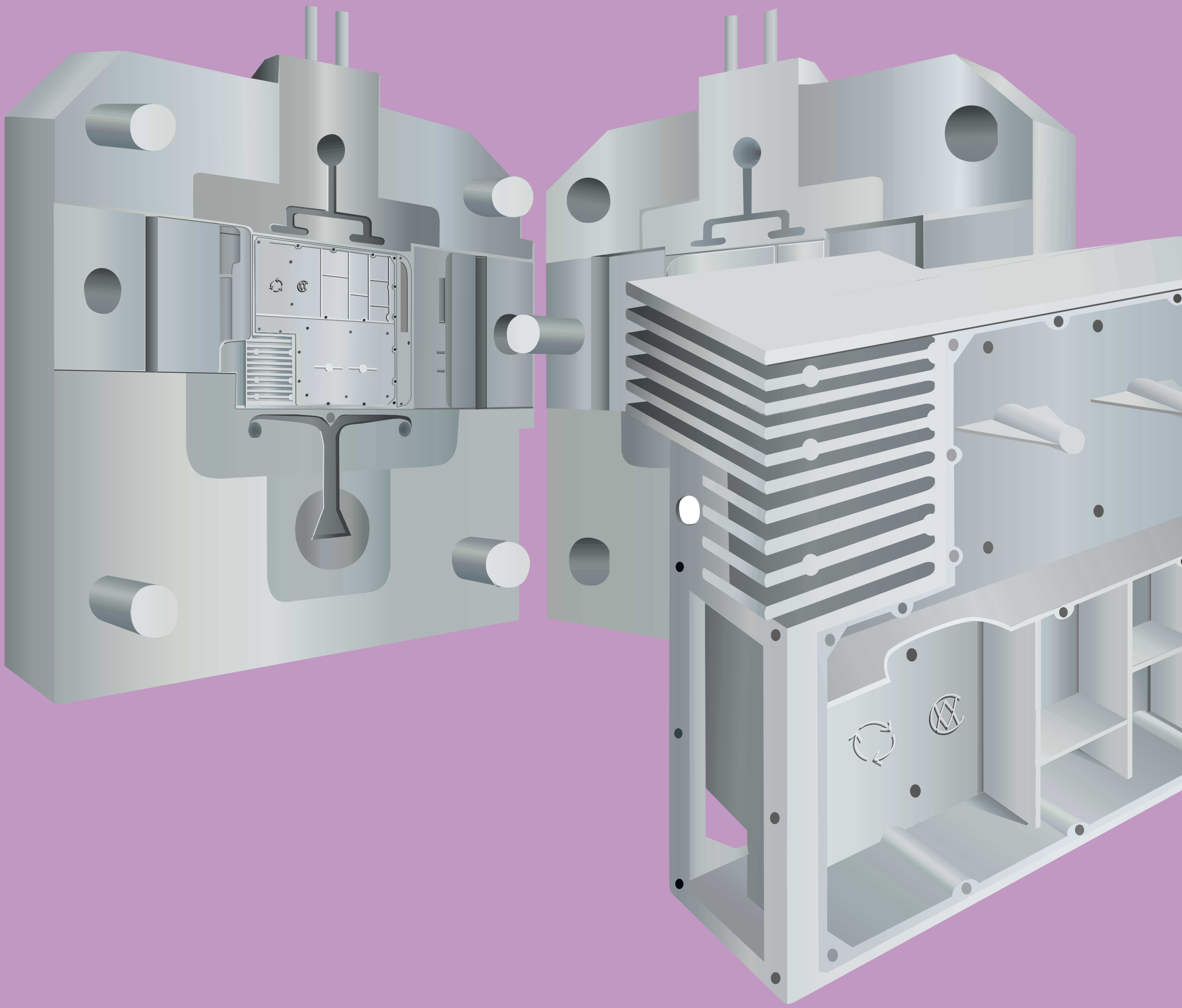
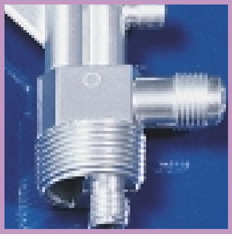
The CWM Die Casting Design and Specification Guide

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 custom production in Aluminum, Magnesium, and Zinc die casting alloys.

Prepared and updated by

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CONTENTS

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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.

They were researched and compiled by Chicago White Metal Casting from its over 70 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 as a concise and easily referenced initial source for the key specification characteristics 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. Note that 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 by instant download in Adobe PDF Reader format from the CWM website's OEM Resource Center, in the Engineering Bulletins section, at www.cwmdiecast.com. This valuable reference volume 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. *All* of the aluminum parts, for example, are die cast from *post-consumer* recycled aluminum, which has the capability of repeatedly meeting the requirements of high-performance applications. The die casting alloy recycling stream, illustrated here, is based on the existing worldwide infrastructure that has been operative for over 60 years. This basic pattern, with varying amounts of reclaimed alloy going to secondary and primary producers, applies to the majority of all metal cast into components by Chicago White Metal Casting.

The environmental management systems of CWM and its division's are ISO 14001 registered. The company is 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.

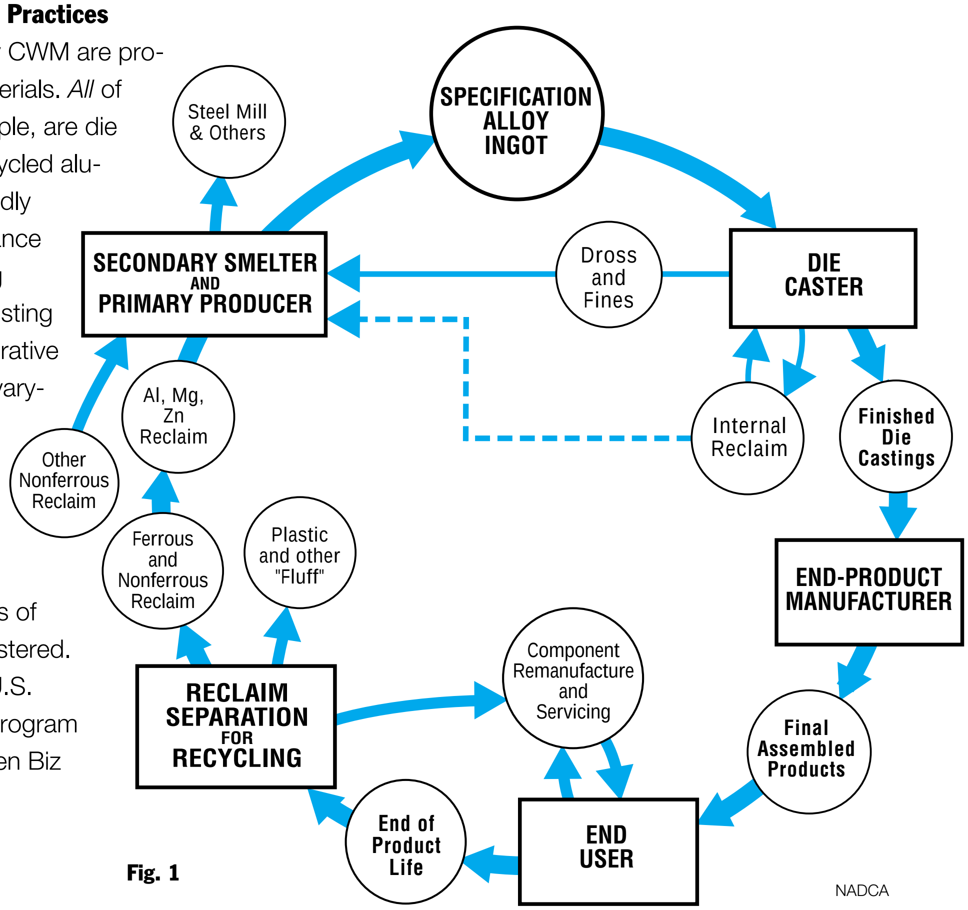


Fig. 1

Anatomy of a CWM Die Set and Die Cast Part

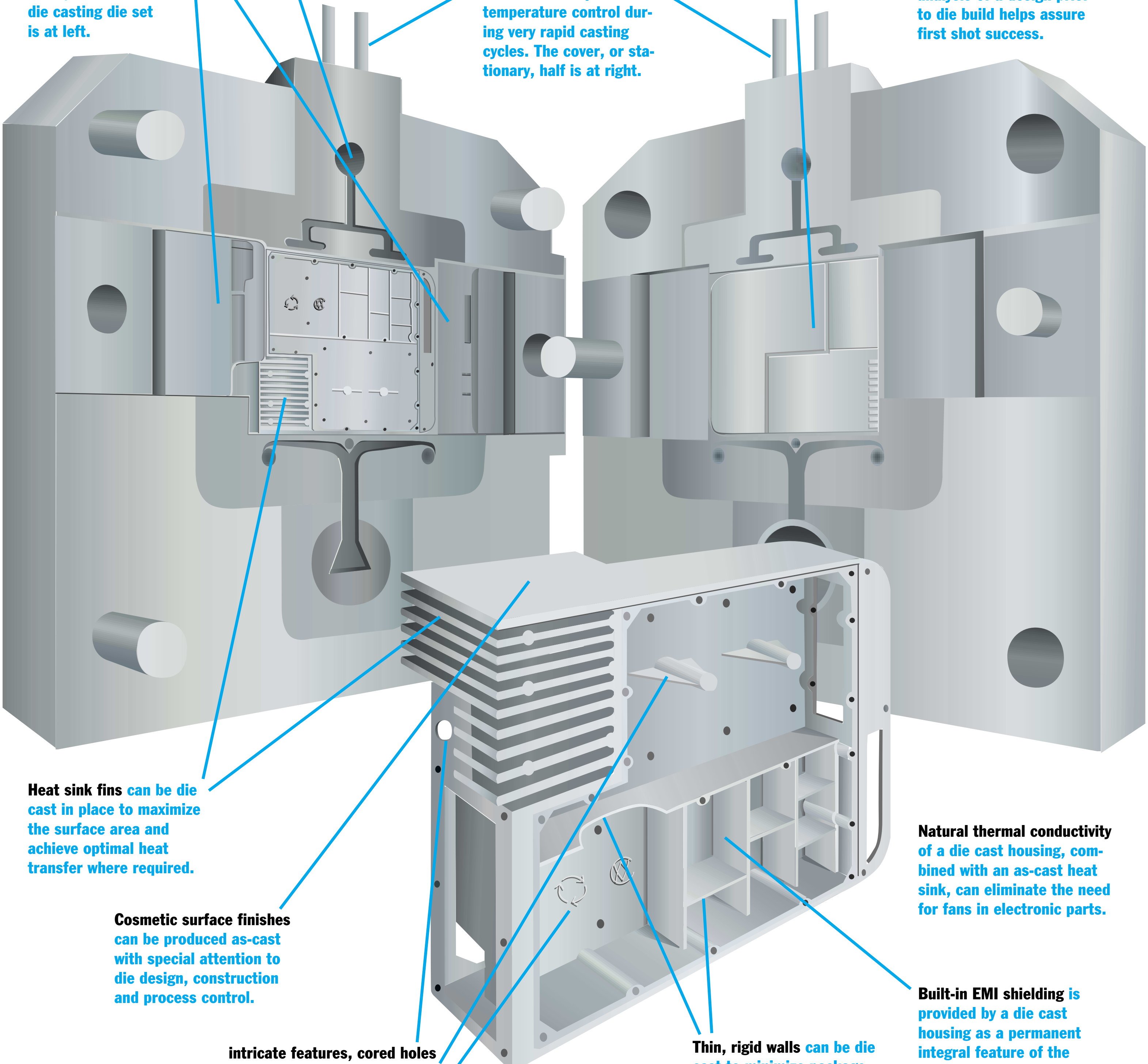
Automatic moveable slides can produce all holes and features as-cast. The ejector half of this die casting die set is at left.

Precision shut-offs, part of 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 right.

Special surface treatment is used on all CWM die cavities to help prevent premature die wear.

Premium tool steel, used to build all CWM die cavities, assures maximum die life and machine performance. Magmasoft®metal-flow simulation & thermal analysis of a design prior to die build helps assure first shot success.



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

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

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

Recyclable Al, Mg & Zn die casting alloys are offered by CWM, certified free of impurities.

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

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

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

KEY DESIGN DECISION STEPS

1 Matching Material Properties

Die casting materials are precisely formulated metal alloys which offer the mechanical properties of medium-strength metals. They are generally several times as strong 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 ksi (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-6-2-2006 and G-6-3-2006 in *NADCA Standards*.)

The die casting process allows the product designer freedom to create extremely intricate contours, varying the wall thicknesses over various sectors of the product. Where strength requirements are not critical, CWM high-tech die casting can produce rigid components with ultra-thin walls. As a result, the designer has much more latitude with die casting than with plastics, powdered metals, or stampings to design relatively thick walls for strength in some areas, and very thin walls for conserving material in others.

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 Al 380 is the most widely used of the aluminum die casting alloys, 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. All aluminum die casting machines operate by the cold-chamber production process.

Magnesium AZ91D Alloy

Magnesium is the lightest commonly used structural metal. Its use in die cast parts has grown dramatically, often replacing plastic parts with greater strength and rigidity at no weight penalty.

Mg alloy AZ91D is the most widely-used magnesium die casting alloy, offering high-purity with excellent corrosion resistance, excellent strength and excellent castability. Corrosion resistance in AZ91D is achieved by enforcing strict limits on metallic impurities.

Utilizing the faster cycling hot-chamber process for its magnesium production, CWM operates

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. (2006 *NADCA Standards. Sec. 3*)

	Die Casting Alloys				Thermoplastics	
Commercial:	Al 380	Mg AZ91D	Zn 3	ZA-8	Lexan®	Torlon®
ANSI/AA:	380.0		AG-40A		3413	4203L
MECHANICAL PROPERTIES						
Ultimate Tensile ksi (MPa)	46 (320)	34 (230)	41 (283)	54 (372)	19 (130)	27.8
Yield StrengthⒶ ksi (MPa)	23 (160)	23 (160)	32 (221)	41-43 (283-296)	- -	- -
Elongation % in 2 in. (51 mm)	3.5	3	10	6-10	3-5Ⓗ	15
HardnessⒷ BHN	80	75	82	100-106	- -	- -
Shear Strength ksi (MPa)	28 (190)	20 (140)	31 (214)	40 (275)	10.5 (72)	18.5
Impact Strength ft-lb (J)	3 (4)	1.6 (2.2)	43Ⓕ (58)	24-35Ⓔ (32-48)	2Ⓘ (100)	- -
Fatigue StrengthⒸ ksi (MPa)	20 (140)	10 (70)	6.9 (47.6)	15 (103)	6Ⓙ (40)	- -
Young's Modulus psi x 10^6 (GPa)	10.3 (71)	6.5 (45)	Ⓖ	12.4 (85.5)	1.25 (8.6)	0.7
PHYSICAL PROPERTIES						
Density lb/in^3 (g/cm^3)	0.099 (2.74)	0.066 (1.81)	0.24 (6.6)	0.227 (6.3)	0.052 (1.43)	0.050 (1.38)
Melting Range °F (°C)	1000-1100 (540-595)	875-1105 (470-595)	718-728 (381-387)	707-759 (375-404)	- -	- -
Specific Heat BTU/lb°F (J/kg°C)	0.230 (963)	0.25 (1050)	0.10 (419)	0.104 (435)	0.27	- -
Coefficient of Thermal Expansion μ in./in./°F x 10^{-6} (μ m/m°K)	12.2 (22.0)	13.8 (25.0)	15.2 (27.4)	12.9 23.2	12.1 (22)	17
Thermal Conductivity BTU/ft hr °F (W/m°K)	55.6 (96.2)	41.8Ⓒ (72)	65.3 (113)	66.3 (115)	150Ⓚ (0.21)	1.77
Electrical Conductivity % IACS	27	n/a	27.0	27.7	23	- -
Electrical ResistivityⒺ $\mu\,\Omega$ in. ($\mu\,\Omega$ cm)	n/a	35.8 (14.1)	n/a	n/a	– –	- -

Table 2 Nominal Chemical Composition: Die Casting Alloys

For detailed chemical composition, request appropriate CWM *Instant Fax Line* Document.

	Al 380	Mg AZ91D	Zn 3	ZA-8
Nominal Comp:	Cu 3.5 Si 8.5	Al 9.0 Zn 0.7 Mn 0.2	Al 4.0 Mg 0.035	Al 8.4 Mg 0.023 Cu 1.0

With mechanical properties, note die casting alloys 380.0, A380.0, 383.0 and 384.0 are substantially interchangeable. Ⓐ 0.2% offset Ⓑ 500 kg load, 10mm ball Ⓒ Rotary Bend 5 x $10^7/10^8$ cycles Ⓓ Notched Charpy. Ⓔ AT 68°F (20°C) Ⓕ ASTM E 23 unnotched 0.25 in. die cast bar Ⓖ Varies with stress level; applicable only for short-duration loads. Use 10^7 as a first approximation. Ⓗ At rupture Ⓘ Izod notched1/8" (3.2mm) ft.lb. (J/M) Ⓙ ASTM D671, 2.5mm cycles. Ⓚ Btu-in/h-ft^2-°F two of among the world's largest hot-chamber Mg machines. Its mag department is one of the largest custom facilities in North America.

Zinc (ZAMAK) No. 3 Alloy
Zinc No. 3 offers the best combination of mechanical properties, castability, and economics among the zinc die casting alloys and is the most widely used Zn alloy in North America. It can produce castings with intricate detail and excellent surface finish at high production rates. In general, thinner sections can be die cast in zinc than in any other commonly used die casting alloy.
All zinc die castings are manufactured in hot-chamber die casting machines.

ZA-8 (Zinc-Aluminum) Alloy
ZA-8, with a nominal aluminum content of 8.4%, is the only ZA alloy that can be cast by the faster-cycling hot-chamber process. It has the highest strength of any hot-chamber zinc alloy, 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 miniature die cast parts to replace more costly miniature 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 at a discount.

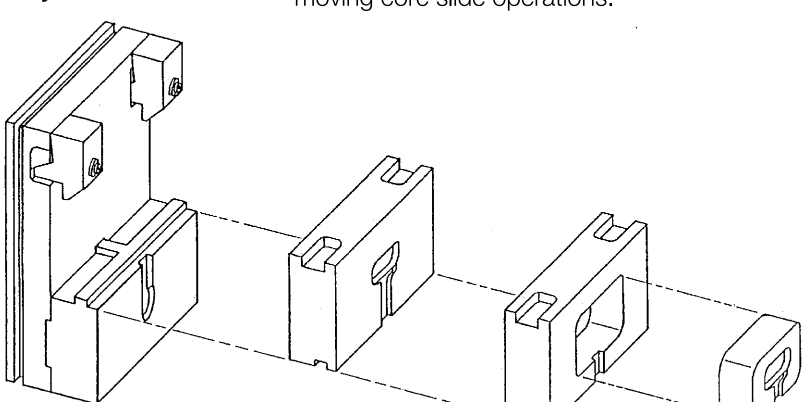
See Table 3a for approximate production part size and weight ranges, and machine tonnages, offered by CWM for each alloy category.

2 Die & Unit Die Construction

The two die halves shown on page 4 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; in some cases, the use of multiple cavities may limit the use of certain moving core slide operations.

Fig. 2 A unit die set is illustrated below. Left to right, the (1) Unit Frame will contain either (2) a Cavity Block, or (3) a Unit Holder Block. The Unit Holder Block can contain (4) a readily removable Cavity Insert.



NADCA

CWM unit dies are standardized unit die frames 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 at smaller volumes. They are available in single and double unit holders.

The limitations of unit dies are that they generally can only accommodate the production of smaller-sized parts, and they restrict, or may eliminate, the use of moving core slides. The configuration of interchangeable unit die inserts, with the resulting limited die area for core slide functions, makes unit dies most appropriate for less complex product designs.

While any die casting die is a major investment, the aggregate manufacturing cost of a component, through final finishing and assembly, should be one of the key production decision criteria. The elimination of secondary machining, cosmetic finishing and assembly operations can often cost-justify more sophisticated die casting die designs.

Cast Features & Die Elements

The features that are required of a cast part determine the complexity of the die. The simpler the part, the lower the cost of the die casting tool.

Castability and die cost will be greatly influenced by the following: Are wall thicknesses as well as the ribs constant, or do they vary greatly? If bosses exist, do they vary widely in diameter? Will any thin channels on the design create thin standing slivers of steel on the die? Is the part number and other engraving recessed into, rather than raised out of, the casting, making the die more difficult to machine? Are the cored holes that may be called for extremely small in diameter and thus more difficult to cast?

For the proper design of production tooling, pressure tightness, secondary machining and surface finishing specifications must be understood in detail. Areas of the casting subject to machining must be fully discussed at the outset, so that the die can be designed to reduce to an absolute minimum the presence of porosity in those areas. Cosmetic surface requirements for the casting will require special finishing of the cavities of the die.

These are among the types of questions that the customer should be prepared to discuss at the earliest planning meetings.

The *NADCA Standards Manual* provides detailed treatment of the tolerancing implications of various casting design features, as well as guidelines which apply under differing casting conditions.

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, which otherwise would have to be produced by additional machining of the die cast part.

Core slides, also called moving die components or moving die parts, are similar to collet or cam movements and can be activated by various sources of motion. Two of the most common are angle pins and hydraulic cylinders.

The angle pin is a mechanical source of motion 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, the placement of slides on any side of the die and avoids interference when removing the casting from the die, as is the case with the angle pin.

The choice of these and other methods of slide motion depend on 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 suited to achieve the desired result.

Importance of a Casting's Parting Line

The parting line is that perimeter on the casting which is the separation point of 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 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 ornamentation to be cast into the part.

With parts requiring a cosmetic surface, it is critical that the customer discuss such specifications in detail in the earliest review meeting. Location of the casting's parting line, as well as its gate, overflows and vents, must not interfere with or blemish any of the part's designated cosmetic surfaces.

Normal, incremental die erosion in production is inherent in the die casting process. Where there are cosmetic requirements, special die maintenance procedures to extend the ability of the die to continue to produce parts to the required high-quality surface finish must be discussed. Secondary surface finishing, such as polishing or buffing, may be complementary to such needs. (Refer to As-Cast Finish Guidelines on page 10.)

Assuring Longer Die Life

The number of parts which can be die cast from a set of die casting dies, before cavity replacement, is dependent on factors such as the quality of the die steel used, the alloy specified, the specific design of part features, and the cosmetic surface requirements for the part.

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, awareness of design features that can drastically shorten die life is important for the product engineer.

Sharp internal or external corners should be modified to reasonable radii. The smooth, highly cosmetic as-cast surfaces, of which the die casting process is uniquely capable, can be expected to result in shorter die life.

A comparison of CWM die life by alloy category appears in the table above.

Die Casting Die Specification Checklist

CWM makes available a *Die Casting Die Specification Checklist* which should be consulted when approaching the production of a new design as a die casting.

CWM PART PRODUCTION & DIE LIFE, BY ALLOY

Table 3a Aluminum, Magnesium and Zinc Alloys Ⓐ

	Al 380	Mg AZ91D	Zn No. 3	Miniature Zn 2, 3, 5, 7, ZA-8
Part Size Range	.75" x .75" to 24" x 24"	.75" x .75" to 24" x 24"	.75" x .75" to 20" x 20"	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	150-500 tons	4-Slide Miniature
Vacuum-Assist Availability	Yes	Yes	No	No
Expected Die Life	1X	3X to 5X	Life of Part Ⓑ	Life of Part Ⓑ

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

Ⓑ CWM guarantees the die casting dies it designs & builds for Zinc 3 die casting and miniature die casting for the life cycle of the product component initially placed in production, excepting die changes and routine die cavity maintenance required during this life cycle.

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 defined 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 videotape of all radiographic images for customer review on any VCR monitor.

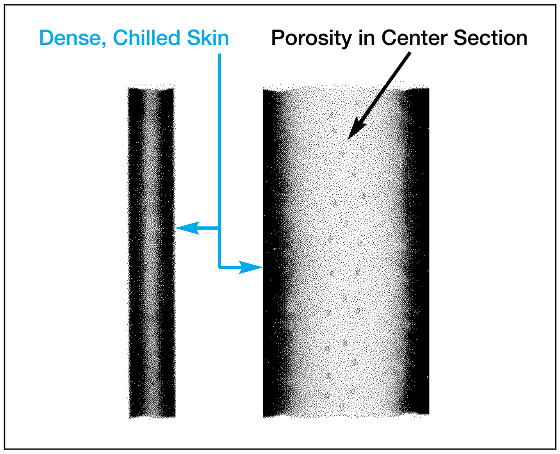


Fig. 3 In a thin-walled die casting, the fine-grained dense "skin" is a large percentage of the section, as in the section above, left, which would contain virtually no porosity. The dense "skin" in a thick section (right) represents a small percentage of the wall.

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 die design, special management of the heating and cooling lines in the die, vacuum casting 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 of all castings may be required. (Refer to Pressure Tightness, Sec. 6, *NADCA Standards*).

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.

All forms of extended surfaces for heat transfer can be die cast: straight fins, "S" shapes and pins. Rectangular fins, easily optimized for width, length and thickness in a die cast design and readily cast in place with the majority of housing designs, are the most commonly used.

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

5 Preplanning 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 important, 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.

If CWM will be contracted to perform secondary machining after die casting, and deliver the part to size, lesser dimensional tolerances may be possible.

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.

6 Tolerancing Guidelines

The extent to which the coordinate dimensioning guidelines shown here for precision die casting tolerances 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:** The design engineer should understand that precision dimensions in every feature of a part are 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 recutting of the die casting die cavity, in combination with the use of machine capability studies. Such procedures will incur added sampling and other costs.

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 draft on inside walls at 3/4 degrees per side, with outside walls requiring half this amount of draft. See *NADCA Standards* for draft equations and details.

Precision tolerances for Cored Holes, i.e., die 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 3b Precision Dimensional TolerancesⒶ

QUICK GUIDE TO COORDINATE DIMENSIONING

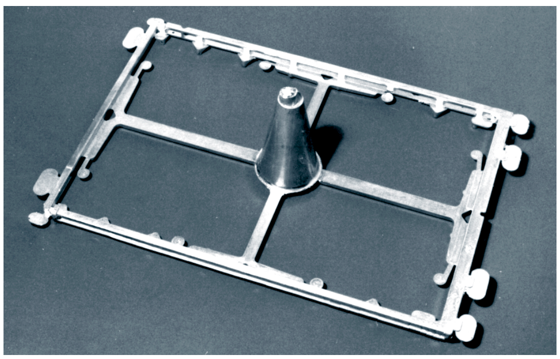
Die Casting Alloy:	Aluminum	Magnesium	Zinc/ZA-8
WALL THICKNESSES			
Nominal wall thicknesses that can be die cast are heavily dependent on part geometry. With small castings, wall thicknesses of 0.030 in. (.762 mm) may be attained with an optimized part design and alloy selection.Ⓑ			
LINEAR DIMENSION TOLERANCES **Length of Dimension** in same die half			
Basic Tolerance up to 1" (25.4 mm)	±0.002 (±0.05 mm)	±0.002 (±0.05 mm)	±0.002Ⓒ (±0.05 mm)
Additional Tolerance for each additional inch over 1" (25.4 mm)	±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			
up to 10 in^2 (64.5 cm^2)	+0.0035 (+0.089 mm)	+0.0035 (+0.089 mm)	+0.003 (+0.076 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.004 (+0.102 mm)	+0.004 (+0.102 mm)	+0.0035 (+0.089 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.005 (+0.153 mm)	+0.005 (+0.153 mm)	+0.004 (+0.102 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.008 (+0.203 mm)	+0.008 (+0.203 mm)	+0.006 (+0.153 mm)
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.012 (+0.305 mm)	+0.012 (+0.305 mm)	+0.008 (+0.203 mm)
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0016 (+0.406 mm)	+0016 (+0.406 mm)	+0.012 (+0.305 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: inches^2** (cm^2)—Tolerances are "plus" values only			
up to 10 in^2 (64.5 cm^2)	+0.006 (+.152 mm)	+0.005 (+.127 mm)	+0.005 (+0.127 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.010 (+0.254 mm)	+0.007 (+.178 mm)	+0.007 (+0.178 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.014 (+0.356 mm)	+0.010 (+0.254 mm)	+0.010 (+0.254 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.018 (+0.457 mm)	+0.014 (+0.356 mm)	+0.014 (+0.356 mm)
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.024 (+0.61 mm)	+0.019 (+0.483 mm)	+0.019 (+0.483 mm)
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0.030 (+0.762 mm)	+0.024 (+0.61 mm)	+0.024 (+0.61 mm)
For projected area of a die casting over 300 in^2 (1935.5 cm^2), **consult CWM.**			
FLATNESS TOLERANCES: inches (mm) **Maximum Dimension of Die Cast Surface**			
Up to 3.00 in. (76.20 mm)	0.005 (0.13 mm)	0.005 (0.13 mm)	0.005 (0.13 mm)
Additional tolerance, in. (mm) for each additional in. (mm)	0.002 (0.05 mm)	0.002 (0.05 mm)	0.002 (0.05 mm)

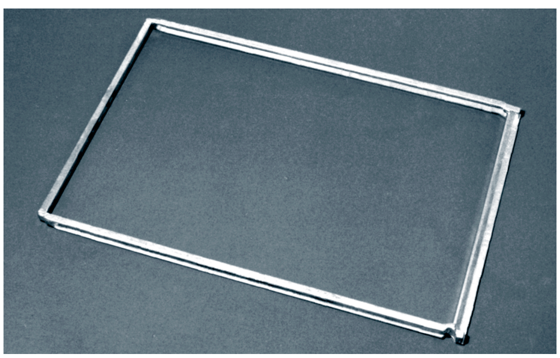
Ⓐ Values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. *(2006 NADCA Standards, Sec. 4A)* Ⓑ Based on CWM recommendations. Ⓒ For some zinc designs, tighter tolerances can sometimes be held, with use of artificial aging.

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

Operation Description	Thick Gates & Overflows ≥ 0.12 (3 mm)	Thin Gates & Overflows ≤ 0.12 (3 mm)	Parting Line & Seam Line Metal Extension	Metal Extension in Cored Holes	Sharp Corners
	Type of Extension & Nominal Amount Remaining After Degating & Trimming				
After Degating only Extension Remaining Before Trimming	Rough within 0.12" (3.0 mm)	Rough within 0.12" (3.0 mm)	Excess Only Broken Off	Not Removed	Not Removed
After Commercial Trimming* Extension Remaining	Within 0.06" (1.59 mm)	Within 0.03" (0.8 mm)	Within .015" (0.38 mm)	Removed within .010" (0.25 mm)	Not Removed

* "Commercially trimmed" does not include washing to remove loose material. For very heavy gates and overflows, consult CWM. (2006 *NADCA Standards, Guidelines G-6-5-2006)*





The die cast frame, right, illustrates the appearance of a center-gated die casting before trimming, showing gate, runners and overflow extension. Photo below 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.

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 cast metal extension, estimated as part of production costs, can be reduced by preplanning in the part design stages and consideration of the amount of metal extension required to be removed and the removal method to be employed.

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

Table 4, above, is the NADCA guide to the types of die casting metal extension (flash) which occurs in typical die castings and the amount of metal extension material which remains after (1) degating (removal of any gates and runners from the casting), and (2) commercial trimming of die casting metal extension. These NADCA guidelines represent normal production practice. Precision trimming, closer than standard commercial trimming, or complete removal of all extension entails additional operations and should be specified only when requirements justify the additional cost.

Note that in some instances, where special surface finish characteristics are not involved, the most economic methods of degating and metal extension removal may include a tumbling or vibratory deburring operation, or hand cleaning.

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, right, 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 (as Bulletin No. 021) in the Engineering Section CWM's Website by (see last page).

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*. See last page for ordering manuals at CWM discount.

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

10 Magmasoft® Die Flow Simulation

Advanced metal flow simulation software offers the opportunity to determine the precise manner in which die casting alloy can be expected to flow into the die cavity for a proposed die cast component— before tooling design has been completed and die construction begun. The benefits of revealing specific die flow problems, until recently very difficult or impossible to predict, are obvious. They can now be easily addressed well in advance of expensive production steps.

The Magmasoft high-pressure die casting process simulation software system is acknowledged as the most advanced current approach to computerized metal flow trouble-shooting at the die casting preplanning stage. It is the in-house software being employed by CWM.

In most cases the software can be effectively applied to a proposed product design using its 3D CAD files even *before* the die cavity design has been developed. The design's expected thermal distribution can be quickly explored. There has been more than one example of just such early intervention by a Magmasoft process simulation analysis that resulted in the avoidance of serious die casting production issues.

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 (flow marks, rubs, surface porosity, lubricant build-up, etc.) are acceptable.	**Used as-cast or with protective coatings:** Anodize (non-decorative) Chromate
2 Functional Grade	Surface imperfections (flow marks, rubs, surface porosity, etc.), that can be removed by spot polishing or can be covered by heavy paint, are acceptable.	**Decorative Coatings:** Lacquers Enamels Plating (Al) Chemical Finish Polished finish
3 Commercial Grade	Slight surface imperfections that can be removed by agreed upon means are acceptable.	Structural Parts (high stress areas) Plating (Zn) 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.	Special Decorative Parts
5 Superior Grade	Surface finish, applicable to limited areas of the casting and dependent on alloy selected, to have an average value in micro inches as specified on print.	O-Ring Seats or Gasket Areas

(2006 *NADCA Standards, Guidelines G-6-6-06)*

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.

Another simulation can then be run, based on the proposed die cavity design, to validate the die design assumptions made.

Further die design modifications and simulation iterations may be indicated to optimize the integrity and surface quality of the proposed part, improve die casting productivity and lower eventual die casting costs.

For more information on the Magmasoft system, download Tech Brief 23 in the Tech Brief section of the CWM website OEM Resource Center.

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

11 Prototyping for Die Casting

Because high-quality die casting dies represent an important production investment, prototyping of a part prior to tooling design and volume die cast manufacturing is a prudent course for a new product design.

Beyond 3-D modeling on the computer, a variety of prototyping alternatives are being used, including machining from stock (hog-outs), investment casting, plaster mold casting, and a range of so-called “rapid prototyping” (RP) techniques. Many RP processes produce components in plastic resins to near-die cast tolerances, but are often too fragile to withstand repeated handling for form and fit, let alone functional testing. Validating both the functional performance of a proposed part as well as form and fit is usually important to the design engineer.

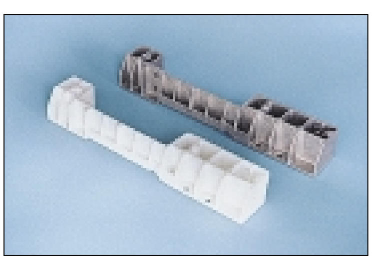
All prototyping strategies for eventual die casting production are approximations to the final performance of a die cast part, and the strengths and limitations of each must be weighed against the designer’s most important prototyping criteria.

Fused Deposition Modeling (FDM)

FDM rapid prototyping technology enables the production of far stronger RP prototypes in durable ABS plastic, directly from STL design files. FDM parts are built and bonded, extruded layer by layer, from 3-D computer data.

An FDM prototype (shown, left, & with final die casting, below) can be geometrically complex and produced 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.

RP prototypes generated for each department can expedite lead times for each casting & post-casting operation.



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

Most RP methods often have difficulty reproducing very tight toleranced sections, such as in sections containing ribs, bosses and holes; in these cases precision CNC machining can be performed on the strong FDM ABS part to the required critical specifications.

FDM prototypes can be generated by on every new die casting project to expedite production and shorten total lead times by providing advance models 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 Collaborate Engineering discussion in Section 13.

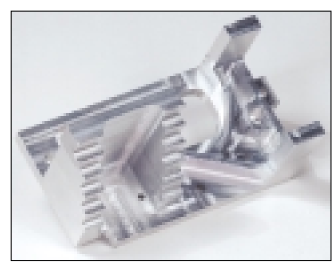
CWM’s in-house FDM prototyping capability can work quickly with customer CAD files to expedite die casting projects.

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 transfer to a CAM program interfacing with CNC workstations, machined prototype total lead times can often approximate RP production scheduling.

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.



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 near identical part weights and to the specified die casting tolerances with precise details as specified. Validation of form and fit under any handling condition is assured, and many functional tests can be performed. Multiple prototypes can be produced for preproduction market research in the same time frame at reasonable additional cost.

For Al 380 die castings, A1 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.

12 Post-Casting Operations

CNC Precision Machining

When net-shape die casting is not feasible for a given part design, post-casting precision machining will be used to achieve final dimensional specifications. CNC machining may also be employed when the unit machining trade-off is less costly compared to the investment in particularly 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. This is especially the case with high-tech die castings in general & high-tech Mg die castings in particular. A higher-level of experience in CNC preplanning and machining center fixture design are critical to cost-effective CNC machining of die cast parts.

While state-of-the-art machining centers and equipment can usually provide the greatest cost advantages on high-volume post-casting projects, more conventional machining units and cells may prove more cost-effective on lower-volume work.

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.

Surface Treatments and Finishing

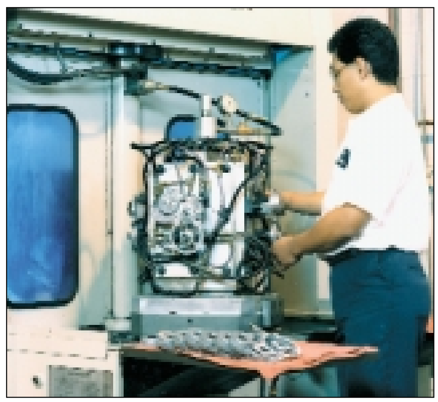
A wide range of proven surface treatment and final finishing systems are available for die castings in all alloys, although many die cast parts are put to use with no surface finishing operations performed after casting and trimming.

These surface treatment systems can be used to (1) solely 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.

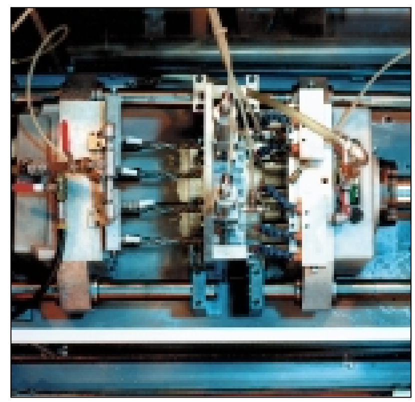
Even when a die casting requires no further surface treatment for decoration, protection or improved performance, a deburring operation is usually recommended.This step removes the metal flash and any burrs, sharp or ragged edges that might remain after trimming, to facilitate handling and any further 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 website's OEM Resource Center (see last page).

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.



Hydraulically interactive fixturing in state-of-the art machining centers makes possible the highest speeds and cutting accuracy.



When a programmable dedicated CNC work cell can reduce your costs, it will be quickly designed and assembled in house.

CWM offers sample die cast plates for surface finishing comparisons.

In addition to a free Guide, CWM maintains a comprehensive surface finishing data bank.

13 CWM Collaborative Engineering

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

CWM has put procedures in place to assure meeting objectives beyond these basic expectations—to assure more rapid time to market. By structuring adherence to the collaborative engineering model described here with every new die casting production project, CWM maximizes the customer's opportunity to reduce unit costs, improve part quality, and accelerate delivery performance.

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 within the originating company, and both within the external supplier-producer organization and between key representatives of the originating company and the supplier. All key elements in the development process should be running in parallel, rather than sequentially, and product requirements and concerns considered and communicated concurrently by all parties.

The Collaborative Engineering Model

To successfully impact on product 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, so that later, costly changes can be avoided and quality and performance improvements can be introduced at little or no cost.

Alternative cost analyses can be drawn up and presented for early trade-off decisions, with no delay in project progress.

These focussed 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 & Die Design

Working from clean customer computer files, which can be transmitted by email or Internet FTP, CWM can proceed with initial 3D CAD evaluation of the component design for die casting 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 which no amount of later casting process adjustments would be able to overcome. 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.

Advanced FDM output enables quick modeling of accurate parts directly from STL design files, in strong ABS plastic, prior to tool building (for details on FDM prototyping, see section 11).

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 subassembly 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.

CAM Die Construction

Final approved component and die casting die designs, together with an approved FDM prototype, proceed through CAM die construction. The FDM prototype, in the hands of the toolmaker, will significantly speed die making and assure initial construction to precise specifications.

With completion of die casting die build, "first piece" will be submitted for customer approval, at the same time that process capability runs from the die will be made.

Process Capability Analysis

Sample runs on the specified production die casting machine will confirm the process parameters to be used in full production and the layout for any SPC charting that might be designated.

When customer approval of "first piece" is received, all succeeding production elements will have already been approved and be in place. Uninterrupted, continuous piece-part production, through any required CNC machining, finishing and assembly, can begin.

ISO 9001 On-line Data

As part of the implementation of CWM's ISO 9001:2000 registered quality system, every department has on-line access to the company's own ISO manual and updated references.

This interactive and searchable electronic database facilitates document control and provides instant availability of updated information.

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, and that a timely communications channel is in place between CWM and the key company team leaders.

14 Design File Transfer Options

Chicago White Metal Casting can accept customer digital design files for die casting production evaluation and for die design development in virtually every popular format.

For complete CAD file transfer information regarding CWM, including preferred 3D and 2D and other file formats, and details on CWM hardware, software & CAD/CAM procedures, visit the CWM Website's CAD File Transfer page in the Quotation section of CWM's website: (www.cwmdiecast.com).

Or phone the CWM Sales or Systems Dept. directly for the latest information.

The Engineering Dept. works with a range of media, software and hardware for convenient, rapid OEM design file transfer.

Design files can be transferred by e-mail attachment (systems@cwmtl.com) or CWM can access the customer's Internet server for secure FTP retrieval.

CWM's secure FTP site accepts file transfers via the Internet, with prior call to CWM Systems Dept. or e-mail (systems@cwmtl.com).

Anonymous, unsecured logins can be made to Chicago White Metal (ftp://ftp.cwmtl.com). Caution: customers should understand this is an *unsecured* address and an e-mail should be sent (systems@cwmtl.com) or phone call made to the CWM Systems Dept. advising that such a product design file transfer will be forthcoming.

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 subassembly, 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.

Complete product subassembly operations can be performed by CWM's Contract Manufacturing unit, with full responsibility for purchased non-die cast components.

Specialized equipment will be employed, as required, to accelerate cost efficiencies. Here an eight-station assembly cell performs two-sided gasketing in volume production.

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, Application/Tech Briefs and Engineering Bulletins mentioned in this guide, are available by instant download from the CWM Website's **OEM Resource Center** section, which includes Reference manuals & Design CDs available at special CWM discounts. You can also download a copy of CWM's capabilities brochure. (See CWM website address below).

CWM Sales-Engineers

As an arm of our engineering and sales departments, CWM sales-engineer representatives are located in major design and production centers in the U.S., and in Canada & Mexico. 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 136,000 sq. ft. facility. They can be located in the **Sales Engineers** section of CWM's Website, or by calling Chicago White Metal.

Visit the CWM CNC Machining and CWM Contract Manufacturing Websites

For a detailed look at CWM's CNC Machining and CWM Contract Manufacturing capabilities, visit the CNC Machining Technologies and CWM-CM Websites listed below. To discuss a current or future die casting project, call or e-mail CWM.

Chicago White Metal Casting, Inc.®

Certified Aluminum, Magnesium, Zinc and ZA-8 Die Casting

EXCELLENCE IS EXPECTED   CWM IS A GREEN BIZ LEADER COMPANY

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MANAGEMENT SYSTEMS ISO 9001 AND ISO 14001 CERTIFIED

Engineering Representation throughout the U.S. and in Canada & Mexico

MEMBER:

North American Die Casting Association   NADCA

International Magnesium Association

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