NADCA Product Specification Standards for Die Casting

Aluminum,
Aluminum-MMC,
Copper,
Magnesium,
Zinc and
ZA Alloys

NADCA
NORTH AMERICAN DIE CASTING ASSOCIATION
Arlington Heights, Illinois

Revised for 2015
9th Edition

NADCA Product Specification Standards for Die Casting

Dedicated to Continuous Improvement

The North American Die Casting Association's mission is to continue as the worldwide leader in stimulating growth and improvement in the die casting industry.

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OEM product engineers and specifiers can contact NADCA for information on a range of materials and services aimed at helping designers achieve product cost reductions and performance improvements through today's advanced die casting technology. These include an OEM design, specification and sourcing website, design engineering publications and a regional and on-site OEM design seminar program.

Product Standards Disclaimer

The standards and guidelines for the specification of products to be produced as die castings presented in this volume are generic in nature. They are offered as a convenient reference for the general direction of die casting component designers and specifiers, whose final decisions must depend on their own engineering and design judgment and predictive testing under application conditions. Use of these standards and guidelines is voluntary.

The unique characteristics and features of a specific die cast component design are the major determinants of the final specifications which can be economically achieved by the die casting process.

The OEM product engineer is urged to consult with their die caster to establish more precisely those guidelines which can be expected to apply to a particular design under consideration.

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Revisions and Additions Schedule

NADCA Product Specifications Standards for Die Castings will be revised as needed on a yearly basis. Major revisions and additions are incorporated on a three (3) year schedule.

Published by:
North American Die Casting Association
3250 N. Arlington Heights Rd., Ste. 101
Arlington Heights, IL 60004

Library of Congress Catalog Card Number 94-70763

ISBN 1-885271-00-x

NADCA Product Specification Standards for Die Casting

Introduction to this Manual

These specification guidelines and standards for die castings have been formulated to aid product designers and specifiers in the successful execution of their designs as die cast components. Significant advances in the capabilities of North American process technology, and the introduction of an expanded number of die casting alloys, have created new opportunities for cost-effective die cast designs. To achieve net-shape or near net-shape components, designers today are using die casting to capitalize on improved dimensional accuracy and stability, cosmetic surface quality, and more dependable product performance. To best capitalize on all of these advantages, designers and specifiers should consult the guidelines presented here at an early design stage, in collaboration with a qualified die caster.

Today's die casting process can offer significant reduction in, or elimination of, part machining costs through its ability to cast dimensions, holes and features to precision tolerances at high volumes. Such major cost reductions can also often make die castings practical in lower production volumes. Through parts consolidation, die castings can reduce finished product assembly costs and improve product integrity and operation. Selected alloys can allow bearing properties to be integrally incorporated into a part, eliminating the need for inserts. The established strength and durability of die castings can allow undamaged disassembly, refurbishing or remanufacture to extend a product's useful life. And at the end of a product's life cycle, die castings allow for optimum reclamation with eventual remelting and realloying, followed by die casting back into high-level applications — without degradation of properties.

The first section of this manual, Process & Material Selection for Product Recyclability, presents the facts on this important new product requirement for process and material selection.

The Tooling Section will familiarize engineers, especially those new to the process, with the unique characteristics of die casting tooling requirements.

The Alloy Data Section provides an updated reference to die casting materials commercially available for component design specification in North American production. These material families include the aluminum alloys; aluminum metal matrix composites; copper alloys including brass and bronze; magnesium alloys; zinc (Zamak) alloys; and zinc-aluminum (ZA) alloys. Lead and tin are rarely die cast because of relatively low mechanical properties. Ferrous-metal die casting is carried out on a limited production basis, with very high melting temperatures necessitating the use of special refractory metals for dies and other special procedures. Alloy tables provide data for comparison of chemical composition and properties for each alloy and their characteristics in die casting and post-casting operations. Poisson's Ratio, where available, is included to aid finite element analysis (FEA).

* Different sets of properties can be achieved with alternate processes (such as high vacuum, squeeze, and semi-solid casting) and alternate alloys (such as A356, Aural 2 or 356, and Silafont 36). Information on these processes and alloys can be found in the Product Specification Standards for Die castings produced by Semi-Solid and Squeeze Cast Processes (NADCA Publication #403) and the High Integrity Die Castings book (NADCA Publication #404).

Replacing the former ADCI/NADCA "E" Series are the comprehensive Engineering and Design Sections. These present die casting coordinate dimensioning specifications for "Standard" Tolerances and "Precision" Tolerances, with values up to 65% tighter than the former "E" Series. In addition, guidelines for Geometric Dimensioning are presented as they relate to die casting part designs.

Sections on Quality Assurance and Commercial Practices will aid the specifier and die caster in reaching agreement on the procedures and practices that should be followed to assure purchaser satisfaction.

A detailed contents page appears at the beginning of Sections 2 through 9. A listing of all numbered standards, guidelines, and checklists appears on the next page. An index and glossary of die casting terms appear in Section 10.

More than one section should be reviewed in making process decisions. The special features and geometry of an individual component to be die cast, its dimensional, functional, finishing and end-use requirements — considered in relation to production parameters — must be carefully weighed.

The appropriate tooling, engineering and quality assurance guideline information provided should be evaluated in combination with alloy data. The benefits of early consultation with an experienced die caster are obvious.

These guidelines are prepared and published by NADCA, in collaboration with OEM engineers and dedicated die casting industry technical specialists. Thanks go to the many industry members who contributed at various stages to the development, research, organization and review that resulted in this volume.

NADCA wishes to acknowledge the Product Standards Task Force for the efforts provided to establish this 8th Edition.

Guideline & Checklist Cross Reference

Cross Reference between former ADCI Product Standards, former NADCA Volume 401 Product Guidelines and NADCA 2012 Product Specification Standards for Die Casting.

ADCI	NADCA #401	NADCA 2015	Subject
ADCI-M2	NADCA-M2	NADCA A-3-1 NADCA A-3-2	Composition & Properties of Standard Aluminum Alloy Die Castings
ADCI-M3	NADCA-M3	NADCA A-3-1 NADCA A-3-2	Composition & Properties of Special Aluminum Alloy
ADCI-M4	NADCA-M4	NADCA A-3-3	Characteristics of Aluminum Alloys
ADCI-M5	NADCA-M5	NADCA A-3-7 NADCA A-3-8	Composition & Properties of Copper Alloy Die Castings
ADCI-M6	NADCA-M6	NADCA A-3-9	Characteristics of Copper Alloys
ADCI-M7	NADCA-M7	NADCA A-3-10 NADCA A-3-11	Composition & Properties of Mg Alloy Die Castings
ADCI-M8	NADCA-M8	NADCA A-3-12	Characteristics of Mg Alloy Die Castings
ADCI-M9	NADCA-M9	NADCA A-3-13 NADCA A-3-14	Composition & Properties of Zn. & ZA Alloy Die Castings
ADCI-M10	NADCA-M10	NADCA A-3-15	Characteristics of Zn. & ZA Alloy Die Castings
ADCI-M11	NADCA-M11	(Discontinued)	Certified Zinc Alloy Plan for Die Casting
ADCI-C1-76	NADCA-C1-88	Comm'l Practices pgs. 8-8	Production Part Orders
ADCI-C2-76	NADCA-C2-88	Comm'l Practices pg. 8-3	Specifying Tolerances
ADCI-C3-76	NADCA-C3-88	Comm'l Practices pg. 8-4	Die Casting Dies & Production Tooling
ADCI-C4-79	NADCA-C4-88	Comm'l Practices pg. 8-11	Price Adjustments
ADCI-C5-76	NADCA-C3-88 NADCA-C5-88	Comm'l Practices pgs. 8-7	Insert: Gauges
ADCI-C6-76	NADCA-C6-88	Comm'l Practices pg. 8-12	Patent Obligations
ADCI-C7-76	NADCA-C7-88	Comm'l Practices pg. 8-12	Warranties
ADCI-C8-76	NADCA-C8-88	Comm'l Practices pgs. 8-10	Limitations on Inspection
ADCI-C9-76	NADCA-C9-88	NADCA C-8-1	Checklist for Die Casting Production Part Purchasing
ADCI-C10-76	NADCA-C10-88	NADCA C-8-2	Checklist for Finished Die Cast Production Part Purchasing
ADCI-Q1	NADCA-Q1	Quality Assurance pgs. 7-9	Drawing & Specifications
ADCI-Q2	NADCA-Q2	Quality Assurance pgs. 7-10	Gage, Measurements & Test Equipment
ADCI-Q3	NADCA-Q3	Quality Assurance pgs. 7-11	Statistical Quality Control

Guideline & Checklist Cross Reference

Cross Reference between former ADCI Product Standards, former NADCA Volume 401 Product Guidelines and NADCA 2015 Product Specification Standards for Die Casting.

ADCI	NADCA #401	NADCA 2015	Subject
ADCI-Q4	NADCA-Q4	Quality Assurance pg. 7-10	FAIR
ADCI-Q5	NADCA-Q5	Quality Assurance pgs.7-12	Porosity
ADCI-Q6	NADCA-Q6	Quality Assurance pg. 7-17	Pressure Tight Castings
ADCI-E1-83	NADCA-E1-83 NADCA-E1-65	NADCA S-4A-1 NADCA P-4A-1	Linear Dimension Tolerances
ADCI-E2-83	NADCA-E2-83 NADCA-E2-65	NADCA S-4A-2 NADCA P-4A-2	Parting Line Tolerances
ADCI-E3	NADCA-E3-83 NADCA-E3-65	NADCA S-4A-3 NADCA P-4A-3	Moving Die Component Tolerances
ADCI-E4	NADCA-E4-83 NADCA-E4-55T	NADCA S-4A-7 NADCA P-4A-7	Draft Tolerances
ADCI-E5	NADCA-E5-83 NADCA-E5-65	NADCA S-4A-8 NADCA P-4A-8	Flatness Tolerances
ADCI-E6	NADCA-E6-83 NADCA-E6-65	(1) (See below)	Depth of Cored Holes
ADCI-E7	NADCA-E7-83 NADCA-E7-65	(1) (See below)	Draft Requirements in Cored Holes
ADCI-E8	NADCA-E8-83 NADCA-E8-65	NADCA S-4A-9 NADCA P-4A-9 NADCA P-4A-10 NADCA S-4A-11	Cored Holes for Threads (1) The Cored Holes for Threads secions requirements include cored hole & draft requirements
ADCI-E9	NADCA-E9-83 NADCA-E9-65	NADCA G-6-4	Ejector Pin Marks
ADCI-E10	NADCA-E10-83 NADCA-E10-65	NADCA G-6-5	Flash Removal
ADCI-E11	NADCA-E11-83 NADCA-E11-65	Engrg. & Design Pg. 5-11	Location Tolerances
ADCI-E12	NADCA-E12-83 NADCA-E12-65	Engrg. & Design Pg. 5-13	Concentricity Tolerances
ADCI-E13	NADCA-E13-83 NADCA-E13-65	NADCA S/P-4A-13	Machining Stock Allowance
ADCI-E14	NADCA-E14-83 NADCA-E14-65	NADCA S-4A-12	Die Cast Threads
ADCI-E15	NADCA-E15-83 NADCA-E15-65	NADCA G-6-2 NADCA G-6-3	Fillets, Ribs & Corners
ADCI-E16	NADCA-E16-83 NADCA-E16-65	NADCA G-6-7	Lettering & Ornamentation
ADCI-E17	NADCA-E17-83 NADCA-E17-63T	NADCA G-6-1	Pressure Tightness
ADCI-E18	NADCA-E18-83 NADCA-E18-64T	NADCA G-6-6	Surface Finish, As-Cast
ADCI-M1	NADCA-M1	Alloy Data Tables Pg. 3-42	Alloy Cross Reference Designations

List of NADCA Standards, Guidelines & Checklists

Current Revisions and Additions

Title	Page	Comment
Die Casting Die Specification Checklist	2-17	Checklist updated to allow specific alloy to be written in
Guidelines to Increase Die Life	2-19	Guidelines 8 and 9 added
Alloy Data	3-11	Tables 7 and 8 added for chemical composition and properties of suggested and company specific alloys
Zinc Alloy Properties at Temperature	3-37	Alloy 2 added More data points and modulus added for other alloys
Aluminum Alloy Data	3-42 & 3-43	EN specifications and chemical composition added for aluminum alloys
Zinc Alloy Data	3-45	Expanded zinc cross reference specifications and added chemical compositions
Parting Line	4A-9 to 4A-12	Clarified terminology for calculating parting line tolerance and parting line shift tolerance
Miniature Die Casting Dies	4B-6	M-2 and H-13 added as die material options in table
Primary, Secondary, and Tertiary Features & Datums	5-4	Rewritten to explain more clearly
Material Conditions	5-8 & 5-9	Rewritten to explain more clearly
Ribs and Corners in Die Cast Parts	6-5	Section on Small Metal Savers added
Ejector Pins, Pin Marks and Pin Flash	6-6	Section on Bumping Ejector Pins added
JIT Delivery	8-9 & 8-10	Just In Time Delivery section removed
Compliance with Laws	8-11	Section on Compliance with Laws added
Intellectual Property	8-13	Section on Intellectual Property added
Edits Made Throughout New photographs and revised line drawings added throughout		

Process and Material Selection for Product Recyclability

SECTION 1

Frequently Asked Questions (FAQ)

1) Are die cast materials recyclable?
   See page 1-4, Die Casting's Unique Environmental Position, Figure 1-1, and page 1-5, Die Castings Recycling Circle.
2) Is there some comparison between recycled aluminum and virgin aluminum?
   See page 1-4, Comparison of Recycled vs. Virgin Aluminum Chart.
3) How do die castings affect the environment?
   See page 1-4, Die Casting's Unique Environmental Position.
4) Are die castings more readily recyclable than plastics or other non-metallic components?
   See page 1-3, Problems Confronting Non-Metallic Recycling.

Introduction

Designers today are faced with material selection considerations that an earlier generation of engineers did not consider.

In addition to optimizing the cost and performance equation of a new or redesigned product, engineering must now more carefully analyze its long-term environmental impact.

An increasing population has available to it a decreasing number of waste disposal sites, with nearly 70% of landfill capacity predicted to be exhausted by the end of the decade. There has been a vast growth in the use of raw materials not readily recyclable. These forces have led to heightened government concern with the environmentally safe disposal of durable goods waste.

Die casting alloys offer the designer concerned with post-consumer recyclability one of the most advantageous material options. Die castings and the die casting process provide the product engineer who is designing for the environment:

- *Components that can maintain their integrity through disassembly, repair, remanufacturing and reassembly.*
- *Product recyclability, at the end of useful life, with the potential for return to high performance applications.*
- *Knowledge that a proven recycling infrastructure is in place to reclaim recycled die cast parts.*

Here is an overview of current North American environmental concerns, the manufacturing process and material alternatives that offer creative solutions for today's product designer.

1 New Design Responsibilities

Most engineers, as concerned citizens of their society, know that the problems of waste disposal are serious. The U. S. Environmental Protection Agency has estimated that we have reached the point where nearly half of the solid-waste landfills in the United States have been closed.

Disappearing waste disposal sites are an even more serious problem in Europe, where the cost of waste disposal in landfills or by burning has increased dramatically. In Germany, with limited availability of waste sites, the government has introduced a bill to attack the problem of automobile disposal, requiring carmakers to take back old vehicles at no charge to the consumer. Legislation there now bans incineration.

Minimum-content laws have been passed by many U.S. states, mandating the use of recycled materials in new products. Washington has issued an executive order requiring government agencies to give preference to recycled materials when purchasing products. Waste disposal alternatives such as incineration and ocean dumping will no longer be acceptable, with government regulations calling on product manufacturers to insure the minimal environmental impact of their manufactured durable goods.

It appears clear that the product designer will soon not only be responsible for the optimum function and easy fabrication of a product, but will also be required to account for the product's ultimate destiny at the end of its service life.

Process and Material Selection for Product Recyclability

2 Implications of the Emerging "Green" Consensus

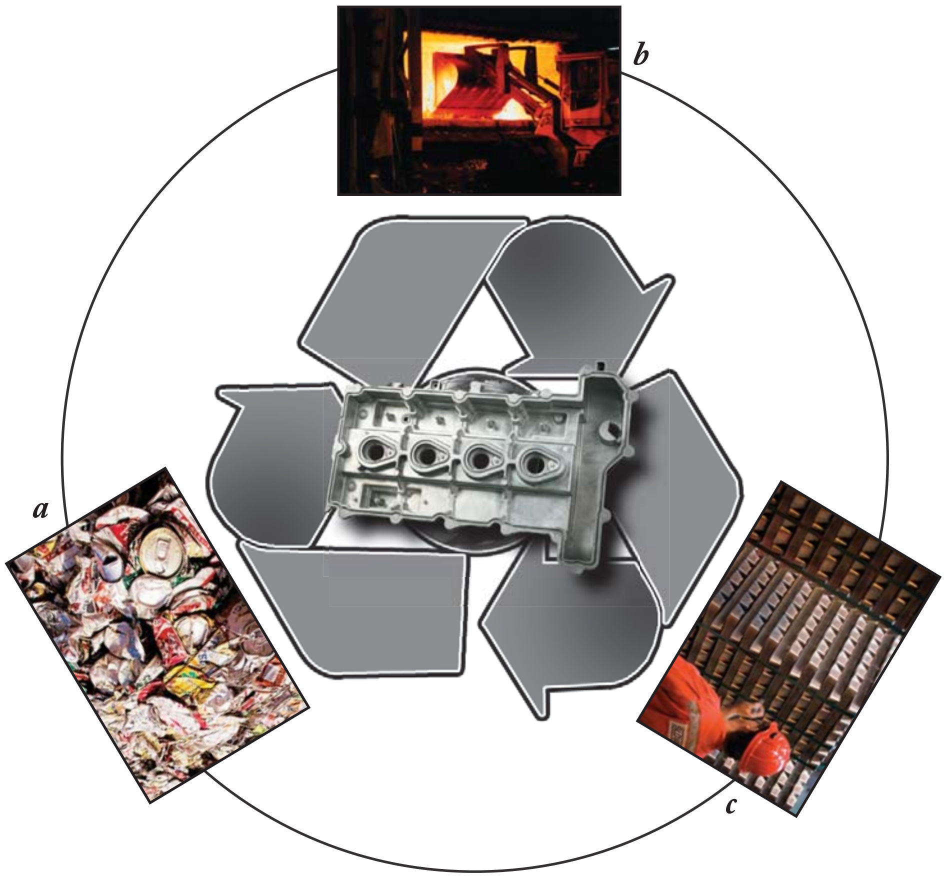


Figure 1-1 Circle of recycling to create a die casting. Recycled cans are collected (a), cans are remelted with other aluminum scrap (b) to create ingots (c), ingots are used to create a die casting (center).
Images Courtesy of © Norsk Hydro, © Alcoa, © NADCA.

The need for manufacturers to focus on ecological consequences has been stated not only by business management scholars from institutions like Northwestern's Kellogg School of Management and the University of Michigan, but by business leaders as well. Companies like AT&T, NCR, Whirlpool Corp., DEC, and Northern Telecom have publicly addressed the issue.

The obvious conflict between business and environmental interests is being altered by a trend toward business "greening" encouraged by a new awareness among consumers. American consumer surveys have shown that 80% of Americans said they would pay more for environmentally safer products. Based on actions that follow from such findings, designing for the environment appears here to stay. The recyclability of a car model or other durable goods may soon become a competitive feature in a consumer's purchasing decision.

Increasing numbers of people are asking more sophisticated questions about products and the environment, such as concerns over the life cycle of the products they use and the potential for recycling.

Companies which address environmental concerns in the design of their products will be at a long-term competitive advantage. Among other guidelines, an orientation involves (1) the minimum use of virgin materials and non-renewable forms of energy, and (2) minimizing the environmental cost of products and services over their entire life cycles, from their creation to disposal or completion.

There are four steps in adopting a strategy for environmental excellence in manufacturing to be competitive in the 21st century:

- *Conducting an environmental vulnerability assessment of processes and products.*
- *Conducting a life-cycle assessment for each product and process.*
- *Designing and developing green products for existing and new markets.*
- *Moving toward zero-waste manufacturing processes.*

3 The Designer's Material Choices

A product engineer designing products for environmental compatibility encounters many material suppliers who claim that their materials and processes offer recyclability. Other considerations being equal, what the designer of today's products must distinguish between are theoretical or future possibilities of reprocessing a material, on the one hand, and in-place recycling, on the other.

The facts are that metals can claim the support of an existing world-wide infrastructure that economically collects, reprocesses and channels these reprocessed materials back into the manufacturing process — to allow reuse at costs significantly less than purchasing virgin materials.

Supporting the automotive industry, a network of automotive dismantlers daily make their living selling salvaged metal auto parts and then placing the remainder of the vehicle in the hands of "shredders." The shredding process, which has proven its economic viability, results in the recycling of almost 75% of the weight of a typical car — nearly all of this as ferrous and nonferrous metal. Over 85% of the aluminum in a car is currently reclaimed and recycled.

The non-metallic portion of a product is generally regarded by recyclers as "fluff," consisting mostly of plastic. Nearly one-quarter of all solid waste is estimated to be plastics, and less than 3% of this plastic is being recycled.

Problems with plastic product recyclability were pointed out by a national task force in 1994 who requested that plastics marketers refrain from use of the universal symbol for recycling in advertisements, since it was regarded as misleading in relation to plastics.

The greater proportion of non-metallics in a product, the less its value to the recycling industry, and, increasingly, there are fewer and fewer places for disposal of this material.

4 Problems Confronting Non-metallic Recycling

While most plastics are capable of being recycled, the infrastructure for such recycling is far from being in place. While many early recycling efforts among consumers have met with cooperation, end results to date have not been promising.

4.1 Reprocessing Gap

With some exceptions in the case of plastic bottles and foam containers, the monetary incentive and basic infrastructure either to handle collected plastics and to reprocess it economically is lacking.

Also, there is no substantial market for most of the durable plastic scrap. Existing recycling organizations continue to regard most plastics as they always have, as non-metallic material with little established value, that must be separated out from profitable, reclaimable metal. For even the lower level of plastics applications, virgin resins remain significantly lower in cost than recycled plastics.

4.2 Separating Plastic

The plastics industry recognizes that it will be some time before a working infrastructure for plastics recycling and reprocessing is in place, particularly for injection-molded resins. The introduction of plastic composites, to approach the strength of cast metal, has caused still further recycling problems.

In Europe there has been action to subject reinforced engineering plastics to additional taxation, based on their incompatibility in the eventual recycling stream. While incineration has been curbed for reasons of air pollution, heat and flame-resistant plastics might further limit such disposal as an economic alternative.

The incompatibility problem in reclamation also occurs with the wide variety of non-reinforced engineering resins in use, as well as with plastic product combinations which join the properties of several plastic resins in a single product. Unlike plastics, a combination of several aluminum alloys made from different processes can be directly recycled. A component produced as a combination aluminum die casting and aluminum extrusion can readily be remelted and reprocessed — as the two have been, separately, since nonferrous alloy recycling began.

4.3 Plastic Degradation

Studies by the plastics industry have indicated that, even with a plastics recycling infrastructure in place, the use of recycled engineering plastics can yield unpredictable results.

Unlike recycled metals, the effects of temperature, time and the environment can degrade the potential performance of a recycled engineering thermoplastic, aside from the obvious effect on the aesthetics of the final product molded from recycled material. While post-consumer recycled resins are already being molded for low appearance uses, unpredictable performance degradation may render such material unusable for stricter engineering applications.

As an alternative to injection-molded engineering thermoplastics, recyclable die cast metals offer the product designer the opportunity to respecify product components as precision die castings, often with newly realized cost savings and strength and performance advantages.

Comparison of Recycled vs. Virgin Aluminum	
Energy Savings	95% Energy savings; recycling of one aluminum can saves enough energy to run a Television for three hours.
Environmental Impact	Reduces pollution by 95%.
Natural Resource Savings	4 lbs. of bauxite saved for every pound of aluminum recycled.
Miscellaneous Information	Enough aluminum is thrown away to rebuild our commercial air fleet four times every year

5 Die Casting's Unique Environmental Position

Nearly all metals — and die castings in particular — have always been readily recyclable. Die castings are not hazardous waste and pose no problems in handling or reprocessing, as do some non-metallics.

Die castings offer the product designer recyclable components with engineering advantages not available in other metalforming processes. The major cost and performance benefits of parts consolidation possible with plastic components can be carried forward in die casting designs with additional advantages.

Net-shape die castings can be produced with thinner walls than comparable plastic parts, and can provide greater strength and product durability over a longer life cycle — with added serviceability.

Cost-effective die cast components can survive higher temperatures and user abuse, compared to plastic counterparts.

Threaded inserts and EMI/RFI shielding, additionally required for many plastic electronic housings, can be eliminated with a die cast housing, resulting in lower unit costs. Metal inserts in plastic housings serve to further complicate plastic recycling.

Parts redesigned as a single die cast unit from a combination of metal and plastic components, or from components produced in a variety of metals, can not only result in significantly lower costs and improved performance, but also yield advantages for recyclability. Many examples exist over a wide range of die cast product applications.

- *The housing frame for a tabletop bundling machine for applying plastic strapping was redesigned as a near net-shape die casting, replacing 27 separate components consisting of stampings and heavily machined parts.*
- *A die cast feed horn wave guide for a satellite receiving system was produced as a single net-shape part, as opposed to multiple components requiring several manufacturing processes.*
- *The die cast design for a passenger car gearshift selector tube, part of a passive restraint steering column, replaced a steel shaft and multiple-piece assembly at a savings of over $1.00 per part, for a $3 million annual cost reduction.*
- *A multiport valve body for a tractor-trailer spring brake release valve became a single die casting, to replace a multiple assembly of fittings with significantly reduced machining costs.*
- *An office machine bracket, redesigned as a single die casting, originally consisted of eight metal components, each produced from six different alloys and processes.*
- *A trimmer-mower housing die casting has enabled a number of significant advantages, such as steerable wheels and a sleek design, setting it apart from competitors who utilize stampings. Housings fabricated from stampings contain more parts and are not lower in cost.*
- *A die cast lower crank case for a motorcycle was designed to eliminate costly secondary machining operations and additional engine parts.*
- *A bracket for an electronic enclosure was converted from a machined part to a die casting. The die casting is cast to net-shape and eliminates all machining.*
- *A die cast modem frame was designed to replace an assembly. The assembly was a plastic part sandwiched between two metal plates and held together with self-tapping screws. The one-piece die casting results in cost savings to the customer.*
- *A die cast head node for a mountain bike was converted from investment cast parts, to a unique design, yielding a 30% weight savings, part and assembly cost savings, better consistency in impact and fatigue and better performance.*

5.1 Eliminating Waste through Increasing Product Life

Since scrap avoidance is one of the most effective ways to reduce waste, a new design emphasis is being placed on increased product life.

A designer should weigh the snap-fit capability of molded plastic against the ability to disassemble and reassemble high-strength die cast components, with product integrity maintained over their useful life. The proven ability of a die cast product to be serviced and/or rebuilt can result in a doubling of its total life cycle. Aluminum die cast brake housing bodies on heavy trucks, for example, can be remanufactured after 750,000 miles of service and reinstalled to perform for an additional 750,000 miles.

6 Die Casting's Recycling Circle

Aluminum die casting alloy recycling has been in place almost from the beginning of custom die casting production. Today newspaper advertisements for aluminum scrap, such as the one shown here, are not uncommon.

Specifications for aluminum alloys have been developed that provide for a full range of compositions that can utilize recycled metal. A wide variety of aluminum scrap can be reprocessed to produce all of the most widely specified die casting alloys.

Over 95% of the aluminum die castings produced in North America are made of post-consumer recycled aluminum. Since the production of recycled aluminum alloy requires approximately 5% as much energy as primary aluminum production, there is a dramatic conservation of non-renewable energy resources.

Die castings, as opposed to forgings or extrusions, for example, can make far greater use of recycled material.

Process and Material Selection for Product Recyclability

The typical life cycle for die cast components is shown in Fig. 1-2. While the recycling circle for aluminum, copper, magnesium and zinc die cast parts is very similar, each will differ in the extent to which internally reclaimed alloy at the die casting plant will be reused directly or will move to a secondary smelter or primary producer for remelting and reprocessing.

When a die cast product is reclaimed at the end of its useful life, it enters the nonferrous alloy reclamation stream. Nonferrous alloy parts can be readily separated from ferrous components by long-established magnetic means.

Large assemblies with a high proportion of metal parts, such as automotive vehicles, are the easiest scrap to be recycled and a well-established infrastructure exists.

High-value components are usually dismantled from vehicles and enter the used parts or remanufactured parts distribution channel. The remaining automobiles are then shredded, with 75% of the weight of a typical car yielding recycled material, virtually all metal. An average vehicle in 1998 produced over 168 lbs of aluminum alone for recycling. Though aluminum makes about 9% or slightly more than 300 pounds of today's car, it can add up to 30% of its recyclable value.

Unlike plastic, there is no necessity to segregate various types of aluminum scrap for remelting and reprocessing. Reclaimed aluminum from siding, trailers, major appliances, and automobiles — produced by a variety of metal forming processes in a range of alloy types — can be recovered by the aluminum smelter using selective thermal processing. Carefully engineered and analytically controlled chemical composition result in precise specification ingot for each of the commonly used die casting alloys.

As product engineers seek to design their new products for optimum servicing, reuse and recycling, aluminum, copper, magnesium and zinc die castings are available to meet their needs. With an infrastructure in place for reclaimed die casting alloys, and a proven ability to capitalize on parts consolidation principles, die castings can be respecified for a wide variety of parts originally conceived as molded plastic.

Where lightest weight is an important product criteria, selected die casting alloys can offer excellent strength-to-weight ratios, with total part weight virtually identical to the plastic component being replaced. In selecting materials and manufacturing processes which meet environmental concerns, the product designer should ask these questions:

- *Does the material allow for efficient and economical maintenance, repair, refurbishing or remanufacturing of the product to extend its life, where this is a design benefit?*
- *Is the material readily recyclable at the end of its useful life?*
- *Can the material be recovered and reused in high performance applications?*
- *Is the necessary infrastructure in place to make recycling of the reclaimed material a practical reality?*

Process and Material Selection for Product Recyclability

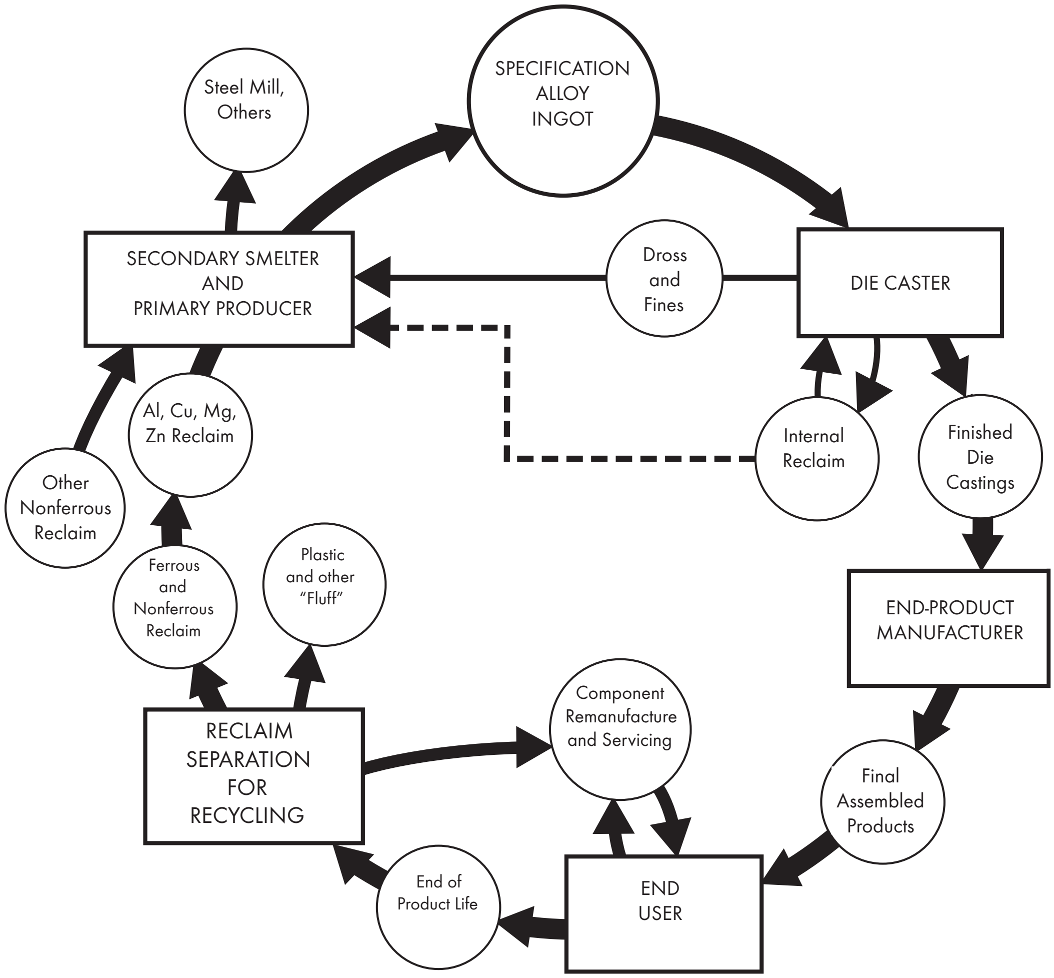


Figure 1-2 The Die Casting Recycling Circle – The die casting alloy recycling stream, illustrated above, is based on an existing worldwide metal reclamation infrastructure that has been operative for more than 40 years. This basic recycling pattern, with variations based on the amount of reclaimed alloy going to secondary and primary producers, applies to the majority of die castings being currently specified.

Process and Material Selection for Product Recyclability

Tooling for Die Casting

SECTION 2

Section Contents

Tooling for Die Casting

A-PARTING LINE
Surface where two die halves come together.

B-LEADER/GUIDE PIN & BUSHING
Guides the two die halves together and maintains die alignment.

C-DIE CAVITY
Die recess in which casting is formed.

D-STATIONARY & MOVING CAVITY INSERT
Premium grade tool steel containing the cavity details.

E-RUNNER & GATES
Precisely designed passage thru which metal flows from sprue hole or cold chamber into die cavity.

F-COLD CHAMBER
Passage thru which metal enters runners and gates.

F1-SPRUE HOLE & SPRUE PIN
Forms passage thru which metal enters runners & gates in a hot chamber die.

G-CORE
Usually a round tapered pin used to cast various hole details.

H-STATIONARY/COVER MOLDBASE
Stationary holder that contains and supports the cover inserts.

I-RETURN PIN
Large ejector pin that resets ejection system.

J-EJECTOR PIN
Pin which pushes casting from die cavity.

K-MOVING/EJECTOR MOLDBASE
Movable holder that contains and supports the ejector inserts.

L-RAILS
Supports the ejector side moldbase and contains clamp slots.

M-RETAINER AND EJECTOR PLATE
Contains and pushes the ejector pins.

N-SUPPORT POST/PILLAR
Additional support members to resist die deflection.

O-GUIDED EJECTION ASSEMBLY (STOP, PIN & BUSHING)
Supports and guides the ejection system.

P-CLAMPING SLOTS
Opening for die clamps to mount die halves to machine platens.

Frequently Asked Questions (FAQ)

1) What type of material should be used for die cavity inserts?
   See page 2-10, Die Materials
2) What is the proper heat treatment procedure for dies?
   See page 2-11, Die Steel Heat Treatment
3) What is the difference between a Prototype Die and a Rapid Tooled Die?
   See pages 2-4, Prototype Dies and 2-5, Rapid Tooled Dies.
4) Why are trim dies used?
   See page 2-6, Trim Dies.
5) What is the difference between a unit die and a self-contained die?
   See pages 2-3 through 2-6, Types of Die Casting Dies.
6) What types of venting air are possible on a die?
   See page 2-11.

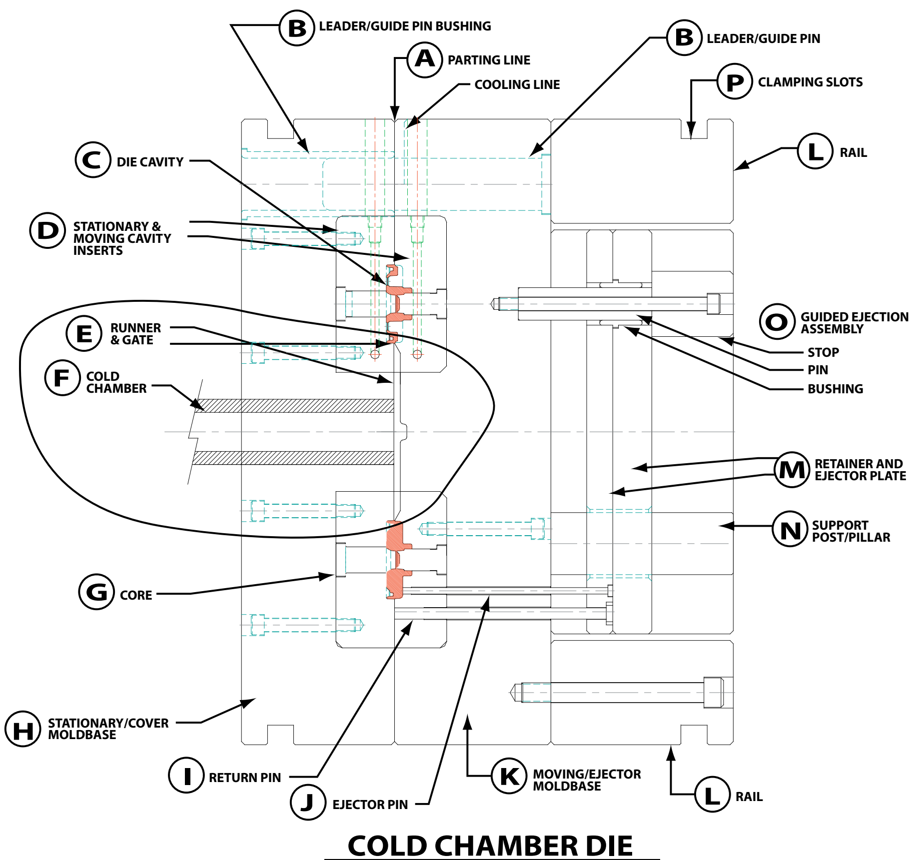
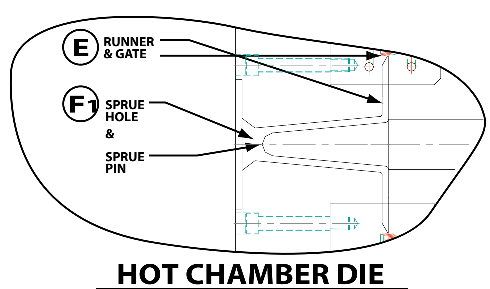


Figure 2-1 Shown above is a multiple-cavity cold chamber die casting die. With this process the metal enters the die runners, gates and cavity through the cold chamber. The Sprue replaces the cold chamber in the hot chamber process which is used for zinc and smaller magnesium components.



Tooling for Die Casting

2

1 Introduction

The die casting die, or mold, is a closed vessel into which molten metal is injected under high pressure and temperature, then rapidly cooled until the solidified part is sufficiently rigid to permit ejection from the mold.

For longevity of operation in this environment the die casting die must be built from high-quality tool steel, heat-treated to the required hardness and structure, with dimensions of the die and cavity machined to exacting specifications. The two die halves run in a die casting machine that is operated at the required temperatures and pressures to produce a quality part to net-shape or near-net-shape customer specifications.

The customer's product design requirements directly affect the size, type, features, and cost of the required tooling. The items involved in the tooling decision include the number of cavities, number of core or slide requirements, weight of the die, machining, finish requirements, polishing and plating to name just a few. A convenient checklist of die construction considerations, intended for use in discussion with your custom die caster, appears at the end of this section (page 2-17).

Explanation of the most important terms related to die design are given in the following sections of this chapter. A complete glossary of die casting terms appears at the end of this volume.

The discussion in this section provides a guide to aid the die casting specifier in understanding the requirements of the die caster that will be necessary to produce the optimum die casting, by the most economical production methods.

The various alloys available for die casting, from aluminum to zinc, require unique and special features in the die that produces them. Because of these differences, the descriptions and parameters described in this text are generic. Where possible, options are listed but should be used only as a general guide, with the final decisions discussed between the customer and the die caster.

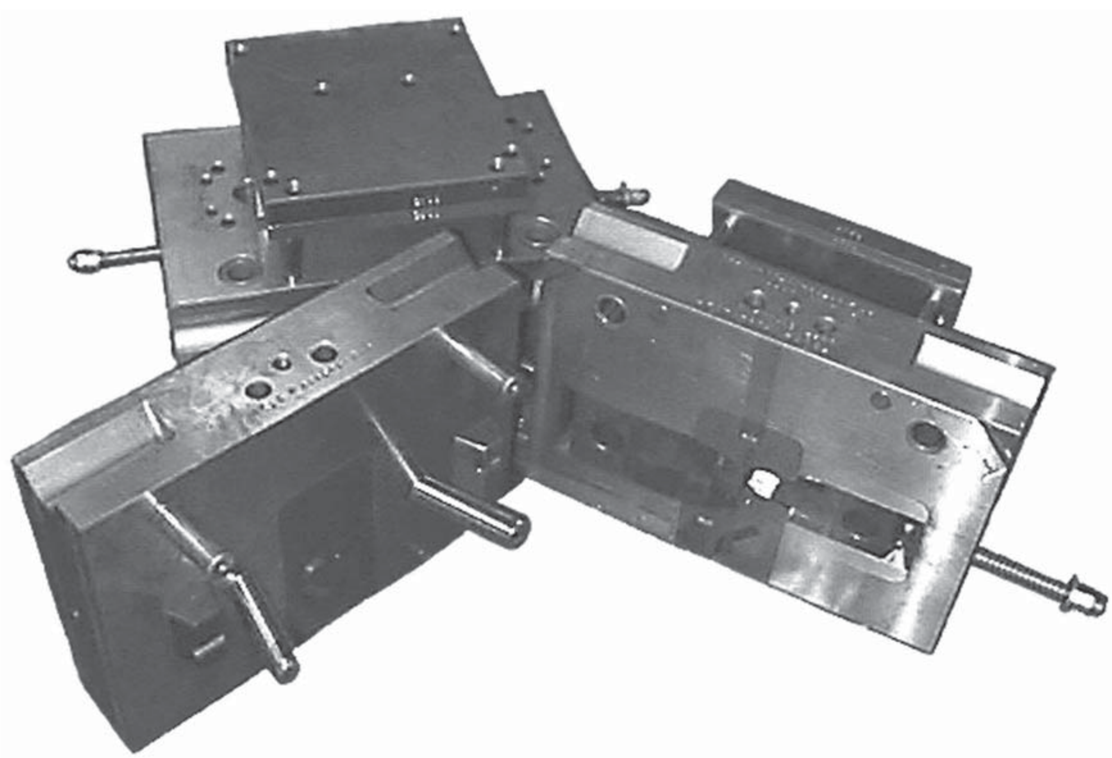


Figure 2-2 A "unit" die casting die, like the one above, allows use of replaceable cavities in standardized main die frames for lower die costs.

Tooling for Die Casting

2 Types of Die Casting Dies

There are various types of die casting dies and each serves a critical need for the customer. The choice of which type of die casting die the customer requires is usually determined by the following:

- *Size of the part to be cast*
- *Volume of parts required*
- *Requirements for "family" sets of parts*
- *Desirability of core slides*
- *Requirements for cast-in inserts.*

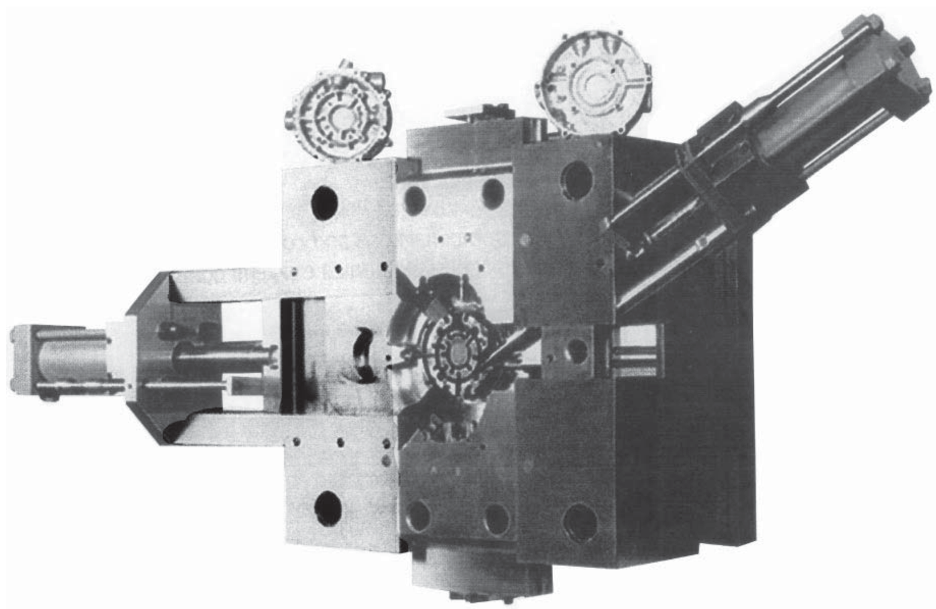


Figure 2-3 This single cavity die uses the moveable die components (slides) to produce complex features in the part shown.

2.1 Prototyping

Prototypes are usually requested by the customer to produce a small number of castings under production conditions. They enable thorough product testing and market exposure before committing to full production dies.

Only production from an actual die casting die can yield a part with precise die cast characteristics. However, there is a range of prototyping strategies that can be employed to approximate a die cast part for eventual production die casting. Among them: gravity casting, including the plaster mold process; machining from previously die cast parts or from wrought and sheet stock; and rapid prototyping techniques such as stereolithography (See the NADCA design manual, Product Design for Die Casting.)

2.2 Rapid Tooled Dies

Rapid tooling is a term that refers to dies and inserts produced by methods shorter in lead-time than the conventional method of rough machining, heat treating, and finish machining. Rapid tooling methods include processes such as LENS (Laser Engineered Net Shaping), EBM (Electron Beam Melting), RSP (Rapid Solidification Process), SLS (Selective Laser Sintering), DMD (Direct Metal Deposition), and high speed machining of unhardened steel or pre-hardened tool steel. Investment casting, and KTEL may also be used. Tools produced by these methods may be utilized as prototype or production dies. Production volume requirements may dictate which rapid tooling methods are most viable.

2.3 Production Dies

These are the most common types of tools produced. They range from a single-cavity die, with no slides, to a mulitple-cavity die with any number of slides. The cavities are made from high-quality tool steel, retained in a quality holder block.

Production dies are built to critical dimensions, coring the maximum amount of stock from the casting, and allowing the agreed-upon amount of machining. A unit die is a special type of production die.

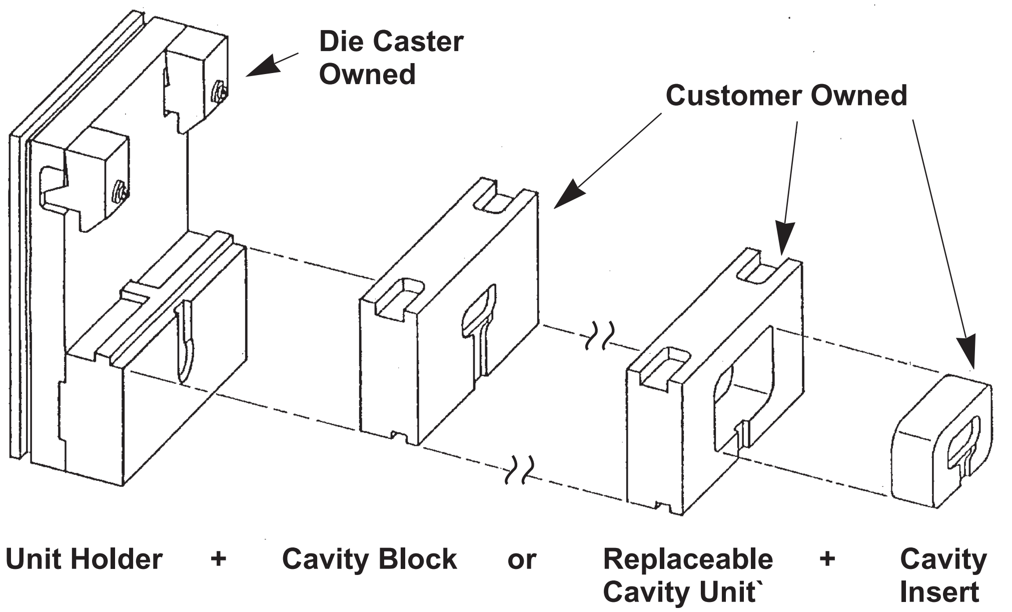
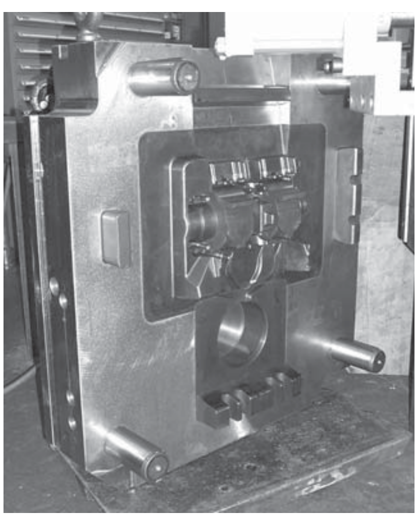
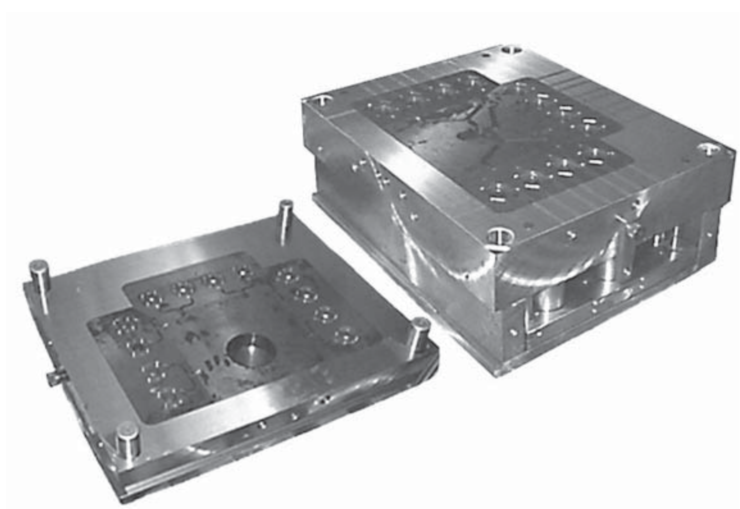


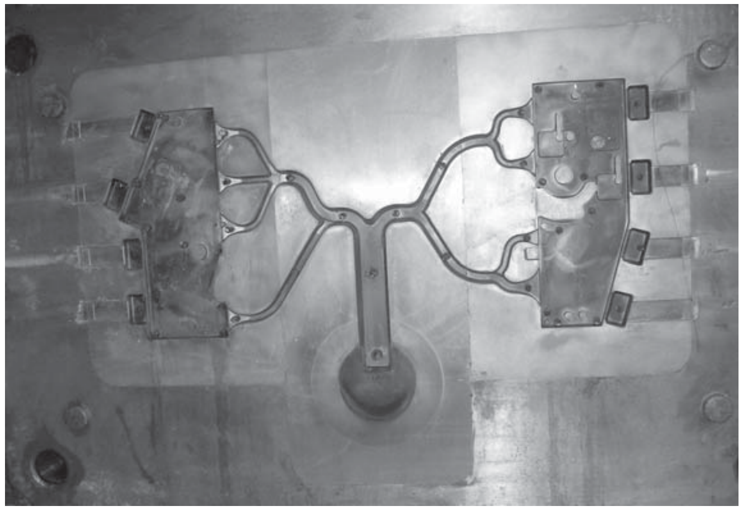
Figure 2-4 Components of a unit die illustrate each part of the assembly and the die construction option of a cavity block or a holder block with cavity insert.



Single-Cavity Die



Multiple-Cavity Die



Family Die

2.4 Unit Dies

A unit die is a lower cost production tool that has a standardized main die frame and replaceable cavity units. These replaceable units are designed to be removed from the main die frame without removing the standard frame from the die casting machine.

The most common commercial types of unit dies are single and double unit holders. These types of dies are generally used for smaller parts, or a family of parts, with no slides or a minimum number of slides. Unit dies limit the use of core slides because of the configuration needed for interchangeable unit inserts and the limited space available.

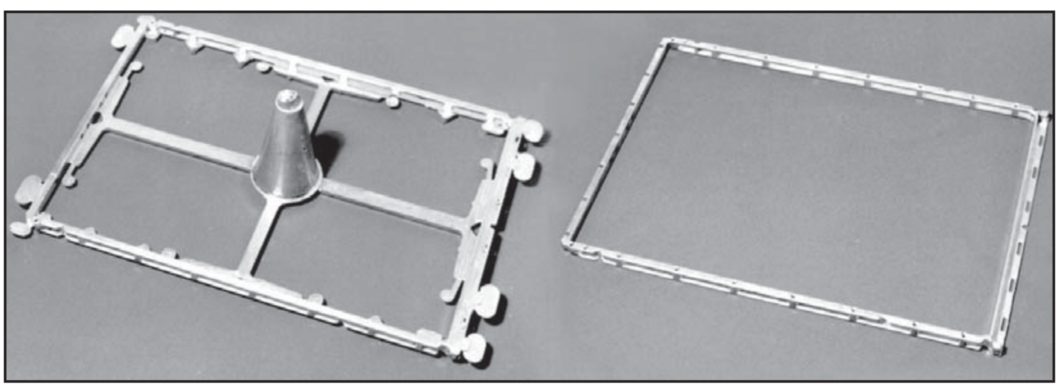


Figure 2-5 Photo on left shows untrimmed zinc die casting as it comes from the die. At right, the same casting after trimming.

2.5 Trim Dies

The trim die is a tool that trims the runner, overflows, and flash from the casting. The trim dies are single or multiple cavity tools, made in the same configuration as the die casting die.

Depending on the shape of the casting, the trim die may be a simple open-and-close trim die or it may include as many slides as the die casting tool. In some cases multiple station trim dies will be used for successive trimming operations.

Trim dies require as much attention to detail in design as the die casting tools and the use of quality materials should be specified to extend their productive life.

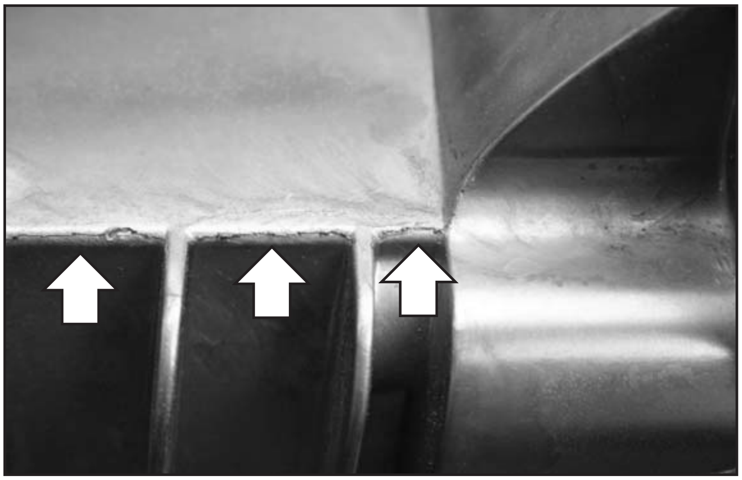


Figure 2-6 Most cracking can be eliminated with larger radii.

3 Casting Features and Die Considerations

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.

The customer should look at the casting in terms of total manufacturing cost. The die caster will aid the customer in examining not only the part design's castability, but also all of the secondary operations that may be required.

Castability and die cost will be determined by answers to the following: Are the 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 difficult to cast? Is the part designed with sharp corners, promoting stress cracks or with generous radii? See the figure 2-6 and fillet information on page 6-4.

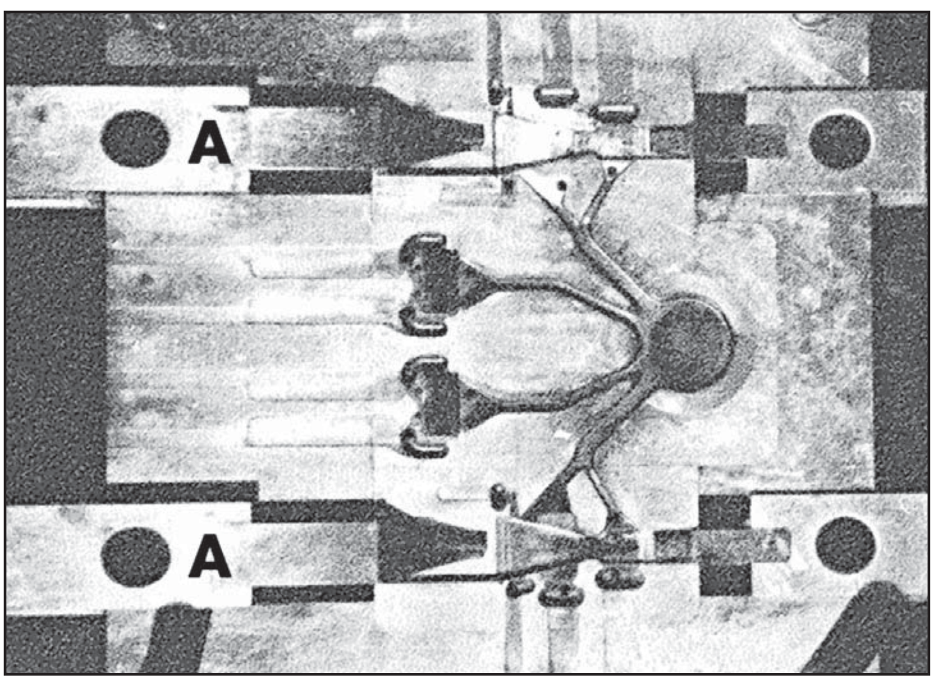


Figure 2-7 This ejector die half shows the two moveable cone-shaped core slides, A, at left which form the interior of the die castings in this two-cavity die. Opposite slides are at the right.

Tooling for Die Casting

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 specific steps in finishing the cavities of the die.

These are among the types of questions that the customer should be prepared to discuss with the die caster while reviewing the supplementary checklist at the end of this section.

The Engineering and Design sections provide detailed treatment of the tolerancing implications of various casting design features, as well as guidelines which apply under differing casting conditions.

3.1 Core Slide Requirements

Fixed cores and core slides (or pulls) can be designed in the die to cast selected features in place, eliminating the need for most – or all – secondary machining of the cast part.

Core slides, similar to collet or cam movements, 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 that is activated by the die opening and closing. 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. It is not recommended for use on top slides. Although the use of springs can make this possible.

The hydraulic method of slide motion permits: a choice of cycles, the placement of slides on the top of the die, and avoids interference when removing the casting from the die (as is the case with the angle pin).

Among the other methods of motion are rack and pinion, ejector lifter, and cam bars. The choice of motion depends on factors such as production volume, size of die, length of travel of slide, size of area being cored out and the configuration of the part. The die caster should be relied upon for the optimum recommendations on core slides, also called moving die components or moving die parts.

3.2 Parting Line: Cover and Ejector Die Halves

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 casting. Tolerancing standards specific to part characteristics at the parting line are presented in Engineering and Design, Section 4A.

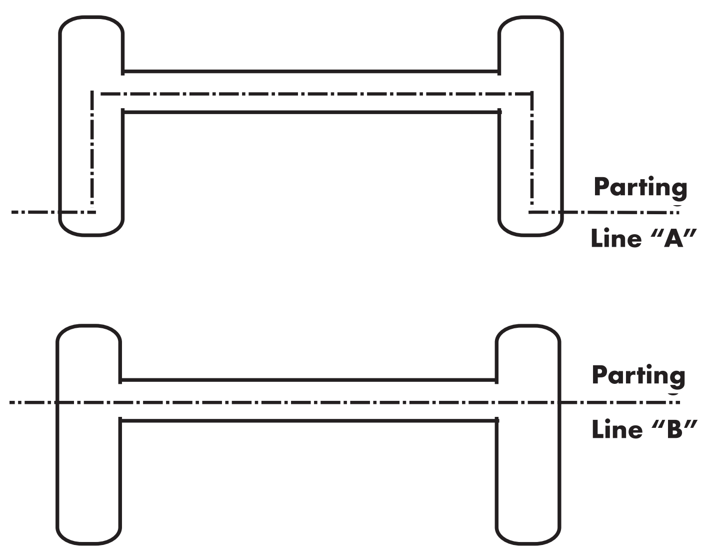


Figure 2-8 Step parting line “A,” originally placed on this casting drawing would not have produced the best production results. The location of the parting line “B” in the bottom drawing will allow better casting fill and cleaner casting trim, plus provide longer die life and a less costly die to build.

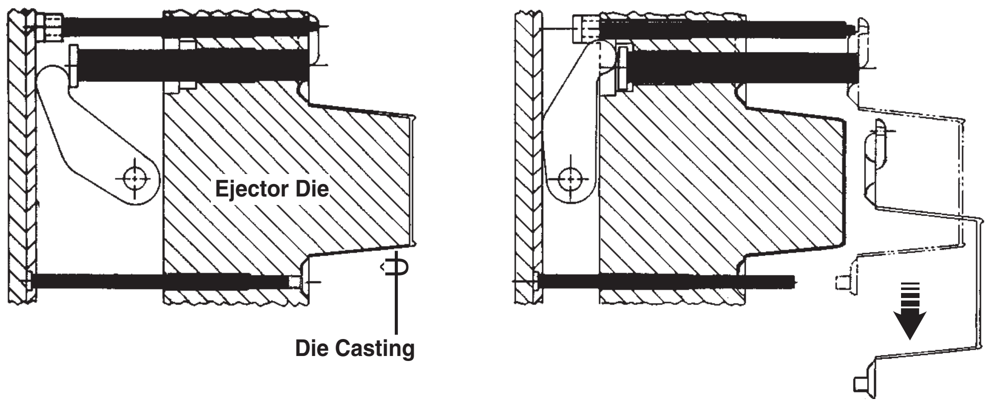


Figure 2-9 Ejector pins, shown in black, are recessed as the metal fills the die cavity (above left); then actuate sequentially to release the casting from the die (above, right).

It is not obvious where the parting line on a casting drawing should be placed. Where the parting line is indicated by the part designer, it is necessary for the die caster to confirm the designer's determination. Agreement on the optimum parting line location is essential for the casting to be produced to the desired specifications.

In the case of a part that must have a cosmetic surface, the cover half will generally be used to produce the cosmetic surface. This permits the ejector half to contain the ejector pins, inserts and any engraving.

If there is no cosmetic surface requirement, the casting can be oriented to suit the most favorable casting conditions. On cosmetic parts, the customer must discuss with the die caster where the gate, overflows and vents will be, to be certain that there is no interference or blemish on the important cosmetic surfaces.

Where there are cosmetic requirements, since normal, incremental die erosion is inherent in the die casting production process, the customer will want to discuss special die maintenance procedures to extend the ability of the die to produce parts with the required high-quality surface finish. Secondary operations to the surface of the part, such as polishing or buffing, should also be discussed to maintain cast part specifications.

3.3 Ejector Pins

Ejector pins are used to push the casting out of the die after the metal shot has been made and casting solidified. The location and size of the ejector pins are dependent on the configuration, size, and other requirements of the casting.

The die caster will always attempt to locate ejector pins in a nonfunctional area of the casting, such as in an overflow, on a boss, in the bottom of a deep pocket, or the bottom of a rib. His recommendations are important as to the size, location and number of ejector pins required for successful part production.

Each ejector pin must be sized to suit the casting configuration in the selected area and will leave a slight impression on the cast surface. For this reason, they are not placed against the cosmetic surface side of the part.

Product standards related to ejector pin locations are discussed in Engineering and Design, Section 6.

3.4 Cast-in Inserts

In some castings, there may be a need for a bearing surface, internal thread, or some other unique feature that could be accommodated by an insert molded into the casting. This requirement can often be met by the die caster within the normal operation of the casting process.

This "insert molding" offers the advantage of firmly setting an insert into the casting so that it can be machined, drilled and tapped. This advantage, however, rarely offsets the added costs of the insert casting operation.

The added costs result from reduced machine cycle time, due to loading the insert into the die and the heating procedure required to heat the inserts before they are placed into the die half. This preheating is recommended to avoid putting moisture into the die, allowing metal to chill around the insert and causing the insert to loosen.

Tooling for Die Casting

Note:
There are many die materials available that vary in both their chemical compositions and mechanical properties. Developments in high speed machining and Wire EDM have led to the use of a wide variety of tool steels based on cavity complexity and position as the material relates to the gate location. Specialty tool steels have their own specific properties but, if used correctly, can increase tool life by up to a factor of two or more. It is also important to note that they usually are more costly as noted in section 4.2. This increased cost can be more than offset by the increase in die life achievable so it is best to consult with the die caster as to what some of the options might be for a given casting design. Specialty tool steels that do not require heat treat or are preheat treated before machining have been successfully used in both Prototype and Rapid Tooled Dies for early production starts.

Some of the (but not limited to) manufactures of these specialty steels are Aubert & Duval, Bohler, CMW, Daido, Dunn Specialty Steel, Elwood Specialty Steel, Kind, Nippon Koshuha, Schmolz & Bickenbach, and Uddeholm. It is best to consult with the die caster as to what some of the tool steel options are for individual casting designs and die construction.

4 Die Materials

The grade of tooling materials to be used in the construction of a die casting die should be specified as high quality, at a minimum, and preferable premium quality. These requirements are based on the extremely high temperatures and pressures used in die casting production.

Tooling grade requirements will vary depending on the tooling component, the alloy being die cast, the critical character of the cast part design and the long-term production quantities desired. Every aspect of the proposed product's design and production specifications must be discussed with the die caster before tooling material can be selected. The following are typical tooling lowest requirements:

4.1 Die and Cavity Materials

- *Die Casting Dies for Zinc Alloys: P-20, H-11, H13, Premium Grade H13 (Per NADCA No. 229), Superior Grade H13 (Per NADCA No. 229), or other grades as defined in NADCA No. 229..*

The zinc alloys, which cast at the lowest temperature in the nonferrous family, cause the least wear on their tooling and thus permit the use of non-premium die material, such as P-20, in cases where part designs are relatively simple. Purchasers are cautioned, however, to be aware of the unwise investment in non-premium grade tooling for zinc parts if there is any possibility that production quantities may reach higher levels than originally anticipated. At higher production levels, such tooling may expire and the cost of replacement dies will far outweigh an original investment in premium material.

- *Die Castings Dies for Aluminum, Magnesium & ZA Alloys (Noncritical part designs, low volume): H-10, H-11, H13.*

Aluminum, magnesium and ZA die casting dies require high quality tool steel, as above. If part designs have very critical features or if high production runs are being contemplated, however, premium grade tooling will always be the wisest investment.

- *Die Casting Dies for Aluminum, Magnesium, ZA-12 & ZA-27 Alloys (Critical part designs, higher volume): Premium Grade H13 (Per NADCA No. 229), Superior Grade H13 (Per NADCA No. 229), or other grades as defined in NADCA No. 229.*

For Al, Mg, ZA-12, and ZA-27 die cast parts, H13 Premium or Superior Grade tool steel is recommended whenever part design features are intricate and specifications tight, and when production volumes will be high. In such cases, non-premium grade tooling will nearly always result in costly premature die failure.

- *Die Casting Dies for Brass Alloys: H13*

Since copper alloy die castings are cast at the highest temperatures of the nonferrous alloys, only H13 high grade tool steel is recommended for brass die casting dies.

Metal certifications for the material grades listed, provided by quality tooling material suppliers, will be made available for inspection by the die caster. The H13 Premium or Superior Grade should meet the NADCA No. 229 tool steel standard (Special Quality Die Steel and Heat Treatment Acceptance Criteria for Die Casting Dies).

4.2 Die Cavity Insert Materials

The materials recommended for use as tool steel for die cavity inserts parallel the recommendations for die cavities, above, with some additions.

In addition to H13 Premium or Superior Grade, the maraging and speciality tool steels* are used for die inserts needing higher hardness to improve their resistance to the heat checking (thermal fatigue cracking) or crazing of the insert's surface caused by thermal cycling of the die from the high temperature molten alloy and die spray/die cooling. The fine cracks that may result can produce corresponding veins on castings.

In high wear (erosion/washout) and temperature areas, especially if internal cooling and/or die spray is difficult, small cores and inserts in aluminum die casting dies can eventually break or wash away due to the velocity of the aluminum entering the cavity. Tungsten- and molybdenum-based alloys are occasionally used successfully in these areas to resist these conditions. Although these materials show superior physical properties compared to conventional steels at high working temperatures, care must be used in machining them. Also, their increased cost must be considered in the overall cost of the die and number of shots required (life of the die).

4.3 Die Steel Heat Treatment

The quality of the heat treatment of the die steel is a very critical step in the tool building process. The use of high quality rapid quenching heat treatment procedures is essential to normal die life. Care must be exercised in the heat treatment procedure to balance the issues of distortion with metallurgial properties that result from rapid quenching. The recommendations of the die caster should be respected.

Just as tool steel source certifications are made available by the die caster, so are the heat treat certifications from the selected heat treatment sources. This documentation will certify that the heat treat was properly carried out to achieve the correct hardness and microstructure.

Tool steel heat treatment should be expected to follow NADCA No. 229 heat treatment guidelines (Recommended Procedures for H13 Tool Steel) and the recommendations of the tool steel manufacturer.

5 Controlling Die Performance

5.1 Porosity Control: Gating, Venting and Vacuum

Although die castings can be expected to exhibit high strength and integrity, some product requirements can call for additional steps in the part design, die design and on-line production stages.

Designers seeking to avoid porosity concerns will be alert to such techniques as eliminating thick wall sections in their designs. (See Product Design for Die Casting for general guidelines). For specific designs, the engineer should always consult with an experienced die caster before design parameters are locked in.

Given the final part design, the die caster will follow specified die design guidelines, and flow simulation (if available), incorporating die gating, overflow and venting configurations to evacuate air properly from the die cavity and reduce porosity to an acceptable level. Where pressure tightness is not a casting specification, the process can be designed so that residual porosity enters only non-functional, internal areas of the casting. Porosity is acceptable in non-critical areas.

While not a substitute for sound product and die design, a vacuum system can also be used to enhance die fill, reduce gas porosity, and improve mechanical properties. A vacuum system is designed to evacuate ambient air from within the die cavity during casting and create a negative pressure or a vacuum. The die must be specially built to accept a vacuum system, so discussions of acceptable porosity levels should be held well in advance of die design.

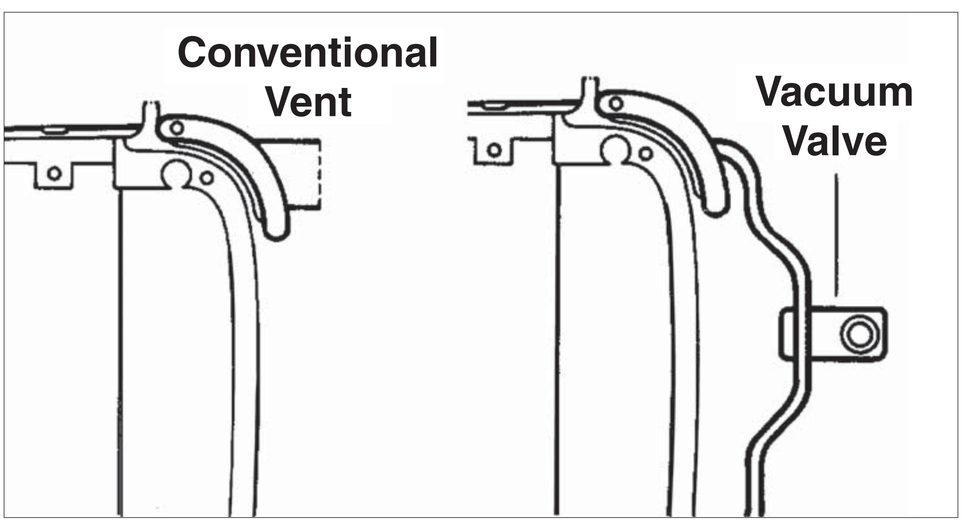


Figure 2-10 Conventional venting in a die casting die, shown at left, vents air to the atmosphere. With a vacuum-equipped die, metal is pulled into a closed system, with air drawn by the vacuum mechanism. A significant reduction in air entrapped in the casting results in lower porosity.

5.2 Thermal Balancing

To achieve maximum product quality, the dies are required to run at a precise, specified temperature. This temperature will vary with such factors as the size of the casting, number of die cavities, alloy being cast and machine cycle time.

The alloy is injected into the die at this exact temperature at high speeds and then rapidly cooled for ejection. This extremely fast and repeated cooling requires careful engineering of a complex network of internal die temperature lines. Infrared imaging and thermocouples placed in the die can help measure and maintain correct die temperatures.

Proper thermal balancing through the strategic placement of these lines reduces die casting cycle time, improves casting quality, and lengthens the life of the die.

Different areas of the die can be heated or cooled to different temperatures, i.e., different cover half and ejector half temperatures can be used to aid control of part density or surface finish.

5.3 Oil Heating Lines

In some cases differential heating of various areas of the die to produce specific casting design features will be achieved by the use of hot oil lines in the die.

Hot oil systems heat a special oil to a given elevated temperature and pipe it through the die in the same manner as water cooling lines. Both water cooling and hot oil heating lines may be used.

5.4 Alternate Surface Textures

Using photoengraving techniques in making the die cavities, a wide range of patterns, grainings and textures can be selected for permanent die casting into the surface of a part. The die caster can exhibit actual samples of the common die cast textures possible. (For illustrations of sample textures, see the Surface Treatment chapter of Product Design for Die Castings.)

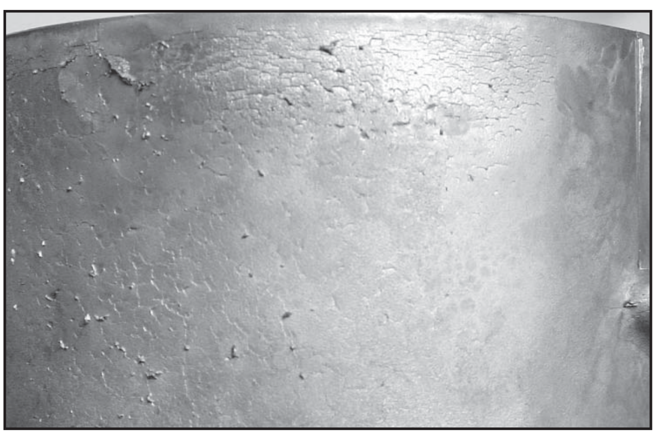


Figure 2-11 Heat checking as seen on a casting.

Figure 2-12 Washout as seen on a casting.

5.5 Extended Die Life

While optimum die life begins with high quality tool steel, several patented processes are available which can be used to extend the life of a die casting die. These processes involve shot peening techniques, submersion in special baths, and chemical treatments of the die. The die caster can discuss the projected effectiveness of such steps to reduce premature die wear in the case of specific part design.

A typical failure mode of dies is heat checking or thermal fatigue cracking.

5.5.1 Heat Checking. Die Casting tools show small cracks (network) as well as bigger (leading) cracks after some time in use, due to thermal fatigue. Both are important to tool life.

The scale in figure 2-13 is designed to give you a combined grading using both network and leading crack values.

Compare the scales with your tool. Give the tool a grading from both scales. Add the two gradings. These two combined readings give you the degree of heat checking.

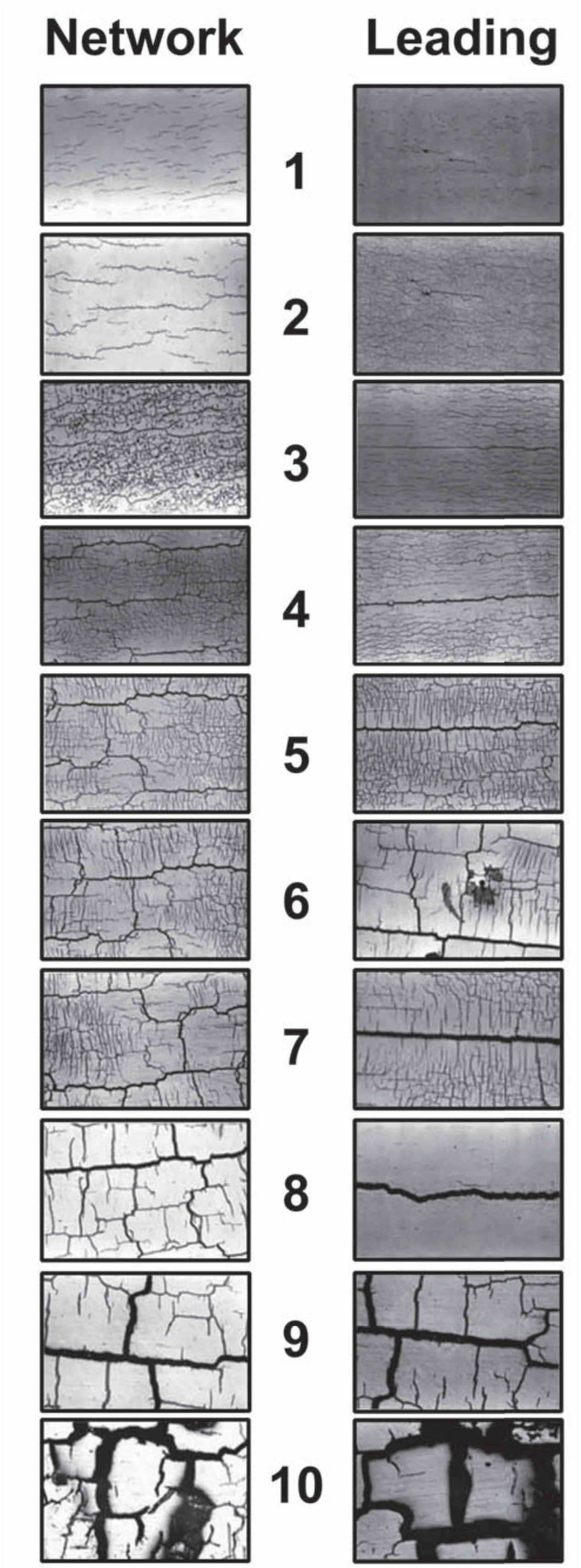


Figure 2-13 Photos of die surface crack patterns reproduced approximately 70% of actual size. The die steel heat check conditions is reflected as raised material on the surface of the casting.

Courtesy of UDDEHOLM

Determine at what point the die will no longer be useful. For critical surfaces, such as those to be polished or chrome plated, you might stop using the die at a combined rating of six. For other surfaces, especially those not seen by users of the finished product, the die might be used until the rating is judged to be greater than 14. As the rating goes up, there is not only an aesthetic loss but an economic loss in the production of the parts.

The scale also provides a concrete basis of comparison between different tools and number of shots.

6 Secondary Machining Preplanning

While most die castings are produced to near-net-shape, and many to net-shape, the close tolerances possible with die casting and the repeatability of the process suits die cast parts to economical high-precision secondary machining operations.

A die casting can be designed to accurately adapt to machining fixtures by casting in locator holes or casting a flush locating datum surface. Die castings can be drilled, tapped, reamed, punched, or have nearly any type of machining operation performed on them.

Machining operations, including gaging and any other secondary operations that may be required, can be performed by the die caster. Properly designing the part and the die for optimum quality and economy in secondary machining will have an important impact on reducing final part costs. Detailed discussions should be held with die caster engineering personnel to establish such machining parameters as the precise location, extent, and depth of the machining required; the surface finish required; and any other specification necessary to result in a quality component.

Decisions on special machining equipment ownership, maintenance and replacement must also be discussed. Such matters are outlined in the Commercial Practices section of this manual (page 8-1).

7 Gaging Considerations

What gages will be used in casting production and in secondary machining, and what they will check, are important elements of the die casting program.

Gages may be used to check the casting in its as-cast state and again after machining. The gage may be an attribute gauge, which is basically a “go” or “no-go” check and results in either a good or bad part.

A variable gage may also be employed which, used with a computer, can document variables, collect data, and record Cpk’s.

More than one gage may be needed to check a casting: one to check it in its as-cast condition and another to check the casting in a fully machined condition. There may be a need for plug and thread gages as well as finished gages or standards for painted surfaces.

The gaging should be considered by the customer as part of the tooling package. Gaging requirements should be resolved early by the quality assurance managers of both the customer and the die caster, so no questions remain on meeting the part print requirements.

8 Inherited Tooling

In some instances a customer may transfer a die casting die from one die caster to another. This generally will raise some operational questions for the receiving die caster of which the customer should be aware.

The die may need to be put into a different type of die casting machine. This may require some modifications to the die's ejector system as well as to the shot sleeve, i.e. the entry for molten metal.

The die's gate and runner system may also need to be modified to suit the new machine conditions. It may be necessary for any residual oil in the hydraulic system of the die to be sent out for sampling to assure that it does not contain any contaminants.

The die must be evaluated by the customer and the die caster's tool room superintendent to assure that there are no visual problems with the die. They should also determine whether the die arrived with any required limit switches and hydraulic cylinders.

Upon this review an adaptation cost can be established and agreed upon before the receiving die caster has invested a large amount of time and expense in preproduction work.

Checklist T-2-1, at the end of this section, will aid in addressing questions regarding transferred or "inherited" tooling.

Die or tooling ownership and replacement is often a point of discussion. Information regarding this topic can be found in Section 8.

9 Engineering Consultation

The customer company, in the person of its engineering and quality assurance personnel, will usually be requested to meet with the custom die caster's engineering and quality assurance personnel as early as possible to discuss the design and function of the part design proposed for die casting.

They will discuss the design's function, fit and precise assembly with other components. The die casting process uniquely lends itself to parts consolidation, decreasing the number of components in a product assembly.

Early involvement with the die caster is essential in avoiding expensive corrective steps in later die construction. It can often simplify product assembly and significantly reduce total product costs.

For example, an attached hinge bracket could be die cast as an integral part of the casting. A slight design modification could assure clearance for a close assembly.

The die caster may be able to cast an integral bearing in the part that the customer was planning to press in. Or the die caster may be able to perform a complete or partial assembly operation more economically, such as installing a gasket after painting the casting, and shipping the part ready for assembly. Many die casters have in-house capabilities for operations such as pressure testing, impregnating, machining, surface finishing and subassembly.

The experienced die caster should be regarded as a invaluable source of expertise in the die casting production and assembly process.

Depending on part configuration, very small high-volume zinc parts, weighing fractions of an ounce, may be recommended for production on special hot-chamber zinc die casting machines. Such parts, usually called "miniature" or "microminiature" die castings, can be cast flash-free, with zero draft, to very close net-shape tolerances.

10 Database Guidelines

When databases are utilized, quotations for castings are often based on the assumption that any CAD databases provided to build tooling and produce parts are complete, usable and are without need of updating.

Databases may be deemed incomplete and unusable if:

1. *The geometry of the part is not physically moldable.*
2. *The necessary draft and radii are not incorporated.*
3. *Line and surface geometry are not connected within 0.001".*
4. *Parting line is not fully developed.*

Note: The database file format may not be compatible with existing capabilities and may require a translator. STL files are usually only used for creation of prototype parts.

Any necessary database manipulation that is caused by incompleteness as described above could add cost and extended lead-time to tooling.

If databases are designed only to nominal dimensions, tool life and casting tolerances may be adversely impacted.

If solid model databases are used for tool construction, they should be accompanied by a limited dimension part print (either paper or database) that contains all tolerancing information and information pertaining to any secondary machining that is to be performed to the part.

The revision control for databases should be as agreed upon between the die caster and customer.

11 New Die/Inherited Die Specifications

Checklist T-2-1, which follows, will aid in discussions between the customer and the die caster regarding the important considerations in the design of a new die casting die or in the production of parts from "inherited" tooling.

12 Die Life

Die casters are frequently asked the question, "How many shots will I get from the die before it needs to be replaced?" or "How many shots will you guarantee the die for?" A better question might be, "What can we do to maximize die life and to minimize replacement costs?"

Aluminum and Copper die casting dies wear out due to the aggressive nature and high melting temperatures of the materials being die cast.

Die life is a consideration of part design, part function, internal part requirements and part cosmetics. In general, cosmetic areas of the part do not last as long as functional areas.

The following is a suggested approach to be used by the customer and die caster at the time of part design. The intent is to define critical areas of the die casting before the start of tool design. This allows areas to be inserted to maximize die life and minimize the replacement costs.

First, is to develop a rating scale by which this information can be used to relate part considerations to estimated tool life. A guideline (T-2-2) has been developed and includes; a Die Life Checklist, sample part, example of tool steel inserting and identification matrix starting on page 2-19

NADCA

T-2-1-15

Checklist

2

This two-part specification checklist is intended for use in consultation with your die caster prior to estimation of new die design and construction, or prior to die casting production using "inherited" tooling. It should be used in combination with checklists C-8-1 and C-8-2 in Commercial Practices, Section 8.

13 Checklist for Die Casting Die Specifications (To be used in consultation with your Die Caster)

Part 1 — New Die Casting Dies: Items to be Addressed

In the case of new die casting dies, all of the items in Part 1, below, should be reviewed. Note, in the case of tooling to be transferred to, or "inherited" by a die caster, the items asterisked (*) in Part 1 should be addressed, plus the items noted in Part 2 on the next page.

Type of New Die	☐ Prototype Die Casting Die ☐ Production Die Casting Die
Cavity Steel*	☐ H13 ☐ Premium Grade H13 ☐ Superior Grade H13 ☐ Other Tool Steel: ______________________________ NADCA No. 229 Certification Required: ☐Yes ☐No Grade ______ Class ______
Cavity Steel Heat Treat*	☐ Hardness Required: ☐ Toughness Required: _____ ft.-lbs NADCA No. 229 Certification Required: ☐ Yes ☐ No
Cored Holes*	☐ All Holes Cored ☐ Cored Holes As Noted On Print ☐ No Cored Holes
Die Operation for Part Features*	☐ Mechanical Movement ☐ Hydraulic Movement ☐ Features To Be Achieved By Secondary Operations
Estimated Part Volume	Monthly: ______________________________ Annual: ______________________________ Expected Product Life: ______________________________
Casting Alloy*	Alloy ☐ Aluminum ______________ ☐ Copper ______________ ☐ Magnesium ______________ ☐ Zinc ______________ ☐ ZA ______________
Casting Weight	Estimated Casting Weight: ______________________________
As-cast Part Finish*	☐ Mechanical Grade (Functional Finish) (Ref. 125 Ra) ☐ Painting Grade (Ref 63 Ra) ☐ Highest Quality (Cosmetic Finish) For Plating, Etc. (Ref. 32 Ra) **Die wear can affect surface finish over the life of the die.*
Class of Die	☐ Unit Die ☐ Single Cavity ☐ Conventional Die ☐ Multiple Cavity ☐ Multiple Cavity - Family Die
Cast-In Date Insert*	☐ In Die Cavity ☐ Other Requirements: ______________________________ ☐ Not Required
Cast-In Part Number*	☐ In Die Cavity ☐ Other Requirements: ______________________________ ☐ Not Required
Other	Write in any other special requirements (ie. tolerances, leak testing, x-rays): ____

NADCA

T-2-1-15

Checklist

This two-part specification checklist is intended for use in consultation with your die caster prior to estimation of new die design and construction, or prior to die casting production using "inherited" tooling. It should be used in combination with checklists C-8-1 and C-8-2 in Commercial Practices, Section 8.

Part 2 — New Die Casting Dies: Items to be Addressed (Continued)

Cast-In Logo, Lettering*	☐ In Die Cavity ☐ Other Include: ____________________ ☐ Customer Logo ☐ Cavity No. ☐ Supplier Logo ☐ Revision No. ☐ Recycling Logo ☐ Part Number
Die Layout	☐ Customer to Approve Layout ☐ Approval by Die Caster
First-Piece Approval	☐ Customer Approval Before Production Run Required ☐ Run on Die Caster Approval ☐ PPAP
Gages*	☐ Customer to Supply Special Gages ☐ Die Caster to Supply Special Gages
Trim Die	☐ Mechanical Movement ☐ Hydraulic Movement ☐ Features To Be Achieved By Secondary Operations
Machining Fixtures	☐ No Secondary machining required ☐ Machining reguired, no special fixtures ☐ Special machining fixtures required, customer to supply ☐ Special machining fixtures required, die caster to supply
Special Items	Special Items to be included in the tooling package: ____________________ ____________________

Part 3 — Inherited Die Casting Dies: Additional Items to be Addressed

In the case of inherited tooling, not the asterisked items (*) in Part 1, plus the items below.

Note that with transferred, or "inherited," tooling for die casting production the existing die casting die, the trim die, and, if required, the secondary machining fixtures, must be available for review and evaluation to determine whether the dies and fixtures are capable of producing to specifications and the extent of maintenance and/or rework required before the onset of production. This would include any adaptations of the die caster's equipment to accommodate production using the inherited dies. Final production estimates will be based on this review.

Inherited Die	☐ Die Casting Die Available for Evaluation ☐ Die to be Available for Evaluation (date): ____________
Inherited Trim Die	☐ Trim Die Not Required ☐ Trim Die Available for Evaluation ☐ Trim Die to be Available for Evaluation (date): ____________
Inherited Machining Fixtures	☐ Special Machining Fixtures Not Required ☐ Machining Fixtures Available for Evaluation ☐ Machining Fixtures to be Available for Evaluation (date): ________
Actual Casting Weight	Weight of Actual Casting: ____________________
Size of Die	Size of Casting Die (for equipment limitations): ____________
Weight of Die	Weight of Casting Die (for crane limitations): ____________
Availability of Die Design	☐ Yes ☐ No

14 Guidelines to Increase Die Life

Before the start of tooling

1) Redesign of part to reduce or eliminate sharp internals corners or features that will promote early cracking of the tool steel.

2) Use of special tool steels in areas where high wear is expected (increases tool costs).

3) Insert area's of cavity blocks for more economical replacement (may increase tool costs) after tool wear has occurred.

4) Do a surface treatment (shot blasting) to the tool steel to help reduce heat checking and cracking (adds to tool cost). Note: This will add a surface texture to the die cast part.

5) Add a vibratory, shot blast or deburring operation to the part to help extend tool life (added part cost).

6) Add a machining operation to remove heat checking and/or cracking in areas that are critical on the part (adds to part cost).

7) Reclaim the surface hardness, if possible, when it drops from the 40's HRC to the high 30's HRC.

8) Coatings can be applied to the die surface to reduce wear and soldering.

9) Use internal cooling instead of die spray to cool the die. Spray is only to be used as a release agent.

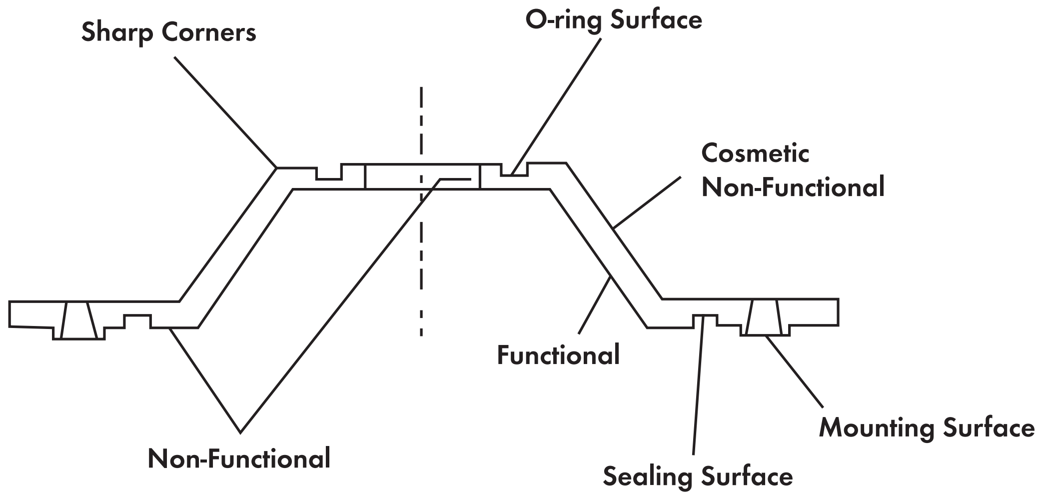
Die Life Checklist

Class	Part Consideration
A	Critical to Function & Cosmetic
B	Cosmetic, No Function
C	Critical to Function
D	Not Critical but Functional
E	No Function

Class	Estimated Die Life/Shots
1	Less than 10,000
2	10,000 to 25,000
3	25,000 to 50,000
4	50,000 to 100,000
5	More than 100,000

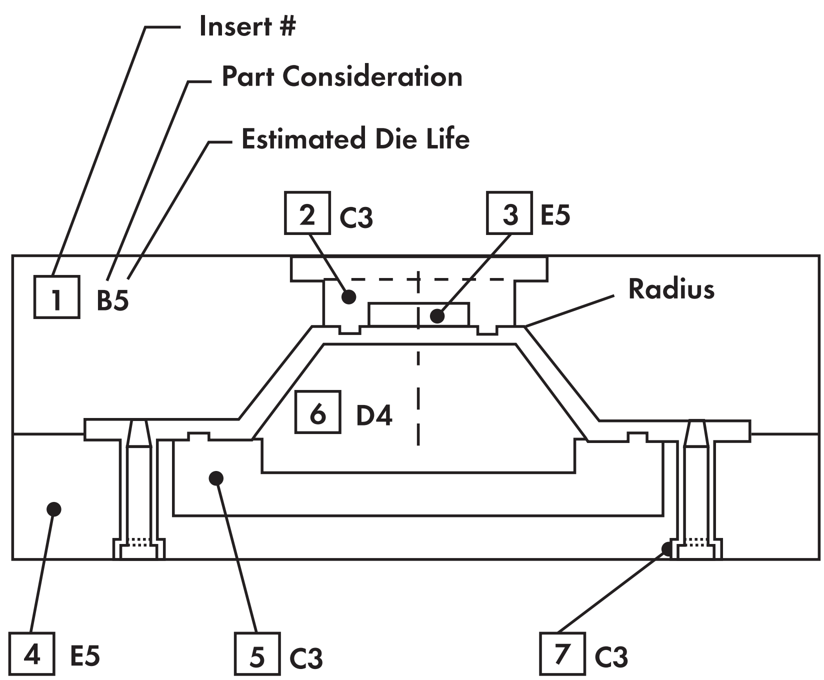
Using the above will develop and itemize the areas of concern of a sample part.

Sample Part



Using the sample, the next step is to develop an inserting plan for the tool steel construction.

Tool Steel Insert Construction



Last is to develop the matrix for communication of tool steel replacement needs and to develop history on each insert. (The information shown in this example represents only what can be done. The actual information to be included should be determined by the customer and the die caster). Two examples of this type of matrix are shown, at the start of a new project and the other as it may appear after the first year of production.

Company: Sample Development Co. Date: xx/xx/xx
Part Name: Liquid Holder Part Number: 1234-50 Rev: D
Die Caster: ZYX Die Castings Co. Tool Number: 6789
Annual Usage: 280,000 Number of Cavities: 2

(Matrix at start of new project)

Insert #	Insert Name	Part Class	Est. Life	Cost Each Insert	Lead Time	Actual Shots	Replacement Date/#	Need P.O.	In Progress	On Shelf
1	Cover Cavity	B	5	14,350	10 wks					
2	O-ring Core	C	3	1,185	4 wks					
3	Center Core	E	5	900	3 wks					
4	Ejector Insert	E	5	19,875	12 wks					
5	Seal Insert	C	3	4,150	6 wks					
6	Fluid Insert	D	4	3,210	5 wks					
7	Core Pin Mtg Sur	C	3	185 ea. (8x)	2 wks					

(Matrix after first year of production)

Insert #	Insert Name	Part Class	Est. Life	Cost Each Insert	Lead Time	Actual Shots	Replacement Date/#	Need P.O.	In Progress	On Shelf
1	Cover Cavity	B	5	14,350	10 wks	118000	xx/xx/xx #2		1	0
2	O-ring Core	C	3	1,185	4 wks	32000	xx/xx/xx #4	x	3	1
3	Center Core	E	5	900	3 wks	80000	xx/xx/xx #3		1	0
4	Ejector Insert	E	5	19,875	12 wks	140000	xx/xx/xx #2		1	0
5	Seal Insert	C	3	4,150	6 wks	45000	xx/xx/xx #4	x	2	2
6	Fluid Insert	D	4	3,210	5 wks	96000	xx/xx/xx #2	x	0	0
7	Core Pin Mtg Sur	C	3	185 ea. (8x)	2 wks	40000	xx/xx/xx #3 set	x	0	2 sets

As mentioned earlier this is just a suggested approach to improving die life and reducing replacement costs. Die casting dies do wear out. It is an advantage to both the customer and the die casters benefit to layout a plan at the start of the project. This allows inserts to be replaced before any actual failure thus preventing any possible loss of production. The examples shown are only one of many possible methods to achieve this. If the customer and die caster choose to use this type of approach, it should be on a part by part basis. The information in the matrix should be relevant to the actual tool construction and the actual annual usage.

Alloy Data

SECTION 3

3

Alloy Data

The cross reference designations shown are for alloy specifications according to widely recognized sources. References apply to the metal in the die cast condition and should not be confused with similar specifications for metal ingot. A "—" in a column indicates that the specific alloy is not registered by the given source.

Frequently Asked Questions (FAQ)

1) Is there a cross reference available for different alloy designations?
   See pages 3-2, 3-3 all charts and pages 3-42 through 3-45.
2) What type of material best fits my application?
   See page 3-33, Quick Guide to Alloy Family Selection.
3) How do die cast properties compare to sand cast properties?
   See pages 3-38 through 3-41, Property Comparison.
4) Where can I find general material properties for Aluminum Alloys?
   See pages 3-4 through 3-11.
5) How can I determine if certain die casting alloys would be a better choice for thermal conductivity? See row "Thermal Conductivity" in tables found on pages 3-6, 3-14, 3-18, 3-22, 3-28, and 3-30.

1 Die Casting Alloy Cross Reference Designations

Aluminum Alloy Specifications

Commercial	UNS	ANSI AA	ASTM B85	Former SAE J452	Federal QQ-A-591 Ⓑ	DIN Ⓖ 1725	JIS H 5302
360	A03600	360.0	SG100B	—	Ⓑ		
A360 Ⓐ	A13600	A360.0	SG100A	309	Ⓑ	233	ADC3
380 Ⓒ	A03800	380.0	SC84B	308	Ⓑ		
A380 Ⓐ Ⓒ	A13800	A380.0	SC84A	306	Ⓑ	226A Ⓔ	ADC10 ⒸⒹ
383	A03830	383.0	SC102A	383	Ⓑ	226A Ⓔ	ADC12 ⒸⒹ
384	A03840	384.0	SC114A	303	Ⓑ		ADC12 ⒸⒹ
A384 Ⓐ	—	A384.0	—	—	Ⓑ		ADC12 ⒸⒹ
B390	A23900	B390.0	SC174B	—	Ⓑ		
13	A04130	413.0	S12B	—	Ⓑ		
A13 Ⓐ	A14130	A413.0	S12A	305	Ⓑ	231D Ⓕ	ADC1 Ⓒ
43	A34430	C443.0	S5C	304	Ⓑ		
218	A05180	518.0	G8A	—	Ⓑ	341	

Ⓐ Similar to preceding entry with slight variations in minor constituents. Ⓑ The Federal specification for aluminum alloy die castings uses the Aluminum Association designations for individual alloys. Military designations superseded by Federal specifications. Ⓒ NADCA and Japanese specifications allow 0.3 magnesium maximum. Ⓓ Japanese specifications allow 1.0 zinc maximum. Ⓔ DIN 1725 spec allows 1.2 max zinc and up to 0.5 max magnesium. Ⓕ DIN 1725 spec allows 0.3 max magnesium. Ⓖ Alloy compositions shown in DIN 1725 tend to be "primary based" and have low impurity limits making it difficult to correlate directly to U.S. alloys.

Note: *Some of these standards are obsolete but included here for historical purposes. For closest cross-reference refer to the tables of foreign alloy designations and chemical constituencies at the end of this section. All specifications are for castings only.*

Table of Symbols

UNS — Unified Numbering System

ANSI — American National Standards Institute

ASTM — American Society for Testing and Materials

AA — Aluminum Association

SAE — Society of Automotive Engineers

FED — Federal Specifications

MIL — Military Specifications

JIS — Japanese Industrial Standard

DIN — German Industrial Standard

Aluminum Metal Matrix Composite Alloy Specifications		
Rio Tinto Alcan CANADA	UNS	AA
F3D.10S-F		380/SiC/10p
F3D.20S-F		380/SiC/20p
F3N.10S-F		360/SiC/10p
F3N.20S-F		360/SiC/20p

Copper Alloy Specifications			
Commercial	UNS	ASTM B176	SAE J461/
857	C85700	—	—
858	C85800	Z30A	J462
865	C86500	—	—
878	C87800	ZS144A	J462
997	C99700	—	—
997.5	C99750	—	—

Magnesium Alloy Specifications						
Commercial	UNS	ASTM B93 & B94	Former SAE J465B	Federal Ⓐ	DIN 1729	JIS H 2222 & H 5303
AZ91B	M11912	AZ91B	501A	QQ-M-38	3.5912.05	MDI1B
AZ91D	M11916	AZ91D	—	—	—	MDI1D
AZ81	—	—	—	—	—	—
AM60A	M10600	AM60A	—	—	3.5662.05	MDI2A
AM60B	M10602	AM60B	—	—	—	MDI2B
AM50	—	—	—	—	—	—
AE42	—	—	—	—	—	—
AS41A	M10410	AS41A	—	—	3.5470.05	MDI3A
AS41B	M10412	AS41B	—	—	—	—
AM20	—	—	—	—	—	—

Ⓐ This Federal Specification has been canceled and is shown for historic reference only.

***Note:** For closest cross-reference refer to the tables of foreign alloy designations and chemical constituencies at the end of this section.*

Zinc and ZA Alloy Specifications						
Commercial	UNS	ASTM B86	Former SAE J469	Federal Ⓐ QQ-Z-363a	DIN	JIS H 5301
2	Z35541	AC43A	921	AC43A	1743	
3	Z33520	AG40A	903	AG40A	1743	ZDC-2
5	Z355310	AC41A	925	AC41A	1743	ZDC-1
7	Z33523	AG40B	—	AG40B		
ZA-8	Z35636	—	—			
ZA-12	Z35631	—	—			
ZA-27	Z35841	—	—			

Ⓐ This Federal Specification has been canceled and is shown for historic reference only.

***Note:** For closest cross-reference refer to the tables of foreign alloy designations and chemical constituencies at the end of this section.*

Table of Symbols

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FED — Federal Specifications

MIL — Military Specifications

JIS — Japanese Industrial Standard

DIN — German Industrial Standard

Alloy Data

2 Aluminum Alloys

Selecting Aluminum Alloys

Aluminum (Al) die casting alloys have a specific gravity of approximately 2.7 g/cc, placing them among the lightweight structural metals. The majority of die castings produced worldwide are made from aluminum alloys.

Six major elements constitute the die cast aluminum alloy system: silicon, copper, magnesium, iron, manganese, and zinc. Each element affects the alloy both independently and interactively.

This aluminum alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for 11 aluminum die casting alloys. This data can be used in combination with design engineering tolerancing guidelines for aluminum die casting and can be compared with the guidelines for other alloys in this section and in the design engineering section.

Alloy A380 (ANSI/AA A380.0) is by far the most widely cast of the aluminum die casting alloys, offering the best combination of material properties and ease of production. It may be specified for most product applications. Some of the uses of this alloy include electronic and communications equipment, automotive components, engine brackets, transmission and gear cases, appliances, lawn mower housings, furniture components, hand and power tools.

Alloy 383 (ANSI/AA 383.0) and alloy 384 (ANSI/AA 384.0) are alternatives to A380 for intricate components requiring improved die filling characteristics. Alloy 383 offers improved resistance to hot cracking (strength at elevated temperatures).

Alloy A360 (ANSI/AA A360.0) offers higher corrosion resistance, superior strength at elevated temperatures, and somewhat better ductility, but is more difficult to cast.

While not in wide use and difficult to cast, alloy 43 (ANSI/AA C443.0) offers the highest ductility in the aluminum family. It is moderate in corrosion resistance and often can be used in marine grade applications.

Alloy A13 (ANSI/AA A413.0) offers excellent pressure tightness, making it a good choice for hydraulic cylinders and pressure vessels. Its casting characteristics make it useful for intricate components.

Alloy B390 (ANSI/AA B390.0) was developed for automotive engine blocks. Its resistance to wear is excellent but, its ductility is low. It is used for die cast valve bodies and sleeve-less piston housings.

Alloy 218 (ANSI/AA 518.0) provides the best combination of strength, ductility, corrosion resistance and finishing qualities, but it is more difficult to die cast.

* Different sets of properties can be achieved with alternate processes (such as high vacuum, squeeze, and semi-solid casting) and alternate alloys (such as A356, Aural 2 or 356, and Silafont 36). Information on these processes and alloys can be found in the Product Specification Standards for Die castings produced by Semi-Solid and Squeeze Cast Processes (NADCA Publication #403) and the High Integrity Die Castings book (NADCA Publication #404).

Machining Characteristics

Machining characteristics vary somewhat among the commercially available aluminum die casting alloys, but the entire group is superior to iron, steel and titanium. The rapid solidification rate associated with the die casting process makes die casting alloys somewhat superior to wrought and gravity cast alloys of similar chemical composition.

Alloy A380 has better than average machining characteristics. Alloy 218, with magnesium the major alloying element, exhibits among the best machinability. Alloy 390, with the highest silicon content and free silicon constituent, exhibits the lowest.

Surface Treatment Systems

Surface treatment systems are applied to aluminum die castings to provide a decorative finish, to form a protective barrier against environmental exposure, and to improve resistance to wear.

Decorative finishes can be applied to aluminum die castings through painting, powder coat finishing, polishing, epoxy finishing, and electro-chemical processing. Aluminum can be plated by applying an initial immersion zinc coating, followed by conventional copper-nickel-chromium plating procedure similar to that used for plating zinc metal/alloys.

Protection against environmental corrosion for aluminum die castings is achieved through painting, anodizing, chromating, and iridite coatings.

Improved wear resistance can be achieved with aluminum die castings by hard anodizing.

Where a part design does not allow the production of a pressure-tight die casting through control of porosity by gate and overflow die design, the location of ejector pins, and the reconfiguration of hard-to-cast features, impregnation of aluminum die castings can be used. Systems employing anaerobics and methacrylates are employed to produce sealed, pressure-tight castings with smooth surfaces. A detailed discussion of finishing methods for aluminum die castings can be found in *Product Design For Die Casting.*

Table A-3-1 Chemical Composition: Al Alloys

All single values are maximum composition percentages unless otherwise stated.

	Aluminum Die Casting Alloys ⒶⒺ										
Commercial:	360	A360	380 Ⓑ	A380 Ⓑ	383	384 Ⓑ	B390*	13	A13	43	218
ANSI/AA	360.0	A360.0	380.0	A380.0	383.0	384.0	B390.0	413.0	A413.0	C443.0	518.0
Nominal Comp:	Mg 0.5 Si 9.0	Mg 0.5 Si 9.5	Cu 3.5 Si 8.5	Cu 3.5 Si 8.5	Cu 2.5 Si 10.5	Cu 3.8 Si 11.0	Cu 4.5 Si 17.0	Si 12.0	Si 12.0	Si 5.0	Mg 8.0
Detailed Composition											
Silicon Si	9.0-10.0	9.0-10.0	7.5-9.5	7.5-9.5	9.5-11.5	10.5-12.0	16.0-18.0	11.0-13.0	11.0-13.0	4.5-6.0	0.35
Iron Fe	2.0	1.3	2.0	1.3	1.3	1.3	1.3	2.0	1.3	2.0	1.8
Copper Cu	0.6	0.6	3.0-4.0	3.0-4.0	2.0-3.0	3.0-4.5	4.0-5.0	1.0	1.0	0.6	0.25
Magnesium Mg	0.4-0.6	0.4-0.6	0.30 Ⓕ	0.30 Ⓕ	0.10	0.10	0.45-0.65	0.10	0.10	0.10	7.5-8.5
Manganese Mn	0.35	0.35	0.50	0.50	0.50	0.50	0.50	0.35	0.35	0.35	0.35
Nickel Ni	0.50	0.50	0.50	0.50	0.30	0.50	0.10	0.50	0.50	0.50	0.15
Zinc Zn	0.50	0.50	3.0	3.0	3.0	3.0	1.5	0.50	0.50	0.50	0.15
Tin Sn	0.15	0.15	0.35	0.35	0.15	0.35	—	0.15	0.15	0.15	0.15
Titanium Ti	—	—	—	—	—	—	0.10	—	—	—	—
Others Each	—	—	—	—	—	—	0.10	—	—	—	—
Total Others Ⓒ	0.25	0.25	0.50	0.50	0.50	0.50	0.20	0.25	0.25	0.25	0.25
Aluminum Al	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Ⓐ Analysis shall ordinarily be made only for the elements mentioned in this table. If, however, the presence of other elements is suspected, or indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements are not present in excess of specified limits. Ⓑ With respect to mechanical properties, alloys A380.0, 383.0 and 384.0 are substantially interchangeable. Ⓒ For RoHS (the European Union's Directive on Restriction of Hazardous Substances) compliance, certification of chemical analysis is required to ensure that the "total others" category does not exceed the following weight percent limits: 0.01% cadmium, 0.4% lead, and 0.1% mercury. Hexavalent chromium does not exist in the alloys and therefore meets the 0.1% limit. Ⓓ Notched Charpy. Sources: ASTM B85-92a; ASM; SAE; Wabash Alloys. Ⓔ Registration for REACH (the European Union's Directive on Registration, Evaluation, and Authorization of Chemicals) is not required for die castings, even if coated, since die castings are considered articles. Notification may be required if some contained substances in the die casting or coating exceed the 0.1% total weight of the article level and are listed as SVHC (substances of very high concern). Ⓕ NADCA allows 0.30 maximum magnesium as opposed to 0.10. A380 with 0.30 magnesium has been registered with the Aluminum Association as E380 and 383 with 0.30 magnesium as B383.

** Two other aluminum alloys, 361 and 369, are being utilized in limited applications where vibration and wear are of concern. There are also other heat treatable specialty alloys available for structural applications, such as the Silafonts and AA365, and high ductility, high strength alloys such as Mercalloy and K-Alloy. Contact your alloy producer for more information. Sources: ASTM B85-92a; Aluminum Association.*

Alloy Data

Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

Table A-3-2 Typical Material Properties: Al Alloys

	Aluminum Die Casting Alloys										
Commercial:	360	A360	380	A380 Ⓔ Ⓕ	383 Ⓔ	384	B390*	13	A13	43	218
ANSI/AA	360.0	A360.0	380.0	A380.0	383.0	384.0	B390.0	413.0	A413.0	C443.0	518.0
Mechanical Properties											
Ultimate Tensile Strength ksi	44	46	46	47	45	48	46	43	42	33	45
(MPa)	(303)	(317)	(317)	(324)	(310)	(331)	(317)	(296)	(290)	(228)	(310)
Yield Strength Ⓐ ksi	25	24	23	23	22	24	36	21	19	14	28
(MPa)	(172)	(165)	(159)	(159)	(152)	(165)	(248)	(145)	(131)	(97)	(193)
Elongation % in 2in. (51mm)	2.5	3.5	3.5	3.5	3.5	2.5	<1	2.5	3.5	9.0	5.0
Hardness Ⓑ BHN	75	75	80	80	75	85	120	80	80	65	80
Shear Strength ksi	28	26	28	27	—	29	—	25	25	19	29
(MPa)	(193)	(179)	(193)	(186)		(200)		(172)	(172)	(131)	(200)
Impact Strength ft-lb	—	—	3	—	3 Ⓓ	—	—	—	—	—	7
(J)			(4)		(4)						(9)
Fatigue Strength Ⓒ ksi	20	18	20	20	21	20	20	19	19	17	20
(MPa)	(138)	(124)	(138)	(138)	(145)	(138)	(138)	(131)	(131)	(117)	(138)
Young's Modulus psi x 10^6	10.3	10.3	10.3	10.3	10.3	—	11.8	10.3	—	10.3	—
(GPa)	(71)	(71)	(71)	(71)	(71)		(81)	(71)		(71)	
Physical Properties											
Density lb/in^3	0.095	0.095	0.099	0.098	0.099	0.102	0.098	0.096	0.096	0.097	0.093
(g/cm^3)	(2.63)	(2.63)	(2.74)	(2.71)	(2.74)	(2.82)	(2.71)	(2.66)	(2.66)	(2.69)	(2.57)
Melting Range °F	1035-1105	1035-1105	1000-1100	1000-1100	960-1080	960-1080	950-1200	1065-1080	1065-1080	1065-1170	995-1150
(°C)	(557-596)	(557-596)	(540-595)	(540-595)	(516-582)	(516-582)	(510-650)	(574-582)	(574-582)	(574-632)	(535-621)
Specific Heat BTU/lb °F	0.230	0.230	0.230	0.230	0.230	—	—	0.230	0.230	0.230	—
(J/kg °C)	(963)	(963)	(963)	(963)	(963)			(963)	(963)	(963)	
Coefficient of Thermal Expansion µ in/in°F	11.6	11.6	12.2	12.1	11.7	11.6	10.0	11.3	11.9	12.2	13.4
(µ m/m°K)	(21.0)	(21.0)	(22.0)	(21.8)	(21.1)	(21.0)	(18.0)	(20.4)	(21.6)	(22.0)	(24.1)
Thermal Conductivity BTU/ft hr°F	65.3	65.3	55.6	55.6	55.6	55.6	77.4	70.1	70.1	82.2	55.6
(W/m °K)	(113)	(113)	(96.2)	(96.2)	(96.2)	(96.2)	(134)	(121)	(121)	(142)	(96.2)
Electrical Conductivity % IACS	30	29	27	23	23	22	27	31	31	37	24
Poisson's Ratio	0.33	0.33	0.33	0.33	0.33	—	—	—	—	0.33	—

Ⓐ 0.2% offset. Ⓑ 500 kg load, 10mm ball. Ⓒ Rotary Bend 5 x 10^8 cycles. Ⓓ Notched Charpy. Sources: ASTM B85-92a; ASM; SAE; Wabash Alloys. Ⓔ A 0.3% Mg version of A380 and 383 have been registered with the Aluminum Association as E380 and B383. Ⓕ Higher levels of Mg and the addition of Sr to alloy A380 have shown positive results. The limited data on pages 3-7 – 3-11 shows the effect.

** Two other aluminum alloys, 361 and 369, are being utilized in limited applications where vibration and wear are of concern. There are also other heat treatable specialty alloys and processes available for structural applications, such as the Silafonts and AA365 (Aural 2), and high ductility, high strength alloys such as Mercalloy and K-Alloy. Contact your alloy producer for more information. More information can also be obtained from Microstructures and Properties of Aluminum Die Casting Alloys Book, NADCA Publication #215 and the High Integrity Aluminum Die Casting Book, NADCA Publication #307.*

Alloy Data

Die casting alloy selection requires evaluation not only of physical and mechanical properties, and chemical composition, but also of inherent alloy characteristics and their effect on die casting production as well as possible machining and final surface finishing.

This table includes selected die casting and other special characteristics which are usually considered in selecting an aluminum alloy for a specific application.

The characteristics are rated from (1) to (5), (1) being the most desirable and (5) being the least. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. A rating of (5) in one or more categories would not rule out an alloy if other attributes are particularly favorable, but ratings of (5) may present manufacturing difficulties.

The benefits of consulting a custom die caster experienced in casting the aluminum alloy being considered are clear.

Table A-3-3 Die Casting And Other Characteristics: Al Alloys
(1 = most desirable, 5 = least desirable)

	Aluminum Die Casting Alloys										
Commercial: ANSI/AA	360 360.0	A360 A360.0	380 380.0	A380 A380.0	383 383.0	384 384.0	390* B390.0	13 413.0	A13 A413.0	43 C443.0	218 518.0
Resistance to Hot Cracking Ⓐ	1	1	2	2	1	2	4	1	1	3	5
Pressure Tightness	2	2	2	2	2	2	4	1	1	3	5
Die-Filling Capacity Ⓑ	3	3	2	2	1	1	1	1	1	4	5
Anti-Soldering to the Die Ⓒ	2	2	1	1	2	2	2	1	1	4	5
Corrosion Resistance Ⓓ	2	2	4	4	3	5	3	2	2	2	1
Machining Ease & Quality Ⓔ	3	3	3	3	2	3	5	4	4	5	3
Polishing Ease & Quality Ⓕ	3	3	3	3	3	3	5	5	5	4	1
Electroplating Ease & Quality Ⓖ	2	2	1	1	1	2	3	3	3	2	5
Anodizing (Appearance) Ⓗ	3	3	3	3	3	4	5	5	5	2	1
Chemical Oxide Protective Coating Ⓘ	3	3	4	4	4	5	5	3	3	2	1
Strength at Elevated Temp. Ⓙ	1	1	3	3	2	2	3	3	3	5	4

Ⓐ Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature ranges. Ⓑ Ability of molten alloy to flow readily in die and fill thin sections. Ⓒ Ability of molten alloy to flow without sticking to the die surfaces. Ratings given for anti-soldering are based on nominal iron compositions of approximately 1%. Ⓓ Based on resistance of alloy in standard type salt spray test. Ⓔ Composite rating based on ease of cutting, chip characteristics, quality of finish, and tool life. Ⓕ Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure. Ⓖ Ability of the die casting to take and hold an electroplate applied by present standard methods. Ⓗ Rated on lightness of color, brightness, and uniformity of clear anodized coating applied in sulphuric acid electrolyte. Ⓘ Rated on combined resistance of coating and prolonged heating at testing temperature. Sources: ASTM B85-92a; ASM; SAE

** Two other aluminum alloys, 361 & 369, are being utilized in limited applications where vibration and wear are of concern. There are also other heat treatable specialty alloys available for structural applications, such as the Silafonts and AA365, and high ductility, high strength alloys such as Mercalloy and K-Alloy. Contact your alloy producer for more information.*

***Note:** Die castings are not usually solution heat treated. Low-temperature aging treatments may be used for stress relief or dimensional stability. A T2 or T5 temper may be given to improve properties. Because of the severe chill rate and ultra-fine grain size in die castings, their "as-cast" structure approaches that of the solution heat-treated condition. T4 and T5 temper results in properties quite similar to those which might be obtained if given a full T6 temper. Die castings are not generally gas or arc welded or brazed.*

Additional A380 Alloy Tensile Data
(Data is from separately cast specimines in the naturally aged condition)

Alloys	Tensile ksi (MPa)	Yield ksi (MPa)	Elong %
A380 at 0.09% Mg	45.5 (243)	23.8 (135)	2.6
A380 with 0.26% Mg	47.0 (201)	26.6 (183)	2.8
A380 with 0.33% Mg + 0.035% Sr*	45.7 (177)	28.5 (196)	2.4

** Identified as AMC380* in research being conducted by WPI and funded by DoD/DLA. The values in this table are the average mean values and are provided to indicate the effect of a higher magnesium content and additional strontium. The properties shown do not represent design minimums and should be used for reference only.*

Alloy Data

Table 1: Composition of Three Experimental Alloys as Compared to A380.

	Composition (%)								
	Si	Cu	Mg	Fe	Mn	Zn	Ni	Ti	Sr
A380	7.5-9.5	3-4	<0.1	<1.3	<0.5	<3	<0.5	–	–
A380*	7.0-8.0	3.8-4.2	0.08-0.12	0.63-0.73	0.47-0.53	2.0-3.0	<0.1	<0.2	<0.005
AMC380	9-10	2.8-3.2	0.27-0.33	0.63-0.73	0.47-0.53	2.0-3.0	–	0.18-0.22	0.018-0.022
AMC 1045Sr	10.5-11.5	1.8-2.2	2.3-2.7	0.27-0.33	0.37-0.43	<0.3	<0.05	<0.01	0.018-0.022

Note: The experimental alloys were developed through research sponsored by NADCA, conducted at WPI, and funded by DOD/DLA.

Table 2: Tensile properties of separately die cast specimens of the experimental alloys compared to separately die cast specimens of alloy A380.

Alloy	Gage length (inch)	UTS		YS		e		Modulus of Elasticity	
		Value (Ksi)	Vs A380 (%)	Value (Ksi)	Vs A380 (%)	Value (%)	Vs A380 (%)	Value (10^3 Ksi)	Vs A380 (%)
A380	1	45.6 ±1.3	–	22.7 ±0.7	–	3.83 ±0.48	–	11.0 ±1.1	–
	2	42.8 ±1.1	–	24.3 ±0.5	–	2.33 ±0.24	–	11.3 ±0.5	–
A380*	1	46.3 ±0.6	+1.4	23.7 ±0.5	+4.4	4.63 ±0.38	+20.8	10.6 ±1.4	-3.5
	2	42.9 ±0.8	+0.3	25.0 ±0.6	+2.8	2.64 ±0.2	+13.4	11.1 ±0.3	-1.1
AMC 380*	1	49.9 ±1.1	+9.4	27.9 ±0.7	+22.9	3.72 ±0.34	-2.7	10.7 ±1.2	-2.8
	2	46.2 ±1.2	+7.9	29.1 ±0.6	+19.8	2.33 ±0.13	-0.2	11.4 ±0.2	+1.1
AMC 1045Sr	1	53.4 ±1.3	+17.1	35.2 ±0.9	+55.1	2.33 ±0.28	-39.2	11.9 ±0.8	+8.7
	2	46.2 ±1.7	+8.1	38.0 ±0.8	+56.2	1.16 ±0.19	-50.2	11.3 ±0.3	+0.3

Note: The experimental alloys were developed through research sponsored by NADCA, conducted at WPI, and funded by DOD/DLA. The properties shown do not represent design minimums and should be used for reference only.

Table 3: Tensile properties measured on specimens that were cut from die cast components.

Alloy	UTS		YS		e		Modulus of Elasticity	
	Value (Ksi)	Vs A380 (%)	Value (Ksi)	Vs A380 (%)	Value (%)	Vs A380 (%)	Value (10^3 Ksi)	Vs A380 (%)
A380	39.4 ±1.8	–	21.4 ±1.7	–	2.32 ±0.47	–	235.2 ±16.0	–
AMC 380	47.1 ±3.2	+19.6	31.0 ±1.4	+45.0	2.38 ±0.64	+2.7	302.6 ±28.4	+28.6
AMC 1045Sr	54.9 ±2.6	+39.4	42.2 ±4.6	+97.4	1.76 ±0.68	-24.3	350.4 ±21.1	+49.0
AMC 1045	53.9 ±2.8	+36.8	45.7 ±2.4	+114	1.17 ±0.29	-49.5	339.8 ±19.2	+44.4

Note: The experimental alloys were developed through research sponsored by NADCA, conducted at WPI, and funded by DOD/DLA. The properties shown do not represent design minimums and should be used for reference only.

Table 4: Elevated temperature and room temperature tensile properties of the experimental alloys and commercial A380 alloy. Tests were conducted at temperature on separately die cast tensile specimens.

Alloy	Test Condition		TS (Ksi)	YS (Ksi)	e (%)	Modules of Elasticity ($X10^3$Ksi)
A380	25°C (as-cast)		45.6±1.3	22.7±0.7	3.83±0.48	11.0±1.1
	100°C	0.5 h	42.0±0.6	23.3±0.3	4.2±0.63	10.2±0.5
		500 h	42.7±0.6	25.4±0.4	4.17±0.6	9.5±0.4
		1000 h	43.4±0.3	26.5±0.2	4.20±0.1	9.8±0.5
	200°C	0.5 h	30.1±0.9	20.7±0.3	6.17±0.78	8.4±0.6
		500 h	25.0±0.3	17.6±0.3	6.7±2.0	8.4±0.7
		1000 h	24.2±0.3	17.0±0.3	7.2±1.3	7.6±2.0
A380*	25°C (as-cast)		46.3±0.6	23.7±0.5	4.63±0.38	10.6±1.4
	100°C	0.5 h	41.1±0.8	23.6±0.4	4.46±0.53	9.6±0.7
		500 h	41.5±0.8	25.4±0.3	4.18±0.6	8.7±0.9
		1000 h	42.50.6	26.5±0.2	4.29±0.4	9.8±0.6
	200°C	0.5 h	30.1±0.6	23.1±0.4	5.01±0.14	8.4±0.6
		500 h	25.6±0.4	19.2±0.6	5.8±1.0	9.2±0.6
		1000 h	24.4±0.2	18.2±0.2	6.3±0.6	8.2±1.6
AMC380	25°C (as-cast)		49.9±1.1	27.9±0.7	3.72±0.34	10.7±1.2
	100°C	0.5 h	46.6±1.0	28.1±0.5	4.20±0.22	9.7±0.3
		500 h	46.5±0.7	30.3±0.4	3.70±0.2	9.8±0.4
		1000 h	46.9±0.6	32.2±0.8	3.21±0.2	9.9±0.4
	200°C	0.5 h	36.5±0.5	28.5±0.5	4.51±0.35	8.7±0.4
		500 h	31.8±0.8	24.9±0.8	4.3±0.4	9.1±0.6
		1000 h	29.3±0.7	22.9±0.6	4.4±1.0	8.6±1.0
AMC1045Sr	25°C (as-cast)		53.4±1.3	35.2±0.9	2.33±0.28	11.9±0.8
	100°C	0.5 h	50.1±1.3	34.4±1.5	2.60±0.43	10.1±0.2
		500 h	50.2±2.7	37.0±0.6	2.27±0.6	9.8±0.4
		1000 h	50.4±1.1	39.0±0.9	1.89±0.3	10.0±0.4
	200°C	0.5 h	45.0±0.4	36.3±0.6	3.18±0.29	8.8±0.5
		500 h	33.5±0.2	25.0±0.2	4.0±0.4	9.5±0.7
		1000 h	30.8±0.5	22.3±0.5	5.0±0.6	8.4±0.4

Note: The experimental alloys were developed through research sponsored by NADCA, conducted at WPI, and funded by DOD/DLA. The properties shown do not represent design minimums and should be used for reference only.

Table 5: Tensile properties of the experimental alloys at temperature and after exposure to temperature. Specimens were separately die cast.

Alloy	Test Condition		TS (Ksi)	YS (Ksi)	e (%)	Modules of Elasticity ($X10^3$Ksi)
A380	25°C (as-cast)		45.6±1.3	22.7±0.7	3.83±0.48	11.0±1.1
	Cooled to 25°C	0.5 h	45.0±0.9	21.8±0.2	3.25±0.47	11.8±1.2
		500 h	38.4±0.7	22.2±1.9	2.91±0.77	11.5±0.5
		1000 h	38.5±0.2	22.4±1.5	2.81±0.49	12.4±1.7
	Tested at 200°C	0.5 h	30.1±0.9	20.7±0.3	6.17±0.78	8.4±0.6
		500 h	25.0±0.3	17.6±0.3	6.7±2.0	8.4±0.7
		1000 h	24.2±0.3	17.0±0.3	7.2±1.3	7.6±2.0
A380*	25°C (as-cast)		46.3±0.6	23.7±0.5	4.63±0.38	10.6±1.4
	Cooled to 25°C	0.5 h	41.4±3.1	25.0±1.9	2.72±0.42	11.2±1.6
		500 h	39.0±0.2	22.7±0.4	3.34±0.50	9.1±0.8
		1000 h	37.3±0.1	21.3±0.2	3.13±0.11	12.5±0.11
	Tested at 200°C	0.5 h	30.1±0.6	23.1±0.4	5.01±0.14	8.4±0.6
		500 h	25.6±0.4	19.2±0.6	5.8±1.0	9.2±0.6
		1000 h	24.4±0.2	18.2±0.2	6.3±0.6	8.2±1.6
AMC380	25°C (as-cast)		49.9±1.1	27.9±0.7	3.72±0.34	10.7±1.2
	Cooled to 25°C	0.5 h	48.0±0.7	27.6±0.5	3.13±0.22	12.5±1.7
		500 h	43.9±0.8	29.3±1.0	2.33±0.36	11.6±2.0
		1000 h	45.1±1.4	29.5±0.8	2.68±0.31	12.2±2.5
	Tested at 200°C	0.5 h	36.5±0.5	28.5±0.5	4.51±0.35	8.7±0.4
		500 h	31.8±0.8	24.9±0.8	4.3±0.4	9.1±0.6
		1000 h	29.3±0.7	22.9±0.6	4.4±1.0	8.6±1.0
AMC1045Sr	25°C (as-cast)		53.4±1.3	35.2±0.9	2.33±0.28	11.9±0.8
	Cooled to 25°C	0.5 h	49.5±3.5	36.0±3.3	1.42±0.39	12.7±1.4
		500 h	45.1±1.3	28.5±0.6	2.47±0.52	12.2±1.7
		1000 h	44.1±1.2	25.7±0.7	3.13±0.09	12.0±0.3
	Tested at 200°C	0.5 h	45.0±0.4	36.3±0.6	3.18±0.29	8.8±0.5
		500 h	33.5±0.2	25.0±0.2	4.0±0.4	9.5±0.7
		1000 h	30.8±0.5	22.3±0.5	5.0±0.6	8.4±0.4

Note: The experimental alloys were developed through research sponsored by NADCA, conducted at WPI, and funded by DOD/DLA. The properties shown do not represent design minimums and should be used for reference only.

Table 6: Fatigue strength of experimental alloys as compare to A380. Specimens were separately die cast and tested using the R.R Moore rotating bending fatigue test.

Alloy	A380		A380*		AMC380		AMC1045Sr	
Cycles	1x10^8	5x10^8	1x10^8	5x10^8	1x10^8	5x10^8	1x10^8	5x10^8
Maximum stress (ksi)	22.6	22.1	20.4	20.1	23.3	22.5	24.4	24.1
Change vs. A380	–	–	-9.75%	-9.22%	+3.34%	+1.39%	+8.33%	+8.98%

Note: The experimental alloys were developed through research sponsored by NADCA, conducted at WPI, and funded by DOD/DLA. The properties shown do not represent design minimums and should be used for reference only.

Table 7: Composition of suggested alloys and company specific alloys as compared to A380

	Composition (%)									
	Si	Cu	Mg	Fe	Mn	Zn	Ni	Ti	Sr	Other
A380	7.5-9.5	3-4	0.1	1.3	0.5	3	0.5	-	-	0.5
High Mg A380	7.5-9.5	3-4	0.5	1.3	0.5	3	0.5	-	-	0.5
F380	8.5-9.5	3-4	0.1-0.3	0.4	0.25-0.35	1	0.1	-	0.05-0.07	0.5
B360	9.0-10.0	0.25	0.4-0.6	0.4	0.25-0.35	0.5	0.1	-	0.05-0.07	0.25
Gibbsalloy MN	0.1-0.3	0.1	2.6-3.7	0.2-0.5	0.4-1.0	0.05	-	0.03-0.07	-	0.5

Table 8: Tensile properties of separately die cast specimens of the suggested and company specific alloys compared to separately die cast specimens of alloy A380.

Alloy	UTS (ksi)	YS (ksi)	e (%)
A380	47.0	23.0	3.5
Hi Mg 380	45.8	27.2	3.0
Hi Mg 380-T5	46.7	39.3	1.2
F380	46.1	23.4	5.0
B360	46.6	23.5	6.1
B360-T5	52	37.1	3.6
Gibbsalloy MN	30.6	15.9	12.1
Gibbsalloy MN-T5	32.5	18.5	11.7

Note: This data was developed through research sponsored by NADCA and funded by DOD/DLA and NADCA. The properties shown do not represent design minimums and should be used for reference only.

3 Aluminum Metal Matrix Composites

Selecting Aluminum Composites

Aluminum metal matrix composites (MMC) are aluminum-based alloys reinforced with up to 20% silicon carbide (SiC) particles, which are now being used for high-performance die cast components.

The mechanical properties of ASTM test specimens made from these materials typically exceed those of most aluminum, magnesium, zinc and bronze components produced by die casting, and match or approach many of the characteristics of iron castings and steel at lighter weight.

The expected properties of MMC parts are higher stiffness and thermal conductivity, improved wear resistance, lower coefficient of thermal expansion, and higher tensile and fatigue strengths at elevated temperature, with densities within 5% of aluminum die casting alloys. These composites can also yield castings with reduced porosity.

Preliminary data also indicates that less vibrational noise is generated by parts made from these composites, under certain conditions, than by identical parts made from unreinforced aluminum.

Duralcan F3D.10%v/v and 20%v/v aluminum metal matrix composites reinforced with SiC ceramic powder are general purpose die casting alloys.

Duralcan F3N.10%v/v and 20%v/v aluminum metal matrix composites reinforced with SiC ceramic powder contain virtually no copper or nickel and are designed for use in corrosion sensitive applications. All of these composites are heat treatable.

Machining Characteristics

Al-MMCs are significantly more abrasive to cutting tools than all other aluminum die cast and gravity cast alloys, except for hypereutectic Al-Si alloys (those containing primary Si phases).

Coarse grades of polycrystalline diamond (PCD) tools are recommended for anything more than prototype quantities of machining.

With the proper tooling, Al-MMC can be readily turned, milled, or drilled. However, cutting speeds are lower and feed rates are higher than for unreinforced alloys. General machining guidelines are described in Volume 1 of the SME Tool & Manufacturing Engineers Handbook.

Surface Treatment Systems

Surface treatments are generally applied to aluminum MMC to provide a protective barrier to environmental exposure, to provide decorative finish, or to reduce the abrasiveness of the MMC to a counterface material. Because of the inherently high wear resistance of the Al-MMCs, surface treatments on these materials are generally not used to improve their wear resistance.

Decorative finishes can be applied by painting, powder coat finishing, epoxy finishing and plating, using procedures similar to those used for conventional aluminum alloys.

Although conventional and hard-coat anodized finishes can be applied to Al-MMC die castings, the results are not as cosmetically appealing as for conventional aluminum. The presence of the SiC particles results in a darker, more mottled appearance. This problem can be minimized, although not entirely eliminated, by using the darker, more intensely colored dyes to color the anodic coatings. Another problem often noted is that the presence of the ceramic particles produces a rougher surface, particularly after chemical etching. This, in turn, leads to a less lustrous anodic coating than usually seen with unreinforced aluminum.

Recommended procedures for painting, plating and anodizing Duralcan MMCs can be obtained through Rio Tinto Alcan, 2040 Chemin de la Reserve, Chicoutimi (Quebec) G7H 5B3, Canada.

This aluminum composite subsection presents guideline tables for chemical composition, typical properties, and die casting and other characteristics for the two families of aluminum matrix composite alloys for die casting. Design engineering tolerancing guidelines have yet to be developed.

Rio Tinto Alcan - Dubuc Works, produces Duralcan metal matrix composites for die casting using a patented process and proprietary technology, mixing ceramic powder into molten aluminum. Further technical and application information can be obtained from Rio Tinto Alcan, 2040 Chemin de la Reserve, Chicoutimi (Quebec) G7H 5B3, Canada.

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Table A-3-4 Chemical Composition: Al-MMC Alloys

	Duralcan Aluminum Metal Matrix Composite Alloys Ⓑ			
Commercial:	F3D.10S-F	F3D.20S-F	F3N.10S-F	F3N.20S-F
Detailed Composition				
SiC Particulate Volume Percent	10%	20%	10%	20%
Silicon Si	9.50-10.50	9.50-10.50	9.50-10.50	9.50-10.50
Iron Fe	0.8-1.20	0.8-1.20	0.8-1.20	0.8-1.20
Copper Cu	3.0-0.50	3.0-3.50	0.20 max.	0.20 max.
Magnesium Mg	0.30-0.50	0.30-0.50	0.50-0.70	0.50-0.70
Manganese Mn	0.50-0.80	0.50-0.80	0.50-0.80	0.50-0.80
Nickel Ni	1.00-1.50	1.00-1.50	—	—
Titanium Ti	0.05 max.	0.20 max.	0.20 max.	0.20 max.
Zinc Zn	0.05 max.	0.05 max.	0.05 max.	0.05 max.
Total Others Ⓐ	0.10 Total 0.03 max.	0.10 Total 0.03 max.	0.10 Total 0.03 max.	0.10 Total 0.03 max.
Aluminum Al	Balance	Balance	Balance	Balance

Ⓐ *For RoHS (the European Union's Directive on Restriction of Hazardous Substances) compliance, certification of chemical analysis is required to ensure that the "total others" category does not exceed the following weight percent limits: 0.01% cadmium, 0.4% lead, and 0.1% mercury. Hexavalent chromium does not exist in the alloys and therefore meets the 0.1% limit.* Ⓑ *Registration for REACH (the European Union's Directive on Registration, Evaluation, and Authorization of Chemicals) is not required for die castings, even if coated, since die castings are considered articles. Notification may be required if some contained substances in the die casting or coating exceed the 0.1% total weight of the article level and are listed as SVHC (substances of very high concern).*
Source: Rio Tinto Alcan Dubuc Works

Alloy Data

Table A-3-5 Typical Material Properties: Al-MMC Alloys
Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

	Duralcan Aluminum Metal Matrix Composite Alloys			
Commercial:	F30D.10S-F	F30D.20S-F	F30N.10S-F	F30N.20S-F
Mechanical Properties				
Ultimate Tensile Strength Ⓐ				
ksi	50	51	45	44
(MPa)	(345)	(352)	(310)	(303)
Yield Strength Ⓐ				
ksi	35	44	32	36
(MPa)	(241)	(303)	(221)	(248)
Elongation Ⓐ				
% in 2in. (51mm)	1.2	0.4	0.9	0.5
Rockwell Hardness Ⓐ				
HRB	77	82	56	73
Impact Energy Ⓑ				
Charpy impact ASTM E-23 (J)	1.9	0.7	1.4	0.7
Fatigue Strength Ⓒ				
ksi	22	22	—	—
(MPa)	(152)	(152)		
Elastic Modulus Ⓐ				
psi x 10^6	10.3	10.3	20	15.7
(GPa)	(71)	(71)	(140)	(108.2)
Physical Properties				
Density				
lb/in^3	0.0997	0.1019	0.0957	0.0979
(g/cm^3)	(2.76)	(2.82)	(2.65)	(2.71)
Melting Range				
˚F	975-1060	975-1060	1067-1112	1067-1112
(˚C)	(524-571)	(524-571)	(575-600)	(575-600)
Specific Heat				
BTU/lb ˚F @ 77 ˚F	0.201	0.198	0.208	0.193
(J/kg ˚C @ 22 ˚C)	(841.5)	(829.0)	(870.9)	(808.1)
Average Coefficient of Thermal Expansion				
μ in/in˚F	10.7	9.4	11.9	9.2
(μ m/m˚K)	(19.3)	(16.9)	(21.4)	(16.6)
Thermal Conductivity				
BTU/ft hr˚F @ 72 ˚F	71.6	83.2	93.0	97.1
(W/m ˚K @ 22 ˚C)	(123.9)	(144.0)	(161.0)	(168.1)
Electrical Conductivity				
% IACS @ 22 ˚C	22.0	20.5	32.7	24.7
Poisson's Ratio	0.296	0.287	—	0.293

Ⓐ *Based on cast-to-size tensile bars.* Ⓑ *Cast-to-size test specimens.* Ⓒ *Axial fatigue, R=0.1, RT (room temperature), 1 x 107 cycles. Source: Alcan ECP Canada*

Alloy Data

Die casting alloy selection requires evaluation not only of physical and mechanical properties, and chemical composition, but also of inherent alloy characteristics and their effect on die casting production as well as possible machining and final surface finishing.

This table includes selected die casting and other special characteristics which are usually considered in selecting an aluminum matrix alloy for a specific application.

The characteristics are rated from (1) to (5), (1) being the most desirable and (5) being the least. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. A rating of (5) in one or more categories would not rule out an alloy if other attributes are particularly favorable, but ratings of (5) may present manufacturing difficulties.

The benefits of consulting a custom die caster experienced in casting the aluminum matrix alloy being considered are clear.

Table A-3-6 Die Casting and Other Characteristics: Al-MMC Alloys
(1 = most desirable, 5 = least desirable)

	Duralcan Aluminum Metal Matrix Composite Alloys			
Commercial: ANSI/AA	F3D.10S-F	F3D.20S-F	F3N.10S-F	F3N.20S-F
Resistance to Hot Cracking Ⓐ	1	1	1	1
Die-Filling Capacity Ⓑ	1	1	1	1
Anti-Soldering to the Die Ⓒ	3	3	2	2
Pressure Tightness	2	2	2	2
Corrosion Resistance Ⓓ	5	5	3	3
Machining Ease & Quality Ⓔ	4	4	4	4
Polishing Ease & Quality Ⓕ	5	5	5	5
Electroplating Ease & Quality Ⓖ	2	2	2	2
Anodizing (Appearance) Ⓗ	4	4	4	4
Anodizing (Protection)	5	5	4	4
Strength at Elevated Temp. Ⓘ	1	1	1	1
Resistance to Wear	1	1	1	1

Ⓐ *Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature range.* Ⓑ *Ability of molten alloy to flow readily in die and fill thin sections.* Ⓒ *Ability of molten alloy to flow without sticking to the die surfaces.* Ⓓ *Based on resistance of alloy in standard type salt spray test.* Ⓔ *Composite rating based on ease of cutting, ship characteristics, quality of finish, and tool life.* Ⓕ *Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedures.* Ⓖ *Ability of the die casting to take and hold an electroplate applied by present standard methods.* Ⓗ *Rated on lightness of color, brightness, and uniformity of clear anodized coating applied in sulphuric acid electrolyte. Generally aluminum die castings are unsuitable for light color anodizing where pleasing appearance is required.* Ⓘ *Rating based on tensile and yield strengths at temperatures up to 500 °F (260 °C), after prolonged heating at testing temperatures. Source: Alcan ECP Canada*

Note: *There are additional metal matrix composites materials being developed. These include Aluminum and Magnesium matrix composites and nano-composites are being produced by means of SHS (Self-propagating high-temperature synthesis) technology under NADCA sponsored research projects. Contact the NADCA Technology Department for more information about these composite materials.*

4 Copper Alloys

Selecting Copper (Brass) Alloys

Copper alloy (Cu) die castings (brass and bronze) have the highest mechanical properties and corrosion resistance of all die cast materials.

The standard copper-base alloys in general use are readily die cast in intricate shapes. The high temperatures and pressures at which they are cast — 1800° to 1950°F (982°-1066°C) — result in shortened die life, compared to the other nonferrous alloys. While this will result in higher die replacement costs for brass castings, total product cost can be lower compared to brass machined parts or brass investment castings.

Where added strength, corrosion resistance, wear resistance and greater hardness are required for a product, the possible economies of brass die castings over other production processes should be carefully considered.

This copper alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for the most commonly used copper die casting alloys. This data can be used in combination with design engineering tolerancing guidelines for copper die casting and compared with the guidelines for other alloys in this section and in the design engineering section.

Copper alloy 858 is a general-purpose, lower-cost yellow brass alloy with good machinability and soldering characteristics.

Alloy 878 has the highest mechanical strength, hardness and wear resistance of the copper die casting alloys, but is the most difficult to machine. It is generally used only when the application requires its high strength and resistance to wear, although its lower lead content makes it environmentally more attractive.

Where environmental and health concerns are a factor in an application, those alloys with low lead content, as shown in table A-3-7, will be increasingly preferred.

Some examples of copper alloys in die casting are lock cases, lids and shrouds for water meters, door hardware, electrical floor plates, plumbing hardware and locomotive components.

Machining

Copper alloy die castings in general are more difficult to machine than other nonferrous components, since their excellent conductivity results in rapid heating during machining operations. However, there are significant differences in machining characteristics among the copper alloys, as can be determined from Table A-3-9.

Ratings in Table A-3-9 are based on free machining yellow brass as a standard of 100. Most copper alloys are machined dry. Three of the six alloys listed have a rating of 80, which is excellent. Copper alloys 878 and 865 are not difficult to machine if carbide tools and cutting oil are used. The chips from alloy 878 break up into fine particles while alloy 865 produces a long spiral which does not break up easily into chips.

Surface Finishing Systems

The temperature characteristics of copper alloy castings require special care in surface finishing. While a range of processes are available, electroplating is especially effective. Brass castings yield a bright chrome plate finish equal to or superior to zinc.

Natural surface color ranges from a golden yellow for the yellow brass, to a buff brown for the silicon brass alloys, to a silver color for the white manganese alloys. Copper alloys may be buffed and polished to a high luster. Polishing shines the metal; sand or shot blasting will give it a satin finish.

Final finishing choices are available through chemical and electrochemical treatments which impart greens, reds, blues, yellows, browns, black, or shades of gray. Clear organic finishes, consisting of nitrocellulose, polyvinyl fluoride or benzotriazole, are also available for copper alloys.

For more detailed finishing information contact the Copper Development Association Inc., 260 Madison Ave., New York, NY 10016 or visit www.copper.org.

Table A-3-7 Chemical Composition: Cu Alloys

All single values are maximum composition percentages unless otherwise stated.

	Copper Die Casting Alloys Ⓐ Ⓒ					
Commercial: ANSI/AA	857 C85700 Yellow Brass	858 C85800 Yellow Brass	865 C86500 Manganese Bronze	878 C87800 Si Bronze	997.0 C99700 White Tombasil	997.5 C99750 White Brass
Nominal Comp:	Cu 63.0 Al 0.3 Pb 1.0 Sn 1.0 Zn 36.0	Cu 61.5 Pb 1.0 Sn 1.0 Zn 36.0	Cu 58.0 Al 1.0 Fe 1.2 Sn 0.5 Mn 0.8 Zn 39.0	Cu 82.0 Si 4.0 Zn 14.0	Cu 56.5 Al 1.8 Pb 1.5 Mn 13.0 Ni 5.0 Zn 22.0	Cu 58.0 Al 1.6 Mn 20.0 Pb 1.5 Zn 20.0
Detailed Composition						
Copper Cu	58.0-64.0	57.0 min	55.0-60.0	80.0-84.2	54.0 min	55.0-61.0
Tin Sn	0.5-1.5	1.5	1.0	0.25	1.0	
Lead Pb Ⓑ	0.8-1.5	1.5	0.4	0.09	2.0	0.5-2.5
Zinc Zn	32.0-40.0	31.0-41.0	36.0-42.0	12.0-16.0	19.0-25.0	17.0-23.0
Iron Fe	0.7	0.50	0.4-2.0	0.15	1.0	1.0
Aluminum Al	0.8	0.55	0.5-1.5	0.15	0.5-3.0	0.25-3.0
Manganese Mn		0.25	0.1-1.5	0.15	11.0-15.0	17.0-23.0
Antimony Sb		0.05		0.05		
Nickel (incl. Cobalt) Ni	1.0	0.5	1.0	0.20	4.0-6.0	5.0
Sulphur S		0.05		0.05		
Phosphorus P		0.01		0.01		
Silicon Si	0.05	0.25		3.8-4.2		
Arsenic As		0.05		0.05		
Magnesium Mg				0.01		
Copper + Sum of Named Elements Ⓑ	98.7 min.	98.7 min.	99.0 min.	99.5 min.	99.7 min.	99.7 min.

Ⓐ *Analysis shall ordinarily be made only for the elements mentioned in this table. If, however, the presence of other elements is suspected, or indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements are not present in excess of specified limits.* Ⓑ *For RoHS (the European Union's Directive on Restriction of Hazardous Substances) compliance, certification of chemical analysis is required to ensure that the "total others" category does not exceed the following weight percent limits: 0.01% cadmium, 0.4% lead, and 0.1% mercury. Hexavalent chromium does not exist in the alloys and therefore meets the 0.1% limit.* Ⓒ *Registration for REACH (the European Union's Directive on Registration, Evaluation, and Authorization of Chemicals) is not required for die castings, even if coated, since die castings are considered articles. Notification may be required if some contained substances in the die casting or coating exceed the 0.1% total weight of the article level and are listed as SVHC (substances of very high concern).*

Alloy Data

Table A-3-8 Typical Material Properties: Cu Alloys

Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

	Copper Die Casting Alloys					
Commercial:	857	858	865	878	997.0	997.5
ANSI/AA:	C85700	C85800	C86500	C87800	C99700	C99750
Common Name:	Yellow Brass	Yellow Brass	Mn Bronze	Si Bronze	White Tombasil	White Brass
Mechanical Properties						
Ultimate Tensile Strength ksi (MPa)	50 (344)	55 (379)	71 (489)	85 (586)	65 (448)	65 (448)
Yield Strength Ⓐ ksi (MPa)	18 (124)	30 (207)	28 (193)	50 (344)	27 (186)	32 (221)
Elongation % in 2in. (51mm)	15	15	30	25	15	30
Hardness BHN (500)	75	55-60HRB	100	85-90HRB	125 (@300kg)	110
Impact Strength ft-lb (J)		40 (54)	32 (43)	70 (95)	—	75 (102)
Fatigue Strength ksi (MPa)	—	—	20 (138)	—	—	19 (128)
Young's Modulus psi x 10^6 (GPa)	14 (87)	15 (103.4)	15 (103.4)	20 (137.8)	16.5 (113.7)	17 (117.1)
Physical Properties						
Density lb/in^3 @ 68 ˚F (g/cm^3) @20 ˚C	0.304 (8.4)	0.305 (8.44)	0.301 (8.33)	0.300 (8.3)	0.296 (8.19)	0.29 (8.03)
Melting Range ˚F (˚C)	1675-1725 (913-940)	1600-1650 (871-899)	1583-1616 (862-880)	1510-1680 (821-933)	1615-1655 (879-902)	1505-1550 (819-843)
Specific Heat BTU/lb ˚F @ 68 ˚F (J/kg ˚K @ 293 ˚K)	0.09 (377.0)	0.09 (377.0)	0.09 (377.0)	0.09 (377.0)	0.09 (377.0)	0.09 (377.0)
Average Coefficient of Thermal Expansion μ in/in˚F x 10^{-6} (μ m/m˚C x 10^{-6})	12 (21.6)	12 (21.6)	11.3 (20.3)	10.9 (19.6)	10.9 (19.6)	13.5 (24.3)
Thermal Conductivity BTU•ft/(hr•ft^2•˚F) @ 68 ˚F (W/m ˚K @ 20 ˚C)	48.5 (83.9)	48.5 (83.9)	49.6 (85.8)	16.0 (27.7)	16.0 (27.7)	—
Electrical Conductivity % IACS @ 20 ˚C	22	20	22	6.7	3.0	2.0
Poisson's Ratio	80	80	26	40	80	80

Ⓐ *Tensile yield strength at -0.5% extension under load. Sources: ASTM B176-93a and Copper Development Association.*

Alloy Data

Die casting alloy selection requires evaluation not only of physical and mechanical properties, and chemical composition, but also of inherent alloy characteristics and their effect on die casting production as well as possible machining and final surface finishing.

This table includes selected die casting and other special characteristics which are usually considered in selecting a copper alloy for a specific application.

The characteristics are rated from (1) to (5), (1) being the most desirable and (5) being the least. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. A rating of (5) in one or more categories would not rule out an alloy if other attributes are particularly favorable, but ratings of (5) may present manufacturing difficulties.

The benefits of consulting a custom die caster experienced in casting the copper alloy being considered are clear.

Table A-3-9 Die Casting and Other Characteristics: Cu Alloys
(1 = most desirable, 5 = least desirable)

	Copper Die Casting Alloys					
Commercial:	857	858	865	878	997.0	997.5
UNS:	C85700	C85800	C86500	C87800	C99700	C99750
Resistance to Hot Cracking Ⓐ	2	2	3	2	2	3
Pressure Tightness	3	3	2	2	3	3
Die-Filling Capacity Ⓑ	2	3	2	2	2	2
Anti-Soldering to the Die Ⓒ	2	2	2	1	3	3
As Cast Surface Smoothness	3	4	2	1	3	3
Corrosion Resistance Ⓓ	4	4	2	3	1	2
Machining Ease & Quality Ⓔ	1	1	4	3	2	2
Polishing Ease & Quality Ⓕ	3	3	3	4	3	3
Electroplating Ease & Quality Ⓖ	1	1	3	2	3	3
High Temperature Strength Ⓗ	3	3	3	1	3	3

Ⓐ *Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature range.* Ⓑ *Ability of molten alloy to flow readily in die and fill thin sections.* Ⓒ *Ability of molten alloy to flow without sticking to the die surfaces.* Ⓓ *Based on resistance of alloy in standard type salt spray test.* Ⓔ *Composite rating based on ease of cutting, chip characteristics, quality of finish, and tool life.* Ⓕ *Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure.* Ⓖ *Ability of the die casting to take and hold an electroplate applied by present standard methods.* Ⓗ *Rating based on tensile and yield strengths at temperatures up to 500°F (260°C), after prolonged heating at testing temperature. Sources: ASTM B176-93a; R. Lavin & Sons, Inc.*

5 Magnesium Alloys

Selecting Magnesium Alloys

Magnesium (Mg) has a specific gravity of 1.74 g/cc, making it the lightest commonly used structural metal.

This magnesium alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for seven magnesium alloys. This data can be used in combination with design engineering tolerancing guidelines for magnesium die casting and can be compared with the guidelines for other alloys in this section and in the design engineering section.

Alloy AZ91D and AZ81 offer the highest strength of the commercial magnesium die casting alloys.

Alloy AZ91D is the most widely-used magnesium die casting alloy. It is a high-purity alloy with excellent corrosion resistance, excellent castability, and excellent strength. Corrosion resistance is achieved by enforcing strict limits on three metallic impurities: iron, copper and nickel.

AZ81 use is minimal since its properties are very close to those of AZ91D. Alloys AM60B, AM50A and AM20 are used in applications requiring good elongation, toughness and impact resistance combined with reasonably good strength and excellent corrosion resistance. Ductility increases at the expense of castability and strength, as aluminum content decreases. Therefore, the alloy with the lowest aluminum content that will meet the application requirements should be chosen.

Alloys AS41B and AE42 are used in applications requiring improved elevated temperature strength and creep resistance combined with excellent ductility and corrosion resistance. The properties of AS41B make it a good choice for crankcases of air-cooled automotive engines.

Among the more common applications of magnesium alloys can be found the following: auto parts such as transfer cases, cam covers, steering columns, brake and clutch pedal brackets, clutch housings, seat frames, and dashboard supports. Non-automotive products would include chain saws, portable tools, vacuum cleaners, lawn mowers, household mixers, floor polishers, blood pressure testing machines, projectors, cameras, radar indicators, tape recorders, sports equipment, calculators, postage meters, computers, telecommunications equipment, fractional horsepower motors, levels, sewing machines, solar cells, snowmobiles and luggage.

Machining

The magnesium alloys exhibit the best machinability of any group of commercially used metal alloys. Special precautions must routinely be taken when machining or grinding magnesium castings.

Surface Treatment Systems

Decorative finishes can be applied to magnesium die castings by painting, chromate and phosphate coatings, as well as plating. Magnesium castings can be effectively plated by applying an initial immersion zinc coating, followed by conventional copper-nickel-chromium plating procedure generally used for plating zinc metal/alloys.

Magnesium underbody auto parts, exposed to severe environmental conditions, are now used with no special coatings or protection. Other Mg die castings, such as computer parts, are often given a chemical treatment. This treatment or coating protects against tarnishing or slight surface corrosion which can occur on unprotected magnesium die castings during storage in moist atmospheres. Painting and anodizing further serve as an environmental corrosion barrier.

Improved wear resistance can be provided to magnesium die castings with hard anodizing or hard chrome plating.

A detailed discussion of finishing methods for magnesium die castings can be found in Product Design For Die Casting.

Table A-3-10 Chemical Composition: Mg Alloys
All single values are maximum composition percentages unless otherwise stated.

	Magnesium Die Casting Alloys Ⓐ Ⓕ						
Commercial:	AZ91D Ⓐ	AZ81 Ⓑ	AM60B Ⓑ	AM50A Ⓑ	AM20 Ⓑ	AE42 Ⓑ	AS41B Ⓑ
Nominal Comp:	Al 9.0 Zn 0.7 Mn 0.2	Al 8.0 Zn 0.7 Mn 0.22	Al 6.0 Mn 0.3	Al 5.0 Mn 0.35	Al 2.0 Mn 0.55	Al 4.0 RE 2.4 Mn 0.3	Al 4.0 Si 1.0 Mn 0.37
Detailed Composition							
Aluminum Al	8.3-9.7	7.0-8.5	5.5-6.5	4.4-5.4	1.7-2.2	3.4-4.6	3.5-5.0
Zinc Zn	0.35-1.0	0.3-1.0	0.22 max	0.22 max	0.1 max	0.22 max	0.12 max
Manganese Mn	0.15-0.50 Ⓒ	0.17 min	0.24-0.6 Ⓒ	0.26-0.6 Ⓒ	0.5 min	0.25 Ⓓ	0.35-0.7 Ⓒ
Silicon Si	0.10 max	0.05 max	0.10 max	0.10 max	0.10 max	—	0.5-1.5
Iron Fe	0.005 Ⓒ	0.004 max	0.005 Ⓒ	0.004 Ⓒ	0.005 max	0.005 Ⓓ	0.0035 Ⓒ
Copper, Max Cu	0.030	0.015	0.010	0.010	0.008	0.05	0.02
Nickel, Max Ni	0.002	0.001	0.002	0.002	0.001	0.005	0.002
Rare Earth, Total RE	—	—	—	—	—	1.8-3.0	—
Others Each Ⓔ	0.02	0.01	0.02	0.02	0.01	0.02	0.02
Magnesium Mg	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Ⓐ *ASTM B94-03, based on die cast part.* Ⓑ *Commercial producer specifications, based on ingot. Source: International Magnesium Association.* Ⓒ *In alloys AS41B, AM50A, AM60B and AZ91D, if either the minimum manganese limit or the maximum iron limit is not met, then the iron/manganese ratio shall not exceed 0.010, 0.015, 0.021 and 0.032, respectively.* Ⓓ *In alloy AE42, if either the minimum manganese limit or the maximum iron limit is exceeded, then the permissible iron to manganese ratio shall not exceed 0.020. Source: ASTM B94-94, International Magnesium Assn.* Ⓔ *For RoHS (the European Union's Directive on Restriction of Hazardous Substances) compliance, certification of chemical analysis is required to ensure that the "total others" category does not exceed the following weight percent limits: 0.01% cadmium, 0.4% lead, and 0.1% murcury. Hexavalent chromium does not exist in the alloys and therefore meets the 0.1% limit.* Ⓕ *Registration for REACH (the European Union's Directive on Registration, Evaluation, and Authorization of Chemicals) is not required for die castings, even if coated, since die castings are considered articles. Notification may be required if some contained substances in the die casting or coating exceed the 0.1% total weight of the article level and are listed as SVHC (substances of very high concern).*

** There are additional magnesium alloys that have been and are being developed for elevated temperature and creep resistant applications. See the data table on page 3-24. Contact your alloy producer for more information.*

Alloy Data

Table A-3-11 Typical Material Properties: Mg Alloys

Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

	Magnesium Die Casting Alloys						
Commercial:	AZ91D	AZ81	AM60B	AM50A	AM20	AE42	AS41B
Mechanical Properties							
Ultimate Tensile Strength Ⓑ							
ksi	34	32	32	32	32	27	33
(MPa)	(230)	(220)	(220)	(220)	(220)	(185)	(225)
Yield Strength Ⓔ Ⓑ							
ksi	23	21	19	18	15	20	20
(MPa)	(160)	(150)	(130)	(120)	(105)	(140)	(140)
Compressive Yield Strength Ⓗ							
ksi	24	N/A	19	N/A	N/A	N/A	20
(MPa)	(165)		(130)				(140)
Elongation Ⓑ							
% in 2 in. (51mm)	3	3	6-8	6-10	8-12	8-10	6
Hardness Ⓕ							
BHN	75	72	62	57	47	57	75
Shear Strength Ⓑ							
ksi	20	20	N/A	N/A	N/A	N/A	N/A
(MPa)	(140)	(140)					
Impact Strength Ⓓ							
ft-lb	1.6	N/A	4.5	7.0	N/A	4.3	3.0
(J)	(2.2)		(6.1)	(9.5)		(5.8)	(4.1)
Fatigue Strength Ⓐ							
ksi	10	10	10	10	10	N/A	N/A
(MPa)	(70)	(70)	(70)	(70)	(70)		
Latent Heat of Fusion							
Btu/lb	160	160	160	160	160	160	160
(kJ/kg)	(373)	(373)	(373)	(373)	(373)	(373)	(373)
Young's Modulus Ⓑ							
psi x 10^6	6.5	6.5	6.5	6.5	6.5	6.5	6.5
(GPa)	(45)	(45)	(45)	(45)	(45)	(45)	(45)
Physical Properties							
Density							
lb/in^3	0.066	0.065	0.065	0.064	0.063	0.064	0.064
(g/cm^3)	(1.81)	(1.80)	(1.80)	(1.78)	(1.76)	(1.78)	(1.78)
Melting Range							
°F	875-1105	915-1130	1005-1140	1010-1150	1145-1190	1050-1150	1050-1150
(°C)	(470-595)	(490-610)	(540-615)	(543-620)	(618-643)	(565-620)	(565-620)
Specific Heat Ⓑ							
BTU/lb °F	0.25	0.25	0.25	0.25	0.24	0.24	0.24
(J/kg °C)	(1050)	(1050)	(1050)	(1050)	(1000)	(1000)	(1000)
Coefficient of Thermal Expansion Ⓑ							
µ in/in°F	13.8	13.8	14.2	14.4	14.4	14.5 Ⓖ	14.5
(µ m/m°K)	(25.0)	(25.0)	(25.6)	(26.0)	(26.0)	(26.1)	(26.1)
Thermal Conductivity							
BTU/ft hr°F	41.8 Ⓒ	30 Ⓑ	36 Ⓑ	36 Ⓑ	35 Ⓑ	40 Ⓑ Ⓖ	40 Ⓑ
(W/m °K)	(72)	(51)	(62)	(62)	(60)	(68)	(68)
Electrical Resistivity Ⓑ							
µ Ω in.	35.8	33.0	31.8	31.8	N/A	N/A	N/A
(µ Ω cm.)	(14.1)	(13.0)	(12.5)	(12.5)			
Poisson's Ratio	0.35	0.35	0.35	0.35	0.35	0.35	0.35

n/a = data not available. Ⓐ Rotating Beam fatigue test according to DIN 50113. Stress corresponding to a lifetime of 5 x 10^7 cycles. Higher values have been reported. These are conservative values. Soundness of samples has great effect on fatigue properties resulting in disagreement among data sources. Ⓑ At 68°F (20°C). Ⓒ At 212-572°F (100-300°C). Ⓓ ASTM E 23 unnotched 0.25 in. die cast bar. Ⓔ 0.2% offset. Ⓕ Average hardness based on scattered data. Ⓖ Estimated. Ⓗ 0.1% offset. Source: International Magnesium Assn.

** There are additional magnesium alloys that have been and are being developed for elevated temperature and creep resistant applications. See the data table on page 3-20. Contact your alloy producer for more information.*

Alloy Data

Die casting alloy selection requires evaluation not only of physical and mechanical properties, and chemical composition, but also of inherent alloy characteristics and their effect on die casting production as well as possible machining and final surface finishing.

This table includes selected die casting and other special characteristics which are usually considered in selecting a magnesium alloy for a specific application.

The characteristics are rated from (1) to (5), (1) being the most desirable and (5) being the least. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. A rating of (5) in one or more categories would not rule out an alloy if other attributes are particularly favorable, but ratings of (5) may present manufacturing difficulties.

The benefits of consulting a custom die caster experienced in casting the magnesium alloy being considered are clear.

Table A-3-12 Die Casting and Other Characteristics: Mg Alloys
(1 = most desirable, 5 = least desirable)

Commercial:	Magnesium Die Casting Alloys						
		AZ81		AM50A	AM20	AE42	
Resistance to Cold Defects [A]	2	2	3 [G]	3 [G]	5 [G]	4 [G]	4 [G]
Pressure Tightness	2	2	1 [G]	1 [G]	1 [G]	1 [G]	1 [G]
Resistance to Hot Cracking [B]	2	2	2 [G]	2 [G]	1 [G]	2 [G]	1 [G]
Machining Ease & Quality [C]	1	1	1 [G]	1 [G]	1 [G]	1 [G]	1 [G]
Electroplating Ease & Quality [D]	2	2	2 [G]	2 [G]	2 [G]	—	2 [G]
Surface Treatment [E]	2	2	1 [G]	1 [G]	1 [G]	1 [G]	1 [G]
Die-Filling Capacity	1	1	2	2	4	2	2
Anti-Soldering to the Die	1	1	1	1	1	2	1
Corrosion Resistance	1	1	1	1	2	1	2
Polishing Ease & Quality	2	2	2	2	4	3	3
Chemical Oxide Protective Coating	2	2	1	1	1	1	1
Strength at Elevated Temperature [F]	4	4	3	3	5	1	2

[A] The ability of alloy to resist formation of cold defects; for example, cold shuts, cold cracks, non-fill "woody" areas, swirls, etc. [B] Ability of alloy to withstand stresses from contraction while cooling through the hot-short or brittle temperature range. [C] Composite rating based on ease of cutting, chip characteristics, quality of finish and tool life. [D] Ability of the die casting to take and hold on electroplate applied by present standard methods. [E] Ability of castings to be cleaned in standard pickle solutions and to be conditioned for pest paint adhesion. [F] Rating based on resistance to creep at elevated temperatures. [G] Rating based upon limited experience, giving guidance only. Sources: ASTM B94-92, International Magnesium Association.

** There are additional magnesium alloys that have been and are being developed for elevated temperature and creep resistant applications. Contact your alloy producer for more information.*

Alloy Data

Additional Magnesium Alloy Tensile Data

(Data is from separately cast specimens in as-cast condition)

Alloy	Temp °F (°C)	Tensile ksi (MPa)	Yield ksi (MPa)	Elong %
AE44-F	Room	35 (243)	20 (135)	8.3
	250 (121)	32 (160)	16 (112)	32.0
MRI 153M-F	Room	29 (201)	27 (183)	1.7
	257 (125)	28 (193)	21 (148)	6.0
	302 (150)	26 (181)	20 (140)	6.6
	356 (180)	24 (166)	20 (137)	8.6
MRI 230D-F	Room	30 (206)	25 (172)	2.9
	257 (125)	26 (177)	21 (144)	3.7
	302 (150	24 (164)	20 (137)	3.2
	356 (180)	22 (151)	19 (132)	3.0
AJ52X-F	Room	34 (234)	20 (136)	9.8
	257 (125)	22 (155)	16 (110)	19.6
	302 (150)	20 (141)	16 (107)	18.5
	356 (180)	18 (125)	16 (112)	15.7
AS21X-F	Room	31 (216)	18 (123)	10.1
	257 (125)	19 (132)	13 (91)	30.6
	302 (150)	17 (144)	12 (85)	26.3
	356 (180)	14 (95)	11 (76)	26.4
AS31-F	Room	31 (212)	18 (127)	7.5
	257 (125)	21 (148)	14 (98)	15.1
	302 (150)	19 (131)	13 (93)	16.7
	356 (180)	16 (108)	12 (84)	16.4
AXJ530-F	Room	31 (213)	22 (155)	3.9
	257 (125)	25 (174)	19 (132)	4.4
	302 (150)	23 (158)	18 (124)	4.4
	356 (180)	20 (139)	17 (115)	4.8

The values in this table are average mean values and are provided for awareness of the new and emerging class of creep-resistant magnesium alloys that are available. The properties shown do not represent design minimums and should be used for reference only.

The property values in this table have been selected from data produced by the Structural Cast Magnesium Development (SCMD) Project and by the Magnesium Powertrain Cast Components (MPCC) Project of USAMP known as AMD-111 and AMD-304 respectively. For information about these projects, please refer to USCAR http://www.uscar.org or the DOE Energy Efficiency and Renewable Energy Vehicle Technologies Program http://www1.eere.energy.gov/vehiclesandfuels/resources/fcvt_reports.htm.

Acknowledgement

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Nos. DE-FC05-95OR22363, DE-FC05-02OR22910, and DE-FC26-02OR22910.

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6 Zinc and ZA Alloys

Selecting Zinc and ZA Alloys

Zinc (Zn) alloy die castings offer a broad range of excellent physical and mechanical properties, castability, and finishing characteristics. Thinner sections can be die cast in zinc alloy than in any of the commonly used die casting alloys.

Zinc alloy generally allows for greater variation in section design and for the maintenance of closer dimensional tolerances. The impact strength of zinc components is higher than other die casting alloys, with the exception of brass. Due to the lower pressures and temperatures under which zinc alloy is die cast, die life is significantly lengthened and die maintenance minimized.

This zinc alloy subsection presents guideline tables for chemical composition, typical properties, and die casting, machining and finishing characteristics for the two groups of zinc die casting alloys. This data can be used in combination with design engineering tolerancing guidelines for zinc die casting and can be compared with the guidelines for other alloys in this section and the Design Engineering section.

The zinc alloys include the traditional Zamak (acronym for zinc, aluminum, magnesium and copper) group, Nos. 2, 3, 5, and 7, and the high-aluminum or ZA® alloy group, ZA-8, ZA-12 and ZA-27.

The Zamak alloys all contain nominally 4% aluminum and a small amount of magnesium to improve strength and hardness and to protect castings from intergranular corrosion. These alloys all use the rapid-cycling hot-chamber process which allows maximum casting speed.

Miniature zinc die castings can be produced at high volume using special hot-chamber die casting machines that yield castings which are flash-free, with zero draft and very close tolerances, requiring no secondary trimming or machining.

Zinc No. 3 is the most widely used zinc alloy in North America, offering the best combination of mechanical properties, castability, and economics. It can produce castings with intricate detail and excellent surface finish at high production rates. The other alloys in the Zamak group are slightly more expensive and are used only where their specific properties are required

Alloys 2 and 5 have a higher copper content, which further strengthens and improves wear resistance, but at the expense of dimensional and property stability. No. 5 offers higher creep resistance and somewhat lower ductility and is often preferred whenever these qualities are required. No. 7 is a special high-purity alloy which has somewhat better fluidity and allows thinner walls to be cast.

The ZA alloys contain substantially more aluminum than the Zamak group, with the numerical designation representing the ZA alloy's approximate percent Al content.

The higher aluminum and copper content of the ZA alloys give them several distinct advantages over the traditional zinc alloys, including higher strength, superior wear resistance, superior creep resistance and lower densities.

ZA-8, with a nominal aluminum content of 8.4%, is the only ZA alloy that can be cast by the faster hot-chamber process. It has the highest strength of any hot-chamber zinc alloy, and the highest creep strength of any zinc alloy.

ZA-12, with a nominal aluminum content of 11%, has properties that fall midway in the ZA group. ZA-27, with a nominal aluminum content of 27%, has the highest melting point, the highest strength, and the lowest density of the ZA alloys.

Machining Characteristics

The machining characteristics of the Zamak and ZA alloys are considered very good. High-quality surface finishes and good productivity are achieved when routine guidelines for machining zinc are followed.

Surface Treatment Systems

In many applications, zinc alloy die castings are used without any applied surface finish or treatment.

Differences in the polishing, electroplating, anodizing and chemical coating characteristics of the Zamak and ZA alloys can be noted in table A-3-15.

Painting, chromating, phosphate coating and chrome plating can be used for decorative finishes. Painting, chromating, anodizing, and iridite coatings can be used as corrosion barriers. Hard chrome plating can be used to improve wear resistance, with the exception of ZA-27.

The bright chrome plating characteristics of the Zamak alloys and ZA-8 make these alloys a prevailing choice for hardware applications.

A detailed discussion of finishing methods for zinc die castings can be found in Product Design for Die Casting.

Table A-3-13 Chemical Composition: Zn Alloys
All single values are maximum composition percentages unless otherwise stated.

	Zamak Die Casting Alloys Ⓒ Ⓓ				ZA Die Casting Alloys Ⓒ Ⓓ		
Commercial: ANSI/AA	No. 2	No. 3 AG-40A	No. 5 AG-41A	No. 7 AG-40B	ZA-8	ZA-12	ZA-27
Nominal Comp:	Al 4.0 Mg 0.035 Cu 3.0	Al 4.0 Mg 0.035	Al 4.0 Mg 0.055 Cu 1.0	Al 4.0 Mg 0.013 Cu 0.013	Al 8.4 Mg 0.023 Cu 1.0	Al 11.0 Mg 0.023 Cu 0.88	Al 27.0 Mg 0.015 Cu 2.25
Detailed Composition							
Aluminum Al	3.7-4.3	3.7-4.3	3.7-4.3	3.7-4.3	8.0-8.8	10.5-11.5	25.0-28.0
Magnesium Mg	0.02-0.06	0.02-0.06 Ⓐ	0.02-0.06	0.005-0.020	0.010-0.030	0.010-0.030	0.010-0.020
Copper Cu	2.6-3.3*	0.1 max Ⓑ	0.70-1.20	0.1 max	0.8-1.3	0.5-1.2	2.0-2.5
Iron Fe (max)	0.05	0.05	0.05	0.005	0.075	0.075	0.075
Lead Ⓒ Pb (max)	0.005	0.005	0.005	0.003	0.006	0.006	0.006
Cadmium Ⓒ Cd (max)	0.004	0.004	0.004	0.002	0.006	0.006	0.006
Tin Sn (max)	0.002	0.002	0.002	0.001	0.003	0.003	0.003
Nickel Ni	—	—	—	0.005-0.020	—	—	—
Zinc Zn	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Ⓐ The magnesium may be as low as 0.015 percent provided that the lead, cadmium and tin do not exceed 0.003, 0.003 and 0.001 percent, respectively. Ⓑ For the majority of commercial applications, a copper content of up to 0.7 percent will not adversely affect the serviceability of die castings and should not serve as a basis for rejection. Sources: ASTM B86 and ASTM B791. Ⓒ As specified, the chemical composition of zinc and ZA alloys are in compliance with RoHS (the European Union's Directive on Restriction of Hazardous Substances) If the presence of mercury is suspected, analysis shall be made to determine that the amount does not exceed 0.1 weight percent. Hexavalent chromium does not exist in the alloys and therefore meets the 0.1% limit. Ⓓ Registration for REACH (the European Union's Directive on Registration, Evaluation, and Authorization of Chemicals) is not required for die castings, even if coated, since die castings are considered articles. Notification may be required if some contained substances in the die casting or coating exceed the 0.1% total weight of the article level and are listed as SVHC (substances of very high concern).

Note: There are newly developed zinc alloys (a result of through NADCA sponsored research) for elevated temperature creep resistance applications (such as ZCA-9). Contact your alloy producer for more information.

Alloy Data

Typical values based on "as-cast" characteristics for separately die cast specimens, not specimens cut from production die castings.

Table A-3-14 Typical Material Properties: Zn and ZA Alloys

	Zamak Die Casting Alloys				ZA Die Casting Alloys		
Commercial:	No. 2	No. 3 AG-40A	No. 5 AG-41A	No. 7 AG-40B	ZA-8	ZA-12	ZA-27
Mechanical Properties							
Ultimate Tensile Strength							
As-Cast ksi (MPa)	52 (359)	41 (283)	48 (328)	41 (283)	54 (372)	59 (400)	62 (426)
Aged ksi (MPa)	48 (331)	35 (241)	39 (269)	41 (283)	43 (297)	45 (310)	52 (359)
Yield Strength (A)							
As-Cast ksi (MPa)	41 (283)	32 (221)	39 (269)	32 (221)	41-43 (283-296)	45-48 (310-331)	52-55 (359-379)
Aged ksi (MPa)					32 (224)	35 (245)	46 (322)
Compressive Yield Strength (B)							
As-Cast ksi (MPa)	93 (641)	60 (414) (C)	87 (600) (C)	60 (414) (C)	37 (252)	39 (269)	52 (358)
Aged ksi (MPa)	93 (641)	60 (414)	87 (600)	60 (414)	25 (172)	27 (186)	37 (255)
Elongation							
As-Cast % in 2 in. (51mm)	7	10	7	13	6-10	4-7	2.0-3.5
Aged % in 2 in. (51mm)	2	16	13	18	20	10	3
Hardness (D)							
As-Cast BHN	100	82	91	80	100-106	95-105	116-122
Aged BHN	98	72	80	67	91	91	100
Shear Strength							
As-Cast ksi (MPa)	46 (317)	31 (214)	38 (262)	31 (214)	40 (275)	43 (296)	47 (325)
Aged ksi (MPa)	46 (317)	31 (214)	38 (262)	31 (214)	33 (228)	33 (228)	37 (255)
Impact Strength							
As-Cast ft-lb	35	43 (E)	48 (E)	43 (E)	24-35 (E)	15-27 (E)	7-12 (E)
(J)	(47.5)	(58)	(65)	(58)	(32-48)	(20-37)	(9-16)
Aged ft-lb	5	41	40	41	13	14	3.5
Fatigue Strength (F)							
As-Cast ksi (MPa)	8.5 (58.6)	6.9 (47.6)	8.2 (56.5)	6.9 (47.6)	15 (103)	—	21 (145)
Aged ksi (MPa)	8.5 (58.6)	6.9 (47.6)	8.2 (56.5)	6.8 (46.9)	15 (103)	—	21 (145)
Young's Modulus							
psi x 10^6 (GPa)	(G)	(G)	(G)	(G)	12.4 (85.5)	12 (83)	11.3 (77.9)
Physical Properties							
Density							
lb/in³ (g/cm³)	0.24 (6.6)	0.24 (6.6)	0.24 (6.6)	0.24 (6.6)	0.227 (6.3)	0.218 (6.03)	0.181 (5.000)
Melting Range							
°F (°C)	715-734 (379-390)	718-728 (381-387)	717-727 (380-386)	718-728 (381-387)	707-759 (375-404)	710-810 (377-432)	708-903 (372-484)
Specific Heat							
BTU/lb °F (J/kg °C)	0.10 (419)	0.10 (419)	0.10 (419)	0.10 (419)	0.104 (435)	0.107 (450)	0.125 (525)
Coefficient of Thermal Expansion							
μ in/in°F (μ m/m°K)	15.4 (27.8)	15.2 (27.4)	15.2 (27.4)	15.2 (27.4)	12.9 (23.2)	13.4 (24.1)	14.4 (26.0)
Thermal Conductivity							
BTU/ft hr°F (W/m °K)	60.5 (104.7)	65.3 (113)	62.9 (109)	65.3 (113)	66.3 (115)	67.1 (116)	72.5 (122.5)
Electrical Conductivity							
μ Ω in.	25.0	27.0	26.0	27.0	27.7	28.3	29.7
Poisson's Ratio	0.30	0.30	0.30	0.30	0.30	0.30	0.30

(A) 0.2% offset, strain rate sensitive, values obtained at a strain rate of 0.125/min (12.5% per minute). (B) 0.1% offset. (C) Compressive strength. (D) 500 kg load, 10 mm ball. (E) ASTM 23 unnotched 0.25 in. die cast bar. (F) Rotary Bend 5 x 10^8 cycles. (G) Varies with stress level; applicable only for short-duration loads. Use 10^7 as a first approximation. Source: International Lead Zinc Research Organization.

Alloy Data

Die casting alloy selection requires evaluation not only of physical and mechanical properties, and chemical composition, but also of inherent alloy characteristics and their effect on die casting production as well as possible machining and final surface finishing.

This table includes selected die casting and other special characteristics which are usually considered in selecting a zinc alloy for a specific application.

The characteristics are rated from (1) to (5), (1) being the most desirable and (5) being the least. In applying these ratings, it should be noted that all the alloys have sufficiently good characteristics to be accepted by users and producers of die castings. A rating of (5) in one or more categories would not rule out an alloy if other attributes are particularly favorable, but ratings of (5) may present manufacturing difficulties.

The benefits of consulting a custom die caster experienced in casting the zinc alloy being considered are clear.

Table A-3-15 Die Casting and Other Characteristics: Zn and ZA Alloys
(1 = most desirable, 5 = least desirable)

	Zamak Die Casting Alloys						
Commercial: ANSI/AA	No. 2	No. 3 AG-40A	No. 5 AG-41A	No. 7 AG-40B	ZA-8	ZA-12	ZA-27
Resistance to Hot Cracking Ⓑ	1	1	2	1	2	3	4
Pressure Tightness	3	1	2	1	3	3	4
Casting Ease	1	1	1	1	2	3	3
Part Complexity	1	1	1	1	2	3	3
Dimensional Accuracy	4	2	2	1	2	3	4
Dimensional Stability	2	3	3	2	2	2	1
Corrosion Resistance	2	3	3	2	2	2	1
Resistance to Cold Defects Ⓐ	2	2	2	1	2	3	4
Machining Ease & Quality Ⓒ	1	1	1	1	2	3	4
Polishing Ease & Quality	2	1	1	1	2	3	4
Electroplating Ease & Quality Ⓓ	1	1	1	1	1	2	3
Anodizing (Protection)	1	1	1	1	1	2	2
Chemical Coating (Protection)	1	1	1	1	2	3	3

Ⓐ *The ability of alloy to resist formation of cold defects; for example, cold shuts, cold cracks, non-fill "woody" areas, swirls, etc.* Ⓑ *Ability of alloy to withstand stresses from contraction while cooling through the hot-short or brittle temperature range.* Ⓒ *Composite rating based on ease of cutting. Chip characteristics, quality of finish and tool life.* Ⓓ *Ability of the die casting to take and hold an electroplate applied by present standard methods. Source: International Lead Zinc Research Organization.*

Zinc HF Alloy Typical Properties	
Mechanical Properties	
Ultimate Tensile Strength (A)	
As-Cast ksi (MPa)	40 (276)
Aged ksi (MPa)	34 (234)
Yield Strength	
As-Cast ksi (MPa)	35 (241)
Aged ksi (MPa)	29 (200)
Elongation	
As-Cast % in 2 in. (51mm)	5.3
Aged % in 2 in. (51mm)	9.9
Hardness (B)	
As-Cast BHN	93
Aged BHN	71
Impact Strength (C)	
As-Cast ft-lb (J)	28 (38)
Aged ft-lb (J)	21 (28)
Young's Modulus (D)	
psi x 106	13.3
(GPa)	91.7

Physical Properties	
Density	
lb/in3	0.239
(g/cm3)	6.602
Melting Range	
˚F	716-723
(˚C)	380-384
Specific Heat	
BTU/lb ˚F at 68-212 ˚F	0.1
(J/kg ˚C) at 20-100 ˚C	403
Coefficient of Thermal Expansion	
µ in/in˚F at 68-212 ˚F	16.5
(µ m/m˚K) at 20-100 ˚C	26.2
Thermal Conductivity (E)	
BTU/ft hr˚F at 158-252 ˚F	113
(W/m ˚K) at 70-140 ˚C	65.3
Poisson's Ratio	0.30
Solidification Shrinkage (in/in)	0.0117

Zinc HF Alloy Chemical Composition	
Detailed Composition	
Aluminum Al	4.3-4.7
Magnesium Mg	0.01 nominal
Copper Cu	0.03 nominal
Iron Fe	0.03 max
Lead Pb	0.003 max
Cadmium Cd	0.002 max
Tin Sn	0.001 max
Nickel Ni	-
Zinc Zn	Remainder

(A) - Sample cross-section dimensions 0.040 x 0.500 in.; tensile strength increased to 54 ksi when sample cross-section was reduced to 0.020 x 0.300 in.

(B) - Tested under 250 kg weight with 5 mm ball

(C) - Sample dimensions 0.25 x 0.25 x 3 in.

(D) - Calculated using stress-strain curve

(E) - Based on published data for Alloy 7

Note: Samples "as-cast" were tested at 68 ˚F (20 ˚C). Samples "aged" were kept at 203 ˚F (95 ˚C) for 10 days.

7 Selecting An Alloy Family

Overview

Although this product specification standards document addresses copper and metal matrix composites (MMC), the four main alloy families are Aluminum, Zinc, Magnesium, and Zinc-Aluminum. This subsection is presented to assist in selecting an alloy family, which is the precursor to selecting a specific alloy within a family. Information on selecting the specific alloys is presented at the beginning of each alloy family subsection.

Typical considerations in selecting an alloy family include; alloy cost and weight, die casting process cost, structural properties, surface finish, corrosion resistance, bearing properties and corrosion resistance, machinability, thermal properties, and shielding (EMI/electrical conductivity).

Cost & Weight

Alloy cost and weight is an important factor in the overall product cost, therefore the amount or volume of material used should be taken into consideration. Aluminum alloys usually yield the lowest cost per unit volume. Magnesium and zinc can be competitive because they can generally be cast with thinner walls, thereby reducing the volume of alloy needed. If weight minimization is the over-riding factor, magnesium alloys are the choice to make. It should be noted that zinc alloys have a distinct advantage in the production of miniature parts and may be the dominant choice if the casting configuration is of a very small size.

Another important component of the overall product cost is the die casting process. Alloys produced by the hot chamber process such as magnesium and much of the zinc are typically run in smaller die casting machines and at higher production rates then those produced by the cold chamber process such as aluminum and zinc-aluminum.

Production tooling maintenance and replacement costs can be significant. Tooling for zinc generally lasts longer than aluminum and magnesium tooling. This is due primarily to the higher casting temperatures of aluminum and magnesium.

Structural Properties

Each alloy has a unique set of properties. However, if one is in search of one or two properties that are most important for a specific design or interested in which properties are characteristic of an alloy family, the following generalizations may be helpful. Aluminum alloys yield the highest modulus of elasticity. Magnesium alloys offer the highest strength-to-weight ratio and the best dampening characteristics. The zinc alloys offer the highest ductility and impact strength. The ZA alloys offer the highest tensile and yield strength.

Surface Finish and Coatings

Whether a high surface finish is for functional or aesthetic reasons, it is often a requirement. As-cast surface finishes are best achieved with zinc and magnesium alloys. Zinc alloys most readily accept electro-coatings and decorative finishes. The relatively higher temperature resistance of the aluminum alloys makes them best suited for elevated temperature coating processes.

Corrosion Resistance

Corrosion resistance varies from alloy family to alloy family and within an alloy family. If corrosion resistance is a concern, it can be improved with surface treatments and coatings. Refer to the information on selecting specific alloys at the beginning of each alloy family subsection to see which specific alloys yield higher corrosion resistance.

Bearing Properties and Wear Resistance

The ZA alloys and some of the aluminum alloys are more resistant to abrasion and wear than the other die casting alloys. As for corrosion resistance, abrasion and wear resistance can be improved with surface treatments and coatings.

Machinability

Even though die castings can be produced to net or near-net shape, machining is often required. When required, machining is easily accomplished on all of the die casting alloys. Magnesium, however offers the best machinability in terms of tool life, achievable finish, low cutting forces and energy consumption.

Thermal Properties and Shielding

Aluminum alloys are typically the best choice for heat transfer applications with zinc alloys as a close second. Aluminum and zinc alloys are top choices for electrical conductivity. Of the die casting alloys, magnesium alloys offer the best shielding of electromagnetic emissions.

8 Quick Guide to Alloy Family Selection

	Aluminum	Magnesium	Zinc	Zinc-Aluminum
Cost	Lowest cost per unit volume.	Can compete with aluminum if thinner wall sections are used. Faster hot-chamber process possible on smaller parts.	Effective production of miniature parts. Significant long-term tooling cost savings (tooling lasts up to 10 times longer than aluminum).	
Weight	Second lowest in density next to magnesium.	Lowest density.	Heaviest of die cast alloys, but castable with thinner walls than aluminum, which can offset the weight disadvantage.	Weight reduction as compared with the Zinc family of alloys.
Structural Properties	High Modules of Elasticity	Highest strength-to-weight ration, best vibration dampening characteristics.	Highest ductility and impact strength.	Highest tensile and yield strength. High Modules of Elasticity
Surface Finish & Coatings	Good choice for coating processes that require high temperatures.	Good as-cast surface finishes can be achieved.	Best as-cast surface finish readily accepts electro-coatings and decorative finishes.	
Wear Resistance	*	*	*	Best as-cast wear resist.
Corrosion Resistance	*	*	*	*
Machinability	Good	Best machinability in terms of tool-life, achievable finish, low cutting forces and energy consumption.	Good	Good
Thermal Properties, Conductive, & Electromagnetic Shielding	Best choice for heat transfer Good electrical conductivity Electromagnetic shielding	Electromagnetic shielding	Best electrical conductor. Good heat transfer Electromagnetic shielding	Electromagnetic shielding

** Wear and corrosion resistance can be improved in all alloys through surface treatments and coatings.*

9 Elevated Temperature Properties

Elevated Temperature Properties of Aluminum —				
Alloy	**Temp °F (°C)**	**Tensile ksi (MPa)**	**Yield ksi (MPa)**	**Elong %**
360	-112° (-80°)	50 (345)	25 (172)	2
	-18° (-26°)	48 (330)	25 (172)	2
	68° (20°)	44 (303)	25 (172)	2.5
	212° (100°)	44 (303)	25 (172)	2.5
	300° (150°)	35 (241)	24 (166)	4
	400° (205°)	22 (152)	14 (97)	8
	500° (260°)	12 (83)	7.5 (52)	20
	600° (315°)	7 (48)	4.5 (31)	35
	700° (370°)	4.5 (31)	3 (21)	40
A360	-112° (-80°)			
	-18° (-26°)			
	68° (20°)	46 (317)	24 (166)	3.5
	212° (100°)	43 (296)	24 (166)	3.5
	300° (150°)	34 (234)	23 (159)	5
	400° (205°)	21 (145)	13 (90)	14
	500° (260°)	11 (76)	6.5 (45)	30
	600° (315°)	6.5 (45)	4 (28)	45
	700° (370°)	4 (30)	2.5 (15)	45
380	-112° (-80°)	49 (338)	23 (159)	2.5
	-18° (-26°)	49 (338)	23 (159)	3
	68° (20°)	46 (317)	23 (159)	3.5
	212° (100°)	45 (310)	24 (166)	4
	300° (150°)	34 (234)	22 (152)	5
	400° (205°)	24 (165)	16 (110)	8
	500° (260°)	13 (90)	8 (55)	20
	600° (315°)	7 (48)	4 (28)	30
	700° (370°)	4 (28)	2.5 (17)	35
A380	-112° (-80°)			
	-18° (-26°)			
	68° (20°)	47 (324)	23 (159)	3.5
	212° (100°)	44 (303)	23 (159)	5
	300° (150°)	33 (228)	21 (145)	10
	400° (205°)	23 (159)	15 (103)	15
	500° (260°)	12 (83)	7 (48)	30
	600° (315°)	6 (41)	6 (41)	45

The values in this table are from various sources and represent typical values. These values do not represent design minimums and should be used for reference only.

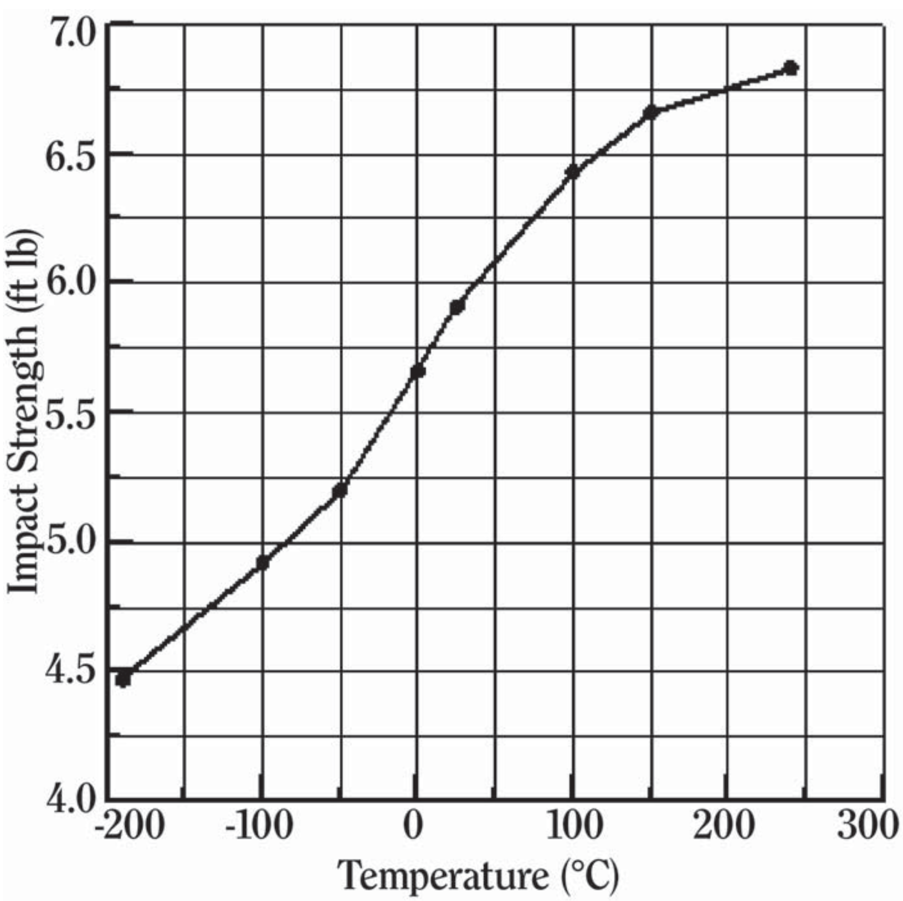
Elevated Temperature Properties of Aluminum —				
Alloy	**Temp °F (°C)**	**Tensile ksi (MPa)**	**Yield ksi (MPa)**	**Elong %**
384	-112° (-80°)			
	-18° (-26°)			
	68° (20°)	48 (330)	24 (165)	2.5
	212° (100°)	44 (303)	24 (165)	2.5
	300° (150°)	38 (262)	24 (165)	5
	400° (205°)	26 (179)	18 (124)	6
	500° (260°)	14 (97)	9 (62)	25
	600° (315°)	7 (48)	4 (28)	45
390	-112° (-80°)			
	-18° (-26°)			
	68° (20°)	46 (317)	36 (250)	< 1
	212° (100°)	41 (283)	27 (186)	1
	300° (150°)	37 (255)		1
	400° (205°)	29 (200)		1
	500° (260°)	19 (131)		2
	600° (315°)			
13	-112° (-80°)	45 (310)	21 (145)	2
	-18° (-26°)	44 (303)	21 (145)	2
	68° (20°)	42 (290)	19 (131)	3.5
	212° (100°)	37 (255)	19 (131)	5
	300° (150°)	32 (221)	19 (131)	8
	400° (205°)	24 (166)	15 (103)	15
	500° (260°)	13 (90)	9 (62)	29
	600° (315°)	7 (48)	5 (34)	35
43	-112° (-80°)	35 (241)	16 (110)	12
	-18° (-26°)	35 (241)	16 (110)	13
	68° (20°)	33 (228)	14 (97)	9
	212° (100°)	28 (193)	14 (97)	9
	300° (150°)	22 (152)	14 (97)	10
	400° (205°)	16 (110)	12 (83)	25
	500° (260°)	9 (62)	6 (41)	30
	600° (315°)	5 (34)	4 (28)	35
218	-112° (-80°)	51 (352)	29 (200)	14
	-18° (-26°)	50 (345)	29 (200)	10
	68° (20°)	44 (310)	28 (193)	5
	212° (100°)	40 (276)	25 (172)	8
	300° (150°)	32 (221)	21 (145)	25
	400° (205°)	21 (145)	15 (104)	40
	500° (260°)	13 (90)	9 (62)	45
	600° (315°)	9 (62)	5 (34)	46

The values in this table are from various sources and represent typical values. These values do not represent design minimums and should be used for reference only.

Impact Strength of Aluminum A380 Die Casting Alloy as a Function of Temperature		
Temperature (°C)	Impact Strength (ft-lb)	Standard Deviation
-190	4.47	0.92
-100	4.92	0.80
-50	5.20	0.90
0	5.66	0.93
25	5.91	0.95
100	6.43	0.89
150	6.66	0.94
240	6.83	0.88

The values in this table are from various sources and represent typical values. These values do not represent design minimums and should be used for reference only.

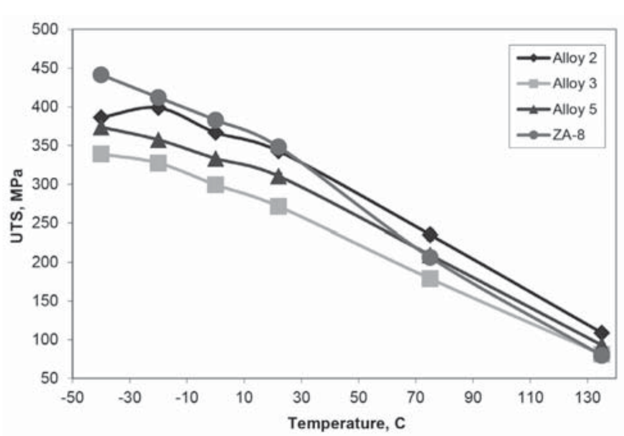
A380 Impact Strength at Temperature



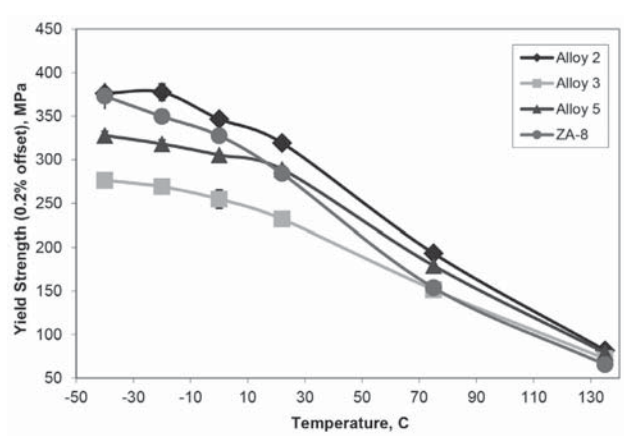
Elevated Temperature Properties of Zinc			
Alloy	**Temp °F (°C)**	**Tensile ksi (MPa)**	**Yield ksi (MPa)**
2	-40° (-40°)	56.0 (386)	54.5 (376)
	-4° (-20°)	57.9 (399)	54.8 (378)
	32° (0°)	53.2 (367)	50.3 (347)
	72° (22°)	49.7 (343)	46.3 (319)
	167° (75°)	34.1 (235)	28.0 (193)
	275° (135°)	15.8 (109)	11.9 (82)
3	-40° (-40°)	49.2 (339)	40.0 (276)
	-4° (-20°)	47.4 (327)	39.0 (269)
	32° (0°)	43.4 (299)	37.0 (255)
	72° (22°)	39.3 (271)	33.6 (232)
	167° (75°)	26.0 (179)	22.0 (152)
	275° (135°)	11.7 (81)	10.4 (72)
5	-40° (-40°)	54.2 (374)	47.6 (328)
	-4° (-20°)	51.8 (357)	46.1 (318)
	32° (0°)	48.3 (333)	44.2 (305)
	72° (22°)	45.0 (310)	41.9 (289)
	167° (75°)	30.3 (209)	26.0 (179)
	275° (135°)	11.7 (81)	11.5 (79)
8	-40° (-40°)	64.0 (441)	54.1 (373)
	-4° (-20°)	59.8 (412)	50.8 (350)
	32° (0°)	55.5 (383)	47.6 (328)
	72° (22°)	50.5 (348)	41.2 (284)
	167° (75°)	29.9 (206)	22.3 (154)
	275° (135°)	11.6 (80)	9.6 (66)

The values in this table are from Omer Dogan and Karol Schrems, "Determination of Mechanical Properties of Die Cast Zinc Alloys for Automotive Applications", Final Report, prepared for International Lead Zinc Research Organization, NETL-A-TR-2007-08, work performed under CRADA 05-05 ILZRO, March 2007.. These values do not represent design minimums and should be used for reference only.

Zinc Tensil Strength at Temperature



Zinc Yield Strength at Temperature



10 Property Comparison

Competitive Performance Chart

Alloy Property	ZA-MAK 3**	ZA-MAK 5**	ZA-8***			ZA-12***			ZA-27***	
	Die Cast	Die Cast	Sand Cast	Perm Mold	Die Cast	Sand Cast	Perm Mold	Die Cast	Sand Cast	Perm Mold
Mechanical Properties										
Ultimate Tensile Strength										
psi x10^3 (MPa)	41 (283)	48 (331)	38 (263)	35 (240)	54 (374)	43 (299)	48 (328)	59 (404)	61 (421)	64 (441)
Yield Strength										
psi x10^3 (MPa)	32 (221)	33 (228)	29 (198)	30 (208)	42 (290)	31 (211)	39 (268)	46 (320)	54 (371)	55 (376)
Elongation										
% in 2in.	10	7	1.7	1.3	8	1.5	2.2	5	4.6	2.5
Young's Modulus										
psi x10^6 (MPa x 10^3)	≥ 12.4**** (≥ 85.5)	≥ 12.4**** (≥ 85.5)	12.4 (85.5)	12.4 (85.5)	12.4 (85.5)	12.0 (82.7)	12.0 (82.7)	12.0 (82.7)	11.3 (77.9)	11.3 (77.9)
Torsional Modulus										
psi x10^6 (MPa x 10^3)	≥ 4.8 (≥ 33.1)	≥ 4.8 (≥ 33.1)	4.8 (33.1)	4.8 (33.1)	4.8 (33.1)	4.6 (31.7)	4.6 (31.7)	4.6 (31.7)	4.3 (29.6)	4.3 (29.6)
Shear Strength										
psi x10^3 (MPa)	31 (214)	38 (262)	N/A	35 (241)	40 (275)	37 (253)	≥ 35 (≥241)	43 (296)	42 (292)	N/A
Hardness										
(Brinell)	82	91	85	87	103	94	89	100	113	114
Impact Strength										
ft-lb (J)	43 (58)	48 (65)	15 (20)	N/A	31 (42)	19 (25)	N/A	21 (29)	35 (48)	N/A
Fatigue Strength Rotoary Bedn (5 x 10^6 cycles)										
psi x10^3 (MPa)	6.9 (47.6)	8.2 (56.5)	N/A	7.5 (57.1)	15 (103)	15 (103)	N/A	17 (117)	25 (172)	N/A
Compressive Yield Strength 0.1% Offset										
psi x10^3 (MPa)	60 (414)	87 (600)	29 (199)	31 (210)	37 (252)	33 (230)	34 (235)	39 (269)	48 (330)	N/A

* Minimum Properties
** Complies with ASTM specification B86.
*** Complies with ASTM specification B669.
**** Varies with stress level; applicable only for shot-duration loads.

		Aluminum					Magnesium		Iron		Plastic	
		380	319	356-T6	713 -F*	6061-T6	AZ-91D	AM60B	Class 30	32510		
	Die Cast	Die Cast	Sand Cast	Sand Cast	Sand Cast	Wrought	Die Cast	Die Cast	Gray Cast Iron	Malleable Iron	ABS	Nylon 6 (30% Glass Filled)
	62 (426)	47 (324)	27 (186)	33 (228)	32 (220)	45 (310)	34 (234)	32 (220)	31 (214)	50 (345)	8	22
	54 (371)	24 (165)	18 (124)	24 (165)	22 (150)	40 (276)	23 (159)	19 (130)	18 (124)	32 (221)		
	2.5	3.0	2	3.5	3	17	3	7	nil	10		7
	11.3 (77.9)	10.3 (71.0)	10.7 (73.8)	10.5 (72.4)	—	—	6.5 (44.8)	6.5 (44.8)	13-16 (89.6)	25 (172.4)	1	1.5
	4.3 (29.6)	3.9 (26.9)	4.0 (27.6)	3.9 (26.9)	—	—	2.4 (16.5)	N/A	N/A	9.3 (64.1)		
	47 (325)	27 (186)	22 (152)	26 (179)	—	30 (—)	20 (138)	N/A	43 296	45 (310)		
	119	80	70	70	60-90	95	63	62	170-269	110-156		
	9 (13)	3 (4)	4 (5)	8 (11)	—	—	2.7 (3.7)	5 (6)	nil	40-65 (54-88)		
	21 (145)	20 (138)	10 (69)	8.5 (58.6)	—	14 (—)	14 (97)	10 (70)	14 (97)	28 (193)	0.15	0.3
	52 (359)	N/A	19 (131)	25 (172)	—	—	23 (159)	19 (130)	109 (752)	N/A		

Alloy Data

Competitive Performance Chart										
Alloy Property	ZA-MAK 3**	ZA-MAK 5**	ZA-8***			ZA-12***			ZA-27***	
	Die Cast	Die Cast	Sand Cast	Perm Mold	Die Cast	Sand Cast	Perm Mold	Die Cast	Sand Cast	Perm Mold
Physical Properties										
Density										
lb/in³ (Kg/m³)	0.24 (6600)	0.24 (6600)	0.227 (6300)	0.227 (6300)	0.227 (6300)	0.218 (6030)	0.218 (6030)	0.218 (6030)	0.181 (5000)	0.181 (5000)
Melting Range										
°F (°C)	718-728 (381-387)	717-727 (380-386)	707-759 (375-404)	707-759 (375-404)	707-759 (375-404)	710-810 (377-432)	710-810 (377-432)	710-810 (377-432)	708-903 (376-484)	708-903 (376-484)
Electrical Conductivity										
% IACS	27	26	27.7	27.7	27.7	28.3	28.3	28.3	29.7	29.7
Thermal Conductivity										
BTU/ft hr°F (W/m °K)	65.3 (113.0)	62.9 (108.9)	66.3 (114.7)	66.3 (114.7)	66.3 (114.7)	67.1 (116.1)	67.1 (116.1)	67.1 (116.1)	72.5 (125.5)	72.5 (125.5)
Coefficient of Thermal Expansion										
1/°F x 10^{-6} (1/°C x 10^{-6})	15.2 (27.4)	15.2 (27.4)	12.9 (23.3)	12.9 (23.3)	12.9 23.3)	13.4 (24.2)	13.4 (24.2)	13.4 (24.2)	14.4 (26.0)	14.4 (26.0)
Pattern Shrinkage										
in/in or mm/mm	0.006	0.006	0.010	0.010	0.007	0.013	0.013	0.0075	0.013	0.013

Alloy Data

		Aluminum					Magnesium		Iron	
		380	319	356-T6	713 -F*	6061-T6	AZ-91D	AM60B	Class 30	32510
	Die Cast	Die Cast	Sand Cast	Sand Cast	Sand Cast	Wrought	Die Cast	Die Cast	Gray Cast Iron	Malleable Iron
	0.181 (5000)	0.098 (2713)	0.101 (2796)	0.097 (2685)	0.100 (—)	—	0.066 (1827)	0.065 (1790)	0.25 (6920)	0.26 (7198)
	708-903 (376-484)	1000-1100 (538-593)	960-1120 (516-604)	1035-1135 (557-613)	1100-1180 (593-638)	1080-1205 (—)	875-1105 (468-596)	1005-1140 (540-615)	>2150 (>1177)	>2250 (>1232)
	29.7	27	27	39	30	43	11.5	N/A	N/A	6
	72.5 (125.5)	55.6 (96.2)	65.5 (113.4)	87 (151)	—	97 (168)	41.8 (72.3)	36 (62)	28-30 (48-52)	N/A
	14.4 (26.0)	11.8 (21.2)	11.9 (21.4)	11.9 (21.4)	13.4 (24.2)	13.1 (23.7)	14 (25.2)	14.2 (25.6)	6.7 (12.1)	6.6 (11.9)
	0.008	0.006	N/A	N/A	—		N/A	N/A	0.010	0.010

11 Cross Reference: Alloy Designations and Alloy Compositions

Cross Reference of Equivalent Aluminum Alloy Specifications and Designations												
ANSI ASTM or AA Number	Former Designation	UNS Unified No. System	SAE	Old ASTM	QQ-A-371c.	Canada	United Kingdom	Japan	Germany	ISO	EN 1706	China
360	360	AO3601	309	SG 100B	360	—	—	JIS H5302 ADC3	—	—	—	—
A360	A360	AO3602	309	SG 100A	360	—	—	—	GD-AlSi10Mg	Al-Si10Mg	EN AC-43400	YL104
380	380	AO3801	306.308	SC84A-B	380	143	—	JIS H5302 ADC10	—	—	—	—
A380	A380	AO3802	306.308	SC84-A	380	—	LM24	—	GD-AlSi8Cu	Al-Si-8Cu3Fe	EN AC-46500	YL112
383	383	AO3831	306.308	—	—	—	LM2	JIS H5302 ADC12	—	—	EN AC-46100	YL113
384	384	AO3841	313	SC114A	384	A143	LM26	—	—	—	—	—
A384	A384	AO3842	303	SC114A	384	—	—	—	—	—	—	—
390	—	AO3902	—	—	—	—	LM28	—	—	—	—	—
B390	—	AO3901	—	—	—	—	—	—	—	—	—	—
413	13	AO4131	305	S12A.B	13	162	LM6	JIS H5302 ADC1	—	—	—	—
A413	A13	A14132	305	S12A	13	—	—	—	—	AlSi-12CuFe	EN AC-47100	YL108
443	43	AO4431	35	S5B	43	123	LM18	—	—	—	—	—
518	218	AO5181	—	—	218	340	—	—	—	—	—	—

International Aluminum Alloy Compositions

JAPAN

	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Each	Total
JIS H5302 ADC1	1.0	0.3	11.0-13.0	1.3	0.3	0.5	0.5	—	0.1	—	—	—
JIS H5302 ADC3	0.6	0.4-0.6	9.0-10.0	1.3	0.3	0.5	0.5	—	0.1	—	—	—
JIS H5302 ADC10	2.0-4.0	0.3	7.5-9.5	1.3	0.3	0.5	1.0	—	0.3	—	—	—
JIS H5302 ADC12	1.5-3.5	0.3	9.6-12.0	1.3	0.3	0.5	1.0	—	0.3	—	—	—

UNITED KINGDOM

B.S.1490	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Others
LM2	0.7-2.5	0.30	9.0-11.5	1.0	0.5	0.5	2.0	0.3	0.2	0.2	—
LM6	0.1	0.10	10.0-13.0	0.6	0.5	0.1	0.1	0.1	0.05	0.2	—
LM18	0.1	0.10	4.5-6.0	0.6	0.5	0.1	0.1	0.1	0.05	0.2	—
LM24	3.0-4.0	0.30	7.5-9.5	1.3	0.5	0.5	0.3	0.3	0.2	0.2	—
LM26	2.0-4.0	0.5-1.5	8.5-10.5	1.2	0.5	0.1	0.2	0.2	0.1	0.2	—

GERMANY

	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Each	Total
GD-Al-Si8Cu3	2.0-3.5	0-0.3	7.5-9.5	1.3	0.2-0.5	0.3	0.7	0.2	0.1	0.15	0.05	0.15
GD-Al-Si10Mg	0.10	0.20-0.50	9.0-11.0	1.0	0-0.4	—	0.1	—	—	0.15	0.05	0.15

ISO

	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Each
Al-Si8Cu3Fe	2.5-4.0	0.3 max	7.5-9.5	1.3 max	0.6 max	0.5 max	1.2 max	0.3 max	0.2 max	0.2 max	0.5 max
Al-Si10Mg	0.1 max	0.15-0.40	9.0-11.0	0.6 max	0.6 max	0.05 max	0.1 max	0.05 max	0.05 max	0.2 max	—

EUROPEAN STANDARD EN 1706

	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Each*	Total*
EN AC-43400	0.1	0.20-0.50	9.0-11.0	1.0	0.55	0.15	0.15	0.15	0.05	0.20	—	—
EN AC-46100	1.5-2.5	0.3	10.0-12.0	1.1	0.55	0.45	1.7	0.25	0.15	0.25	0.05	0.25
EN AC-46500	2.0-4.0	0.05-0.55	8.0-11.0	1.3	0.55	0.55	3.0	0.35	0.15	0.25	0.05	0.25
EN AC-47100	0.7-1.2	0.35	10.5-13.5	1.3	0.55	0.30	0.55	0.20	0.10	0.20	0.05	0.25

*AC=Component cast in aluminum *=other trace elements*

China

	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti
YZA1Si10Mg	≤0.3	0.17--0.3	8-10.5	≤1.0	0.2-0.5	—	≤0.3	≤0.05	≤0.01	—
YZA1Si12Cu2	1-2	0.4--1	11-13	≤1.0	0.3-0.9	≤0.05	≤1.0	≤0.05	≤0.01	—
YZA1Si9Cu4	3-4	≤0.3	7.5-9.5	≤1.2	≤0.5	≤0.5	≤1.2	≤0.1	≤0.1	—
YZA1Si11Cu3	1.5-3.5	≤0.3	9.6-12	≤1.2	≤0.5	≤0.5	≤1.0	≤0.1	≤0.1	—

Alloy Data

CROSS REFERENCE OF EQUIVALENT MAGNESIUM ALLOY SPECIFICATIONS AND DESIGNATIONS		
U.S.A STM	ISO 16220	EN-1753/1997
AZ91D	MgAl9Zn1	AZ91
AM60B	MgAl6Mn	AM60
AM50A	MgAl5Mn	AM50
AM20	MgAl2Mn	AM20
AS21	MgAl2Si	AS21
AS41B	MgAl4Si	AS41

International Magnesium Alloy Composition									
U.S. ASTM	%Al	%Zn	%Mn	%Si	%Fe	%Cu	%Ni	0 Each	Fe/Mn Max.
AZ91D	8.3-9.7	0.35-1.0	0.15-0.50	0.10	0.005	0.030	0.002	0.01	0.032***
AM60B	5.5-6.5	0.22	0.24-0.6	0.10	0.005	0.010	0.002	0.02	0.021**
AM50A	4.4-5.4	0.22	0.26-0.6	0.10	0.004	0.010	0.002	0.02	0.015**
AM20	—	—	—	—	—	—	—	—	—
AS21	—	—	—	—	—	—	—	—	—
AS41B	3.5-5.0	0.12	0.35-0.7	0.50-1.5	0.0065	0.02	0.002	0.02	0.010**

ISO 16220									
MgAl9Zn1	8.3-9.7	0.35-1.0	0.15-0.50	0.10	0.005	0.030	0.002	0.01	0.032**
MgAl6Mn	5.5-6.5	0.2 0.2	0.24-0.60	0.10	0.005	0.010	0.002	0.01	0.021*
MgAl5Mn	4.4-5.5	0.2	0.26-0.60	0.10	0.004	0.010	0.002	0.01	0.015*
MgAl2Mn	1.6-2.6	0.2	0.33-0.70	0.10	0.004	0.010	0.002	0.01	0.012*
MgAl2Si	1.8-2.6	0.2	0.18-0.70	0.7-1.2	0.004	0.010	0.002	0.01	0.022*
MgAl4Si	3.5-5.0	0.2	0.18-0.70	0.5-1.5a	0.004	0.010	0.002	0.01	0.022*

EN-1753/1997									
AZ91	8.3-9.7	0.35-1.0	min. 0.1	0.10	0.005	0.030	0.002	0.01	—
AM60	5.5-6.5	0.2	min. 0.1	0.10	0.005	0.010	0.002	0.01	—
AM50	4.4-5.5	0.2	min. 0.1	0.10	0.005	0.010	0.002	0.01	—
AM20	1.6-2.6	0.2	min. 0.1	0.10	0.005	0.010	0.002	0.01	—
AS21	1.8-2.6	0.2	min. 0.1	0.7-1.2	0.005	0.010	0.002	0.01	—
AS41	3.5-5.0	0.2	min. 0.1	0.50-1.5	0.005	0.010	0.002	0.01	—

Cross Reference of Equivalent Zinc Alloy Specifications and Designations									
U.S. Commercial	ASTM	SAE	Canada	United Kingdom	Japan	Germany	ISO	EN	UNS
#2	AC43A	-	-	-	-	-	ZP0430	ZnAl4Cu3	Z35541
#3	AG40A	903	AG40	A	Class 2	Z400	ZP0400	ZnAl4	Z33521
#5	AC41A	905	-	B	Class 1	Z410	ZP0410	ZnAl4Cu1	Z35531
ZA-8	ZA8	-	-	-	-	-	ZP0810	ZnAl8Cu1	Z35636
ZA-12	ZA12	-	-	-	-	-	ZP1110	ZnAl11Cu1	Z35631
ZA-27	ZA27	-	-	-	-	-	ZP2720	ZnAl27Cu2	Z35841

International Zinc Alloy Composition									
EN 12844	% Al	% Cu	% Mg	% Pb	% Cd	% Sn	% Fe	% Ni	% Si
ZnAl4-P	3.7-4.3	0.1	0.025-0.06	0.005	0.005	0.002	0.05	0.02	0.03
ZnAl4Cu1-P	3.7-4.3	0.7-1.3	0.4-0.6	0.005	0.005	0.002	0.05	0.02	0.03

Chemical Composition of Zinc Alloy Castings								
ISO 15201	Short Designation	% Al	% Cu	% Mg	% Pb	% Cd	% Sn	% Fe
ZP0430	ZP2	3.7-4.3	2.6-3.3	.02-.06	.005	.004	.002	.05
ZP0400	ZP3	3.7-4.3	.1	.02-.06	.005	.004	.002	.05
ZP0410	ZP5	3.7-4.3	.7-1.2	.02-.06	.005	.004	.002	.05
ZP0810	ZP8	8.0-8.8	.8-1.3	.01-.03	.006	.006	.003	.075
ZP1110	ZP12	10.5-11.5	.5-1.2	.01-.03	.006	.006	.003	.075
ZP2720	ZP27	25.0-28.0	2.0-2.5	.01-.02	.006	.006	.003	.075

Engineering & Design: Coordinate Dimensioning

Engineering & Design: Coordinate Dimensioning

Tolerance in any part is a three-dimensional characteristic. Many different types of tolerance will be discussed throughout sections 4A and 4B. Most feature tolerances will have Linear Tolerance in combination with Projected Area Tolerance to give an overall feature "volumetric" tolerance like Parting Line, Moving Die Component (MDC) and Angularity Tolerances.

Projected Area is the area of a specific feature projected into a plane. For parting line and parting line shift the Projected Area is the open area of the die cavity in the parting line plane. For example, if a die half was laid down and filled with liquid, the surface of the liquid at the parting line is the Projected Area. For the MDC, the Projected Area is determined using the same method as for a parting line. See the applicable figures in the appropriate sections for Projected Area.

Linear Tolerance is calculated from a line perpendicular to any feature. The Parting Line line is the total depth of molten material on both die halves, which is perpendicular to the parting line plane. The MDC line is the length of the core slide which is perpendicular to the head of the core slide. Length of a core slide is determined from the point where the core first engages the die to its full insertion point.

Projected Area Tolerance plus Linear Tolerance equals feature tolerance (tolerance of the volume of the part).

See Volumetric Tolerance diagram on the facing page.

Frequently Asked Questions (FAQ)

1) What is the difference between Standard and Precision Tolerances?
   See pages 4A-3 and 4A-4, Standard and Precision Tolerances.
2) What is a Parting Line Shift?
   See pages 4A-19 and 4A-20, Parting Line Shift.
3) If my casting requires machining, how should the casting be dimensioned?
   See page 4A-40 and 4A-41, Machining Stock Allowances.
4) How large should a cast-in hole be if threads need to be tapped or formed in the casting?
   See page 4A-34 and 4A-35, Cored Holes for Cut Threads. Also see pages 4A-36 and 4A-37, Cored Holes for Formed Threads.
5) What type of draft should be used on exterior and interior walls?
   See pages 4A-21 through 4A-24, Draft Requirements.
6) What type of flatness tolerance can be expected on a cast surface?
   See pages 4A-29 and 4A-30, Flatness Requirements.

1 Introduction

Die casting requires a specific degree of precision for the end product to meet the requirements of form, fit and function. However there is a cost associated with increased precision.

Some of the costs associated with a higher degree of tolerance include:

- *Decreased die life due to wear that puts die dimensions outside of specified high precision tolerance*
- *More frequent die repair or replacement to maintain a high precision tolerance*
- *More frequent shutdown (shorter production runs) to repair or replace dies*
- *More frequent part or die inspections to ensure high precision tolerance is maintained*
- *Potential for higher scrap rate for not maintaining specified high precision tolerance*

A good casting design will take into account not only the precision required to meet the requirements of form, fit and function, but will also take into account maximizing tolerance to achieve a longer die life and longer production runs with less inspections. This will result in less potential for scrap and more acceptable parts because the tolerance range for acceptable parts has increased.

In section 4A tolerance will be specified in two values. Standard Tolerance is the lesser degree of precision that will meet most applications of form, fit and function. It is specified in thousandths of an inch (0.001) or hundredths of a millimeter (0.01). Degree of variation from design specified values is larger than that of Precision Tolerance as shown in graphical representation at the end of section 4A.

Precision Tolerance is a higher degree of precision used for special applications where form, fit and function are adversely affected by minor variations from design specifications. Precision Tolerance is also specified in thousandths of an inch or hundredths of a millimeter. However, its variation from design specified values is less than that of Standard Tolerances.

Examples of tolerance application may be an engine casting that uses Standard Tolerance. Form, fit and function are not critical since moving parts will be encased in sleeves that are cast into place. Variations in size will be filled with cast metal.

Standard Tolerance meets the criteria for this application as part of the design. However a gas line fitting may require a higher degree of precision so that mating parts fit together to prevent leaks. Precision gas fittings may cost more to produce because of the higher degree of precision that must be maintained.

Degree of precision depends on the applications of form, fit and function which resides with the design engineer's expectation of part performance.

Cast components can be specified and produced to an excellent surface finish, close dimensional tolerances and to minimum draft, among other characteristics.

All of the capabilities of the casting process, specified to maximum degree, will rarely, if ever, be required in one cast part. For the most economical production, the design engineer or specifier should attempt to avoid such requirements in a single component.

It is important for the product designer and engineer to understand precisely how today's die casting process can be specified in accordance with the capabilities of the die casting industry.

Engineering & Design: Coordinate Dimensioning

2 Section Objectives

The Engineering and Design Sections of this document are prepared to aid product specifiers in achieving the most cost-effective results through net-shape and near-net-shape casting production. They present both English and Metric values on the same page.

Section 4A presents standard/precision tolerances and other specifications for die cast parts ranging from a fraction of an inch (several millimeters) to several feet (meter) in size. Material weight ranges from a fraction of an ounce (several milligrams) to thirty pounds (kilograms) or more.

Section 4B presents standard/precision tolerances and other specifications for miniature die cast parts ranging from hundredths of an inch (tenths of a millimeter) to several inches (several centimeters) in size. Material weights ranging from a fraction of an ounce (several milligrams) to about 16 ounces (454 grams).

Section 5 presents Geometric Dimensioning, which provides guidelines for applying tolerances to cast part specifications.

These sections provide information for developing the most economically produced design that meets the specifications of form, fit and function.

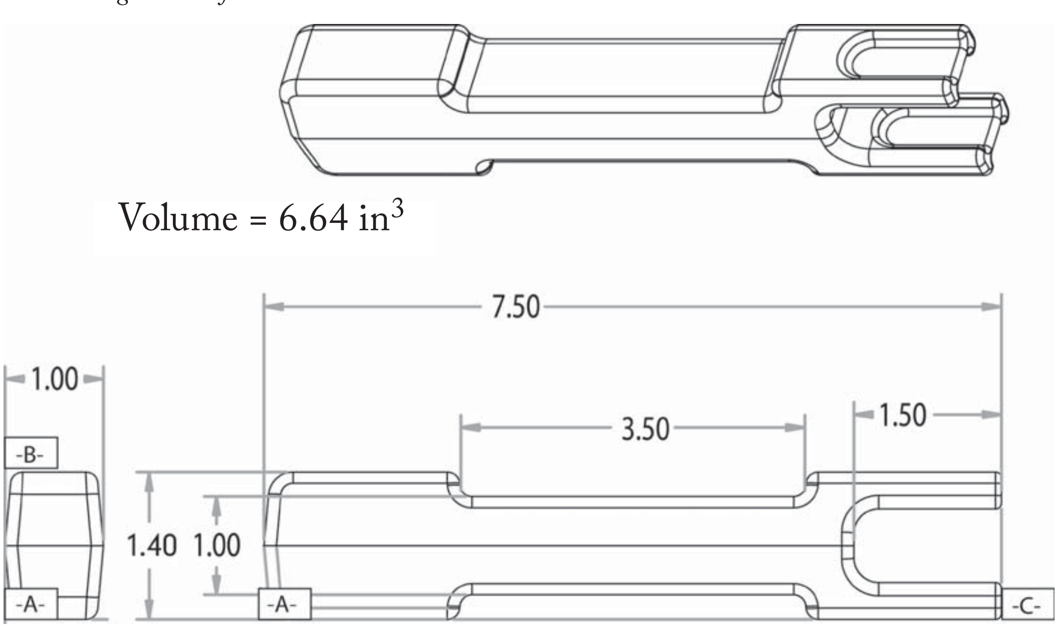
3 Standard and Precision Tolerances

As noted in the contents for this section, seven important sets of tolerancing guidelines are presented here as both "Standard" and "Precision" Tolerances:

- *Linear dimensions*
- *Dimensions across parting Lines*
- *Dimensions formed by moving die components (MDC)*
- *Angularity*
- *Draft*
- *Flatness*
- *Cored holes for threads*

The following features are only specified in Standard Tolerance. Unlike the features above, parts that exceed the following tolerances will not meet the requirements of form, fit and function. These features are specified at the maximum tolerance to meet their requirements. These features include:

- *Concentricity*
- *Parting Line Shift*



Volumetric Tolerance for Across Parting Line Features

(See diagram on this page.) Parting Line Projected Area is defined by the horizontal center line shown in the figure below. Its dimensions are 1.00 inch wide by (7.50 - 1.50) inches long. The Projected area is (1.00 x 6.00) or 6.00 in. sq. This is the surface area used for features across the parting line. Tolerance is expressed in inches.

Linear Dimension (depth of cavity on both die halves) is 1.40 inches. This is the linear dimension used to determine Linear Tolerance.

Feature Tolerance is Projected Area Tolerance plus Linear Area Tolerance.

Graphical Representation

Throughout section 4A there is graphical representation of specific feature tolerances. Precision tolerances are generally closer to design specifications than standard tolerances. The x-axis along y-axis at zero indicates actual design specification. Graph lines indicate the maximum allowable deviation from design specification.

Standard Tolerances

Standard Tolerances cover expected values consistent with high casting cycle speeds, uninterrupted production, reasonable die life and die maintenance costs, as well as normal inspection, packing and shipping costs.

Such tolerances can normally be achieved by the widely available production capabilities of casters practicing standard methods and procedures. Conformity to these standards by designers assures the most predictable service and lowest cost.

Precision Tolerances

Critical requirements for dimensional accuracy, draft, etc.., beyond the Standard Tolerances presented, can be specified when required.

Precision Tolerances are presented on the page following the Standard Tolerances for the same characteristic. The values shown for Precision Tolerances represent greater casting accuracy. See graphical comparison of Standard and Precision Tolerances throughout section 4A. Part precision tolerances involve extra precision in die construction and/or special process controls during production. The use of new technologies and equipment aid in maintaining Precision Tolerance.

While early consultation with the caster can sometimes result in selected special precision requirements being incorporated with little additional cost, such tolerances should be specified only where necessary.

It should be noted that the tolerances shown must, of necessity, be guidelines only—highly dependent on the particular shape, specific features and wall thickness transitions of a given part design. These factors, under the control of the product designer, greatly influence the ability of the casting process to achieve predetermined specifications in the final cast part.

Where a number of critical requirements are combined in a single casting, early caster evaluation of a proposed design is essential. Design modifications for more cost-efficient casting can nearly always be made. Without such feedback, additional costs can usually be expected and the design, as originally planned, may not be producible by die casting.

When specific designs are examined, tolerances even closer than the Precision Tolerances shown can often be held by repeated production sampling and recutting of the die casting die, together with production capability studies. While such steps will result in additional tooling and production costs, the significant savings that can result by eliminating substantial secondary machining and/or finishing operations can prove highly cost effective.

When attempting to hold tolerances closer than Precision Tolerances steel safe practrices should be utilized when building dies and tooling.

4 Production Part Technologies

This section presents advantages and limitations of various production technologies for a simple part such as the one shown in Fig. 4A-1. The section that follows presents the die cast alternative and its advantages and limitations.

Metal Stamping Alternative

This part design, as pictured in Fig. 4A-1 and if designed to a minimum thickness without additional complexities, could be considered for volume production by the metal stamping process.

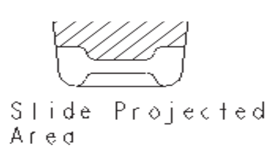


Fig. 4A-1 *Proposed component.*

Metal stamping lends itself to high-speed production with infrequent die replacement or repair. However, the stamping process can only produce features that are apparent on both sides of a thin part. Indentations on one side of the part appear as ridges on the other side of the part. Critical bends in the metal surface of stamped products become areas of weakness where metal is formed to make the bend. Complex features within the layer of metal are impossible without additional stamped parts and assembly. Thicker parts require higher stamping pressure which compounds metal fatigue at critical bends. This is similar to a large tree snapping in the wind where a sapling will bend. Multiple stamped layers and assembly would exceed the cost of the die cast alternative.

Extrusion Alternative

If the part design required stock depth beyond stamping capabilities, the extrusion process might be a production alternative for creating such a profile—unless complex additional interior features were desirable, such as those shown in Fig. 4A-1.

When total costs of a product assembly can be significantly reduced by a more robust part design, as that suggested by Fig. 4A-1, the production process which allows such design freedom is the better choice. The extrusion process produces a uniform internal structure in one axis such as a bar or a tube. End features or variations within the axis are impossible. A part, such as the one shown in Fig. 4A-1, has design feature variations on all axes therefore extrusion of this part is not possible without multiple operations which would exceed the cost of the die cast alternative.

Machining Alternative

Automated machining could produce product features as shown in Fig. 4A-1. Complex features would require additional operations for each piece. This would be very time consuming and would place tremendous wear on production equipment especially during large volume production. As volumes increased, machining would become a very high-cost production option.

Foundry Casting Alternative

Foundry casting plus secondary machining might be an alternative for this part. Foundry casting involves pouring molten metal into a mold. Without the pressure of die, SSM or squeeze casting to force metal into critical paths, around tight turns, and into small features of the mold. Foundry casting can not achieve the detail and precision of die, SSM or squeeze casting. The Foundry casting process is relatively slow in that gravity fills and mold positions take time to achieve.

Extensive secondary machining is required for Foundry castings when close tolerances are required. This is not only costly but time consuming. Foundry casting is usually reserved for large iron castings with very little intricate detail. It is not considered as a high volume process. Net-shape die casting can become the more cost-effective solution, often at low production volumes.

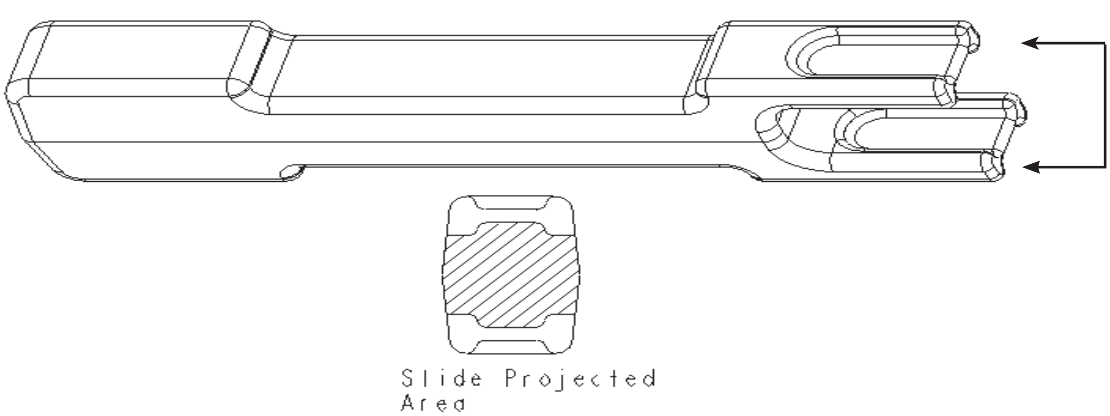


Fig. 4A-1A Proposed component with added features and design modified for cost-effective die casting production, showing orientation in the die casting die and core slide (moving die component) to cast the additional features.

Investment Casting Alternative

At low volumes the investment casting process could be considered to achieve precision tolerances. At higher volumes die casting would be the clear choice.

Powdered Metal Alternative

The powdered metal process offers dimensional accuracy for many parts. It cannot achieve the more complex configurations, detailed features or thinner walls which die casting can easily produce to net or near-net shape.

Plastic Molded Alternative

Plastic injection molding could achieve the designed configuration shown in Fig. 4A-1, but if requirements of rigidity, creep resistance, and strength—particularly at elevated temperatures—were important, plastics would be questionable. The longevity of plastic components is normally substantially less than that of metal components. Plastics products are subject to failure modes such as sunlight, radiation, heat and various chemicals. The designer needs to ensure that the application and duration of the end product will meet the customers needs and expectations. Additionally, the preference for use of a recycled raw material as well as the potential for eventual recycling of the product at the end of its useful life would also support a decision for die casting.

5 Die Casting, SSM and Squeeze Cast Part Design

Fig. 4A-1A, illustrates a good design practice for die, SSM and squeeze casting production.

Sharp corners have been eliminated and the design has been provided with the proper draft and radii to maximize the potential die life and to aid in filling the die cavity completely under high production cycle speeds.

Typical wall thicknesses for a cast design range from 0.040 in. (1.016 mm) to 0.200 in. (5.08 mm), depending on alloy, part configuration, part size and application.

Smaller castings with wall sections as thin as 0.020 in. (0.50 mm) can be cast, with die caster consultation. For extremely small zinc parts, miniature die casting technology can be used to cast still thinner walls. See section 4B for information on miniature die casting.

Fig. 4A-1 will be used elsewhere in this section to present dimensional tolerances, specifically as they relate to part dimensions on the same side of the die half, across the parting line, and those formed by moving die components.

Note: Because dies wear over the course of producing castings, it should be noted that the number of shots on a die prior to repair or replacement will be less for tighter casting tolerances and greater for wider casting tolerances.

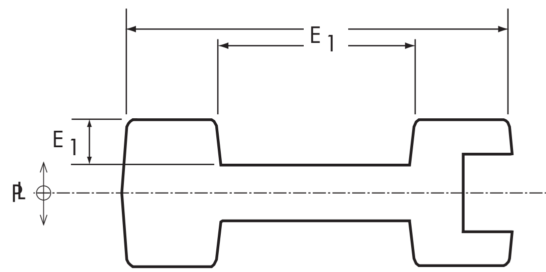
Fig. 4A-1 will also be used in the Geometric Dimensioning Section to show how datum structure can influence tooling and tolerances.

6 Linear Dimensions: Standard Tolerances

The Standard Tolerance on any of the features labeled in the adjacent drawing, dimension "E_1" will be the value shown in table S-4A-1 for dimensions of features formed in the same die part. Tolerance must be increased for dimensions of features formed by the parting line or by moving die parts to allow for movement such as parting line shift or the moving components in the die itself. See tables S-4A-2 and S-4A-3 for calculating tolerance of moving die components or parting line shift. Linear tolerance is only for fixed components to allow for growth, shrinkage or minor imperfections in the part.

Tolerance is the amount of variation from the part's nominal or design feature.

For example, a 5 inch design specification with ±0.010 tolerance does not require the amount of precision as the same part with a tolerance of ±0.005. The smaller the tolerance number, the more precise the part must be (the higher the precision). Normally, the higher the precision the more it costs to manufacture the part because die wear will affect more precise parts sooner. Production runs will be shorter to allow for increased die maintenance. Therefore the objective is to have as much tolerance as possible without affecting form, fit and function of the part.



Example:

Aluminum Casting

E_1 = 5.00 in (127 mm)

Standard Tolerance (from Table S-4A-1)

First inch (25.4 mm)		±.010 in (±0.25 mm)
Each additional inch (25.4 mm)	4x	±.001 in (±0.025 mm)
		±.014 in (±0.35 mm)

Linear dimension tolerance only applies to linear dimensions formed in the same die half with no moving components.

Table S-4A-1 Tolerances for Linear Dimensions (Standard)

In inches, two-place decimals (.xx); In millimeters, single-place decimals (.x)

Length of Dimension "E_1"	Casting Alloys: Zinc	Aluminum	Magnesium	Copper
Basic Tolerance up to 1" (25.4mm)	±0.010 (±0.25 mm)	±0.010 (±0.25 mm)	±0.010 (±0.25 mm)	±0.014 (±0.36 mm)
Additional Tolerance for each additional inch over 1" (25.4mm)	±0.001 (±0.025 mm)	±0.001 (±0.025 mm)	±0.001 (±0.025 mm)	±0.003 (±0.076 mm)

Note: Because dies wear over the course of producing castings, it should be noted that the number of shots on a die prior to repair or replacement will be less for tighter casting tolerances and greater for wider casting tolerances.

The values shown represent Standard Tolerances, or normal casting production practice at the most economical level. For greater casting accuracy see Precision Tolerances for this characteristic on the facing page. Be sure to also address the procedures referred to in Section 7, "Quality Assurance," sub-section 3, 4 and 5.

Significant numbers indicate the degree of accuracy in calculating precision. The more significant numbers in a specified tolerance, the greater the accuracy. Significant number is the first non-zero number to the right of the decimal and all numbers to the right of that number. For example, 0.014. The degree of accuracy is specified by the three significant numbers 140. This is not to be confused with tolerance precision. A tolerance limit of 0.007 has a higher degree of precision because it is closer to zero tolerance. Zero tolerance indicates that the part meets design specifications exactly. Linear Standard and Linear Precision tolerances are expressed in thousandths of an inch (.001) or hundredths of a millimeter (.01).

Notes:

Casting configuration and shrink factor may limit some dimension control for achieving a specified precision.

Linear tolerances apply to radii and diameters as well as wall thicknesses.

It is important to note that this section covers tolerances that are achievable for both Standard and Precision Die Castings. However, in today's Six Sigma World, Capability may still be a question. Die Cast Tools are often built to allow for maximum tool life and process variations that can detract from the process and actual tool capabilities. Six Sigma variation and CPK should be discussed with the Die Caster in advance of tool construction. Frequently repeatability (CP rather than CPK) is the goal in the as cast state. To build a tool at nominal dimensions to get a good CPK will lead to shorter tool life and added rejects to the die caster for process variations.

NADCA

P-4A-1-15

PRECISION TOLERANCES

The Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved. Be sure to also address the procedures referred to in Section 7, "Quality Assurance," sub-section 3, 4 and 5.

Linear tolerances apply to radii and diameters as well as wall thicknesses.

Methods for Improving Precision:

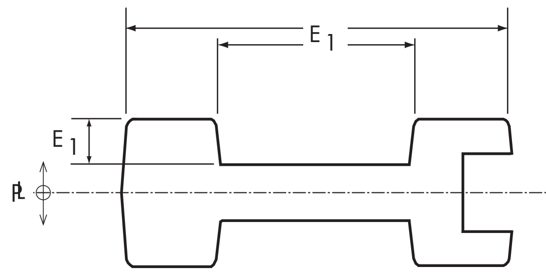
1. By repeated sampling and recutting of the die cast tool, along with capability studies, even closer dimensions can be held. However, additional sampling and other costs may be incurred.
2. For zinc die castings, tighter tolerances can be held, depending on part configuration and the use of artificial aging. Artificial aging (also known as heat treating) may be essential for maintaining critical dimensions in zinc, particularly if the part is to be machined, due to the creep (growth) characteristics of zinc. The die caster should be consulted during the part design stage.
3. In the case of extremely small zinc parts, weighing fractions of an ounce, special die casting machines can achieve significantly tighter tolerances, with zero draft and flash-free operation. See Section 4B, Miniature Die Casting.

Note:
It is important to note that this section covers tolerances that are achievable for both Standard and Precision Die Castings. However, in today's Six Sigma World, Capability may still be a question. Die Cast Tools are often built to allow for maximum tool life and process variations that can detract from the process and actual tool capabilities. Six Sigma variation and CPK should be discussed with the Die Caster in advance of tool construction. Frequently repeatability (CP rather than CPK) is the goal in the as cast state. To build a tool at nominal dimensions to get a good CPK will lead to shorter tool life and added rejects to the die caster for process variations.

Engineering & Design: Coordinate Dimensioning

Linear Dimensions: Precision Tolerances

Precision Tolerance on any of the features labeled in the adjacent drawing, dimension "E_1" will be the value shown in table P-4A-1 for dimensions between features formed in the same die part. Tolerance must be increased for dimensions of features formed by the parting line or by moving die parts to allow for movement such as parting line shift or the moving components in the die itself. See tables P-4A-2 and P-4A-3 for calculating precision of moving die components or parting line shift. Linear tolerance is only for fixed components to allow for growth, shrinkage or minor imperfections in the part.



Example:
Aluminum Casting
E_1 = 5.00 in (127 mm)

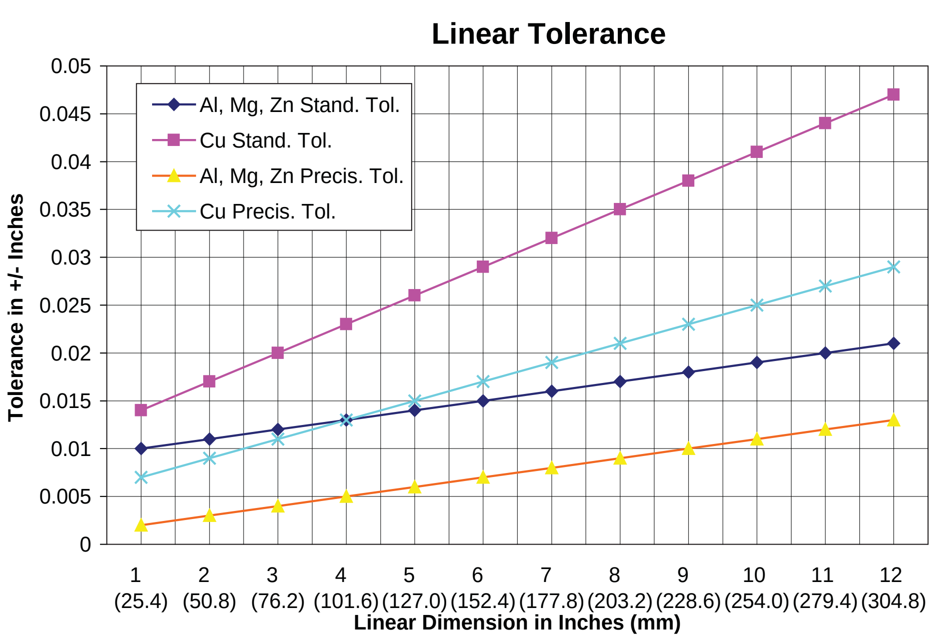
Precision Tolerance (from Table P-4A-1)		
First inch (25.4 mm)		±.002 in (±0.05 mm)
Each additional inch (25.4 mm)	4x	±.001 in (±0.025 mm)
		±.006 in (±0.15 mm)

Linear dimension tolerance only applies to linear dimensions formed in the same die half with no moving components.

Table P-4A-1 Tolerances for Linear Dimensions (Precision)
In inches, three-place decimals (.xxx); In millimeters, two-place decimals (.xx)

	Casting Alloys			
Length of Dimension "E_1"	Zinc	Aluminum	Magnesium	Copper
Basic Tolerance up to 1" (25.4mm)	±0.002 (±0.05 mm)	±0.002 (±0.05 mm)	±0.002 (±0.05 mm)	±0.007 (±0.18 mm)
Additional Tolerance for each additional inch over 1" (25.4mm)	±0.001 (±0.025 mm)	±0.001 (±0.025 mm)	±0.001 (±0.025 mm)	±0.002 (±0.05 mm)

Note: Because dies wear over the course of producing castings, it should be noted that the number of shots on a die prior to repair or replacement will be less for tighter casting tolerances and greater for wider casting tolerances.



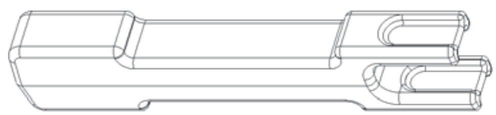
Engineering & Design: Coordinate Dimensioning

7 Parting Line: Standard Tolerances

Parting Line Tolerance is the additional tolerance needed for cross parting line dimensions in order to account for die separation (die blow).. This is not to be confused with Parting Line Shift Tolerance (cavity mismatch) which is the maximum amount die halves shift from side to side in relation to one another.

Parting Line Tolerance is a function of the Projected Area of the part. The Projected Area is a two dimensional area measurement calculated by projecting the three dimensional part onto a plane, which in this case is the cavity surface at the parting line. An easy way to visualize the Projected Area is by what shadow a casting would project onto the cavity surface.

SECTION A-A



The Parting Line Tolerance is always a plus tolerance since a completely closed die has 0 separation. Excess material and pressure will force the die to open along the parting line plane creating an oversize condition. The excess pressure will cause the part to be thicker than the ideal specification. It is important to understand that Table S-4A-2 (Parting Line Tolerance) does not provide the Total Cross Parting Line Tolerance by itself. The Total Cross Parting Line Tolerance for any dimension is the sum of the Linear Tolerance (derived from the part thickness) in addition to the Parting Line Tolerance.

Thus, information from the Parting Line Tolerance table S-4A-2 in combination with the formerly discussed Linear Tolerance table S-4A-1 give a true representation of Total Cross Parting Line Tolerance. Note that the tolerances in the table apply to a single casting regardless of the number of cavities.

Example: An aluminum die casting has 75 in^2 (483.9 cm^2) of Projected Area on the parting die plane. From table S-4A-2, the Parting Line Tolerance is +0.012. This is combined with the total part thickness tolerance from table S-4A-1 to obtain the Total Cross Parting Line Tolerance.

The total part thickness including both die halves is 5.00 in. (127 mm) which is measured perpendicular to the parting die plane (dimension "E_2 E_1"). From table S-4A-1, the Linear Tolerance is ±0.010 for the first inch and ±0.001 for each of the four additional inches. The Linear Tolerance of ±0.014 inches is combined with the Parting Line Tolerance of +0.012 to yield a Standard Cross Parting Line Tolerance of +0.026/-0.014 in. or in metric terms ±0.35 mm from Linear Tolerance table S-4A-1 plus +0.30 mm from Parting Line Tolerance table S-4A-2 = +0.65/-0.35 mm.

Table S-4A-2 Parting Line Tolerances (Standard) — Added to Linear Tolerances

Projected Area of Die Casting inches^2 (cm^2)	Casting Alloys (Tolerances shown are "plus" values only)			
	Zinc	Aluminum	Magnesium	Copper
up to 10 in^2 (64.5 cm^2)	+0.0045 (+0.114 mm)	+0.0055 (+0.14 mm)	+0.0055 (+0.14 mm)	+0.008 (+0.20 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.005 (+0.13 mm)	+0.0065 (+0.165 mm)	+0.0065 (+0.165 mm)	+0.009 (+0.23 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.006 (+0.15 mm)	+0.0075 (+0.19 mm)	+0.0075 (+0.19 mm)	+0.010 (+0.25 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.009 (+0.23 mm)	+0.012 (+0.30 mm)	+0.012 (+0.30 mm)	—
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.012 (+0.30 mm)	+0.018 (+0.46 mm)	+0.018 (+0.46 mm)	—
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0.018 (+0.46 mm)	+0.024 (+0.61 mm)	+0.024 (+0.61 mm)	—

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

The values shown represent Standard Tolerances, or normal die casting production practice at the most economical level. For greater casting accuracy see Precision Tolerances for this characteristic on the facing page. Be sure to also address the procedures referred to in Section 7, "Quality Assurance," sub-section 3, 4 and 5.

Die Shift:

Parting line die shift, unlike parting line separation and moving die component tolerances, is a left/right relationship with possible ± consequences. It can shift in four directions, based on a combination of part features, die construction and operation factors. It can occur at any time and its tolerance consequences should be discussed with the die caster at the design stage to minimize any impact on the final die casting.

Notes:
All values for part dimensions which run across the die parting line are stated as a "plus" tolerance only. The die casting die at a die closed position creates the bottom of the tolerance range, i.e., 0.000 (zero). Due to the nature of the die casting process, dies can separate imperceptibly at the parting line and create only a larger, or "plus" side, tolerance.

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P-4A-2-15

PRECISION TOLERANCES

The Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved. Be sure to also address the procedures referred to in Section 7, “Quality Assurance,” subsection 3, 4 and 5.

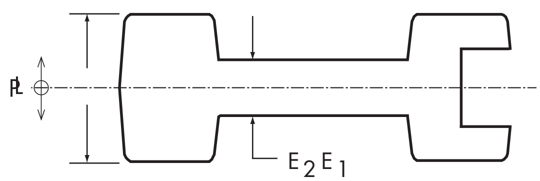
Methods for Improving Precision:

1. By repeated sampling and recutting of the die cast tool, along with capability studies, even closer dimensions can be held. However, additional sampling and other costs may be incurred.
2. For zinc die castings, tighter tolerances can be held, depending on part configuration and the use of artificial aging. Artificial aging (also known as heat treating) may be essential for maintaining critical dimensions in zinc, particularly if the part is to be machined, due to the creep (growth) characteristics of zinc. The die caster should be consulted during the part design stage.
3. In the case of extremely small zinc parts, weighing fractions of an ounce, special die casting machines can achieve significantly tighter tolerances, with zero draft and flash-free operation. See Section 4B, Miniature Die Casting.

Engineering & Design: Coordinate Dimensioning

Parting Line: Precision Tolerances

Precision Tolerances on dimensions such as “E_2 E_1”, which are perpendicular to (across) the die parting line, will be the linear dimension tolerance from table P-4A-1 plus the value shown in table P-4A-2. The value chosen from the table below depends on the “projected area” of the part, in inches squared or millimeters squared, in the plane of the die parting. Note that the tolerances shown below are “plus side only” and based on a single cavity die casting die.



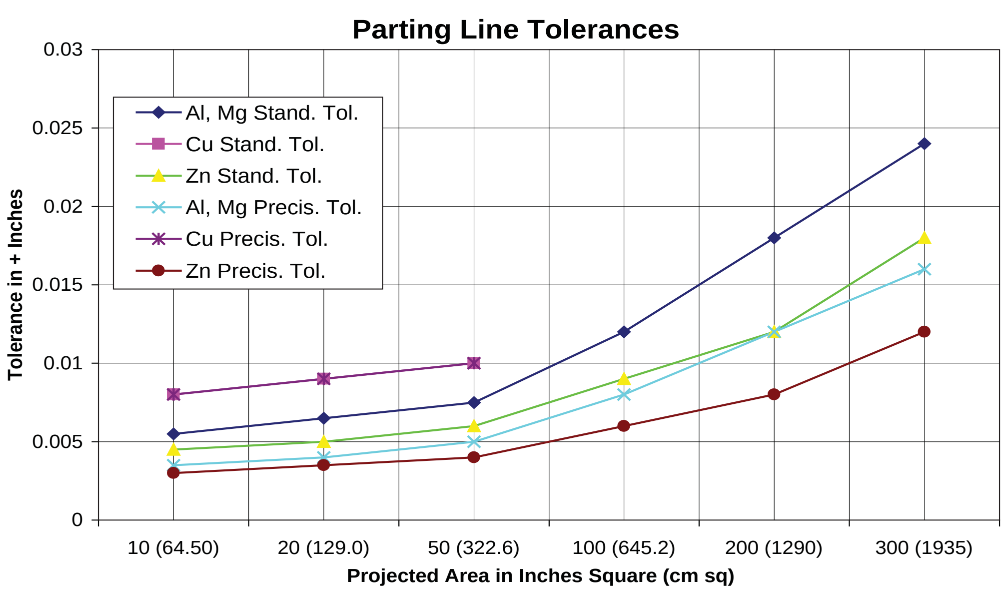
Example: An aluminum die casting has 75 in^2 (483.9 cm^2) of Projected Area on the parting die plane. From table P-4A-2, Parting Line Tolerance is +0.008. This is combined with the total part thickness tolerance from table P-4A-1 to obtain the Total Cross Parting Line Tolerance.

Total part thickness including both die halves is 5.000 in. (127 mm) which is measured perpendicular to the parting die plane (dimension “E_2 E_1”). From table P-4A-1, the Linear Tolerance is ±0.002 for the first inch and ±0.001 for each of the four additional inches. The Linear Tolerance of ±0.006 is combined with the Parting Line Tolerance of +0.008 to yield a Precision Cross Parting Line Tolerance of +0.014/-0.006 in. or in metric terms (±0.15 mm plus +0.20 mm) = +0.35/-0.15 mm on dimensions that are formed across the parting line.

Table P-4A-2 Parting Line Tolerances (Precision) – Added to Linear Tolerances

Projected Area of Die Casting inches^2 (cm^2)	Die Casting Alloys (Tolerances shown are "plus" values only)			
	Zinc	Aluminum	Magnesium	Copper
up to 10 in^2 (64.5 cm^2)	+0.003 Ⓐ (+0.076 mm)	+0.0035 (+0.089 mm)	+0.0035 (+0.089 mm)	+0.008 (+0.20 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.0035 (+0.089 mm)	+0.004 (+0.102 mm)	+0.004 (+0.102 mm)	+0.009 (+0.23 mm)
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.004 (+0.102 mm)	+0.005 (+0.153 mm)	+0.005 (+0.153 mm)	+0.010 (+0.25 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.006 (+0.153 mm)	+0.008 (+0.203 mm)	+0.008 (+0.203 mm)	—
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.008 (+0.203 mm)	+0.012 (+0.305 mm)	+0.012 (+0.305 mm)	—
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0.012 (+0.305 mm)	+0.016 (+0.406 mm)	+0.016 (+0.406 mm)	—

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

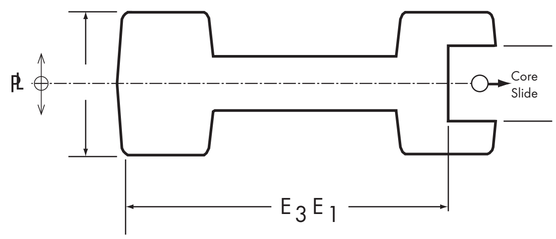


The values shown represent Standard Tolerances, or normal die casting production practice at the most economical level. For greater casting accuracy see Precision Tolerances for this characteristic on the facing page. Be sure to also address the procedures referred to in Section 7, "Quality Assurance," subsection 3, 4 and 5.

8 Moving Die Components (MDC): Standard Tolerances

Moving Die Components Tolerance can affect final part performance similar to Parting Line Tolerance. When the core is fully inserted into the die, the minimum tolerance is zero. As excess material and pressure are exerted in the die, the core can slide out creating an oversized condition. A MDC Tolerance has been developed to ensure minimal impact on form, fit and function by specifying limits to the oversize condition.

Similar to Parting Line Tolerance, MDC Standard Tolerance is a function of the Moving Die Component (MDC) Tolerance plus Linear Tolerance. Linear Tolerance is calculated based on the length of movement of the core slide along dimension "E_3 E_1". Table S-4A-1 is used to determine Linear Tolerance. The linear dimension is not the entire length of "E_3 E_1" but is only the length of the core slide from where the core slide first engages the die to its full insertion position. Linear dimension is normally perpendicular to the Projected Area.



Projected Area is the area of the core head that faces the molten material. MDC Tolerance for moving die components is determined from table S-4A-3. The open area (cavity) on the end view of the part in figure 4A-1A at the beginning of this section shows the projected area. Projected Area Tolerance plus Linear Tolerance provide MDC Standard Tolerance for the volume of the part. Note that the tolerances in the table apply to a single casting regardless of the number of cavities.

Example: An aluminum casting has 75 in^2 (483.9 cm^2) of Projected Area calculated from the core slide head facing the molten material. From table S-4A-3, MDC Tolerance is +0.024. This is combined with the length of the core slide Linear Tolerance from table S-4A-1 to obtain the MDC Standard Tolerance. The total core slide length of 5.00 in. (127 mm) is measured from where the core engages the part to full insertion in the plane of dimension "E_3 E_1" to determine Linear Tolerance length. From table S-4A-1, the Linear Tolerance is ±0.010 for the first inch and ±0.001 for each of the four additional inches.

The Linear Tolerance of ±0.014 inches is combined with the MDC Tolerance of +0.024 to yield a MDC Standard Tolerance of +0.038/-0.014 in.

MDC Metric Standard Tolerance is +0.96/-0.35 mm = (±0.35 mm) + (+0.61 mm) on dimensions formed by moving die components.

Table S-4A-3 MDC Tolerances (Standard) — Added to Linear Tolerances

Projected Area of Die Casting inches^2 (cm^2)	Die Casting Alloys (Tolerances shown are "plus" values only)			
	Zinc	Aluminum	Magnesium	Copper
up to 10 in^2 (64.5 cm^2)	+0.006 (+0.15 mm)	+0.008 (+0.20 mm)	+0.008 (+0.20 mm)	+0.012 (+0.305 mm)
11 in^2 to 20 in^2 (71.0 cm^2 to 129.0 cm^2)	+0.009 (+0.23 mm)	+0.013 (+0.33 mm)	+0.013 (+0.33 mm)	—
21 in^2 to 50 in^2 (135.5 cm^2 to 322.6 cm^2)	+0.013 (+0.33 mm)	+0.019 (+0.48 mm)	+0.019 (+0.48 mm)	—
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	+0.019 (+0.48 mm)	+0.024 (+0.61 mm)	+0.024 (+0.61 mm)	—
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	+0.026 (+0.66 mm)	+0.032 (+0.81 mm)	+0.032 (+0.81 mm)	—
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	+0.032 (+0.81 mm)	+0.040 (+1.0 mm)	+0.040 (+1.0 mm)	—

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

Die Shift:

Parting line die shift, unlike parting line separation and moving die component tolerances, is a left/right relationship with possible ± consequences. It can shift in four directions, based on a combination of part features, die construction and operation factors. It can occur at any time and its tolerance consequences should be discussed with the die caster at the design stage to minimize any impact on the final die casting.

Notes:
All values for part dimensions which run across the die parting line are stated as a "plus" tolerance only. The die casting die at a die closed position creates the bottom of the tolerance range, i.e., 0.000 (zero). Due to the nature of the die casting process, dies can separate imperceptibly at the parting line and create only a larger, or "plus" side, tolerance.

Engineering & Design: Coordinate Dimensioning

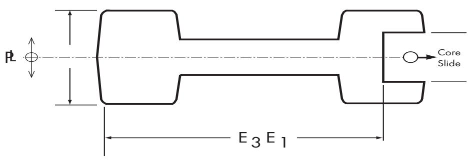
Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved. Be sure to also address the procedures referred to in Section 7, "Quality Assurance," sub-section 3, 4 and 5.

Methods for Improving Precision:

1. By repeated sampling and recutting of the die casting tool, along with production capability studies, even closer dimensions can be held—at additional sampling or other costs.
2. The die casting process may cause variations to occur in parting line separation. Thus, tolerances for dimensions that fall across the parting line on any given part should be checked in multiple locations, i.e., at four corners and on the center line.
3. In the case of extremely small zinc parts, weighing fractions of an ounce, special die casting machines can achieve significantly tighter tolerances, with zero draft and flash-free operation. See section 4B Miniature Die Casting.

Moving Die Components (MDC): Precision Tolerances

Precision Tolerances attainable on die cast dimensions such as "E_3 E_1" formed by a moving die component will be the linear tolerance from table P-4A-1 plus the value shown in table P-4A-3. Linear Tolerance is the length of the core slide. Projected Area is the area of the head of the core slide facing the molten material. The value chosen from table P-4A-3 depends on the Projected Area of the portion of the die casting formed by the moving die component (MDC) perpendicular to the direction of movement. Note that tolerances shown are plus side only.



Example: An aluminum die casting has 75 in² (483.9 cm²) of Projected Area calculated from the core slide head facing the molten material. From table P-4A-3, MDC Tolerance is +0.018. This is combined with the length of the core slide Linear Tolerance from table P-4A-1 to obtain the MDC Precision Tolerance.

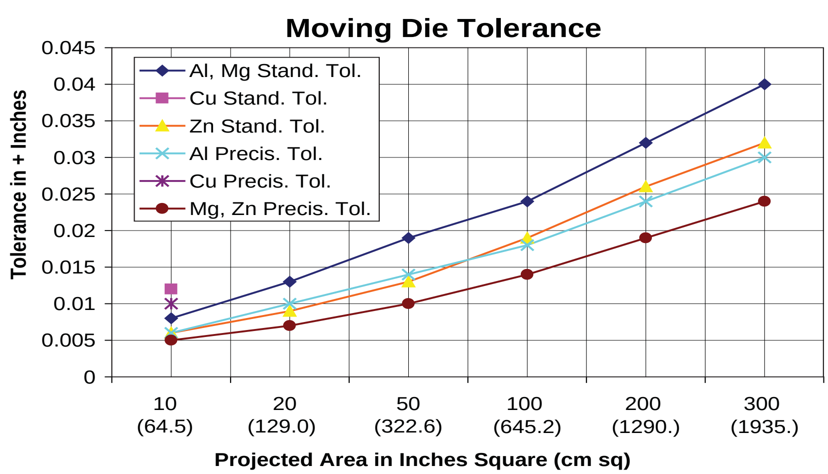
The total core slide length of 5.00 in. (127 mm) is measured from where the core engages the part to full insertion in the plane of dimension "E_3 E_1" to determine Linear Tolerance length from table P-4A-1, the Linear Tolerance is ±0.002 for the first inch and ±0.001 for each of the four additional inches. The Linear Tolerance of ±0.006 inches is combined with the MDC Tolerance of +0.018 to yield a MDC Precision Tolerance of +0.024/-0.006 in.

MDC Metric Precision Tolerance is +0.607/-0.15 mm = (±0.15 mm) +(+0.457 mm) on dimensions formed by MDC.

Table P-4A-3 MDC Tolerances (Precision) – Added to Linear Tolerances

Projected Area of Die Casting inches² (cm²)	Die Casting Alloys (Tolerances shown are "plus" values only) Zinc	Aluminum	Magnesium	Copper
up to 10 in² (64.5 cm²)	+0.005 A (+0.127 mm)	+0.006 (+0.152 mm)	+0.005 (+0.127 mm)	+0.010 (+0.254 mm)
11 in² to 20 in² (71.0 cm² to 129.0 cm²)	+0.007 (+0.178 mm)	+0.010 (+0.254 mm)	+0.007 (+0.178 mm)	—
21 in² to 50 in² (135.5 cm² to 322.6 cm²)	+0.010 (+0.254 mm)	+0.014 (+0.356 mm)	+0.010 (+0.254 mm)	—
51 in² to 100 in² (329.0 cm² to 645.2 cm²)	+0.014 (+0.356 mm)	+0.018 (+0.457 mm)	+0.014 (+0.356 mm)	—
101 in² to 200 in² (651.6 cm² to 1290.3 cm²)	+0.019 (+0.483 mm)	+0.024 (+0.61 mm)	+0.019 (+0.483 mm)	—
201 in² to 300 in² (1296.8 cm² to 1935.5 cm²)	+0.024 (+0.61 mm)	+0.030 (+0.762 mm)	+0.024 (+0.61 mm)	—

For projected area of die casting over 300 in² (1935.5 cm²), consult with your die caster.



Standard Tolerances shown represent normal die casting production practice at the most economical level. Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved.

9 Angularity Tolerances (Plane surfaces): Standard & Precision Tolerances

Angularity refers to the angular departure from the designed relationship between elements of the die casting. Angularity includes, but is not limited to, flatness, parallelism and perpendicularity. The angular accuracy of a die casting is affected by numerous factors including size of the die casting, the strength and rigidity of the die casting and die parts under conditions of high heat and pressure, position of moving die components, and distortion during handling of the die casting. Angularity is not a stand alone tolerance. Angularity Tolerance is added to other part feature tolerances. For example, if determining tolerance for angular features at the Parting Line, Parting Line Tolerance and Angularity Tolerance would be added to yield total part tolerance.

Angularity is calculated from the following tables based on the surface length that is impacted by angularity and where the surface is located.

There are four tables for calculating Standard and Precision Angularity Tolerance.

- Table S/P-4A-4A provides Angularity Tolerance for features in the same die half.
- Table S/P-4A-4B provides Angularity Tolerance for features that cross the parting line.
- Table S/P-4A-4C provides Angularity Tolerance for MDC features that are in the same die half.
- Table S/P-4A-4D provides Angularity Tolerance for multiple MDC features or MDC features that cross the parting line. The more MDCs involved, the more tolerance is necessary hence multiple tables.

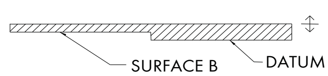
Applicability of Standard

This standard may be applied to plane surfaces of die castings for all alloys. Its tolerances are to be considered in addition to those provided by other standards.

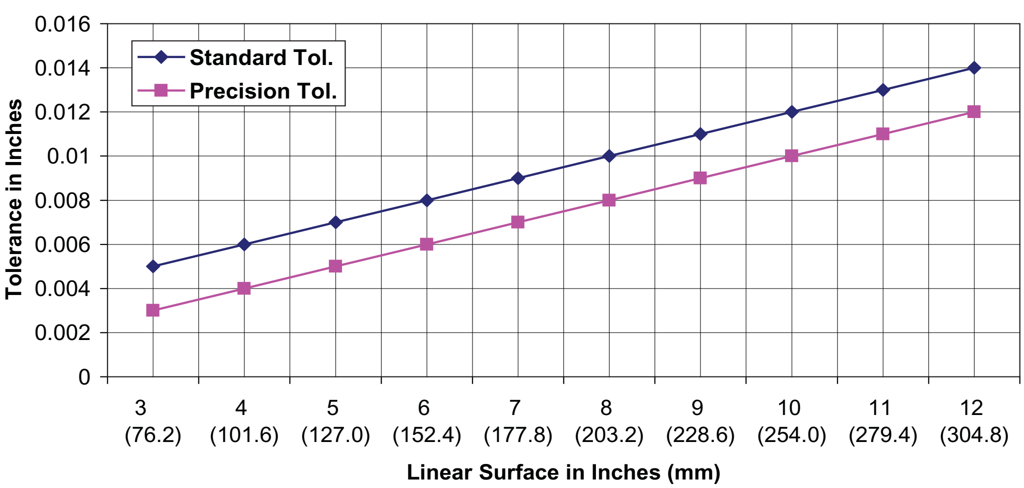
Angularity Tolerances - All Alloys

Tolerances required vary with the length of the surface of the die casting and the relative location of these surfaces in the casting die.

Table S/P-4A-4A Angularity Tolerance – Features in Same Die Half

Type	Surfaces 3″ (76.2 mm) or less	Each 1″ (25.4 mm) over 3″ (76.2 mm)	
Standard	.005 (.13 mm)	.001 (.025 mm)	
Precision	.003 (.08 mm)	.001 (.025 mm)	

Fixed Angularity Tolerance Same Die Half



Engineering & Design: Coordinate Dimensioning

Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved.

Methods for Improving Precision:

1. By repeated sampling and recutting of the die casting tool, along with production capability studies, even closer dimensions can be held—at additional sampling or other costs.
2. The die casting process may cause variations to occur in parting line separation. Thus, tolerances for dimensions that fall across the parting line on any given part should be checked in multiple locations, i.e., at four corners and on the center line.
3. In the case of extremely small zinc parts, weighing fractions of an ounce, special die casting machines can achieve significantly tighter tolerances, with zero draft and flash-free operation. See section 4B Miniature Die Casting.

Angularity Tolerances (Plane surfaces): Standard & Precision Tolerances

Same Die Half

Example: Standard Tolerances — Surface -B- and the datum plane -A- are formed by the same die half. If surface -B- is 5" (127 mm) long it will be parallel to the datum plane -A- within .007 (.18 mm). [.005 (.13 mm) for the first 3" (76.2 mm) and .002 (.05 mm) for the additional length.]

Example: Precision Tolerances — Surface -B- and the datum plane -A- are formed by the same die half. If surface -B- is 5" (127 mm) long it will be parallel to the datum plane -A- within .005 (.13 mm). [.003 (.08 mm) for the first 3" (76.2 mm) and .002 (.05 mm) for the additional length.]

Across Parting Line

Example: For Standard Tolerances — Surface -B- and the datum plane -A- are formed in opposite die sections. If surface -B- is 7" (177.8 mm) long it will be parallel to the datum plane -A- within .014 (.36 mm).

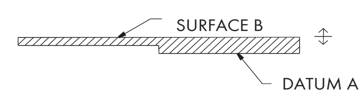
[.008 (.20 mm) for the first 3" (76.2 mm) and .006 (.15 mm) for the additional length.]

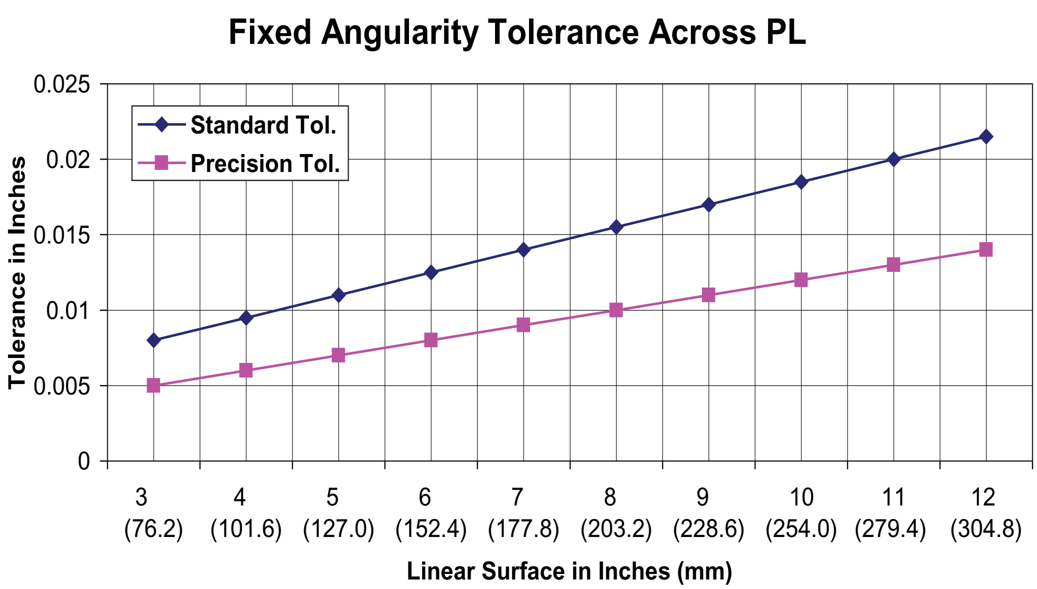
Example: For Precision Tolerances — Surface -B- and the datum plane -A- are formed in opposite die sections. If surface -B- is 7" (177.8 mm) long it will be parallel to the datum plane -A- within .009 (.23 mm).

[.005(.13 mm) for the first 3" (76.2 mm) and .004 (.10 mm) for the additional length.]

Table S/P-4A-4B Angularity Tolerance – Feature that Cross Parting Line

Type	Surfaces 3" (76.2 mm) or less	Each 1" (25.4 mm) over 3" (76.2 mm)
Standard	.008 (.20 mm)	.0015 (.038 mm)
Precision	.005 (.13 mm)	.001 (.025 mm)





Angularity Tolerances (Plane surfaces): Standard & Precision Tolerances

Example: For Standard Tolerances — Surface -B- is formed by a moving die member in the same die section as datum plane -A-. If surface -B- is 5” (127 mm) long it will be perpendicular to the datum plane -A- within .011 (.28 mm).

[.008 (.20 mm) for the first 3” (76.2 mm) and .003 (.08 mm) for the additional length.]

Example: For Precision Tolerances — Surface -B- and the datum plane -A- are formed in opposite die sections. If surface -B- is 7” (177.8 mm) long it will be parallel to the datum plane -A- within .009 (.23 mm).

[.005(.13 mm) for the first 3” (76.2 mm) and .004 (.10 mm) for the additional length.]

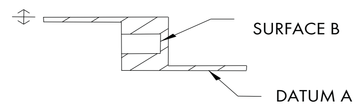
Standard Tolerances shown represent normal die casting production practice at the most economical level.

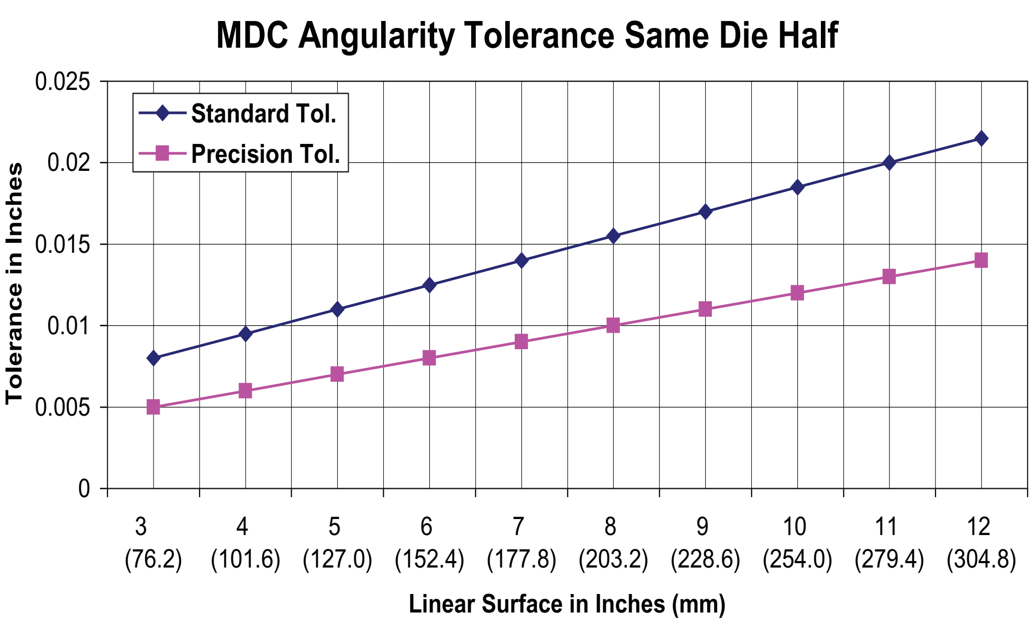
Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved.

4A

Table S/P-4A-4C Angularity Tolerance – MDC Features in Same Die Half

Type	Surfaces 3” (76.2 mm) or less	Each 1” (25.4 mm) over 3” (76.2 mm)
Standard	.008 (.20 mm)	.0015 (.038 mm)
Precision	.005 (.13 mm)	.001 (.025 mm)





Standard Tolerances shown represent normal die casting production practice at the most economical level.

Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional costs may be involved.

Engineering & Design: Coordinate Dimensioning

Angularity Tolerances (Plane surfaces): Standard & Precision Tolerances

Example: For Standard Tolerances — Surface -B- is formed by a moving die member and the datum plane -A- is formed by the opposite die section. If surface -B- is 5" (127 mm) long it will be perpendicular to the datum plane -A- within .017 (.43 mm). [.011 (.28 mm) for the first 3" (76.2 mm) and .006 (.15 mm) for the additional length.]

Surfaces -B- and -C- are formed by two moving die members. If surface -B- is used as the datum plane and surface -B- is 5" (127 mm) long, surface -C- will be parallel to surface -B- within .017 (.43 mm).

[.011 (.28 mm) for the first 3" (76.2 mm) and .006 (.15 mm) for the additional length.]

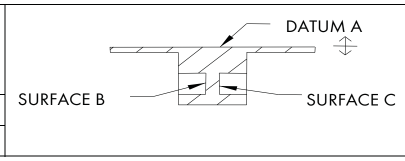
Example: For Precision Tolerances — Surface -B- is formed by a moving die member and the datum plane -A- is formed by the opposite die section. If surface -B- is 5" (127 mm) long it will be perpendicular to the datum plane -A- within .012 (.30 mm). [.008 (.20 mm) for the first 3" (76.2 mm) and .004 (.10 mm) for the additional length.]

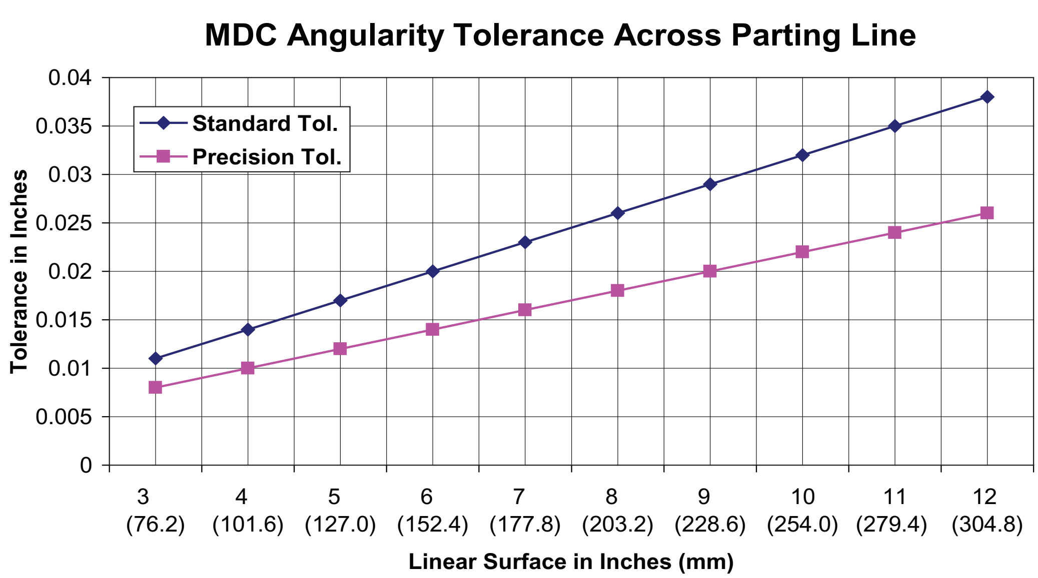
Surfaces -B- and -C- are formed by two moving die members. If surface -B- is used as the datum plane and surface -B- is 5" (127 mm) long, surface -C- will be parallel to surface -B- within .012 (.30 mm).

[.008 (.20 mm) for the first 3" (76.2 mm) and .004 (.10 mm) for the additional length.]

Table S/P-4A-4C Angularity Tolerance – Multiple MDC Features or MDC Features that Cross Parting Line

Type	Surfaces 3" (76.2 mm) or less	Each 1" (25.4 mm) over 3" (76.2 mm)
Standard	.011 (.28 mm)	.003 (.076 mm)
Precision	.008 (.20 mm)	.002 (.05 mm)





10 Concentricity Tolerances: Varying Degrees of Standard Tolerance

The concentricity of cylindrical surfaces is affected by the design of the die casting. Factors, such as casting size, wall thickness, shape, and complexity each have an effect on the concentricity of the measured surface. The tolerances shown below best apply to castings that are designed with uniformity of shape and wall thickness.

It should be noted that concentricity does not necessarily denote circularity (roundness). Part features can be considered concentric and still demonstrate an out of roundness condition. See section 5.11, Runout vs. Concentricity, in Geometric Dimensioning & Tolerancing for further explanation.

Concentricity Tolerance is added to other tolerances to determine maximum tolerance for the feature. For example, a concentric part that may cross the parting line, the tolerance would be the Concentricity Tolerance added to Parting Line Tolerance to give overall part tolerance. Note that the tolerances in the table apply to a single casting regardless of the number of cavities.

One Die Section

Concentricity Tolerance in a fixed relationship in one die section is calculated by selecting the largest feature diameter, (Diameter A) and calculating the tolerance from Table S-4A-5A using the chosen diameter. See information in the side column regarding selecting diameters for oval features. Selected diameter directly impacts degree of precision.

Example: Tolerance in One Die Section — An oval feature has a minimum diameter of 7 inches and a maximum diameter of 8 inches identified by the largest oval in the drawing below. This feature must fit into a hole with a high degree of precision. The minimum diameter (Diameter A) is chosen to give the highest degree of precision. From Table S-4A-5A, the basic tolerance for the first 3 inches is 0.008 inches (0.20 mm). 0.002 inches (0.05 mm) is added for each of the additional 4 inches to yield a total Concentricity Tolerance of +0.016 inches (+0.40 mm) for the 7" diameter.

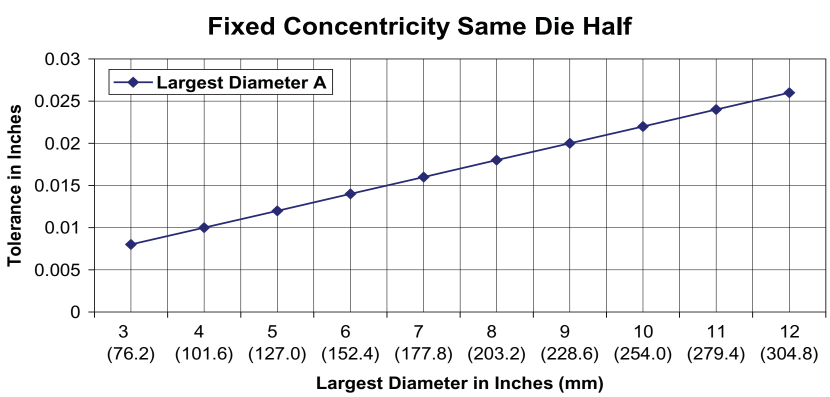
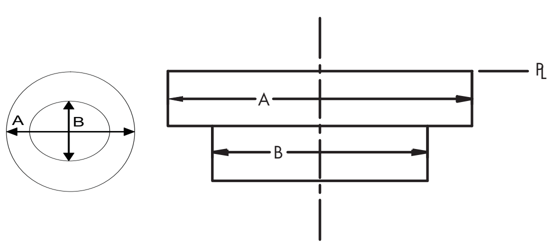


Table S-4A-5A: Concentricity Tolerance - Same Die Half (Add to other tolerances)



Surfaces in Fixed Relationship in One Die Section	
Diameter of Largest Diameter (A)	Tolerance (T.I.R.) inches (mm)
Basic Tolerance up to 3" (76.2mm)	.008 (.20 mm)
Additional Tolerance for each additional inch (25.4 mm) over 3" (76.2mm)	+.002 (.05 mm)

Concentricity is defined as a feature having a common center and is usually round, circular or oval. Half the diameter is the center of the feature.

Standard and Precision Tolerance are not specified for Concentricity Tolerance since tolerance is determined from diameter.

As noted in the Concentricity Tolerance description, concentricity does not denote roundness. The feature may be oval and still be concentric. Therefore tolerance precision may be variable depending where diameter is measured.

If minimum diameter is chosen, the calculated tolerance from the table will be less indicating a higher degree of precision.
If maximum diameter is chosen, then calculated tolerance will be more indicating a more "standard" degree of precision.

Diameters chosen between minimum and maximum will determine varying degrees of precision.

Engineering & Design: Coordinate Dimensioning

Concentricity is defined as a feature having a common center and is usually round, circular or oval. Half the diameter is the center of the feature.

Standard and Precision Tolerance are not specified for Concentricity Tolerance since tolerance is determined from calculated area.

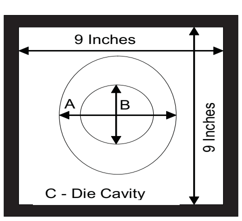
As noted in the Concentricity Tolerance description, concentricity does not denote roundness. The feature may be oval and still be concentric. Concentricity Tolerance precision is determined from chosen area and how the area is calculated.

Concentric Area Calculation

Round Features are those with equal diameter (D) regardless of where measured. Their area is calculated by:

(3.14) x [(1/2 D)^2]

Oval Feature areas are determined by averaging the minimum and maximum diameters and then using the same formula as that for Round Features.



Concentricity Tolerances: Varying Degrees of Standard Tolerance

Opposite Die Halves

When concentric features are in opposite die halves, the area of the cavity at the parting line determines Concentricity Tolerance. If two concentric features meet at the parting line, it is the area of the larger feature that determines Concentricity Tolerance from table S-4A-5B. See the side column for determining the area of a concentric feature. As noted in the side column, degree of precision is determined from the calculated area when crossing the parting line.

If there is a cavity at the parting line between concentric features that are located in opposite die halves such as area C on the figure below, area of the cavity determines Concentricity Tolerance from table S-4A-5B.

Total part tolerance is the combination of Concentricity Tolerance plus other feature tolerances for the part.

Example: Tolerance in One Die Section — An oval feature has a minimum diameter of 6 inches and a maximum diameter of 8 inches identified as Diameter A. Diameter B is 5 inches. However, the area of cavity C is 9 by 9 inches. If concentric features meet at the parting line through the squared area C, Concentricity Tolerance is determined from table S-4A-5B by the 9 by 9 area which is 81 inches square. From table S-4A-5B the Concentricity Tolerance is +.012 inches (+.30 mm).

If concentric features meet at the parting line directly, the area of the larger oval is used to determine the Concentricity Tolerance from table S-4A-5B. For example, if the minimum diameter is 6 inches and the maximum diameter is 8 inches, the average diameter is 7 inches. Using the Concentricity Area Calculation formula in the side column, the area is determined to be 38.5 inches square therefore the Concentricity Tolerance is +.008 inches (+.20 mm).

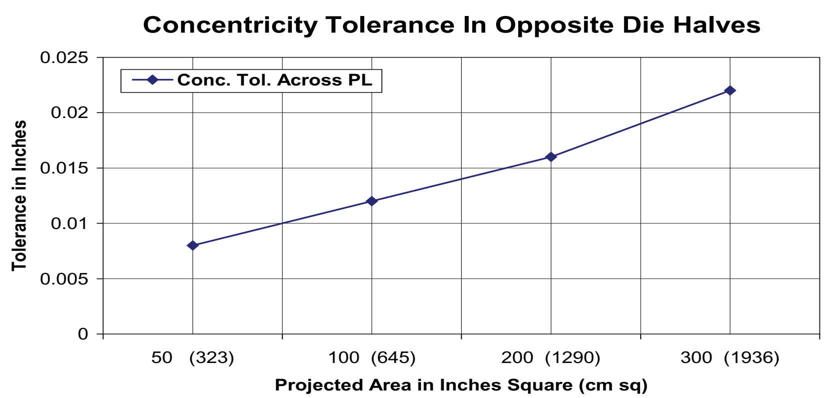
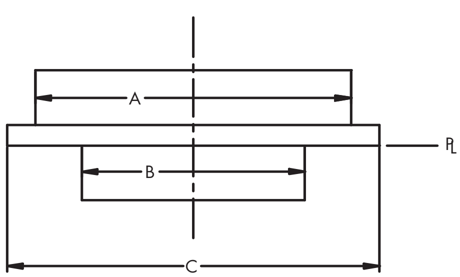


Table S-4A-5B: Concentricity Tolerance - Opposite Die Halves (Add to other tolerances)



Surfaces formed by Opposite Halves o Die (single cavity)	
Projected Area (C) of casting	Additional Toleran inches (mm)
Up to 50 in^2 (323 cm^2)	+.008 (.20 mm)
51 in^2 to 100 in^2 (329 cm^2 to 645 cm^2)	+.012 (.30 mm)
101 in^2 to 200 in^2 (652 cm^2 to 1290 cm^2)	+.016 (.41 mm)
201 in^2 to 300 in^2 (1297 cm^2 to 1936 cm^2)	+.022 (.56 mm)

Parting Line Shift: Standard Tolerance

Parting Line Shift Tolerances are specified as standard tolerances, only. If a higher degree of precision is required, the caster should be consulted for possible steps that can be taken.

Parting Line Shift Tolerance is only specified in Standard Tolerance because this is the lowest limit to meet the requirements of form, fit and function at the most economical value. Parting line variation has a compounding affect on feature tolerances across the parting line.

Parting line shift or die shift is a dimensional variation resulting from mismatch between the two die halves. The shift is a left/right type relationship that can occur in any direction parallel to the parting line of the two die halves. It has consequences to dimensions unlike parting line separation and moving die component tolerances. Parting line shift will influence dimensions that are measured across the parting line including concentricity of features formed by opposite die halves, and datum structures with datums in opposite die halves. Parting line shift compounds the affects of other tolerances measured across the parting line plane. Parting line shift can cause a part not to meet the requirements of form, fit and function.

Dies are designed and built with alignment systems to minimize parting line shift. However, effectiveness of alignment systems in minimizing parting line shift will depend on temperature variations, die construction, type of die and wear.

Variations in temperature between the two die halves of the die occur during the die's run. With die steel changing size with temperature variation, the two die halves will change size with respect to each other. To accommodate these changes in size, the alignment systems are designed with clearance to eliminate binding during opening and closing of the die. This clearance is necessary for the operation of the die but will allow a certain amount of parting line shift. One side of the die may be heated or cooled to compensate for temperature variation between die halves. One method to compensate for temperature variation is in the design and gating of the die. Another method is to apply additional die lube between shots to cool the hotter die half. Minimizing temperature variation between die halves allows for a more precise alignment system which will limit temperature induced parting line shift.

Moveable components (slides) within a die can also lead to parting line shift. Mechanical locks used to hold the slide in place during the injection of the metal can introduce a force that induces a parting line shift in the direction of the pull of the slide.

The type of die will also affect parting line shift. Due to their design for inter-changeability, unit dies will inherently experience greater parting line shift than full size dies. If parting line shift is deemed critical during part design, a full size die should be considered rather than a unit die.

Steps can be taken during the part design stage to minimize the impact of parting line shift. Datum structures should be set with all of the datum features in one half of the die. If this is not possible, additional tolerance may need to be added (see Geometric Dimensioning, Section 5). Another consideration during part design is to adjust parting lines so those features where mismatch is critical are cast in one half of the die.

Steps can also be taken during the die design to minimize parting line shift. Interlocks and guide blocks can be added to dies to improve alignment, but result in a higher maintenance tool. Placement of the cavities in the die can also be used to minimize the effect of mismatch between the two die halves.

Die wear and alignment system wear may impact parting line shift. As components wear, there is increasing lateral movement that will directly impact parting line shift. The method for decreasing wear induced parting line shift is to minimize moving parts when designing a die system, provide good cooling and lubrication, and have a good preventive maintenance program.

It is important to note that parting line shift can occur at any time and its tolerance consequences should be discussed with the die caster at the design stage to minimize its impact on the final die casting.

There are two components to calculate the affect of parting line shift on a part. The first component is to determine Linear Tolerance. Linear Tolerance is obtained from table S/P-4A-1 which was discussed earlier in this section. The second component is to determine Parting Line Shift Tolerance. Cavity area at the parting line is used to determine Projected Area Tolerance from table S-4A-6.

Parting Line Shift Tolerance is added to the Linear Tolerance to obtain the volumetric affect of total Parting Line Shift Tolerance on the part.

Parting Line Shift Tolerance is added to other feature tolerances to determine overall part tolerance.

Note that the tolerances in the table apply to a single casting regardless of the number of cavities.

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Parting Line Shift: Standard Tolerance

Example: Parting Line Shift Tolerance

The cavity area at the parting line is 75 inches squared. From Table S-4A-6, the Projected Area Parting Line Shift Tolerance is ± 0.006 (±0,152 mm). This is added to the Linear Tolerance from table S/P-4A-1.

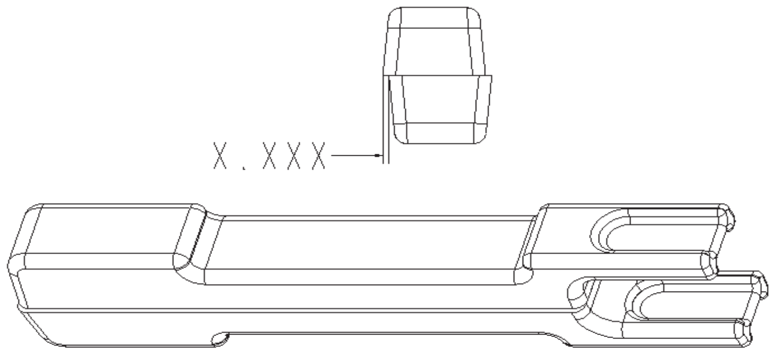
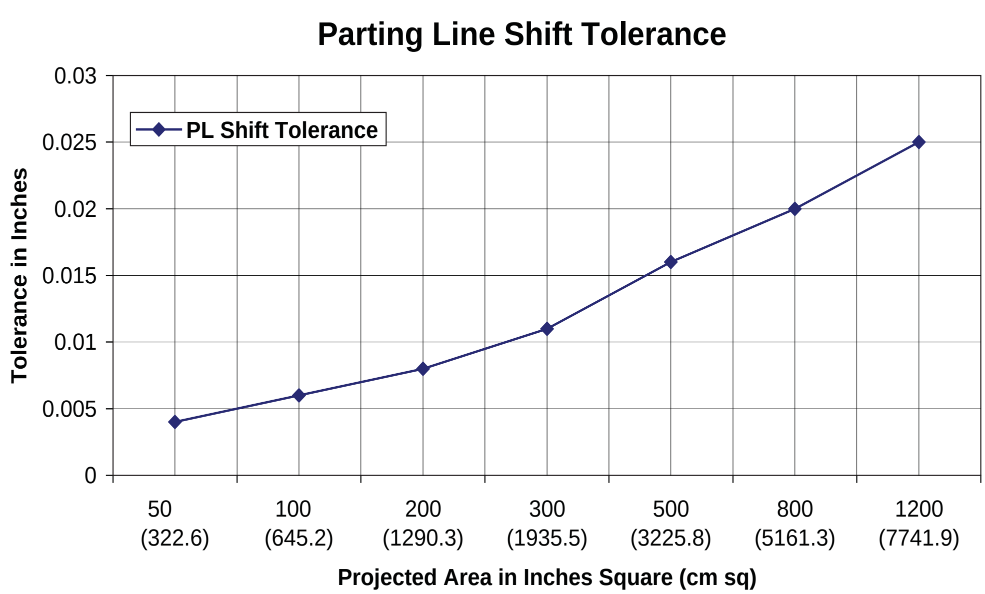


Table S-4A-6: Parting Line Shift Tolerance (Excluding unit dies)

Projected Area of Die Casting inches ^{2} (cm ^{2})	Additional Tolerance inches (mm)
up to 50 in ^{2} (322.6 cm ^{2})	±.004 (±.102 mm)
51 in^2 to 100 in^2 (329.0 cm^2 to 645.2 cm^2)	±.006 (±.152 mm)
101 in^2 to 200 in^2 (651.6 cm^2 to 1290.3 cm^2)	±.008 (±.203 mm)
201 in^2 to 300 in^2 (1296.8 cm^2 to 1935.5 cm^2)	±.011 (±.279 mm)
301 in^2 to 500 in^2 (1941.9 cm^2 to 3225.8 cm^2)	±.016 (±.406 mm)
501 in^2 to 800 in^2 (3232.3 cm^2 to 5161.3 cm^2)	±.020 (±.508 mm)
801 in^2 to 1200 in^2 (5167.7 cm^2 to 7741.9 cm^2)	±.025 (±.635 mm)



Draft Requirements: Standard Tolerances

Draft is the amount of taper or slope given to cores or other parts of the die cavity to permit easy ejection of the casting.

All die cast surfaces which are normally perpendicular to the parting line of the die require draft (taper) for proper ejection of the casting from the die. This draft requirement, expressed as an angle, is not constant. It will vary with the type of wall or surface specified, the depth of the surface and the alloy selected.

Draft values from the equations at right, using the illustration and the table below, provides Standard Draft Tolerances for draft on inside surfaces, outside surfaces and holes, achievable under normal production conditions.

Draft Example (Standard Tolerances):

In the case of an inside surface for an aluminum cast part, for which the constant "C" is 30 (6 mm), the recommended Standard Draft at three depths is:

Depth	Draft Distance	Draft Angle
in. (mm)	in. (mm)	Degrees
0.1 (2.50)	0.010 (0.250)	6˚
1.0 (25)	0.033 (0.840)	1.9˚
5.0 (127)	0.075 (1.890)	0.85˚

Calculation for Draft Distance

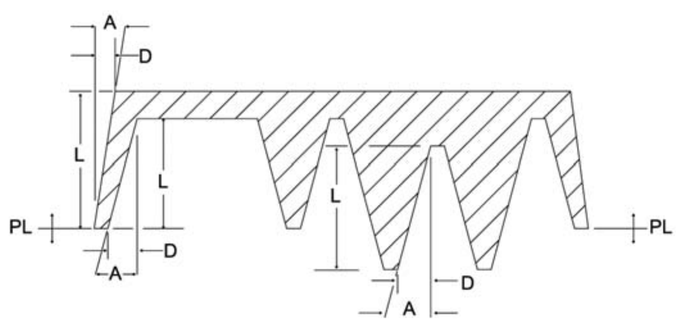
$$D = \frac{\sqrt{L}}{C}$$

Calculation for Draft Angle

$$A = \frac{\left(\frac{D}{L}\right)}{0.01746} \quad \text{OR} \quad \frac{57.2738}{C\sqrt{L}}$$

To achieve lesser draft than normal production allows, Precision Tolerances maybe specified (see opposite page).

Where: **D**= Draft in inches
L= Depth or height of feature from the parting line
C= Constant, from table S-4A-7, is based on the type of feature and the die casting alloy
A= Draft angle in degrees Draft



Drawing defines draft dimensions for interior and exterior surfaces and total draft for holes (draft is exaggerated for illustration).

The formula for draft shown here represents Standard Tolerance, or normal casting production practice at the most economical level. For Precision Tolerance for draft, see the facing page.

Note:
As the formula indicates, draft, expressed as an angle, decreases as the depth of the feature increases. Twice as much draft is recommended for inside walls or surfaces as for outside walls/surfaces. This provision is required because as the alloy solidifies it shrinks onto the die features that form inside surfaces (usually located in the ejector half) and away from features that form outside surfaces (usually located in the cover half). Note also that the resulting draft calculation does not apply to cast lettering, logotypes or engraving. Such elements must be examined individually as to style, size and depth desired. Draft requirements need to be discussed with the die caster prior to die design for satisfactory results.

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Draft Requirements: Standard Tolerances

Table S-4A-7: Draft Constants for Calculating Draft and Draft Angle

Values of Constant "C" by Features and Depth (Standard Tolerances)

Alloy	Inside Wall For Dim. in inches (mm)	Outside Wall For Dim. in inches (mm)	Hole, Total Draft for Dim. in inches (mm)
Zinc/ZA	**50** (9.90 mm)	**100** (19.80 mm)	**34** (6.75 mm)
Aluminum	**30** (6.00 mm)	**60** (12.00 mm)	**20** (4.68 mm)
Magnesium	**35** (7.00 mm)	**70** (14.00 mm)	**24** (4.76 mm)
Copper	**25** (4.90 mm)	**50** (9.90 mm)	**17** (3.33 mm)

It is not common practice to specify draft separately for each feature. Draft is normally specified by a general note with exceptions called out for individual features. The formula should be used to establish general draft requirements with any exceptions identified.

For example, an aluminum casting with most features at least 1.0 in. deep can be covered with a general note indicating 2° minimum draft on inside surfaces and 1° minimum on outside surfaces (based on outside surfaces requiring half as much draft).

** For tapped holes cored with removable core pins for subsequent threading see page 4A-34 through 4A-38.*

Draft Requirements: Precision Tolerances

All cast surfaces normally perpendicular to the parting line of the die require draft (taper) for proper ejection of the casting from the die. Minimum precision draft for inside walls is generally recommended at 3/4 degrees per side; with outside walls requiring half as much draft.

Draft values from the equation at right, using the illustration and the table below, estimate specific Precision Draft Tolerances for draft on inside surfaces, outside surfaces and holes. Precision Draft Tolerances will vary with the type of wall or surface specified, the depth of the wall, and the alloy selected.

Draft Example (Precision Tolerances):

In the case of an inside surface for an aluminum cast part, for which the constant "C" is 40 (7.80 mm), the recommended Precision Draft at three depths is:

Depth	Draft Distance	Draft Angle
in. (mm)	in. (mm)	Degrees
0.1 (2.50)	0.006 (0.150)	3.6°
1.0 (25)	0.020 (0.510)	1.1°
2.5 (63.50)	0.032 (1.140)	0.72°

To achieve lesser draft than normal production allows, Precision Tolerances maybe specified (see opposite page).

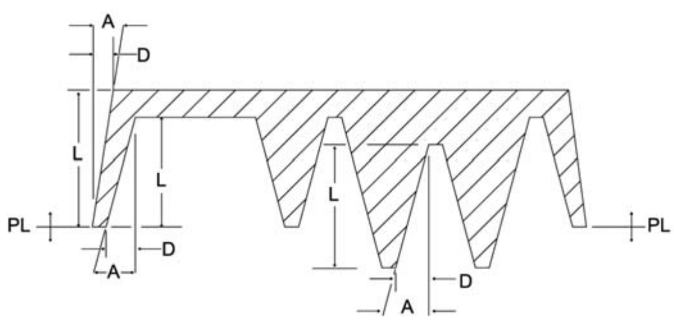
Calculation for Draft Distance

$$D = \frac{\sqrt{L} \times 0.8}{C}$$

Calculation for Draft Angle

$$A = \frac{\left(\frac{D}{L}\right)}{0.01746} \quad \textit{or} \quad \frac{45.819}{C\sqrt{L}}$$

Where: **D=** Draft in inches
L= Depth or height of feature from the parting line
C= Constant, from table P-4A-7, is based on the type of feature and the die casting alloy
A= Draft angle in degrees Draft



Drawing defines draft dimensions for interior and exterior surfaces and total draft for holes (draft is exaggerated for illustration).

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P-4A-7-15

PRECISION TOLERANCES

Precision Tolerances for draft resulting from the calculations outlined here involve extra precision in die construction and/or special control in production. They should be specified only when necessary. Draft or the lack of draft can greatly affect castability. Early die caster consultation will aid in designing for minimum draft, yet sufficient draft for castability.

Note:
As the formula indicates, draft, expressed as an angle, decreases as the depth of the feature increases. See graphical representation on the following pages for various alloys. Twice as much draft is recommended for inside walls or surfaces as for outside walls/surfaces. This provision is required because as the alloy solidifies it shrinks onto the die features that form inside surfaces (usually located in the ejector half) and away from features that form outside surfaces (usually located in the cover half). Note also that the resulting draft calculation does not apply to die cast lettering, logotypes or engraving. Such elements must be examined individually as to style, size and depth desired. Draft requirements need to be discussed with the die caster prior to die design for satisfactory results.

Engineering & Design: Coordinate Dimensioning

Draft Requirements: Precision Tolerances

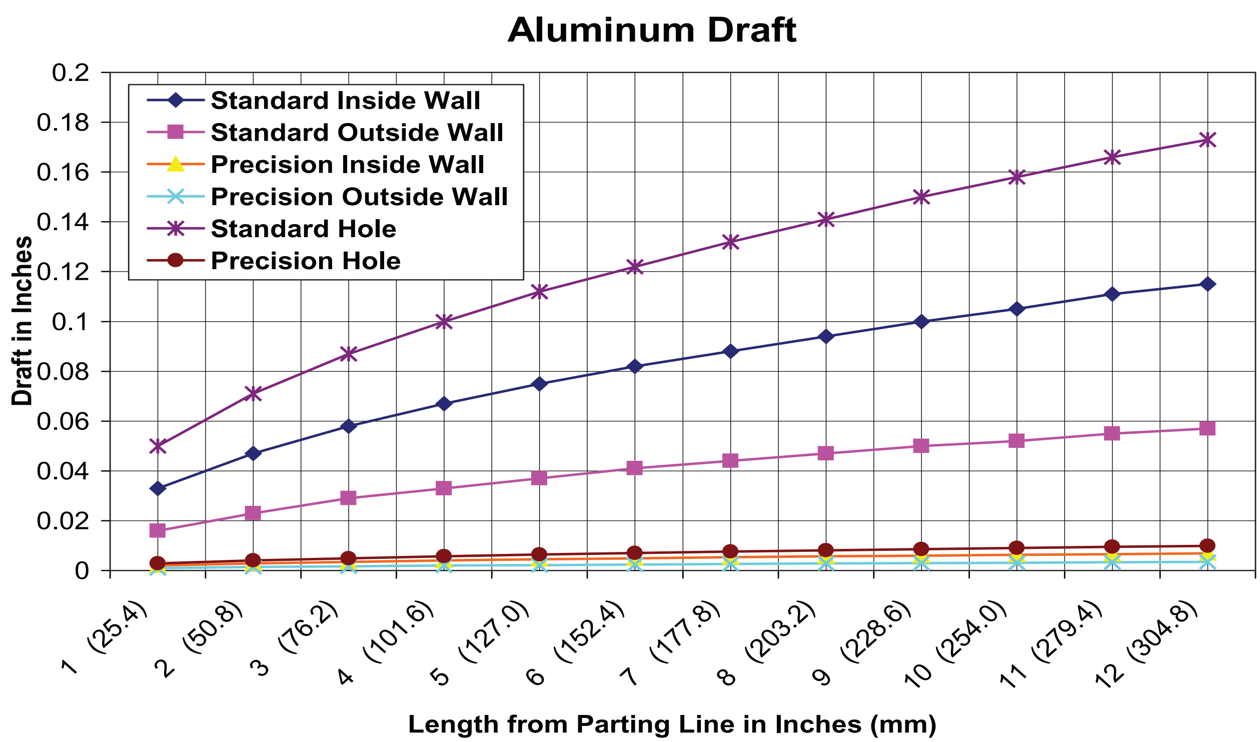
Table P-4A-7: Draft Constants for Calculating Draft and Draft Angle

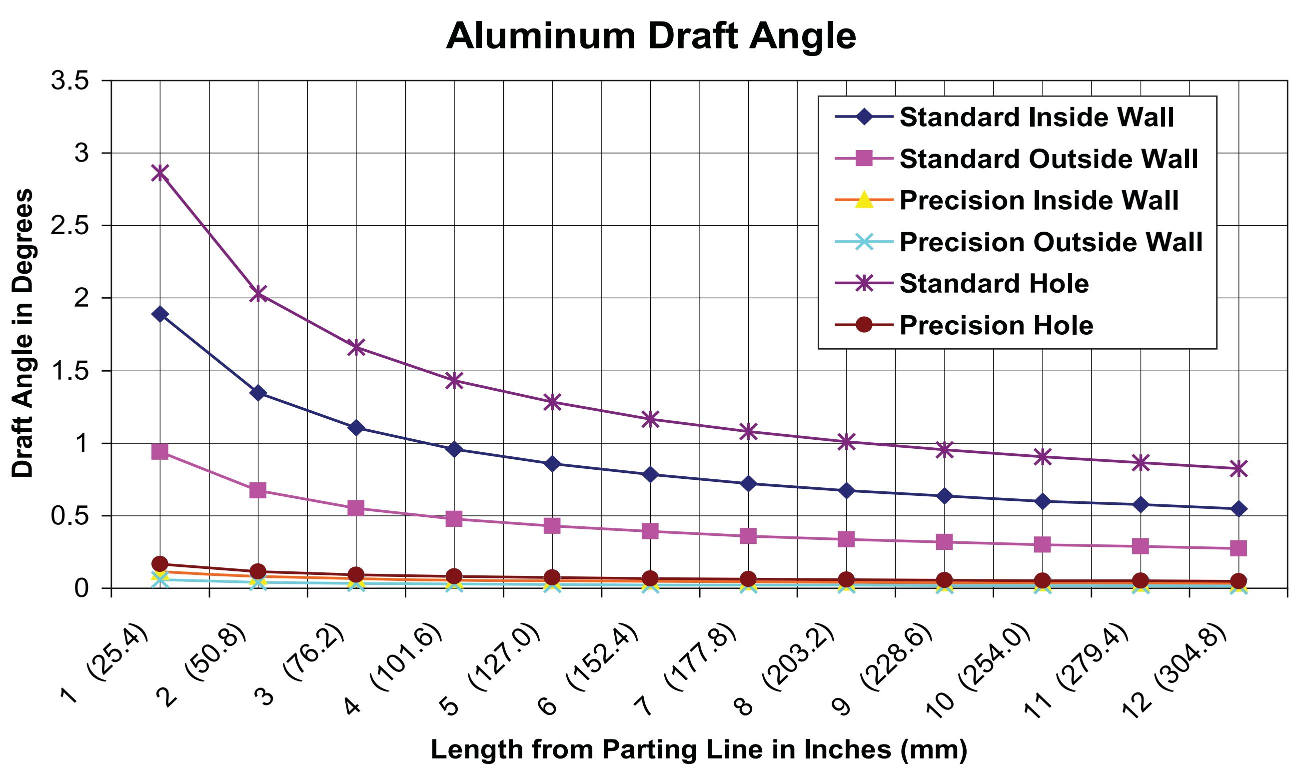
Values of Constant "C" by Features and Depth (Precision Tolerances)

Alloy	Inside Wall For Dim. in inches (mm)	Outside Wall For Dim. in inches (mm)	Hole, Total Draft For Dim. in inches (mm)
Zinc/ZA	**60** (12.00 mm)	**120** (24.00 mm)	**40** (7.80 mm)
Al/Mg/Cu	**40** (7.80 mm)	**80** (15.60 mm)	**28** (5.30 mm)

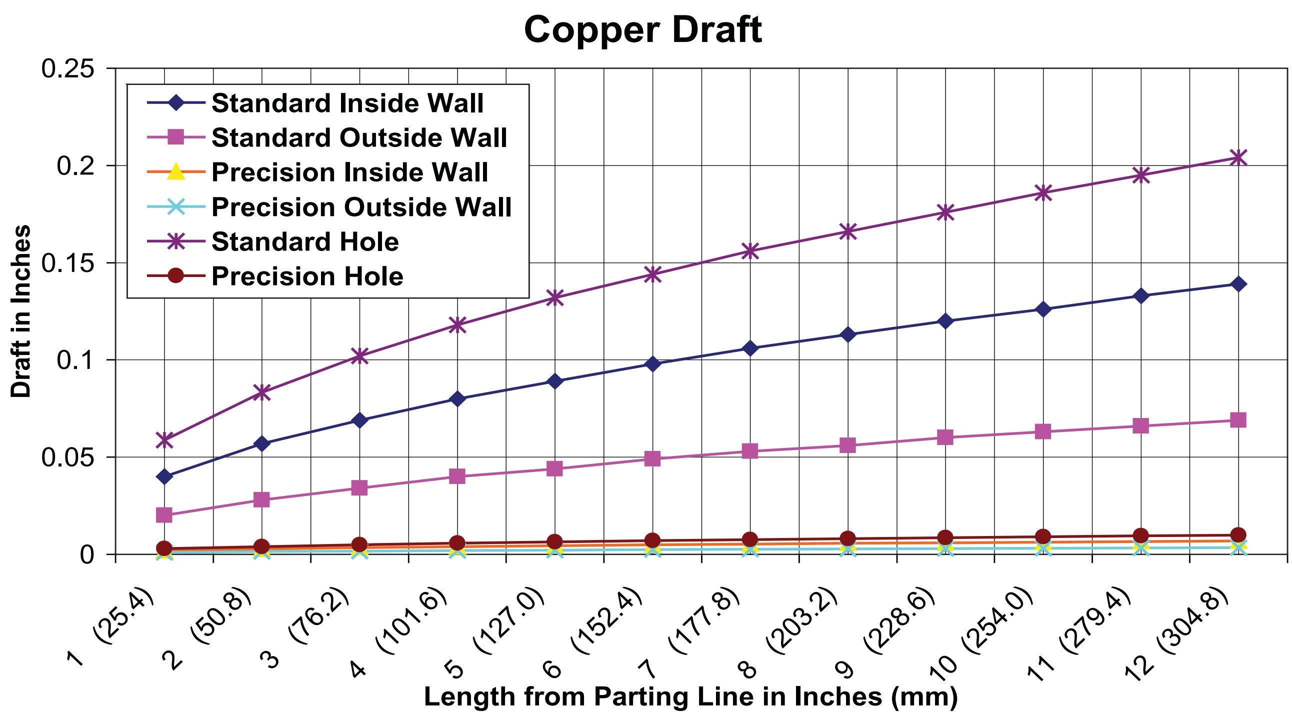
It is not common practice to specify draft separately for each feature. Draft is normally specified by a general note with exceptions called out for individual features. The formula should be used to establish general draft requirements with any exceptions identified.

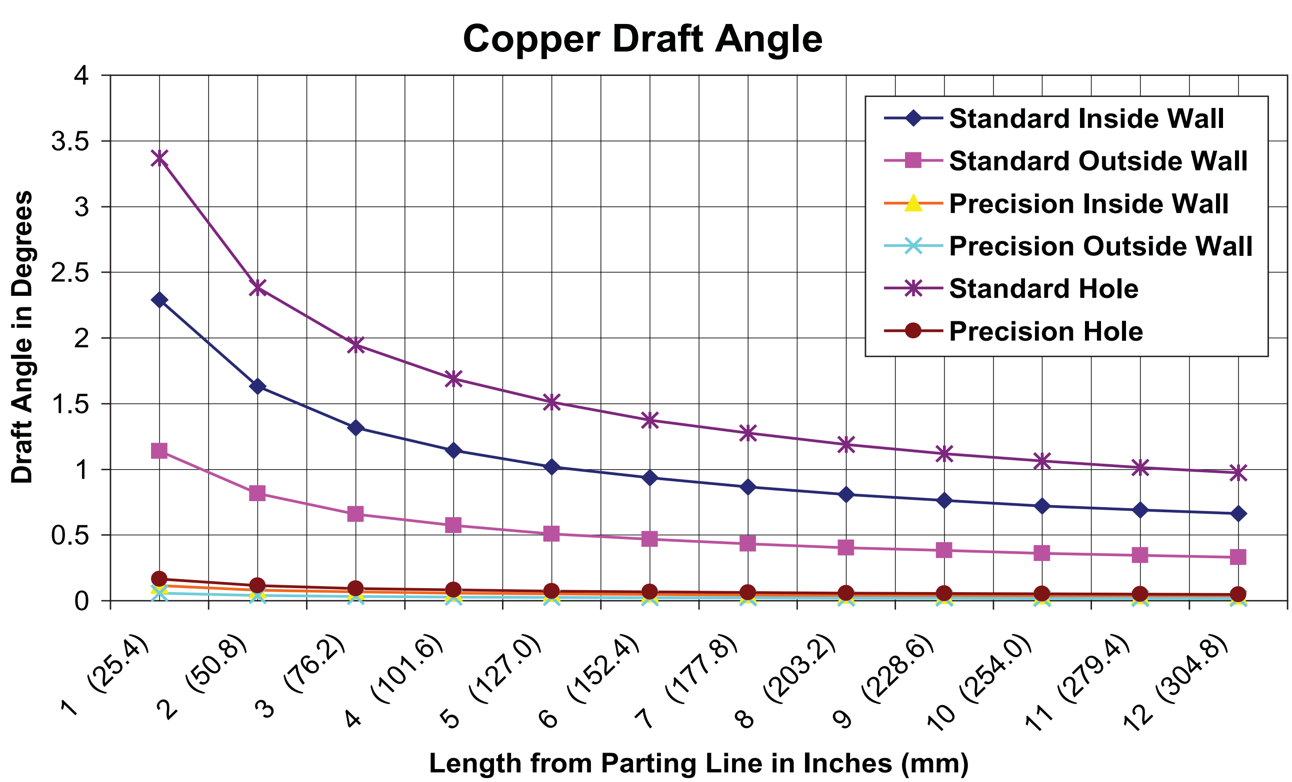
For example, an aluminum casting with most features at least 1.0 in. deep can be covered with a general note indicating 1° minimum draft on inside surfaces and 0.5° minimum on outside surfaces (based on outside surfaces requiring half as much draft).

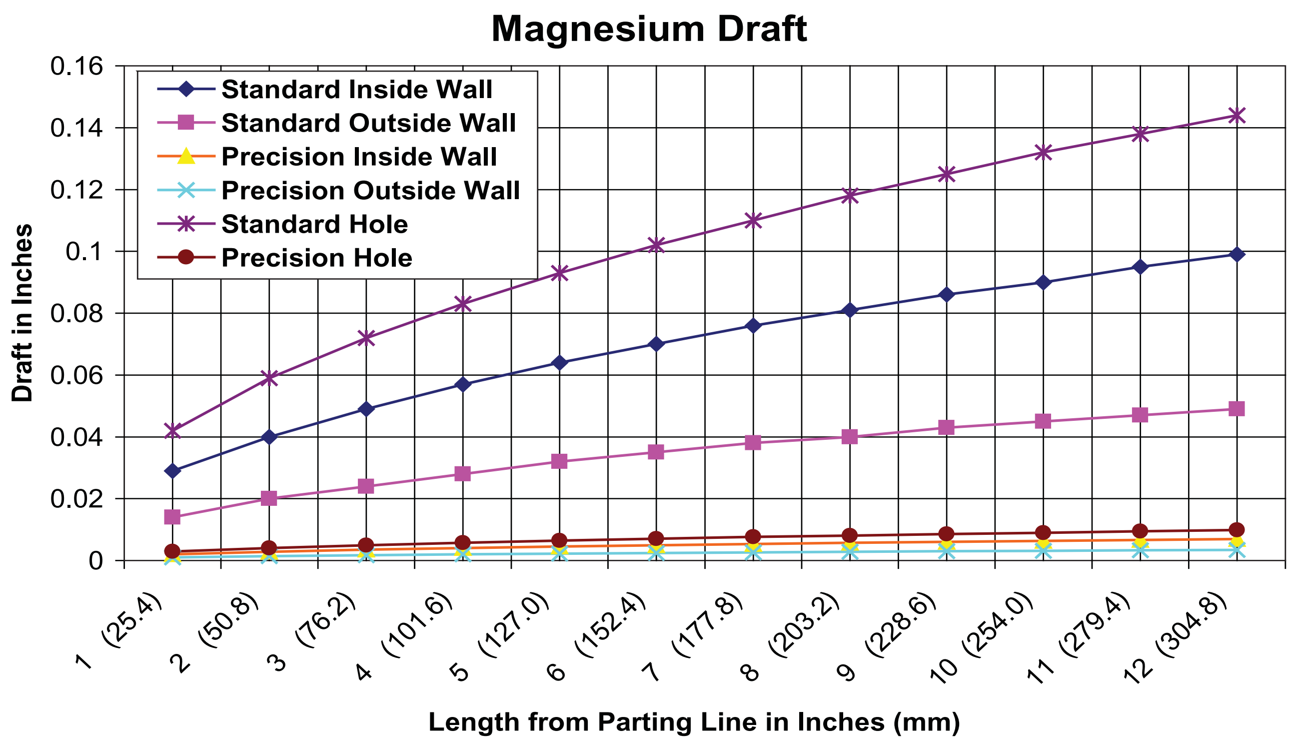

Aluminum Draft
Standard Inside Wall
Standard Outside Wall
Precision Inside Wall
Precision Outside Wall
Standard Hole
Precision Hole
Draft in Inches
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 (25.4)
2 (50.8)
3 (76.2)
4 (101.6)
5 (127.0)
6 (152.4)
7 (177.8)
8 (203.2)
9 (228.6)
10 (254.0)
11 (279.4)
12 (304.8)
Length from Parting Line in Inches (mm)

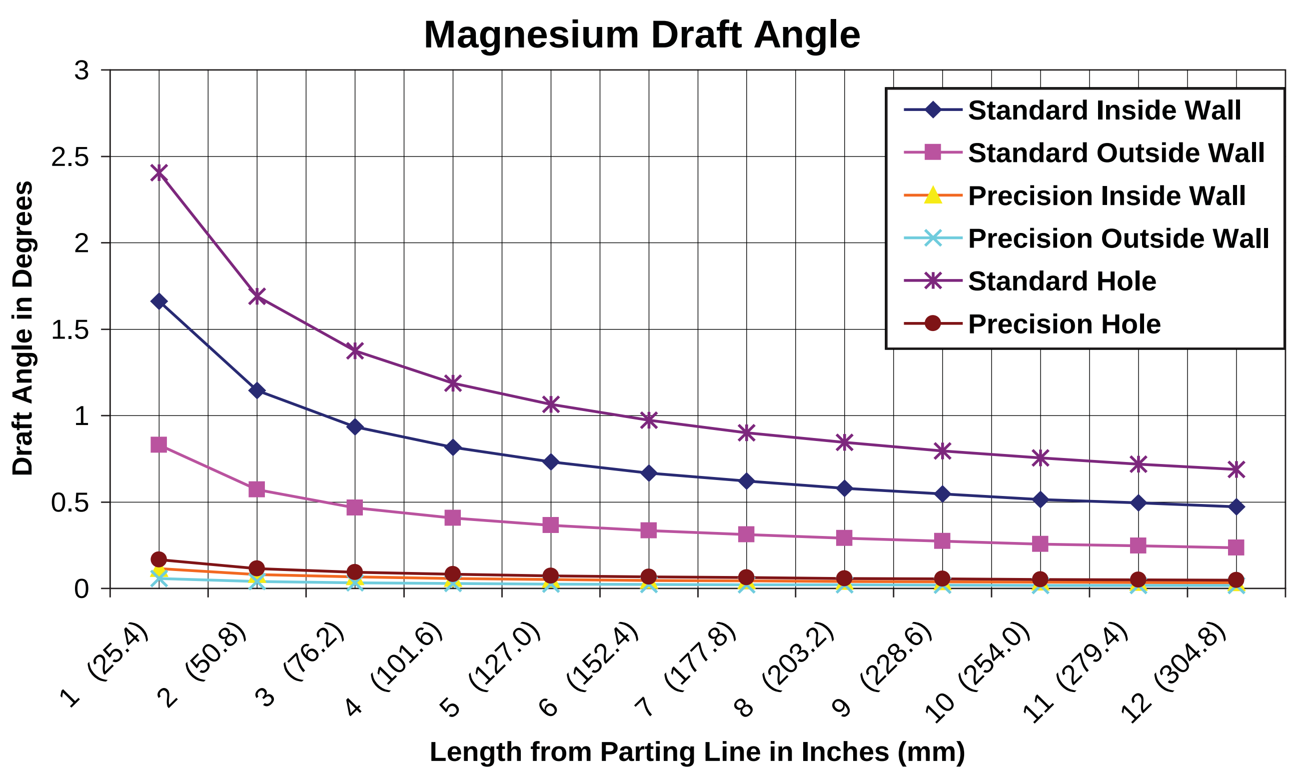

Aluminum Draft Angle
Standard Inside Wall
Standard Outside Wall
Precision Inside Wall
Precision Outside Wall
Standard Hole
Precision Hole
Draft Angle in Degrees
3.5
3
2.5
2
1.5
1
0.5
0
1 (25.4)
2 (50.8)
3 (76.2)
4 (101.6)
5 (127.0)
6 (152.4)
7 (177.8)
8 (203.2)
9 (228.6)
10 (254.0)
11 (279.4)
12 (304.8)
Length from Parting Line in Inches (mm)

Engineering & Design: Coordinate Dimensioning

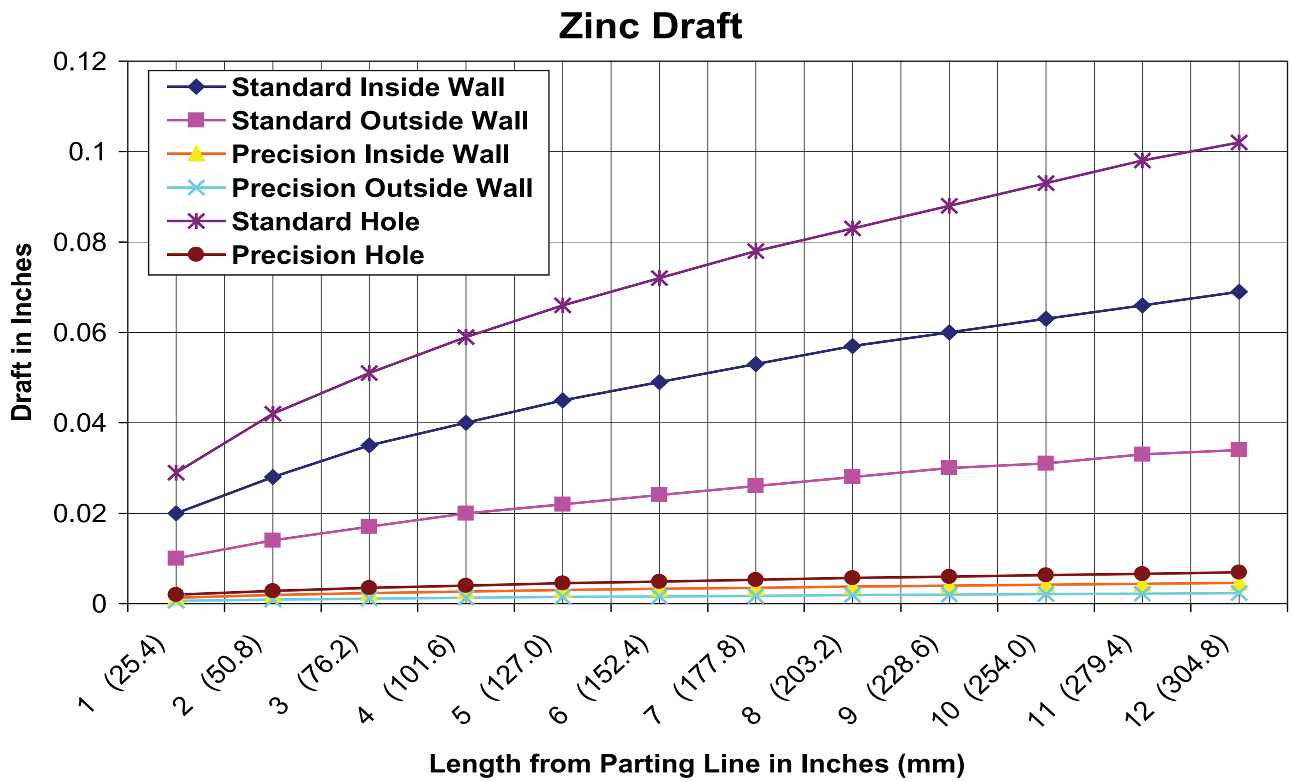


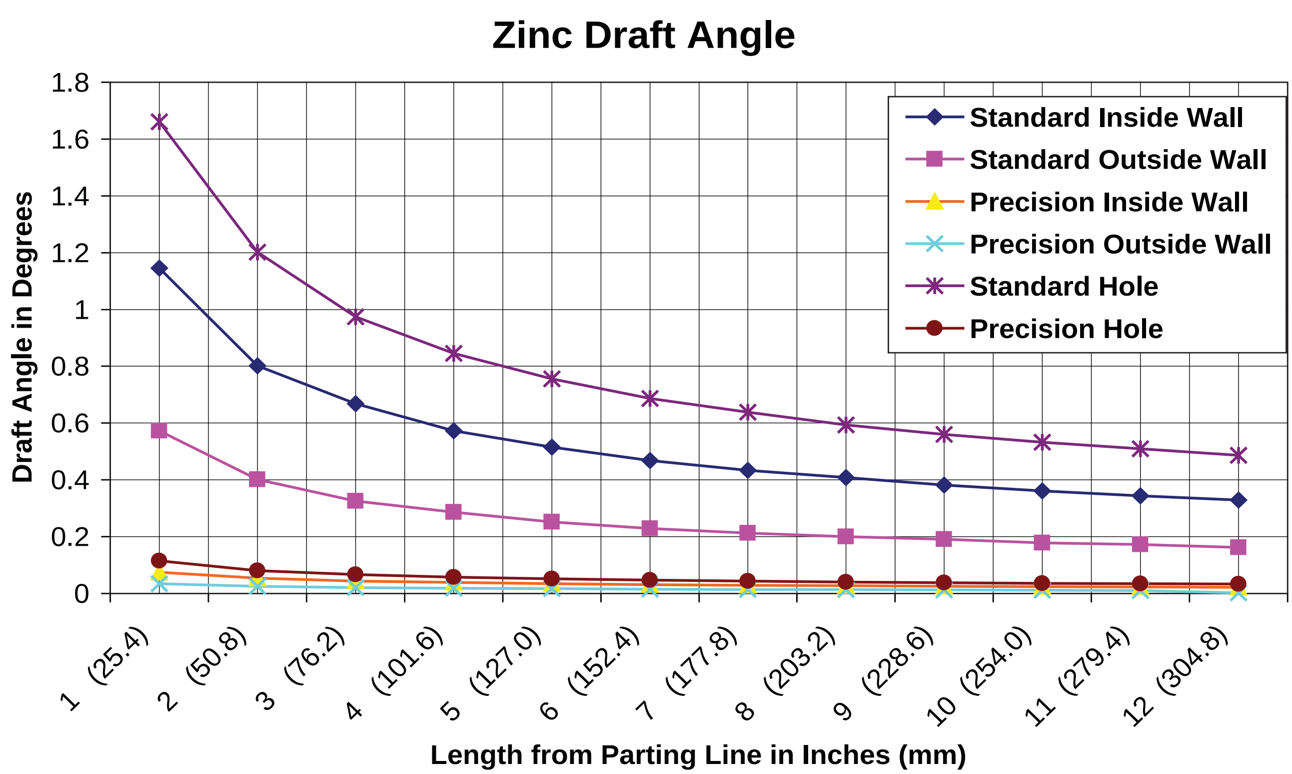



Magnesium Draft
Standard Inside Wall
Standard Outside Wall
Precision Inside Wall
Precision Outside Wall
Standard Hole
Precision Hole
Draft in Inches
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1 (25.4)
2 (50.8)
3 (76.2)
4 (101.6)
5 (127.0)
6 (152.4)
7 (177.8)
8 (203.2)
9 (228.6)
10 (254.0)
11 (279.4)
12 (304.8)
Length from Parting Line in Inches (mm)


Magnesium Draft Angle
Standard Inside Wall
Standard Outside Wall
Precision Inside Wall
Precision Outside Wall
Standard Hole
Precision Hole
Draft Angle in Degrees
3
2.5
2
1.5
1
0.5
0
1 (25.4)
2 (50.8)
3 (76.2)
4 (101.6)
5 (127.0)
6 (152.4)
7 (177.8)
8 (203.2)
9 (228.6)
10 (254.0)
11 (279.4)
12 (304.8)
Length from Parting Line in Inches (mm)

Engineering & Design: Coordinate Dimensioning





Engineering & Design: Coordinate Dimensioning

Flatness Requirements: Standard Tolerance

Flatness defines surface condition not part thickness. See the flatness explanation on the opposite page.

Standard Tolerance is calculated using the largest dimensions defining the area where the tolerance is to be applied. If flatness is to be determined for a circular surface such as the top of a can, the largest dimension is the diameter of the can. If flatness is to be determined for a rectangular area, the largest dimension is a diagonal.

For greater accuracy, see Precision Tolerances for flatness on the opposite page.

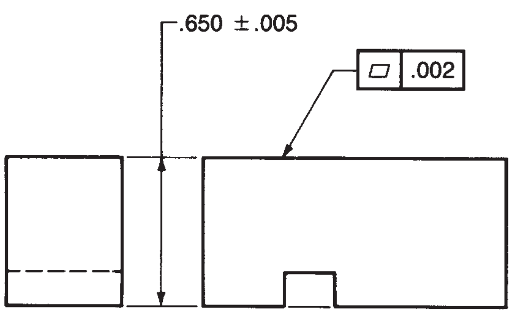
Example: Flatness Tolerance - Diagonal

For a part where the diagonal measures 10 inches (254 mm), the maximum Flatness Standard Tolerance from table S-4A-8 is 0.008 inches (0.20 mm) for the first three inches (76.2 mm) plus 0.003 inches (0.08 mm) for each of the additional seven inches for a total Flatness Standard Tolerance of 0.029 inches (0.76 mm).

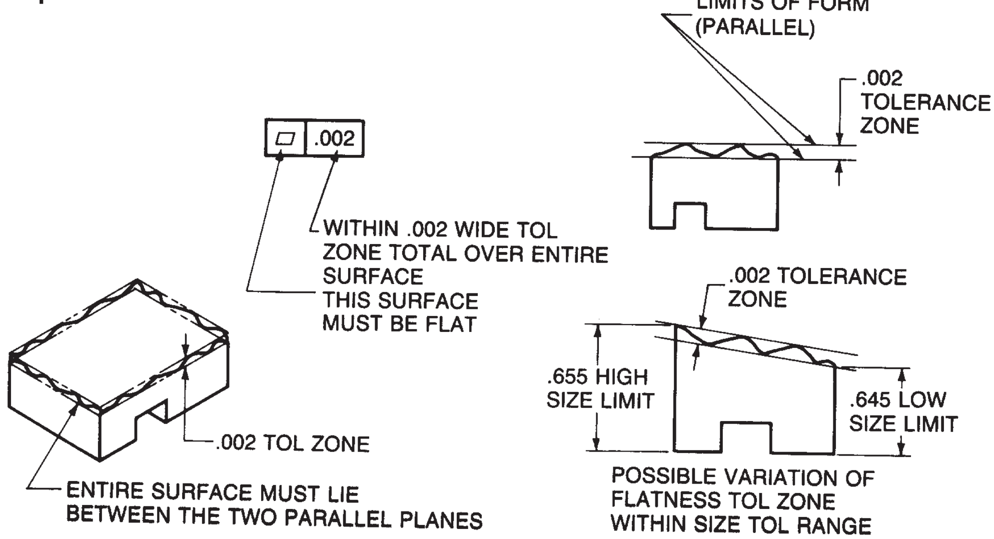
Table S-4-8 Flatness Tolerances, As-Cast: All Alloys

Maximum Dimension of Die Cast Surface	Tolerance inches (mm)
up to 3.00 in. (76.20 mm)	0.008 (0.20 mm)
Additional tolerance, in. (25.4 mm) for each additional in. (25.4 mm)	0.003 (0.08 mm)

Flatness Example



Explanation



The flatness values shown here represent Standard Tolerances, or normal casting production practice at the most economical level. For greater casting accuracy see Precision Tolerances for this characteristic on the facing page.

Flatness is described in detail in Section 5, Geometric Dimensioning & Tolerancing. Simply put, Flatness Tolerance is the amount of allowable surface variation between two parallel planes which define the tolerance zone. See the figures below.

Flatness of a continuous plane surface on a casting should be measured by a method mutually agreed upon by the designer, die caster and the customer before the start of die design.

Note:
The maximum linear dimension is the diameter of a circular surface or the diagonal of a rectangular surface.

Flatness Design Guidelines:

1. All draft on walls, bosses and fins surrounding and underneath flat surfaces should be standard draft or greater.
2. Large bosses or cross sections can cause sinks and shrinkage distortions and should be avoided directly beneath flat surfaces.
3. Changes in cross section should be gradual and well filleted to avoid stress and shrinkage distortions.
4. Symmetry is important to obtain flatness. Lobes, legs, bosses and variations in wall height can all affect flatness.

Engineering & Design: Coordinate Dimensioning

Precision Tolerance values for flatness shown represent greater casting accuracy involving extra precision in die construction. They should be specified only when and where necessary since additional cost may be involved.

Notes:
The maximum linear dimension is the diameter of a circular surface or the diagonal of a rectangular surface.

Flatness Design Guidelines:

1. All draft on walls, bosses and fins surrounding and underneath flat surfaces should be standard draft or greater.
2. Large bosses or cross sections can cause sinks and shrinkage distortions and should be avoided directly beneath flat surfaces.
3. Changes in cross section should be gradual and well filleted to avoid stress and shrinkage distortions.
4. Symmetry is important to obtain flatness. Lobes, legs, bosses and variations in wall height can all affect flatness.

Flatness Requirements: Precision Tolerance

The values shown for Precision Tolerance for flatness represent greater casting accuracy involving extra steps in die construction and additional controls in production. They should be specified only when and where necessary since additional costs may be involved.

Even closer tolerances may be held by working with the die caster to identify critical zones of flatness. These areas may be amenable to special die construction to help maintain flatness.

Flatness Explanation

As noted in the explanation diagram, at the bottom of the page, flatness is independent of all other tolerance features including thickness.

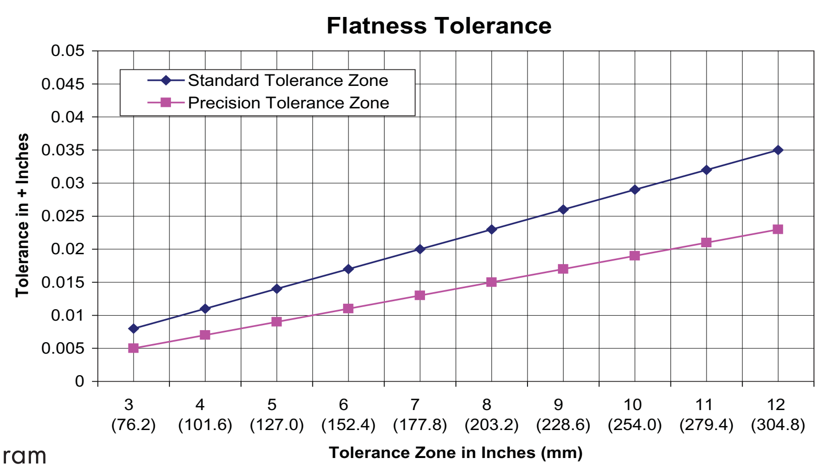
Part thickness has a nominal thickness of 0.300 ±0.010. Flatness Tolerance is 0.005. Therefore at the high limit thickness the part surface flatness can be between 0.305 and 0.310. Nominal thickness flatness can be between .2975 and .3025. Low limit thickness flatness can be between 0.290 and 0.295. Flatness can not range between 0.290 and 0.310. Using both high and low thickness in combination with flatness defeats the purpose for specifying flatness.

Example: Flatness Tolerance - Diagonal

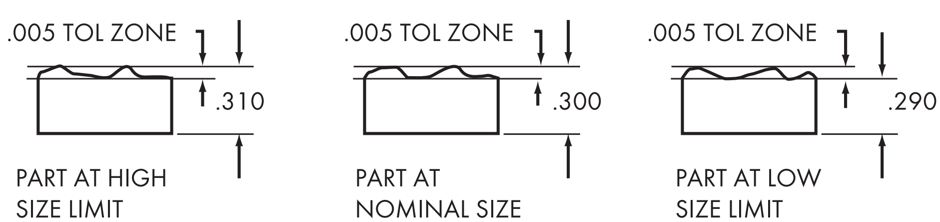
For a part where the diagonal measures 10 inches (254 mm), the maximum Flatness Precision Tolerance from table P-4A-8 is 0.005 inches (0.13 mm) for the first three inches (76.2 mm) plus 0.002 inches (0.05 mm) for each of the additional seven inches for a total Flatness Standard Tolerance of 0.019 inches (0.48 mm).

Table P-4A-8 Flatness Precision Tolerance

Maximum Dimension of Die Cast Surface	Tolerance inches (mm)
up to 3.00 in. (76.20 mm)	0.005 (0.13 mm)
Additional tolerance, in. (25.4 mm) for each additional in. (25.4 mm)	0.002 (0.05 mm)



Explanation Diagram



Design Recommendations: Cored Holes As-Cast

Cored holes in die castings can be categorized according to their function. There are three major classifications.

- Metal savers
- Clearance holes
- Function/locating holes

Each of these functions implies a level of precision. Metal savers require the least precision; function/locating holes require the greatest precision. Leaving clearance holes in-between.

Specifications for cored holes are the combination of form, size and location dimensions and tolerances required to define the hole or opening.

Metal Savers

Metal savers are cored features, round or irregular, blind or through the casting, whose primary purpose is to eliminate or minimize the use of raw material (metal/alloy). The design objective of the metal saver is to reduce material consumption, while maintaining uniform wall thickness, good metal flow characteristics, good die life characteristics with minimal tool maintenance.

In the design of ribs and small metal savers the designer needs to be aware to avoid creating "small" steel conditions in the tool that can be detrimental to tool life.

Design recommendation:

1. Wall thickness
Design for uniform wall thickness around metal savers. Try to maintain wall thickness within ±10% of the most typical wall section.

2. Draft
Use draft constant per NADCA S-4A-7 for inside walls. Keep walls as parallel as practical.

3. Radii/fillets
Use as large a radius as possible, consistent with uniform wall thickness. Refer to NADCA guidelines G-6-2. Consider 0.06 inch radius (1.5 mm radius) as a minimum. A generous radius at transitions and section changes will promote efficient metal flow during cavity filling.

Clearance Holes

Clearance holes are cored holes, round or irregular, blind or through the casting, whose primary purpose is to provide clearance for features and components. Clearance implies that location of the feature is important.

Design recommendation:

1. Tolerance
Dimensions locating the cored hole should be per NADCA Standard tolerances; S-4A-1 Linear Dimension, S-4A-2 Parting Line Dimensions and S-4A-3 Moving Die Components.

2. Wall thickness
Design for uniform wall thickness around clearance holes. Try to maintain wall thickness within ±10% of the most typical wall section. If hole is a through hole, allowance should be made for any trim edge per NADCA G-6-5, Commercial Trimming within 0.015 in. (0.4 mm).

3. Draft
Use draft constant per NADCA S-4A-7 for inside walls. Keep walls as parallel as practical.

4. Radii/fillets
Use as large a radius as possible, consistent with uniform wall thickness. Refer to NADCA guidelines G-6-2. Consider 0.06 inch radius (1.5 mm radius.) as a minimum. A generous radius at transitions and section changes will promote efficient metal flow during cavity filling.

For holes with less than a 0.25 inch diameter, wall stock may be a minimum of one half the hole diameter. Unless wall thickness is required for strength. However, Ribbing Should be applied first.

For holes with larger than a 0.25 inch diameter, the wall stock shall be the nominal wall thickness (subject to part design).

These rules can be broken if the product requires more strength. However, ribbing should be attempted first.

Functional/Locating Holes

Functional/locating holes are cored holes whose purpose is to provide for a functional purpose such as threading, inserting and machining or location and alignment for mating parts or secondary operations.

Design recommendation:

1. Tolerance

Dimensions locating the cored hole to be per NADCA Precision tolerances; P-4A-1 Linear Dimension, P-4A-2 Parting Line Dimensions and P-4A-3 Moving Die Components.

2. Wall thickness

Design for uniform wall thickness around functional/locating holes. Try to maintain wall thickness within ±10% of the most typical wall section. If hole is a through hole, allowance should be made for any trim edge per NADCA G-6-5, Commercial Trimming within 0.015 inch (0.4 mm) or if this is not acceptable, a mutually agreed upon requirement.

3. Draft

Use draft constant per NADCA P-4A-7 for inside walls. Keep walls as parallel as practical.

4. Radii/fillets

Use as large a radius as possible, consistent with uniform wall thickness. Refer to NADCA guidelines G-6-2. Consider 0.03 inch radius (0.8 mm radius.) as a minimum. A generous radius at transitions and section changes will promote efficient metal flow during cavity filling.

Other Design Considerations

Hole depths

	Diameter of Hole — Inches								
	1/8	5/32	3/16	1/4	3/8	1/2	5/8	3/4	1
Alloy	Maximum Depth — Inches								
Zinc	3/8	9/16	3/4	1	1-1/2	2	3-1/8	4-1/2	6
Aluminum	5/16	1/2	5/8	1	1-1/2	2	3-1/8	4-1/2	6
Magnesium	5/16	1/2	5/8	1	1-1/2	2	3-1/8	4-1/2	6
Copper				1/2	1	1-1/4	2	2-1/2	5

Note:

The depths shown are not applicable under conditions where small diameter cores are widely spaced and, by design, are subject to full shrinkage stress.

Perpendicularity

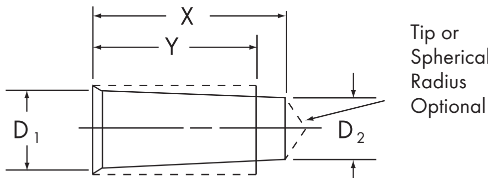
See Section 5 pages 5-19 and 5-20 Orientations Tolerances.

Engineering & Design: Coordinate Dimensioning

The values shown represent Standard Tolerances, or normal casting production practice at the most economical level. For greater casting accuracy see Precision Tolerances for the characteristic on the facing page.

Cored Holes for Cut Threads: Standard Tolerances

Cored holes for cut threads are cast holes that require threads to be cut (tapped) into the metal.



The table below provides the dimensional tolerances for diameter, depth and draft for each specified thread type (Unified and Metric Series). When required, cored holes in Al, Mg, Zn and ZA may be tapped without removing draft. This Standard Tolerance recommendation is based on allowing 85% of full thread depth at the bottom D_2 (small end) of the cored hole and 55% at the top D_1 (large end) of the cored hole. A countersink or radius is also recommended at the top of the cored hole. This provides relief for any displaced material and can also serve to strengthen the core.

Threads extend through the cored hole as by Y. X shows the actual hole depth. As with the countersink at the top of the hole, the extra hole length provides relief for displaced material and allows for full thread engagement. Tolerances below apply to all alloys.

Table S-4A-9: Cored Holes for Cut Threads (Standard Tolerances) – Unified Series and Metric Series

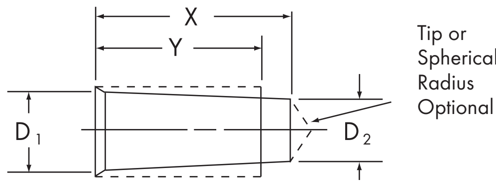
Unified Series/ Class	Hole Diameter D_1, Max.	D_2, Min.	Thread Depth Y, Max.	Hole Depth X, Max.
	inches	inches	inches	inches
6-32, UNC/2B, 3B	0.120	0.108	0.414	0.508
6-40, UNF/2B	0.124	0.114	0.345	0.420
8-32, UNC/2B	0.146	0.134	0.492	0.586
8-36, UNF/2B	0.148	0.137	0.410	0.493
10-24, UNC/2B	0.166	0.151	0.570	0.695
10-32, UNF/2B	0.172	0.160	0.475	0.569
12-24, UNC/2B	0.192	0.177	0.648	0.773
12-28, UNF/2B	0.196	0.182	0.540	0.647
1/4A-20, UNC/1B, 2B	0.221	0.203	0.750	0.900
1/4A-28, UNF/1B, 2B	0.230	0.216	0.500	0.607
5/16-18, UNC/1B, 2B	0.280	0.260	0.781	0.948
5/16-24, UNF/1B, 2B	0.289	0.273	0.625	0.750
3/8-16, UNC/1B, 2B	0.339	0.316	0.938	1.125
3/8-24, UNF/1B, 2B	0.351	0.336	0.656	0.781
7/16-14, UNC/1B, 2B	0.396	0.371	1.094	1.308
7/16-20, UNF/1B, 2B	0.409	0.390	0.766	0.916
1/2-13, UNC/1B, 2B	0.455	0.428	1.250	1.481
1/2-20, UNF/1B, 2B	0.471	0.453	0.750	0.900
9/16-12, UNC/1B, 2B	0.514	0.485	1.406	1.656
9/16-18, UNF/1B, 2B	0.530	0.510	0.844	1.010
5/8-11, UNC/1B, 2B	0.572	0.540	1.563	1.835
5/8-18, UNF/1B, 2B	0.593	0.573	0.781	0.948
3/4A-10, UNC/1B, 2B	0.691	0.657	1.688	1.988
3/4A-16, UNF/1B, 2B	0.714	0.691	0.938	1.125
7/8- 9, UNC/1B, 2B	0.810	0.772	1.750	2.083
7/8-14, UNF/1B, 2B	0.833	0.808	1.094	1.308
1- 8, UNC/1B, 2B	0.927	0.884	2.000	2.375
1-12, UNF/1B. 2B	0.951	0.922	1.250	1.500

Metric Series Thread Size Ⓐ	Hole Diameter D_1, Max.	D_2, Min.	Thread Depth Y, Max.	Hole Depth X, Max.
	mm	mm	mm	mm
M3.5 X 0.6	3.168	2.923	7.88	9.68
M4 X 0.7	3.608	3.331	9.00	11.10
M5 X 0.8	4.549	4.239	11.25	13.65
M6 X 1	5.430	5.055	13.50	16.50
M8 X 1.25	7.281	6.825	18.00	21.75
f M8 X 1	7.430	7.055	14.00	17.00
M10 X 1.5	9.132	8.595	22.50	27.00
f M10 X 0.75	9.578	9.285	10.00	12.25
f M10 X 1.25	9.281	8.825	20.00	23.75
M12 X 1.75	10.983	10.365	27.00	32.25
f M12 X 1	11.430	11.055	15.00	18.00
f M12 X 1.25	11.281	10.825	18.00	21.75
M14 X 2	12.834	12.135	31.50	37.50
f M14 X 1.5	13.132	12.595	24.50	29.00
f M15 X 1	14.430	14.055	15.00	18.00
M16 X 2	14.834	14.135	32.00	38.00
f M16 X 1.5	15.132	14.595	24.00	28.50
f M17 X 1	16.430	16.055	15.30	18.30
f M18 X 1.5	17.132	16.595	24.30	28.80
M20 X 2.5	18.537	17.675	40.00	47.50
f M20 X 1	19.430	19.055	15.00	18.00
f M20 X 1.5	19.132	18.595	25.00	29.50
f M22 X 1.5	21.132	20.595	25.30	29.80
M24 X 3	22.239	21.215	48.00	57.00
f M24 X 2	22.834	22.135	30.00	36.00
f M25 X 1.5	24.132	23.595	25.00	29.50
f M27 X 2	25.834	25.135	33.75	39.75
M30 X 3.5	27.941	26.754	60.00	70.50

f = Fine Pitch Series

The Precision Tolerance values shown represent greater casting accuracy involving extra precision in die construction and/or special control in production. They should be specified only when and where necessary, since additional cost may be involved.

Cored Holes for Cut Threads: Precision Tolerances



Cored holes for cut threads are cast holes that require threads to be cut (tapped) into the metal. The table below provides the dimensional tolerances for diameter, depth and draft for each specified thread type (Unified and Metric Series). When required, cored holes in Al, Mg, Zn and ZA may be tapped without removing draft. This Precision Tolerance recommendation is based on allowing 95% of full thread depth at the bottom D_2 (small end) of the cored hole and the maximum minor diameter at the top D_1 (large end) of the cored hole. A countersink or radius is also recommended at the top of the cored hole. This provides relief for any displaced material and can also serve to strengthen the core.

Table P-4A-9: Cored Holes for Cut Threads (Precision Tolerances) – Unified Series and Metric Series

Table P-4A-9 Cored Holes for Cut Threads (Precision Tolerances) — Unified Series and Metric Series

Unified Series/ Class Ⓐ	Hole Diameter D_1, Max.	D_2, Min.	Thread Depth Y, Max.	Hole Depth X, Max.
	inches	inches	inches	
0-80, UNF/2B, 3B	*(0.051)*	*(0.047)*	*(0.130)*	*(0.163)*
1-64, UNC/2B, 3B	*(0.062)*	*(0.057)*	*(0.200)*	*(0.250)*
1-72, UNF/2B, 3B	*(0.064)*	*(0.059)*	*(0.160)*	*(0.200)*
2-56, UNC/2B, 3B	*(0.074)*	*(0.068)*	*(0.240)*	*(0.300)*
2-64, UNF/2B, 3B	*(0.075)*	*(0.070)*	*(0.200)*	*(0.250)*
3-48, UNC/2B, 3B	*(0.085)*	*(0.078)*	*(0.280)*	*(0.350)*
3-56, UNF/2B, 3B	*(0.087)*	*(0.081)*	*(0.220)*	*(0.275)*
4A-40, UNC/2B, 3B	*(0.094)*	*(0.086)*	*(0.320)*	*(0.400)*
4A-48, UNF/2B, 3B	*(0.097)*	*(0.091)*	*(0.240)*	*(0.300)*
5-40, UNC/2B, 3B	0.106	0.099	0.280	0.350
5-44, UNF/2B, 3B	0.108	0.102	0.240	0.300
6-32, UNC/2B, 3B	0.114	0.106	0.350	0.438
6-40, UNF/2B	0.119	0.112	0.270	0.338
8-32, UNC/2B	0.139	0.132	0.290	0.363
8-36, UNF/2B	0.142	0.135	0.260	0.325
10-24, UNC/2B	0.156	0.147	0.390	0.488
10-32, UNF/2B	0.164	0.158	0.240	0.300
12-24, UNC/2B	0.181	0.173	0.340	0.425
12-28, UNF/2B	0.186	0.179	0.270	0.338
1/4A-20, UNC/1B, 2B	0.207	0.199	0.370	0.463
1/4A-28, UNF/1B, 2B	0.220	0.213	0.270	0.338
5/16-18, UNC/1B, 2B	0.265	0.255	0.440	0.550
5/16-24, UNF/1B, 2B	0.277	0.270	0.310	0.388
3/8-16, UNC/1B, 2B	0.321	0.311	0.470	0.588
3/8-24, UNF/1B, 2B	0.340	0.332	0.340	0.425
7/16-14, UNC/1B, 2B	0.376	0.364	0.570	0.713
7/16-20, UNF/1B, 2B	0.395	0.386	0.400	0.500
1/2-13, UNC/1B, 2B	0.434	0.421	0.640	0.800
1/2-20, UNF/1B, 2B	0.457	0.449	0.370	0.463
9/16-12, UNC/1B, 2B	0.490	0.477	1.280	1.600
9/16-18, UNF/1B, 2B	0.515	0.505	0.880	1.100
5/8-11, UNC/1B, 2B	0.546	0.532	1.430	1.788
5/8-18, UNF/1B, 2B	0.578	0.568	0.930	1.163
3/4A-10, UNC/1B, 2B	0.663	0.647	1.590	1.988
3/4A-16, UNF/1B, 2B	0.696	0.686	0.950	1.188
7/8- 9, UNC/1B, 2B	0.778	0.761	1.750	2.188
7/8-14, UNF/1B, 2B	0.814	0.802	1.200	1.500
1- 8, UNC/1B, 2B	0.890	0.871	1.900	2.375
1-12, UNF/1B. 2B	0.928	0.914	1.340	1.675

Metric Series Thread Size ⒶⒷ	Hole Diameter D_1, Max.	D_2, Min.	Thread Depth Y, Max.	Hole Depth X, Max.
	mm	mm	mm	mm
M1.6 X 0.35	*(1.32)*	*(1.24)*	*(2.40)*	*(3.45)*
M2 X 0.4	*(1.68)*	*(1.59)*	*(3.00)*	*(4.20)*
M2.5 X 0.45	*(2.14)*	*(2.04)*	*(3.75)*	*(5.10)*
M3 X 0.5	*(2.60)*	*(2.49)*	*(4.50)*	*(6.00)*
M3.5 X 0.6	2.99	2.88	5.25	7.05
M4 X 0.7	3.42	3.28	6.00	8.10
M5 X 0.8	4.33	4.17	7.50	9.90
M6 X 1	5.15	4.96	9.00	12.00
M8 X 1.25	6.91	6.70	12.00	15.75
f M8 X 1	7.15	6.96	12.00	15.00
M10 X 1.5	8.68	8.44	15.00	19.50
f M10 X 0.75	9.38	9.23	12.50	14.75
M10 X 1.25	8.91	8.70	15.00	18.75
M12 X 1.75	10.44	10.17	18.00	23.25
f M12 X 1	11.15	10.96	15.00	18.00
f M12 X 1.25	10.91	10.70	15.00	18.75
M14 X 2	12.21	11.91	21.00	27.00
f M14 X 1.5	12.68	12.44	21.00	25.50
f M15 X 1	14.15	13.96	18.75	21.75
M16 X 2	14.21	13.91	28.00	34.00
f M16 X 1.5	14.68	14.44	24.00	28.50
f M17 X 1	16.15	15.96	17.00	20.00
f M18 X 1.5	16.68	16.44	22.50	27.00
M20 X 2.5	17.74	17.38	30.00	37.50
f M20 X 1	19.15	18.96	20.00	23.00
f M20 X 1.5	18.68	18.44	20.00	24.50
f M22 X 1.5	20.68	20.44	22.00	26.50
M24 X 3	21.25	20.85	36.00	45.00
f M24 X 2	22.21	21.91	30.00	36.00
f M25 X 1.5	23.68	23.44	25.00	29.50
f M27 X 2	25.21	24.91	27.00	33.00
M30 X 3.5	26.71	26.31	37.50	48.00

f = Fine Pitch Series

Values in italics and parentheses are achievable but should be discussed with the die caster prior to finalization of a casting design.

Cored holes for formed threads are specified in die castings as Precision Tolerances, because they require special control in production. The specific diameter, depth and draft required will determine the added cost.

Note:
Tolerances for cored holes for thread forming fasteners (self tapping screws) should be provided by the manufacturer of the specific type of thread forming fastener to be used.

Engineering & Design: Coordinate Dimensioning

Cored Holes for Formed Threads: Precision Tolerances

The Precision Tolerance recommendations for cored holes for formed threads, on the opposite page, are based on allowing 75% of full thread depth at the bottom D_2 (small end) of the cored hole and 50% at the top D_1 (large end) of the cored hole. When required, cored holes in aluminum, zinc and magnesium may be tapped without removing draft.

Cold form taps displace material in an extrusion or swaging process. As a result, threads are stronger because the material is work hardened as a part of the process for forming threads. Because material is displaced, a countersink is recommended at the ends of through holes and at the entry of blind holes.

Tests indicate that thread height can be reduced to 60% without loss of strength, based on the fact cold formed threads in die castings are stronger than conventional threads. However, the use of 65% value is strongly recommended.

Since cored holes in castings must have draft (taper), the 65% thread height Y should be at a depth that is an additional one-half of the required engagement length of the thread in the hole.

Blind holes should be cored deep enough to allow a four (4) thread lead at the bottom of the hole. This will result in less burr around the hole and longer tool life. Hole sizes of #6 or less, or metric M3 or less, are recommended for through holes only.

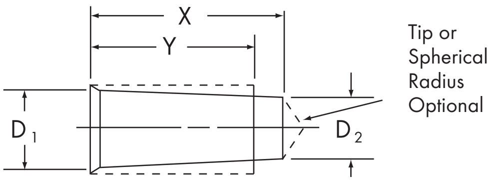
Cold form tapping is not recommended for holes with a wall thickness less than two-thirds the nominal diameter of the thread.

The Precision Tolerance recommendation should be considered as a starting point with respect to depth recommendations. There are many applications that do not require the percent of thread listed here. If a lesser percent of thread can be permitted, this would, in turn, allow more draft and a deeper hole. Amount and direction of required strength can be determined by testing.

Cored Holes for Formed Threads: Precision Tolerances

The Precision Tolerance values shown represent greater casting accuracy involving extra precision in construction and/or special control in production. They should be specified only when and where necessary, since additional cost may be involved.

The tolerances below apply to AI, Mg, Zn and ZA die casting alloys, as footnoted. Note that, when required, cored holes in aluminum, zinc, and magnesium may be tapped without removing draft.



Guidelines are provided on the opposite page regarding thread height, depth, and limitations on wall thickness.

Table P-4A-10: Cored Holes for Formed Threads (Precision Tolerances) – Unified Series and Metric Series

Unified Series Class Ⓐ	Hole Diameter D_1, Max. inches	Hole Diameter D_2, Min. inches	Thread Depth Y, Max. inches	Hole Depth X, Max. inches
0-80, UNF/2B, 3B	(0.0558)	(0.0536)	(0.090)	(0.120)
1-64, UNC/2B, 3B	(0.0677)	(0.0650)	(0.110)	(0.146)
1-72, UNF/2B, 3B	(0.0683)	(0.0659)	(0.110)	(0.146)
2-56, UNC/2B, 3B	(0.0799)	(0.0769)	(0.129)	(0.172)
2-64, UNF/2B, 3B	(0.0807)	(0.0780)	(0.129)	(0.172)
3-48, UNC/2B, 3B	(0.0919)	(0.0884)	(0.149)	(0.198)
3-56, UNF/2B, 3B	(0.0929)	(0.0899)	(0.149)	(0.198)
4A-40, UNC/2B, 3B	(0.1035)	(0.0993)	(0.168)	(0.224)
4A-48, UNF/2B, 3B	(0.1049)	(0.1014)	(0.168)	(0.224)
5-40, UNC/2B, 3B	(0.1165)	(0.1123)	(0.188)	(0.250)
5-44, UNF/2B, 3B	(0.1173)	(0.1134)	(0.188)	(0.250)
6-32, UNC/2B, 3B	(0.1274)	(0.1221)	(0.207)	(0.276)
6-40, UNF/2B	(0.1295)	(0.1253)	(0.207)	(0.276)
8-32, UNC/2B	0.153	0.148	0.328	0.492
8-36, UNF/2B	0.155	0.150	0.328	0.492
10-24, UNC/2B	0.176	0.169	0.380	0.570
10-32, UNF/2B	0.179	0.174	0.380	0.570
12-24, UNC/2B	0.202	0.195	0.432	0.648
12-28, UNF/2B	0.204	0.198	0.432	0.648
1/4A-20, UNC/1B, 2B	0.233	0.225	0.500	0.750
1/4A-28, UNF/1B, 2B	0.238	0.232	0.500	0.750
5/16-18, UNC/1B, 2B	0.294	0.284	0.703	0.938
5/16-24, UNF/1B, 2B	0.298	0.291	0.703	0.938
3/8-16, UNC/1B, 2B	0.354	0.343	0.844	1.125
3/8-24, UNF/1B, 2B	0.361	0.354	0.844	1.125
7/16-14, UNC/1B, 2B	0.413	0.401	0.984	1.313
7/16-20, UNF/1B, 2B	0.421	0.412	0.984	1.313
1/2-13, UNC/1B, 2B	0.474	0.461	1.125	1.500
1/2-20, UNF/1B, 2B	0.483	0.475	1.125	1.500
9/16-12, UNC/1B, 2B	0.534	0.520	1.266	1.688
9/16-18, UNF/1B, 2B	0.544	0.534	1.266	1.688
5/8-11, UNC/1B, 2B	0.594	0.579	1.406	1.875
5/8-18, UNF/1B, 2B	0.606	0.597	1.406	1.875
3/4A-10, UNC/1B, 2B	0.716	0.699	1.500	2.250
3/4A-16, UNF/1B, 2B	0.729	0.718	1.500	2.250
7/8- 9, UNC/1B, 2B	0.837	0.818	1.750	2.625
7/8-14, UNF/1B, 2B	0.851	0.839	1.750	2.625
1- 8, UNC/1B, 2B	0.958	0.936	2.000	3.000
1-12, UNF/1B, 2B	0.972	0.958	2.000	3.000

Metric Series Thread Size ⒶⒷ	Hole Diameter D_1, Max. mm	Hole Diameter D_2, Min mm	Thread Depth Y, Max. mm	Hole Depth X, Max. mm
M1.6 X 0.35	*(1.481)*	*(1.422)*	*(2.4)*	*(3.2)*
M2 X 0.4	*(1.864)*	*(1.796)*	*(3.0)*	*(4.0)*
M2.5 X 0.45	*(2.347)*	*(2.271)*	*(3.8)*	*(5.0)*
M3 X 0.5	*(2.830)*	*(2.745)*	*(4.5)*	*(6.0)*
M3.5 X 0.6	3.296	3.194	7.0	10.5
M4 X 0.7	3.762	3.643	8.0	12.0
M5 X 0.8	4.728	4.592	10.0	15.0
M6 X 1	5.660	5.490	12.0	18.0
M8 X 1.25	7.575	7.363	16.0	24.0
f M8 X 1	7.660	7.490	16.0	24.0
M10 X 1.5	9.490	9.235	20.0	30.0
f M10 X 0.75	9.745	9.618	12.5	30.0
f M10 X 1.25	9.575	9.363	20.0	30.0
M12 X 1.75	11.41	11.11	24.0	36.0
f M12 X 1	11.66	11.49	18.0	36.0
f M12 X 1.25	11.58	11.36	18.0	36.0
M14 X 2	13.32	12.98	28.0	42.0
f M14 X 1.5	13.49	13.24	21.0	42.0
f M15 X 1	14.66	14.49	18.8	45.0
M16 X 2	15.32	14.98	32.0	48.0
f M16 x 1.5	15.49	15.24	24.0	48.0
f M17 X 1	16.66	16.49	17.0	51.0
f M18 X 1.5	17.49	17.24	27.0	54.0
M20 X 2.5	19.15	18.73	40.0	60.0
f M20 X 1	19.66	19.49	20.0	60.0
f M20 X 1.5	19.49	19.24	30.0	60.0
f M22 X 1.5	21.49	21.24	27.5	66.0
M24 X 3	22.98	22.47	48.0	72.0
f M24 X 2	23.32	22.98	36.0	72.0
f M25 X 1.5	24.49	24.24	31.3	75.0
f M27 X 2	26.32	25.98	40.5	81.0
M30 X 3.5	28.81	28.22	60.0	90.0

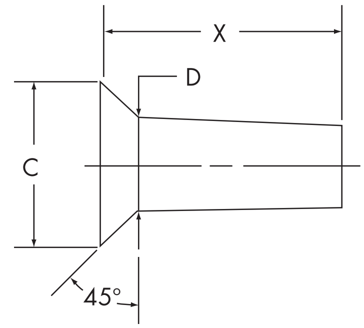
f = Fine Pitch Series

Values in italics and parentheses are achievable but should be discussed with the die caster prior to finalization of a casting design.

The values shown for tapered pipe threads represent Standard Tolerances, or normal die casting production practice at the most economical level. N.P.T. threads should be specified, where possible, for most efficient production.

Engineering & Design: Coordinate Dimensioning

Cored Holes for Pipe Threads: Standard Tolerances



Most pipes require taper to ensure that the connections seal as more of the thread is engaged. For example, when a garden hose is first threaded onto a threaded connection, it is very loose. As more of the thread is engaged by screwing the hose on, there is less play as the fitting gets tighter. A good fitting will become tight before the threads bottom out. Additional hole beyond the threads is provided so that fitting can be tightened against the taper to achieve the desired seal. Taper also allows for part wear.

There are two pipe thread taper standards. National Pipe Taper (N.P.T.) is the most common standard. A fitting should seal with at least one revolution of turn still available on the thread. The fitting should not bottom out in the hole. Standard taper is normally ¾ inches per foot. However, taper for special applications is determined by required strength formerly discussed in Cored Holes for Formed Threads.

Aeronautical National Pipe Taper (A.N.P.T.) is basically the same as N.P.T. pipe threads. However, diameter, taper and thread form are carefully controlled for military and aviation use. There is an associated cost increase using the A.N.P.T. standard since tighter controls are required.

The cored holes specified below are suitable for both N.P.T. and A.N.P.T. threads. The 1° 47' taper per side is more important for A.N.P.T. than N.P.T. threads. There is no comparable metric standard for pipe threads.

For the most economical die casting production, N.P.T. threads should be specified where possible. A.N.P.T. threads may require additional steps and cost.

The required taper for all N.P.T. and A.N.P.T. sizes is 1° 47'±10'per side.

The differences in measurement of these threads represent the differences in function. The N.P.T. thread quality in determined by use of the L1 thread plug gauge. This thread is intended as a tapered sealing thread using pipe dope or another sealing agent to provide a leak tight seal.

The A.N.P.T. thread, as well as the N.P.T.F. (American National Taper Dryseal Pressure-Tight Joints) thread, represents a tapered thread that is capable of sealing without the aid of sealing agents; thus their identification as dry seal threads. These threads are checked with the use of an L1 and L3 thread member as well as a six step plug gauge to verify thread performance on the crests. The difference of the A.N.P.T. and N.P.T.F. is in the tolerance of the gauging. The dry seal threads are more difficult to cast as the draft angle of the cores must be 1° 47' per side and without drags to avoid lobing at the tapping operation or an L3 failure.

Table S-4A-11: Cored Holes for Tapered Pipe Threads Both N.P.T. and A.N.P.T.

Tap size	"D" Diameter	Minimum Depth "X" for Standard Tap	Minimum Depth "X" for Short Projection Tap	"C" Diameter ±.020
1/16 - 27	0.245 ±0.003	0.609	0.455	0.327
1/8 - 27	0.338 ±0.003	0.609	0.458	0.421
1/4 - 18	0.440 ±0.003	0.859	0.696	0.577
3/8 - 18	0.575 ±0.004	0.875	0.702	0.702
1/2 - 14	0.713 ±0.004	1.109	0.918	0.890
3/4 - 14	0.923 ±0.004	1.109	0.925	1.077
1 - 11 1/2	1.160 ±0.005	1.343	1.101	1.327
1 1/4 - 11 1/2	1.504 ±0.006	1.375	1.113	1.656
1 1/2 - 11 1/2	1.743 ±0.007	1.390	1.127	1.921
2 - 11 1/2	2.217 ±0.008	1.375	1.205	2.515
2 1/2 - 8	2.650 ±0.008	1.953	1.697	2.921
3 - 8	3.277 ±0.009	2.031	1.780	3.546

Cast Threads

Threads can be cast in aluminum, magnesium, or zinc. Normally, cast threads are confined to external threads where precision class fits are not required. If a precision class fit is required, the die caster should be consulted. Secondary machining may be required.

External threads can be formed either across the parting line of a die (fig.1) or with slides (fig. 2). Tolerances shown in Table S-4A-12 reflect the method by which the threads are formed.

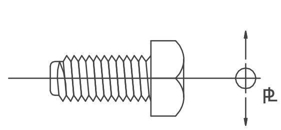
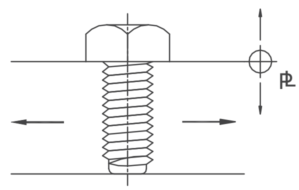
The Major diameter shall be in compliance with the specified thread form definition as agreed upon between the purchaser and the die caster.

Threaded parts are identified by a series of numbers known as a thread callout. A typical thread callout may be 1/16-28-0.960-0.580-0.12-7.02 where:

1/16 is the nominal thread size

28 is the number of Threads Per Inch (TPI)

Table S-4A-12: Die Cast Threads Tolerances

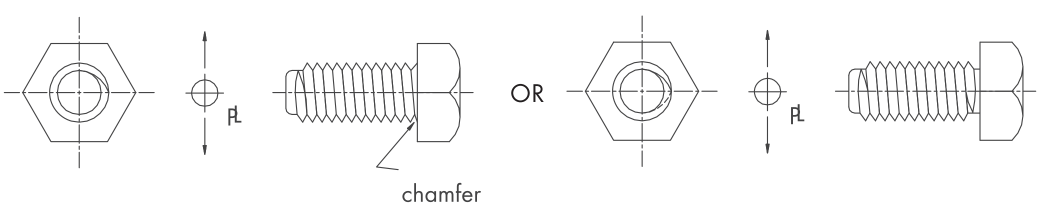
Method of Forming Threads	Figure 1 		Figure 2 	
Tolerances	**Zinc**	**Aluminum/ Magnesium**	**Zinc**	**Aluminum/ Magnesium**
Minimum pitch or maximum number of threads per inch	32	24	32	24
Minimum O.D.	0.187” (4.763 mm)	0.250” (6.350 mm)	0.187” (4.763 mm)	0.250” (6.350 mm)
Tolerance on thread lead per inch of length	±.005” (±.127 mm)	±.006” (±.152 mm)	±.005” (±.127 mm)	±.006” (±.152 mm)
Minimum Pitch Diameter Tolerance	±.004” (±.102 mm)	±.005” (±.127 mm)	±.005” (±.127 mm)	±.006” (±.152 mm)

Notes:

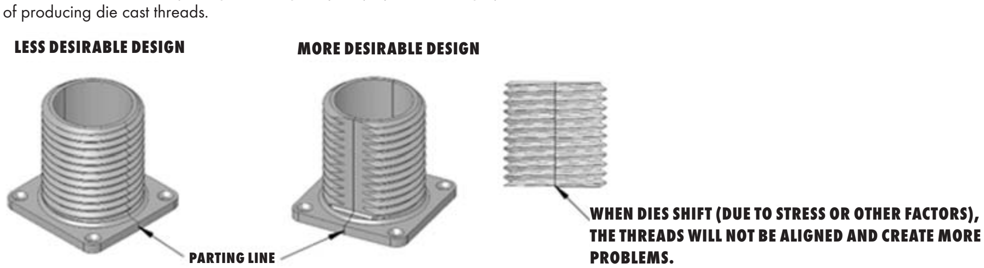
1. An additional trim or chasing operation may be necessary to remove flash formed between threads.
2. Direct tolerances shown should be applied wherever possible rather than specifying thread class or fit.
3. The values indicated include parting line, moving die component and linear dimension tolerances. If tighter tolerances are required, the caster should be consulted.

Figure 3. Design Considerations

The recommended designs for terminating a die cast external thread are shown below:



Flats on the thread at the parting line will greatly simplify the trimming operation and result in the most economical means of producing die cast threads.



Engineering & Design: Coordinate Dimensioning

Machining stock allowances are a function of linear dimensions tolerances and parting line tolerances, and whether Standard or Precision Tolerances are required. Precision Tolerance values will usually represent greater casting accuracy involving extra precision in die construction and/or special control in production. For economical production, they should be specified only when and where necessary.

Note:
No consideration was given to flatness in the above examples. The part shape may dictate a flatness tolerance that exceeds the sum of the linear and across parting line tolerances. (See Flatness Tolerances S-4A-8 and P-4A-8.) Additional machining would then be required unless the part can be straightened prior to machining.

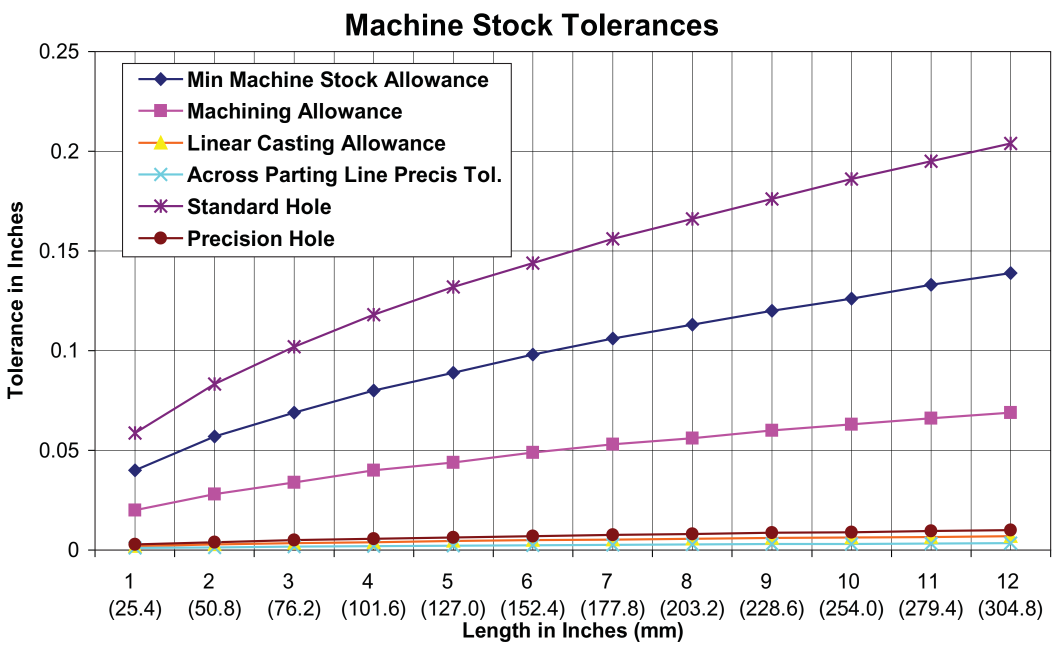
Machining Stock Allowance (Standard and Precision)

It is important to understand that the optimum mechanical properties and density of a casting are at or near the surface. If machining is to be performed on a casting, a minimum amount of material should be removed so as not to penetrate the less dense portion. However, to assure cleanup, an allowance must be provided for both the machining variables and the casting variables covered by NADCA Standards in this section.

Datum structure is very important to help minimize or eliminate the effect of these variables. (See Datum Reference Framework in Geometric Dimensioning, Section 5, for a preferred datum framework.) Best results are attained if the casting is located from datum points that are in the same die half as the feature to be machined.

Consulting with your caster early will help minimize the effect of tolerance accumulation and unnecessary machining.

Normal minimum machining allowance is 0.010 in. (0.25 mm) to avoid excessive tool wear and minimize exposure of porosity. The maximum allowance is the sum of this minimum, the machining allowance and the casting allowance.



Machining Stock Allowance (Standard and Precision)

Example:

Assume a 5.00 ± 0.001 in. (127 ± 0.025 mm) finish dimension on an aluminum die cast part that is 8.00 x 8.00 in. (203.2 x 203.2 mm).

In example "A" in the table on the facing page, surface to be machined is formed in the same die half as the datum points. In example "B", surface to be machined is formed in the opposite half of the die as the datum points. Both examples are shown using the Precision Tolerances for linear dimensions and parting line. The Standard Tolerances for linear dimensions and parting line would utilize the same format.

Machining Stock Allowance Comparative Example: Precision Tolerances

	Example A Datum Points In Same Die Half	Example B Datum Points In Opposite Die Half
Minimum Machine Stock Allowance inches (mm)	0.010 (0.25 mm)	0.010 (0.25 mm)
Machining Allowances (± 0.001 in. or ± 0.026 mm)	0.002 (0.05 mm)	0.002 (0.05 mm)
Linear Casting Allowance on 5.000 in. (127 mm) Dimension Precision Tolerance Ⓐ	0.012 (0.356 mm)	0.012 (0.356 mm)
Across Parting Line Precision Tolerances Ⓑ	—	0.008 (0.020 mm)
Maximum Stock	0.026 (0.56 mm)	0.034 (0.86 mm)
Casting Dimension Ⓒ	5.017 ± 0.006 (127.45 ± 0.18 mm)	5.026 +0.014/-0.006 (127.66 +0.38/-0.18 mm)

Ⓐ ±0.007 (±0.18 mm) P-4A-1-03 Precision Tolerance

Ⓑ ±0.008 (±0.20 mm) P-4A-2 Precision Tolerance

Ⓒ Casting dimension would not be needed if drawing was a combined drawing, only finish dimension of 5.00 ± 0.001 in. (127 ± 0.025 mm) would be needed.

Additional Considerations for Large Castings

1 Wall Thickness:

1.1: Definition: Wall thickness is the distance between two parallel or nearly parallel surfaces. Wall thickness may vary depending on the application of draft. Wall thickness should be maintained as uniform as possible. A general guideline would be to keep the range of thickness within 2X of the thinnest wall. A second guideline is to keep the wall as thin as possible to meet the castings functional requirements.

1.2: General: 0.14" (3.5mm (+/- 0.5mm)

1.2.1 Deviations: from the nominal condition are based upon product function and manufacturing process requirements.

2 Radii:

2.1 Fillet Radii:

2.1.1 General: 0.14" (+0.08/-0.04") [3.5mm (+2.0mm/-1.0mm)]

2.1.1.1 Deviations: from the nominal condition are based upon product function and manufacturing process requirements.

2.1.2 Minimum: 0.060" (1.5mm)

2.2 Corner Radii:

2.2.1 General: 0.060" (+0.08/-0.04") [1.5mm (+2mm/-1mm)]

2.2.1.1 Deviations: from the nominal condition are based upon product function and manufacturing process requirements.

2.2.2 Minimum: 0.020" (0.5mm)

3 Cores:

3.1 Guidelines: Cores should be used to minimize machining stock, and should be pulled perpendicular to each other. Use stepped cores where possible to minimize finish stock, reduce heavy sections, and minimize porosity.

3.2 Minimum: Cored hole diameter to be 0.25" (6.0mm) in and parallel to the direction of die draw.

3.3 For holes Less Than: 0.50" (12.5mm) diameter the core hole length to diameter (L/D) ratio should not exceed 4:1.

3.4 For Holes Greater Than: 0.50" (12.5mm) diameter the core pin length to diameter (L/D) ratio should not exceed 10:1.

4 Bosses:

4.1: Minimize the boss height as much as possible.

4.2: When the height to diameter ratio of the boss exceeds 1, it is recommended that ribs be used to improve filling.

4.3: Design adjacent bosses with a minimum 0.25" (6.5mm) gap between bosses to minimize porosity.

Additional Considerations for Large Castings

5: Machining Stock:

5.1 General:

5.1.1: Machining stock should be minimized. Because die casting exhibit a "skin", the densest fine-grained casting structure is near the surface.

5.1.2: Deviations from nominal condition are based upon product function and manufacturing process requirements.

5.2: 0.06" (1.5mm) maximum, on all faces, features found in the locator core, on remainder of part.

6 Ejector Pin Bosses:

6.1 Boss Diameter:

6.1.1: In functional areas the size and location is dependent upon product function and manufacturing requirements.

6.1.2: In non-functional areas and on machined surfaces the ejector pin diameter is to be 0.38" (10.0mm) minimum and the location is by mutual agreement of OEM and die caster.

6.2 Surface Geometry:

6.2.1: 0.06" (1.5mm) raised to 0.03" (0.8mm) depressed.

7 Trimming & Cleaning:

7.1 Parting Lines:

7.1.1 Trim Ribs-Gate and Parting Line: 0.12" maximum (1.5mm)

7.1.2 Gates & Overflows: 0-0.059" (0-1.5mm)

7.1.3 Flash: As specified in normal standard.

7.2 Cored Holes: 0-0.02" (0-0.5mm)

7.3 Openings:

7.3.1: 0-0.06" (0-1.5mm) at the finish machined face

7.3.2: 0-0.03" (0-0.8mm) on as-cast surfaces

7.3.3: 0-0.01" (0-2.5mm) of corner radii

7.4 Corners - Sharp: Not removed.

7.5 Ejector Pin Flash (Max. Projection):

7.5.1: 0-0.12" (0-3.0mm) on machined surfaces.

7.5.2: 0-0.04" (0-1.0mm) on as-cast surfaces.

7.6 Machined Surfaces: 0.12" (0-0.3mm) max.

7.7 Seam Lines: 0-0.02" (0-0.5mm)

7.8 Negative trim (shearing): condition is allowed when the nominal wall thickness is maintained.

Engineering & Design: Miniature Die Casting

SECTION **4B**

Section Contents

Frequently Asked Questions (FAQ)

1) What is the difference between Section 4A and Section 4B, Miniature Die Casting?
   See page 4B-2, Introduction.
2) What is a Miniature Die Cast Machine?
   See page 4B-4, Miniature Die Cast Machines.
3) How tight can dimensional tolerances be held for mini-zinc castings?
   See page 4B-3, Typical Design and Tolerance Data.

1 Introduction

Miniature die casting is a precision fabricating process similar to conventional hot chamber die casting, but capable of much faster cycle times, tighter tolerances and minimal secondary operations. It is often possible to combine multiple assembled components in a single cast piece with significant total cost reduction. The process is capable of producing castings ranging in weight from fractions of an ounce up to 16 ounces. Tolerances less than .001 of an inch with virtually no "part to part" dimensional variation are routinely achieved. Miniature die casting can yield flash-free, net-shape components of complex design from a variety of metals, specifically zinc, zinc-aluminum and magnesium. Zinc die cast components are often used "as-cast" with no further treatment, however, various surface finishes can be applied to increase corrosion resistance, provide aesthetic appeal, and/or improve mechanical properties.

Cycling up to 100 times per minute, automated, hot chamber, direct injection die casting machines produce a component ready for tumble degating and subsequent shipment. Generally, single cavity dies are preferred but when large volumes are required multiple cavity dies are used. The single cavity principle insures that all parts are exactly alike. This can be a very important consideration when automatic assembly equipment is used. High production rates from single cavity tooling and the precision inherent in the machines, have combined to make this process essential in numerous industries.

It is not uncommon for finished castings to cost as little as $.050 USD. Complete one time tooling charges range from $7,000 to $75,000 depending on the complexity of the part and cavity configuration. Miniature die casting has been successful for over 50 years and technological advances continue to expand process capabilities with each year. Consult your miniature die caster regarding your small component needs. There is probably a way he can save you time and money.

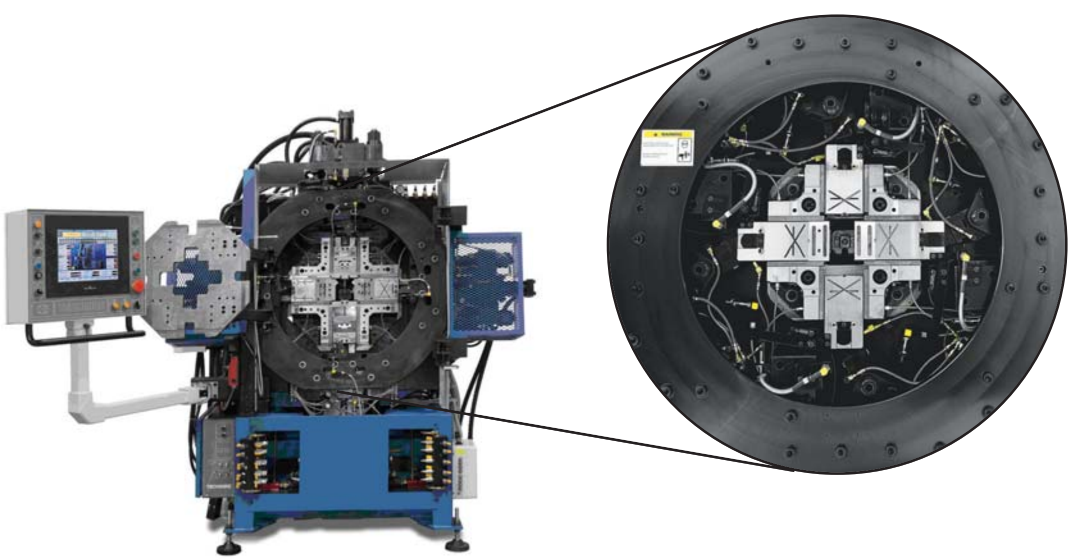


Figure 4B-1: 44NTX multiple slide die casting maching. Image courtesy of Techmire

2 Typical Design and Tolerance Data

Because of their size and the specialized machines used, miniature die castings can be produced to closer dimensional tolerances than larger castings. One of the advantages of miniature die casting is that 'part to part' variations are virtually nonexistent.

Tolerances on hole locations and other details that are influenced by shrinkage are obviously easier to hold on small parts. Tooling is crucial to successful miniature die casting (see page 4B-4 Miniature Die Casting Dies) and when designed and built properly can produce castings that are clean, flash-free and ready-to-use without secondary operations. This leaves the hard dense surface of the casting undisturbed and thus increases wear resistance and strength.

Note:
It is important to note that this section covers tolerances that are achievable for both standard and precision die castings. However, in today's six sigma world, capability may still be a question. Die cast tools are often built to allow for maximum tool life and process variations that can detract from the process and actual tool capability. Six sigma variation and CPK should be discussed with the die caster in advance of tool construction. Frequent repeatability (CP rather than CPK) is the goal in the as-cast state. To build a tool at nominal dimensions to get a good CPK will lead to shorter tool life and added rejects to the die caster for process variations.

Figure 4B-2 Examples of mini-zinc castings.

Note: *Tolerances given below have been achieved and are strictly applied to multiple slide, miniature die casting. The values may vary with size, design, and configuration of the component. Please consult your die caster for establishing tolerances for specific part features.*

Linear Dimension	+/-0.0008" up to 1" and +/-0.001 for each additional inch	+/-0.020mm up to 25.4mm" and +/-0.025 for each additional 25.4mm

The following values are typical for a 1.18" (30mm) component.		
Flatness	0.002"	0.05 mm
Straightness	0.001"	0.03 mm
Circularity	0.001" (// to parting line)	0.03 mm (// to parting line)
Angularity	0.001 in/in	0.001 mm/mm
Concentricity	0.002" (// to parting line)	0.05 mm (// to parting line)
Minimum Wall Thickness	0.020"	0.50 mm
Surface Finish *(See paragraph 5.7)*	to 32 to 64 microinches	0.8-1.6 microns
Gears *(See paragraph 5.14)*	AGMA 6 - AGMA 8	
Threads-External As-Cast *(See paragraph 5.15)*	2A	6g

3 Miniature Die Casting Machines

Miniature die casting machines may be small versions of traditional die casting machines or can be what is referred to as multiple-slide machines (see Figure 4B-1). These machines are made by several different manufacturers around the world. State of the art technology is available in these completely automated, computer controlled machines. Some die casters custom build their own machines or modify commercial machines to better meet the needs of their customers. Miniature die casting machines commonly use two to four slides. Five and even six slides have been used in very complex applications. The most common "multiple-slide" machine is built to accommodate a two inch square die, but machines made for four, six and eight inch square dies are also utilized.

With four sliding dies forming the details of a component, very intricate features are relatively easy to cast to extremely tight tolerances that are nearly flash-free. Operating at approximately 2000 psi injection pressure, a two inch square, four slide machine, can cycle 100 times per minute. Although average running speeds generally are in the 15-25 cycles per minute range. Pneumatic and/or hydraulic cylinders are used to inject the molten metal into the cavity as well as move the slides in and out. Some larger shots may require the use of hydraulic cylinders in order to accommodate necessary metal pressure and die lock up pressures. Smaller castings require less metal pressure to fill properly and less time to solidify. Usually a blue print of the component is enough to indicate what type of machine is needed to meet specified requirements.

4 Miniature Die Casting Dies

As with any form of die casting, miniature die cast tooling requires several basic considerations when designing a die to best meet your needs. Remember your die caster can make this very easy for you since they have specific machine and process requirements that must be addressed. The most obvious factors are: the shape or geometry of the part, the physical size of the part, the part weight and the production requirements.

The shape or geometry of a part is probably the most important issue to be considered because the part must be castable and still maintain its intended function. Usually a component(s) in an assembly can be engineered to develop a practical part both castable and functional. If the parts intended function can not be maintained, modifications mentioned after this section are extremely important when developing a part. Your die caster will be able to advise on the most cost effective way to meet your needs.

The physical size of the part is one of the first factors considered in designing the die. There must be an adequate amount of "shut off" steel outside the cavity that forms the part in order to contain the metal during the injection phase. The amount of shut off steel necessary can vary. A good rule of thumb is to maintain a minimum of 15% of the die head size per side (ex: 4" x 4" die head * 15% = 0.60 shut off per side). Therefore the part length and width should not exceed 2.8" x 2.8" if intended for a standard 4" x 4" die (fig. 4B-3).

The part weight or volume of metal required will influence the type of die used. A heavier part may effectively eliminate the use of a pneumatic machine and require a hydraulically operated machine. Generally, air machines can consistently produce good quality zinc castings up to 2 oz. Hydraulic machines are used when exceeding 2 oz. Air is usually preferred over hydraulics because the machine can cycle approximately 30% faster. This allows for an improved piece part price.

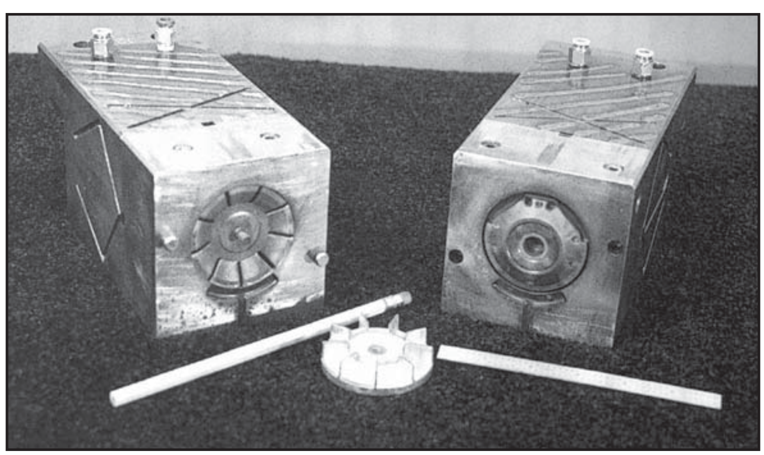


Figure 4B-3 Example of a 4" x 4" die.

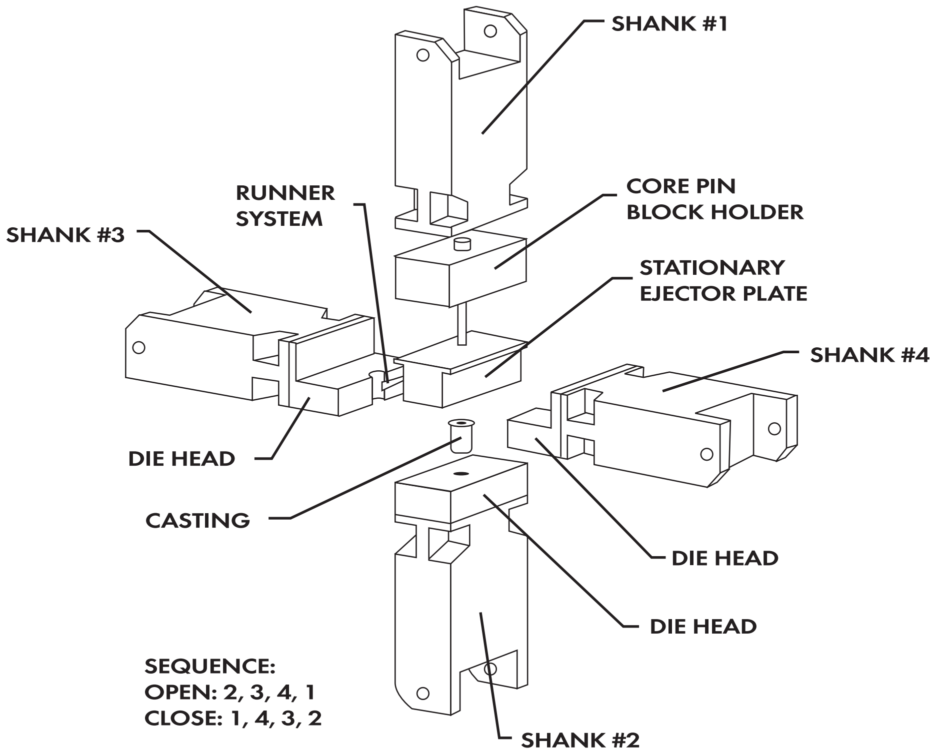


Figure 4B-4 Basic components of a miniature die casting die.

The production requirements will determine if miniature die casting is the right process to consider, and if so, should multiple cavities be used. When high volume production is a must, multiple cavity dies should be addressed. If casting tolerances are extremely tight, with stringent cosmetic callouts, it may be necessary to limit cavity configurations in order to meet these requirements. Depending on casting complexity, generally, fewer cavities means better attention to strict detail.

The basic components of a miniature die casting die are depicted in figure 4B-4. A die and a shank comprise a slide. This illustration shows a four slide die using an ejector plate to strip the casting from the die. The other method of ejection is to use standard ejector pins, which tend to leave marks on the castings. Both are acceptable and common practices. The decision on which type to use must be addressed during the design stages. The machine is programmed to move the slides in and out to a specific sequence. This illustration would have the top slide (ejector) come in first after the die is sprayed with lubricant followed by the bottom slide, then the left or right slides last. The metal is then injected from beneath the die using the hot chamber principle. A typical gating system is shown in figure 4B-5. After a very brief solidification period, the slides cycle out in the reverse sequence allowing the ejector plate to strip the casting free and be blown into a container where it can be transported to a degating operation.

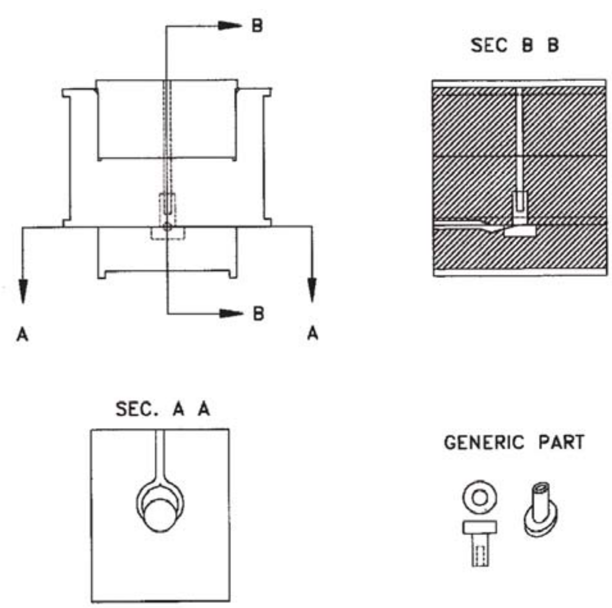


Figure 4B-5 Typical gating system in a miniature die casting die.

COMPONENT	MATERIAL	HARDNESS
Die	T-1 M-2 H-13	56-58 HRC 56-58 HRC 46-48 HRC
Inserts/Subinserts	H-13	46-48 HRC
Shank	S-7	54-56 HRC
Ejector Plate & Carrier	S-7	54-56 HRC
Ejector Pins	H-13	65-74 HRC Case Hardened
Core Pins	H-13	50-55 HRC Hardened Through
Crosshead/Frame	Gray Cast Iron	N/A

Construction materials and hardness requirements for typical miniature die components.

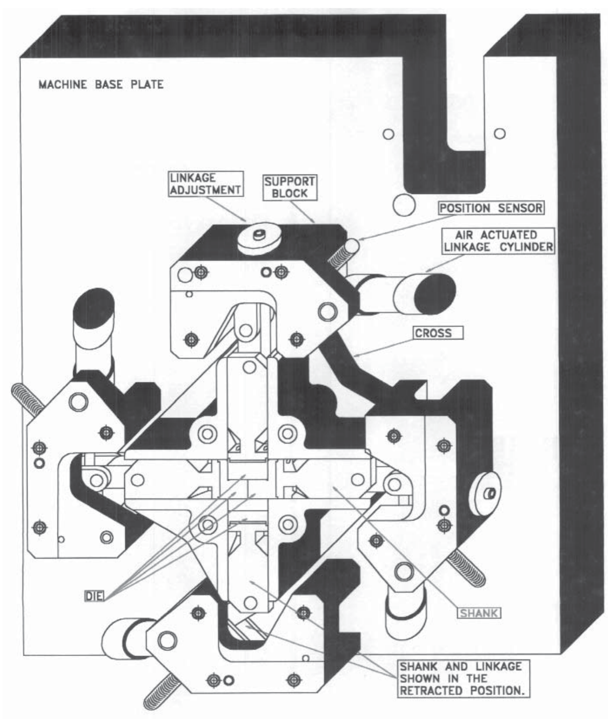


Figure 4B-6 *Miniature die casting die shown without clamps.*

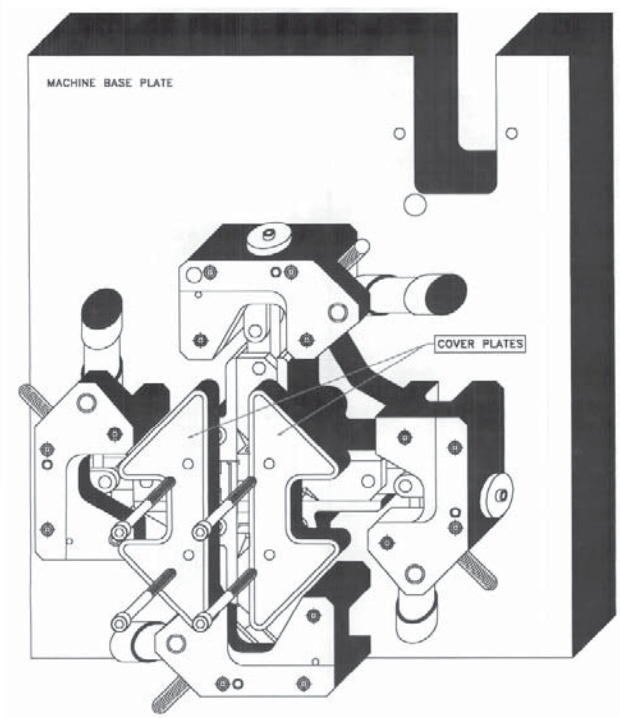


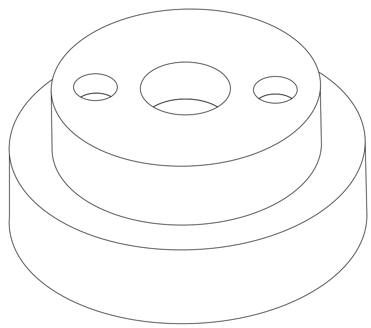
Figure 4B-7 *Miniature die casting die shown with clamps.*

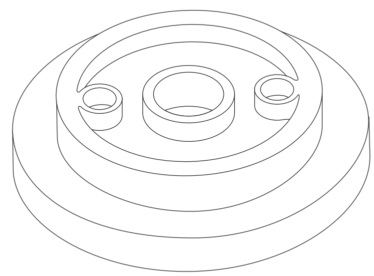
5 Design Consideration for Miniature Die Castings

One of the factors that separate miniature die casting from conventional die casting is the use of tools with fewer cavities. While production costs can be greatly reduced by the use of dies with multiple cavities instead of a single cavity, it must be remembered that the cost of the die increases with each cavity and that some loss of dimensional continuity will probably occur from cavity to cavity. However, because they produce several parts for every casting cycle, multi-cavity dies are practical for designs where quantities are very high.

Both the casting designer and the purchaser will benefit from a basic understanding of the following design hints and by involving your die caster as early as possible. The experience that he can share with you will help you design a better part at lower cost.

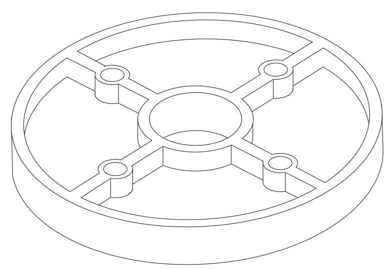
5.1 Weight Reduction





Reducing the volume of material needed to produce a part will reduce material cost. The more metal the part contains the longer the time required to fill the die cavity and cool the metal prior to ejection, thus adversely affecting run rates. Weight reduction can be achieved by reducing the cross section or by designing pockets. These thinner sections can be strengthened if needed with ribs which can also improve metal flow. The size and location of weight reduction pockets need to be carefully considered as they can sometimes cause irregular shrinkage which may affect accuracy.

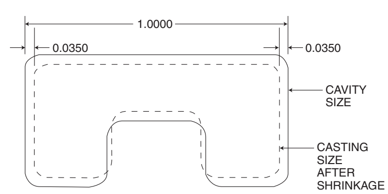
5.2 Ribs



Ribs can be added to thin walled castings to increase part strength. In addition, these ribs provide an ideal location for ejector pins and assist in metal flow. Where possible, ribs should be blended with fillets and radii to eliminate sharp corners and rapid changes in cross section.

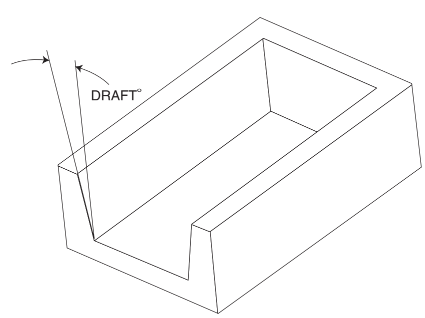
5.3 Shrinkage

Virtually all metals shrink as they cool to room temperature. With the two most commonly used zinc alloys, #3 and #5, this shrinkage is approximately .007 in. per inch. This shrinkage, which is always towards the theoretical center, permits the casting to be released from the outside walls of the cavity but tends to lock it onto any die section that projects into it. This tendency can be reduced by designing "draft" into the part.



5.4 Draft

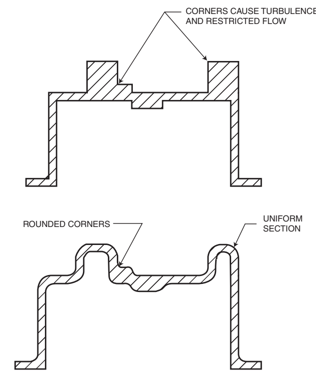
Draft is the slight taper on the sides of cavity inserts which form any internal features of a die casting. Draft is needed to make it easier for the ejector pins to push the casting out of the cavity. Surfaces of the cavity that have draft are usually highly polished for improved ejection. If no draft is provided the die caster may be forced to use some of the dimensional tolerance for draft. However, minimal or no draft is required to push or strip the casting out of the cavity when a stripper is used.



4B

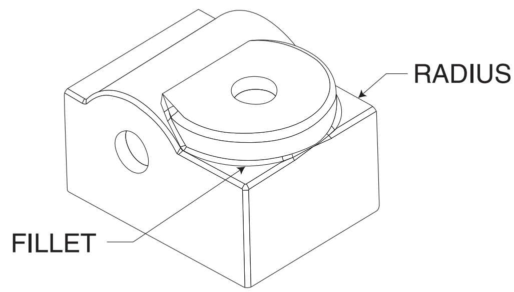
5.5 Uniform Cross Section

By improving metal flow through the die, uniform cross sections can speed up the casting cycle. On the other hand, excessive changes in cross section can cause turbulence in the die cast metal. This tends to trap air which results in porosity. A further consideration is that castings with large differences in cross sections tend to shrink irregularly.



5.6 Fillets & Radii

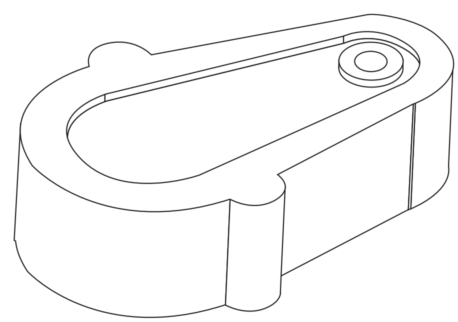
It is very important to avoid sharp corners, especially when they are associated with a rapid change in cross section. Whenever possible, an inside corner should be designed with a fillet – an outside corner with a radius. This is necessary to ensure good results when plating operations are a requirement. Eliminating sharp inside corners also gives added strength to the casting and can improve fill by reducing turbulence. Radii & fillets as small as .005" can make noticeable improvements to a casting.



5.7 Surface Finish

The surface finish of die castings are directly related to the finish on the tool itself. As a result, highly polished tooling can be expected to give good surface finishes on the castings. Miniature die cast parts are generally cast with surface finishes between 32 and 64 microinches.

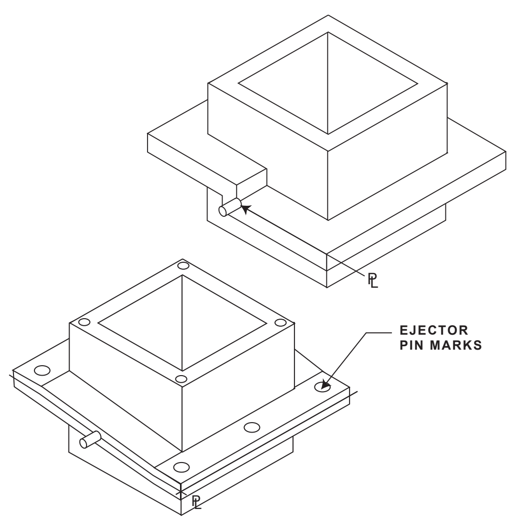
Of the many textured finishes that your die caster can produce, a matte finish is usually the easiest. Matte finishes are usually specified to improve the appearance of a casting or to highlight a logo or trademark.



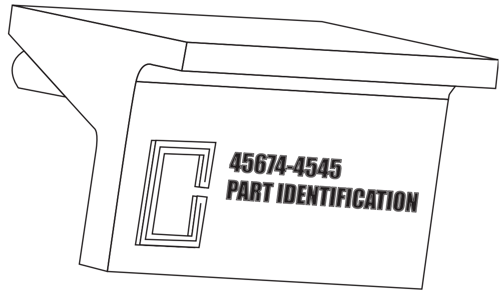
5.8 Parting Lines & Ejector Pins

The plane where the two halves of the die meet, is called the parting line. The outside shape of the part determines where the parting line must go. As a general rule the parting line should be kept as flat or straight as possible. If this cannot be done, changes from one level to another should be as gradual as possible.

Castings are removed from the die by ejector pins. Good toolmaking practices can reduce the "witness" marks, but you will still be able to see where they are located. A designer may specify certain surfaces which must be free of parting lines and ejector pins but you should give your die caster as much leeway as possible.

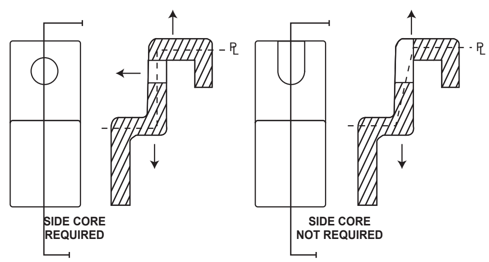


5.9 Part Identification



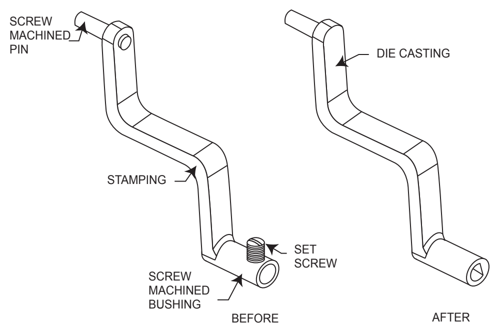
The designer should consider what identification marks are to be cast into the part and where they can be permitted. All too often the die caster is asked to add a part number or other identification to the casting after the die has been built and sampled. This can be very costly to do at this stage. Many die casters like to identify their castings with their logo and the cavity number in which the part was cast. Die casters usually find it easier to produce raised letters as these require less work in the die.

5.10 Side Cores



Side cores are required to produce holes or undercuts that are parallel with the major parting line of the die. As they add substantially to the tool cost, side cores should be designed out wherever possible. The line drawing showing one of the ways side cores can be avoided.

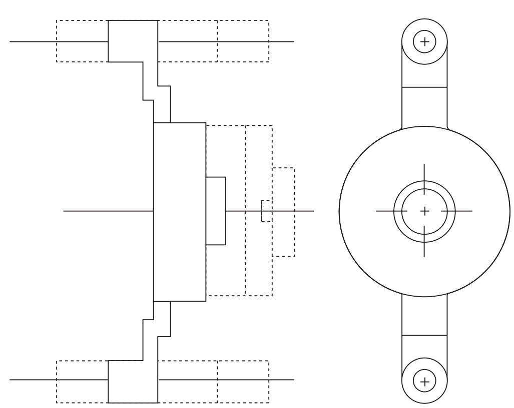
5.11 Combining Functions



Probably the most effective way to reduce costs is to combine several parts into one die casting. There are many benefits from this, including reduced production costs, as well as less handling, storage and assembly costs. Often this results in a superior product as the design is less complex. The part illustrated was originally produced in steel from two screw machined parts and a stamping. Die casting eliminates the need to manufacture the parts separately, drill and tap the cross hole, as well as pressing the parts together. The "D" shaped hole eliminated the set screw and tightening operation when the part was used in the final assembly.

5.12 Variations

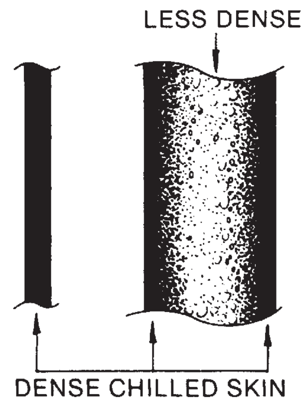
VARIATION



Savings can also be realized when there are a number of different, but similar parts to be made. For instance, an appliance manufacturer may use the same electric motor to power several different appliances. To accommodate this, several variations of bearing brackets having slightly different configurations, may be required. In these instances, a die can be designed with multiple inserts so that one basic tool is capable of producing the different variations. If variations of the part being considered will be required in the future you should give your die caster all the details before he begins designing the tool. The line drawing illustrates some of the different parts that could be produced from one basic die which is designed with replaceable inserts.

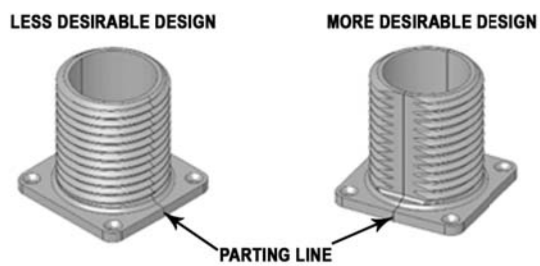
5.13 Skin

One big advantage of "as-cast" parts is the dense "chilled skin" on the outer surface which has higher mechanical properties than the rest of the casting. Designers should therefore avoid machining this harder, denser material especially on wear surfaces.



5.14 Gears

Miniature die casting can produce external, internal, face, helical, spur and worm gears. Virtually any tooth form can be cast, including one with up to a 20° helix angle. AGMA 6-8 standards can be maintained depending on the component configuration. Shafts, ratchets and cams can also be incorporated into gear components through insert die casting.



5.15 Threads

External Threads -Unlimited configurations of external threads can be miniature die cast and can incorporate up to 100 threads per inch. However, to cast full diameter threads (360°) very demanding toolmaking standards must be maintained as the parting line runs the full length of the thread. Though possible and very impressive when done properly, full diameter threads are generally not necessary. Wherever possible, flats to the root diameter of the thread should be allowed at the parting line. This will reduce complexity in the die and thus lower initial tooling charges and piece part costs.

Internal Threads - Internal threads can be cast using a mechanism designed to rotate a core in the die cast die. This adds cost to the die and the piece part. Generally internal threads are tapped as a secondary operation for cost efficiency and speed. Form taps are typically used to eliminate the process of removing cutting chips from the hole.

5.16 Insert Die Casting

Insert die casting can be used when design requirements necessitate the integration of components manufactured from other materials. There are systems available that load the components into the cavity of the die cast die and the zinc component is then die cast around it. Insert die casting can be a costly option and may require a dedicated die casting machine.

5.17 Crimping, Staking, Bending and Forming

Zinc alloys are capable of being crimped or staked, after die casting for assembly operations. Secondary operations are dependent on wall thickness, alloy type, gate location and application temperature.

6 Available Finishes

Chromates, platings, paints and powder coatings are the most common surface finishes. Chromates are conversion coatings applied through electro-chemical treatments to improve corrosion resistance. These treatments convert the metal surface to a superficial layer containing a mixture of chromium compounds of various colors and resistance.

Chromated components are corrosion tested in a 5% continuous salt spray environment as outlined in ASTM standard B117. The following colors exhibit the varying performances; olive drab – 96 hours of protection, bright yellow – 48 hours of protection and clear – 24 hours of protection.

Platings are applied to small zinc components for aesthetic purposes, and to improve corrosion resistance, conductivity, hardness, wear resistance and solderability. The most common applied platings are: Nickel, Brass, Tin, Copper, Silver and Gold.

Paints are used primarily for decoration, protection, identification, concealing surface irregularities or for increasing/decreasing surface friction.

Powder coatings provide a protective and attractive finish to components. They cover evenly, have the ability to conceal surface imperfections, and provide good corrosion resistance.

For more information on finishes and coatings, see Section 6.

7 Castable Zinc Alloys

Zinc alloys are used in the production of small components because they are versatile, dependable, cost effective materials which can be used in an unlimited range of applications. As precisely formulated metal alloys, they offer the mechanical properties of medium strength metals.

The most commonly used zinc alloys in miniature die casting are #2, #3, #5, #7 and ZA-8. These alloys offer higher tensile strengths than most aluminum and magnesium alloys, higher yield strengths, greater impact resistance, higher Brinell hardness and better ductility.

Zinc alloys facilitate higher die casting cycle speeds versus aluminum and magnesium, more complex shapes, thinner wall sections, smoother surface finishes, and higher standards of dimensional accuracy.

Compared to plastic, zinc alloys are generally several times stronger and many times more rigid. Their mechanical properties compare favorably with powdered iron, brass and screw-machined steel.

Engineering & Design: Geometric Dimensioning

SECTION **5**

5

Frequently Asked Questions (FAQ)

1) Is Geometric Dimensioning used on just Die Castings and why should it be used?
See page 5-2 - Why should GD&T be used?
2) What is a Location Tolerance?
See page 5-11, Location Tolerances
3) How do I convert a linear tolerance to true position?
See pages 5-32 through 5-34, Conversion of Position.
4) Is a list of GD&T symbols availible?
See page 5-8, GD&T Symbols and Meanings.
5) When can I use Profile of a surface instead of flatness?
See page 5-14, Profile Tolerances.

1 Introduction

The concept of Geometric Dimensioning and Tolerancing (GD&T) was introduced by Stanley Parker from Scotland in the late 1930's. However, it was not used to any degree until World War II (WW II) because until then the vast majority of products were made in-house. The designer could discuss with the manufacturing personnel (die designer, foundry foreman, machinist, and inspectors) what features were to be contacted to establish the so called "centerlines" that were used on the drawing to locate features such as holes and keyways. Also when two (2) or more features were shown coaxial or symmetrical around these "centerlines", the questions that needed to be answered by the designer was, "how concentric or symmetrical do these features have to be to each other"?. During WW II companies had to "farm out" parts because of the quantities/schedules. This meant the new manufacturer had to interpret the drawing hence the "centerlines" were often established by contacting features that were not functional or important and features produced from these incorrect "centerlines" were not at the location required. The parts did not assemble and/or did not function properly and had to be fixed or scrapped. GD&T was the solution to this major problem. GD&T provides a designer the tools to have clear, concise, and consistent instructions as to what is required. It eliminates ambiguities so that everyone involved with the part will not have to interpret the dimensioning.

2 What is GD&T?

It is compilation of symbols and rules that efficiently describe and control dimensioning & tolerancing for all drawings (castings, machined components,etc.). It is documented in ASME Y14.5M which has the symbols, rules, and simple examples. Also ASME Y14.8 has guidance for casting and forging drawings.

3 Why should GD&T be used?

a. It is a simple and efficient method for describing the tolerancing mandated by the designer of the part.

b. It eliminates ambiguities as to what Datum features are to be contacted to establish the Datum planes and/or Datum axis that are to be used for locating other features. All inspection will result in the same result – the dimension is within or out of tolerance. Fig. 5-1 illustrates a simple example of ambiguities associated with the "old" type drawing. Fig. 5-2 illustrates the same example with GD&T.

c. It simplifies inspection because hard gages can often be utilized and inspection fixtures are often mandated which simplifies inspection for production quantities.

d. It forces the designer to totally consider function, manufacturing process, and inspection methods. The result is larger tolerances that guarantee function, but reduce manufacturing amd inspection costs. Also the "bonus" or extra tolerance for certain conditions can result in significant production cost savings. In addition the time to analyze whether a missed dimension is acceptable is dramatically reduced.

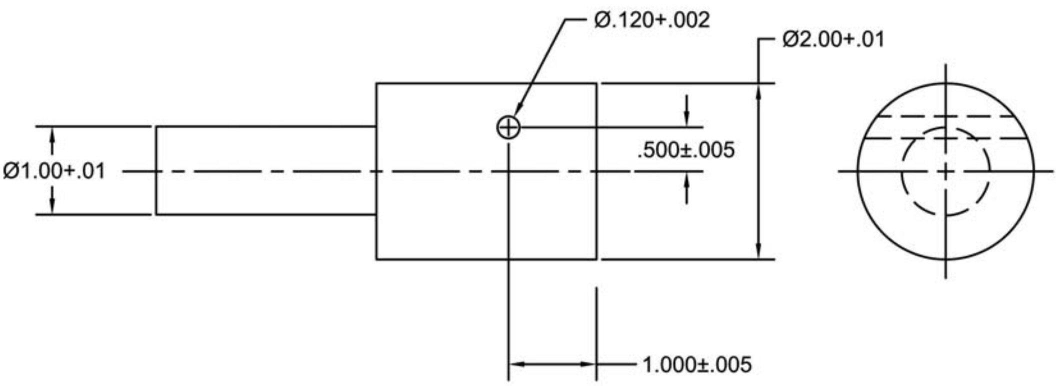


Figure 5-1 "OLD" Drawing without GD&T.

Questions:

1) What is the relationship (coaxiality tolerance) between the ∅1.00 and the ∅2.00?

2) Which feature (∅1.00 or ∅2.00) is to be used for measuring (locating) the .500±.005 dimension for locating the ∅.120 hole?

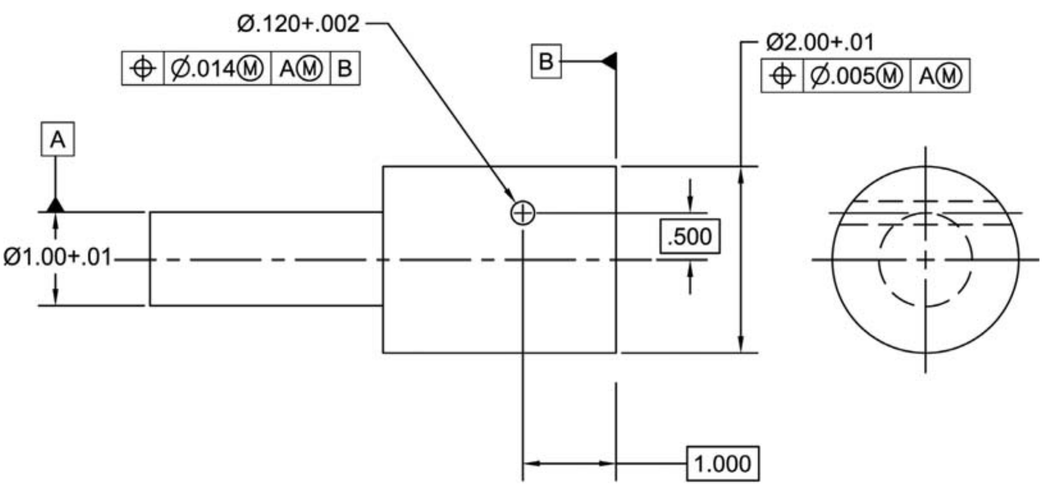


Figure 5-2 "NEW" Drawing with GD&T.

Questions asked in Fig. 5-1 answered:

1) The axis of the ∅2.00 has to be coaxial with the axis of the ∅1.00 within a tolerance zone that is a ∅.005 if the ∅ is 2.01 which is the Maximum Material Condition (MMC).

2) The ∅1.00 is the feature to be used for measuring the .500 dimension for locating the n.120 hole. The tolerance for locating the ∅.120 hole is a ∅ of .014 (the diagonal of the rectangular tolerance zone shown in Fig. 5-1) when the hole is a MMC (∅.120).

5

4 Datum Reference Frame (DRF)

The DRF is probably the most important concept of GD&T. In order to manufacture and/or inspect a part to a drawing , the three (3) plane concept is necessary. Three (3) mutually perpendicular (exactly 90° to each other) and perfect planes need to be created to measure from. In GD&T this is called Datum Reference Frame whereas in mathematics it is the Cartesian coordinate system invented by Rene Descartes in France (1596-1650). Often one would express this concept as the need to establish the X,Y, and Z coordinates. The DRF is created by so-called Datum Simulators which are the manufacturing, processing, and inspection equipment such as surface plate, a collet, a three jaw chuck, a gage pin, etc. The DRF simulators provide the origin of dimensional relationships. They contact the features (named Datum Features) which of course are not perfect hence measurements from simulators (which are nearly perfect) provides accurate values and they stabilize the part so that when the manufacturer inspects the part and the customer inspects the part they both get the same answer. Also if the part is contacted during the initial manufacturing setup in the same manner as when it is inspected, a “layout” for assuring machining stock is not required. The final result (assuming the processing equipment is suitable for the tolerancing specified) will be positive.

4.1 Primary, Secondary, and Tertiary Features & Datums

The primary is the first feature contacted (minimum contact at 3 points), the secondary feature is the second feature contacted (minimum contact at 2 points), and the tertiary is the third feature contacted (minimum contact at 1 point). Contacting the three (3) datum features simultaneously establishes the three (3) mutually perpendicular datum planes or the datum reference frame. If the part has a circular feature that is identified as the primary datum feature then as discussed later a datum axis is obtained which allows two (2) mutually perpendicular planes to intersect the axis which will be the primary and secondary datum planes. Another feature is needed (tertiary) to be contacted in order orientate (fix the two planes that intersect the datum axis) and to establish the datum reference frame. Datum features have to be specified in an order of precedence to properly position a part on the Datum Reference Frame. The desired order of precedence is obtained by entering the appropriate datum feature letter from left to right in the Feature Control Frame (FCF) (see Section 5 for explanation for FCF). The first letter is the primary datum, the second letter is the secondary datum, and the third letter is the tertiary datum. The letter identifies the datum feature that is to be contacted however the letter in the FCF is the datum plane or axis of the datum simulators. Note that there can be multiple datum sets used to reference different features on the casting. See Fig. 5-3 for Datum Features & Planes.

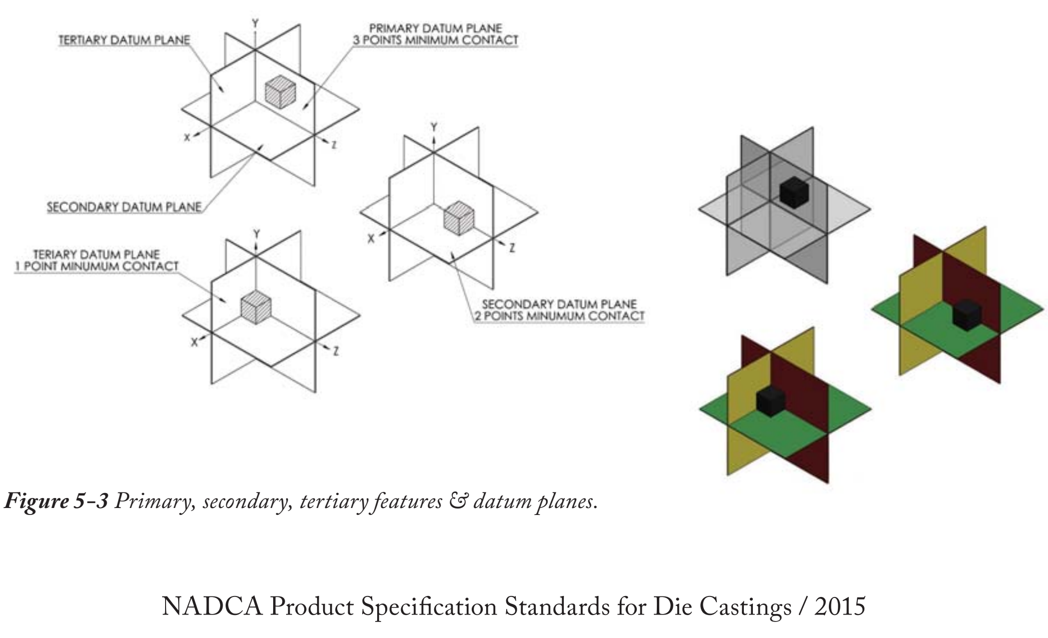


Figure 5-3 *Primary, secondary, tertiary features & datum planes.*

4.2 Datum Feature vs Datum Plane

The datum features are the features (surfaces) on the part that will be contacted by the datum simulators. The symbol is a capital letter (except I,O, and Q) in a box such as [A] used in the 1994 ASME Y14.5 or -A- used on drawings made to the Y14.5 before 1994. The features are selected for datums based on their relationship to toleranced features, i.e., function, however they must be accessible, discernible, and of sufficient size to be useful. A datum plane is a datum simulator such as a surface plate. See Fig. 5-4 for a Datum Feature vs a Datum Plane.

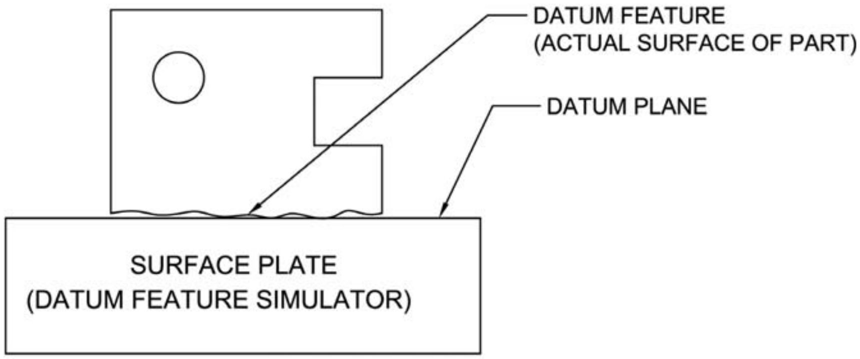


Figure 5-4 *Datum feature vs. datum plane.*

4.3 Datum Plane vs Datum Axis

A datum plane is the datum simulator such as a surface plate. A datum axis is also the axis of a datum simulator such as a three (3) jaw chuck or an expandable collet (adjustable gage). It is important to note that two (2) mutually perpendicular planes can intersect a datum axis however there are an infinite number of planes that can intersect this axis (straight line). Only one (1) set of mutually perpendicular planes have to be established in order to stabilize the part (everyone has to get the same answer – does the part meet the drawing requirements?) therefore a feature that will orientate or "clock" or "stabilize" has to be contacted. The datum planes and datum axis establish the datum reference frame and are where measurements are made from. See Fig. 5-5 for Datum Feature vs Datum Axis.

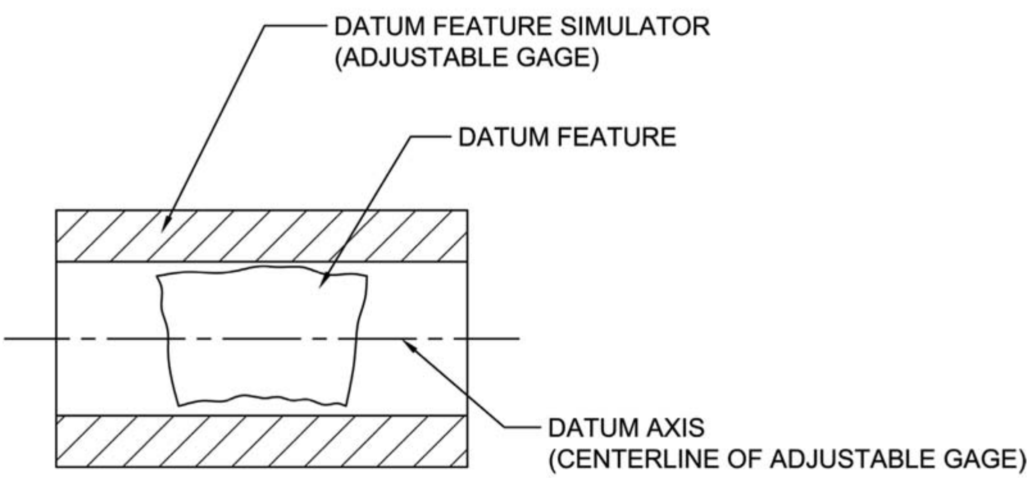
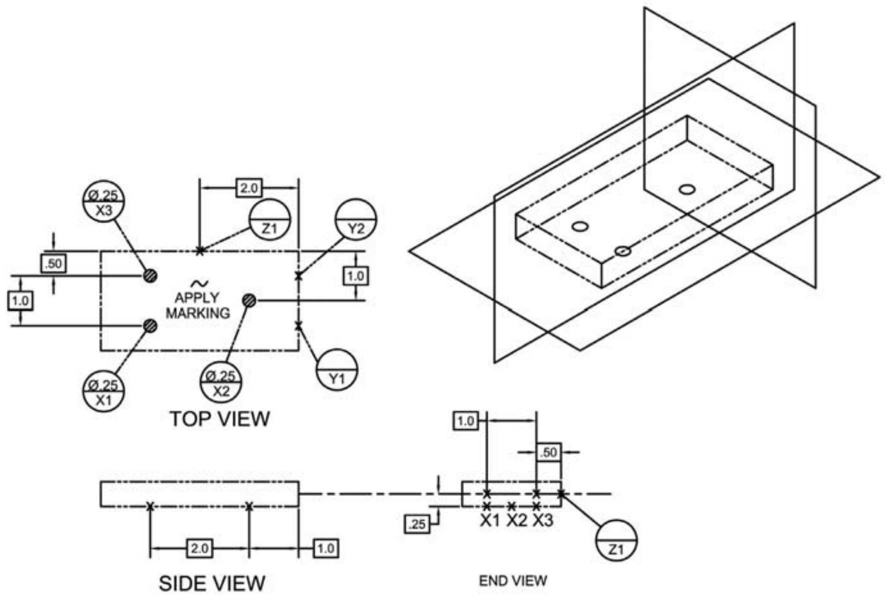


Figure 5-5 *Datum feature vs. datum axis.*

5

4.4 Datum Target Sizes & Locations

Datum targets are datum simulators such as spherical pins or round flat bottom pins or three (3) jaw chucks or centers that establish datum planes or a datum axis. They contact the datum features and are often specified to be used for inspecting parts that are inherently not round or straight or flat or they are large parts. If targets are not used then the entire datum feature has to contact a datum simulator. An example of what can result is the part could "rock" on a surface plate if the part was not relatively flat which would result in an unstable scenario and conflicting results. If the datum feature is large a datum simulator that contacts the entire feature may not exist or would be extremely expensive to produce. The datum targets are the datum planes and datum axis and often are assembled together to create an inspection fixture and or a manufacturing fixture. See Fig. 5-6 for Datum Target Sizes & Locations.



Component configuration shown as phantom lines on separate drawing
• Illustrates orientation when targets contact component
• Illustrates that targets are physically separate from the component
• Apply marking is shown to depict which side is to be contacted by the targets

Figure 5-6 *Target sizes & locations.*

5 Feature Control Frame

The geometric tolerance for an individual feature is specified in the Feature Control Frame which is divided into compartments – see Fig 5-7. The first compartment contains the type of geometric characteristic such as true position, profile, orientation, etc. The second compartment contains the tolerance (where applicable the tolerance is preceded by a diameter symbol and followed by a material condition symbol). The remaining compartments contain the datum planes or axis in the proper sequence (primary datum is the first letter).

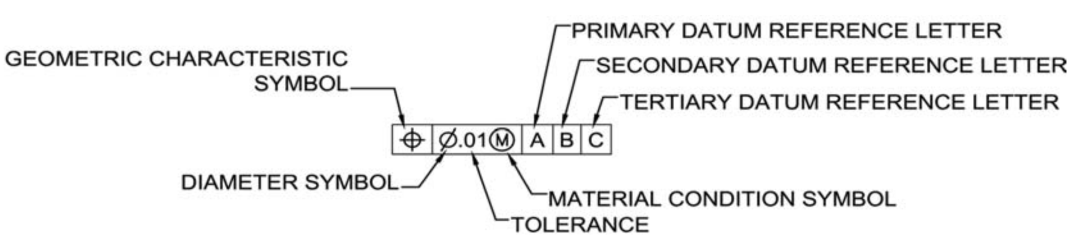


Figure 5-7 *Feature control frame.*

6 Rule # 1 – Taylor Principle (Envelope Principle)

When only a size tolerance is specified for an individual feature of size the form of this feature shall not extend beyond a boundary (envelope) of perfect form at maximum material condition (MMC). In other words, when the size is at MMC the feature has to be perfectly straight. If the actual size is less than the MMC the variation in form allowed is equal to the difference between the MMC and the actual size. The relationship between individual features is not controlled by size limits. Features shown perpendicular, coaxial or symmetrical to each other must be controlled for location or orientation otherwise the drawing is incomplete. In other words Fig. 5-1 is an incomplete drawing. Fig. 5-8 shows the meaning of Rule #1 for an external cylinder (pin or shaft) and an internal cylinder (hole). Note that a hard gage can be used to inspect this principle or requirement.

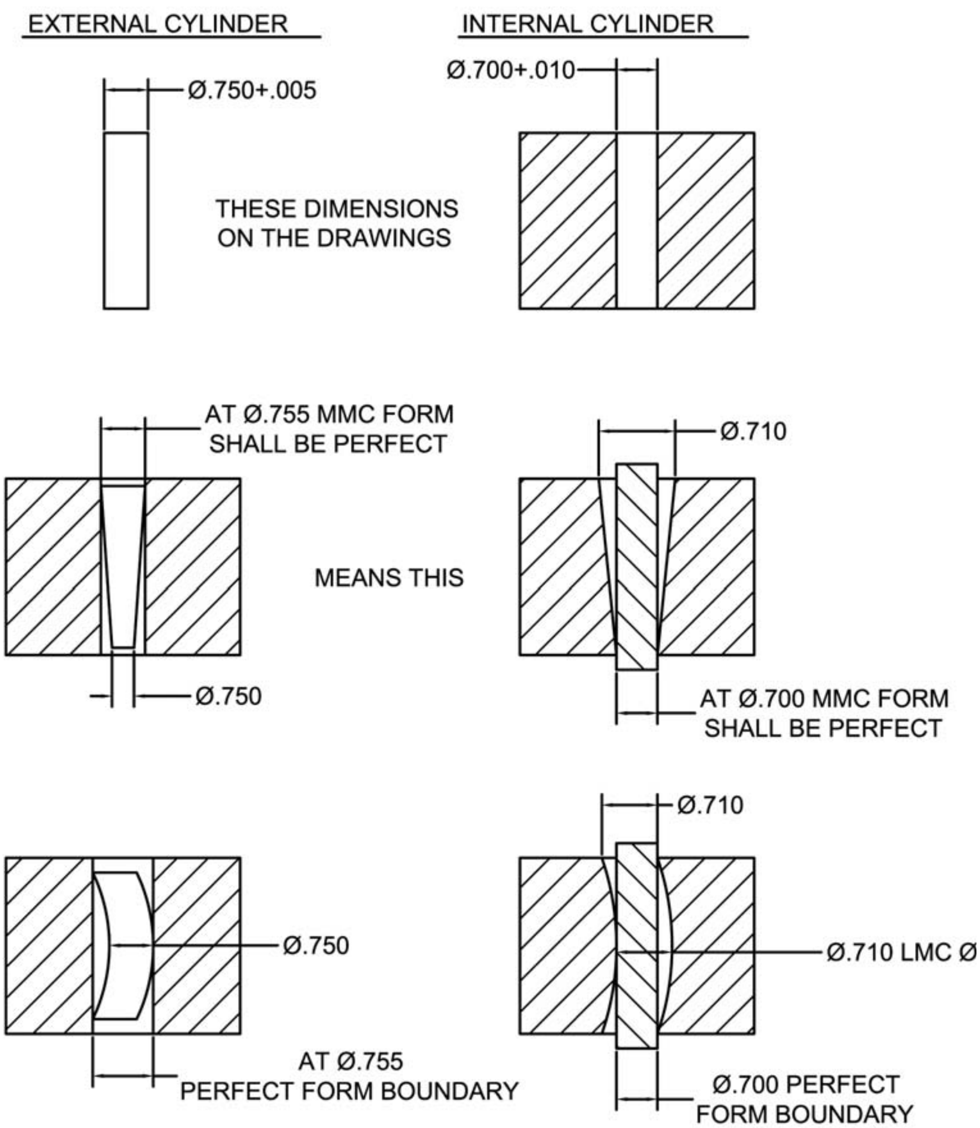


Figure 5-8 *Rule #1.*

5

7 GD&T Symbols / Meanings

<table>
<tr><th rowspan="2">Tolerance Type</th><th rowspan="2">Geometric Characteristics</th><th rowspan="2">Symbol</th><th colspan="2">Applied To</th><th rowspan="2">Datum Reference Required</th><th rowspan="2">Use Ⓛ or Ⓜ Material Condition</th><th rowspan="2">Gages Used</th></tr>
<tr><th>Feature Surface</th><th>Feature of Size Dim.</th></tr>
<tr><td rowspan="4">Form</td><td>Straightness</td><td>⏤</td><td rowspan="4">YES</td><td>YES</td><td rowspan="4">NO</td><td>YES</td><td>YES***</td></tr>
<tr><td>Flatness</td><td>⏥</td><td rowspan="3">NO</td><td rowspan="3">NO</td><td rowspan="3">NO</td></tr>
<tr><td>Circularity</td><td>○</td></tr>
<tr><td>Cylindricity</td><td>⌭</td></tr>
<tr><td rowspan="3">Location</td><td>Positional Tolerance</td><td>⌖</td><td rowspan="3">NO</td><td rowspan="3">YES</td><td rowspan="3">YES</td><td>YES</td><td>YES***</td></tr>
<tr><td>Concentricity</td><td>◎</td><td rowspan="2">NO</td><td rowspan="2">NO</td></tr>
<tr><td>Symmetry</td><td>⌯</td></tr>
<tr><td rowspan="3">Orientation</td><td>Perpendicularity</td><td>⊥</td><td rowspan="3">YES</td><td rowspan="3">YES</td><td rowspan="3">YES</td><td rowspan="3">YES</td><td rowspan="3">YES***</td></tr>
<tr><td>Parallelism</td><td>∥</td></tr>
<tr><td>Angularity</td><td>∠</td></tr>
<tr><td rowspan="2">Profile</td><td>Profile of a Surface</td><td>⌓</td><td rowspan="2">YES</td><td rowspan="2">NO</td><td rowspan="2">YES*</td><td rowspan="2">YES**</td><td rowspan="2">NO</td></tr>
<tr><td>Profile of a Line</td><td>⌒</td></tr>
<tr><td rowspan="2">Runout</td><td>Circular Runout</td><td>↗</td><td rowspan="2">YES</td><td rowspan="2">YES</td><td rowspan="2">YES</td><td rowspan="2">NO</td><td rowspan="2">NO</td></tr>
<tr><td>Total Runout</td><td>⌰</td></tr>
</table>

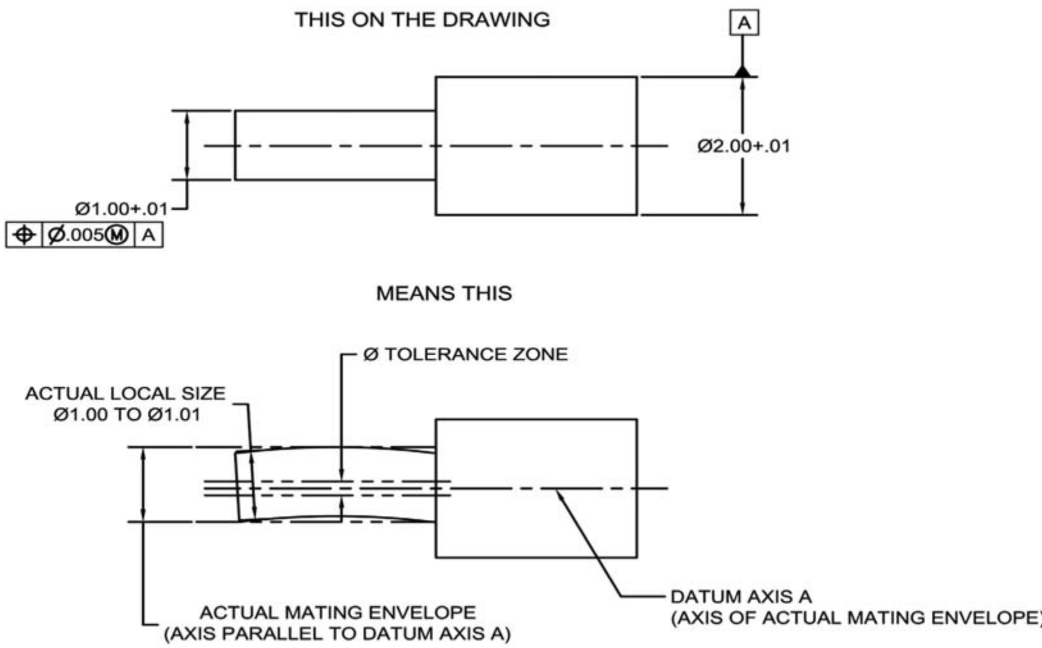
** Can be used to control form without a datum reference.*
*** Datum reference only.*
**** – Yes if Ⓜ is specified for the feature of size being controlled*
– No if Ⓢ or Ⓛ are specified for the feature of size being controlled.

8 Material Conditions

Features of size which includes datum features have size tolerances hence the size condition or material (amount of metal) condition can vary from the maximum metal condition (MMC) to the least metal condition (LMC). Consequently if the center planes or axes of a feature of size are controlled by geometric tolerances a modifying symbol can be specified in the feature control frame that applies the tolerance value at either the maximum or the least material condition. It also can be specified for a datum that is a feature of size. If a symbol is not specified the tolerance value applies regardless of material condition which is named regardless of feature size (RFS).

8.1 Maximum Material Condition (MMC)

This is the condition when the actual mating size or envelope size is at the maximum material condition which is maximum size for an external feature such as a cylinder and the minimum size for an internal feature such as a hole. Another way to look at MMC is that it always allows components to be assembled. The symbol is Ⓜ. The tolerance value specified for the feature being controlled in the FCF applies only if the actual mating envelope is the MMC size. If the actual mating envelope deviates from MMC an additional tolerance is allowed. The added tolerance is the difference between the actual mating envelope size and the MMC size hence the largest actual mating envelope named virtual condition is equal to the MMC size plus the tolerance specified in the FCF for an external feature and minus for an internal feature. The MMC symbol is used to assure that parts will assemble and it allows the use of so called hard gages (go gages) for quick inspections. An example of position with MMC is shown in Fig. 5-9. It should be noted that actual local size has to meet the size tolerance however the actual local size does not affect the geometric characteristic tolerance.

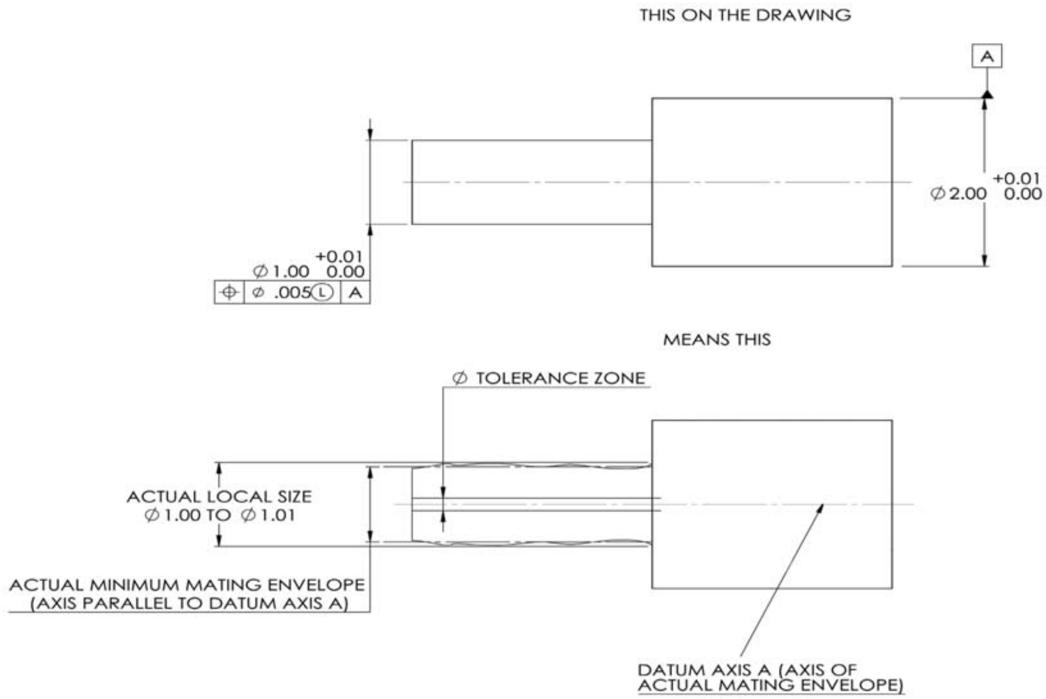


ACTUAL MATING ENVELOPE Ø OF FEATURE BEING CONTROLLED	Ø TOLERANCE ZONE
Ø1.01	.005
Ø1.00	.015

Figure 5-9 *Position control with MMC.*

8.2 Least Material Condition (LMC)

This is the opposite of MMC consequently this is the condition when the actual minimum mating size or envelope is at the minimum material condition which is minimum size for an external feature such as a cylinder and the maximum size for an internal feature such as a hole. Another way to look at LMC is that it always prevents components from being assembled. The symbol is Ⓛ. Additional tolerance is allowed if the actual minimum envelope deviates from LMC and is the difference between the actual mating size and the LMC size hence the smallest actual mating size is equal to the LMC size minus the tolerance specified in the FCF for an external feature and plus for an internal feature. The LMC symbol is used to assure a minimum amount of machining stock for features that are to be machined and for assuring a minimum amount of wall thickness between external and internal features. Hard gages cannot be used for inspection. An example of position with LMS is shown in Fig. 5-10. It should be noted that the actual local size has to meet the size tolerance however the local size does not affect the geometric characteristic tolerance.

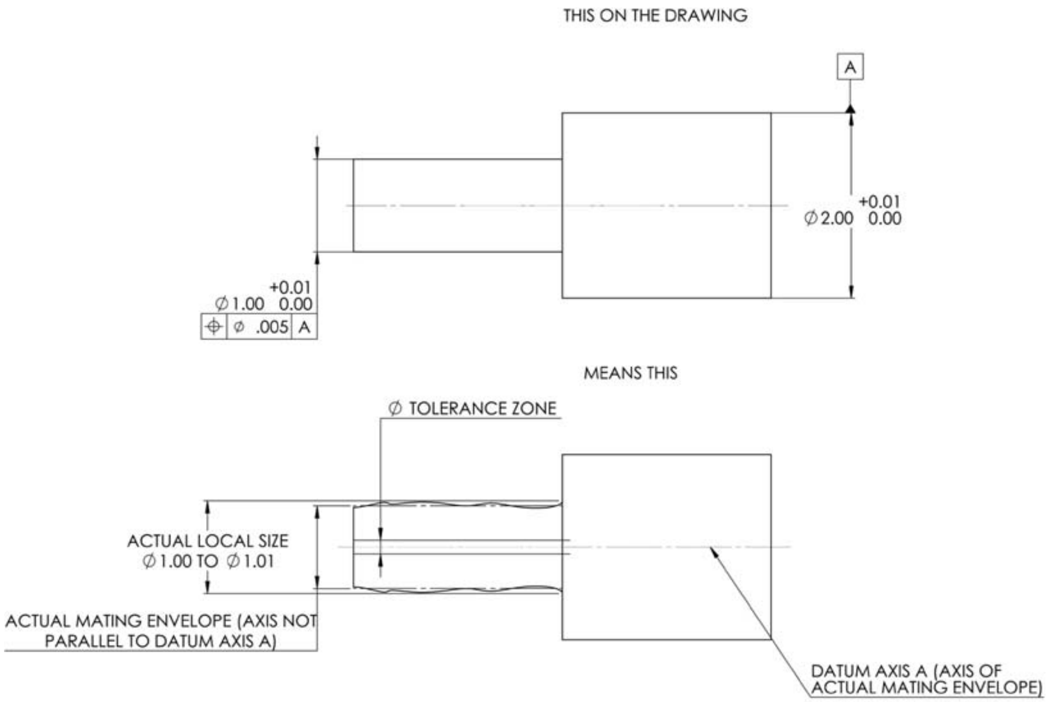


ACTUAL MINIMUM MATING ENVELOPE FEATURE BEING CONTROLLED	Ø TOLERANCE ZONE
Ø 1.00	.005
Ø 1.01	.015

Figure 5-10 *Position control with LHC.*

8.3 Regardless Of Feature Size (RFS)

There is no symbol in the 1994 Y14.5 whereas it was Ⓢ for the 1982 Y14.5. It is applicable if the MMC or the LMC are not specified for individual features of size tolerances or for datum features of size. The tolerance is limited to the specified value in the FCF and if applied to a datum feature of size the actual axis or center plane have to be established regardless of the feature size. It is always used for run out, concentricity, and symmetry controls as will be discussed in those sections. It is also used when targets are specified to establish datum axes and center planes because the targets have to contact the datum features to be useful. Also it is used to control wall thickness variation between external and internal features. Hard gages are not applicable since there is no additional or bonus tolerance as allowed for MMC and LMC. An example of position with RFS is shown in Fig. 5-11.



ACTUAL MINIMUM MATING ENVELOPE FEATURE BEING CONTROLLED	Ø TOLERANCE ZONE
Ø 1.00	.005
Ø 1.01	.005

Figure 5-11 *Position control with RFS.*

9 Location Tolerances

These include position, concentricity, and symmetry tolerances. Position is used to control coaxiality of features, the center distance between features, and the location of features as a group. Concentricity and symmetry are used to control the center distance of feature elements. These three (3) tolerances are associated with datum's because the obvious question is – located from what?

9.1 Position Tolerance

Positional tolerances are probably used more than any other geometric control. It is used to locate features of size from datum planes such as a hole or keyway and used to locate features coaxial to a datum axis. The tolerance defines a zone that the axis or center plane of a feature of size may vary from. The concept is there is an exact or true position that the feature would be if it was made perfect however since nothing is made perfect a tolerance zone allows deviation from perfection. The exact location of a feature of size is defined by basic dimensions which is shown in a box (☐) and are established from datum planes or axes. Coaxial controls are typically a cylindrical tolerance zone which has a diameter value and the true position is a datum axis. A positional control is indicated by the position symbol (∅), a tolerance value (diameter symbol precedes the tolerance value if desired), the applicable material condition modifier (Ⓜ or Ⓛ) if desired, and the appropriate datum references placed in a feature control frame. When a material condition modifier is specified a boundary named virtual condition is established. It is located at the true position and it may not be violated by the surface or surfaces of the considered feature. Its size is determined by adding or subtracting depending on whether the feature is an external or an internal feature and whether the material condition specified is Ⓜ or Ⓛ. An example for controlling the location of holes is shown in Fig. 5-12 and of a keyway in Fig. 5-13.

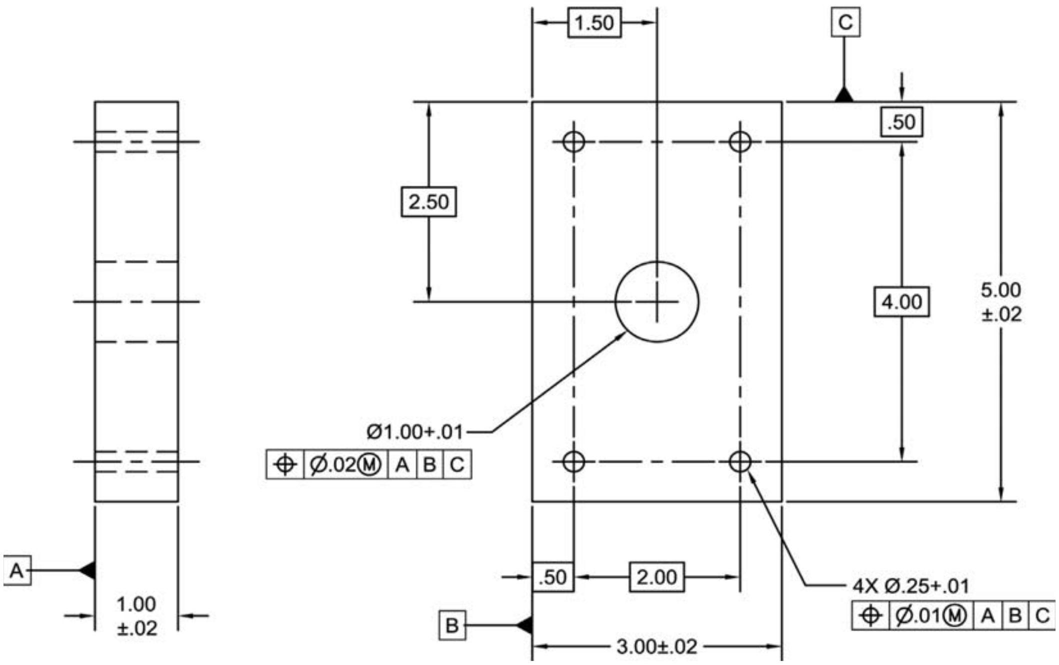


Figure 5-12 *Positional tolerancing of holes.*

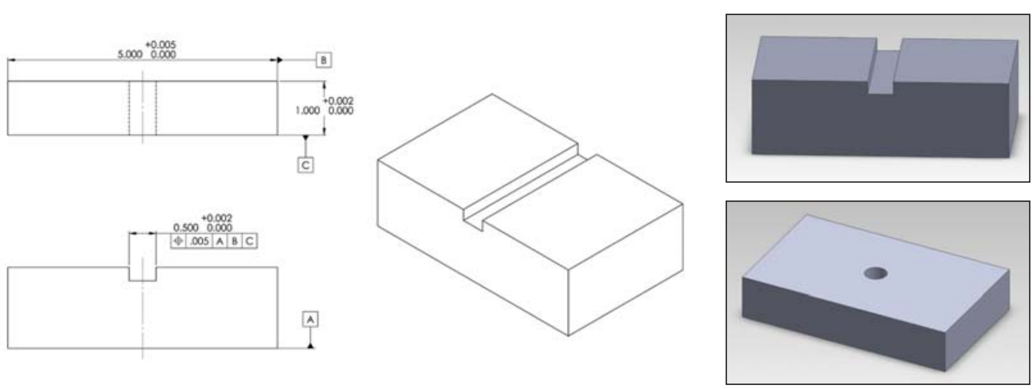


Figure 5-13 *Positional tolerance for keyway.*

Notes:

1) *Datum B is the feature of size (5.000+.005) hence the true position for the keyway is the midplane of datum B.*

2) *No material condition modifier specified for either the keyway location tolerance .005 or the datum B, hence the material condition is 'regardless of feature size' for both features.*

9.2 Concentricity & Symmetry Tolerances

These both control the median points of a feature of size: concentricity (◎) is applied to circular features (often where the part or nearby parts are rotating) whereas symmetry (⌯) is applied to non circular features. Both require that the median points of the controlled feature, regardless of its size, to be within the tolerance zone (cylindrical zone for concentricity and two parallel planes for symmetry). The tolerance zone is equally disposed about the datum axis for concentricity and datum plane for symmetry. These controls are not used very often because median points are difficult to establish due to irregularities of form and the only reason to use these controls is for controlling the out of balance that can exist if the mass center is not close to the axis of rotation or center plane. Examples of controlling concentricity and symmetry are shown in Fig. 5-14 & 5-15 respectively.

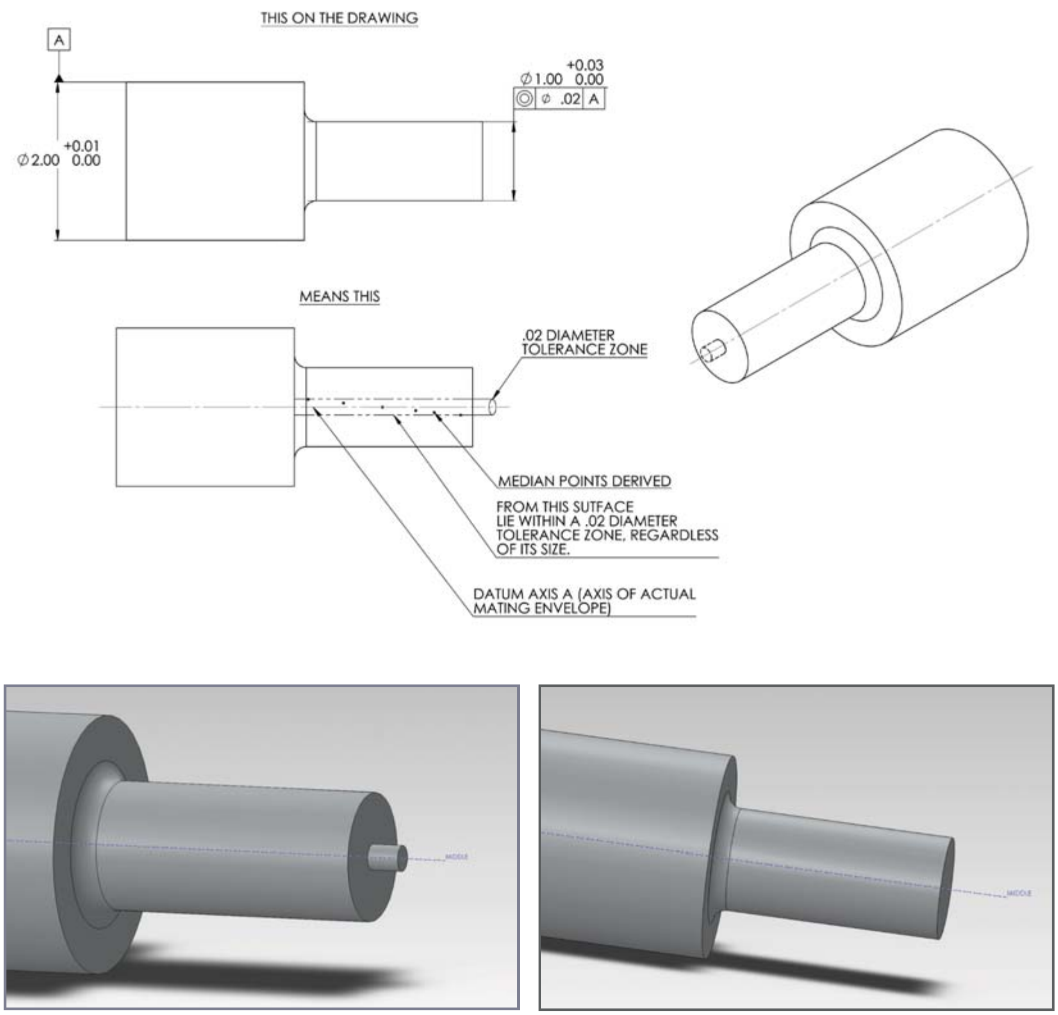


Figure 5-14 *Concentricity tolerancing.*

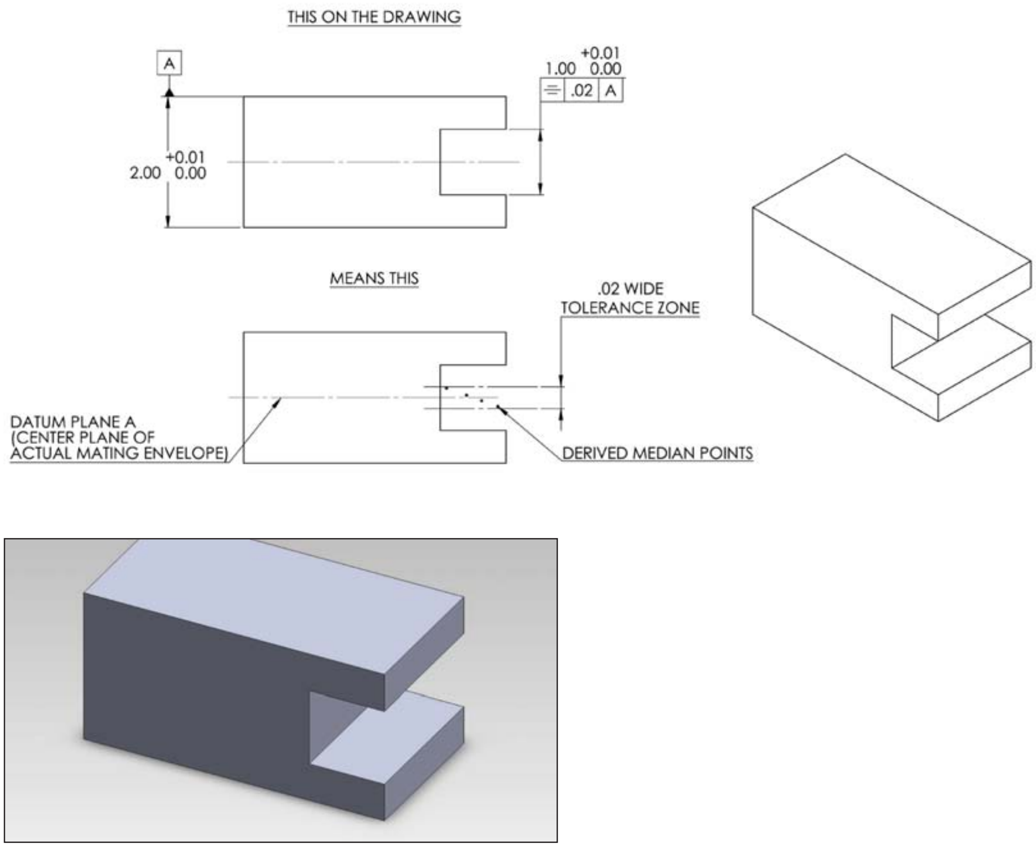
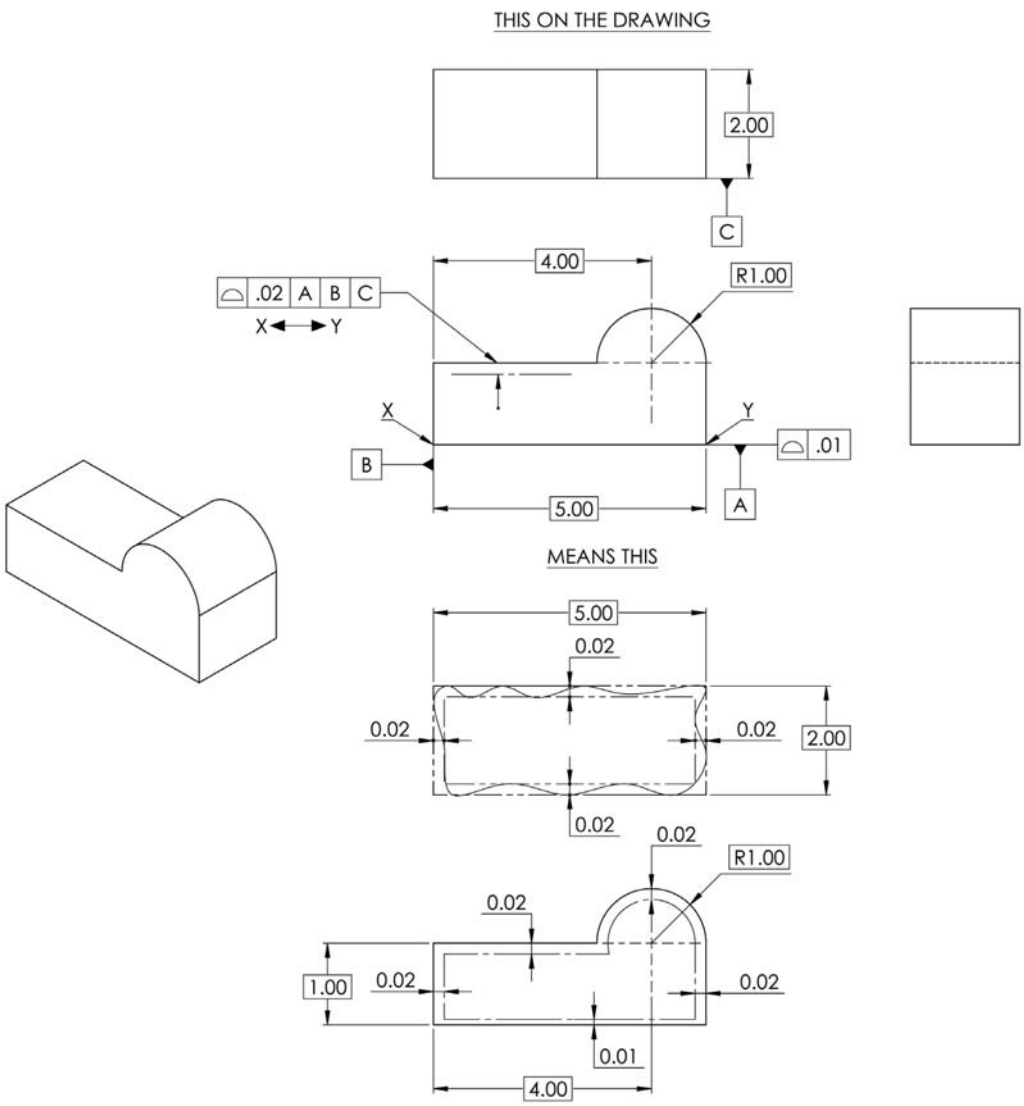


Figure 5-15 *Symmetry tolerancing.*

10 Profile Tolerances

Profile tolerances can control the location, orientation, and form of a feature that has no size (surface). There are two (2) types – profile of a surface (⌓) and profile of a line (⌒). The exact or true profile of a feature is established by basic dimensions of radii, angular dimensions, and coordinate dimensions established from datums however a profile tolerance can be specified to an individual surface without specifying a datum – see Fig. 16. The elements of a profile (outline of an object in a given plane) are straight lines or arcs. The tolerance is a boundary of two (2) parallel planes disposed (equally – see Fig. 17 or in one direction – see Fig. 16) and normal (perpendicular) along the perfect or true profile within which the entire surface must lie. The profile can be controlled between two (2) points – see Fig 16. Also if datum planes are established by targets – see Fig. 18 the tolerance zone is equally disposed about the datum planes whereas if the datum planes are established by complete contact with the datum features the tolerance zone is unidirectional and ½ the tolerance value in the FCF – see Fig. 17 vs Fig. 18.



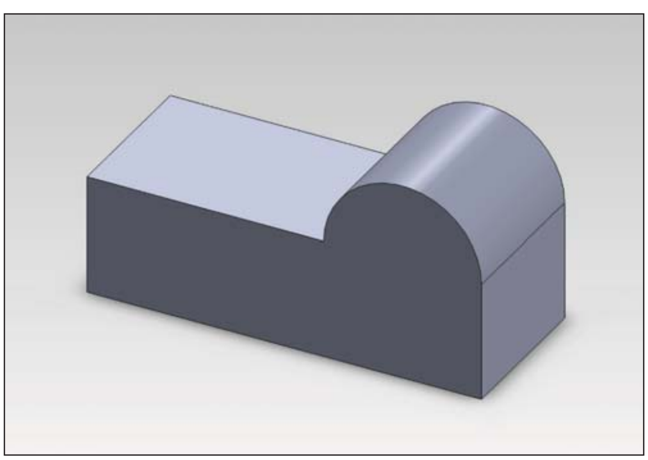
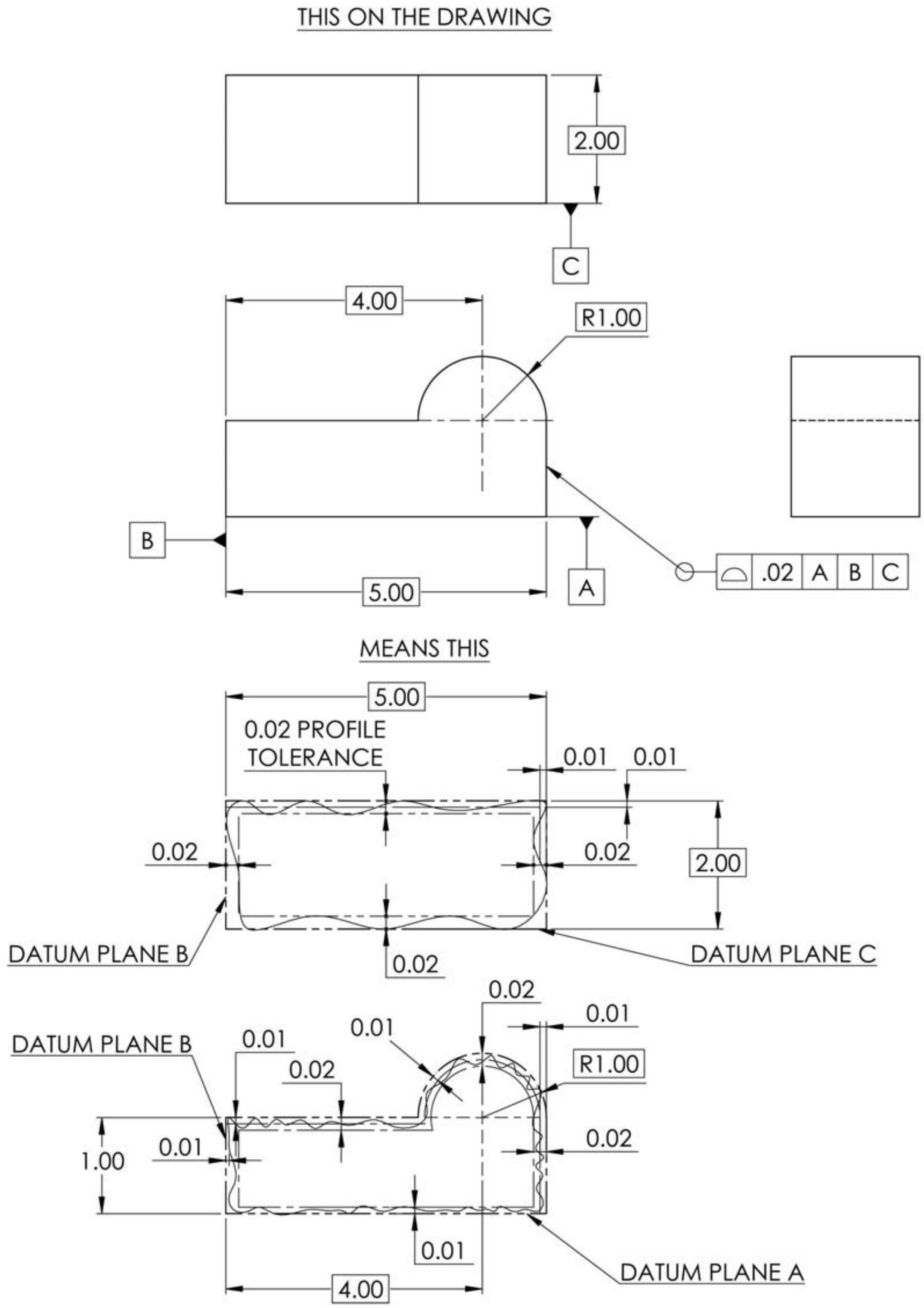


Figure 5-16 *Profile control – unidirectional and between points.*



Notes:

1) *All surfaces to be within .02±.01 tolerance zone of true or perfect profile.*

2) *Datum* A B and C to be within *.01 of datum planes A, B, and C.*

Figure 5-17 *Profile control – all around entire part without targets.*

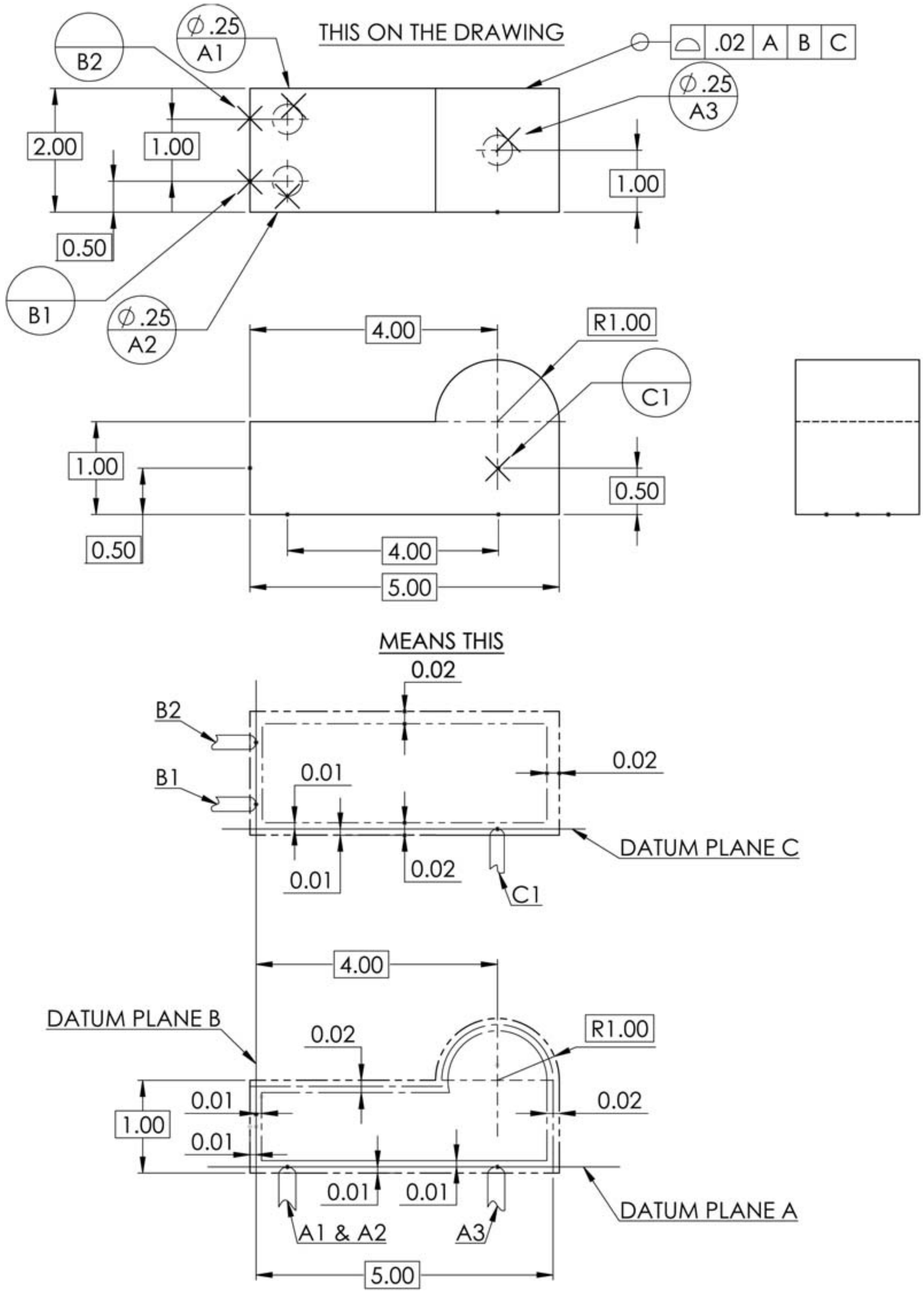


Figure 5-18 *Profile control – all around entire part with targets.*

11 Run Out Tolerances

Run out tolerances control the relationship of a feature relative to a datum axis established from one (1) diameter or two (2) diameters separated axially – see Fig. 5-19. The material condition applied to the feature being controlled and the datum feature or features is always RFS because 360˚ rotation is required to conduct the inspection. If targets are not specified to establish the datum axis the entire datum feature has to be contacted which may not be practical. There are two (2) types of run out controls – circular (↗) and total (⌰). Circular run out controls the cumulative variation of circularity (roundness) and coaxiallity for features constructed around a datum axis and circular elements of a surface constructed an angle not parallel to the datum axis (control wobble). The tolerance is the full indicator movement (FIM) for each circular element independently as the part is rotated 360˚. For each measurement the dial indicator is removed from the part after each 360˚ rotation and reset at a new location. Total run out controls the entire surface simultaneously hence it controls cumulative variations in circularity, coaxiality, straightness, taper, angularity, and profile of a surface. The dial indicator is not removed from the part after each 360˚ rotation. If applied to surfaces that are at an angle to the datum axis it controls variation in angularity (wobble) and flatness (concavity or convexity). See Fig. 5-19 for circular run out and Fig. 5-20 for total run out.

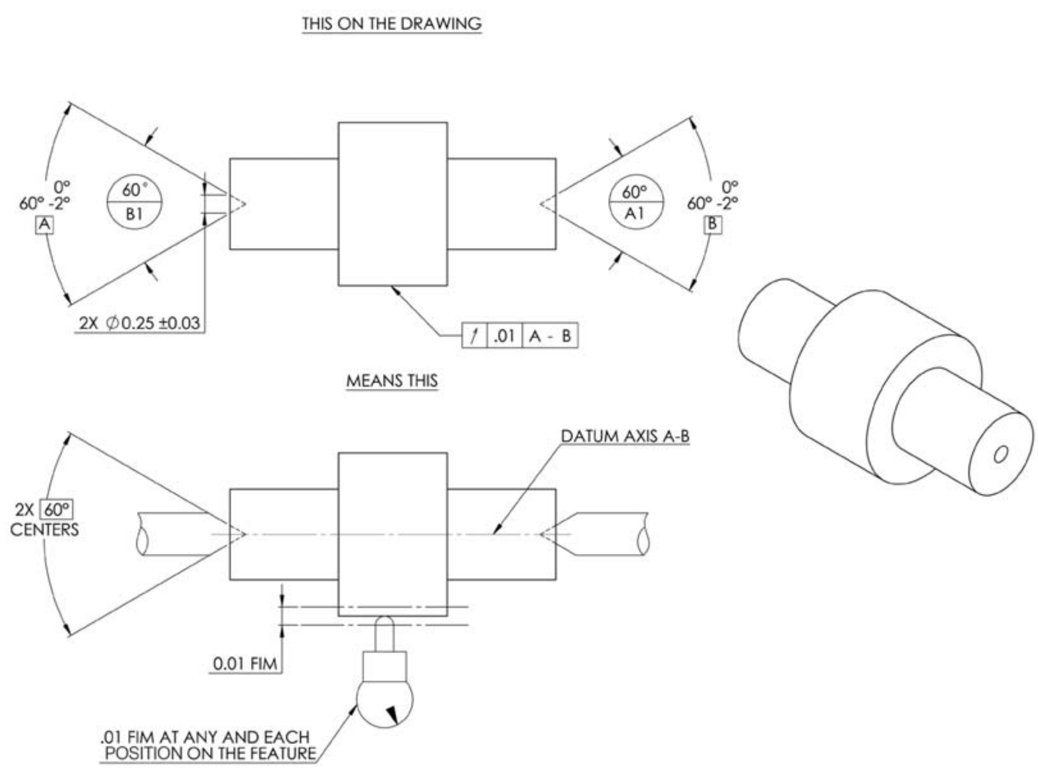
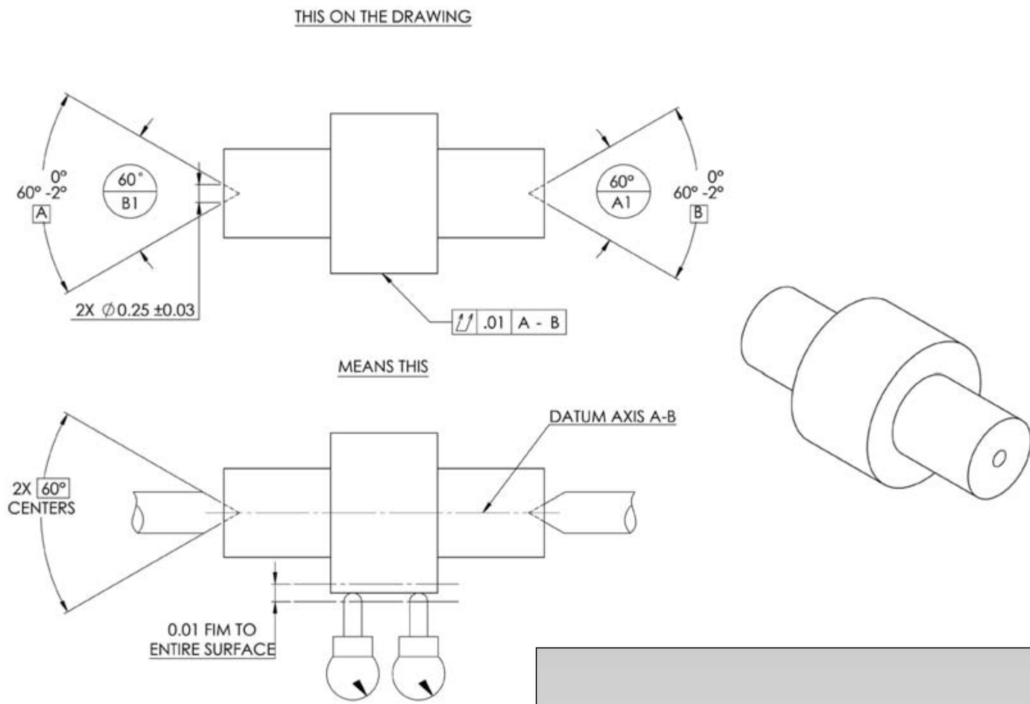


Figure 5-19 Circular runout with targets.



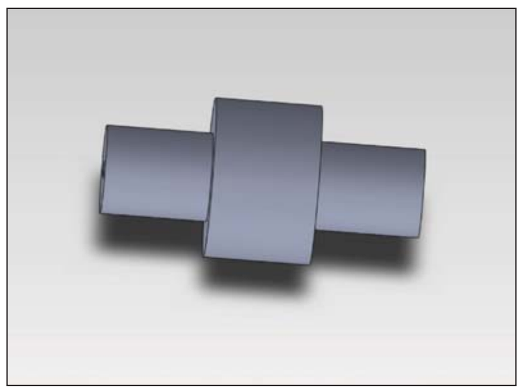
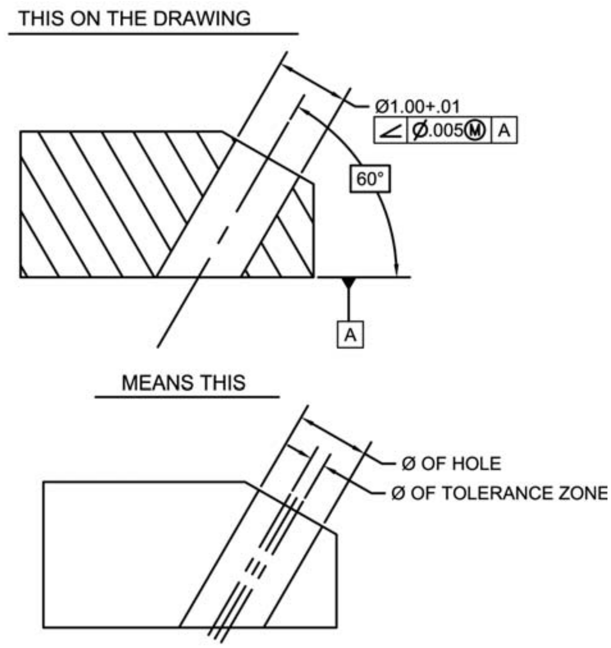


Figure 5-20 *total runout with targets.*

5

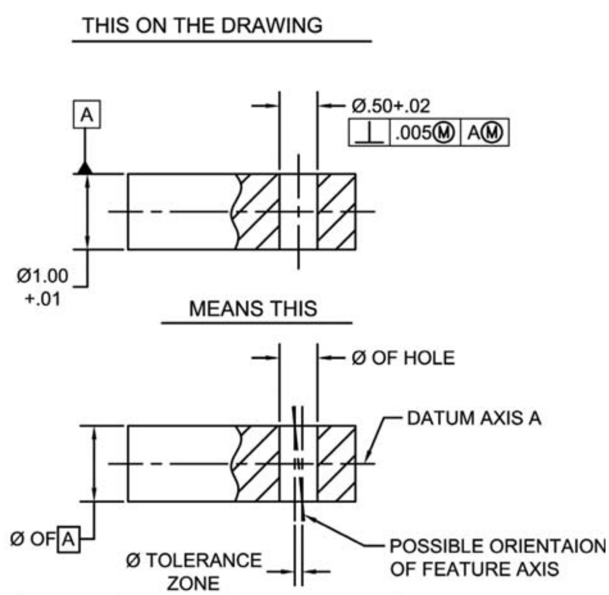
12 Orientation Tolerances

There are three (3) separate orientation tolerances however two (2) of the three are specific values of the general tolerance named angularity. The two (2) specific tolerances are named perpendicularity (90° to a datum) and parallelism (180° to a datum). These tolerances control the orientation of features to a datum plane or axis. Angularity controls a surface (non feature of size), a center plane or an axis of a feature of size to a specified angle and its symbol is ∠. Perpendicularity symbol is ⊥ and parallelism symbol is ∥ and they do the same as angularity except the angles are specific as previously stated. The tolerance zone may be either two (2) parallel planes at the specified basic angle from a datum plane or axis within which the surface, center plane or axis must lie or it may be a cylindrical zone within which the axis of the considered feature must lie. Of course if angularity tolerance is specified for a feature of size the material condition modifiers Ⓜ or Ⓛ may be specified. If neither Ⓜ or Ⓛ is specified then as always the regardless of feature size (RFS) is applicable. See Fig's 5-21 thru 5-23 for examples of ∠, ⊥, and ∥.



HOLE Ø	TOL. ZONE Ø
1.00	.005
1.01	.015

Figure 5-21 *Angularity of a feature of size axis at MMC.*



Ø OF A	HOLE Ø	TOL. ZONE Ø
1.01	.50	.005
1.01	.52	.025
1.00	.50	.015
1.00	.52	.035

Figure 5-22 *Perpendicularity of a feature of size axis at MMC with datum feature of size at MMC.*

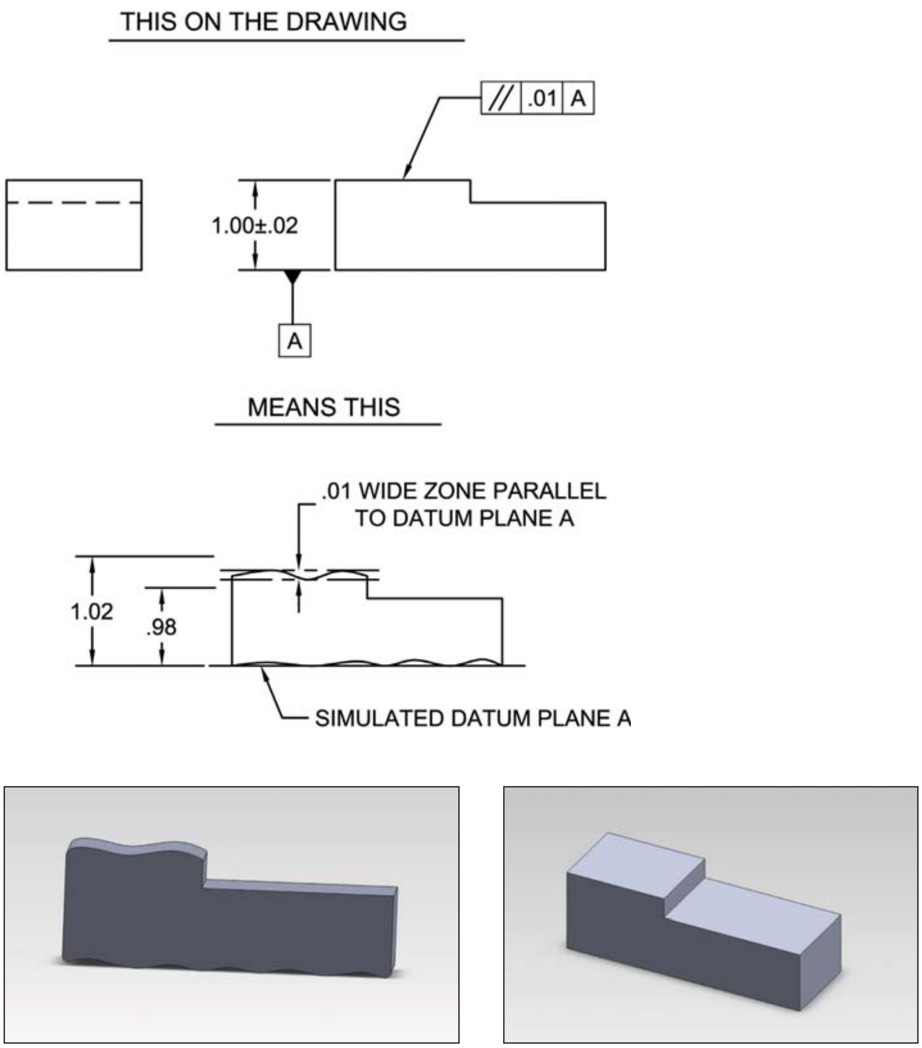


Figure 5-23 *Parallelism – surface.*

13 Form Tolerances

There are four (4) form tolerances : straightness, flatness, circularity, and cylindricity. They apply to individual features therefore the tolerances are not related to datums. Straightness can be used to control the straightness of median line of a feature of size hence material condition modifiers can be applied. The other form tolerances control surfaces hence material condition modifiers are not applicable.

13.1 Straightness

There is one symbol (—) for straightness but there are two (2) kinds of controls that are very different from each other. One control is for line elements of surfaces (FCF attached to the surface) and the other is control of an axis or median plane of feature of sizes (FCF attached to the size tolerance). The axis or median plane control relaxes the form control provided by Rule #1 because a perfect form boundary at MMC can be violated if the Ⓜ symbol is specified. Fig. 5-24 illustrates control of line straightness and Fig's 5-25 & 5-26 illustrate control of axis and median plane straightness respectively. The surface straightness tolerance is only for line elements in the view that the FCF is attached.

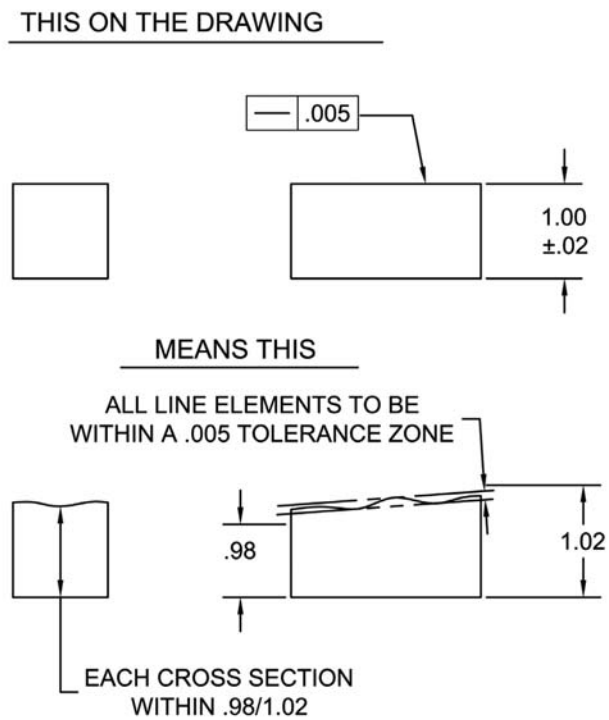


Figure 5-24 *Straightness of a surface.*

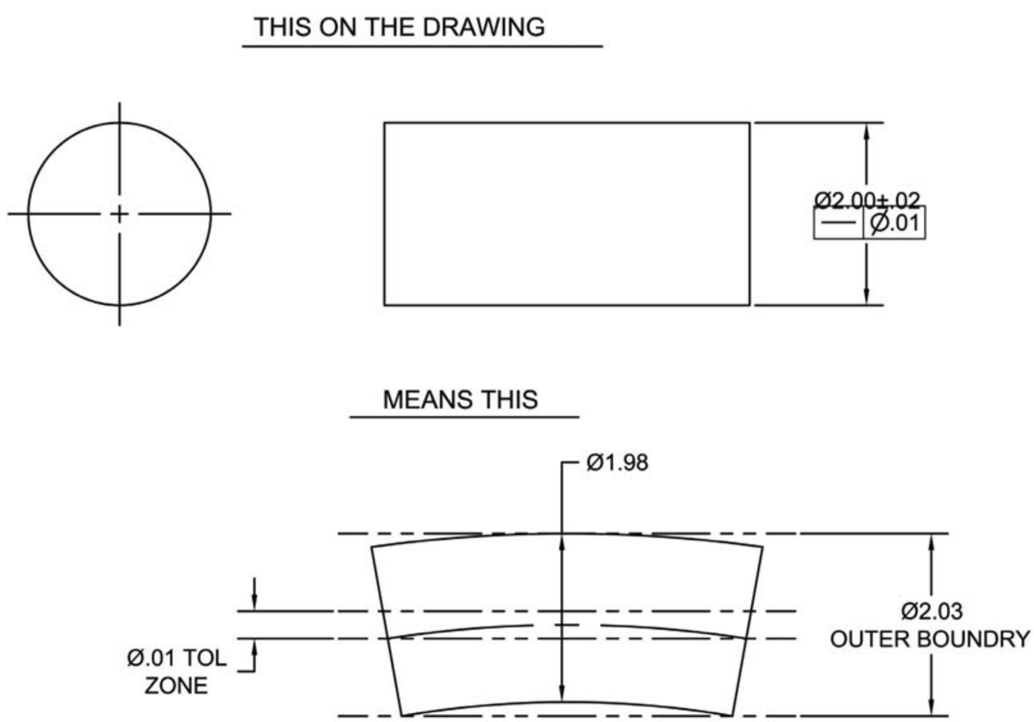


Figure 5-25 *Straightness of an axis RFS.*

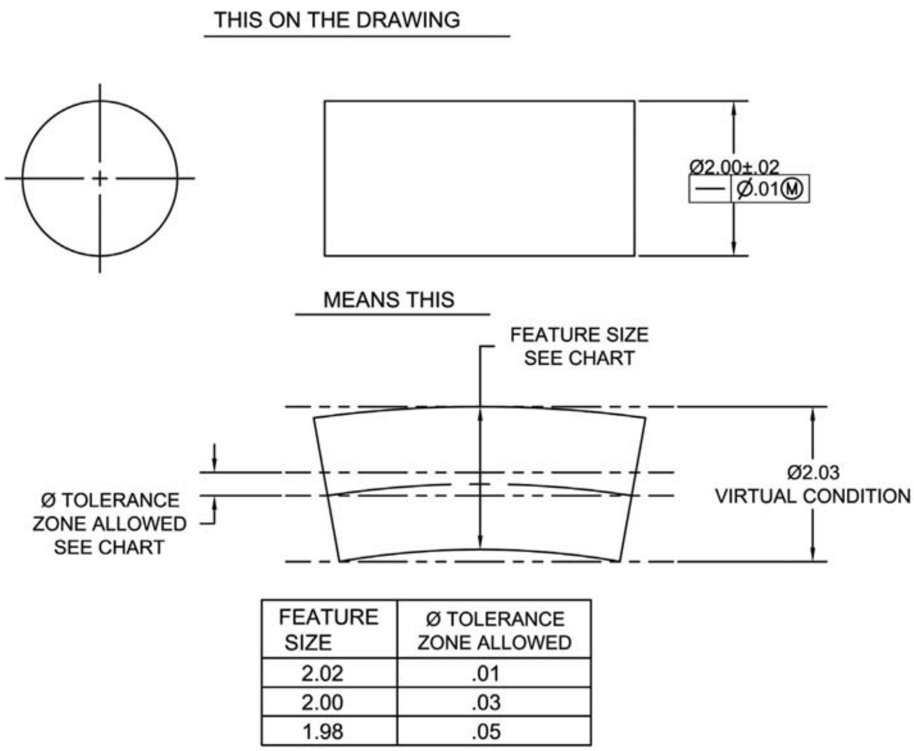


Figure 5-26 Straightness of an axis at MMC.

13.2 Flatness

Flatness controls the distance between the high and low points of a surface. The tolerance zone is the distance between two parallel planes that have no particular orientation. All elements of the entire surface must lie between these two planes. See Fig. 5-27 for an illustration of flatness control. The symbol is ⏥. Flatness is the same as straightness of a surface except straightness controls line elements only in the view that the control is applied whereas flatness controls the entire surface, i.e., all views.

13.3 Circularity (Roundness)

Circularity controls each circular element of a cylinder independent of each other. The circular elements of the surface in a plane perpendicular to an axis must lie between two concentric circles whose radii differ by the tolerance value in the FCF. The symbol is ○. See Fig. 5-28 for an illustration.

13.4 Cylindricity

Cylindricity controls the entire surface of a cylinder. The tolerance zone is two (2) concentric cylinders parallel to the axis of the actual mating envelope. The radii of the concentric cylinders differ by the tolerance value specified in the FCF. It is a composite tolerance that controls circularity, straightness, and taper. The symbol is ⌭. See Fig. 5-29 for an illustration.

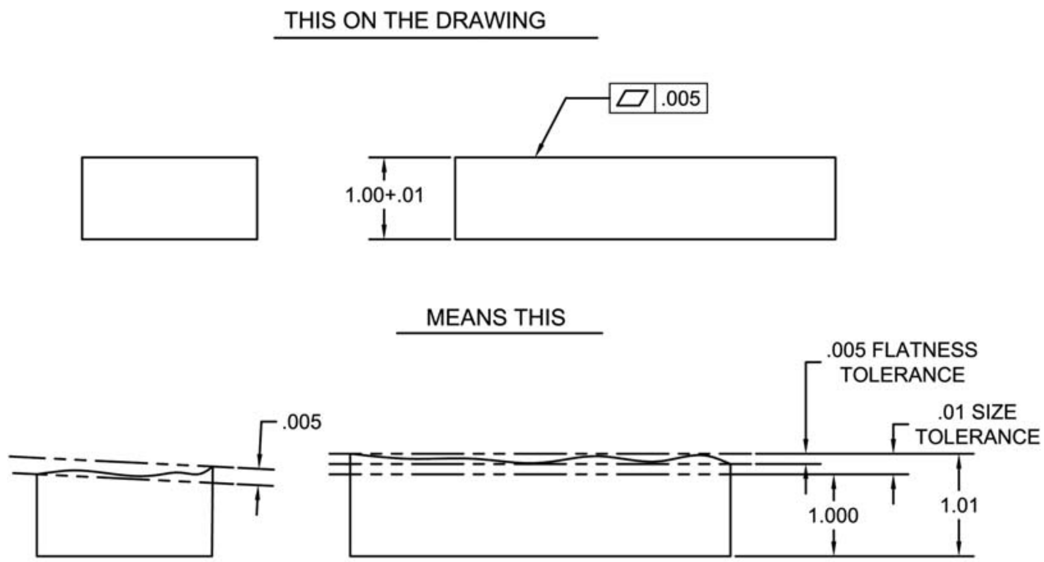
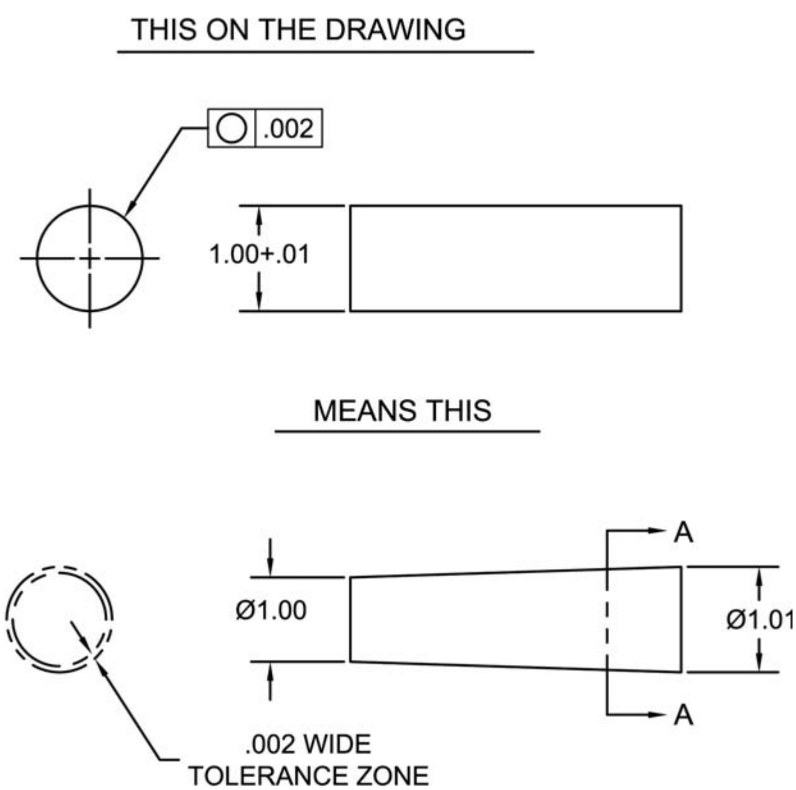


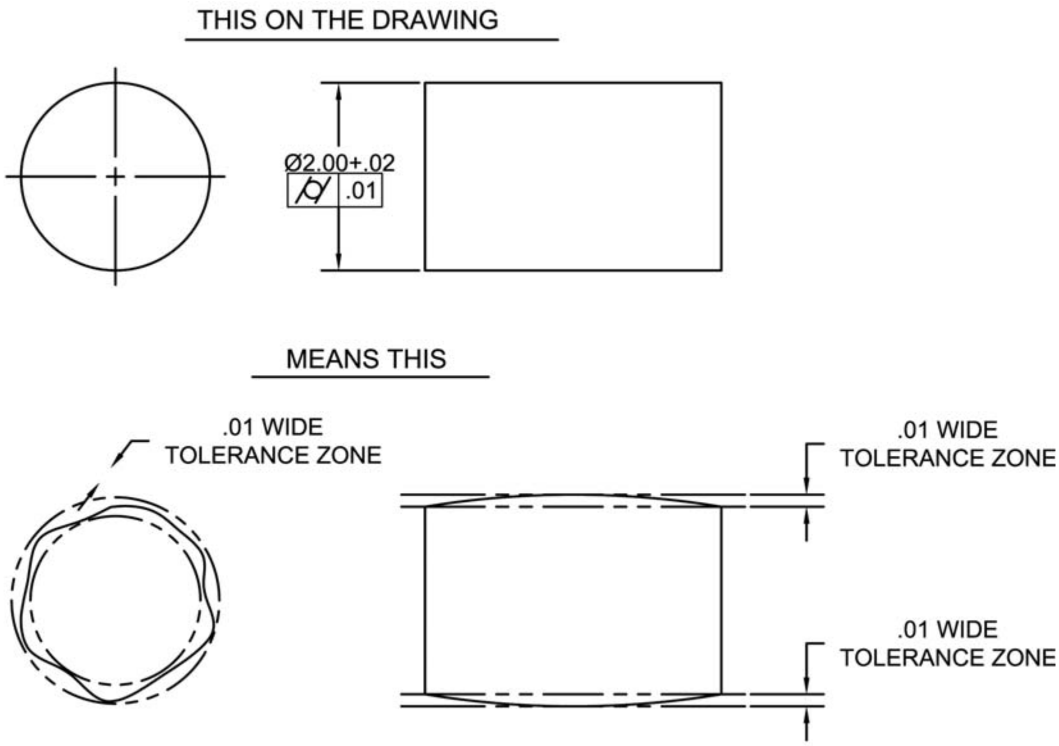
Figure 5-27 *Straightness of an axis at MMC.*



Notes:

Each circular element in a plane perpendicular to an axis must be between two concentric circles with radii that differ by .002. Also each element must be within the size limits.

Figure 5-28 *Circularity.*



Notes:

Cylindrical surface has to lie between two concentric cylinders with radii that differ by .01. Also the surface must be within the specified size tolerance.

Figure 5-29 *Cylindricity.*

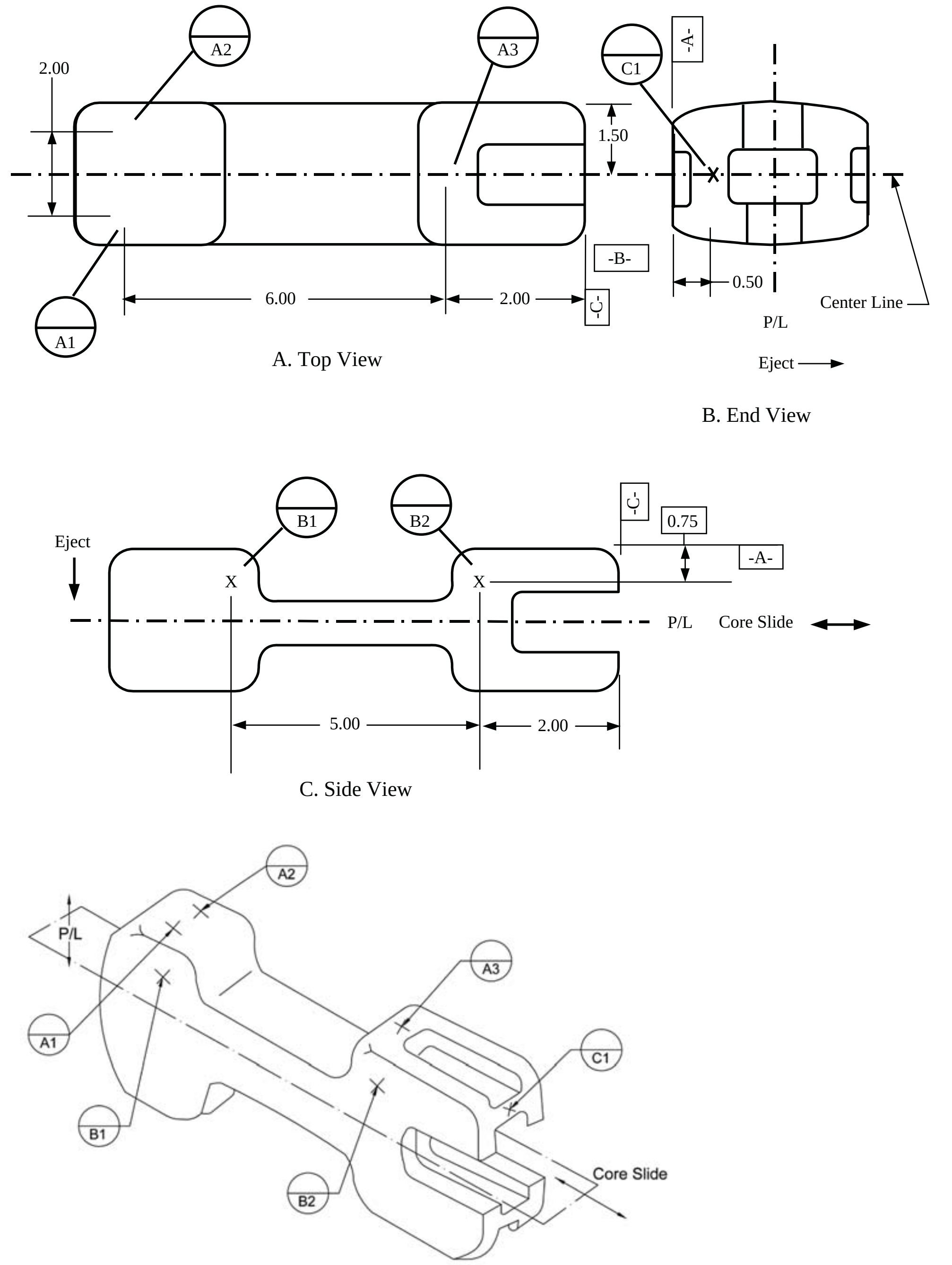


Figure 5-30 *Example of an optimal datum reference framework for a die cast part design (all datums on same side of p/l).*

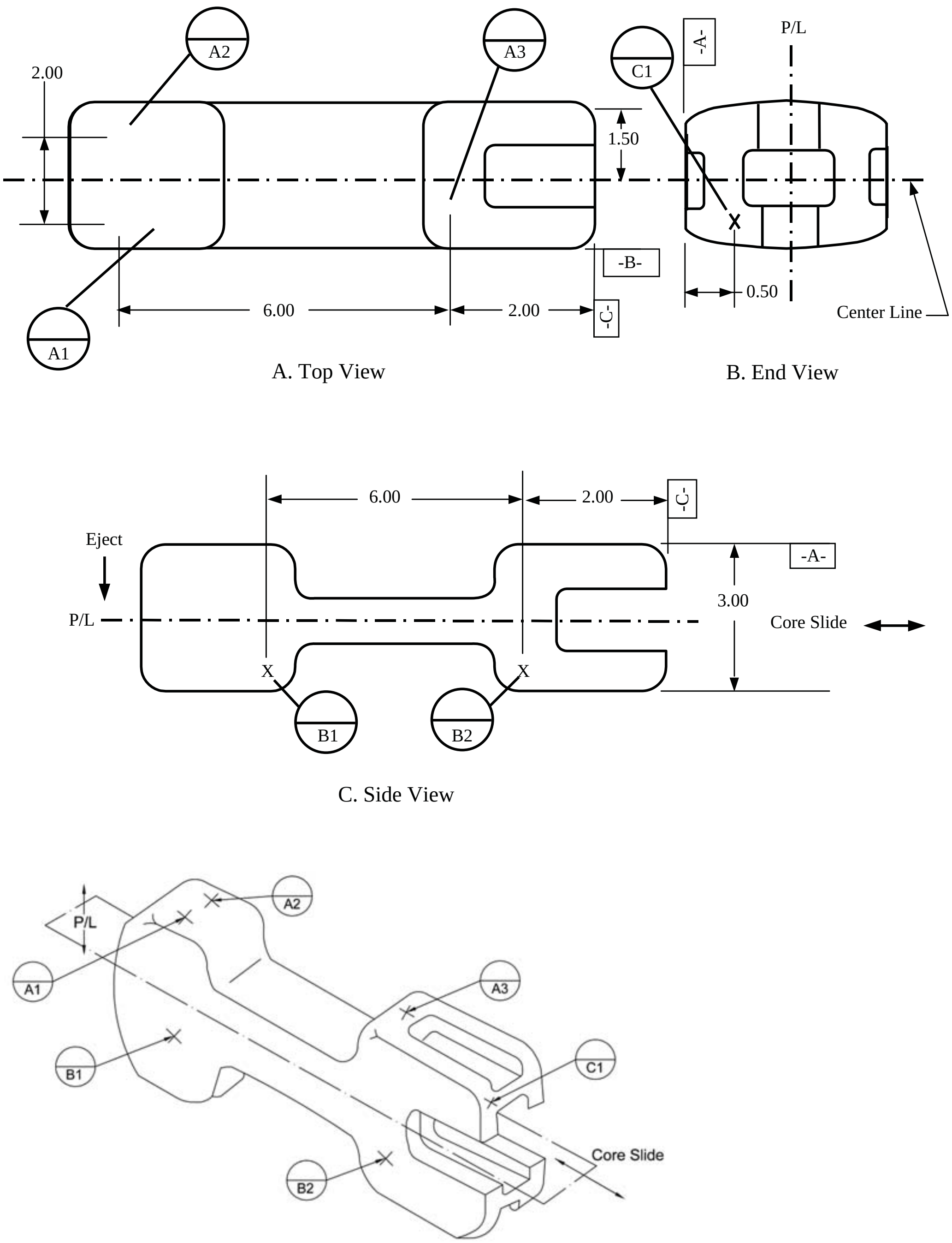


Figure 5-31 Example of a less desirable datum reference framework for a die cast part design (datums across p/l). May require additional qualification of some datums.

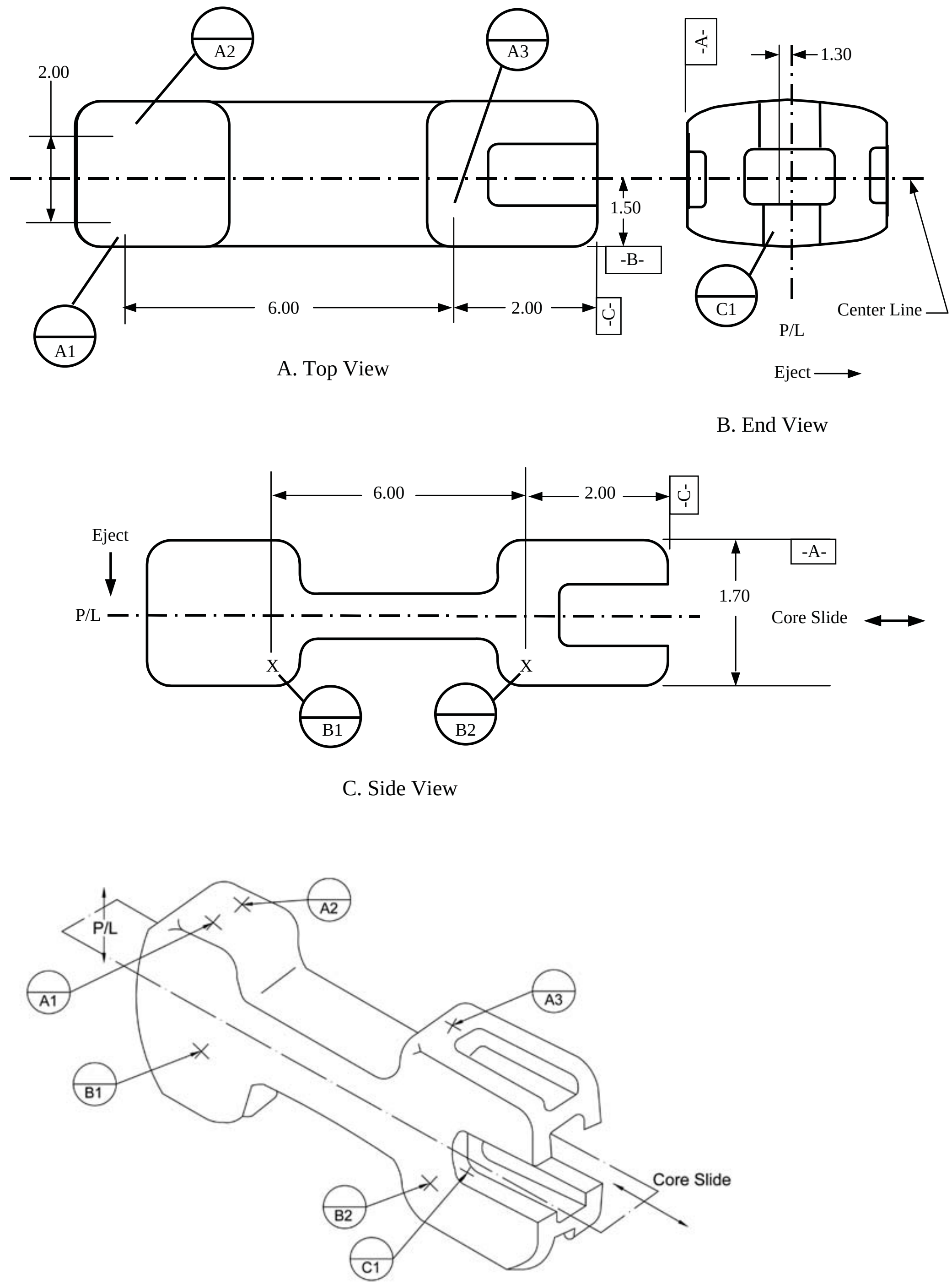


Figure 5-32 Example of a least preferred datum reference framework for a die cast part design (datums across p/l and datum on moving component). Will require qualification of all datums.

14 Conversion Charts

Coordinate dimensioning defines parts by their location on a three-dimensional grid, utilizing the X-Y-Z coordinate system as in Fig. 5-2. Since the Coordinate Dimensioning System may not consider part function when defining dimensions and tolerances, GD&T is a preferred method of defining and dimensioning parts based on functional relationships to other parts and part features. Sometimes it is necessary for dimensions and tolerances to be converted from one system to the other. Geometric dimensioning and tolerancing is steadily replacing coordinate dimensioning as more emphasis is placed on "designing for manufacturing" early in the product design stage. This section will demonstrate how to convert between coordinate dimensioning and geometric dimensioning.

14.1 Conversion of Position (Cylindrical) Tolerance Zones to/from Coordinate Tolerance Zones

When converting total position (cylindrical) tolerance zones to total coordinate tolerance zones, a general rule of thumb is that total coordinate zone is approximately 70% of total position tolerance zone. This is only useful for non-critical applications. For example, for a non-critical part to be converted from position (cylindrical) tolerance zone to coordinate tolerance zone, the position (cylindrical) tolerance is multiplied by 0.7 (70%). The total coordinate tolerance zone is then divided by 2 to obtain the bilateral tolerance zone.

Figure 5-33 visually demonstrates the conversion from coordinate tolerance zone to position (cylindrical) tolerance zone.

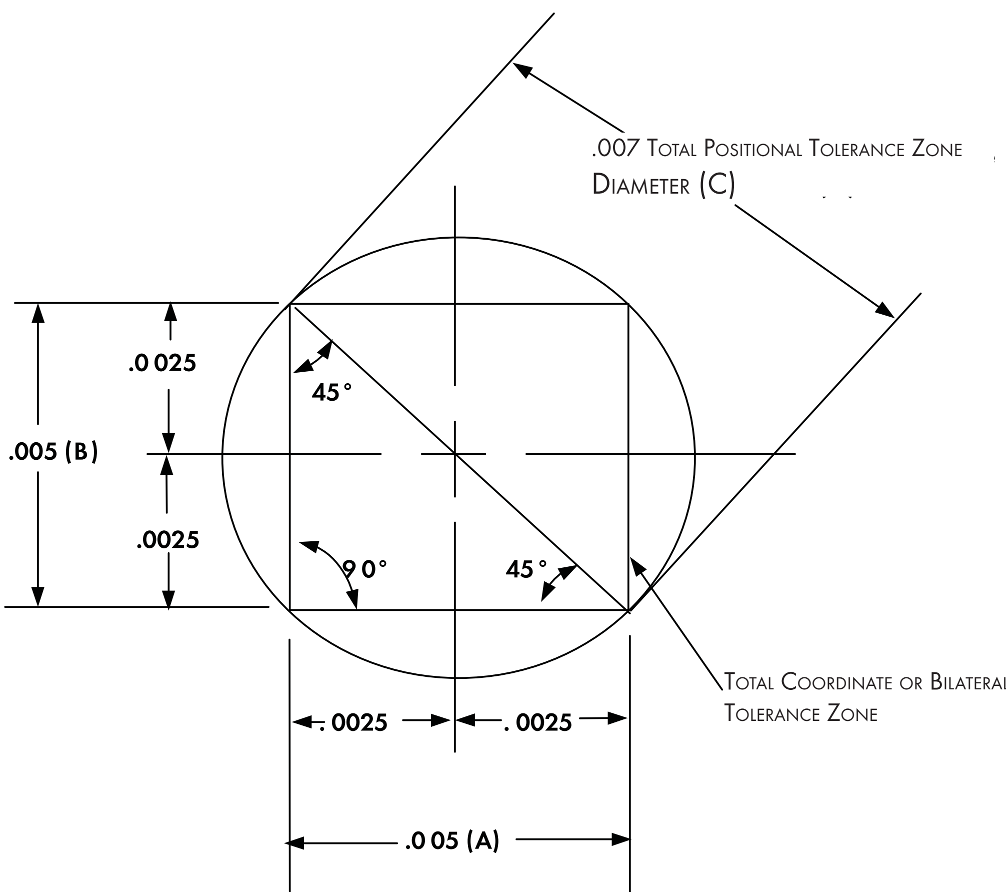


Figure 5-33 *Conversion of positional (cylindrical) tolerance zones to/from coordinate tolerance zones.*

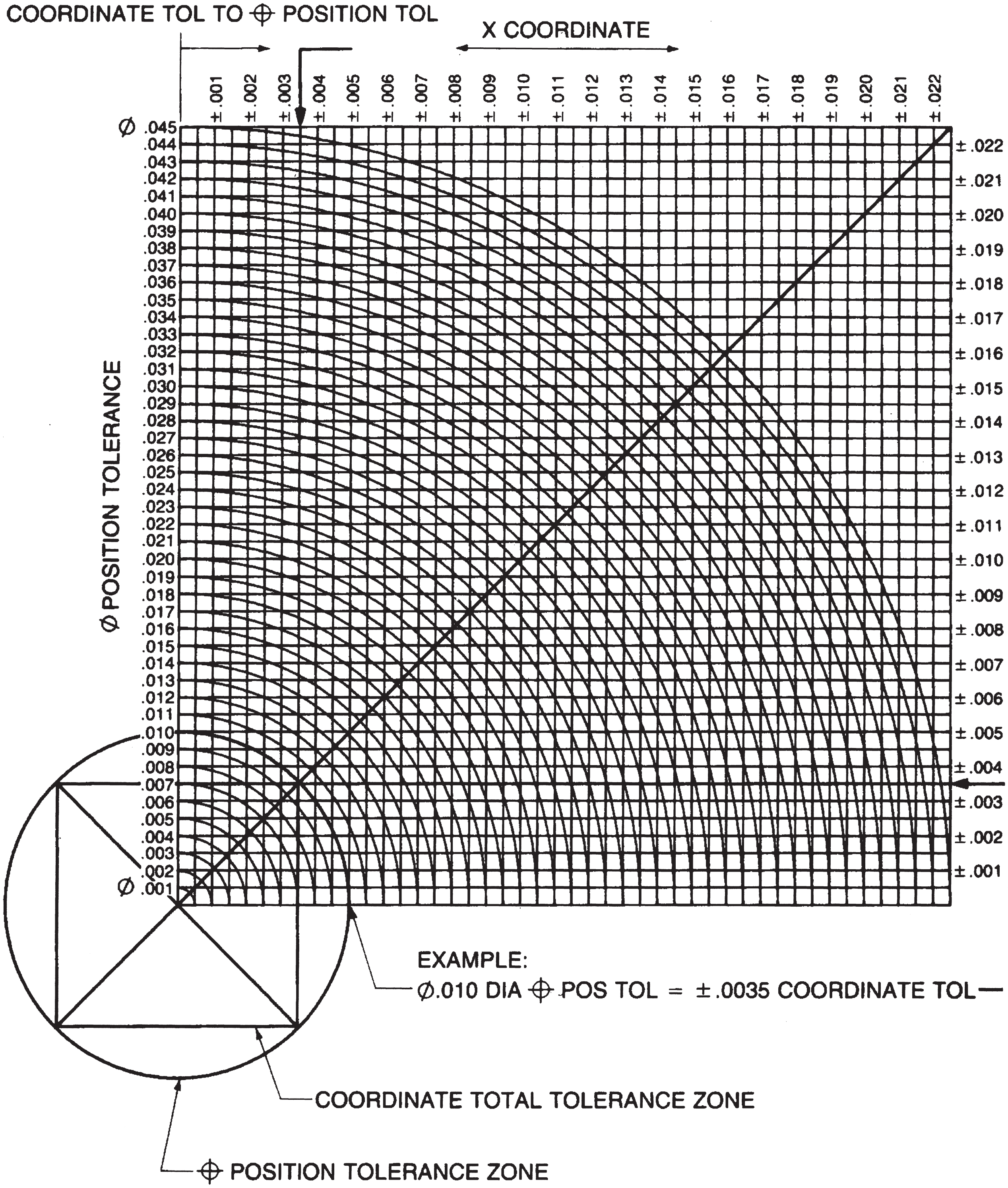


Figure 5-34 *Conversions chart for converting between position tolerance and coordinate tolerance.*

Total Coordinate Tolerance Zone =
[Total Position (Cylindrical) Tolerance Zone] X [0.7]

Example: Bilateral Tolerance Zone = [Total Coordinate Tolerance Zone] / 2

Sometimes parts require a more precise conversion. When a critical application is required, the conversion factor is 0.70711. The position tolerance will be multiplied by 0.70711 (70.711%) to obtain the total coordinate tolerance.

Total Coordinate Tol. Zone = [Total Position (Cylindrical) Tol. Zone] X [0.70711]

Bilateral Tolerance Zone = [Total Coordinate Tolerance Zone] / 2

For example, to convert 0.007 total position (cylindrical) tolerance to total coordinate tolerance:

Total Pos. Tol. Zone X Conversion Factor = Total Coordinate Tolerance Zone
0.007 Tol. X 0.70711 = 0.00495 ~ 0.005 Tot. Coordinate Tol.

Or

Total Coordinate Tol. Zone / 2 = Bilateral Tol. Zone 0.005 / 2 = 0.0025 Bilateral Tolerance

The following example demonstrates a simple conversion from total position tolerance zone to total coordinate tolerance zone and bilateral tolerance zone. Figure 5-36 visually demonstrates the conversion from position (cylindrical) tolerance zone to the coordinate tolerance zone.

When converting from total coordinate tolerance zone to total position (cylindrical) tolerance zone, the total coordinate tolerance zone is multiplied by 1.4142. A bilateral tolerance zone is multiplied by 2 then multiplied by 1.4142 to obtain the total position (cylindrical) tolerance zone.

For non-critical applications, it is acceptable to multiply the total coordinate tolerance zone by 1.4 to obtain the total position tolerance zone. A bilateral tolerance may be multiplied by 2 to obtain the total coordinate tolerance zone, then multiplied by 1.4 to get the total position tolerance zone.

Total Position Tol. Zone =[Total Coordinate Tol. Zone] X [1.4142]

Total Position Tol. Zone = [Bilateral Tol. Zone] X [2] X [1.4142]

For example, to convert .005 total coordinate tolerance to total position (cylindrical) tolerance:

[Total Coordinate Tolerance Zone] X [Conversion Factor] = Total Position Tol. Zone
[0.005 Total Coordinate Tol. Zone] X [1.4142] = 0.007 Total Tol. Zone

Or
[Bilateral Tolerance Zone] X [2] X [Conversion Factor] = Total Position Tol. Zone
[0.0025 Bilateral Tol.] X [2] X [1.4142] = 0.007 Total Tol. Zone

14.2 Conversion of Position Tolerance Zone to/from Coordinate Tolerance Zone

Figure 5-34 is a chart for converting position tolerance zones to coordinate tolerance zones, and for converting coordinate tolerance zones to position tolerance zones.

When looking at the conversion chart in Fig. 5-34, coordinate tolerance zones are listed across the top of the grid and increasing from left to right, and on the right side of the grid increasing from bottom to top. The position tolerances are listed on the left side of the grid and increase from bottom to top. The position tolerances, however, follow the arced line across the grid. The diameter of a position tolerance is given on the drawings, however, the diameter of a coordinate tolerance is given by the length of the diagonal line. A diagonal line is drawn from the lower left corner of the grid at a 45° angle to the upper right corner of the chart. The diameter is calculated by using $A^2 + B^2 = C^2$. In figure 5-33, A is the total length of the horizontal line at the bottom and connected to the circle, squared, plus B, the square of the vertical line at the left or right edge and connected to the circle. Take the square root of the sum of the two sides will equal the diameter C.

For example, suppose one wanted to convert a 0.010 diameter position tolerance to a coordinate tolerance. While looking at the chart in Fig. 5-34, begin at the 0.01 position tolerance on the left side of the chart. Follow the corresponding arced line until it crosses the diagonal line on the chart. Where the arced line and the diagonal line intersect, follow the horizontal line across to the right side of the chart. The number on the right side of the chart that corresponds with the horizontal line will give the appropriate bilateral coordinate tolerance. In this example, the corresponding bilateral tolerance is ± 0.0035. To quickly verify this conversion, use the multipliers identified in on page 5-31. Multiplying the coordinate tolerance by 0.7 will yield the total coordinate tolerance. This number is then divided by 2 to obtain the bilateral coordinate tolerance.

Position Tolerance = 0.010
Total Coordinate tolerance = Position Tol. X Conversion Factor = [0.010] X [0.7] = 0.007
Bilateral Tolerance Zone = Total Coordinate Tolerance / 2 = [0.007] / [2] = ±0.0035

Bilateral Position Tol. = ± 0.0035
Total Position Tol = Bilateral Position Tol. X 2 = [0.0035] X [2] = 0.007
Position Tol. X Conv. Factor = [0.007] X [1.4] ~ 0.01

The number obtained from the conversion chart and the number obtained by using the multiplier should be approximately the same.

Suppose it was desired to convert a coordinate tolerance such as 0.007 to a position tolerance. In order to use the conversion chart in Fig. 5-34, the coordinate tolerance must be in bilateral coordinates, so 0.007 is divided by 2. This yields a bilateral coordinate tolerance of ± 0.0035. Next, the number .0035 is located on the left side of the conversion chart. Follow the corresponding horizontal line across to the left until it intersects the diagonal line. At this intersection, follow the intersecting arced line all the way across and to the left. The number corresponding to that arced line on the left of the chart gives the associated position tolerance. If done correctly, the position tolerance identified on the chart should be 0.010. This can be double-checked by using the multipliers on page 5-31.

The number obtained from the conversion chart and the number obtained by using the multiplier should be approximately the same.

To convert between position tolerancing and coordinate tolerance, either the conversion table identified in Fig. 5-34, or the multiplication factor identified on page 5-31 may be used.

.020	.0400	.0402	.0404	.0408	.0412	.0418	.0424	.0431	.0439	.0447	.0456	.0466	.0477	.0488	.0500	.0512	.0525	.0538	.0552	.0566
.019	.0380	.0382	.0385	.0388	.0393	.0398	.0405	.0412	.0420	.0429	.0439	.0449	.0460	.0472	.0484	.0497	.0510	.0523	.0537	.0552
.018	.0360	.0362	.0365	.0369	.0374	.0379	.0386	.0394	.0403	.0412	.0422	.0433	.0444	.0456	.0469	.0482	.0495	.0509	.0523	.0538
.017	.0340	.0342	.0345	.0349	.0354	.0360	.0368	.0376	.0385	.0394	.0405	.0416	.0428	.0440	.0453	.0467	.0481	.0495	.0510	.0525
.016	.0321	.0322	.0325	.0330	.0335	.0342	.0349	.0358	.0367	.0377	.0388	.0400	.0412	.0425	.0439	.0452	.0467	.0482	.0497	.0512
.015	.0301	.0303	.0306	.0310	.0316	.0323	.0331	.0340	.0350	.0360	.0372	.0384	.0397	.0410	.0424	.0439	.0453	.0469	.0484	.0500
.014	.0281	.0283	.0286	.0291	.0297	.0305	.0313	.0322	.0333	.0344	.0356	.0369	.0382	.0396	.0410	.0425	.0440	.0456	.0472	.0488
.013	.0261	.0263	.0267	.0272	.0278	.0286	.0295	.0305	.0316	.0328	.0340	.0354	.0368	.0382	.0397	.0412	.0428	.0444	.0460	.0477
.012	.0241	.0243	.0247	.0253	.0260	.0268	.0278	.0288	.0300	.0312	.0325	.0339	.0354	.0369	.0384	.0400	.0416	.0433	.0449	.0466
.011	.0221	.0224	.0228	.0234	.0242	.0250	.0261	.0272	.0284	.0297	.0311	.0325	.0340	.0356	.0372	.0388	.0405	.0422	.0439	.0456
Y .010	.0201	.0204	.0209	.0215	.0224	.0233	.0244	.0256	.0269	.0283	.0297	.0312	.0328	.0344	.0360	.0377	.0394	.0412	.0429	.0447
.009	.0181	.0184	.0190	.0197	.0206	.0216	.0228	.0241	.0254	.0269	.0284	.0300	.0316	.0333	.0350	.0367	.0385	.0402	.0420	.0439
.008	.0161	.0165	.0171	.0179	.0189	.0200	.0213	.0226	.0241	.0256	.0272	.0288	.0305	.0322	.0340	.0358	.0376	.0394	.0412	.0431
.007	.0141	.0146	.0152	.0161	.0172	.0184	.0198	.0213	.0228	.0244	.0261	.0278	.0295	.0313	.0331	.0349	.0368	.0386	.0405	.0424
.006	.0122	.0126	.0134	.0144	.0156	.0170	.0184	.0200	.0216	.0233	.0250	.0268	.0286	.0305	.0323	.0342	.0360	.0379	.0398	.0418
.005	.0102	.0108	.0117	.0128	.0141	.0156	.0172	.0189	.0206	.0224	.0242	.0260	.0278	.0297	.0316	.0335	.0354	.0374	.0393	.0412
.004	.0082	.0089	.0100	.0113	.0128	.0144	.0161	.0179	.0197	.0215	.0234	.0253	.0272	.0291	.0310	.0330	.0349	.0369	.0388	.0408
.003	.0063	.0072	.0085	.0100	.0117	.0134	.0152	.0171	.0190	.0209	.0228	.0247	.0267	.0286	.0306	.0325	.0345	.0365	.0385	.0404
.002	.0045	.0056	.0072	.0089	.0108	.0126	.0146	.0165	.0184	.0204	.0224	.0243	.0263	.0283	.0303	.0322	.0342	.0362	.0382	.0402
.001	.0028	.0045	.0063	.0082	.0102	.0122	.0141	.0161	.0181	.0201	.0221	.0241	.0261	.0281	.0301	.0321	.0340	.0360	.0380	.0400
X	.001	.002	.003	.004	.005	.006	.007	.008	.009	.010	.011	.012	.013	.014	.015	.016	.017	.018	.019	.020

Figure 5-35 *Conversions chart for converting between coordinate measurement and position measurement.*

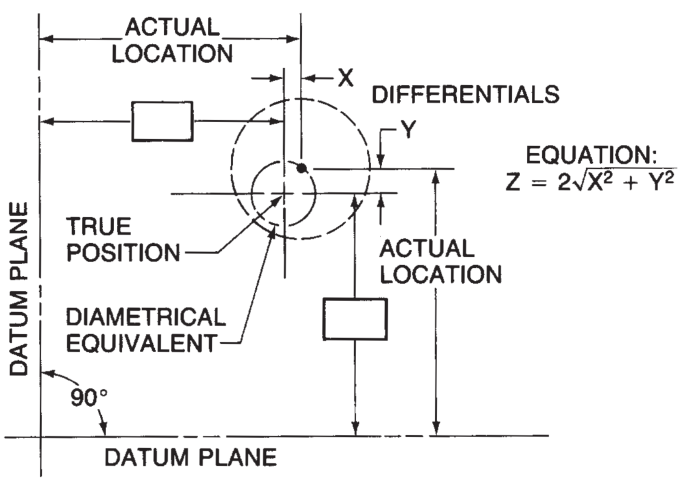


Figure 5-36 *Schematic of conversion of coordinate measurements to position location.*

14.3 Conversion of Coordinate Measurements to Position Location Measurements

In addition to sometimes having to convert between position tolerance zones and coordinate tolerance zones, it is also necessary to convert coordinate measurements to position location measurements. When converting from coordinate measurements to position measurements, the chart identified in Fig. 5-35 is used.

For example, if it was necessary to convert the position measurement 0.0311 to coordinate measurements the following steps need to be accomplished. First, locate the number 0.0311 on the chart in Fig. 5-35. Once the number is located, follow the vertical column down to the X-axis of the chart. The number identified at the very bottom of the column is the X-coordinate measurement. In this example, the X-coordinate is 0.011. Now, relocate the number 0.0311 on the chart and follow the horizontal row to the right until it crosses the Y-axis. The number on the very left end of that row is the Y-coordinate measurement. In this example, the Y-coordinate is 0.011. Since position measurements are three-dimensional, a Z-coordinate must also be identified. To find the corresponding Z-coordinate measurement, a simple equation must be performed. This equation is as follows:

$$Z = 2\sqrt{X^2 + Y^2}$$

For this example, Z = 2 times the square root of X squared plus Y squared.

$$Z = 2\sqrt{(0.011)^2 + (0.011)^2}$$
$$Z = 2\sqrt{(0.000121) + (0.000121)}$$
$$Z = 2\sqrt{0.000242}$$
$$Z = 2\sqrt{2(0.015556)}$$
$$Z = 0.031112$$

The coordinate measurements that are associated with the 0.0311 position are

X = 0.011, Y = 0.011, and Z + 0.031112.

Engineering & Design: Additional Specification Guidelines

SECTION

6

6

Engineering & Design: Additional Specification Guidelines

Pressure-tightness specifications for die castings, to assure containment of liquids or gases in use, require deviations from standard production and inspection practice. Extra steps, including special pressure-testing equipment and testing procedures, are usually needed.

Frequently Asked Questions (FAQ)

1) How much flash can be expected to remain on a die casting after degating and trimming?
   See page 6-7, Metal Extension (Flash) Removal.
2) If lettering is cast into the part, what are the options?
   See page 6-10, Die Cast Lettering.
3) Are ejector pin marks required on the casting and will they have flash?
   See page6-6, Ejector Pins, Pin Marks and Pin Flash.
4) What is a typical pressure tightness that die castings can withstand?
   See page 6-3, Pressure Testing.
5) What is the best surface condition I can expect on die cast surfaces?
   See page 6-8, Typical As-Cast Surface Roughness Guide.
6) Why add ribs to the casting in-place of thick sections?
   See page 6-5, Ribs and Corners.

Introduction

The die casting specifications discussed in this section relate to aspects of die casting design and production for which precise standards are difficult to set forth. As in previous Engineering sections, they replace the former ADCI/NADCA "E" Series.

They include characteristics which are highly dependent on the design and shape of the particular part to be die cast, such as pressure tightness of the finished part; the proper design of fillets, ribs and corners in a part; the consideration of ejector pin locations, pin marks and pin flash; casting flash and its removal; as-cast surface finish specifications; and the casting of lettering, logos and ornamentation on the part surface.

While specifications will vary with the desired characteristic, certain guidelines have been established for die casting production under normal practice which can yield the most economic results.

It is obvious that close consultation with the die caster prior to freezing design decisions is the wisest course to follow.

1 Pressure Tightness in Cast Parts

Assurance of pressure tight castings is highly dependent on the design configuration of the part. Consultation with the caster in the early design stages is essential where a specification for pressure tightness exists, in order to take advantage of basic product design, casting die design, and production processing factors. All of these factors are involved in insuring pressure tightness of the final cast part.

While most cast part designs can be cast pressure tight, specific castings may require impregnation to achieve required pressure tightness.

Special Notification Required

Specifications for pressure tightness will require deviations from standard production and inspection practice. Special pressure testing equipment and testing procedures are usually needed.

The requirement for pressure tightness should be made only where it is essential to the performance of the finished part. Where so specified, test methods and inspection procedures should be agreed upon in advance between the customer and the caster. Duplicate test fixtures and test methods are recommended wherever possible.

The discussion of "Porosity" and "Pressure Tightness" under Quality Assurance, Section 7 of this manual, should be reviewed.

Engineering & Design: Additional Specification Guidelines

NADCA

G-6-1-15

GUIDELINES

Pressure-tightness specifications for die castings, to assure containment of liquids or gases in use, require deviations from standard production and inspection practice. Extra steps, including special pressure-testing equipment and testing procedures, are usually needed.

Guidelines for Pressure Tightness

Important considerations relating to the economical production of pressure-tight castings include the following guidelines:

1. Product Design and Die Design

Successful casting of pressure-tight castings require close conformance to the principles of good casting product design.

a. *Guidelines concerning fillets, ribs and corners (G-6-2 and G-6-3), in this section, should be followed very carefully.*

b. *Part wall sections should be of uniform thickness as much as possible.*

c. *Holes and passages requiring pressure tightness should be cored to reduce porosity, as opposed to machined after casting.*

d. *Ample draft should be provided in all cored holes and passages which are not to be machined. Cored holes which are to be machined should be given minimum draft (see Draft Tolerances pg. 4A-21).*

e. *Heavy sections, as well as abrupt changes in sectional thickness, should be avoided.*

f. *Special vacuum casting techniques may be required in addition to special steps in temperature control, the use of squeeze pins and other procedures to achieve final part specifications where the part design does not conform to good casting design guidelines.*

2. Secondary Machining

The nature of the casting process is such that the outer surface of a casting is usually dense. Thus, thinner walls will be largely free of porosity, while thicker walls can be expected to contain some porosity within. Pressure-tight designs must set strict limitations on secondary machining.

a. *A minimum amount of machining stock should be removed, to avoid exposing porosity by cutting deeply into a casting (see Machining Stock Allowance Tolerances, pg. 4A-40).*

b. *Large draft angles, which would require the removal of a large amount of stock from a surface to be machined, should be avoided, particularly where holes are cored.*

c. *Machining both sides of the same section of a pressure-tight casting should be avoided.*

d. *Where machining can expose porosity, impregnation may be required to insure pressure tightness. (See figure 7-5 in Section 7.)*

3. Die Casting Alloy Selection

Certain alloys are best for producing pressure-tight castings. Refer to the Alloy Data sections for alloy comparisons of pressure-tightness characteristics to aid in the selection of the most favorable alloys.

4. Pressure Testing

Pressure-tightness testing for castings is generally specified in the range of 5 to 40 psi. Higher pressures will require special consideration by the caster and will be almost entirely a function of the part design.

In the case of pressure-tight casting requirements, review inspection procedures in of Commercial Practices, Section 8, and Porosity Control on pg. 2-11.

6

Engineering & Design: Additional Specification Guidelines

These recommendations regarding the design of fillets, ribs and corners represent guidelines which will result in die casting at the most economic level under normal production practice. Sharp inside surface junctions, acute angle corner conditions and delicate, deep and closely spaced ribs should be specified only where and when necessary, since additional costs may be involved.

2 Fillets in Die Cast Parts

Fillets

Intersecting surfaces forming junctions are best joined with fillets to avoid high stress concentrations in both the die castings and the die casting die. This will reduce die maintenance costs and increase the life of the die.

In the sketches below, consideration has been given to the normal stresses on the die cast part in use and to the stresses induced in the die castings by the casting process itself, as well as to other manufacturing and die maintenance considerations.

Fillet Draft

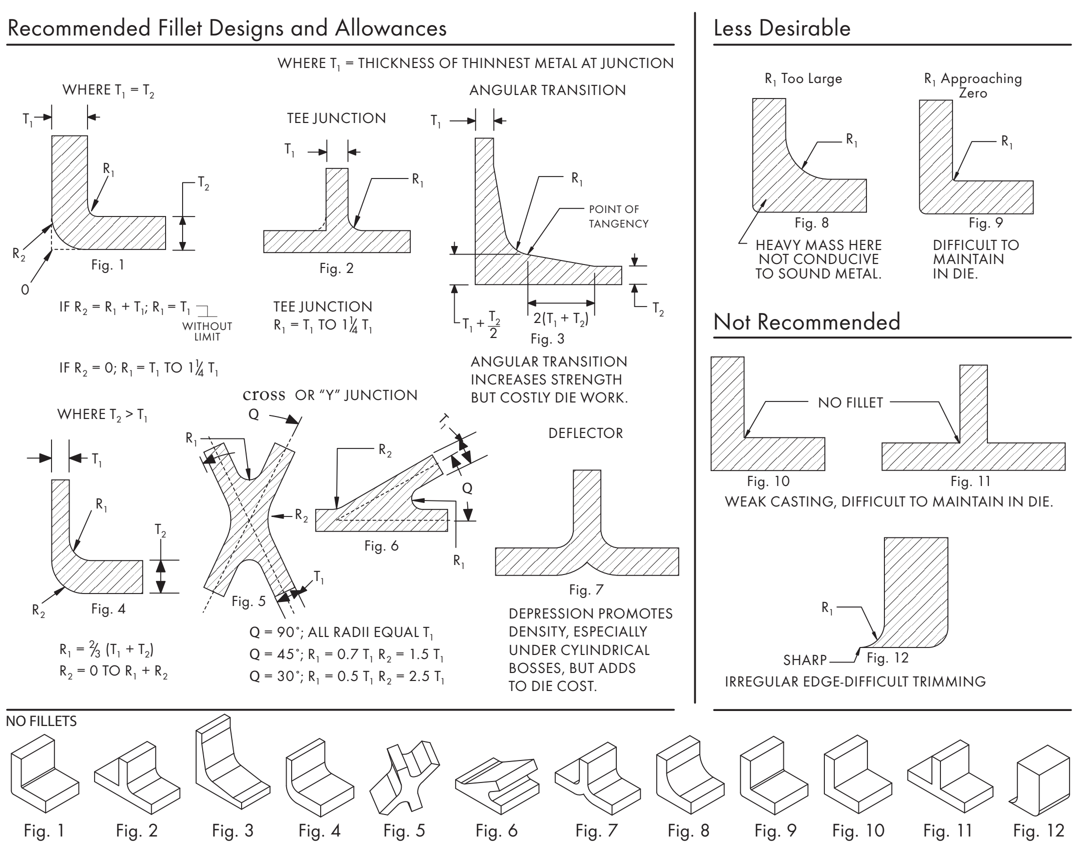
Fillets projected in a direction normal (perpendicular) to the parting line require draft. The amount of draft is always governed by the draft of the intersecting surface, if a constant fillet radius is maintained.

Shallow vs. Deep Die Casting Designs

These suggestions apply to fillets on corners which are projected normal to the parting plane in die castings of moderate depth. Shallow die castings may have much smaller fillets, while deep pockets and other inside corners should have larger fillets.

Avoid Long, Sharp Corners

Long, sharply squared corners projecting in a direction normal to the parting plane may cause spalled edges on the die casting and should be avoided.



Engineering & Design: Additional Specification Guidelines

3 Ribs and Corners in Die Cast Parts

These recommendations regarding the design of fillets, ribs and corners represent guidelines which will result in die casting at the most economic level under normal production practice. Sharp inside surface junctions, acute angle corner conditions and delicate, deep and closely spaced ribs should be specified only where and when necessary, since additional costs may be involved.

Ribs

Ribs are used to increase the stiffness of, or add strength to, a die casting and to aid in making sound die cast parts. Often, ribs add more strength to die castings than solid material due to porosity. Ribs are sometimes misused and can be a detriment if working stresses are concentrated by their use or if high stresses are created at the edges of the ribs by their design.

External Corners

Sharply squared external corners may be used in some locations if die construction permits. This type of corner is mandatory at parting line locations and die block intersections. Elsewhere, corners of die castings should have radii to prevent early die failure, to reduce the probability of nicking the edge of the die casting in handling and assembly, and to minimize material handling hazards for personnel.

Small Metal Savers

Ribs are often an integral part of making a die casting stronger, but a die cast part designer needs to be cognizant of the steel as well. The empty space left in between ribs that serves no functional purpose on the part is called a metal saver. Often, adding ribs close together can result in thin or weak metal savers required in the die cast die to form the rib features in the part. The designer should review the part for:

- Relatively deep metal saver pockets
- Relatively sharp edges to metal saver pockets
- Relatively small draft on the sides of the metal saver pockets

All of the above should be avoided when designing the die cast part. The die caster or tool maker can be consulted for design suggestions as well.

Recommended Rib Designs and Allowances

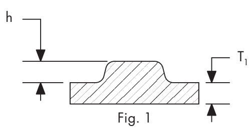


Fig. 1

$h = T_1$

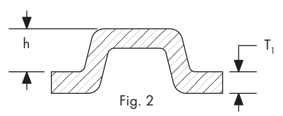


Fig. 2

WHERE $h > T_1$ CORE OUT UNDERNEATH
TO AVOID UNDESIRABLE HEAVY MASS OF METAL.

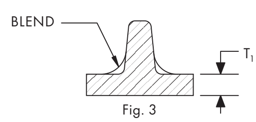


Fig. 3

BLENDING AS SHOWN
MAY BE DESIRABLE.

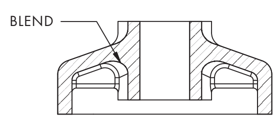


Fig. 4

RIBS INSIDE – GOOD DISTRIBUTION
OF METAL FOR ALL PURPOSES.

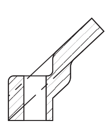


Fig. 5

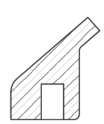


Fig. 6

GOOD DISTRIBUTION OF STRESSES

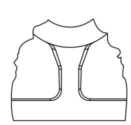


Fig. 7

RIB FROM FLANGE TO BOSS –
GENEROUS DRAFT AND FILLETS –
NOTE ANGULAR TRANSITION.

Not Recommended

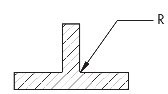


Fig.8

SHARP CORNERS –
SMALL RADII.

NO RIBBING – BOSS
EXTENSIONS LESS
DESIRABLE FOR
CASTABILITY

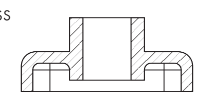


Fig.9

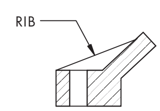


Fig.10

EXTERNAL RIBS MAY CAUSE
POOR DISTRIBUTION
OF STRESS

SHARP CORNERS –
SMALL RADII –
LITTLE DRAFT

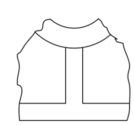


Fig.11

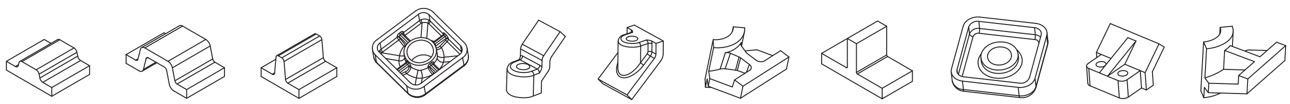


Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5 Fig. 6 Fig. 7 Fig. 8 Fig. 9 Fig. 10 Fig. 11

Engineering & Design: Additional Specification Guidelines

The guidelines presented here for the location of ejector pins, pin mark tolerances and procedures regarding pin flash represent standard die casting production practice at the most economic level. Disregarding these guidelines should be done only when and where essential to the product design, since additional cost may be involved.

4 Ejector Pins, Pin Marks and Pin Flash

Ejector Pin Marks

Moveable ejector pins must be used to eject a die casting from the die casting die and will result in a residual ejector pin mark on the die cast part.

In addition to automatically pushing the casting from the die after part solidification, ejector pins also serve to keep the casting from bending.

The sequential illustrations at right demonstrate the action of the ejector pins in a die casting cycle.

Ejector Pin Operation

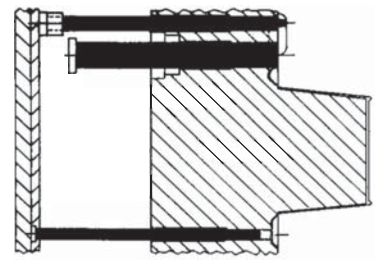


Figure A

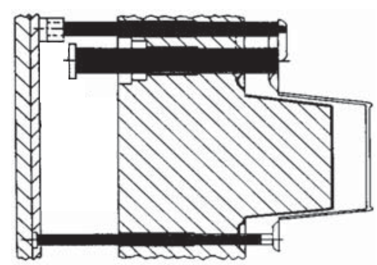


Figure B

Location Of Ejector Pins

Ejector pin locations should be at the option of the die caster, subject to the customer's agreement. Where considerations of cast surface cosmetics are important, ejector pin locations should always be discussed in advance of die design.

The number, size and location of ejector pins and bosses required will vary with the size and complexity of the die casting, as well as with other factors.

Acceptable Ejector Pin Marks

Ejector pin marks on most die castings may be raised or depressed .015" (.381 mm). Raised ejector pin marks are preferred for optimum production. Larger castings may require additional ejector pin tolerances for proper casting ejection.

Ejector Pin Operation

With each die casting cycle, the die opens and the ejector plate in the ejector half of the die (Fig. A) automatically moves all ejector pins forward (Fig. B), releasing the casting from the die. Then, the die casting is removed from the die manually or mechanically.

Ejector Pin Flash

Ejector pin marks are surrounded by a flash of metal. Normally, ejector pin flash will not be removed, unless it is objectionable to the end use of the part.

Alternatively, ejector pin flash may be specified as crushed or flattened.

In the case of either nonremoval or crushing/flattening, flash may flake off in use.

Complete removal of ejector pin marks and flash by machining or hand scraping operations should be specified only when requirements justify the added expense.

Bumping Ejector Pins

When ejector pins are placed on a flat surface, it can sometimes cause the side opposite the ejector pinto bulge out on the part (called bumping). Bumping can be minimized by:

- Increasing the wall thickness (increasing locally is an option as well).
- Placing ejector pins neat veticle walls (distributes some ejection force to ribs).
- Placing ejector pins on top of ribs.
- Increasing draft.

Engineering & Design: Additional Specification Guidelines

5 Metal Extension (Flash) Removal

The guidelines for removal of die casting metal extension (flash) presented here represent normal production practice at the most economic level. Precision flash trimming, closer than standard commercial trimming, or the complete removal of all extension involves additional operations and should be specified only when requirements justify the additional cost.

Metal Extension (Flash) Formation and Location

An extension of metal is formed on die castings at the parting line of the two die halves and where moving die components (also called moving die parts) operate (see Figure 6-1).

A seam of metal extension may also be formed where separate die parts cast a part feature. Residual metal extension is also formed by the normal operation of ejector pins and is discussed on the previous page.

Simplifying Extension (Flash) Removal

Necessary casting metal extension removal costs can be reduced by consideration, in the design stages, of the amount of metal extension to be removed and the removal method to be employed.

Early consultation with the die caster can often result in production economies in the treatment of metal extension removal.

Guidelines to Extent of Removal

The table below provides a 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.

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

Guide to Nominal Metal Remaining by Type of Extension

	Type of Metal Extension and Nominal Amount Remaining After Degating and Trimming				
Operation Description	Thick Gates & Overflows > 0.12" (3.0 mm)	Thin Gates & Overflows ≤ 0.12" (3.0 mm)	Parting Line and Seam Line Metal Extension	Metal Extension in Cored Holes	Sharp Corners
After Degating Nominal Flash Remaining	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* Nominal Extension Remaining	Within 0.06" (1.59 mm)	Within 0.03" (0.8 mm)	Within 0.015" (0.38 mm)	Removed within 0.010" (0.25 mm)**	Not Removed

** "Commercially trimmed" does not include additional operations to remove loose material. For very heavy gates and overflows, consult your die caster.*
*** Shave trimming may be available to reduce amount of metal remaining in cored holes. Consult your die caster to determine what options are available.*

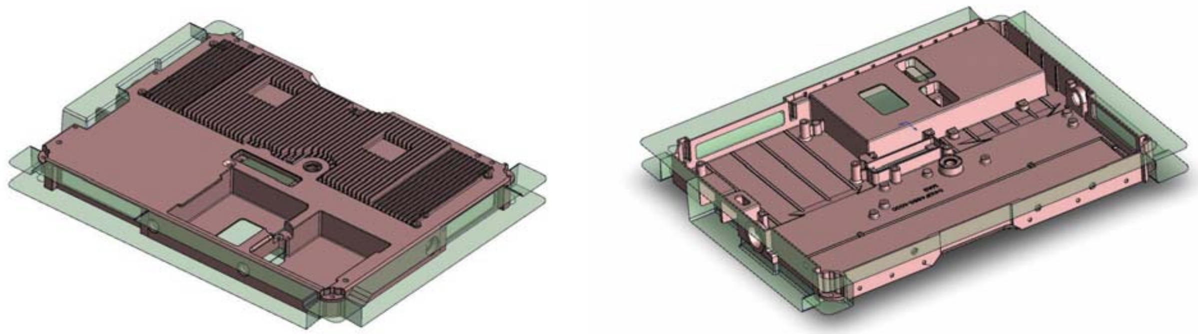


Figure 6-1: *Examples of complex parting lines that can make flash extension removal more difficult.*

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GUIDELINES

The as-cast external surface finish classifications shown here illustrate variations in production practice. Surface finish requirements should be specified for production at the most economic level. Generally, extra steps in die design, die construction and casting production are required for the more exacting finishes, and additional cost may be involved. Selection of the lowest classification number, commensurate with the die cast part application, will yield the lowest cost.

Engineering & Design: Additional Specification Guidelines

6 Surface Finish, As-Cast

General Guidelines for As Cast Surface Finish on Die Cast Parts

The specification of external surface finish requirements is desirable for selected die casting applications and, in the case of some decorative parts, essential.

The purpose of the guidelines presented here is to classify as-cast surface finish for die castings into a series of grades so that the type of as-cast finish required may be addressed and defined in advance of die design.

These guidelines should be used for general type classification only, with final surface finish quality requirements specifically agreed upon between the die caster and the customer.

The first four classes listed relate to cosmetic surfaces. Class five relates to selected surface areas where specified surface finish limitations are required.

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 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 a maximum value in micro inches as specified on print.	O-Ring Seats or Gasket Areas

NOTE:

As-cast surface finish classification does not apply to machined surfaces. Finished machined surface requirements shall be as agreed upon between the die caster and customer and separately identified on the engineering part drawing.

Typical As-Cast Surface Roughness Guide

Alloy Family / Alloy	Typical Surface Roughness (μ-inches) Expected in a New Die	 Over the Life of a Die
Aluminum, ZA-12, ZA-27	63 or better	100-125
Magnesium	63 or better	63 should be maintainable
Zinc, ZA-8	32 or better	63 should be maintainable

Notes:

1. *Part design, gate location, draft, flow lines, die surface treatments and other factors can impact surface roughness.*
2. *Roughness values for Over the Life of a Die do not include heat checking in the die.*
3. *Die lubricants utilized for special applications may impact surface roughness and the values in the table may not be achievable.*

Coatings for Castings

Operations	Group	Coating	Applicable Material	Advantages	Price
OPERATIONS	PRETREATMENTS	Alodine 5200	Al, Mg	1, 2, 3	Low
		Chromate (Class 1A & 3)	Al, Zn	1, 2, 3, 4	Low
		Iron Phosphate	Al, Mg, Zn	1, 3	Low
		NH 35	Mg	1, 2, 3	Low
	PRIMERS	Urethane	Al, Mg, Zn	1, 3, 5	Medium
		Epoxy	Al, Mg, Zn	1, 2, 3, 6	Medium
		Zinc Rich	Al, Mg, Zn	1, 2, 3, 6	High
		Zinc Chromate	Al, Mg, Zn	1, 2, 3, 5, 6	Medium
		Vinyl Acid Wash	Al	1, 2, 3, 5	Low
		E-Coat	Al, Mg, Zn	1, 2, 3, 6	Low
	LIQUID TOPCOATS	Urethane	Al, Mg, Zn	1, 3, 5, 6, 7	Medium
		Epoxy	Al, Mg, Zn	1, 2, 3, 6	Medium
		Acrylic	Al, Mg, Zn	1, 3, 5, 6, 7	Medium
		Waterbase	Al, Mg, Zn	1, 2, 3, 5, 6, 7	Medium
		Fluropons/ Architect	Al, Mg, Zn	1, 2, 3, 5, 6, 7	High
	POWDER COATS	Polyester	Al, Mg, Zn	3, 5	Low
		TGIC	Al, Mg, Zn	1, 2, 3, 5, 7	Medium
		Urethane	Al, Mg, Zn	3, 5, 7	Low
		Epoxy	Al, Mg, Zn	1, 2, 3	Medium
		Hybrid	Al, Mg, Zn	1, 2, 3	Medium
	ANODIC FILMS	Anodize	Al*, Mg	1, 2, 3, 5, 6, 7	Low
		Hardcoat - Hard Anodizing	Al, Mg	1, 2, 3, 6, 7	Medium
	ELECTROPLATING	Copper	Al, Mg, Zn	1, 2, 4, 6, 8	High
		Copper/Nickel	Al, Mg, Zn	1, 2, 4, 6, 8	High
		Cu/Ni/Chrome	Al, Mg, Zn	1, 2, 4, 6, 8	High
		Brass	Al, Zn	1, 2, 4, 6, 8	High
		Bronze	Al, Zn	1, 2, 4, 6, 8	High
		Zinc	Al, Zn	1, 2, 4, 6, 8	High
		Silver	Al, Zn	1, 2, 4, 6, 8	Very High
		Gold	Al, Zn	1, 2, 4, 6, 8	Very High
	ELECTROLESS PLATING	Electroless Nickel	Al, Mg, Zn	1, 2, 3, 4, 6, 8	High
		Electroless Copper	Al, Mg, Zn	1, 2, 3, 4, 6, 8	High

For more details contact a viable coating source.

Note: Not all die castings readily accept electro-coatings. Vacuum plating films such as PVD and CVD coatings, mechanical plating such as Zinc/Tin, and thermal spray coatings may also be applied. Consult with the the applicable coating suppliers.

Legend for Advantages:

1 *Corrosion protection*
2 *Chemical resistance*
3 *Adhesion enhancement*
4 *Conductivity*
5 *Flexibility*
6 *Hardness/ wear resistance/ durability/ mar resistance*
7 *UV resistance*
8 *Decorative finish*

* Anodizing of aluminum is contingent upon the specific alloy and may not yield an aesthetically pleasing surface.

Engineering & Design: Additional Specification Guidelines

The guidelines presented here for incorporating logotypes, lettering and ornamentation in a die cast part represent normal production practices at the most economic level. Fine detail in lettering and art styles can be achieved but may involve additional costs.

7 Die Cast Lettering and Ornamentation

Lettering, medallions, logotypes, trademarks and a range of identification symbols may be reproduced on the surfaces of die cast parts.

Such as-cast ornamentation may be raised or depressed, but note that raised lettering will result in lower die construction costs and reduced die maintenance over the life of the die.

Raised lettering on a depressed panel can be an economical substitute for depressed letters, as shown in the illustration below.

Cast-in Lettering/Ornamentation Guidelines

In addition to the avoidance of depressed lettering or symbols in the casting surface, the following guidelines will achieve the most satisfactory results. The terms used refer to the illustrations below.

1. *The Line Thickness (or "face") of any letter to be clearly cast should be 0.010 in. (0.254 mm) or greater.*
2. *The Height (or raised dimension) of a cast letter or symbol should be equal to or less than the line thickness.*
3. *The Draft Angle should be greater than 10°.*
4. *Letters or symbols containing fine serifs or delicate lines cannot be expected to die cast cleanly.*

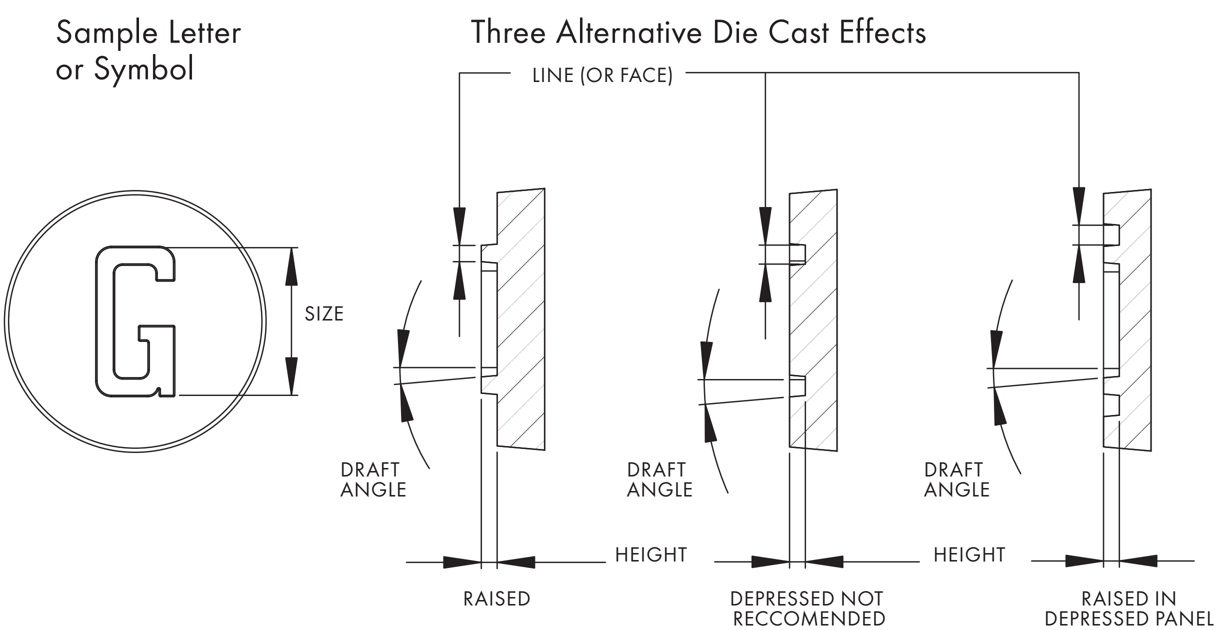


Fig. 1a Fig. 2a Fig. 2a

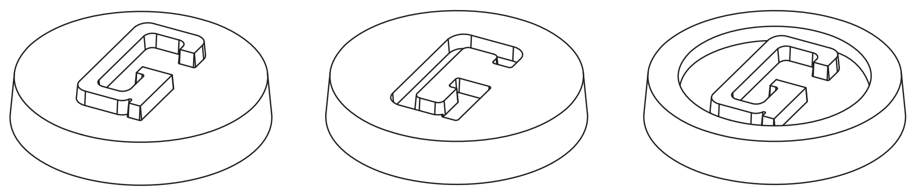


Fig. 1b Fig. 2b Fig. 2b

Quality Assurance

SECTION 7

Section Contents | Page

Quality Assurance

Frequently Asked Questions (FAQ)

1) Is there information available about porosity in a die casting?
   See pages 7-12 through 7-17 starting at Porosity.
2) What process variables affect the quality of die castings?
   See page 7-11, Process Variables.
3) Where can information on die casting defects be found?
   See page 7-7, Internal Defects.
4) When should CP or CPK be used?
   See page 7-12, Capability.
5) Is a simulation really necessary?
   See page 7-3, Simulation.
6) What are some typical images of porosity and/or breakout at parting lines?
   See pages 7-12 through 7-17, Porosity.
7) Can x-ray be used to view porosity?
   See page 7-16.

Introduction

Continuing advances in die cast processing and control technologies allow the specifier of die castings today to achieve very high levels of precision.

However, custom production requirements that are beyond readily manageable process capabilities can increase costs. It is therefore essential that the user of die castings discuss process capabilities with the die caster early to keep costs in line with expectations.

This section deals with the control of the variables in die casting production to achieve the specifications presented in the earlier Engineering and Design Sections. It is the aim of this section to clarify terminology and establish the criteria necessary to maintain acceptable product quality under normal die casting practice.

Communications by means of purchase orders, part drawings, CAD/CAM databases, corporate standards, manufacturing specifications, die casting industry standards and guidelines should all be used to clarify the job content. Working together to clearly define areas in doubt will obviously result in optimum service at lowest costs.

1 Balancing Process Capabilities With Product Requirements

The best opportunity to reduce costs and enhance quality lies in carefully specifying those characteristics that are clearly needed in the product, i.e., distinguishing between critical and less critical features. When the functional requirements have been clearly defined, the die caster can determine, in advance, the precise processing steps necessary to achieve them.

1.1 The Engineering/Quality Team

Developing the optimum set of product requirements consistent with process capabilities is best accomplished by forming a cross-functional engineering and quality team involving all parties who are concerned with the success of the product.

Often called a "concurrent engineering" or "simultaneous engineering" team, it should include representatives of design engineering, manufacturing engineering (from both the die caster and customer), quality assurance and marketing.[1]

If a formal cross-functional engineering team is not set up, an informal team of key personnel from both the customer and the die caster should be formed to meet several times during the product development process to address important questions.

1.2 Standard vs. Precision Tolerances

The die casting process can offer very high casting precision, as discussed under "Standard" and "Precision" Tolerances in "Engineering and Design," Section 4A. Precision Tolerance levels should be specified only when product requirements justify the additional production steps that may be required. Otherwise industry Standard Tolerances should be used.

It is always advantageous, in terms of faster delivery and lower production costs, to avoid unnecessarily stringent tolerances and specifications.

1.3 Simulation

The term "Lean" is used to describe a manufacturing process. Lean is continually striving for perfection, continually declining costs, zero defects, zero inventories, and an increase in business. There are five major principles used in "Lean Thinking!"

- **Value**: Only the ultimate customer can determine value!
- **Value Stream**: All the actions and services required to bring a specific casting to market.
- **Flow**: Flow is a continuum from the order desk to the shipping dock. No stopping or storing!
- **Pull**: The customer can pull the product from the caster because of the quick turnaround time. Pulling is like turning on a switch for the desired product.
- **Perfection**: There is no end to the process of reducing effort, time, space, cost, and mistakes.

Lean employs five principles, but we will use two of those principles to highlight our improvement for Product Integrity. Value Stream is one of those concepts: "All the actions and services required to bring a specific casting or family of castings to market in a logical, timely sequence that promotes perfection. Perfection is an overriding principle for our premise of improvement: "Make sure we know exactly what the customer wants."

Recent software tools such as CAD/CAM, shot monitors, and simulation programs all assist the industry in achieving perfection. Often times these tools are not used at all or are used out of the proper sequence for achieving perfection. As technology in software improves, the industry must use the advantages offered for a profitable timesaving. When NADCA metal flow principles are properly employed it increases the probability for sample castings to be approved. When a shot monitor is employed the engineering department can easily determine machine capabilities and create a realistic PQ^2 analysis. When vacuum metal flow simulation software is used the runners, gating, vents, overflows and vacuum vents can all be properly placed for minimal defect metal flow. It may take several simulation iterations to ensure the runners and gate placement creates the desired metal flow pattern.

There are many automated features on the die cast machine, trim dies, and subsequent machining operations. If the mold is not producing an acceptable casting the speed created is not in the Perfection Mode of Lean Thinking.

For example, the following steps are used for a typical metal flow simulation:

- Engineering will create a 3-D model of the casting with runners and gates connected and export the file in an STL format for the simulation. A PQ^2 analysis will yield the desired fill time and optimum gate area. The gate depth and location can be determined for the simulation.
- A fast simulation, in the initial design stage can be made to ensure the position of inlets will yield the desired perfection. This is a critical stage to ensure the holder and mold will be oriented for machining. The neglect of this sequence in the value stream may result in welding and refashioning runners & gates, resulting in a time and material loss. If the gates have to be moved the result may result in a shortage of tool steel for the new gates. Emphasis must be placed on the proper sequence to avoid mistakes, rework and ultimate delays in the delivery of the mold. Perfection is a must at this step in the value stream.

Critical questions to ask at this critical stage are:

- Does the inlet gate satisfy the feeding of each cavity?
- Is the last place to fill well defined? (Figure 7-1)
- Are the overflows and/or vacuum lines in the last place to fill?
- Are there areas that may be porous or not filling properly? (Figure 7-2)
- Does it seem the gates are placed correctly? (Figure 7-3)
- Has a PQ^2 analysis determined gate size and filling speed? (Figure 7-4)
- Has the casting been checked for square corners or areas of difficult fill? (Figures 7-5a & 7-5b)
- Will major changes have to be made to ensure perfection?
- If the simulation determines a change, the recommendations are put into a new model and STL for another iteration. If it seems the gate is adequate or a slight change is needed the mold can be aggressively machined. A fine, more accurate simulation can verify all the data.

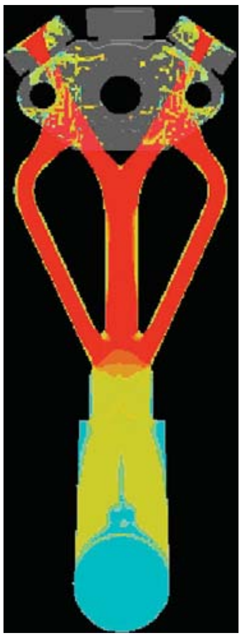


Figure 7-1: This is an example of the overflows filling first instead of being the last place to fill. An initial fast simulation will detect such undesirable characteristics.

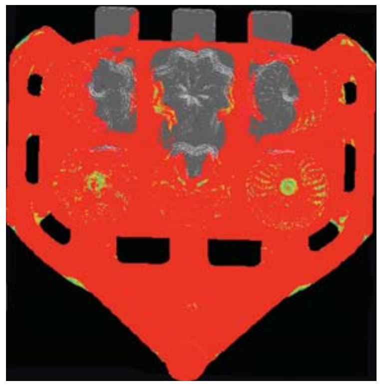


Figure 7-2: This simulation shows the end and top overflows are of no value. The cavity areas encircled are filled with porosity. The scrap rate was 75%. A new gate/runner with confirming simulations yielded a 1.5% scrap rate. The simulation will save hours of rework and lost time.

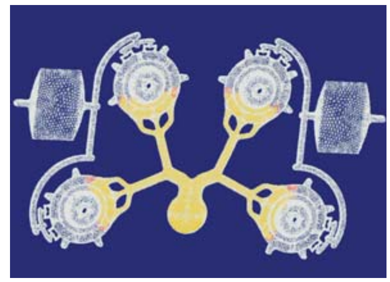


Figure 7-3: The metal flow in the outer runners is well past the two inner runner/gates. Gate placement must ensure the maximum use of available gate area. The angle of metal entry must be within metal flow capabilities per NADCA standards. Seeing the flow enhances the needed changes for proper fill.

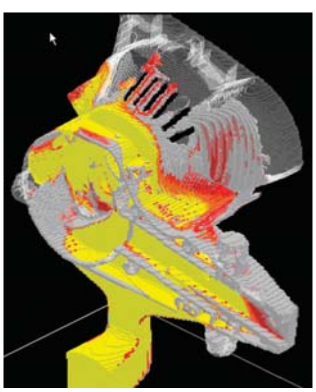


Figure 7-4: This simulation is depicting a velocity that is too slow, the metal flow is freezing before the final fill. A PQ^2 analysis will render a proper gate and metal flow velocity to ensure a complete fill. Simulations show very accurately the filling characteristics.

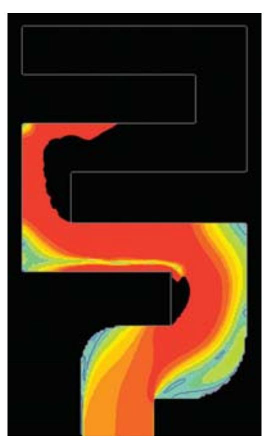


Figure 7-5a: Square corners in a runner or casting result in porosity. pockets.

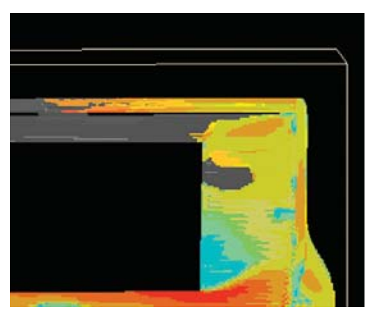


Figure 7-5b: A zinc cosmetic casting that has square corner metal flow that results in unacceptable porosity. A visual defect!

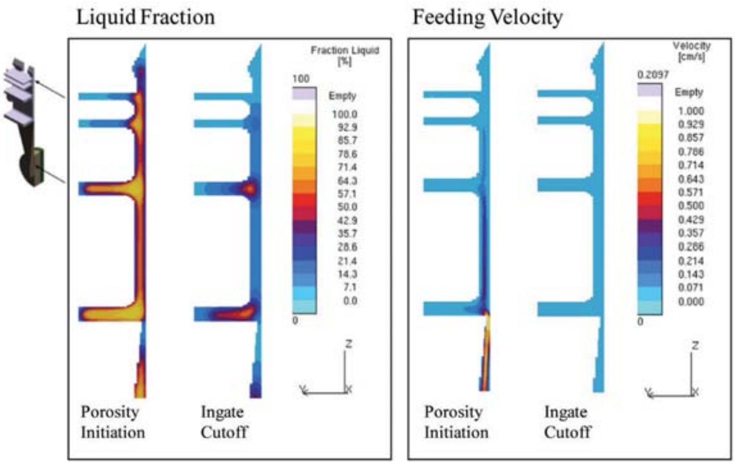


Figure 7-6: Simulations of liquid fraction (left) and feeding velocity (right) at porosity initiation and ingate cutoff for a ribbed casting configuration.

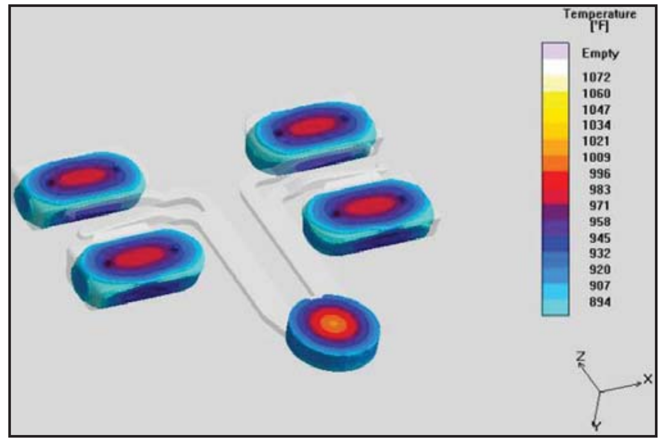


Figure 7-7: Thermal simulation showing the temperature gradient at a given point in time of castings in a 4-cavity die.

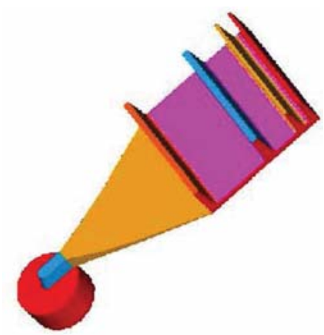


Figure 7-8: The selected part for simulation.

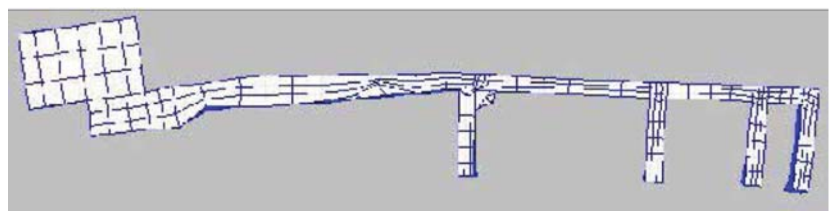


Figure 7-9: An example of distortion modeling, 20x magnification factor.

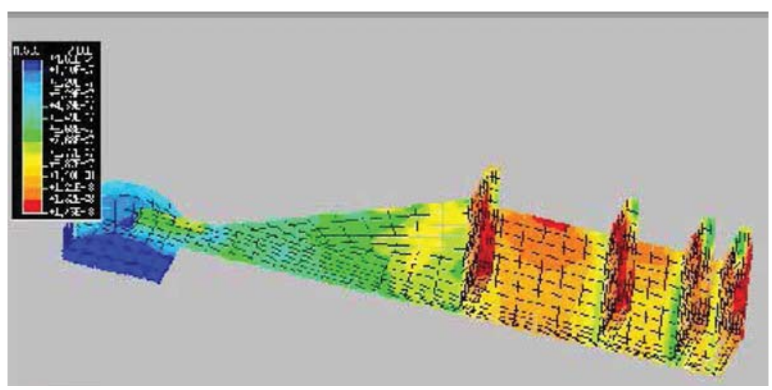


Figure 7-10: An example of residual stress prediction at time of ejection using elastic-plastic analysis.

Simulations can be used to optimize heat flow, determine the location of cooling lines and cooling requirements. Simulations can also be used to predict die distortion, casting ejection temperatures and dimensional capability, last place to fill, and areas of poor fill or non-fill, and pockets of porosity. They also indicate where the overflows should be placed as indicated by the last area of the casting to fill.

A time and cost saving for the entire supply chain is to have accurate information for the mold-maker to complete the mold building. Time and price increase when the project is delayed because of minute changes or uncertainty of design. The customer, caster, and mold maker must all be informed of the part design and specific areas of special concern. All questions must be answered so every party can be aggressive in executing their expertise. Then the project can mature in an orderly and speedy fashion.

FAQ Concerning Simulation:

What is the value or benefit of a simulation?

The simulation will give an accurate, graphic depiction of the filling process and will verify the suggested gating profile. Many times a runner and gate are cut only to find the results are not in the perfection mode of desirability. The simulation must be done prior to cutting steel.

Are the simulation results easy to understand or read?

It requires a skilled engineer or experienced person to explain the results. Any computer literate individual can create the simulation, but experience is required to understand the results.

Is the simulation cost effective?

If a caster or mold maker owns the software it can and should be used on virtually every project. There are also consultants who will be cost effective in conducting a simulation. The process saves countless hours of die changes, welding and machining of gates to enhance flow. The relative small cost of the simulation saves time, money and increases the availability for increased business. The true reward for a proper value stream sequence is realized when the project goes into production as a result of careful planning and timely execution. All the members of the value stream make a profit and have capacity for increased business.

Finite Element and Finite Difference Methods

Both finite element and finite difference methods are used to numerically solve the partial differential equations that describe physical phenomena including heat transfer, fluid flow, stress, displacement, distortion and others. Both techniques require discretizing the object or spatial domain of analysis into a grid of nodes and applying numerical techniques to solve the problem of interest at these nodes. The main differences in the methods arise from differences in the solution techniques used.

Finite difference uses a grid of points, almost always uniform, and the derivatives present in the differential equations are approximated by differences constructed using neighboring points, hence the name. The problem is thereby reduced to a set of simultaneous equations that are solved iteratively. Because the grid is uniform, finite difference grids may not perfectly follow the surface of the object and may have a stair step like appearance. Newer grid generation procedures minimize these effects but not all finite difference-based programs support them.

Finite element also discretizes the space into a grid, but it is not necessarily uniform. Instead the spatial domain of the analysis is decomposed into discrete elements. The elements generally are polyhedra either with 6 rectangular sides and 8 corner nodes (brick elements) or four triangular sides and 4 corner nodes (tetrahedral elements). Accurate tetrahedral meshes are easily created by automatic meshing programs. Because of the meshing procedure FE meshes provide excellent surface fidelity.

Finite element methods solve the differential equations by using an approximate solution defined within the element in terms of the solution value at the nodes. Neighboring elements share nodes and the solution much match at these nodes leading to a set of simultaneous equations that must be solved consistent with specified boundary condition. Each element has so called fitting functions that are used to interpolate the solution within the elements and, because the element contains the approximate solution, different element types are required for each type of problem to be solved. That is, even with the same geometry and mesh, different elements are used for heat transfer and stress analysis for example. Finite elements will always have nodes at the corners and may have nodes at the center of each edge and at the center of the element depending on the element type and the solution approximation technique that is used. Even with the extra nodes, finite element meshes generally contain a smaller number of nodes than a finite difference grid for the same problem.

In principle either technique can be used to solve the differential equations of any of the common engineering problems although finite difference tends to the method of choice for fluid dynamics problems (such as metal flow analysis) and finite element for stress and deflection. Both methods handle heat flow equally well. For either type of system, there can be wide differences in the implementation of a particular type of solution across vendors. Also, for both special and general purpose packages, not all will have the ability to address nonlinearities such as contact and movement between components of the system (e.g., contact between the die and the machine platen or contact between the casting and cavity wall). The quality of the solution depends more on the quality of the implementation than on the method.

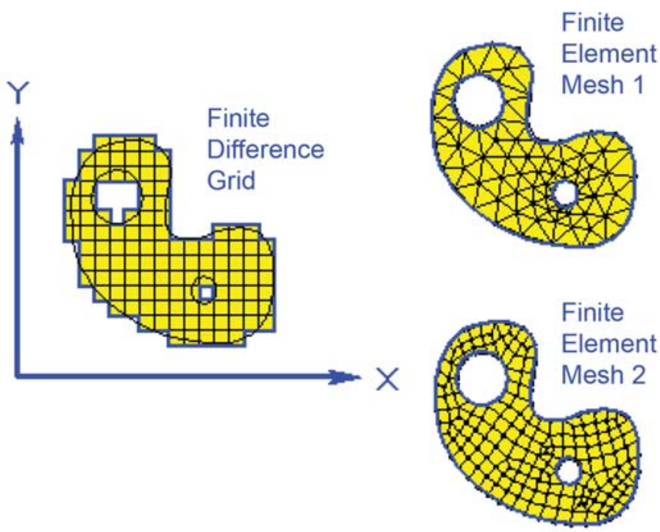


Figure 7-11 A: 2D illustration of the difference between finite difference and finite element meshes.

2 Defining Product Quality

The definition of product quality is fitness for end use. The definition will vary from design to design and usually varies for different areas of the same part.

The designer should expect to commit sufficient time and resources with the custom die caster, in the preliminary design stages before final drawings are completed, to determine what constitutes casting defects, and to precisely define acceptable product quality. This critical step will reduce rejections and rework, promote smooth operations between the die caster and the customer's design and procurement staff and increase successful results.

The checklists C-8-1 and C-8-2, which appear at the end of Commercial Practices, Section 8, should be used in specifying quality requirements.

It is rarely, if ever, practical to eliminate all casting discontinuities. Any attempt at total elimination will usually increase the cost of the casting unnecessarily.

There are two general types of discontinuities: internal and external. Internal defects can affect the structure of the casting, and may or may not be visible on the surface.

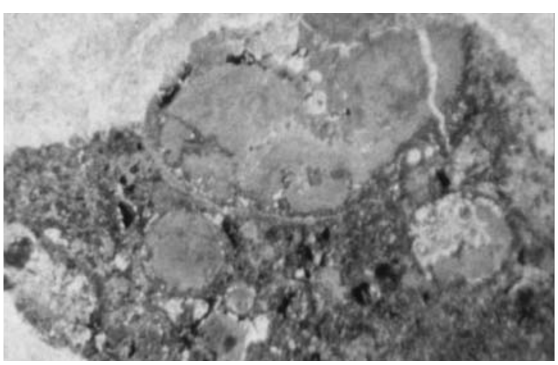
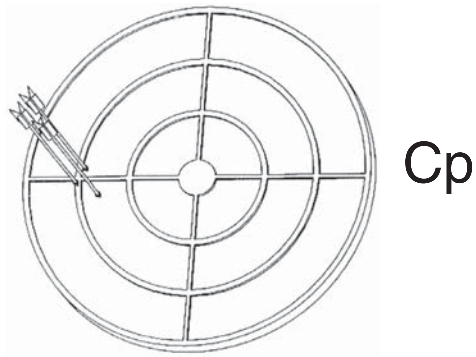


Figure 7-12: Magnified view of a non-metallic inclusion as an example of an internal defect other than porosity.

2.1 Internal Defects

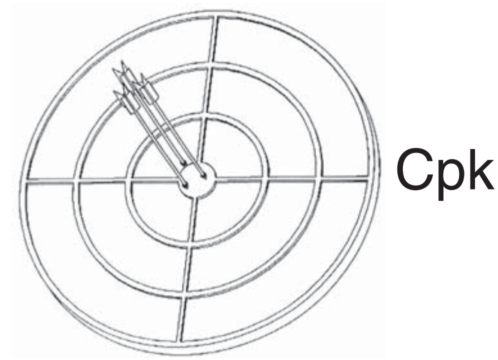
Porosity is the most common type of internal defect (see page 7-14 Internal Porosity). In many cases internal porosity will have little or no effect on the overall strength and integrity of a casting.

Where pressure tightness for a gas or liquid application is not a requirement, a mechanical strength test (by a standard weight drop or torque wrench application) per an agreed upon sampling plan can be a cost-effective approach to quality assurance for casting strength.



Target equals tolerance zone.

Figure 7-13: Cp is the raw capability index or in simpler terms = repeatability.



Target equals tolerance zone.

Figure 7-14: Cpk is the Total Process Capability or = accuracy and repeatability.

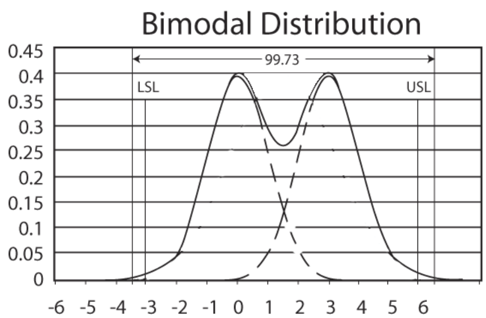


Figure 7-15: Cp can be applied to a bimodal distribution that allows for migration from one side of the tolerance range to the other. The higher the Cp number the more repeatable the process is.

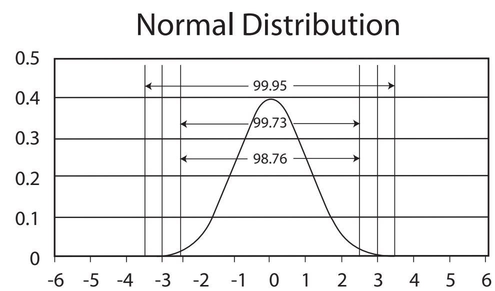


Figure 7-16: CPK indicates a normal distribution that allows within the distribution the maximum allowance of plus/minus tolerance that yields the greatest number of good parts in production. The higher the CPK number the more repeatable and accurate the process is.

2.2 External Defects

External, or surface defects, do not generally affect the structure of the casting. Surface defects are especially sensitive to the particular design of gates and runners in the die casting die. Calculated design parameters using proven metal flow design and process simulation techniques have been shown to be very effective.

The type and severity of external defect that can be accepted depends greatly on the type of final surface treatment to be applied. For example, a powder coating application deposits a relatively thick coat compared with painting systems, and will tolerate greater levels of surface roughness. Bright plating, such as chrome or brass, requires a very smooth surface finish.

Surface finish standards for die castings are normally developed on a part-by-part basis between the producer and the user.

It is important that the final finish acceptance standards developed be understood and agreed upon by all parties, with reference to a specific viewing standard such as "no objectionable imperfections, as specified, when viewed under normal lighting conditions at XX feet viewing distance." This can be addressed on checklist C-8-2, in Section 8, checklist item Q.

Reference sample standards should be retained by all parties after agreement on the acceptable standard.

Some common types of surface defects that may occur in production over time are cold shuts (knit lines), swirls (surface roughness), build-up (die lube or soldering accumulation) and heat checking (very small raised fins on parts). See Guideline G-6-6 Surface Finish, As-Cast on page 6-8 for more details.

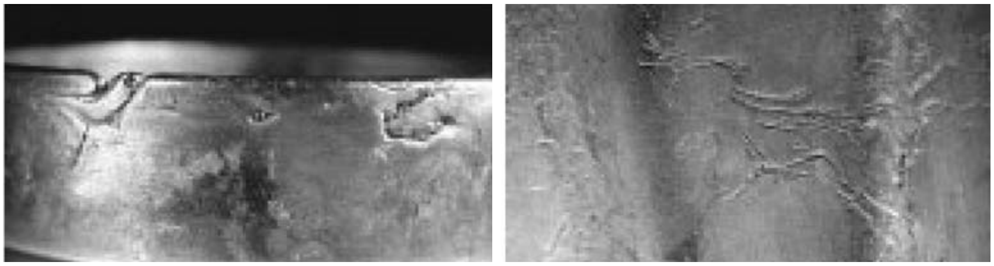


Figure 7-17: Examples of external defects.

Heat checking occurs during the life of a die when small cracks appear in the die due to thermal cycling. They sometimes cause concern on structural features because they appear, to the untrained eye, as cracks on a part. However, they do not affect the structural integrity of the casting, and are not generally objectionable on structural features that do not have cosmetic requirements.

Raised fins are routinely removed by surface blasting with shot or grit, or by vibratory finishing (which is normally the procedure used to prepare the surface for painting). How external defects are to be removed or eliminated depends on the type of surface finish required, whether painted, plated, or functional. The method to be used should always be discussed with the die caster. For more information on die casting defects see NADCA publication #E-515 Die Casting Defects – Causes and Solutions.

3 Drawings and Specifications

To insure uninterrupted production to specifications at the most economical level, it is important to supply all drawings and specifications to the die caster with the "Request for Quotation" (RFQ).

For correlation purposes, it is necessary that the drawings and specifications contain the following information:

01. *Dimensions or areas that are of critical, major or minor importance, and the Acceptance Quality Level (AQL) or Parts-Per-Million (PPM) level to which they will be checked, including the dimensions for which the customer will be requesting control charts.*
02. *Datum locations to be used for machining or gaging and the areas to be used for special checking*
03. *The gaging procedures the customer intends to follow and the special gages that will be furnished.*
04. *Special requirements and the areas to which they pertain.*
05. *Coded surfaces on parts to be plated, painted, etc., designating classification of surfaces.*
06. *Indication as to where die trimmed edges are not acceptable and specification of degree of metal extension removal required (See "Metal Extension," G-6-5, in Section 6).*
07. *Indication of any engineering change level requirements by purchase orders and accompanying drawings.*
08. *Specification of those surfaces which may not be used for location of the ejector pins.*
09. *A list of generic print tolerances which will adequately describe all the non-critical areas on the print.*
10. *Clear description of all standards for approval or rejection.*

Providing detailed and complete specifications at the time of the RFQ will benefit both the customer and the supplier. It will enable the die caster to submit more accurate, competitive quotes and help assure that the customer will receive quality die castings at the most economical level.

7

4 Gage, Measurement and Testing Equipment

Proper gaging equipment must be provided for effective measurement of product conformance. The customer is expected to furnish special-purpose gages which are required for inspection of specific die castings.

Special gaging requirements should be stated and the responsibility for maintenance of special gages should be established on the RFQ and on subsequent contracts between the die caster and customer. Gaging labor, when applicable, is included in the price quoted for the die casting.

When special gaging fixtures are necessary, they should be made in duplicate by the customer and one set furnished to the die caster. The customer should also furnish complete inspection methods and gage design information to the die caster at the time of the request for quotation. A gage and measurement instrument calibration system, with records maintained by the die caster, will assure consistent measurement control.

It is also suggested that gage Reproducibility and Repeatability (R & R) studies be done on all customer-supplied special gages. Further, it is recommended that all gaging sets be qualified by both the customer and die caster.

The responsibility for any preventative maintenance to be performed on customer-owned gaging should be made clear.

5 First Article Inspection Requirements (FAIR)

Whether the die caster or the customer is to perform the inspection of initial samples produced from a die casting die should be decided at the time the purchase order is issued.

When the inspection of initial samples is completed by the die caster, a report of the findings will be submitted to the customer. This is frequently referred to as a First Article Inspection Report (FAIR). Unless otherwise specified, first piece samples are supplied for dimensional check only. (Inspection of initial samples by the die caster may result in added cost.)

At the customer's request, the die caster will be responsible, after the inspection of initial samples, for correction of tooling for out-of-specification part dimensions before the start of production.

The customer should change the print for those dimensions for which tooling correction is not required in order to agree with the initial samples report. The general print tolerance will apply to the changed dimensions as noted, unless there is agreement to a new tolerance. Any automotive or other industry requirements such as preproduction approval pieces (PPAP) should also be known at the time of quoting. See figure 7-22 on an example PPAP flow chart.

In the event a print change will not be made, the customer should furnish an inspection report specifying those dimensions or tooling corrections which are not required. Any dimension not requested to be corrected or changed on the print is considered a valid dimension with normal tolerances, after the start of production, for the life of the tool.

The customer must acknowledge part acceptance by a formal letter before production is run. Such acknowledgment indicates either conformance to print or acceptance of a permanent deviation from specifications. The general print tolerances will apply to any deviations. Any die castings received by the customer which conform to the approved sample dimensions will be considered acceptable product.

If capability studies are to be done at the time of first-piece inspection, or in place of first piece inspection, this requirement should be specified at the time of the RFQ. Any automotive or other industry requirement such as Pre-Production Approval Process (PPAP) should be known at the time of quoting.

6 Statistical Quality Control

To assure uniform quality control standards acceptable sampling procedures and tables for inspection by attributes, such as ANSI/ASQC Z1.4, should be used.

Characteristics to be inspected for product conformity should be agreed upon by the customer and supplier prior to the first production run.

The classification of particular characteristics and AQL or PPM levels should be determined at the time the contract is negotiated. Classification of defects (critical, major, minor) should be in accordance with the latest revision of the acceptable sampling procedures to be utilized.

Normal inspection, as per ANSI/ASQC Z1.4 for instance, should be used.

Sampling plans to be used by the die caster will be left to the discretion of the individual die caster, recognizing, however, the responsibility to meet the agreed upon AQL or PPM levels.

6.1 SPC Procedures

Where the current revision of ANSI/ASQC Z1.4 is not desired or appropriate, a negotiated standard of sampling and acceptance should be established prior to die design, with early determination of SPC recording. Any requirement for process potential data or process capability studies should also be outlined at that time.

Dimensions and/or parameters requiring SPC data and Cp and Cpk values should be agreed upon by the customer and die caster prior to the first production run. This should include types of SPC charts, subgroup size, and sampling frequencies.

Determination must be made prior to production as to all specific SPC reporting requirements, data maintenance and its transmission. The die caster should be expected to point out to the customer the impact on Cpk values when cast die features are built on the "steel safe" or "wear safe" side of nominal, to allow the tooling maximum tool life and wear towards nominal dimensions.

6.2 Process Variables

There are five process variables that affect the quality of the die casting:

1. *Metal analysis*
2. *Metal temperature*
3. *Die temperature*
4. *Die lubricant characteristics*
5. *Die filling conditions*

In general, die casting is a setup-dominant process that exhibits variation of a serial, rather than random, nature. Of the five variables only No. 5, "die filling conditions," exhibits the "continuous drift" variation that the traditional X bar-R control charts were conceived to monitor.

Variables 2 and 3, metal and die temperature fluctuations, exhibit more of "cyclic drift" and are thus not well suited for periodic inspection associated with traditional SPC. A continuous monitoring system is better suited to measure the variability of temperature-related process variables. Monitoring within part variation will document significant temperature differences that can occur.

Variable 5, die filling conditions, consists of the elements of the shot profile that shot monitoring equipment can monitor and measure. Capability studies can be used to establish the range in the shot profile that the process will produce in casting production. More often than not, changes in the shot profile due to random, constant-cause conditions are minimal compared with the non-random conditions that are traceable to machine maintenance requirements.

Any special production requirements should be reviewed early with the die caster. Not all die casters may be able to apply SPC to machine parameters and may have to monitor the process, or the results of the process, through a less sophisticated method.

6.3 Capability

Capability studies have become increasingly more popular in the last several years. In the past, SPC and capability studies were tools used mainly by machine houses, but more and more die casters are being required to do them to qualify the die cast tooling. Capability studies can be very important in determining process ranges as well as helping to determine PPM levels. However, misuse of Cp vs. Cpk can take away much needed process variation and tool life in the die casting operation.

Due to the pressures used in the die cast process, several variables can come into play. These include parting line separation, mismatch at the parting line, core slide blow back and core slide shift or a combination of the above. Normally, dimensions that are affected by these conditions are built into the die cast die on the low side of the tolerance range. These dimensions should be considered as a plus side tolerance dimensions only.

In addition, the die cast process can be very abrasive on the die surface causing rapid tooling wear. Part features that are affected by this wear are normally built on the high side of the tolerance range. These dimensions should be considered as a minus side tolerance dimension only.

$$Cp = \frac{(USL-LSL)}{(6 \times \sigma)}$$

$$Cpk = \frac{(X-LSL)}{(3 \times \sigma)} \qquad Cpk = \frac{(USL-X)}{(3 \times \sigma)}$$

On as-cast features Cp should be used as the primary measurement if the dimension targeted is in tolerance and on the right side of the tolerance range. For example a cast hole dimensioned at 2.000 +/- 0.010 (50.8mm +/- 0.25mm) checks 2.008 with a Cp index of 6.0 and a Cpk of +0.85, should be considered a good dimension to yield maximum tool life and process repeatability.

On cored hole locations and machined features Cpk should be used as the primary measurement. For example a machined hole dimensioned at 2.000 +/- 0.010 (50.8mm +/- 0.25mm) checks 2.008 with a Cp index of 6.0 and a Cpk of +0.85, should be considered as bad and the size adjusted to get closer to 2.000.

6.4 PPM Levels

PPM goals and requirements are becoming increasingly popular in the procurement of die castings and die cast assemblies. Since the part complexity, customer requirements and level of processing contribute to the reject level, a threshold PPM level is not specified by NADCA.

Process capability studies may be used to assist in predicting PPM levels for specific castings, secondary processes, and/or assemblies. Ultimately, the PPM goal or requirement should be as agreed upon between the die caster and customer.

7 Porosity

It is usually necessary to address porosity when specifying die castings. While porosity specifications are very difficult to define generically, there are existing guidelines that provide a good starting point.

Solidification begins at the surface of die castings and progresses to the center generating two distinct zones in each wall section, as shown in Figure 7-18. The skin, which has finer grain structure, begins at each surface and extends inward to a typical thickness of .015 to .020 in. (.38 to .50 mm). This area is usually free of porosity compared to the center of the section. The porosity is located between the skins in the core. The finer grain structure and absence of porosity give the skin superior mechanical properties. Skin thickness of a die casting is relatively constant and is not a function of total wall thickness; therefore, thin-wall sections can actually be stronger and more consistent than thick sections. The removal of the skin to a depth greater than .020 in. (.50mm) by secondary processes, such as machining, increases the chance of exposing porosity in the core as can be seen in Figure 7-19. These important points are not widely recognized by designers.

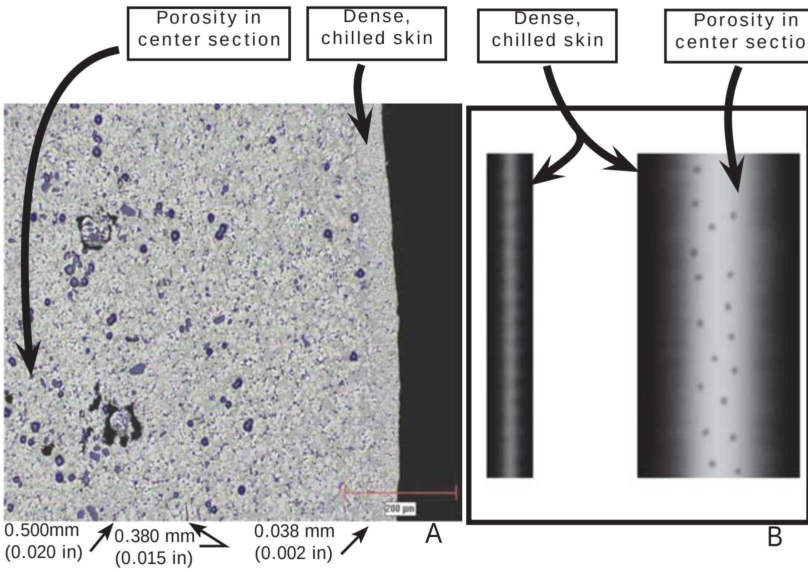


Figure 7-18: Skin Effect Due to rapid solidification in the die, a die castings outer skin has a dense, fine grained structure with a higher strength than underlying metal. According to Borland and Tsumagari (2007), the skin extends inward to a typical depth of 0.38 to 0.50mm (0.015 to 0.020"). The rapid solidification of the skin tends to drive porosity to the center of the section as portrayed here.

Exterior or surface porosity can be identified with the naked eye, magnification or with penetrant inspection methods.

The as-cast surface is more dense than the core, and hence, stock removal by machining should be minimized. The die caster should be aware of critical areas as porosity can be managed to large extent via gating, overflows, chills and various process parameters.

Castings can be inspected utilizing non-destructive inspection techniques NDT. When specified, reasonable detection levels should be employed. Non-destructive testing methods for internal porosity detection include ultrasound (UT), radiography/X-ray (film, real-time, ADR automatic defect recognition), eddy current (EC) and various weight techniques. Methods for external porosity detection include visible and fluorescent die penetrant (DPI).

If porosity is a major concern due to leakage/pressure tightness issues, the employment of a pressure test should be considered.

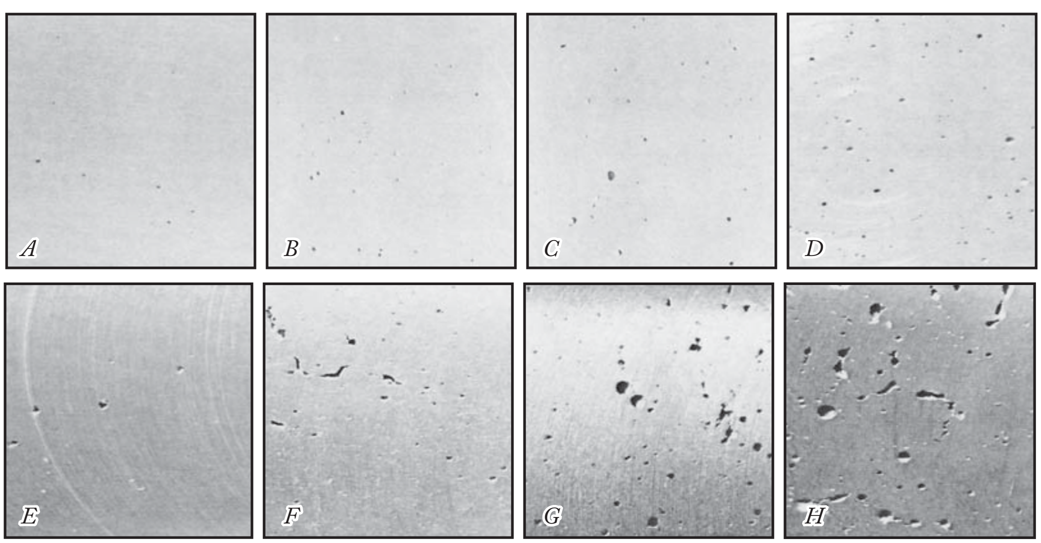


Figure 7-19: Various degrees of porosity exposed after machining.

7.1 Internal Porosity

Interior porosity can be detected by a range of techniques, including detection by fluoroscope, X-ray and ultrasonic procedures. Internal porosity can also be detected in the die casting plant through sectioning or simulated machining techniques, when the die caster is advised of the areas to be machined.

Part prints should call out the areas where only the lowest levels of pinpoint porosity can be tolerated, areas where additional porosity can be tolerated and areas where larger porosity will have no effect on the casting application.

Whether porosity levels are defined by "X-ray" or "sectioning" procedures, each party should retain a sample radiograph or part section that defines the minimum acceptance standard (see fig. 7-19).

It is important that the user not specify porosity limits that are more stringent than required for the application. It is also usually necessary to establish specific porosity standards independently for each component design. The specification of special porosity detection operations will increase the cost of the castings.

The type of porosity may be important in defining porosity standards. A small dispersion of smooth, round holes (salt and pepper generally less than 1mm in diameter), which are caused by release of disolved hydrogen or entrapped gas bubbles, may have a minimal effect on part strength and will not tend to cause leaks. Individual, non-grouped pores are generally less than 2mm in diameter. These types of gas porosity are those most commonly found in die casting. See figure 7-19A through 7-19E.

In critical areas of a casting. where porosity is a concern, the acceptable porosity is often specified in the following format:

1. *The maximum allowable size of individual porosity pores.*
2. *The minimum allowable spacing between pores.*
3. *The maximum allowable density of pores in a defined area (pores/distance2)*

For example a note based on this format may look like:
Porosity specification in crosshatched marked areas on print: 1mm maximum porosity pore size, 2mm minimum spacing between pores, maximum of 10 pores per 12mm^2.

More jagged-shaped shrinkage porosity, caused by solidification, can cause more problems. This is typically a part design-related issue, and is caused by heavy sections in the casting. Shrink porosity can be interconnected and may result in leakers. The shrink porosity does not have to be visible to cause leakers and is often microscopic in nature. Shrinkage porosity, when exposed, can be larger than gas porosity. For instance, a typical specification for a large drilled and tapped boss is < 2 mm on the first three threads, < 5 mm on other threads. See figures 7-19F through 7-19H and 7-19C, as well, as subsection 7.

Minimizing porosity begins with up-front planning in the design of the part and die casting die and the management of heat in both the die and the castings. Sophisticated process control and monitoring equipment as well as simulation software is best utilized for castings with stringent porosity requirements.

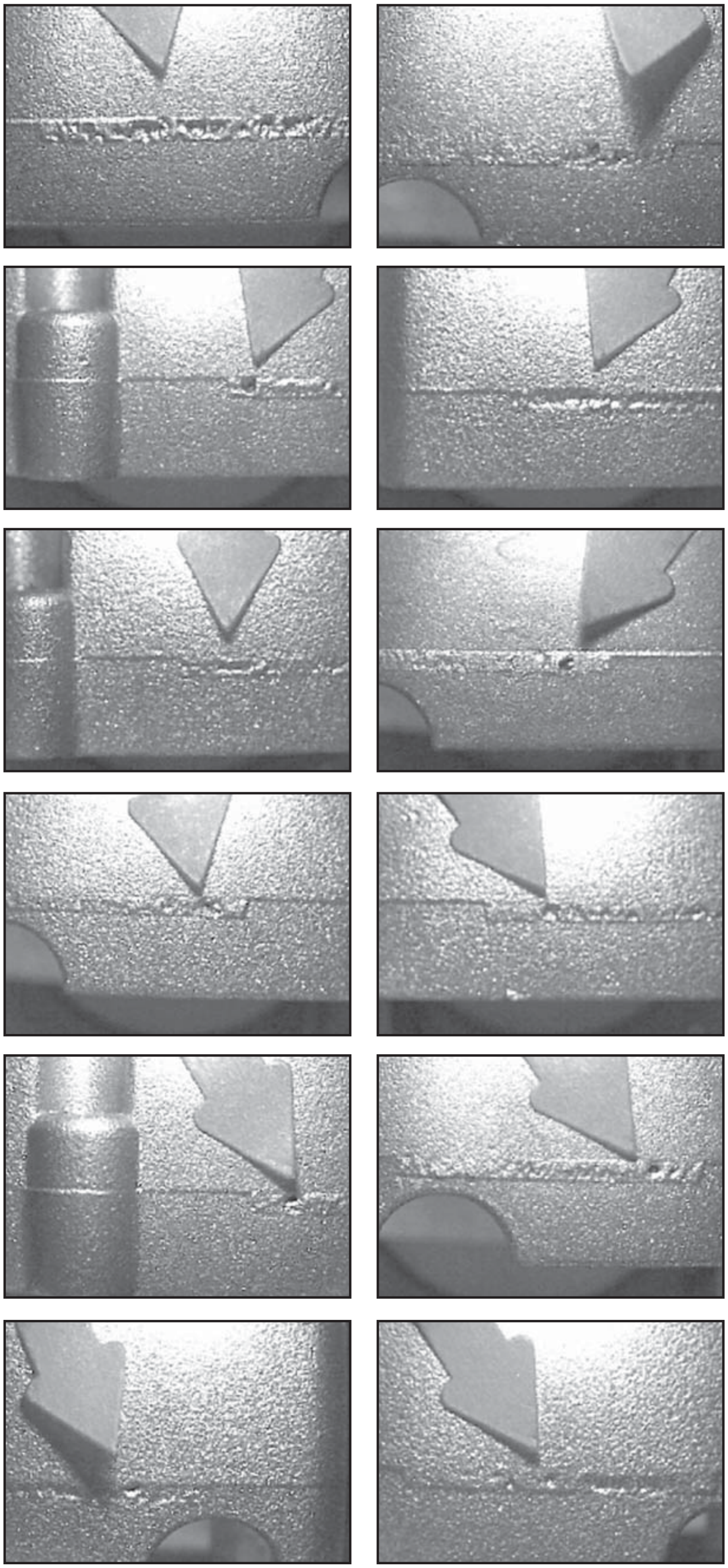
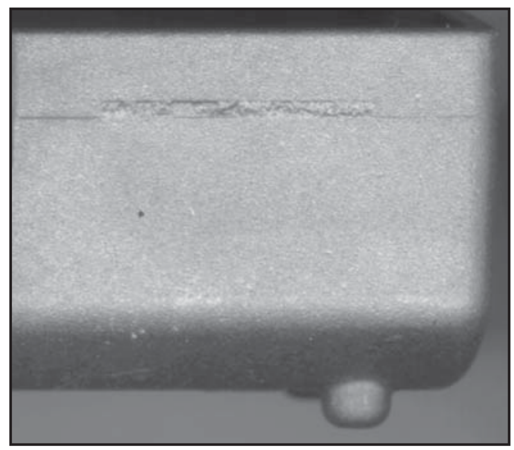
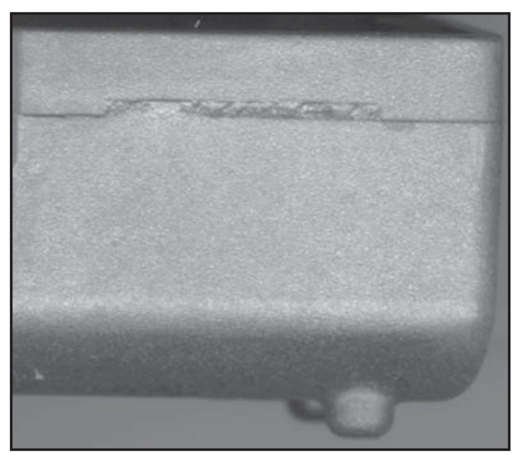


Figure 7-20A: Parting line porosity at various severity levels.

Minor



Moderate



Major

Figure 7-20B: Parting Line Break-Out placed into 3 groups.

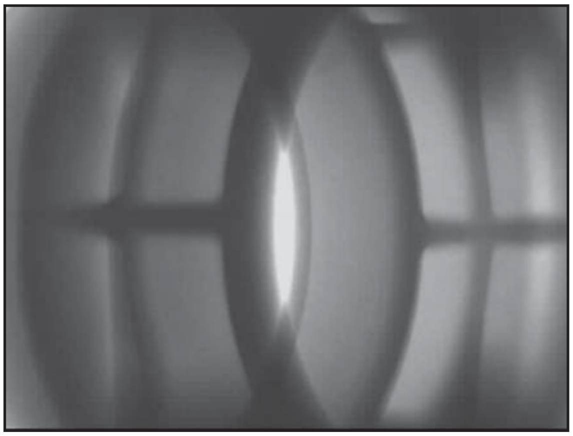


Figure 7-21A: Example radiograph of a casting with no visible porosity revealed by radiography. This level of soundness is achievable through consultation with your die caster and good part design, process design and process monitoring.

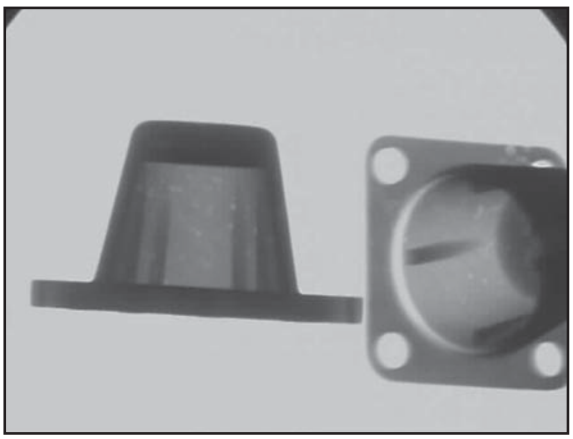


Figure 7-21B: Example radiograph of porosity that does not impact part form, fit or function. The user should be agreeable to accepting a specified amount of porosity in areas of the casting where it does not impact form, fit, or function.

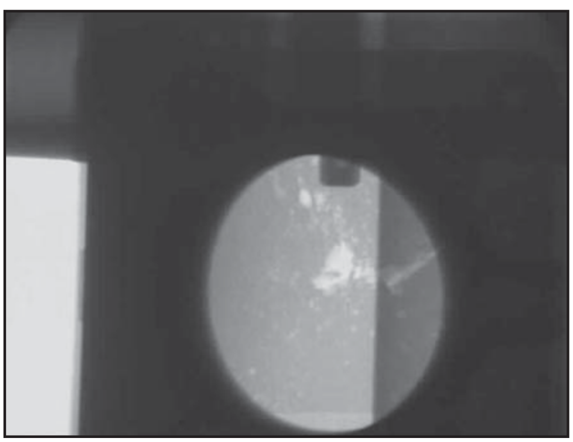


Figure 7-21C: Example radiograph of shrinkage in a thick cross-section.

If specific porosity will be detrimental to the use of the product being cast, the die caster must be informed of the areas that will require special control to reduce the incidence of such porosity. This information must be supplied in detail at the time of the RFQ, so that measures such as part design change requests, accountability for higher scrap or utilization of special processes, can be taken in advance of die design and construction.

Since zero porosity is virtually impossible to achieve in a die casting, the size, nature and location of permissible porosity should be identified by the customer, with the agreement of the die caster. The user should be agreeable to accepting a specified amount of porosity in areas of the casting where it does not impact form, fit or function. See figure 7-19.

Note: ASTM Nondestructive Testing Standard E505 provides reference radiographs for inspection of aluminum and magnesium die castings.

7.2 Parting-Line Porosity

It should be noted that some parting-line porosity may exist in some die castings. Whenever possible, castings should be designed to avoid parting lines on complex functional or cosmetic surfaces. Special measures will need to be taken when this cannot be done, such as adding changes in the parting line, adding a CAM-type movement or a hand-removal operation to blend surfaces. Parting line porosity should not be confused with parting line break-out (see figures 7-17A & B).

8 Pressure-Tight Castings

Pressure tightness (leakage) requirements for components add to die design and casting costs and should not be specified unless required for the application.

When a pressure-tight die casting is desired, the customer should specify at the time of quotation the pressure the die casting is expected to withstand and the relevant testing method to be employed.

Common leak testing methods for die castings include pressurized air bubble testing (to discover the location of the leak), gas pressure decay and mass flow testing (to determine the magnitude of the casting leakage in pressure loss or flow rate per unit time), and helium detection probe (when very low leak rates are required).

When the die casting is expected to withstand specified pressures, the die caster can offer pressure testing of a statistical sample of parts, 100% sampling or impregnating of parts to meet the pressure specification.

If machining of the pressure-tight die casting is required, it must be recognized that impregnation may be required after machining. The die caster should be advised of the specific areas to be machined in advance of the die design.

The die caster will not be responsible for machining, impregnating or testing costs if the machining is done by the customer. By mutual agreement, the die caster may accept for replacement or credit the die castings that have failed the pressure test after the machining and impregnation process.

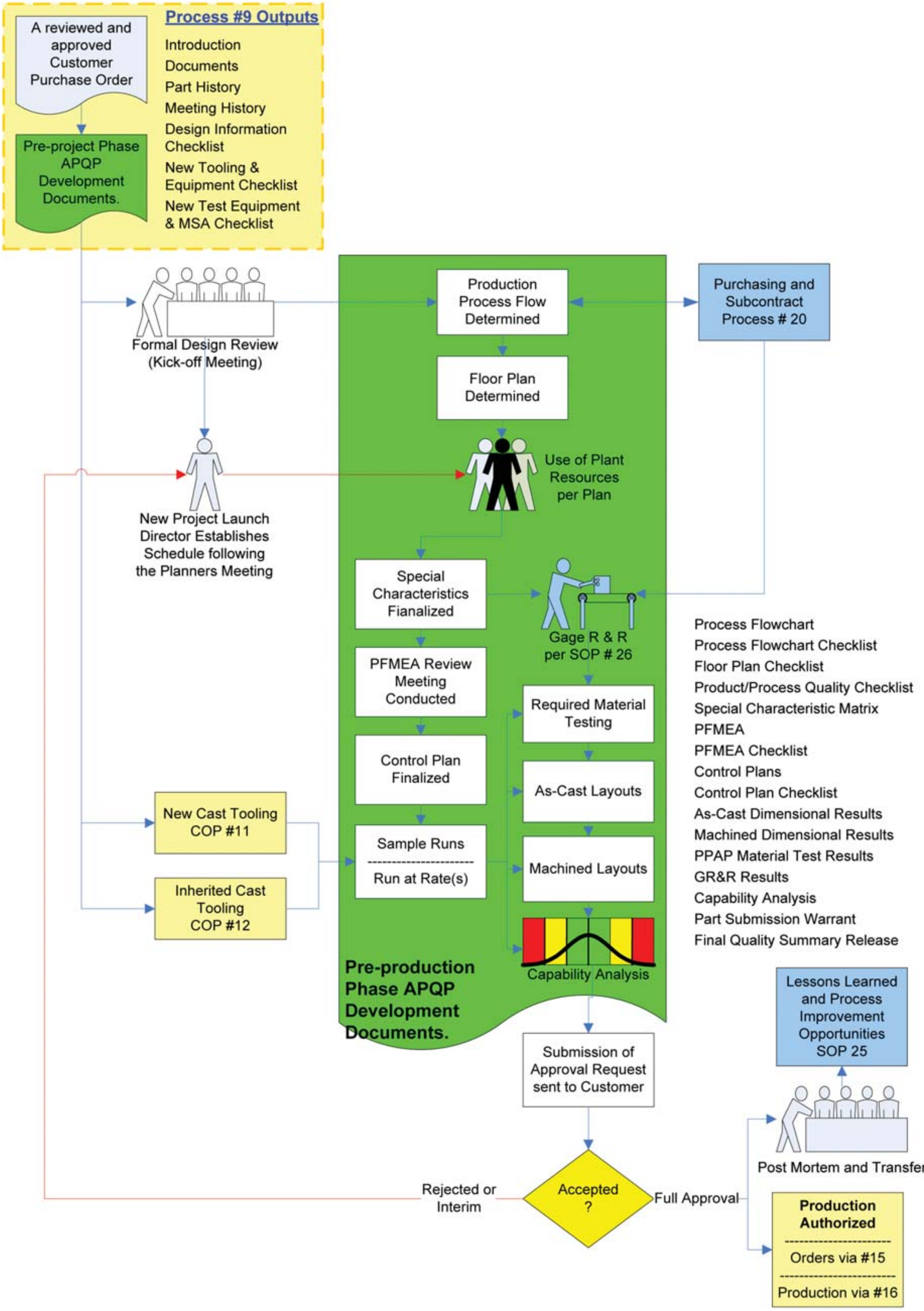


Figure 7-22: Example Advanced Product Quality Planning process flow chart.

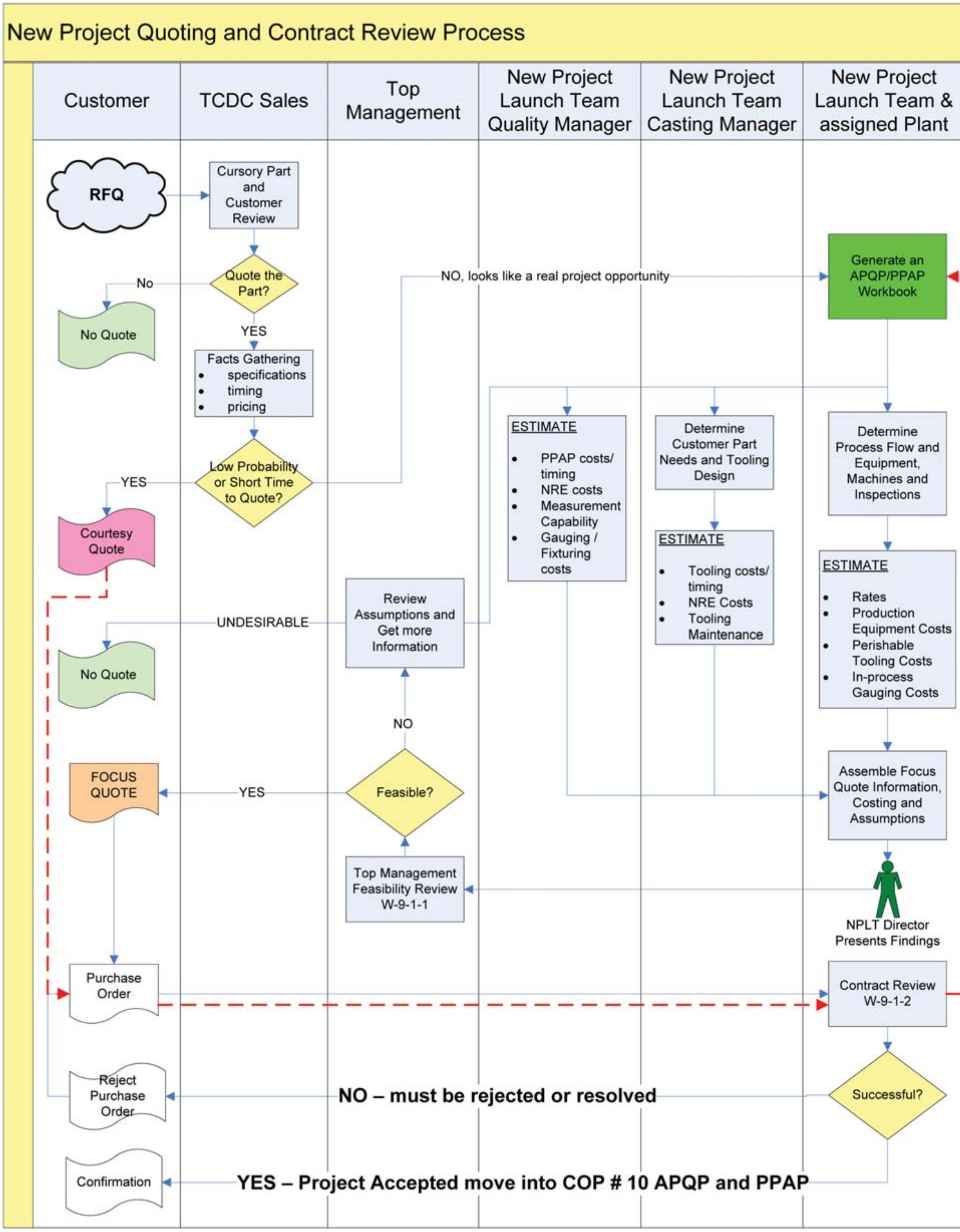


Figure 7-23: Example New Project process flow chart.

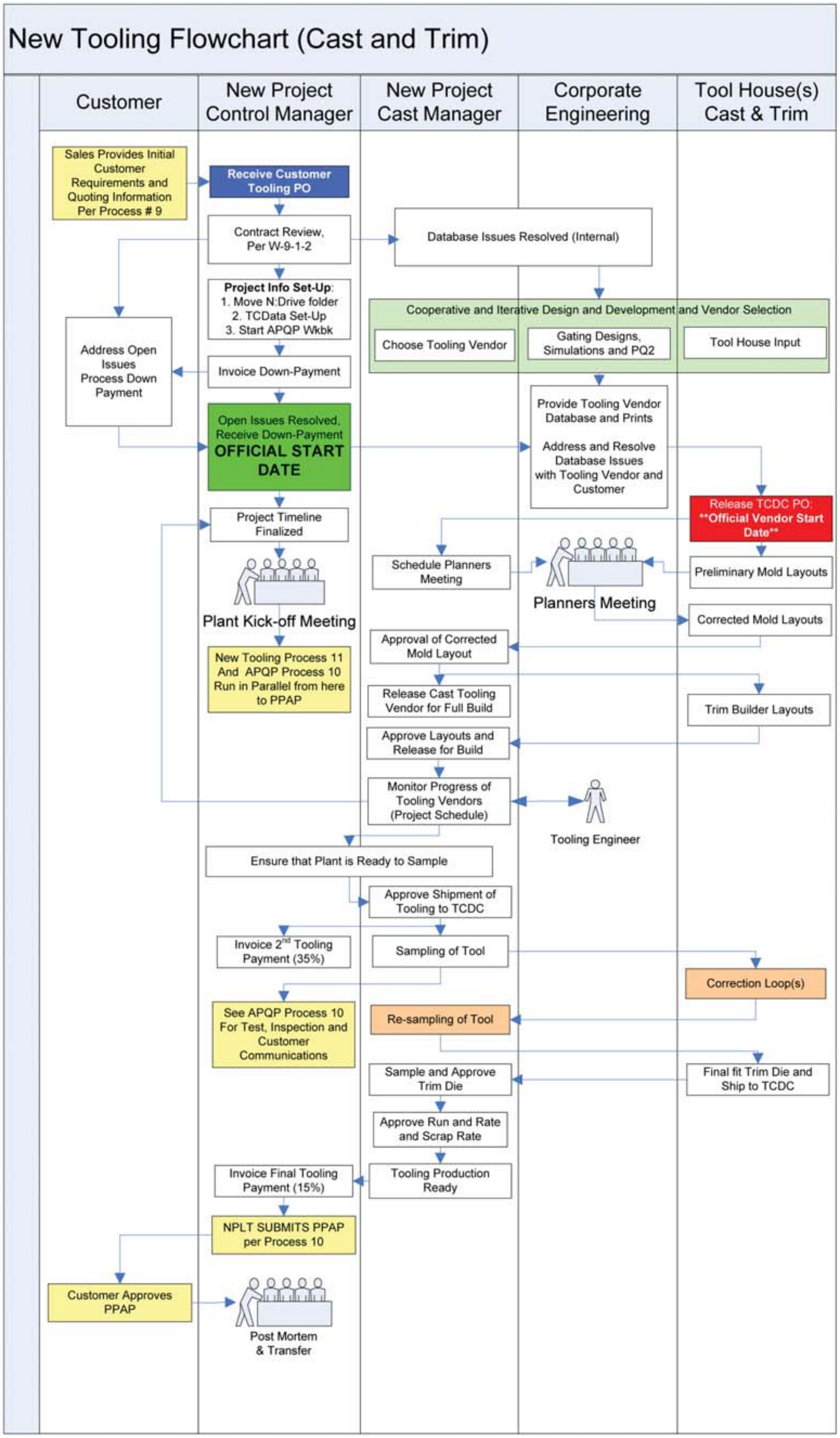


Figure 7-24: Example New Tooling processes flow chart.

Commercial Practices

SECTION 8

Section Contents

8

Commercial Practices

Frequently Asked Questions (FAQ)

1) Who owns the die cast die?
   See page 8-4, Die Ownership.
2) Are there checklists available that can be used for cast or finished specifications?
   See pages 8-14 and 8-15 for checklists.
3) How long do dies last?
   See page 8-5 and 8-6, Die Life, Maintenance, Repair and Replacement.
4) Are there any recommendations for creating CAD data files?
   See page 8-3, General Database Guidelines.
5) What is involved with die maintenance/repair/replacement?
   See page 8-5 and 8-6, Die Life, Maintenance, Repair and Replacement.

1 Introduction

In specifying die cast production, the purchase contract can be viewed as the purchase of a comprehensive engineering service from the die caster who will use the purchaser's tool to convert metal to the precise form desired by the purchaser.

The die caster will usually provide other important services, such as designing, constructing or maintaining the tool and performing machining and surface finishing operations on die cast parts. Sub-assembly services may also be provided.

The proposal and subsequent order for die castings sets forth a contract embodying the business practices governing a transaction in which custom engineered parts will be supplied on a continuing basis. Quality production of a high volume of custom parts, at the most economic level, involves a thorough understanding of the variables of the die casting process, its tooling requirements and related trimming, secondary machining and finishing operations.

The physical properties and constants of metals and alloys used for die castings are set forth in Alloy Data (Section 3 of this volume) and should be referred to with other accepted metallurgical specifications.

Aid in determining the detailed part design requirements to be specified for cost-effective production can be obtained from the Engineering and Design standards and guidelines in this volume (Sections 4, 5 and 6), together with other recognized engineering data. If geometric dimensioning is not being used on part prints, GD&T (discussed in relation to die cast parts in Section 5) is strongly recommended for optimizing quality and lowest costs.

Tooling (Section 2) and Quality Assurance (Section 7) should likewise be reviewed well before drawing up final product specifications.

Of equal importance to careful specification are the commercial arrangements which affect the buying of die castings. These trade customs have evolved from a half-century of industry-wide production experience and have generally been accepted as good business practice. The commercial arrangements are normally found in the proposal and acknowledgement forms used by the North American die casting industry.

These specialized inter-relationships, among others, govern the ability of the custom producer to supply die castings to specifications on prearranged quantity schedules at competitive levels on a continuing basis. They are described in this section together with convenient die casting product specification checklists.

2 Using Die Casting Specification Checklists

The C-8-1 Checklist (Die Cast Product Specifications) and C-8-2 Checklist (Die Cast Surface Finishing Specifications), which appear at the end of this section, can help the purchaser to more clearly define the die casting requirements that will impact final costs. They can serve as a production guide to help provide accurate communication between the purchaser and the die caster, avoiding misunderstandings later. The die caster should review these specification levels with the purchaser to assure that the most cost-effective level is selected and, if necessary, provide samples of various specification levels.

2.1 Defining Quality Requirements

The checklists also mention the use of SPC and other inspection requirements. It is highly desirable to define such requirements so there is no question about record-keeping responsibilities. While most die casters use these techniques regularly, some purchasers have special requirements (ie. critical feastures) that must be defined early in the process.

When using statistical techniques for quality control, it is important for the purchaser to specify the parameters when requesting a price quotation. For example, general definitions of process capability, such as Cpk, can affect tooling dimensions that are built towards one side of the tolerance to allow for future die wear. These dimensions can vary in one direction only, as in the outside dimensions of a cavity (see “Moving Die Components” – Section 4A). When applying general definitions in this situation, the tool will appear to be out of limits, while it is actually built to high quality standards for long life.

It is most important that agreement on procedures be reached prior to establishment of the quality standards. The costs for the quality level of a feature are calculated by the die caster during the quoting process, and any changes in standards at a later time may require a revision to the quotation.

Many of the specifications, such as the quality of a surface finish or the severity of internal porosity, are subjective. The methods of establishing subjective standards can vary considerably, but it is always beneficial to spend the effort required to define the standards as closely as possible.

One way of defining subjective standards is to define borderline acceptable and acceptable samples, which should be retained as “limit” samples by the customer and the die caster. In addition, it is desirable to have pictures or a complete written description of the defects that would cause rejection. Such provisions can be improved upon during the initial production phase.

2.2 Specifying Tolerances

It is well known that the die casting process can achieve very high dimensional precision. The Engineering & Design Tolerance Standards for coordinate dimensioning of parts to be die cast (Section 4A) are presented at two levels: as Standard Tolerance and as Precision Tolerance specifications. Most die casters can improve on the Standard Tolerances, but a cost penalty in increased cycle times will often be the trade-off.

Tolerance improvements are most directly related to part shape. If tolerance requirements are clearly discussed in advance with the die caster, precision tolerances can often be maintained for a cast part with significant improvements in product performance and reduced secondary machining and finishing operations.

Machining processes should also be considered well before any order for the tooling is released. A careful evaluation of machining requirements can lead to a redesign for net-shape die casting or near-net-shape production, with a reduced number of operations or setups.

2.3 General Database Guidelines

Computer Aided Design (CAD) databases usually consist of a two-dimensional drawing (2-D) and a three-dimensional model (3-D). Software compatibility is a common problem between customer and die caster. To expedite communications, the die caster and customer should be aware of each other’s CAD software capabilities early on in the project. In the event that the die caster and customer do not utilize the same software packages, universal file formats can be used to communicate. Although there are many available, the most common formats are DXF or DWG (for 2-D drawings) and IGES or STEP (for 3-D models). Often, translation software is needed to convert files into the appropriate format.

When databases are utilized for quoting purposes, these general guidelines apply:

1. If only a 2-D drawing is provided, it should contain dimensions and general views of the part and major features. Physical properties such as mass and part volume should be included as well.

2. If only a 3-D model is provided, the die caster should be able to retrieve dimensions and properties from the model.
3. Secondary operations, such as machining, can be included in the database or supplied separately.

Some general requirements when databases are being utilized for tool construction:

1. When only a 2-D drawing is provided:
    - 1.1. Drawing should contain complete dimensions of all features.
    - 1.2. Parting line, draft, radii, datums and tolerance (dimensional and geometric) requirements should be clearly defined.
    - 1.3. Secondary operations that are to be performed on the part and other requirements should be clearly stated.
2. When only a 3-D model is provided:
    - 2.1. All necessary draft, parting line and radii should be included in the model. Ideally the 3-D model will indicate machined surfaces.
    - 2.2. Lines and surfaces of the model should be connected within 0.001".
    - 2.3. The 3-D model should be accompanied by a limited dimension part print that contains all tolerancing information and shows any secondary machining to be performed.

An incomplete database could result in an inaccurate quote and possibly require considerable database manipulation, which leads to additional cost and extended lead-time. The die caster and customer should also indicate whether the 2-D drawing or the 3-D model controls the project.

3 Die Casting Dies and Production Tooling

Any die casting can be produced in a number of different ways and every die casting plant possesses different equipment and utilizes a range of production techniques. Optimum economy and maximum efficiency for the production of any die casting, therefore, must be considered in the light of the particular equipment with which it will be produced. The experience, technology, skill and ingenuity of the die caster are all involved in selecting the method of production on which the proposal is based.

Each die caster sells die casting dies, trim dies and specialized production tooling on its own individual terms and conditions. Normally, these terms provide for an advance payment for dies and tooling, with the balance paid upon receipt of, or approval of, a sample produced from the dies and tools. Length of time for approving parts to be 30 days if not otherwise agreed upon between die caster and customer.

3.1 Die Ownership

Generally, the purchaser of die castings will retain ownership of the die casting die, even though the die remains with the die caster. It has also been the custom that the design and construction of the die casting die are performed by the die caster to its own specifications, even though the purchaser owns the die. The custom generally works to everyone's advantage.

The practice has developed because most purchasers lack the extensive experience and expertise required to design and build a die casting die that will produce acceptable castings. There are also a number of features of the die that need to precisely match the die casting machine selected by the die caster.

These die construction and ownership practices are generally being maintained today, although other options are available for the purchaser. The increasing technical capacity of designers is making it possible for a knowledgeable purchaser to contract for the design and construction of a die from a tooling vendor, then select a die caster to run the tool. However, this procedure can potentially create a number of serious conflicts with the eventual die caster. For example, if the castings are of low quality, who is responsible? The problem could stem from die design, die construction or production operations.

Consequently it is preferable for the die caster to be responsible for die design and construction. In addition to eliminating questions of responsibility, this procedure also ensures that the die will match the casting equipment. In addition, the die caster has a vested interest in building a high-quality die that will give few problems in production.

The die casting die, usually owned by the purchaser, is housed and maintained at the die caster. The die caster will be responsible for loss or damage to the die and tooling while housed at the die caster's facility. Some die casters offer the option of joint ownership of the die. In either case, there are some considerations that should be addressed during the purchasing discussions.

An ownership record should be established by both parties, which will include a description of the die and all additional components of the die. Each die should have a method of identification, which is best done with engraving or welding (riveted tags can come off). Typically a number is assigned to the die by the die caster, which is engraved on the die, slides and cores and included in the purchaser's record of the die.

All components purchased originally with the die should be noted in the record, such as shot sleeves or extra slides or cores. These components usually wear out much more rapidly than the rest of the die and they may be worn out and unavailable if the die is claimed by the purchaser.

The question of Tool Ownership as well as Replacement is often overlooked when general discussion begins at the start of a possible new project. Since there are multiple types of tools available for the die cast process the following descriptions for tooling and ownership is to provide a starting point for those decisions.

New tools are generally paid for by the Customer, the Die Caster is responsible for normal maintenance and care (as the caretaker), the customer (as the owner) for replacement. It is the responsibility of the die caster to inform the customer of any atypical maintenance or care required. If the customer elects not to follow the maintenance advice of the die caster the quality of the part could suffer. In today's rapid development world sometimes who owns what is not clear. In the following cases an example will be given as to typically who owns what portion of the tool.

1) Rapid Tooled projects frequently use a tool (mold base) that is owned by the die caster and becomes a type of Universal Holder for Die Cavity inserts (for multiple customers). The inserts that are used to make the part configuration are owned by the customer and frequently will have a shorter tool life than Production made tooling.
2) For Unit Dies, the Master or Universal Holder (as above) is usually owned by the Die Caster and the individual units and their inserts are owned by the Customer. As long as a Unit Die is the equivalent of an Industry standard it should be able to move to a new die caster if needed without major cost factors involved.
3) Dies by themselves are owned by the Customer and may have different shot life attached to them based on part design and function.

Replacement is usually limited to the cavity inserts but in certain cases could be the entire die. Normally the customer is notified at the 1/2 life that replacement is needed so that enough time is allowed to get the replacement components approved before the original tool wears out. This can be paid for at the time of construction of the replacement or in cases of a very high volume part an amortization account may have been set-up. This type of account allows for a small amount to be added to the part price that will cover the cost of the replacement when needed. It becomes the Die Caster's responsibility to manage tool replacement and to notify the Customer when new replacements are submitted for approval.

Tooling Amortization must be started at the time of the fist part being produced for sale so that the account can cover the cost of replacement start and the balance due at approval. If it is not started at this time the tool may have to be pushed beyond normal life to pay for a new tool and to not interrupt Customer production. This usually results in added operations to the part which can increase costs. This process does not work with inherited tooling because of questions concerning actual shot count on the tool but can be applied after the first replacement is completed. Either the Customer or the Die Caster can be holder of the amortized funds for replacement but usage terms need to be clearly defined.

The Die Caster and the Customer need to agree on both the initial tool and replacement plans (as needed) and payment terms at the start of the project so that on-going needs are met and ownership is clear.

3.2 Die Life

The purchaser should be aware that the life of a die can be unpredictable. Die life is a function of many factors. Among them are part design, part configuration in the die, part quality expectations, release quantity, type of tool steel used for the die, the heat treatment of the die and the type of alloy being die cast.

Even when the die caster makes every effort to extend die life, early failure is still possible. It is also possible for a die to have an unpredicted very long life. An understanding of expected die life should be discussed in the initial phases of a project.

Progressive die casters can provide tool steel specifications and heat treat specifications that have been developed through extensive NADCA research programs. It is recommended that the purchaser reference these specifications for the building and heat treating of the casting die. The specifications include recommendations for stress relief during machining, the removal of the "white layer" after EDM operations and a number of other considerations.

When tooling is procured through a reputable die caster, tooling costs may be somewhat higher than if a purchaser dealt directly with the tool builder. The die caster will be closely involved in evaluations and decisions that will translate the product design into the optimum die casting die for successful production. The increased costs almost always represent a bargain in terms of overall costs during the life of the die.

An inexperienced purchaser who purchases tooling purely on a cost basis will find that the costs over the life of a die are significantly higher because of a lower-quality tool, although this will not be immediately apparent when the tool starts running. It cannot be emphasized too strongly that good quality tooling will cost more in the beginning but pay for itself many times over in the life of a typical die casting die.

3.2.1 Die Maintenance, Repair and Replacement

The responsibility and criteria for maintaining tooling, on the one hand, and replacing the tooling, on the other, should be understood. In some cases, the die replacement cost is requested to be amortized into the piece price. The most common way of structuring this portion of the contract is for the die caster to provide minor maintenance, and the purchaser to provide major repair and replacement.

Minor maintenance is generally described as "run-to-run" maintenance of a serviceable die to maintain die casting production. Major maintenance would cover the replacement or rebuilding of an entire die cavity, die section, or complex core slide that makes up a significant percentage of the casting detail, or major die resurfacing. Most die casters have a preferred way of handling maintenance and it should be made clear.

The rapid wear components should be covered in the die maintenance understanding between the purchaser and the die caster. These components are frequently replaced by the die caster, although each purchaser should expect to make an individual agreement for each casting. If the components are replaced by the die caster, ownership usually remains with the die caster, although this can vary for individual agreements.

The purchaser should review the die maintenance practices of the die caster and agree on the expected maintenance. For example, if the purchaser expects the die to be stress relieved after a certain number of shots, then the die caster should be aware of this requirement so that it can be included in the costs.

Die preheating practices, gating design and die temperature control are particularly important to long die life. Reviewing these practices may be difficult, but there are some steps a purchaser can take.

1. The purchaser should ascertain the die preheating practices of the die caster. The best results are achieved by preheating dies to a specified temperature, depending on the alloy being cast, before the first casting is made.
2. Smooth metal flow at the correct velocities from a carefully designed gate is important to reduce the die erosion at the gate, as well as having a significant effect on casting quality. Die erosion can be repaired by welding, but the onset of welding significantly reduces the ultimate life of the die.
3. The die caster should be able to discuss the use of good die design practices with the purchaser. A die caster using trial and error without calculations for gating will have many more problems with die erosion and part quality than one who uses calculation techniques developed by NADCA or other authorities.

Note: Computer software is available for flow simulation, thermal and distortion analysis.

4. Die temperature control, involving careful cooling line control and proper cooling line placement, will influence casting cycle time and have an important effect on casting quality. Working with a quality die caster assures the purchaser that all aspects of die design and construction follow practices that maximize production as well as die life.

3.3 Credit

The die caster generally reserves the right to change his terms of payment if a change in the customer's financial condition requires it. Such changes are usually requested in writing and, when necessary, may require the die caster to stop design and/or construction pending agreement.

3.4 Changes or Cancellations

If any changes are required by the purchaser to finished die casting dies or production tooling which deviate from the original print and/or model provided for the dies and tooling at the time of quotation, the die caster reserves the right to requote the quality, expected die life, cost and delivery of the tooling. Any changes to the order must be agreed to by the die caster, in writing.

The die caster will usually require some payment for cancelled orders. Payment is necessary to compensate the die caster for costs of work in process to the date of cancellation and commitments made by the die caster for purchases relating to the order.

3.5 Die Retention and Removal

It is customary for the die caster to retain control and possession of die casting dies and production tooling. Since the full cost of engineering, designing, obtaining, and maintaining the die casting dies and production tooling is not fully reflected in the charges to the purchaser for these items, an additional charge may be necessary for these unreimbursed costs if the die casting dies and production tooling are removed prematurely from the die caster's plant.

It is also customary to allow die casting dies and production tooling which have not been used for three consecutive years for production of die castings to be scrapped following proper notification, via certified mail, to the purchaser by the die caster.

Rules for the accessibility of the die should be established. If the die is to be claimed by the purchaser, it should be available after notice has been provided, and all outstanding invoices due the die caster are paid in full.

3.6 Insurance

It is customary for the insurance of die casting dies and production tooling to be the responsibility of the purchaser, unless specifically agreed upon, in writing, to the contrary.

Die casters normally have liability insurance protection against fire and theft or vandalism. However, fire insurance usually excludes tools, which do not burn, except for the clean-up costs following a fire. Insurance should be reviewed in each case, and business interruption in case of fire may need to be considered. Die casters will provide worker's compensation insurance as required by law.

3.7 Gaging

Good gaging is critical to obtaining good quality parts, both during the process and at final acceptance, and can also help reduce part cost, especially if a casting is heavily machined. It is important that this aspect be discussed early in the project.

The die caster can be expected to furnish standard gages. The purchaser is expected to furnish any special gages needed in the inspection process, such as those required for determining conformance to feature and location specifications and any gages needed for functional or statistical requirements.

All gages and gaging methods should be agreed upon in advance by the purchaser and die caster, including any need for duplicate gages. This will aid in both part function and fit, in instances where the die casting will be mated or assembled with other parts not manufactured by the die caster.

3.8 First-Piece Acceptance

After the first die cast samples are received from a die casting die, the die caster or purchaser will usually be required to measure the samples and verify that they meet specifications. Modifications from the original print which have no effect on part function or appearance can be discussed at this time to ensure that high production rates can be maintained and premature die maintenance avoided.

Procedures for handling changes in the print specifications for the die casting should be agreed upon. Any costs and delivery delay incurred by such changes should be quoted by the die caster immediately after they are received. Authorization for the changes should be given by the purchaser in writing on each change order.

4 Die Cast Production Part Orders

The commercial terms of the contract items and conditions between the purchaser and the die caster for die cast part production are discussed below. Note that the trade customs outlined represent the historic and customary practices prevailing in the die casting industry. Contract forms of individual die casters will vary in some details. A model of terms and consitions can be found at www.diecastingdesign.org/terms/

4.1 Metal and Metal Pricing

Quality metal is the foundation for good castings. Even a chemical analysis does not fully define all the metal quality specifications that are necessary for good die casting. Low-cost, low-quality metal cannot be expected to meet all die casting requirements.

For example, when aluminum or magnesium alloy does not meet established criteria, machining may be more difficult or surface corrosion accelerated. When zinc alloy does not meet established criteria, mechanical properties will be progressively and seriously reduced in use with time.

Metal price is commonly established from quotations from an approved metal supplier, or based on known industry indicators such as the daily American Metal Market, the London Metal Exchange, Platts or other major markets. If the purchaser elects to use an industry indicator, he may forfeit the advantage of spot metal buys at lower than market price.

4.2 Acceptance of Orders & Reorders

4.2.1 Acceptance of Orders

Proposals for the production of die castings are prepared on the basis of the specifications and prints known at the time of estimating. Die casting proposals are, therefore, for immediate acceptance on the basis specified. Similarly, since orders are accepted on the basis of the requirements known at the time of the order, changes from the original proposal on which the order is based may result in the need for price adjustment for the parts. The die caster reserves the right to review all orders before acceptance.

The proposal, the order and its acceptance, signed by an authorized representative of the die caster, constitute the entire contract with the exception that, when any provisions of the order conflict with the proposal, the proposal and acceptance always prevail. Modifications, changes, additions, cancellations or suspensions of an order are not binding upon the die caster, unless accepted in writing by an authorized representative of the die caster and upon terms that will indemnify him against all loss.

4.2.2 Reorders

Reorders for die castings are covered by the same conditions as was the original order, provided no revised proposal and acceptance has intervened. Pricing of reorders will, of course, be affected by quantity alloy, labor and other costs prevailing at the time the reorder is placed.

4.3 Changes, Cancellation and Errors

4.3.1 Changes or Cancellation

Any changes to the order deviating from the original basis upon which the order was accepted must be agreed to, in writing, by the die caster. These changes may result in the adjustment of prices. Changes could include, but are not restricted to, delivery dates, quantities, release dates, part prints, etc.

The die caster usually will require some payment for cancelled orders. Payment is necessary to compensate the die caster for costs of work in process to the date of cancellation and commitments made by the die caster for purchases relating to the order, including dedicated equipment specifically acquired for a cancelled project.

Any change to the delivery schedule or release dates beyond 90 days must be subject to negotiation between the die caster and the customer.

4.3.2 Errors

Clerical errors are, of course, subject to correction regardless of whether they favor the buyer or the seller and enforceable if discovered within a period of one year.

4.4 Credit, Payment Terms and Taxes

4.4.1 Credit

The die caster generally reserves the right to change terms of payment if changes in the customer's financial condition requires it. Such changes are usually requested in writing and, when necessary, may require the die caster to stop production or suspend shipment pending agreement.

4.4.2 Terms of Payment

Each die caster sells its products on its own individual terms and conditions. Shipments are generally FOB the city in which the die casting plant is located. Payment is normally net 30 days with provision for metal market and escalation clauses.

4.4.3 Taxes and Duties

Sales or use taxes, excise taxes, taxes on transportation, other direct taxes and applicible duties are the responsibility of the purchaser whether such taxes are federal, state or local.

4.5 Packaging and Delivery

4.5.1 Shipping Tolerances

Since the die caster cannot determine in advance the exact loss factor in a particular run, it is generally recognized that he may manufacture and ship 10% over or 10% under the number of die castings ordered or released. If no deviation is to be allowed, with pricing affected accordingly, this should be so specified in the purchasing agreement.

4.5.2 Packaging

Die castings are generally packed in bulk as the most suitable and economical method. Any special requirements, such as specifying layer packed, separated or cell-packed shipments, must be communicated to the die caster in the RFQ; otherwise a price change may be required later. If recyclable packaging is required, it should be carefully spelled out in the quoting phase. While this type of packaging can have a positive impact on pricing, it may increase up-front costs. The die caster will be responsible for cleaning and reusing recyclable packaging.

4.5.3 Deliveries

Unless otherwise specified, deliveries of die castings generally begin as soon as the die caster's schedules permit and, in the case of a new die, after approval of samples. Deliveries are made at a rate approximately equal to the capacity of the tools until orders are completed. The purchaser selects the method of delivery and, unless otherwise specified on the purchaser's order, the die caster will use his best judgement in routing the shipment and seeing that deliveries are effected as specified. Acceptance of the goods by the carrier shall constitute a delivery. Any charges in connection with postponement or cancellation of delivery are the responsibility of the purchaser. The purchaser will also be responsible for any additional costs of expedited or other special transportation as result of changes in delivery schedules not caused by die caster.

Penalties upon the die caster for delayed delivery, whatever the cause, are not normally acceptable unless agreed upon at the time the order is being placed.

Many die casters today can provide an electronic connection to high volume purchasers to facilitate placing orders, as well as provide bar coding. It is frequently desirable to anticipate emergencies and provide for backup tooling, a small amount of emergency inventory or some other way of addressing the catastrophic failure that can occur in any volume production process based on sophisticated tooling.

4.5.4 Lot Size versus Cost

Because of the cost of setup, die casting is usually a high-volume process where the cost of a small lot is significantly increased by setup costs. It is therefore imperative that lot sizes be considered in the discussions of the purchasing contract. Each die caster will have his own costs for setup, so the break-even point for minimum lot sizes will vary among die casters. Some purchasers use consignment inventory agreements to address the reality of die setup costs and tooling life factors that are adversely affected by the short runs.

Lot size should be considered in the early stages of determining the tooling requirements. For example, in some cases fewer cavities on a smaller die will result in lower tooling costs, lower setup costs and a smaller economical lot size. This may be more desirable even though the piece-price may be slightly higher.

If small lot sizes are required often, quick setup aids, such as quick-disconnects, can be built into the tooling. Advising the die caster of small lot requirements at the time of quotation will enable him to optimize the use of these aids.

It is desirable for the purchaser to take time to explore the options of economical lot size, costs of maintaining inventory and tooling options during the tooling quotation phase. Since there may be many options, it is suggested that the purchaser provide the die caster with those considerations that are important for the project and let the die caster propose several options. This will allow the die caster to maximize the efficiency of the equipment available in his plant and provide the most economical quote to the purchaser.

4.6 Limitations on Inspection Procedures

4.6.1 Prints and Approved Samples

Die castings may not be rejected because of variation from print dimensions if they are made to, and are unchanged from, approved samples with respect to dimensions, finish and analysis. When the purchaser has specified or approved the design, failure with regard to function or fitness for use shall be the purchaser's responsibility. If sample die castings have not been approved and conflicting models and prints have been submitted, the basis of acceptance shall be agreed to in writing.

4.6.2 Accuracy

Die castings may not be rejected if they vary from finished sizes or dimensions within limits agreed upon. Where a very close tolerance or particular dimensional accuracy is specified, the permissible variations shall be agreed upon before die work is begun. In the absence of applicable standards, tolerances will be subject to the commercial variations generally prevailing in the industry.

4.6.3 Inspection and Sampling Procedures

If specified and specifically acknowledged and agreed to by the die caster, die castings can be inspected on the basis of statistical quality control or other sampling procedures.

Use of statistical quality control standards and other related procedures require specific detailing by prior mutual agreement on all aspects involved.

4.7 Compliance with Laws

Die caster will comply with applicable laws, rules and regulations of the country where the casting is made. Die caster will provide customer with material safety data sheets and, upon request, provide other information reasonably required in order to comply with applicable laws.

5 Purchased Components

Innovation in the design of die castings and flexibility in the industry's manufacturing process have led to the use of purchased components for insertion or assembly by the die caster. The procurement and subsequent responsibilities for the delivery and quality of such components lies with the purchaser of the die casting unless otherwise agreed upon and included in the quote and the order. These components may be "insert cast" as an integral part of the die casting or may be assembled to the die casting in a separate operation.

5.1 Cast-in-Place Inserts

If the finished casting contains cast-in-place inserts, the responsibility of providing them to the proper specifications should be clearly defined. The design of the purchased component is the responsibility of the die casting purchaser and is subject to approval by the die caster. In many cases the clearances in the die will require that the insert tolerances be tighter than the purchaser would normally supply for the required end use. If the purchaser is supplying the inserts, provision must be made to ensure that all supplied inserts are within tolerance. An out-of-tolerance insert can seriously damage the die.

5.2 Inventory Costs

Regardless of who purchases an additional component, there must be consideration given for in-process spoilage and rejects. As a result, the quantities of purchased components will always exceed the number of die castings purchased. It is understood that there are costs associated with handling, storing, counting and inspecting of purchased components. Inventory of purchased components required to meet the die casting purchaser's delivery schedule are the responsibility of the die casting purchaser. The labor cost for inserting or assembling the component is normally included in the quoted piece price.

6 Price Adjustments

Because of the job-shop nature of production and the variation in product design and specifications, the prices for die castings are determined by the use of price estimating formulas.

Each die caster employs an individual pricing formula constructed in accordance with their individual methods and costs. All price estimating formulas contain a number of factors which may require adjustment, upward or downward, because of conditions beyond the control of the estimator. Significant unexpected increases in the cost of either natural gas and/or electricity may result in negotiated energy surcharges per mutual written agreement.

Commercial Practices

6.1 Quotations and Metal Market Pricing

6.1.1 Order Quotations

Order quotations for die cast products, and die casting dies and production tooling necessary to make the die cast products, are normally valid for a fixed period of time. After this time has expired, the die caster reserves the right to requote based upon price adjustment provisions as discussed above.

To establish a uniform basis of comparison, the estimated weight and monthly and/or yearly quantity requirements should be specified when soliciting quotations, and it should be requested that the material cost be itemized.

6.1.2 Metal Market Pricing

Prices for die castings are based on the die caster's prevailing cost for the alloy specified on the day the estimate is prepared. In some instances, the die caster's quotation may make reference to various published alloy prices or other indicators. The cost for the alloy is subject to fluctuation beyond the control of either the purchaser or the die caster and the actual price charged for the die casting will reflect the changes required to adjust for all metal market variations. Similar adjustments may be made on each release and/or reorder.

6.2 Labor and Operating Costs

6.2.1 Labor Costs

Many die casting dies are in production over extended periods, often over many years. For this reason, the piece-part labor cost may change over the life of the order. If piece-part labor costs change after the date of the original price estimate, it is generally necessary to change the piece-part price for future deliveries.

Customer schedules often are expanded and sometimes require production beyond the normal schedules of the die caster.

Since all die casting prices are estimated on the basis of production at straight-time rates, an adjustment is generally required if premium labor rates are necessary to meet the customer's expanded needs.

Die casting price estimates and quotations reflect labor costs based on continuous operation for the quantity specified for any delivery release. Reductions in scheduled deliveries or production interruptions by the customer, may affect labor and other piece part costs. In such cases, a price adjustment may be necessary.

6.2.2 Operating Costs

Costs of outside services (such as painting, plating and machining), or of purchased supplies and components (such as inserts, packing materials and fasteners), or action of governmental or regulatory agencies may cause periodic increases in the costs of manufacturing. These added costs must be reflected in changes to quoted prices. Also, changes in acceptance criteria by the customer may significantly affect the die caster's operating costs, making an adjustment to the part price necessary.

7 Patent Obligations

Die casting is essentially a conversion process by which metal shapes are produced for a purchaser. Therefore, if a die casting infringes, or is claimed to infringe on any letters patent or copyright, the purchaser must assume the responsibility involved.

While the die caster does provide input into the design of the customer's component for die casting manufacturing feasibility, the die caster is not responsible for the design or functionality of the customer's product or device or for the design of the die casting as part of such product or device. The purchaser of die castings is liable for his own product or device and for all patent infringement claims relating to it or any of its parts.

Die casting proposal and acknowledgment forms generally include clauses which provide that the die caster shall be indemnified and held harmless of and from all expenses arising from all such claims. When patents, design or otherwise, are involved, they should be specifically called to the attention of the die caster.

8 Intellectual Property

Die Caster is not required to provide any intellectual property used to produce parts for the purchaser. Purchaser has the right to use parts in purchaser's product.

9 Warranties Covering Die Castings

9.1 Extent of General Warranty

Die casters, like other responsible manufacturers, stand behind their product. However, it should be understood that the die caster in assuming this proper responsibility focuses its engineering efforts upon the die cast manufacturing feasibility of the component, rather than the component's product function which is the responsibility of the purchaser.

In general, die casters agree, at their option, to correct, replace or issue credit for, defective die castings, subject to specific limitations and exceptions. Reference NADCA Terms and Conditions for more details on warrenties.

9.2 Limitations on Warranty

9.2.1 Processing After Delivery

No warranty attaches to a die casting which has been altered, machined or finished after delivery to the purchaser by the die caster.

9.2.2 Reasonable Time

No claim for defective die castings will be recognized unless made in writing within 90 days (or as agreed upon between die caster and purchaser) after delivery.

9.2.3 Returns

Die castings claimed to be defective are not to be returned to the die caster without specific approval and inspection by the die caster. Returned goods accepted by the receiving department of the die caster are not exempted from the right of the die caster to inspect the die castings or to determine the extent, if any, of his liability.

9.2.4 General Limitations

Losses, damages or expenses arising from the use of a die casting, or labor costs or other charges incurred outside of the die caster's plant, or transportation costs, as well as losses due to other causes, are not acceptable basis for claims against die casters under the warranty provisions. The Warranty as stated in paragraph 8.1, above, is limited to the repair or replacement of defective die castings or the issuance of credit for their return as stated.

10 Product Liability

Die casters cannot be expected to have technical knowledge relating to the end product of the many industries they service. While they may freely offer design services to make a product easier to manufacture, at no time does this imply a knowledge of the strengths, stresses or other forces that may be induced in the product's end use. This must be exclusively the liability of the buyer and design suggestions are offered by the die casters with this understanding.

The die casting industry has always maintained the position that a die caster is not liable for the failure of a die casting in a buyer's product, if the part furnished to the buyer meets the prescribed specification.

Die casters accept the responsibility of manufacturing a part to the buyer's specifications within the agreed acceptance level. This means the buyer will accept a percentage of parts that do not conform to the specifications. Die casters cannot be held liable for any failure in the end product because of the decision on the part of the buyer to use statistical quality control in its incoming inspection.

If a buyer approves a sample for production of parts that do not meet specification in any way, this approval constitutes a change in specification and the die caster's responsibility is then altered to only meet this altered specification.

It is anticipated that the buyer will indemnify and defend the die caster from any damages or claims arising from the use of die castings or other goods produced to the buyer's specifications.

11 Production and Finishing Specification Checklists

The C-8-1 Checklist (Die Cast Production Specifications) and C-8-2 Checklist (Die Cast Surface Finishing Specifications) appear on the following pages.

It is recommended that, prior to final quotations, and always before any die design commences, the casting requirements defined by these checklists be reviewed with the die caster, together with the specifications and procedures listed in Section 7, "Quality Assurance." All of these items impact final costs and should be thoroughly discussed to assure accurate communication between the purchaser and the die caster.

This checklist is for use in consultation with your die caster prior to estimating production costs. Use in combination with the Finishing Checklist C-8-2. Also review Checklists T-2-1A and T-2-1B, for Die Casting Die Specification, in Section 2.

Casting Production Specifications

To be used in consultation with your caster (Use in combination with Checklist C-8-2)*

Checklist for Die, SSM and Squeeze Casting Production Part Purchasing

This Production Checklist provides a convenient method for assuring important factors involved in purchasing cast parts are evaluated and clearly communicated between the purchaser and the caster.

It should be used as a supplement to the essential dimensional and alloy specifications detailed on part prints submitted for quotation, since the listed factors directly affect the basis on which the casting quotation is made. The checklist may be reproduced for this purpose. Your caster will clarify any item requiring further explanation.

This checklist provides a numbering system in which the lowest numbered description for each requirement can be met at the lowest production cost, as follows:

No. Cost Effect

- ☐ 1 Most economical basis for production
- ☐ 2 Involves additional work which may affect cost
- ☐ 3 Additional work which may increase cost
- ☐ 4 Special Requirements which may increase cost

Part # ______________________________

A	Casting Cleanliness	☐ 1 Some residue and chips not objectionable ☐ 2 Shop run — blown reasonably free of chips but not degreased ☐ 3 Clean, dry and free of chips ☐ 4 Special requirements
B	Cast Surface Finish	☐ 1 Mechanical quality — finish is not significant ☐ 2 Painting quality — streaks and chill areas coverable with paint ☐ 3 Highest quality — for electroplating, decorative finishing, O-ring seats
C	Metal Extension (Flash) Removal *Parting Line External Profile*	☐ 1 No die trimming — break off gates and overflows ☐ 2 Die trimmed to within 0.0150″ (0.38 mm) of die casting surface *(See NADCA Guideline G-6-5)* ☐ 3 Hand filed or polished — flush with die casting's surface ☐ 4 Customer defined requirements (such as thermal, tumble or vibratory deburring, or shot or grit blasting)
D	Metal Extension (Flash) Removal *Cored Holes*	☐ 1 Flash not removed ☐ 2 Flash trimmed to within 0.010″ (0.25 mm) of die casting surface ☐ 3 Flash to be machined
E	Metal Extension (Flash) Removal *Ejector Pins*	☐ 1 Not removed *(See NADCA Guidelines G-6-4)* ☐ 2 Crushed or flattened *(See NADCA Guidelines G-6-4)* ☐ 3 Removed from specific locations
F	Pressure Tightness	☐ 1 No requirement ☐ 2 Pressure-tight to agreed-upon psi (kPa). Testing medium: ___________________ ☐ 3 Other arrangements to be agreed upon
G	Flatness	☐ 1 No requirement ☐ 2 To NADCA "Standard" specification tolerances (S-4A-8) ☐ 3 Critical requirement — to NADCA "Precision" specification tolerances (P-4A-8) ☐ 4 Customer defined requirements
H	Dimensions	☐ 1 Normal: per NADCA "Standard" specification tolerances ☐ 2 Semi-critical: "Precision" tolerances on specified dimensions, others "Standard" ☐ 3 Critical: Special tolerances to be agreed upon
I	Customer's Receiving Inspection	☐ 1 No unusual inspection requirements — no Statistical Quality Control ☐ 2 Statistical quality control: Acceptable at Cpk 1.33 or higher (or AQL over _________________) ☐ 3 Statistical quality control: Acceptable at Cpk 2.0 or higher (or AQL over _________________)
J	Packaging	☐ 1 Not critical — bulk packed ☐ 2 Layer packed, with separators, or weight restriction ☐ 3 Packed in cell-type separators or individually wrapped ☐ 4 Customer defined requirements

** The specification provisions and procedures listed in Section 7, "Quality Assurance," should also be addressed.*

NADCA

C-8-2-15

CHECKLIST

This checklist is for use in consultation with your die caster prior to estimating production costs. Use in combination with the Finishing Checklist C-8-2. Also review Checklists T-2-1A and T-2-1B, for Die Casting Die Specification, in Section 2.

Commercial Practices

Casting Surface Finishing Specifications

To be used in consultation with your caster (Use in combination with Checklist C-8-1)*

Checklist for Finished Die, SSM and Squeeze Casting Part Purchasing

No. Cost Effect

- ☐ 1 Most economical basis for production
- ☐ 2 Involves additional work which may affect cost
- ☐ 3-4 Additional work which may increase cost
- ☐ 5 Most difficult surface to cast on a production basis

Part #______________________________

This Finishing Checklist provides a convenient method for assuring that important factors involved in the surface finishing of cast parts are evaluated and clearly communicated between the purchaser and the caster.

It should be used as a supplement to the essential dimensional and alloy specifications detailed on part prints submitted for quotation, since the listed factors directly affect the basis on which the casting quotation is made. The checklist may be reproduced for this purpose. Your caster will clarify any item requiring explanation.

This checklist provides a numbering system in which the lowest numbered description for each requirement can be met at the lowest production cost, as follows:

K	Casting Insert	☐ 1 No insert used in cast part ☐ 2 Inserts required, to be supplied by customer at 10% overage ☐ 3 Inserts required, to be supplied by caster
L	Parting Lines	☐ 1 Polishing not required ☐ 2 Polish only where marked on drawing ☐ 3 Polish all parting lines (except as noted)
M	Surface Preparation	☐ 1 No buffing required ☐ 2 Mechanical (burnishing, tumbling, etc.) ☐ 3 Buff as indicated on drawing
N	Plating, Anodizing or Other Special Finish	☐ 1 Protective Only — Specify: ______________________ ☐ 2 Decorative Paint — Specify: ______________________ ☐ 3 Severe Exposure Protection — Specify: ______________________
O	Painting	☐ 1 Heavy Paint, Protective Only — Specify: ______________________ ☐ 2 Decorative Paint — Specify: ______________________ ☐ 3 Application requires base coat or special treatment: ______________________ Specify: ______________________
P	Environmental	☐ 1 Normal interior use only ☐ 2 Exposure to weather — Specify: ______________________ ☐ 3 Exposure to unusual chemistry — Specify: ______________________
Q	As-Cast Surface *See NADCA Guidelines G-6-6*	☐ 1 Utility Grade — surface imperfections acceptable, nondecorative coatings ☐ 2 Functional Grade — slight, removable surface imperfections, heavier coatings ☐ 3 Commercial Grade — removable imperfections ☐ 4 Consumer Grade — no objectionable imperfections, as agreed upon, when viewed under normal lighting conditions at ____________ feet viewing distance ☐ 5 Superior Grade — specified average surface finish value of ____________ microinches, per print
R	Special Requirements	For special flash removal requirements, see *Checklist* C-8-1, items C & E For special packaging/weight restrictions, see *Checklist* C-8-1, item J

** The specification provisions and procedures listed in Section 7, "Quality Assurance," should also be addressed.*

Casting Examples

SECTION

9

9

Casting Examples

Aluminum

Part Name: Pistol Frame

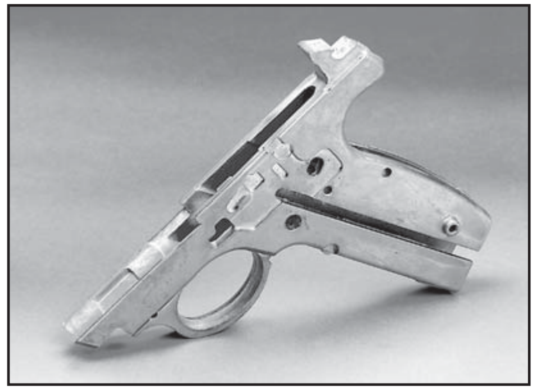
Application: 0.22 Caliber Pistol

Part Weight: 0.35 lbs.

Alloy: A380

Comments: Part was previously machined from stock. This is the first aluminum die casting used by Smith & Wesson.

Customer: Smith & Wesson



Aluminum

Part Name: Rocker Arm

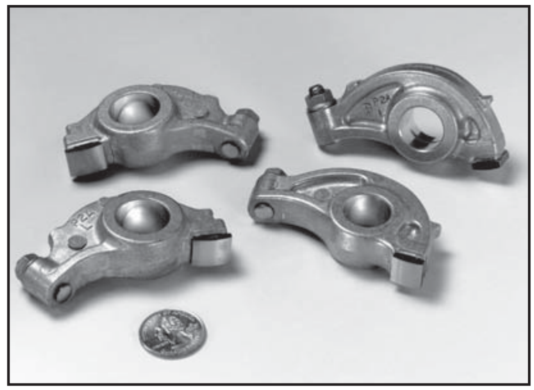
Application: Honda Civic Engine

Part Weight: 0.48 lbs.

Alloy: 383

Comments: Process improvements and strict attention to detail resulted in cost savings on these high integrity, near porosity-free parts. The parts include a special “wear” insert chip and meet very tight specifications.

Customer: Honda of America Mfg., Inc.



Aluminum

Part Name: Right/Left Hand Bracket

Application: BRP Skidoo

Part Weight: 0.75 lbs.

Alloy: Aural-2

Comments: Part was previously made from low pressure perma-nent mold with extensive machining. High vacuum die casting created a heat treatable and weldable part for structural applica-tion, requiring minimal machining. Overall piece price reduction was on the order of 40%.

Customer: BRP Skidoo

Aluminum

Part Name: Endbell

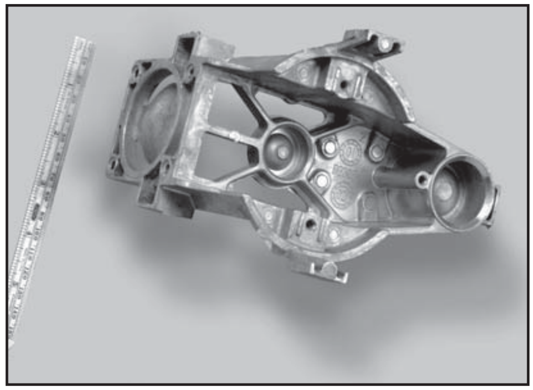
Application: Air Compressors

Part Weight: 0.85 lbs.

Alloy: 380

Comments: Major tooling and process improvements resulted in scrap reduction, increased cost savings, production and quality. Completed cast units highly competitive in the market against lower entry models produced using stamped steel.

Customer: Devilbiss Air Power Company



Aluminum

Part Name: Engine Base Bracket

Application: Honda Accord Engine

Part Weight: 6.2 lbs.

Alloy: ADC3SF jointly developed with Honda, compatible with SF36, Aural 2

Comments: Replacing a previously stamped, 16 piece part, the new part is 27 in. long, thin-walled, with screw bosses, eliminating the welding operation and reduced weight by 43.6%.

Customer: Honda

Aluminum

Part Name: Water Passage

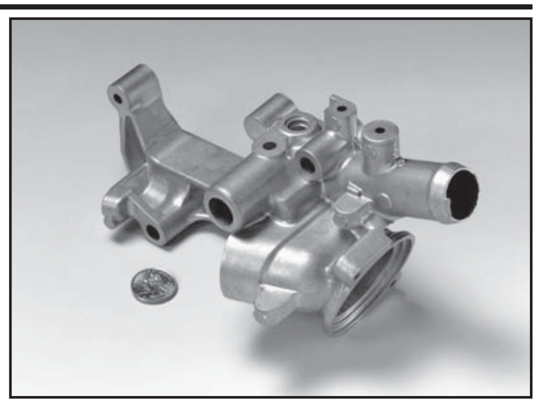
Application: Honda Civic Engine

Part Weight: 1.4360 lbs.

Alloy: 383

Comments: The Water Pasage hose mating surface is cast to specifications allowing the shipping of the part to the customer without any machining to the snout. This tight tolerance allows a cost savings to the customer. The customer saves the cost of machining for the snout, which is estimated at a 23% cost savings.

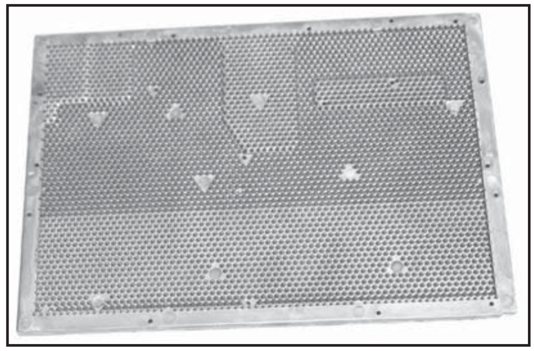
Customer: Honda of America Mfg. Inc.



Casting Examples

Aluminum

Part Name: Heat Sink Front & Back



Application: Garmin G-1000
Flat Panel Flight Display

Part Weight: 1.91 lbs.

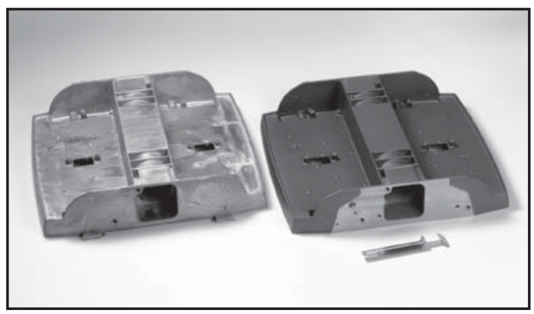
Alloy: 360

Comments: Parts are assembled to collect & disperse heat from an LCD unit. Converted from machined parts to die castings. Increased production rate & reduced piece part cost. First time use of aluminum heat sink for this type of application. 360 alloy was selected based on it's corrosion resistance which protects the assembly from oxidation & other corrosion resulting from frequent atmospheric changes experienced by components used in general aviation. Painting or coatings are not required & are ready for assembly upon arrival at customer location.

Customer: Garmin International

Aluminum

Part Name: Chassis



Application: Human Transporter

Part Weight: 8.2 lbs.

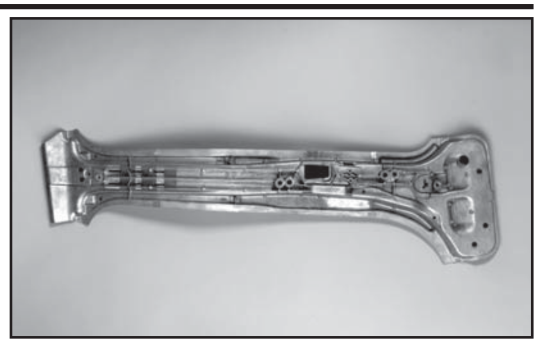
Alloy: 380

Comments: The casting is produced to net shape and meets strict specifications. True position tolerances on critical dimensions were reduced resulting in reductions in machining and substantial cost savings.

Customer: Segway

Aluminum

Part Name: B Pillar



Application: Automotive Structural Support

Part Weight: 9.2 lbs.

Alloy: 380

Comments: A new part cast for automobile body framing support application. Yields weight savings benefit over fabricated steel components.

Customer: –

Casting Examples

Aluminum

Part Name: Trimmer Deck Housing

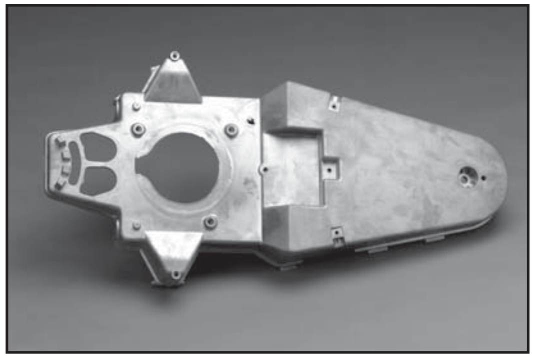
Application: Walk Behind Trimmer

Part Weight: 9.2 lbs.

Alloy: 380

Comments: As compared to a previous die casting design and tooling design, newly designed tooling allowed for scrap reduction (34%), cycle time reduction (52 sec.) and weight reduction (2 lbs.).

Customer: Garden Way, Inc.



Aluminum

Part Name: RFU Enclosure

Application: Microwave Communications

Part Weight: 15.8 lbs.

Alloy: 413

Comments: Formerly produced as an investment casting. Provides heat dissipation and electrical conductivity. Die casting reduced lead time and machining requirements.

Customer: Harris Corporation, Microwave Communications Division

Aluminum

Part Name: Impeller

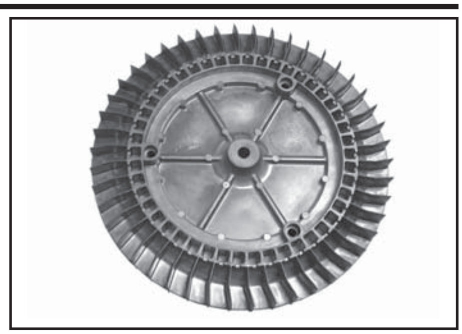
Application: Industrial/Commercial Blower

Part Weight: 10.29 lbs

Alloy: A380

Comments: Impeller used in industrial and commercial blowers. The application of the die cast part enabled the unit to operate at higher speeds, with less noise, while reducing the amount of secondary machining.

Customer: Ametek Rotron



9

Casting Examples

Aluminum

Part Name: Lower Crankcase

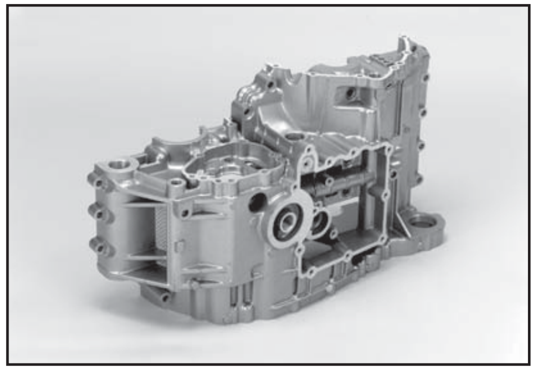
Application: Motorcycle

Part Weight: 16.31 lbs.

Alloy: LM2 to JVM Specifications

Comments: Redesign of original T120, 1959 Bonneville high performance version of Triumph's 650cc twin. Eliminated costly secondary machining operations, additional engine parts and fully utilized the benefits of high pressure die casting process.

Customer: Triumph Motorcycles



Aluminum

Part Name: Differential Carrier

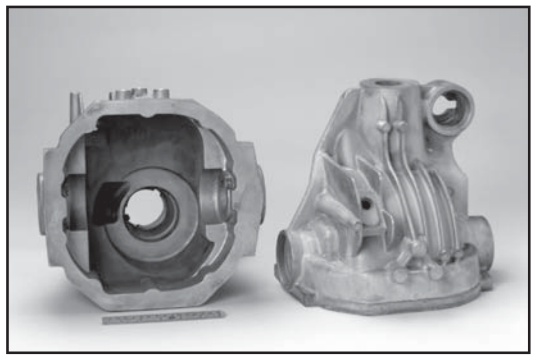
Application: Independent Rear Suspension

Part Weight: 16.5 lbs.

Alloy: ADC-12 -T6 Heat Treatment

Comments: Past generation was an iron casting. First high volume squeeze casting used in an independent rear suspension axel carrier. Squeeze casting decreased weight by 22 pounds over cast iron process.

Customer: Visteon Corporation



Aluminum

Part Name: Beta Crankcase Right & Left

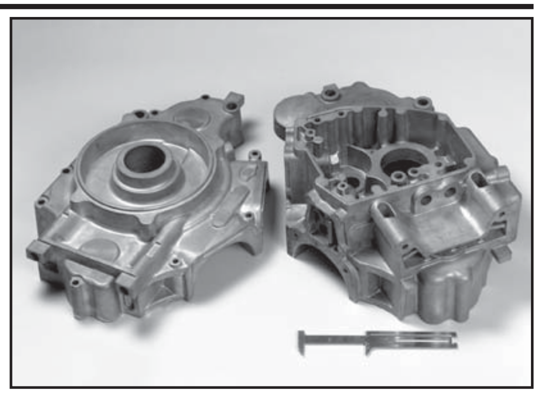
Application: Motorcycle

Part Weight: 16.8 lbs.

Alloy: 383

Comments: These net-shape, complex castings were converted from the permanent mold process to meet stringent specifications of improved quality, pressure tightness, cosmetic appearance, higher volume and cost reductions.

Customer: Harley-Davidson



Casting Examples

Aluminum

Part Name: Scooter Monocoque Frame

Application: Honda Scooter Super Sport

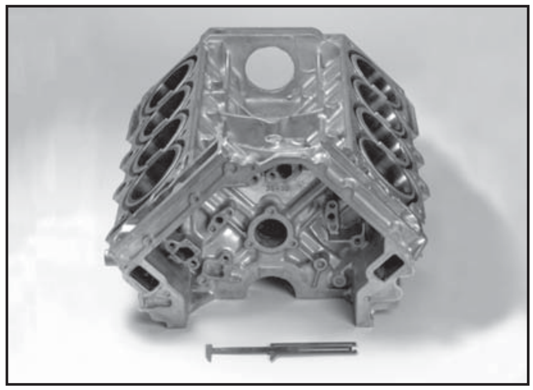
Part Weight: 23.4 lbs.

Alloy: JIS ADC12; 383 equivalent

Comments: Previously fabricated from steel sheet stamping and pipes. Die casting provided weight savings and cost reduction.

Customer: Honda R&D Co., Ltd.

Aluminum



Part Name: Rear Wheel Drive Northstar Block Casting

Application: Rear Wheel Drive Northstar Engine

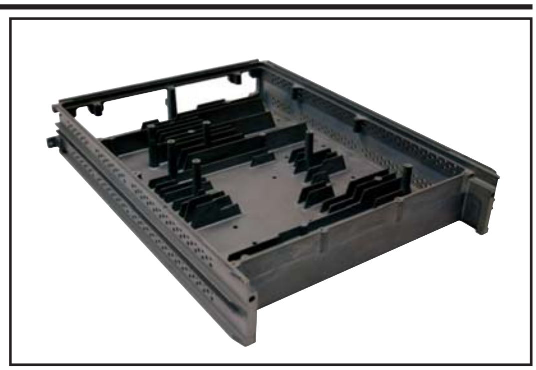
Part Weight: 79.83 lbs.

Alloy: A380

Comments: –

Customer: GM Powertrain

Aluminum



Part Name: Power Conditioning Module Chassis

Application: Computer/Electronics

Part Weight: 2.3 lbs.

Alloy: 380

Comments: Originally machined from a roughly shaped ingot, this chassis gained significant cost savings after being converted to an aluminum die casting.

Customer: Novatel Wireless Technologies, LTD

9

Casting Examples

Aluminum

Part Name: Aluminum MMC Brake Drum

Application: Commercial, Military, and Special Vehicles

Part Weight: 38.5 lbs.

Alloy: A356.2

Comments: Originally produced in cast iron. A unique horizontal squeeze cast process allowed a selectively placed ceramic preform to be infiltrated, creating a selectively reinforced, Metal Matrix Composite (MMC) aluminum brake drum. The new brake drum weights at least 45% less.

Customer: Century 3+ Inc.

Aluminum

Part Name: Automotive AWD Clutch Housing

Application: Automotive

Part Weight: 2.4 lbs.

Alloy: ADC12-T5

Comments: Originally produced as a multi-step forged steel housing, but this part was successfully convert this part to an aluminum squeeze casting. The new squeeze cast design incorporated 33 spline teeth with 0.1 degree draft. A significant mass reduction was obtained resulting in better fuel efficiency and reduced inertia for improved all wheel drive engagement response time.

Customer: Borg Warner TTS, PTC

Aluminum

Part Name: RWD Transmission

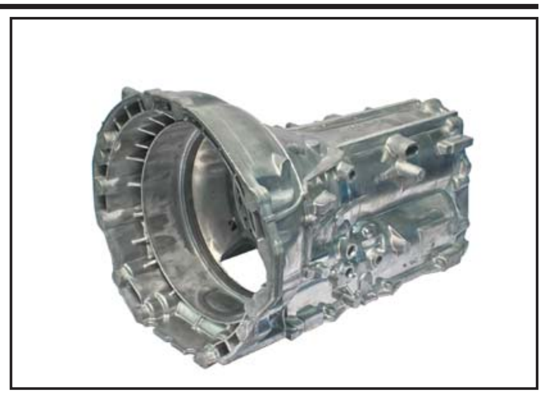
Application: Automobile Industry

Part Weight: 37.4 lbs.

Alloy: A380

Comments: Utilizes a unique process, involving 2 cast-in steel tubes, which have to be inserted in the ejector die and maintain location.

Customer: Chrysler



Casting Examples

Magnesium

Part Name: Frame

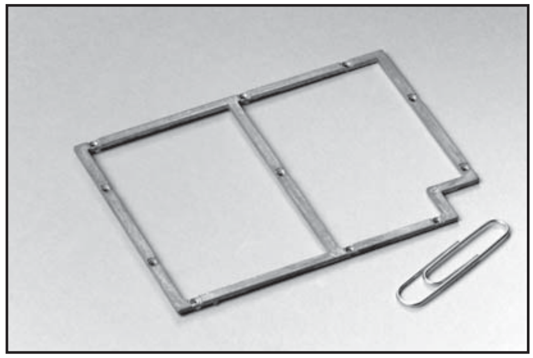
Application: Novatel Expedite Modem

Part Weight: 0.01 lbs.

Alloy: AZ91D

Comments: Converted from a plastic part. The magnesium casting eliminated a plastic part sandwiched between two metal plates and held together with self tapping screws, resulting in cost savings to the customer.

Customer: Novatel Wireless Technologies, LTD



Magnesium

Part Name: Head Node

Application: Mountain Bike

Part Weight: 0.22 lbs.

Alloy: AZ91D

Comments: Originally designed as two aluminum investment cast parts, this unique die cast mag design and application yields a 30% weight savings, part and assembly cost savings, better consistency in impact and fatigue and better performance.

Customer: Cannondale

Magnesium

Part Name: Fishing Reel

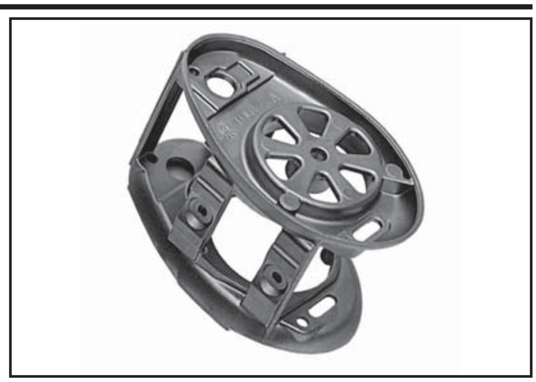
Application: Ardent XS Fishing Reel

Part Weight: 31.3 grams

Alloy: AZ91D

Comments: Converted from plastic & die cast aluminum components. Complex geometry & varying wall thickness. Tooling uses 3 slides to form entire exterior of part. Tight tolerance machining of bores and surfaces for mating components. 100% made in USA (Components & Assembly).

Customer: Marsh Technologies, Inc.



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Casting Examples

Magnesium

Part Name: Clutch Cover

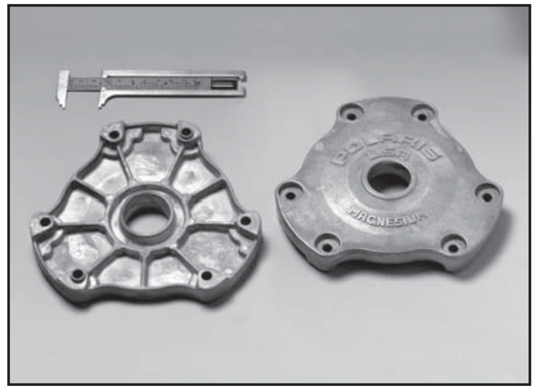
Application: All Terrain Vehicle Clutch

Part Weight: 0.44 lbs.

Alloy: AZ91D

Comments: A conversion from aluminum die casting to magnesium die casting resulted in a weight reduction of 45% and a significant cost reduction by eliminating machining.

Customer: Polaris Industries, ATV Div.



Magnesium

Part Name: Camera Assembly

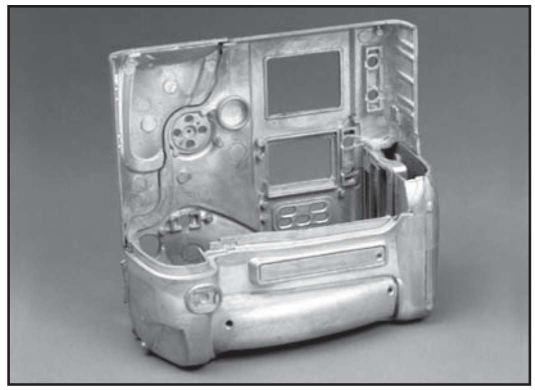
Application: Digital Camera

Part Weight: 0.48 lbs.

Alloy: AZ91D

Comments: Originally designed as aluminum investment cast parts, the design complexity and required precision mandated a transition to magnesium die cast parts.

Customer: Eastman Kodak



Magnesium

Part Name: Hand-Held Computer Housing

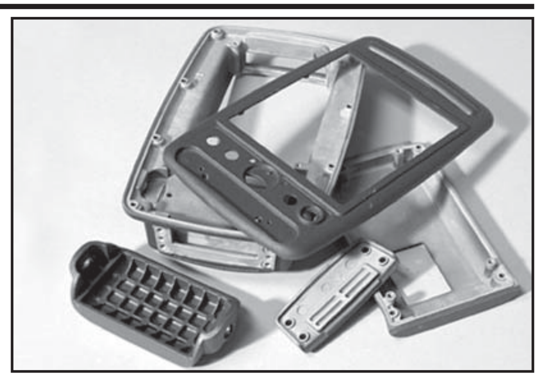
Application: Hand-Held Computer

Part Weight: Over 0.5 lbs.

Alloy: AZ91D

Comments: –

Customer: Telxon Corporation



Casting Examples

Magnesium

Part Name: Gear Case Housing Assembly

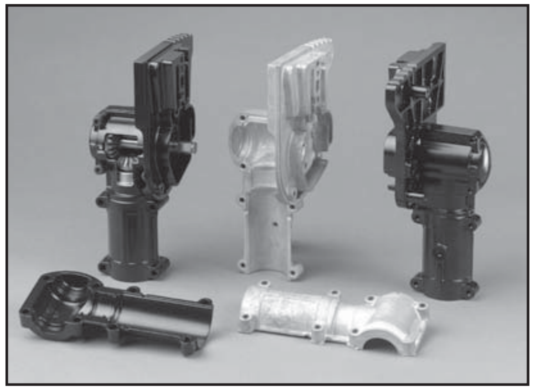
Application: Automatic Power Pruner

Part Weight: 0.64 lbs.

Alloy: AZ91D

Comments: Magnesium was chosen for it's strength and low weight for this application over plastic and aluminum. Bearing diameter tolerances of 0.001" are required and eliminate machining and masking cost.

Customer: Echo



Magnesium

Part Name: Lock Housing

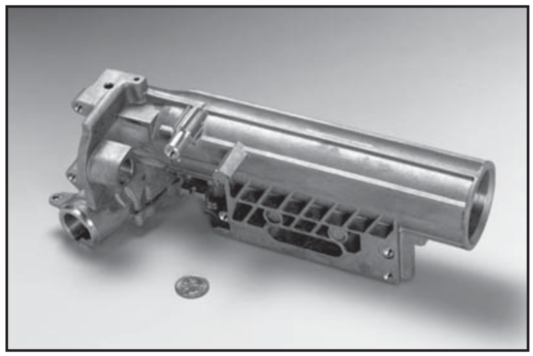
Application: SUV Tilt Steering Column

Part Weight: 2.02 lbs.

Alloy: AM60B

Comments: This die casting controls the tilt/telescoping features in the steering column and incorporates the ignition switch, shift lever and brake-shift interlock into one casting. In addition to tight dimensional control, the higher elongation in AM60B alloy provides good crash energy management.

Customer: Visteon/Ford



Magnesium

Part Name: Fairing Support Bracket

Application: Buell 1125R Superbike

Part Weight: 2.71 lbs.

Alloy: AZ91D

Comments: This bracket provides support for the motorcycle's instrument cluster, windshield/cowling, direction signals and rearview mirror with increase copacity and a cost savings of aproximatly 26%.

Customer: Buell Motercycle Co.

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Casting Examples

Magnesium

Part Name: Seat Back and Cushion

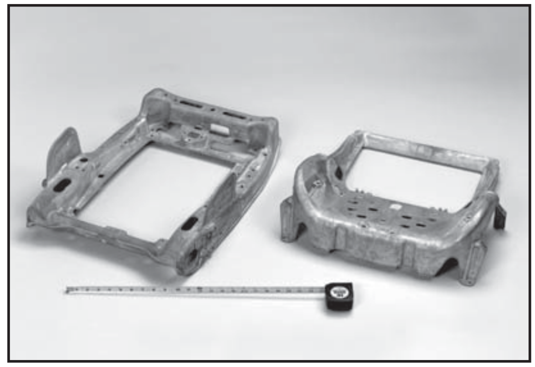
Application: Luxury Car Seat Back and Cushion

Part Weight: –

Alloy: AM60B

Comments: –

Customer: –



Magnesium

Part Name: Vehicle Lift Gate Inner Panel

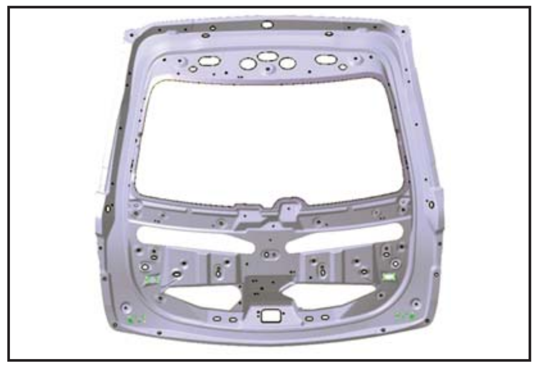
Application: Automotive

Part Weight: 18 lbs.

Alloy: AM60

Comments: Replacing a stamped steel assembly, this large die cast magnesium lift gate reduced weight, added design flexibility and reduced assembly time through the integration of various components. The die cast lift gate is 54 x 52 inches.

Customer: Ford Motor Co.



Magnesium

Part Name: Cross Car Beam for Instrument Panel

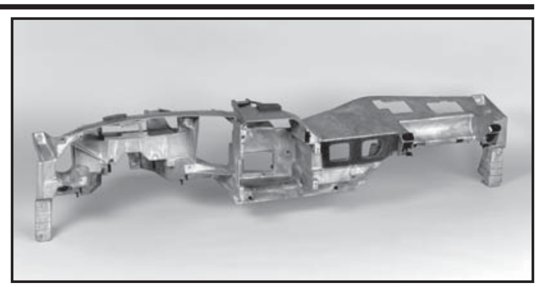
Application: General Motors Medium Duty Trucks

Part Weight: 21.5 lbs.

Alloy: AM60B

Comments: An example of maximizing the die casting process, machine and die to obtain substantial cost savings. The improvements resulted in weight savings & cost reductions through decreased material, downtime, and elimination of machining/repair.

Customer: General Motors Truck



Casting Examples

Magnesium

Part Name: Oil Tank

Application: Snowmobile

Part Weight: 2.03 lbs.

Alloy: AZ91D

Comments: This magnesium oil tank replaces one that was a stamped aluminum and brazed assembly. The case is comprised of 3 separate magnesium die castings. It is lighter and more tunable than the aluminum it replaces.

Customer: Arctic Cat Inc.

Magnesium

Part Name: SAWZALL Gear Case Assembly

Application: Power Tool

Part Weight: .293 lbs.

Alloy: AZ91D

Comments: Met customer requirements of eliminating machining and reducing cost of similar aluminum castings. Magnesium die casting holds dimensional tolerances that eliminate the need to machine.

Customer: Milwaukee Electric Tool Co.

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Casting Examples

Zinc

Part Name: Knot

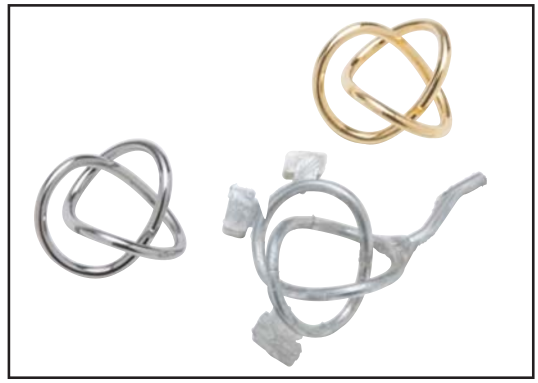
Application: Marketing

Part Weight: 5.5 Grams

Alloy: ZP5

Comments: This item's shape has never been industrially manufactured and displays ingenious part and tooling design.

Customer: Nyrstar



Zinc

Part Name: Bracket

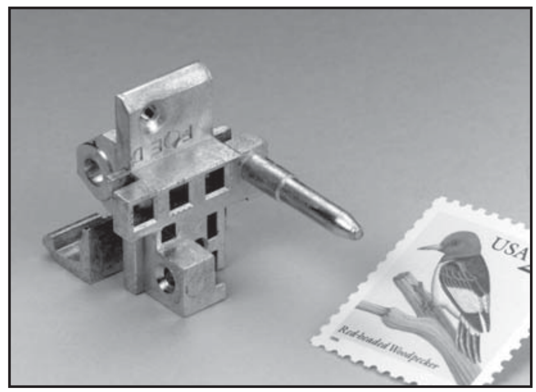
Application: Electronics Enclosure

Part Weight: 15.42 Grams

Alloy: Zamak No. 3

Comments: Converted from a machined aluminum alloy resulting in cost savings. The part is cast to net-shape thereby totally eliminating any machining.

Customer: –



Zinc

Part Name: Faucet Handle

Application: Two Handle Lavatory Faucet

Part Weight: 119 Grams

Alloy: Zamak No. 3

Comments: Major cost savings were achieved from tooling changes, which eliminated trimming, reduced polishing the parting line and machining operations.

Customer: Delta Faucet Company

Casting Examples

Zinc

Part Name: Connector

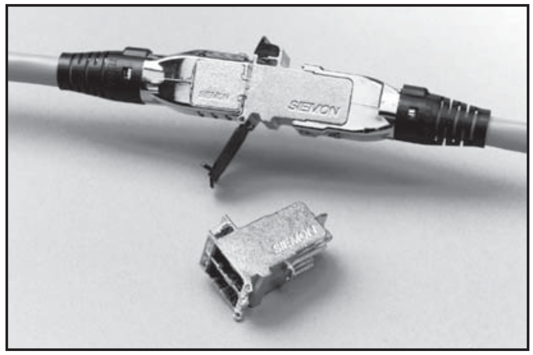
Application: "TERA" Connector

Part Weight: 0.4 oz.

Alloy: Zamak No. 3

Comments: Die casting offered superior EMI shielding and mechanical integrity at a favorable cost.

Customer: Siemon Company



Zinc

Part Name: Kitchen Faucet Hub

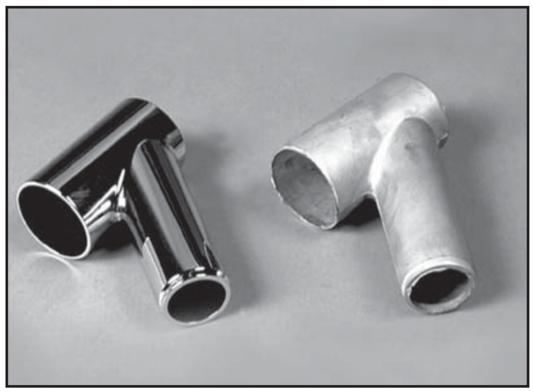
Application: Pull-Out Faucet

Part Weight: –

Alloy: Zamak No. 3

Comments: –

Customer: Delta Faucet Company



Zinc

Part Name: Fuel Fitting

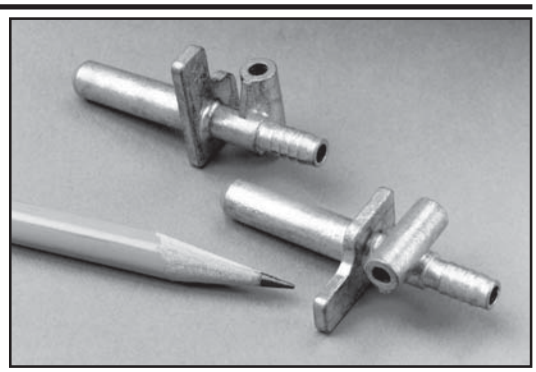
Application: Dragon Fly™ Cook Stove

Part Weight: 0.5 oz.

Alloy: Zamak No. 3

Comments: Originally designed as an assembly of three screw-machined components. Converting the component to die cast Zamak 3 provided a cost reduction and allowed for the streamlining.

Customer: Mountain Safety Research



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Casting Examples

Zinc

Part Name: Reverse Valve Casting

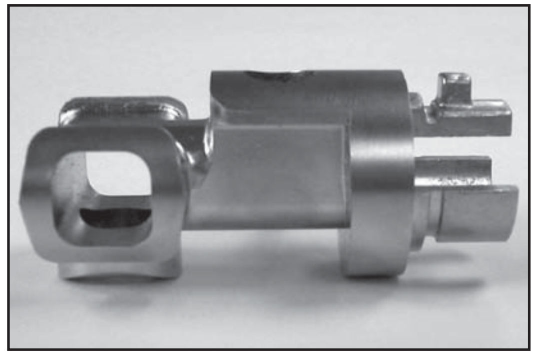
Application: Snap-On Tools

Part Weight: 1.06 oz.

Alloy: Zamak No. 5

Comments: Exceedingly complex, high tolerance die casting produced in high volumes & requiring minimum machining. Zinc die casting selected over powder metallurgy, machining & metal injection molding because of lower production costs. 50 mils to 230 mils casting thickness & a stepped hole (to a final ID of 0.3000") extending the length of the cylinder with minimum draft.

Customer: Vic Royal



Zinc

Part Name: Casket Arm

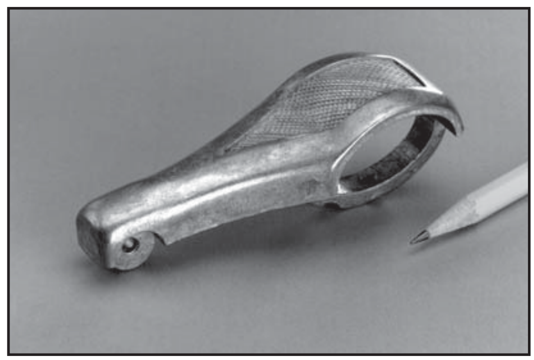
Application: Casket

Part Weight: 3.5 oz.

Alloy: Zamak No. 3

Comments: This precisely cored zinc die casting provides the right amount of friction with the hinge to allow the lift bar to remain in the position it was last set. Was a steel stamping.

Customer: Vic Royal



Zinc

Part Name: Display Frame Component

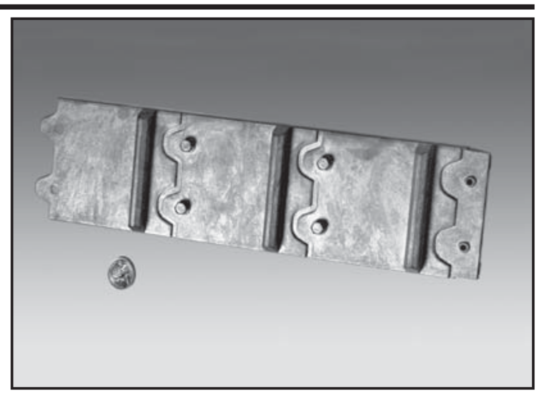
Application: Store Display Unit

Part Weight: 26.16 oz.

Alloy: Zamak No. 3

Comments: Conversion from a steel weldment to a die casting resulted in substantial cost savings. The casting is used as the frame for a track running shoe display rack.

Customer: CDC Marketing



Zinc

Part Name: Outside Cover

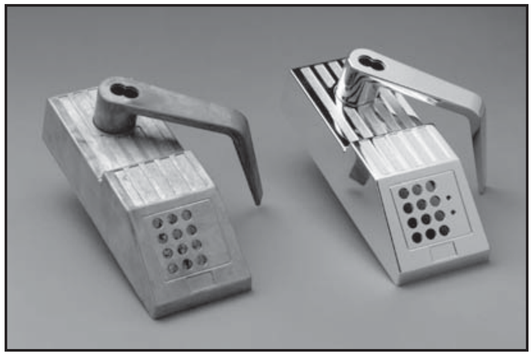
Application: Power Lever Door Lock

Part Weight: 3.0 lbs.

Alloy: Zamak No. 3

Comments: Converted from a permanent mold casting, these die cast parts offer thinner walls, less prep for plating due to the extraordinary surface finish and cost savings (39%).

Customer: Mas-Hamilton Group



Zinc

Part Name: Front Plate L-20

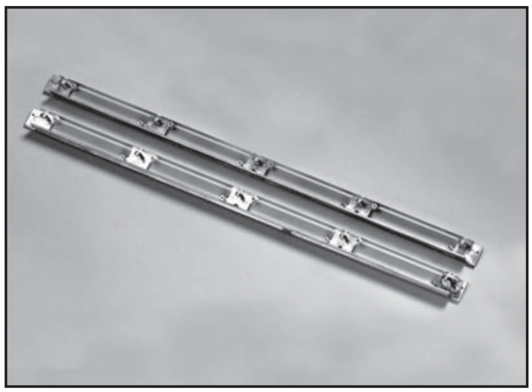
Application: Telecommunications Extension Shelf

Part Weight: 3.53 oz.

Alloy: Za4Cu1

Comments: New part for mounting optical and electrical cartridges. Challenge of fill very thin walls and narrow (0.2 mm) flatness tolerance. Success related to vacuum technology, die thermal conditioning and precision and sprue runner design.

Customer: ALCATEL ITALIA S.p.A.



Zinc

Part Name: Connector Housing

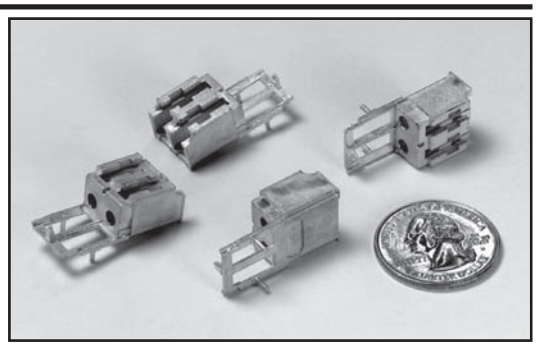
Application: Fiber Optic Transceiver

Part Weight: 0.19 oz.

Alloy: Zamak No. 2

Comments: Previously produced from multiple machined cast metal or sheet metal fabricated parts, which lacked precision for speedy assembly of components. Cost savings in material, production methods and labor were achieved with the conversion to die casting.

Customer: Agilent Technologies



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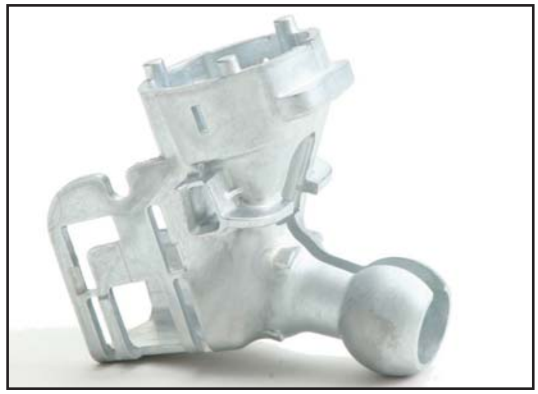
Casting Examples

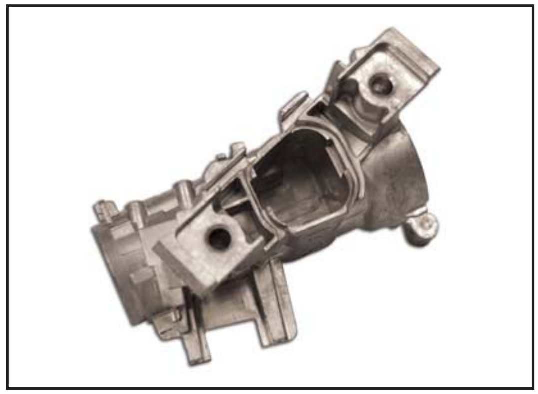
Zinc

Part Name:	Rearview Mirror Mount
Application:	Windshild-to-mirror head transition housing
Part Weight:	4.1 oz.
Alloy:	Zamak No. 5
Comments:	The part was designed around the mirror mount's humidity sensor for the smallest possible footprint.
Customer:	Gentex Corporation



Zinc

Part Name:	Steering Wheel Ignition and Lock Housing
Application:	Automotive
Part Weight:	13.9 oz
Alloy:	Zamak #5
Comments:	The ignition and lock housing is a safety-critical component of the automotive steering column. It keeps the steering wheel locked until the car is ready to start and drive.
Customer:	Valeo Sisitemas Electronics, SA de CV



Zinc

Part Name:	Headlamp Visor
Application:	Harley-Davidson Motorcycle
Part Weight:	2.78 lbs.
Alloy	ZA8
Comments:	Combined two parts into one to reduce cost and part numbers. As the center point of the integrated motorcycle handlebar assembly it needs to be functional and aesthetic. Carefully controlled process produces a surface finish conducive for a highly cosmetic chrome plate finish.
Customer:	Harley-Davidson

Zinc

Part Name:	Bracket, Camera, ASIC
Application:	Infrared Interactive Whiteboard
Part Weight:	0.065 oz.
Alloy	Zamak #3
Comments:	This zinc die casting replaces an ABS plastic part. It improves the product durability and performance. The casting is used to hold an infrared camera ridigly in place on an interactive whiteboard. This whiteboard connects to a computer and employs infrared light to locate all interactions with the whiteboard.
Customer	SMART Technologies

Casting Examples

ZA (Zinc-Aluminum)

Part Name: Tool Housing & Components

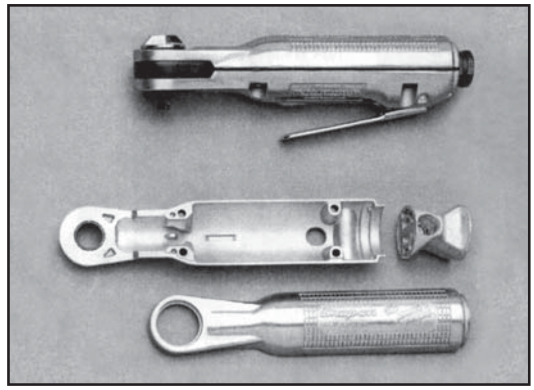
Application: Air-Powered Hand Tool

Part Weight: –

Alloy: ZA-8 and ZA-27

Comments: The components for this air ratchet tool consist of two die cast ZA-27 split halves incorporating as-cast "grip" surface embossing, logos and identification and a one-piece ZA-8 air manifold that does not require machining. ZA alloys allowed wall thicknesses of 0.060 inch for the handles and enhanced sound suppression for quieter operation. Previously an assembly of a machined steel head and a cast aluminum handle housing that required extensive machining was used.

Customer: Snap-On



ZA (Zinc-Aluminum)

Part Name: Transmission Shift Selector Tube Unit

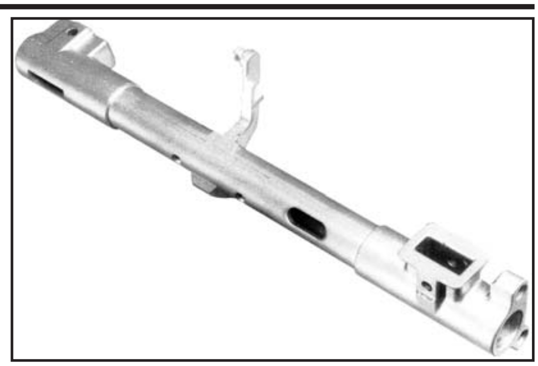
Application: Passenger Car & Light Truck

Part Weight: 1.1 lb.

Alloy: ZA-8

Comments: This single die casting replaced a four piece assembly and resulted in an estimated 50% cost savings.

Customer: –



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Glossary

This glossary of terms is presented to aid the product designer and specifier in communicating with the custom die caster during product development and production. It includes definitions involved in product prototyping, the design and construction of the die casting die and trim die, die casting production and post-casting machining and surface finishing operations.

Abrasive blasting

A process for cleaning or finishing by which abrasive particles are directed at high velocity against a casting or work piece.

Acid pickle

A method to remove oxides and other contaminants from metal surfaces.

Aging

A change in the metallurgical structure of an alloy occurring over a period of time following casting, which affects the properties and dimensions. Heating accelerates aging.

Aging, artificial

A low temperature heat treatment meant to accelerate aging, generally applied to increase strength and/or to stabilize properties.

Aging, natural

Aging that occurs at room temperature.

Alloy

A substance having metallic properties and composed of two or more chemical elements, of which at least one is metal. Alloy properties are usually different from those of the alloying elements.

Alloy, primary

Any die casting alloy whose major constituent has been refined directly from ore, not recycled scrap metal.

Alloy, secondary

Any die casting alloy whose major constituent is obtained from recycled scrap metal. Nearly 95% of die castings provided in North America are made from secondary alloys.

Alloy, standard

Any die casting alloy that has been assigned an ASTM designation.

Alloying

The process of making a die casting alloy from its various constituents. The process usually consists of melting the major constituent and adding the others to the bath where they then dissolve. The molten metal is then cleaned of contamination by fluxing.

Amortization

A financial method to defer tooling cost and include the tooling cost with casting production on a prorated basis. For example, if tooling life is agreed to be 100,000 acceptable castings and the tooling cost is $100,000, the prorated cost is $1.00 per each acceptable casting shipped, and invoiced at shipment.

Anode

The electrode in a plating bath at which metal ions are formed, negative ions are discharged or other oxidizing reactions occur.

Anodic metal

Any metal that tends to dissolve, corrode or oxidize in preference to another metal when the metals are connected electrically in the presence of an electrolyte.

Glossary

Anodizing

To subject a metal to electrolytic action as the anode of a cell in order to coat with a protective or decorative film.

ANSI

American National Standards Institute.

AQL

Acceptable Quality Level, as agreed upon for the fulfillment of production orders.

As-Cast

Condition of a casting that has not been given a thermal treatment subsequent to casting. This is also termed as the “F temper.”

ASQ

American Society for Quality.

ASTM

American Society for Testing and Materials.

Atmospheric corrosion

Surface corrosion caused by exposure in the environment to gasses or liquids that attack the metal.

Bailment

The voluntary transfer of property, such as dies, fixtures, gages, etc., in trust by the Bailor (customer) to the Bailee (vendor). This can be codified with a “Bailment Agreement”.

Ball burnishing

The smoothing of surfaces by means of tumbling parts in the presence of hardened steel balls, without abrasives.

Barrel burnishing

The smoothing of surfaces by means of tumbling a part in rotating barrels in the presence of metallic or ceramic shot, without abrasives.

Barrel plating

Plating in which a part is processed in bulk in a rotating container.

BHN

Brinell Hardness Number, scale used to indicate hardness.

Biscuit

Excess metal left at the end of the injection cylinder of a cold-chamber die casting machine, formed at the end of the plunger stroke. Also called a slug.

Black chromium

Nonreflective, black chromium coating electrodeposited from a sulfate-free bath.

Black nickel

Nonreflective, decorative, black nickel coating having little protective value, produced by electroplating or simple immersion.

Blister

A surface defect or eruption caused by expansion of gas, usually as a result of heating trapped gas within the casting, or under metal which has been plated on the casting.

Blow holes

Voids or holes in a casting that may occur due to entrapped air or shrinkage during solidification of heavy sections.

Bright finish

A finish with a uniform nondirectional smooth surface of high specular reflectance.

Bright nickel

Decorative nickel plate that is deposited in the fully bright condition.

Bright plating

A process that produces an electrodeposit having a high degree of specular reflectance in the as-plated condition. Abrasive particles are applied in liquid suspension, paste or grease stick form.

Buffing

Smoothing a surface with a rotating flexible wheel, to the surface of which fine abrasive particles are applied in liquid suspension, paste or grease-stick form.

Burnishing

The smoothing and polishing of a metal surface by rubbing or tumbling in the presence of metallic or ceramic balls and in the absence of abrasives.

Butyrates

Organic coatings based on butyric acid derivatives having excellent initial color and good resistance to weathering.

Cp

Capability index.

Cpk

Total process capability. A production process capability index of both a process dispersion and its central tendancy, taking into account the spread of the distribution and where the distribution is in regard to a specification midpoint.

CQI

Continuous Quality Improvement, an approach to quality management that builds upon traditional quality assurance methods by emphasizing the organization and systems. It focuses on “process” rather than the individual; recognizes both internal and external “customers”; and, promotes the need for objective data to analyze and improve processes.

Cadmium plate

A coating of cadmium metal applied to an aluminum or steel substrate for corrosion protection or improved solderability. Cadmium plate on zinc die castings requires an intermediate barrier layer of nickel.

Cass test

(Copper accelerated salt spray) An accelerated corrosion test for electroplated substrates (ASTM 368-68).

Castability

The relative ease with which an alloy can be cast; includes the relative ease with which it flows and fills out a die/mould cavity, and its relative resistance to hot cracking and tearing.

Casting rate

The average number of shots that can be cast during one hour of steady running.

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Casting section thickness

The wall thickness of the casting. Since the casting may not have a uniform thickness, the section thickness may be specified at a specific place on the casting. Also, it is sometimes useful to use the average, minimum or typical wall thickness to describe a casting.

Casting yield

The weight of casting or castings divided by the total weight of metal injected into the die, expressed as a percent.

Casting cycle

The total number of events required to make each casting. For die castings, the casting cycle generally consists of solidification time, machine movement and sequencing time and the operator's manual movements.

Casting drawing

The engineering drawing that defines the size, shape and tolerances of the casting. This is a detailed drawing of the casting only and not an assembly of the product in which the casting is included.

Casting, functional

A die casting that serves a structural or mechanical purpose only. It has no decorative value.

Casting thickness

See Casting section thickness.

Casting, thin wall

A term used to define a casting which has the minimum wall thickness to satisfy its service function.

Casting volume

The total cubic units (i.e. cu. in. or cu. mm) of cast metal in the casting.

Cathode

The electrode in electroplating at which metallic ions are discharged, negative ions are formed or other reducing actions occur.

Cathode robber

An auxiliary cathode so placed as to divert electrical current to itself from portions of the articles being plated which would otherwise receive too high a current density.

Cathodic metal

Any metal that does not tend to dissolve, corrode or oxidize in preference to another metal when the metals are connected electrically in the presence of an electrolyte.

Cavity

The recess in the die in which the casting is formed.

Cavity block

The portion of the die casting die into which most, if not all, the cavity is formed. There are usually at least two cavity blocks in each die set.

Cavity fill time

That period of time required to fill the cavity with metal after the metal begins to enter the cavity.

Center line shrinkage

Shrinkage or porosity occurring along the central thermal plane or axis of a cast part.

Glossary

Charpy

Name of an impact test in which the specimen, forming a simple beam, is struck by a hammer while resting against anvil supports spaced 40 mm apart.

Checking

See **Fatigue, thermal**.

Chemical cleaning

The removal of foreign material from a surface by means of immersion or spraying without the use of current.

Chromate

A conversion coating consisting of trivalent and hexavalent chromium compounds.

Chromating

The application of a chromate coating.

Chrome pickle

A chemical treatment for magnesium in nitric acid, sodium dichromate solution. The treatment gives some protection against corrosion by producing a film that is also a base for paint.

Chromium plate

A coating of electrodeposited chromium metal which affords superior resistance to tarnishing and abrasion.

Clamping capacity

The force a die casting machine is capable of applying against the platen to hold the die closed during metal injection.

Clamping force

Actual force applied by a die casting machine to a die clamp to keep the die closed. This may be less than the clamping capacity of the die casting machine.

Cold chamber

The molten metal chamber of a cold-chamber, die casting machine. This is a hardened tube (shot sleeve) through which the shot plunger moves to inject the molten metal into die. The cold chamber and plunger combine to form a metal pump. It is called the cold chamber because it is cold relative to the metal put into it.

Cold forming

Bending of a die casting without the application of heat to achieve a desired shape that is different than that as cast. Cold forming is frequently used to hold an assembled part to the die casting.

Cold shut

A lapping that sometimes occurs where metal fronts join during the formation of solidified metal that sometimes occurs in the formation of die castings which constitutes an imperfection on or near the surface of the casting.

Cold-Chamber machine

A die casting machine designed so that the metal chamber and plunger are not continually immersed in molten metal.

Color anodize

An anodic coating that is dyed before sealing with an organic or inorganic coloring material.

Glossary

Coloring

The production of desired colors on metal surfaces by appropriate chemical or electrochemical action, or light buffing of metal surfaces for the purpose of producing a high luster; also called Color Buffing.

Combination die

A die with two or more different cavities each producing a different part, also called a family die.

Composite plate

An electrodeposit consisting of two or more layers of metal deposited successively.

Compressive yield strength

The maximum stress that a metal, subjected to compression, can withstand without a predefined amount of yield (normally 0.2% for die castings).

Contraction

The linear change typically occurring in metals and alloys on cooling to room temperature.

Contraction Factor

A factor used to multiply casting dimensions to obtain casting die dimensions. It accommodates differences in Coefficients of Thermal Expansion of the die steel and alloy, and die operating temperatures.

Conversion coating

A coating produced by chemical or electrochemical treatment of a metallic surface that forms a superficial layer containing a compound of the metal; example: chromate coatings on zinc and cadmium, oxide coating on steel.

Cooling channel

A tube or passage in a die casting die through which a coolant (typically water, oil or air) is forced to cool the die.

Copper plate

A coating of copper deposited by electrolytic or electroless plating methods. Copper electroplated from a cyanide solution is generally used as the initial layer in plating zinc die castings. Acid copper is used as a leveling deposit under nickel-chromium plate.

Core

A part of a die casting die that forms an internal feature of the casting (usually a feature with considerable dimensional fidelity) and is a separate piece from the cavity block. A core may be fixed in a stationary position relative to the cavity block or may be actuated through some movement each time the die is opened.

Core pin

A core, usually of circular section. Core pins are hot work tool steel pins, usually H-13, used for a cored hole in a die casting and may be fixed or movable. A core is made from a core pin.

Core plate

The plate to which the cores are attached and which actuates them.

Core slide

Any moving core.

Core, fixed

A core that, as the die opens and closes, does not move relative to the cavity block into which it is mounted.

Core, moving

A core that must move through some travel as the die opens or immediately after the die has opened, to allow the unrestricted ejection of the casting.

Corrodkote

An accelerated corrosion test for electroplated substrates (ASTM 380-65).

Corrosion

Degradation of a metal by chemical or electro-chemical reaction with its environment.

Corrosion endurance

Resistance to corrosion as a function of time.

Cover gas

A mixture consisting of sulfur hexafloride, carbon dioxide and air, used to protect and minimize oxide formation on the surface of molten magnesium.

Cover; cover die

The stationary half of a die casting die.

Covering power

The ability of a plating solution, under a specified set of plating conditions, to deposit metal on the surfaces or recesses of a part, or in deep holes.

Creep

Plastic deformation of metals held for long periods under stresses less than the normal yield strength.

Creep strength

The constant nominal stress that will cause a specified amount of creep in a given time at a constant temperature.

Current shield

A nonconducting medium for altering the current distribution on an anode or cathode.

Damping

Ability of material to dampen vibration in components and thus lower noise levels.

DOE

Design of Experiments

Deburring

The removal of burrs, sharp edges or fins by mechanical, chemical, electrochemical or electrical discharge means.

Decorative finish

A plated, painted or treated surface having aesthetic qualities and the ability to maintain those qualities in service.

Defect

Imperfections in a cast part - such as pores, inclusions, cracks, cold shuts, laps or the like.

Deflection

The bending or twisting of a die casting or a tool when a load is imposed on it. Deflection is normally used to describe elastic strain (i.e., the item will return to its original shape when the load is removed) rather than permanent (plastic) deformation.

Glossary

Deformation, plastic

Bending or twisting of a die casting or a tool by a load that is beyond its elastic limits, and the casting or tool does not return to its original shape when the load is removed.

Degasifier

A substance that can be added to molten metal to remove soluble gases that might otherwise be entrapped in the metal during solidification.

Degassing

(1) A chemical reaction resulting to remove gases from the metal. Inert gases are often used in this operation. (2) A fluxing procedure used for aluminum alloys in which nitrogen, chlorine, chlorine and nitrogen and chlorine and argon are bubbled up through the metal to remove dissolved hydrogen gases and oxides from the alloy. See also **flux**.

Degreasing

The removal of grease and oils from a surface.

Dendrite

A crystal that has a tree-like branching pattern most evident in cast metals slowly cooled through the solidification range.

Deoxidizing

(1) The removal of oxygen from molten metals through the use of a suitable deoxydizer. (2) Sometimes refers to the removal of undesirable elements other than oxygen through the introduction of elements or compounds that readily react with them. (3) In metal finishing, the removal of oxide films from metal surfaces by chemical or electrochemical reaction.

Dichromate process

A chemical treatment for aluminum, magnesium and zinc alloys in a boiling dichromate solution, resulting in a surface film that resists corrosion.

Die

A metal block used in the die casting process, incorporating the cavity or cavities that form the component, the molten metal distribution system and means for cooling and ejecting the casting.

Die block

The large block of steel that forms the base for one half of a die casting die. All other components of the die are attached to or mounted on the die block.

Die cast skin

The metal on the surface of a die casting, to a depth of approximately 0.020 in. (0.8 mm), characterized by fine grain structure and freedom from porosity.

Die casting

A process in which molten metal is injected at high velocity and pressure into a mold (die) cavity.

Die halves

A die casting die is made in two parts, the cover and the ejector. These are called the "halves" of the die.

Die insert

A removable liner or part of a die body.

Die life

(1) The number of usable castings that can be made from a die before it must be replaced or extensively repaired. (2) The distance, in inches or millimeters, measured in the direction of the trimming action that a die cast trimming die is fitted to the casting. As trim dies are repeatedly sharpened, die life distance is reduced. When the die life is completely sharpened off, the die steels must be replaced.

Die release

Die coating to improve casting surface quality and facilitate removal from die.

Die or steel safe

A technique employed in close-tolerance die casting in which exterior surfaces of the casting are deliberately made slightly under size, and interior surfaces slightly over size. After a trial casting run, all dimensions are brought within specified tolerances. This technique ensures that all final die modifications, no matter how slight, are made by removing, rather than adding, metal.

Die temperature

A die casting die has a very complex pattern of temperatures across its parting surface and through its thickness. The expression “die temperatures” is usually used to mean die surface temperatures.

Die temperature control

The use of thermocouples in the die casting die to regulate flow rate of the cooling fluid through the die, keeping die temperature within preset range.

Die weight

The mass (weight) of a die. The weight is stamped on the die so individuals handling it can select the proper lifting equipment.

Die, miniature

Die casting dies for making die castings that weigh less than two ounces (55 grams) are usually considered to be miniature die casting dies.

Die, multiple-cavity

A die having more than one casting cavity.

Die, single cavity

A die casting die that has only one cavity.

Dimension, critical

A dimension on a part that must be held within the specified tolerance for the part to function in its application. A noncritical tolerance is specified for weight saving or for manufacturing economy, and is not essential for the product’s function.

Dimension, linear

Any dimension to features of the die casting that are formed in the same die component (half). Any straight line dimension on a part of die print.

Dimension, nominal

The size of the dimension to which the tolerance is applied. For example, if a dimension is 2.00 ±0.02, the 2.00 is the nominal dimension and the ±0.02 is the tolerance.

Dimension, parting line

A dimension on a casting, or in a die casting die cavity, that is parallel to the direction of die pull and crosses the die parting line.

Dimensional stability

Ability of an alloy to retain its size and shape unchanged with time.

Discontinuity

Any interruption in the normal physical structure or configuration of a part, such as cracks, laps, seams, inclusions or porosity. A discontinuity may or may not affect the utility of the part.

Dolomite

A mineral made up of calcium and magnesium carbonate.

Double-Layer nickel

An electroplated, double-layer nickel coating, of which the bottom layer is semi-bright nickel containing less that 0.005% sulfur and the top layer is bright nickel containing more than 0.04% sulfur; the thickness of the bottom layer is not less than 60% of the total nickel thickness, except on steel where it is not less than 75%.

Dowel pin

A guide to ensure registry between two die sections.

Draft allowance

The maximum angle of the draft that is allowed by the casting's specification.

Draft

The taper given to cores and other parts of the die cavity to permit easy removal of the casting.

Drag-Out

The solution that adheres to the objects removed from cleaning and plating baths.

Dross

Metal oxides in or on the surface of molten metal.

Dull finish

A finish virtually lacking both diffuse and specular reflectance.

Eject

To push the solidified casting out of the cavity of the die casting die.

Ejection, accelerated

A system, usually within the die casting die, that causes selected ejector pins to move faster and further than the others during the final portion of the ejection travel. Also called **Secondary Ejection**.

Ejector marks

Marks left on castings by ejector pins, frequently including a light collar of flash formed around the ejector pin.

Ejector pin

A pin actuated to force the casting out of the die cavity and off the cores.

Ejector plate

Plate to which the ejector pins are attached and which actuates them.

Ejector; ejector die

The movable half of a die casting die containing the ejector pins.

Electrolyte

A substance, usually liquid, in which the conduction of electricity is accompanied by chemical decomposition. An electrolyte is one of the factors required for electrolytic corrosion to occur.

Electromotive series

A list of elements arranged according to their standard electrode potential.

Electroplate

An adherent metallic coating applied by electrodeposition on a substrate for the purpose of improving the surface properties.

Electropolishing

The improvement in surface finish of a metal effected by making it anodic in an appropriate solution.

Elongation

Amount of permanent extension in the vicinity of the fracture in a tensile test, usually expressed as a percentage of original gage length.

Engraved finishes

Designs etched on die cavity surfaces by chemical dissolution to produce specified patterns in the as-cast part.

Entrained air

Air or other gases that are mixed with the flowing molten metal as the die cavity is filling.

Epoxies

Organic coatings applied to parts, having superior corrosion resistance and adhesion.

Erosion

A damaged condition in the die cavity or die runners caused by the impingement of the molten metal during injection.

Expansion, thermal coefficient of

A numerical value of the unit change in length of a substance with each degree of temperature change. These values are arrived at by experimentation and are tabulated in reference books.

Extractor

In die casting, a mechanical apparatus that enters the space between the two halves of the opened die casting die, grips the cast shot, pulls it free from the ejector pins and removes it from the die space.

FAIR

First Article Inspection Report

FMEA

Failure Mode and Effect Analysis

FEA

See Finite element analysis.

Glossary

Fatigue

The phenomenon leading to fracture under repeated or fluctuating stresses that have a maximum value less than the tensile strength of the material.

Fatigue, thermal

The cracking (or crazing) of the die cast die cavity surface. This is caused by the expansion and contraction of the cavity surface which happens every time molten metal is injected into the die.

Feedback

A process control principle in which information about the actual performance of a machine, tool, die or process is inputted into the machine control system for the purpose of possible machine adjustments to correct any inaccurate variable.

Feeding

The process of supplying molten metal to the die cavity to compensate for volume shrinkage while the cast part is solidifying.

Ferric nitrate treatment

Process for producing a bright, corrosion-resistant finish on magnesium.

Fillet

Curved juncture of two surfaces; e.g., walls that would otherwise meet at a sharp corner.

Fin

See Flash.

Finish machining

(1) The last machining operation on the cavity of a die casting die before the hand work (benching or polishing) is started. (2) Machining operations on a part that has been die cast to bring the part to final specified tolerances, where die casting to net-shape was not economically feasible.

Finish

The smoothness of the surface of a die casting or a die casting die cavity. The finish quality of a cavity surface may be specified as the grit size to be used in the final polishing, microinch RMS value or SPI/SPE finish standard number.

Finite element analysis

A numerical simulation procedure that can be used to obtain solutions to a large class of engineering problems including stress analysis, fluid flow, heat transfer and many more.

Fit

The preciseness or accuracy with which two parts must be fitted together. The clearance or interference between two interconnected parts. When a die casting must be made to unusually close tolerances to achieve a specified fit, it may impose a higher cost on its manufacture.

Fixture

Any apparatus that holds a part, such as a die casting, firmly in a predetermined position while secondary operations are being performed on the part.

Flash (metal extension)

The thin web or fin of metal on a casting occurring at die partings, air vents, and around movable cores. The excess metal is due to the working pressure and operating clearances in the die.

Flash, clearance

In die casting dies, spaces deliberately provided between parts of the die for the formation of flash. In trim dies and other secondary tooling, spaces provided for the positioning of the casting flash.

Flash, trimmed

The excess material that has been trimmed from a die casting that will be remelted and used over again.

Flow lines

Marks appearing on the surface of a casting that indicates the manner of metal flow.

Flow pattern

The pattern with which the molten metal progressively fills the cavity of a die casting die.

Flow rate

The volume per unit time of molten metal entering a cavity in a die casting die. Flow rates are expressed in cubic inches or cubic millimeters per second.

Fluid bed coating

A process in which the metal to be coated is heated and inserted into the powdered resin which is fluidized in air.

Fluidity

Having fluidlike properties. In die casting: the distance the molten metal will travel through a channel before it freezes, at a given temperature.

Flux

A substance such as halide salts used to protect and minimize oxide formation on the surface of molten metal. Also used to refine scrap metals.

Form

The shape of a die casting.

Forming, cold

Any of several processes in which a die casting is reshaped by a tool or fixture, usually in a power press, without the application of heat. Spinning, which generates some localized heat, is still considered a cold forming operation. Heat staking, which utilizes heated punches, is not a cold forming operation.

Fracture test

Breaking a specimen and examining the fractured surfaces to determine such things as composition, grain size, soundness or presence of defects.

Freezing range

That temperature range between liquidus and solidus temperatures in which molten and solid constituents coexist.

GD&T

Geometric Dimensioning and Tolerancing

Gage

A fixture or apparatus that checks the dimensional accuracy of a produced part such as a die casting. A gage performs no work on the part.

Glossary

Gaging

The process of using a gage to determine if a part is dimensionally usable.

Galling

Tearing out of particles from a metal surface by sliding friction.

Galvanic corrosion

Corrosion associated with the current of a galvanic cell consisting of two dissimilar conductors in an electrolyte or two similar conductors in dissimilar electrolytes.

Gas, trapped

A defect in a die casting where gases (such as air, steam, hydrogen and gases from the decomposition of the parting material) have become entrapped within the casting and have formed one or more voids.

Gate erosion

Die damage induced by the long term high-temperature and high-velocity metal stream from the die inlet gate(s).

Gate runner

The runner in a die casting die that is directly adjacent to the gate. The transition from gate opening to runner cross-section.

Gate

(1) The passage connecting a runner or overflow with a die cavity. (2) The entire ejected content of a die, including the casting or castings and the gates, runners, sprue (or biscuit) and flash.

Gate, center

A gating arrangement in a die casting die that causes the injected metal to enter the cavity from the center of the part instead of along an outer edge. The casting must be open in the center, like a wheel or bezel, to be center gated.

Gating system

The passages, except the cavity, in a die casting die through which the injected metal must flow. The gating system includes the sprue or biscuit, main runner, branch runners (if any), gate runners, approach, the gate, overflows and vents.

Geometric characteristics

Geometric characteristics refer to the basic elements or building blocks which form the language of geometric dimensioning and tolerancing. Generally, the term refers to all the symbols used in form, orientation, profile, runout and location tolerancing.

Globular microstructure

A microstructure in which the primary phase is globular, rather than dendritic. This is the typical microstructure for semi-solid castings after heating to the semi-solid forming temperature. See also degenerate dendrites.

Gooseneck

In hot-chamber die casting, a spout connecting a metal pot or chamber with a nozzle or sprue hole in the die and containing a passage through which molten metal is forced on its way to the die.

Grain

A region within a solidified metal where the crystalline structure of the atoms is relatively perfect. The entire structure of the metal is made up of such grains. During cooling the grains are formed by growing larger from chance joining of atom pairs or from an impurity. As the grains grow they meet each other and the crystalline structure ends at these boundaries.

Grain refinement

The manipulation of the solidification process to cause more (and therefore smaller) grains to be formed and/or to cause the grains to form in specific shapes. The term "refinement" is usually used to mean a chemical addition to the metal, but can refer to control of the cooling rate.

Grain structure

The size and shape of the grains in a metal.

Grit blasting

Abrasive blasting with small irregular pieces of ferrous or ceramic material.

Growth

(1) Volumetric increase of a casting as a result of aging, intergranular corrosion or both. (2) Growth is the opposite of shrinkage.

Hard anodizing

A variation of the sulfuric acid anodizing process using lower temperatures and higher voltages.

Hard buffing

Procedure for cutting down rough surfaces using buffs made with a high thread count and an aggressive compound.

Hard chromium

Chromium that is plated for engineering rather than decorative applications, and is not necessarily harder. It provides a wear-resistant surface and can be used to salvage worn or undersized parts.

Hard spots

Dense inclusions in a casting that are harder than the surrounding metal.

Hardware finish

An especially smooth, as-cast surface requiring no polishing and little buffing in preparation for plating.

Heat checking

See Fatigue, thermal.

Heat sink

(1) Feature of a die casting die designed to remove heat from the die or from a specific region within the die. Water channels are the most common type of heat sink. However, high thermal conductivity materials are also used. (2) A die casting designed to function as a heat sink in an assembly.

Heat transfer coefficient

The rate a material will transfer heat energy per unit time through a distance due to a temperature difference. The heat transfer coefficients for different materials are given in Btu/hr-ft-°F and W/m-°C. Also called the Coefficient of Thermal Conductivity.

Hiding power

The ability of a paint to hide or obscure a surface to which it has been uniformly applied.

Glossary

Hole, cored

In a die casting, any hole that is formed by a core in the die casting die. A cored hole is distinguished from a hole that is added after the casting has been made (as by drilling).

Hot-chamber machine

A die casting machine designed with the metal chamber and plunger, or metal pump, continually immersed in molten metal, to achieve higher cycling rates.

Hot cracking

A rupture occurring in a casting at or just below the solidifying temperature by a pulling apart of the soft metal, caused by internal thermal contraction stress.

Hot short

Brittle or lacking strength at elevated temperatures.

Hot shortness

A tendency for some alloys to separate along grain boundaries when stressed or deformed at temperatures near the melting point. Hot shortness is caused by a low melting constituent, often present only in minute amounts, that is segregated at grain boundaries.

Hot tear

A fracture formed in a metal during solidification because of hindered contraction. Compare with hot crack.

ISIR

Initial Sample Inspection Report

Impact strength

Ability to absorb shock/energy, as measured by a suitable testing machine.

Impression

(1) A cavity in a die. (2) The mark or recess left by the ball or penetrator of a hardness tester.

Inclusions

Particles of foreign material in a metallic matrix. The particles are usually compounds (such as oxides, sulfides or silicates), but may be of any substance that is foreign to (and essentially insoluble in) the matrix.

Ingate

The passage or aperture connecting a runner with a die cavity.

Ingot

A pig or slab of metal or alloy.

Injection

The act or process of forcing molten metal into a die.

Injection profile

The preprogrammed change in speed with time of the injection ram. Speed is often changed during the injection stroke to minimize air entrapment and die filling time.

Insert

A piece of solid material, usually metal, that becomes an integral part of the casting. Inserts are commonly set in the die so that metal is cast around that portion left exposed in the die cavity. Alternatively, inserts are often applied subsequent to casting. (Note: inserts become a part of the casting, whereas die inserts are a part of the die.)

Intergranular corrosion

A type of corrosion that preferentially attacks the grain boundaries of a metal or alloy, resulting in deep penetration.

Izod

Name of an impact test and testing machine in which the specimen is clamped at one end only and acts as a cantilever beam when struck by the hammer.

Jewelry finish

The highest-quality, defect-free, electroplated decorative finish for a die cast part.

Knock-Out; loose piece

A core positioned by, but not fastened to, a die and so arranged as to be ejected with the casting. The knock-out is subsequently removed and used repeatedly.

Lacquer

A coating composition which is based on synthetic thermoplastic film-forming material dissolved in organic solvent and which dries primarily by solvent evaporation.

Laminated object manufacturing (LOM)

A method of rapid prototyping for producing a prototype part which uses CAD data to position a laser beam over a sheet of heat-activated, adhesive-coated paper, bonding each layer on top of the last.

Leveling electroplate

An electroplate that produces a surface smoother than the substrate.

Logo (logotype)

A symbol used to identify a company, often cast into a die cast part.

Lot size

The number of pieces made with one die and machine setup.

Metal distribution ratio

The ratio of the thickness of metal upon two specified areas of a cathode.

Metal extension (flash)

The thin web or fin of metal on a casting occurring at die partings, air vents and around movable cores. The excess metal is due to the working pressure and operating clearances in the die.

Metal saver

A core used primarily to reduce the amount of metal in the casting and to avoid sections with excessive thickness.

Glossary

Metal, hot delivery of

The practice of transferring molten metal from the smelting plant to the die casting plant. Hot-metal delivery results in considerable energy and dross savings since the metal does not have to be remelted at the die casting plant. Metal may be transported in the molten state for several hundred miles.

MHD Casting

Magneto-Hydro Dynamic casting is a casting process in which the metal is vigorously stirred by a magnetic field during solidification.

Microthrowing power

The ability of a plating solution or specified set of plating conditions to deposit metal in fissures, pores or scratches.

Moving core mechanism

The parts of a die casting die that hold and move a moving core. These may include gibs, locking wedge, angled pins, dogleg cams, racks, pinions and/or hydraulic cylinders.

NADCA

North American Die Casting Association, consolidation of the Society of Die Casting Engineers and the American Die Casting Institute.

NADCA Product Standards

Die casting product standards originally published by the American Die Casting Institute, which this publication supersedes. ADCI and SDCE (the Society of Die Casting Engineers) merged to become NADCA, the North American Die Casting Association.

Net casting yield

See Casting yield.

Nickel plate

A coating of nickel, deposited by electrolytic or electroless plating methods, for decorative purposes and corrosion resistance. It is usually coated with a chromium flash plate for greater resistance to tarnish and wear.

Nitric acid pickle

A pre-pickle for the ferric nitrate treatment of magnesium.

Nitriding

A heat treating process for increasing the surface hardness of tool steels by diffusing nitrogen into the surface.

Nozzle

The outlet end of a gooseneck or the tubular fitting that joins the gooseneck to the sprue hole.

Operation, secondary

A manufacturing operation, or step, that is performed on, or to, a die casting after the casting is produced but before it is shipped to the customer or assembled into the finished product.

Overflow

A recess in a die, connected to a die cavity by a gate, remote from the entrance gate (ingate).

Overflow gate

A passage or aperture connecting a die cavity to an overflow.

Oxidation

A reaction in which electrons are removed from a reactant, as in the formation of ions at the anode surface in electrolysis. The combination of a reactant with oxygen or an oxidizing agent.

Oxide coating

A coating produced on a metal by chemical or electrochemical oxidation for the purpose of coloring or providing corrosion and wear resistance.

PPAP

Pre-Production Approval Process

PPM, Parts per Million

The acceptance level for the fulfillment of a production order based on the number of defective parts permissible per million parts shipped.

Part print

An engineering drawing (sometimes a reproduction of the engineering drawing) showing the part design. Usually "part print" refers to the drawing of a die casting rather than a die, tool or machine.

Parting face

The surface of a die casting die half that closes against a mating surface on the opposite die half. See Surface, parting.

Parting line

The junction between the cover and ejector portions of the die or mold. Also, the mark left on the casting at this die joint.

Parting line, stepped

A condition on a die casting where the parting line changes abruptly from one level to another.

Passive stirring

Another process for producing the feed material for semi-solid casting. The liquid metal is forced through restrictive channels as it cools, breaking up the dendrites.

Phosphate coating

A conversion coating applied to metal surfaces for the purpose of improving paint adhesion and corrosion protection.

Phosphoric acid pickle

A treatment to remove surface segregation from magnesium die castings and improve corrosion resistance.

Pickling

Removing surface oxides by chemical or electrochemical reaction.

Pin

A core, usually of circular section, normally having some taper (draft). Also, a dowel (or guide pin) to ensure registry between two die sections.

Pitting

The appearance of small depressions or cavities produced during solidification or as a result of corrosion and cavitation.

Platen

Portion of a casting machine against which die sections are fastened, or of trim presses against which trim dies are fastened.

Glossary

Plating rack

A frame for suspending parts and carrying current to articles during plating operations.

Plunger

Combination of tip and rod that forces metal into the die.

Polishing

The smoothing of a metal surface by means of the action of abrasive particles attached by adhesive to the surface of wheels or endless belts usually driven at a high speed.

Porosity

Voids or pores, commonly resulting from solidification shrinkage; air (primarily the nitrogen component of air) trapped in a casting or hydrogen exuded during electroplating.

Porosity dispersion

The degree to which the porosity is spread throughout the casting, as opposed to being all in one place.

Porosity, internal

Porosity that is completely encased within the die casting.

Porosity, surface

Porosity in a die casting that is open to the surface of the casting.

Port

Opening through which molten metal enters the injection cylinder of a hot-chamber machine or is ladled into the injection cylinder of a cold-chamber machine.

Pouring hole/slot

Port through which molten metal is ladled into the cold-chamber of a die casting machine.

Powder coating

This method involves electrostatically spraying a premixed granulated powder onto a workpiece and then curing at an elevated temperature to obtain final coating properties. Powder coating has many advantages, including the absence of organic solvents, a wide choice of coating materials for many service conditions, minimal material waste, and easy handling.

Preheating

The process of heating a die casting die prior to making castings to minimize the thermal shock from the first few castings. Also applies to die heating prior to die placement in the machine, for more rapid die changing and onset of production.

Press, trimming

A power press (either mechanical or hydraulic) used to trim the flash, runners and overflows from die cast parts after casting.

Pressure tightness

A measure of the integrity of a die casting in which a fluid under pressure will not pass through the casting. The method of testing and the pressure used must be specified.

Process capabilities

The range, or variation, of critical casting quality parameters (such as dimensional tolerances) within which a particular die and machine combination will operate.

Quench

The cooling of a die casting from its ejection temperature to room temperature.

Quench, water

The cooling of a die casting from its ejection temperature to room temperature (or to nearly room temperature) by placing it in water.

Quick-Change

(1) Any construction for a tooling component that allows the component to be replaced without removing the tool or die from the machine in which it is operated. (2) Die casting die features and procedures, such as preheating, which enable dies to be changed on die casting machines with a minimum of interrupted production. Such features usually add cost to the original construction of the tool or die, but can save considerable machine downtime costs.

R&R

Repeatability and Reproducibility.

Radiograph

A picture produced on a sensitive surface, as a photographic plate, by electromagnetic radiation of wavelength less than 500 angstrom units. The most common is the X-ray. X-ray pictures of die castings can often reveal flaws inside the castings.

Radius

A convex arc blending two surfaces on a die casting or on the model from which a die casting is to be made. See **Fillet**.

Rapid prototyping

Production of a full-scale model of a proposed design more quickly and inexpensively than by traditional methods like single-cavity prototype die casting, gravity casting or machining. See also: Stereolithography, Selective laser sintering, Laminated object manufacturing.

Reclaim

The process of smelting trimmings, scrapped parts, dross and machine turnings back to original alloy specifications.

Refine

In magnesium melting practice, the removal of magnesium oxide and other suspended non-metallic matter by use of flux that preferentially wets the impurities and carries them to the bottom of the pot as sludge.

Reflective defect

A casting surface defect that “reflects” an undesirable surface condition of the die cavity steel. For example, fatigue or heating checking of the die steel may manifest itself as cracks and craters in the steel. This will leave raised features on the casting that “reflect” the die surface condition.

Release agent

A material that is applied to the surface of the die cavity to keep the casting from sticking to the die. Such materials are usually applied frequently, sometimes every cycle, and are usually applied by spraying. To facilitate the spraying, the material is mixed with water or a mineral solvent which evaporates from the cavity surface.

Remelt

Sprues, gates, runners and as-cast defective castings returned directly to the melting pot.

Glossary

Rheocasting

Another term for semi-solid metal casting.

Rib

A wall normal to a second wall or surface to strengthen or brace the second wall or surface.

Robber

See **Cathode robber**.

Runaround scrap

See **Remelt**.

Runner

A die passage connecting the sprue hole or plunger hole of a die to the gate or gates where molten metal enters the cavity or cavities.

Salt fog test

An accelerated corrosion test in which specimens are exposed to a fine mist of a solution usually containing sodium chloride.

Satin finish

A surface finish that behaves as a diffuse reflector, which is lustrous but not mirror-like.

Scale

A build-up of material that forms on the die cavity surface during the operation of the die casting die. The build-up material is usually a combination of the oxide of the metal being cast and the parting material. The scale leaves an imprint on the casting and in extreme instances can even change dimensions on the casting.

SDCE

Society of Die Casting Engineers, which merged with the American Die Casting Institute to become the North American Die Casting Association (NADCA).

Sealed chrome pickle

A treatment for magnesium consisting of a chrome pickle, followed by sealing in a dichromate solution.

Sealing of anodic coating

A process which, by absorption, chemical reaction or other mechanism, increases the resistance of an anodic coating to staining and corrosion, improves the durability of colors produced in the coating or imparts other desirable properties.

Section, heavy

Any place in a die casting where the thickness is significantly greater than (at least double) that of the majority of the casting.

Segregation

Non-uniform distribution of alloying elements, impurities, or microstructures.

Selective laser sintering (SLS)

A method of rapid prototyping which uses a modulated laser beam on specialized powders to transform CAD data into full size prototypes in polycarbonate, nylon, or investment wax.

Semi-bright nickel

Nickel plate, containing less than 0.005% sulfur, that requires polishing to give full brightness or is used as-plated for the bottom layer in a double-layer nickel plate.

Shield

A nonconducting medium for altering current distribution on an anode or cathode.

Shot

Die filling or part of the casting cycle in which molten metal is forced into the die.

Shot peening

The procedure of impacting a metal surface with a high-velocity stream of metal shot or glass beads for the purpose of (1) cleaning or (2) improving resistance to stress corrosion by producing a compressive stress.

Shot size

The cubic volume of a die cast shot or the cubic volume of die casting alloy that a die casting machine is capable of injecting into a die. Shot sizes are sometimes expressed in weight or mass units.

Shrink mark

A surface depression, often called a shadow mark, that sometimes occurs at a thick section that cools more slowly than adjacent sections. Also known as a sink.

Shrinkage factor

See **Contraction factor**.

Shrinkage pits

A condition on a die casting where the solidification shrinkage has resulted in small holes on the surface of the casting. These holes are sometimes called "heat holes." When they form along the gate, they are called "gate holes."

Shrinkage, internal

Condition during the solidification of a casting where volumetric shrinkage results in the formation of a void inside the casting.

Shrinkage, solidification

Volume reduction that accompanies the freezing (solidification) of metal in passing from the molten to the solid state.

SIMA

(Strain Induced, Melt Activated) A wrought process for producing feed material for semi-solid metal casting. The metal is generally hot extruded and cold drawn.

Skin

See Die cast skin.

Sleeve, shot

The molten metal chamber of a cold-chamber die casting machine. This is a hardened steel tube through which the shot plunger moves to inject the molten metal into the die. See **Cold chamber**.

Slide

Portion of a die generally arranged to move parallel to the parting line. The inner end forms a part of the die cavity wall and sometimes includes a core or cores.

Slug

See **Biscuit**.

SMED

Single minute exchange of dies, a technique from Lean Manufacturing disciplines to reduce die set up times.

Glossary

Soldering

The sticking or adhering of molten metal to portions of the die following casting.

Solidification shrinkage

See **Shrinkage, solidification**.

Solution heat treatment

Heating an alloy to a suitable temperature, holding at that temperature long enough to allow one or more constituents to enter into solid solution and then cooling rapidly enough to hold the constituents in solution.

SPC, statistical process control

Statistical techniques to measure and analyze the extent a process deviates from a set standard.

Sprue

Metal that fills the conical passage (sprue hole) that connects the nozzle or hot chamber to the runners of a hot-chamber machine. (Most cold-chamber machines form a biscuit and have no sprue.)

Sprue pin

A tapered pin with rounded end projecting into a sprue hole and acting as a core to keep the casting in the ejector portion of the die.

Sputter coating

The formation of a deposit by the condensation of atoms or particles formed by ejection from a surface subjected to high-energy ion bombardment.

SQC, statistical quality control

Statistical techniques to measure and improve the quality of a given process.

Staking

A cold forming operation to a die casting. Staking is usually performed in a power press to bend tabs or swage heads onto studs.

Stereolithography

A method of rapid prototyping which converts 3-D CAD data into a series of very thin slices and uses a laser-generated ultravioliet light beam to trace each layer onto the surface of a vat of liquid poly-mer, forming and hardening each layer until the complete, full-size prototype is formed.

Strength, ultimate tensile

The maximum tensile (pulling) stress a metal can stand before rupturing.

Strength, yield

The stress at which a material exhibits a specified limiting permanent strain or permanent deformation.

Stress corrosion cracking

Cracking due to the combined effects of stress and corrosion. Usually this type of failure occurs as a fine hairline crack that propagates across the section without any exterior sign of corrosion.

Stress

Force per unit area. When a stress is applied to a body (within its elastic limit) a corresponding strain (i.e., change in shape) is produced, and the ratio of strain to stress is a characteristic constant of the body.

Stress, thermal

Stress induced into a material when a temperature change causes a force trying to change the size or shape of the part, but the part is restrained and cannot re-spond to the thermally induced force.

T&T

Taper and Tolerance.

TQM

Total Quality Management.

Unit system

A die casting die built to a standardized design and dimensions. Also, a series of units, for a variety of castings, that are installed and run in the die holder as the need for various castings dictates.

Vacuum

A space completely devoid of matter, even gases. Shrinkage voids in a die casting can be a vacuum. It is not necessary for a void to include entrapped air.

Vacuum assist

The action of voiding the die casting die of gasses during or prior to the flow of molten metal to form the casting.

Vent

A thin narrow passage that permits air to escape from the die cavity as it is filled with metal.

Vibratory finishing

A process for deburring and finishing mechanically by means of abrasive media in a container subjected to high-rate oscillations.

Void

A large pore or hole within the wall of a casting usually caused by solidification shrinkage or gas trapped in the casting. Also, a blow hole.

Water line

See **Cooling Channel**.

Wet blasting

A process for cleaning or finishing by means of a slurry of abrasive in water, directed at high velocity against the parts being processed.

Wire brushing

The method of burr removal, edge blending and surface finishing by contacting the work surface with a variety of rotating wire brushes.

Yield

See **Casting yield**.

ZA

A designation followed by a number, which is used to designate a group of three zinc based casting alloys. The number indicates the approximate nominal aluminum content.

Zamak

An acronym for zinc, aluminum, magnesium and copper, used to designate the zinc alloys 2, 3, 5 and 7.