.20 mm)	**+0.008** (+0.20 mm)	**+0.008** (+0.20 mm)
Precision Tolerance	**+0.005** (+0.13 mm)	**+0.005** (+0.13 mm)	**+0.005** (+0.13 mm)
Add'l tolerance, in. (25.4 mm) for ea. add'l in. (25.4 mm)			
Standard Tolerance	**+0.003** (+0.08 mm)	**+0.003** (+0.08 mm)	**+0.003** (+0.08 mm)
Precision Tolerance	**+0.002** (+0.05 mm)	**+0.002** (+0.05 mm)	**+0.002** (+0.05 mm)

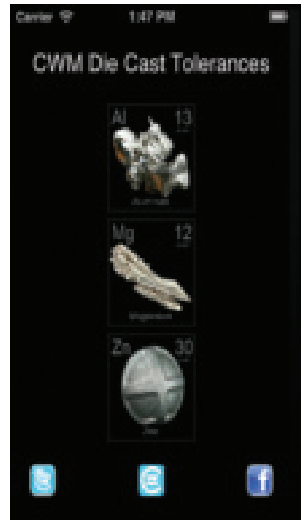
Reference: (2015 NADCA Standards, Sec. 4A) Based on CWM recommendations.

6 Tolerancing Guidelines

The extent to which the dimensioning guidelines shown here can be achieved in production for a given die cast part design is highly dependent on part size and configuration, shrink factors, and the precise feature in which the dimension is planned.

Caution: *Both standard and precision tolerances are shown. The design engineer should understand that requiring precision dimensions for every feature of a part is not possible in production. Precision tolerances should only be specified in agreed upon critical areas, since assuring these tolerances nearly always involves extra precision in die construction and/or special controls in processing, with additional costs often involved. Consultation with CWM engineering in the final part design stage is important to cost-effective production and part quality assurance.*

Note, in some cases and on specific features, even closer dimensions than those shown can be held by repeated sampling and re-cutting of the die casting die cavity, in combination with capability studies. Such procedures will incur added costs and timing.



Download the DC_Calc App from Apple or Android App Stores today, at no cost to you! This app calculates tolerance guidelines based on feature size, tool design, and alloy.

Standard & Precision Tolerance Qualifications

In the case of Linear Dimension, Parting Line, Moving Die Component, and Flatness Tolerances, the complete individual standards for each in the *NADCA Product Specification Standards for Die Castings* manual should be consulted for proper interpretation and qualifications.

For example, Section 5 of the *NADCA* manual provides guidelines on "parting line die shift," which can result in dimensional variations based on a mismatch between two die halves. In the case of Flatness Tolerances, the *NADCA* manual provides design guidelines to aid in specifying part flatness requirements.

Draft and Cored Holes

Precision tolerances for draft call for a minimum of ¾ degree angle per side on a 5-inch long inside wall, with outside walls requiring half this amount. More draft is needed for shorter features. See *NADCA Standards* for draft equations and details.

Precision tolerances for cored holes, such as cast holes planned for tapping, are provided in *NADCA Standards*, in terms of diameter, thread depth, and hole depth requirements.

Geometric Dimensioning & Tolerancing

A growing number of design engineers are utilizing GD&T markup on their part engineering drawings. When used properly, geometric dimensioning can help reduce the cost of a die cast part by facilitating functional gaging. Product engineers not already familiar with GD&T procedures are urged to become so.

An introductory discussion, as applied to die cast part drawings, appears in NADCA Standards, together with more detailed GD&T references.

Table 4 Guide to Nominal Metal Remaining by Type of Extension (Flash)

Type of Extension & Nominal Amount Remaining After Degating & Trimming					
	Large Part Thick Gates & Overflows	Medium Part Thin Gates & Overflows	Parting Line & Seam Line	Metal Extension in Cored Holes	Sharp Corners or other geometries not conducive to flash removed via commercial trim dies
After Commercial Trimming* Extension Remaining	Within 0.060" (1.59 mm)	Within 0.030" (0.76 mm)	Within 0.015" (0.38 mm)	Removed within 0.010" (0.25 mm)	Not Removed

** "Commercially trimmed" does not include hand filing, sanding or polishing to remove sharp edges or loose material. Very small parts can often be trimmed closer than these standards would indicate. Shave trimming may be possible in cored holes and on certain features (G-6-5-15).*

7 Metal Extension (Flash) Guidelines

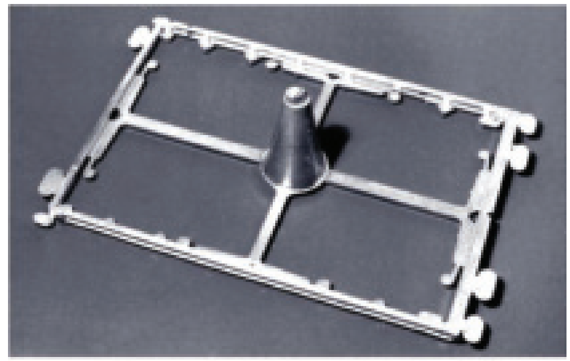
An extension of metal (or flash) is normally formed on a die casting at the parting line of the two die halves and where moving die components operate. A seam of extended metal may also occur where separate die parts cast a part feature.

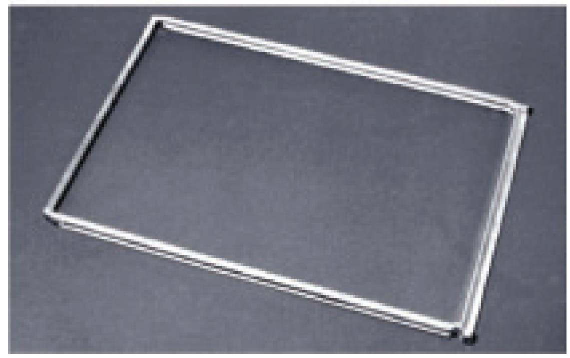
The cost of required trimming of any flash can be reduced by preplanning in the part design stages and is affected by the amount of metal extension required to be removed and the removal method employed.

Early consultation with CWM can often result in production economies in this removal step.

Table 4 is the *NADCA* guide to the types of flash which occur in typical die castings and the amount of flash material that remains after trimming. These *NADCA* guidelines represent normal production practice. Precision trimming, closer than standard commercial trimming, or complete removal of all flash may entail additional operations and should be specified only when requirements justify the additional cost. Generally, it is assumed that unless specified, parting line flash or gate vestige remaining on the part is treated separately and is in addition to the print tolerance of a feature.

Note that in some instances, depending upon the part geometry and the surface finish requirements, the most economic methods of de-gating and metal extension removal may include a tumbling or vibratory deburring operation, or hand cleaning.





The die cast frame (above) illustrates the appearance of a center-gated die casting before trimming, showing gate, runners and overflow extension. The bottom photo is the same die cast frame after receiving its normal die cast trimming operation. In many cases, the trim die will require multiple "slides" similar to the die casting die, with comparable attention to quality materials and die design details.

Note: All CWM tooling orders include a trim die that meets or exceeds NADCA "Commercial Trimming" standards.

8 As-Cast Finish Guidelines

The die casting process is uniquely qualified to provide metal parts with a superior as-cast external surface, important to many component applications—and essential for consumer product housings and other decorative parts.

The *NADCA* surface finishing guidelines presented in Table 5 classify as-cast surface finishes for die castings into a series of five grades so that the type of cast finish required may be defined early in the product planning stage and well in advance of die casting die design.

These guidelines should be used for general type classification purposes only, not to take the place of specific discussion with CWM regarding the steps necessary to assure satisfying as-cast product finishing specifications. Such specifications should be agreed upon with CWM prior to die design to assure cost-effective production. Note that important steps can be taken in the planning of part design features enabling an optimum surface to be produced in specified areas. For exacting cosmetic finishes, extra steps in die design, die construction and casting production are required, and additional cost may be involved. Selection of the lowest finishing grade, commensurate, of course, with the die cast part application, will yield the lowest die and part costs.

A detailed discussion of the factors that relate to success in designing dies for highly cosmetic, thin wall die cast parts, specifically as they relate to magnesium die castings, appears in an article by Chicago White Metal Casting, titled *Designing Dies for Thin Wall, Highly Cosmetic Mg Die Castings*. It is available on request from CWM.

The first four as-cast surface finish classifications listed in Table 5 relate to cosmetic surfaces. Class Five, "Superior Grade," relates to the surface specification required over a very selective area for special applications.

9 Further Design Assistance

As emphasized throughout this guide, product design details—based on sound die casting part design principles—can greatly influence the costs of both tooling and production parts.

The Engineering Bulletin, *Designing Optimum Part Shapes*, contains introductory information on developing the optimum product design configuration for cost-effective die casting production. This engineering bulletin can be downloaded from the Die Cast Design Center: *www.cwmdiecast.com/design-center.html*.

Design considerations are treated in detail throughout the *NADCA Product Design for Die Casting* manual, with a chapter specifically covering the following: utilizing die cast fillets, corners, and ribs to add strength and aid metal flow, reducing heavy masses in die cast parts, designing features that simplify die construction, and redesigning to eliminate undercuts. Guidelines to the proper design of die cast fillets, ribs and corners also appear in the *NADCA Standards*. Chicago White Metal Online Store, also in the Design Center, has Design Guides available for order at a special discount.

Table 5 As-Cast Surface Finish Classifications and Final Finish or End Use

Class	As-Cast Finish	Final Finish or End Use
1 Utility Grade	No cosmetic requirements. Surface imperfections (cold shut, rubs, surface porosity, lubricant build-up, etc.) are acceptable.	**Used as-cast or with protective coatings: Anodize (non-decorative) Chromate (yellow, clear)**
2 Functional Grade	Surface imperfections (cold shut, rubs, surface porosity, etc.), that can be removed by spot sanding or can be covered by heavy paint, are acceptable.	**Structural Parts: Blasted or Tumbled Heavy textured, low gloss paint**
3 Commercial Grade	Slight surface imperfections that can be removed by agreed upon means are acceptable.	**Medium texture & gloss paint Electrostatic Painting Transparent Paints**
4 Consumer Grade	No objectionable surface imperfections. Where surface waviness (flatness), noted by light reflection, is a reason for rejection, special agreement should be reached with the die caster.	**Plating Decorative High Gloss, smooth decorative paint**
5 Superior Grade	Surface finish, applicable to limited areas of the casting and dependent on alloy selected, to have a maximum value in micro inches as specified on print.	**O-Ring Seats or Gasket Areas**

CWM's interpretation of 2015 NADCA Standards, Guidelines G-6-6-15)

CWM sales engineers and the CWM engineering staff are available to ensure your early design decisions are the correct ones for product success.

10 Magmasoft® Die Flow Simulation

Use of Magmasoft die casting simulation by CWM has resulted in reduced production lead times, improved part quality & lower manufacturing costs.

Advanced metal flow simulation software offers the opportunity to determine the precise manner in which metal can be expected to flow into the die cavity for a proposed component, before tooling design or construction. The benefits of revealing specific die flow problems can now be easily addressed well in advance.

The Magmasoft high-pressure die casting process simulation software system is acknowledged as the most advanced approach to computerized metal flow trouble-shooting at the preplanning stage. CWM utilizes this software on all new tool builds.

The initial die casting die cavity design can now be based on the die designer's experience plus the results of this invaluable early metal flow data. For more information on the Magmasoft system, download Tech Brief 23 in the OEM Solutions/Tech Brief section of the CWM Design Center.

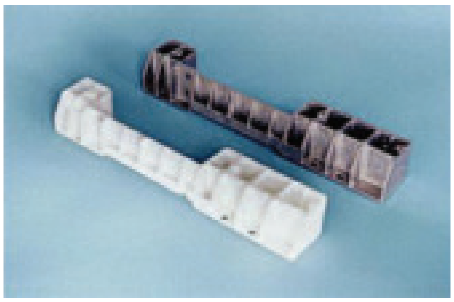
11 Prototyping

Because high quality production die casting dies represent a significant capital investment, prototyping of a part prior to production tool build is a prudent course for a new product design.

Beyond 3D modeling on the computer, a variety of prototyping alternatives are being used, including machining from stock (hog-outs), gravity casting, or prototype die casting.

All prototyping strategies based on alternative process for eventual die casting production are approximations to the final performance of a die cast part, and the strengths and limitations of each must be weighed against the designer's most important prototyping criteria.

3D Printing



3D prototypes in strong ABS can be precision machined to precise specs. Final casting shown at right.

The technology of 3D printing enables the production of rapid prototypes in durable ABS plastic, directly from STL design files. Fused Deposition Modeling (FDM) parts are built and bonded, extruded layer by layer, from 3D computer data.

An FDM machine can produce geometrically complex shapes to tolerances of ±0.005 in. (±.127mm).

Because of the strength of the ABS plastic part, it can be evaluated rigorously for form and fit and used in many functional tests.

Most 3D printed processes have difficulty reproducing very tight toleranced features, such as sections containing ribs, bosses and holes; CNC machining can be performed on the strong FDM ABS part to the required critical specifications.

FDM prototypes are generated on every new die casting project to expedite production and shorten total lead times by providing models in advance to all departments involved; these multiple FDM models help assure that die designs result in first-piece success and aid in the simultaneous construction of die cast tooling, trim dies, machining fixtures, finishing masks, and any required subassembly gauges or fixtures. See Collaborative Engineering discussion in Section 13.

CWM's in-house FDM prototyping capability can work quickly with customer CAD files to expedite die casting projects.

Efforts are underway to develop the ability to 3D print metal parts, and CWM is working on several projects where this approach is employed, either to produce a prototype part, or to produce tooling or tooling components. Stay tuned... as this is a rapidly developing technology.

Machined Prototypes

Product designers have long specified accurately machined prototypes as test models for eventual die casting. Developments in 3D CAD, CAM and CNC programming have made the machining alternative increasingly desirable.

Parts can be machined from billet or sheet stock with CNC machining performed by working directly from customer CAD files, depending on the type and accuracy of the files. After transferring a machined prototype to a CAM program interfacing with CNC workstations, the total lead times of the prototype can often approximate RP production scheduling.

Machined stock for hog-out prototypes is selected to approximate the material properties of the eventual die casting alloy. CNC machining can produce parts to almost identical part weights and to the specified die casting tolerances with precise details. Under any handling condition, validation of form and fit is assured and many functional tests can be performed.

Prior to die casting die construction, CNC machined prototype can be produced, matched to the specified die casting alloy, for any pre-release requirement— directly from CAD design files.

For Al 380 die castings, Al 6061-T6 aluminum plate is generally used for CNC prototypes. For Mg AZ91D die castings, AZ31 Mg plate is recommended. Zamak 3 stock is available to prototype Zamak No. 3 zinc die castings.

Secondary coatings and finishes can be applied to machined hog-outs to closely approximate the appearance of the proposed die casting. CWM is one of the few North American custom die casters with in-house hog-out capabilities.

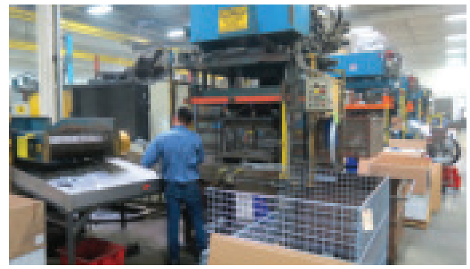
Gravity Cast Prototypes

Sand casting, investment casting, and rubber plaster-mold castings are some of the gravity cast processes that can be used to prototype a die casting design. Because of the longer solidification times, alloys specific to those processes, combined with various heat treatments, are used in order to approximate the properties of a high pressure die casting. Also, compared to high pressure die casting, these processes usually require thicker walls and larger tolerances, so machine stock often has to be added and more features will need to be machined than with a die casting. These processes use lower cost tooling than high pressure die casting, but have much higher piece prices. All of these design, property, and cost tradeoffs have to be considered when evaluating the best prototype approach.

Die Cast Prototypes

A high pressure die casting prototype die is often the best approach if you want the same properties, alloy, geometry, etc., that will be in place for production.

Prototype die casting dies can be produced in shorter lead times and at less cost because they can utilize standardized components (such as an existing die base), and pre-hardened, uncoated tool steels. The tool will not last as long and the die will not run as efficiently as a typical production die, but this is a non-issue when you only need a small quantity of parts (1,000 or less). Design changes can be made faster and at less cost with a prototype die than would be the case on a custom, hardened/coated production die. Parts made from the prototype die are generally hand cleaned of flash, avoiding the lead time and cost of a trim die.



The high pressure die casting process is an option for prototypes.

12 Post-Casting Operations

CNC Precision Machining

CNC machining may be employed when the unit machining trade-off is less costly compared to the investment in complex automated die casting die slide components to achieve net-shape components.

At the same time, post-casting machining of die castings is a more complex production process than machining directly from billet stock. A higher level of experience in CNC pre-planning and machining center fixture design is critical to economical CNC machining of die cast parts.

While state-of-the-art machining centers and equipment usually provide the greatest cost advantages, more conventional machining units and cells may prove cost-effective. As outlined in section 5 of this guide, die caster engineer consultation and careful preplanning in the product design stage is critical to quality post-casting machining results. It is essential that all of the specific machining requirements to be executed after the part has been die cast must be made clear *before* a design goes forward: *prior to any* CAD metal flow simulations, prototyping, or the development of die design drawings.

Hydraulic and pneumatic fixturing in state-of-the-art machining centers makes the highest speeds and cutting accuracy possible. With a depth of experience in machining Al, Mg and Zn alloys, CWM's in-house precision CNC machining facility, using advanced high-speed centers, assures highest quality results.

Chicago White Metal utilizes robotic automation in several operations, such as CNC.

Surface Treatments and Finishing

A wide range of proven surface treatment and final finishing systems are available for die castings in all alloys, although many die cast parts are used with no surface finishing operations performed after casting and trimming.

These surface treatment systems can be used to (1) provide a decorative finish, (2) form a protective barrier against environmental or galvanic corrosion, (3) achieve pressure tightness if interconnected subsurface porosity cannot be eliminated, or (4) improve a product's resistance to wear. Non-toxic coatings are available to meet U.S. & European Union environmental mandates.

Even when a die casting requires no further surface treatment for decoration, protection or improved performance, a deburring operation is usually recommended. This step removes the metal flash and any burrs, sharp or ragged edges that might remain after trimming, to facilitate handling and any further finishing treatment.

The CWM *Quick Guide to Surface Finishing for Die Castings*, with a comprehensive ratings chart design guidelines to optimize final finishing results, is available by PDF download at the CWM web-site's OEM DC2 Design Center *(dc2.cwmdiecast.com)*.

CWM offers sample die cast plates for surface finishing comparisons.

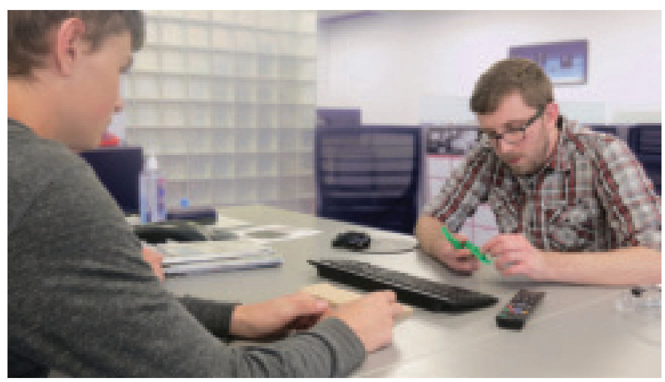
13 CWM Collaborative Engineering

A well-organized custom production resource works closely with its customers and the end product requirements to develop precise manufacturing protocols and specifications that meet the OEM's product design intent.

CWM has procedures in place to meet objectives beyond these basic expectations and assure more rapid time to market. By adhering to the collaborative engineering model described herein, CWM maximizes the customer's opportunity to reduce unit costs, improve part quality, and accelerate lead time.

Customer-CWM Interaction

Successful collaborative engineering hinges on the timely and accurate exchange of information on the part of all persons responsible for the conception, design, development, evaluation, production, quality, sales, delivery, servicing, and eventual disposal of the final product. This requires close coordination of functions between the customer and CWM.



The Collaborative Engineering Model

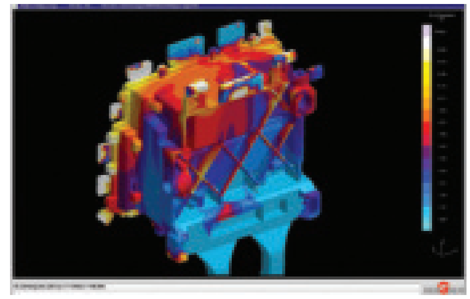
To successfully impact unit costs, quality and time to market, Chicago White Metal has instituted a special structure and specific tools to implement its collaborative engineering commitment. This covers every aspect of CWM's involvement in the design and production process.

CWM Design Team Checklists

The CWM Design Team assigned to each new die casting production project interacts with their customer team during initial meetings using a detailed New Project Questionnaire.

Responses during these meetings help assure that CWM will be in a position to raise all critical design-for-manufacturing issues at the earliest point in the component development cycle. This approach will prevent costly changes that may occur, and quality and performance improvements can be introduced at little or no cost. These focused customer responses should cover all aspects of component requirements and quality planning which can be expected to influence the final engineered die cast product.

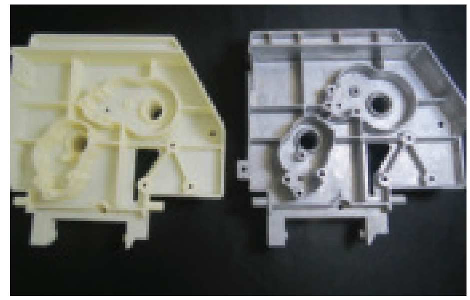
Magmasoft® Software Simulation & Part Design



Once the appropriate drawings, specifications, and part model files are exchanged, CWM can proceed with initial Design for Manufacturing (DFM) evaluation of the component design followed by Magmasoft® process simulation.

CWM's use of advanced Magmasoft® metal flow simulations and thermal analysis, prior to die design, can flag possible casting problems and call for minor product feature modifications. These simulations will aid in optimizing die gating, runner and venting configurations in the final die design to assure proper metal flow and die fill. For more on this simulation software in use, see section 10.

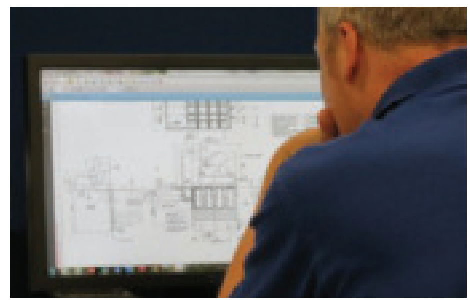
Prototyping for Concurrent Processing



Product design prototypes, produced by Fused Deposition Modeling, are generated by CWM in-house for every new die casting project.

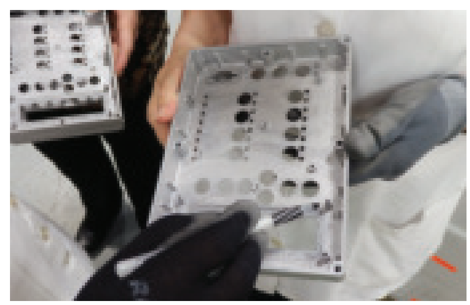
With individual prototypes simultaneously available to each team member, they can be used to validate the die tooling design and provide final die casting die build instructions, aid in accurately drawing up all QA plans, provide trim die construction details required for the part, as well as information for any gauges, machining fixtures, and secondary finishing masks that are indicated—all in advance of production of the first die cast part samples. If CWM is to perform sub-assembly operations, arrangements for the required assembly cells, fixtures, and other materials or purchased components will have likewise been made in advance, based on the prototype.

Die Design & Construction



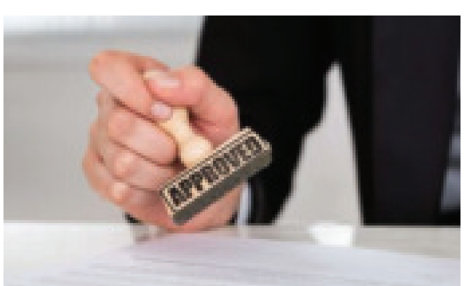
Once the 3D model component design is complete with all of the recommendations developed during the DFM and Magmasoft® Analysis stages in place, CWM, along with our tooling vendor, will proceed with the die cast die design and construction. Though CWM is able to accommodate most changes after design and build have started, the impact on cost and timing is difficult to predict and must be addressed on a case-by-case basis. For this reason, Chicago White Metal puts considerable effort into working with your team so that the design is optimized prior to die design and construction.

Sampling



Once the die build is complete, the tool is set into the appropriate machine and sampled. Raw castings are sent to CWM's Quality Assurance (QA) lab for an initial First Article Inspection (FAI) report and for cosmetic evaluation. Typically, samples are also submitted for initial customer approval, but Chicago White Metal will accommodate individual customer requirements. If there are any issues, a CWM Engineering Project Manager will coordinate production, tool room, and process teams to find a solution. Once all tooling and process adjustments are made, sample runs on the specified production die casting machine, together with capability studies, will confirm the process parameters to be used in full production. The samples will serve as the basis for finalizing control plans and inspection documents.

When customer approval of the FAI report is received, all succeeding production elements will be established and uninterrupted, continuous piece-part production – through any required CNC machining, finishing and assembly – can begin.



Customer Responsibilities

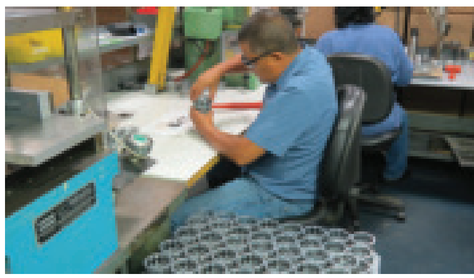
A tightened production timeline places additional responsibility on the customer to confirm that all product and design requirements have been signed off on by all relevant company departments before die design begins. This also ensures that a timely communications channel is in place between CWM and the key company team leaders.

14 Design File Transfer Options

The engineering department works with a range of media, software and hardware for convenient, rapid OEM design file transfer. CWM can accept customer digital design files for die casting production evaluation and for die design development in virtually every popular format. Design files can be transferred by email attachment *(sales@cwmtl.com)* or CWM can access the Customer's Internet server for secure FTP retrieval or arrange a download via a secure web link.

Contact Sales at **630-595-4424** or *email sales@cwmtl.com* for the latest information.

15 Contract Manufacturing



With most end products, a die cast part is a component of a larger assembly, precision-mated to other custom and stock manufactured parts.

Based on a depth of experience in subassembly production, CWM can offer special efficiencies and complete flexibility in performing this manufacturing role through its CWM Contract Manufacturing unit. This work can range from limited assembly steps to comprehensive, single-source turnkey production of a complex product sub-assembly, with appropriate testing equipment on-line. Contracts can include the procurement of all non-die cast components from qualified third-party sources and final packaging of assemblies to your exact specifications.

CWM subassembly projects make use of customized manufacturing cells, specially designed CWM fixtures and experienced materials management. Well-supervised personnel operate in a clean, 16,000 sq. ft. air conditioned space.

CWM Design & Specification Resources at Your Disposal

To aid OEM product design engineers and specifiers in making the right design for die casting decisions early in the product concept stage, Chicago White Metal Casting offers a variety of resources for ready access. We counsel and work with some of the world's leading companies on their high precision components.

Design Information from the CWM Website by Instant Download

Design Guides, Tech Briefs, Webinars, Case Studies, and Engineering Bulletins mentioned in this guide are available by instant download from the CWM Website's DC^2 (Die Cast Design Center), which includes reference manuals and other design aids. You can also download a copy of CWM's capabilities brochure.

Browse the DC^2 today at:

dc2.cwmdiecast.com.

CWM Sales Engineers

As an arm of our engineering and sales departments, CWM sales engineer representatives are located throughout the United States. They can answer your initial questions, provide copies of CWM printed literature, arrange for a "Design for Die Casting" seminar at your company or your visit to CWM's 125,000 sq. ft. facility.

sales@cwmtl.com

Chicago White Metal Casting, Inc.

Aluminum, Magnesium and Zinc Die Castings

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