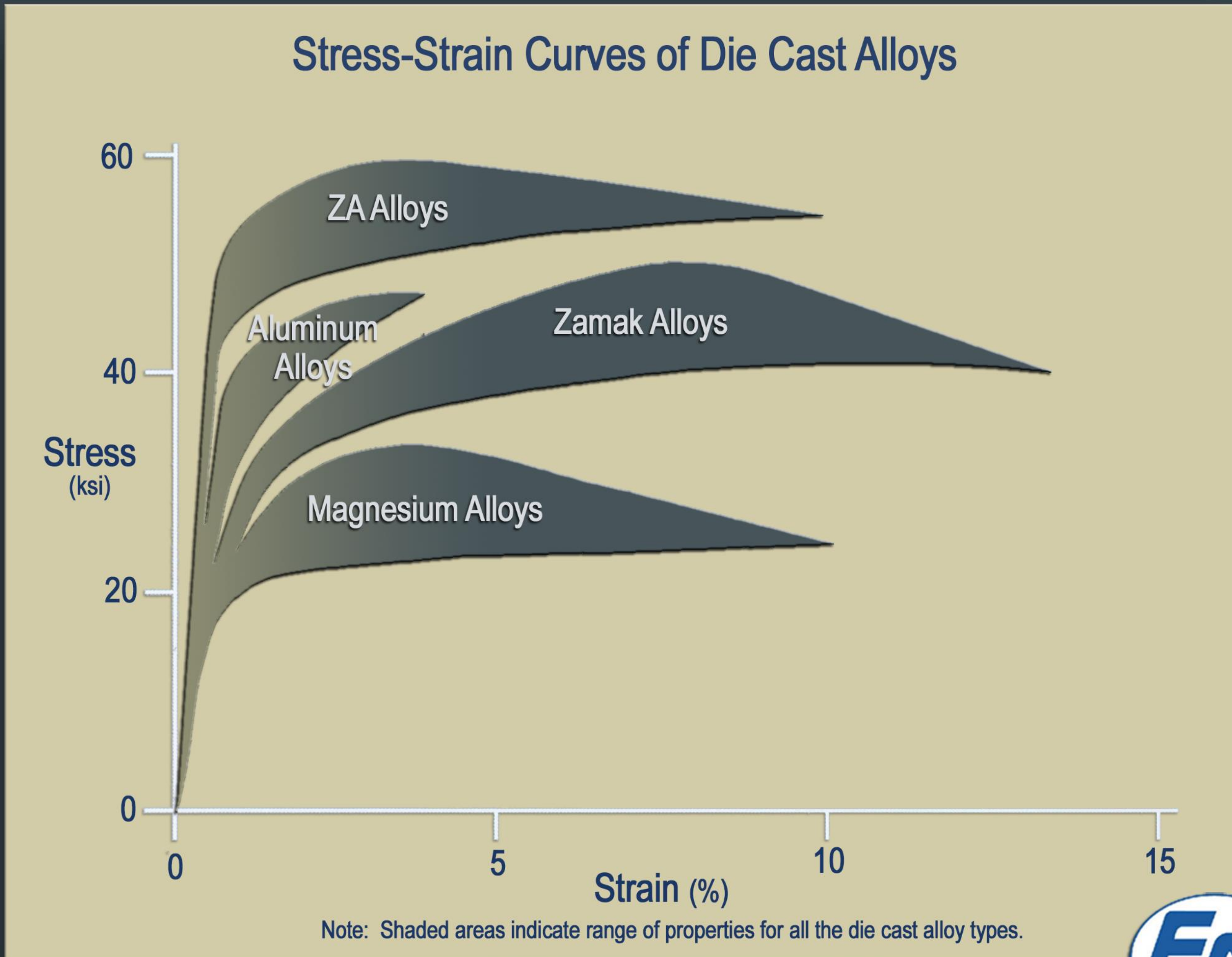
ZINC DIE CASTING PROPERTIES GUIDE



EASTERN ALLOYS, INC.

ZINC DIE CASTING ALLOYS

This guide was created to help designers and material specifiers better understand the capabilities of zinc die casting alloys for product applications.

ADVANTAGES

Zinc casting alloys are versatile engineering materials. No other alloy system provides the combination of strength, toughness, rigidity, bearing performance and economical castability. Listed are zinc alloy attributes which can reduce component costs. Improving precision, quality and product performance are other zinc alloy design advantages discussed in this brochure.

Process Flexibility: Virtually any casting process can be used with zinc alloys to satisfy any quantity and quality requirement. Precision, high-volume die casting is the most popular casting process. Zinc alloys can also be economically gravity cast for lower volumes using sand, permanent mold, graphite mold and plaster casting technologies.

Precision Tolerances: Zinc alloys are castable to closer tolerances than other metals or molded plastics, presenting the opportunity to reduce or eliminate machining. "Net Shape" or "Zero Machining" manufacturing is a major advantage of zinc casting.

Strength & Ductility: Zinc alloys offer high strengths (up to 60,000 psi) and superior elongation for applications requiring both strength and formability for secondary process applications such as bending, crimping and riveting.

Toughness: Few materials provide the strength and toughness of zinc alloys. Impact resistance is significantly higher than cast aluminum alloys, plastics, and grey cast iron.

Rigidity: Zinc alloys have the rigidity of metals with modulus of elasticity characteristics equivalent to other die castable materials. Stiffness properties are, therefore, far superior to engineering plastics.

Anti-Sparking: Zinc alloys are non-sparking and suitable for hazardous location applications such as coal mines, tankers and refineries.

Bearing Properties: Bushing and wear inserts in component designs can often be eliminated because of zinc's excellent bearing properties. For example, zinc alloys have outperformed bronze in heavy duty industrial applications.

Easy Finishing: Zinc castings are readily polished, plated, painted, phosphated, or chromated for decorative and/or functional service.

Thin Wall Castability: High casting fluidity, regardless of casting process, allows for thinner wall sections to be cast in zinc compared to other metal.

Machinability: Fast, trouble-free machining characteristics of zinc materials minimize tool wear and machining costs.

Low Energy Costs: Because of their low melting temperature, zinc alloys require less energy to melt and cast versus other engineering alloys.

Long Tool Life: Low casting temperatures result in less thermal shock and, therefore, extended life for die casting tools. For example, tooling life can be more than 10 times that of aluminum dies.

Clean and recyclable: Zinc alloys are among the cleanest melting materials available. Zinc metal is non-toxic, and scrap items are a reusable resource which are efficiently recycled.

ZINC ALLOYS

There are two basic families of zinc casting alloys: ZAMAK alloys and ZA alloys. The ZAMAK alloys were developed for pressure die casting during the 1920's and have seen widespread usage since then. It is for this reason that specifiers often relate zinc as synonymous with die casting. However, the development of the ZA (Zinc-Aluminum) Alloys during the 1970's have radically changed zinc's production design and manufacturing capabilities.

ZA Alloys were initially developed for gravity casting. Their mechanical properties compete directly with bronze, cast iron and aluminum using sand, permanent mold and plaster mold casting methods. Distinguishing features of the ZA alloys are their high aluminum content, high strength, and bearing properties.

During the 1980's, ZA alloys evolved as valuable die casting materials. It is important to note that when considering a ZA alloy for die casting, only ZA-8 can be hot chamber die cast. Hot chamber casting (which the ZAMAK alloys employ) is highly automated and the most efficient die casting process. ZA-12 and ZA-27 require special melting procedures and must be die cast like aluminum using the less efficient cold chamber die casting process.

Brief Alloy Description:

ZAMAK 3

This alloy is usually the first choice when considering zinc for die casting. Its excellent balance of desirable physical and mechanical properties, superb castability and long-term dimensional stability are the reasons why over 70% of all zinc die castings are made from this alloy. It is therefore the most widely available alloy from die casting sources. Zamak 3 also offers excellent finishing characteristics for plating, painting and chromate treatments. It is the "standard" by which other zinc alloys are rated in terms of die casting.

ZAMAK 5

This alloy is marginally stronger and harder than Zamak 3. However, these improvements are tempered with a reduction in ductility which can affect formability during secondary bending, riveting, swaging or crimping operations. Zamak 5 has approximately 1% copper which accounts for these property changes.

Because of Zamak 3's wide availability, designers often strengthen components through design modifications, instead of changing alloys. However, when extra performance is necessary, Zamak 5 alloys can be a viable alternative.

ZAMAK 7

This alloy is a modification of Zamak 3 in which lower magnesium content is specified to improve fluidity. To avoid problems with intergranular corrosion, lower levels of impurities are called for and a small quantity of nickel is specified. Zamak 7 also has slightly better ductility than Zamak 3, with other properties remaining relatively equal.

Zamak 7 is a popular choice for those special cases where the die caster is making thin walled components requiring a good surface finish. However, research testing has shown that metal and die temperatures have a greater effect than changing alloys. Close attention to control of the die casting process parameters is important so as to eliminate defects and achieve a consistent quality.

ZAMAK 2

This alloy offers the highest tensile strength, creep resistance and hardness properties compared to the alloys in the ZAMAK family. However, its high copper content (3%) results in property changes upon long term aging. These changes include slight dimensional growth (0.0014 in/in after 20 years), lower elongation and reduced impact performance.

ZA-8

This is the only hot chamber zinc die casting alloy in the ZA family. It has improved tensile strength, creep performance and hard properties compared to the ZAMAK alloys (except for ZAMAK 2, which is similar in performance). ZA-8 can be plated and finished using the same standard techniques as the ZAMAK alloys. ZA-8 offers an excellent alternative to ZAMAK alloys when greater properties are required.

ZA-12

Although more readily recognized as a gravity casting alloy, this alloy can also be die cast when a higher strength is required. It has the best combination of strength (yield strength is 46 ksi) and castability of all the ZA alloys. The cold chamber die casting process is required for this alloy due to the higher attack rate on the shot end components.

ZA-27

This alloy is the strongest of all the ZAMAK and ZA alloys with a reported yield strength of 55 ksi. It also is the lightest alloy available, and has excellent bearing and wear performance. Additional care is needed when casting this alloy to ensure a sound casting. It may also need a stabilization heat treatment if tight dimensional tolerances are required. ZA-27 is not recommended for plating. When brute strength or wear resistant properties are needed, ZA-27 has demonstrated extraordinary performance.

ACuZinc® 5

This alloy was developed by GM, and has improved tensile strength, hardness and creep performance compared to the ZAMAK alloys. ACuZinc® 5's strength and hardness properties are comparable to ZA-12. Testing has also shown ACuZinc® 5 to have excellent wear characteristics.

Although this alloy is a hot chamber die casting alloy, it is known to be much more difficult to die cast with a higher wear rate of the shot end components in the die casting machine.

EZAC®

EZAC(R) is the strongest, hardest, and most creep resistant of all the zinc die castings alloys. It has over over an order of magnitude improvement in creep strength over ZAMAK 5 and ZA-8. EZAC(R)'s improved fluidity also allows the alloy to be cast with thinner walls and more complex shapes to help compete in weight with lower density alloys such as aluminum.

Due to its low melting temperature, EZAC(R) can be cast in a hot chamber die casting machine, and does not exhibit the same tooling wear as shown with ACuZinc 5.

Consider this alloy when other zinc alloys do not exhibit enough strength or converting from other more costly materials.

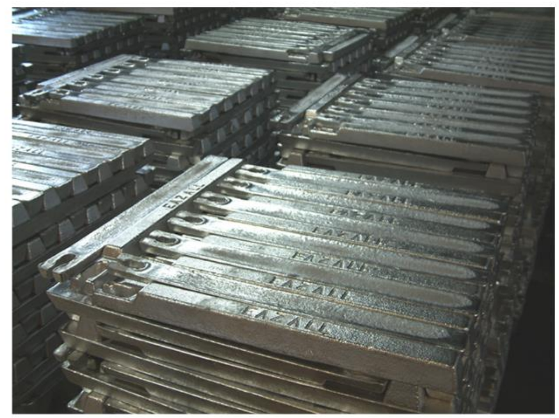
ZINC DIE CASTING ALLOY PROPERTIES AND COMPARISON GUIDE

Alloy	Zamak 3	Zamak 5	Zamak 7	Zamak 2	ZA-8	ZA-12	ZA-27	EZAC(R)	Al 380[9]	AZ91D[9]	FC-0208-R[10] (Sintered Cu-Steel)	Brass[11] (C37700)	Nylon[12] (30% glass)
Mechanical Properties	**Hot Chamber**	**Hot Chamber**	**Hot Chamber**	**Hot Chamber**	**Hot Chamber**	**Cold Chamber**	**Cold Chamber**	**Hot Chamber**	**Cold Chamber**	**Hot Chamber**			
Ultimate Tensile Strength: ksi (MPa)	41 (283)	48 (328)	41 (283)	52 (359)	54 (374)	58 (400)	61 (421)	60 (416)	47 (324)	34 (234)	60 (415)	52 (360)	11.5 (79.3)
Yield Strength - 0.2% Offset: ksi (MPa)	32 (221)	39 (269)	32 (221)	41 (283)	42 (290)	46 (317)	55 (379)	57 (396)	23 (160)	23 (159)	48 (330)	20 (140)	n/a
Elongation: % in 2″	10	7	13	7	6-10	4-7	1-3	1	3.5	3	1	45	50
Shear Strength: ksi (MPa)	31 (214)	38 (262)	31 (214)	46 (317)	40 (275)	43 (296)	47 (325)	38-46[4]	27 (190)	20 (138)	-	-	10 (69)
Hardness: Brinell	82	91	80	100	95-110	95-115	105-125	120[8]	80	63	110	78 HRF	85 HRM
Impact Strength: ft-lb (J)	43[1] (58)	48[1] (65)	43[1] (58)	35[1] (48)	31[2] (42)	21[2] (29)	9[2] (5)	25-35[4]	-	-	5 (6.8)	-	-
Fatigue Strength Rotary Bend: 5 x 10^8 cycles ksi (MPa)	6.9 (48)	8.2 (57)	6.8 (47)	8.5 (59)	15 (103)	17 (117)	21 (145)	8.2[4]	20 (140)	14 (97)	2.5 (17.2)	-	-
Compressive Yield Strength - 0.1% Offset: ksi (MPa)	60[3](414)	87[3] (600)	60[3] (414)	93[3] (641)	37 (252)	39 (269)	52 (385)	TBD	52 (385)	23 (159)	-	-	12.5 (86)
Modulus of Elasticity - psi x 10^6 (MPa x 10^3)	12.4[4] (85.5)	12.4[4] (85.5)	12.4[4] (85.5)	12.4[4] (85.5)	12.4[5] (85.5)	12.0[5] (82.7)	11.3[5] (77.9)	16.2 (112)[7]	10.3 (71)	6.5 (44.8)	-	15.2 (105)	0.43 (2.9)
Poisson's Ratio	0.27	0.27	0.27	0.27	0.29	0.30	0.32	TBD	0.33	0.35	-	0.35	-

Physical Properties	Zamak 3	Zamak 5	Zamak 7	Zamak 2	ZA-8	ZA-12	ZA-27	EZAC(R)	Al 380[9]	AZ91D[9]	FC-0208-R[10] (Sintered Cu-Steel)	Brass[11] (C37700)	Nylon[12] (30% glass)
Density: lb/cu in (g/cm^3)	0.24 (6.6)	0.24 (6.6)	0.24 (6.6)	0.24 (6.6)	0.227 (6.3)	0.218 (6.0)	0.181 (5.0)	0.234 (6.49)	0.098 (2.71)	0.066 (1.81)	0.242 (6.70)	0.305 (8.44)	0.042(1.15)
Melting Range: °F (°C)	718-728(381-387)	717-727(380-386)	718-728(381-387)	715-734(379-390)	707-759(375-404)	710-810(377-432)	708-903(376-484)	715-775(379-413)	1000-1100(540-595)	875-1105	-	1626-1640	500 (melting point)
Electrical Conductivity: %IACS	27	26	27	25	27.7	28.3	29.7	26-29[4]	23	11.5	-	27	-
Thermall Conductivity: BTU/ft/hr/°F (W/m/°C)	65.3 (113.0)	62.9 (108.9)	65.3 (113.0)	60.5 (104.7)	66.3 (114.7)	67.1 (116.1)	72.5 (125.5)	60-67[4]	55.6 (96.2)	41.8 (72.3)	25 (44) est.	69	1.7
Coefficient of Thermal Expansion 68-212 °F uin/in/°F (100-200°C um/mm/°C)	15.2 (27.4)	15.2 (27.4)	15.2 (27.4)	15.4 (27.8)	12.9 (23.3)	13.4 (24.2)	14.4 (26.0)	13-15[4]	12.1 (21.8)	14 (25.2)	5.1 (9.2)	-	-
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 (448)	0.125 (534)	0.10[4]	0.230 (963)	0.230 (963)	-	-	
Pattern or Die Shrinkage: in/in	0.007	0.007	0.007	0.007	0.007	0.0075	0.008	0.0075	0.006	-	-	-	

Chemical Specifications[6] (Per ASTM) (% by weight)	Zamak 3 Ingot	Zamak 3 Casting	Zamak 5 Ingot	Zamak 5 Casting	Zamak 7 Ingot	Zamak 7 Casting	Zamak 2 Ingot	Zamak 2 Casting	ZA-8 Ingot	ZA-8 Casting	ZA-12 Ingot	ZA-12 Casting	ZA-27 Ingot	ZA-27 Casting
Aluminum - Al	3.9-4.3	3.7-4.3	3.9-4.3	3.7-4.3	3.9-4.3	3.7-4.3	3.9-4.3	3.7-4.3	8.2-8.8	8.0-8.8	10.8-11.5	10.5-11.5	25.5-28.0	25.0-28.0
Magnesium - Mg	.03-.06	.02-.06	.03-.06	.02-.06	.010-.020	.005-.020	.025-.05	.02-.06	.02-.03	0.01-0.03	.02-.03	.01-.03	.012-.020	.01-.02
Copper - Cu	.10 max	.1 max	.7-1.1	.7-1.2	.10 max	.1 max	2.7-3.3	2.6-3.3	.9-1.3	.8-1.3	.5-1.2	.5-1.2	2.0-2.5	2.0-2.5
Iron - Fe (Max)	.035	.05	.035	.05	.035	.05	.035	0.05	.035	.075	.05	.075	.07	.075
Lead - Pb (Max)	.0040	.005	.0040	.005	.003	.003	.0040	.005	.005	.006	.005	.006	.005	.006
Cadmium - Cd (Max)	.0030	.004	.0030	.004	.002	.002	.0030	.004	.005	.006	.005	.006	.005	.006
Tin - Sn (Max)	.0015	.002	.0015	.002	.001	.001	.0015	.002	.002	.003	.002	.003	.002	.003
Nickel - Ni (Max)	-	-	-	-	.005-.020	.005- .020	-	-	-	-	-	-	-	-
Zinc - Zn	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance

Industry Standards	Zamak 3 Ingot	Zamak 3 Casting	Zamak 5 Ingot	Zamak 5 Casting	Zamak 7 Ingot	Zamak 7 Casting	Zamak 2 Ingot	Zamak 2 Casting	ZA-8 Ingot	ZA-8 Casting	ZA-12 Ingot	ZA-12 Casting	ZA-27 Ingot	ZA-27 Casting
ASTM	B240	B86	B240	B86	B240	B86	B240	B86	B240	B86	B240	B86	B240	B86
	AG40A	AG40A	AC41A	AC41A	AG40B	AG40B	AC43A	AC43A						
SAE	J468B	J468B	J468B	J468B			Former							
	903	903	925	925			921							
UNS	Z33521	Z33520	Z33530	Z33531	Z33522	Z33523	Z35540	Z35541	Z35635	Z35636	Z35630	Z35631	Z35840	Z35841



Notes: 1: 1/4″ square specimen unnotched. **2:** 10 mm square specimen unnotched. **3:** Compressive Strength. **4:** Estimated values to be confirmed by research. **5:** Values for permanent mold condition which should be similar for the die casting process. **6: For all notes pertaining to chemical specifications, please refer to ASTM b240 (ingot) and ASTM b86 (casting). 7:** Data collected from research. Same research showed that Zamak 2 had a Modulus of 111 GPa & ACuZinc 5 had a modulus of 117GPa (for comparison purposes). **8:** The hardness value reported for EZAC was perfomed on die casting samples using a Rockwell B scale (converted to Brinell), along the outer surface of the cross sectional area (not on the casting skin). EZAC is expected to have a surface hardness value similar to ZA-27. **9:** Reference - "NADCA Product Specification Standards for Die Castings". **10:** Reference - ASTM b426. **11:** Reference - ASM Handbook.. **12:** Reference - www.aptllc.net/datasheets/nylon66.pdf.

PROTOTYPING ZINC DIE CASTINGS

Prototyping is an essential step when developing a component's design, helping prove out the ability of the material to withstand the necessary stress requirements. Modifications to the design of the component are much less costly during the prototyping stage compared to when modifications are made to the die steel after the tool is designed and built.

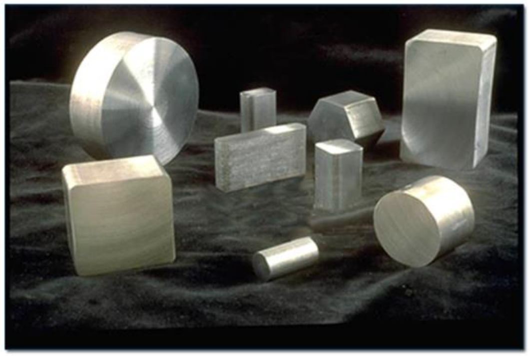
There are many ways to prototype Zinc die casting alloys. One of the quickest and easiest approaches to prototyping Zinc components is using Zinc "Con-Cast" (continuous cast) bar stock. This material is free from shrinkage and gas porosity voids that are generally present in standard ingot bars used for the die casting process. Eastern Alloys keeps a large inventory of Con-Cast bar stock consisting of many sizes, shapes and alloys. This material is also easily machined, using similar techniques when machining Bronze and Aluminum alloys.

The mechanical properties of Zinc Con-Cast bar stock are very similar to Zinc Die Castings, which makes it a perfect prototyping material. The following table compares the aged and "as-cast" properties of Con-Cast bar stock and Zinc die castings:

	Zamak 3			Zamak 5			ZA-8			ZA-12			ZA-27			ACuZinc 5		EZAC		
	Con-cast (as-cast)	Con-cast (aged)	Die Cast (as-cast)	Con-cast (as-cast)	Con-cast (aged)	Die Cast (as-cast)	Con-cast (as-cast)	Con-cast (aged)	Die Cast (as-cast)	Con-cast (as-cast)	Con-cast (aged)	Die Cast (as-cast)	Con-cast (as-cast)	Con-cast (aged)	Die Cast (as-cast)	Con-cast (as-cast)	Die Cast (as-cast)	Con-cast (as-cast)	Con-cast (aged)	Die Cast (as-cast)
UTS (ksi)	45.6	32.2	41.0	46.7	36.6	48.0	64.0	41.3	54.5	67.8	45.5	58.5	76.0	49.8	61.5	57.0	59.0	67.2	39.4	60.0
Yield (ksi)	38.1	25.0	32.0	40.7	31.4	39.0	50.7	32.7	42.0	53.3	35.6	46.5	58.3	39.8	53.5	47.0	49.0	51.6	-	57.0
Elongation (%)	1.6	3.2	10.0	1.7	1.8	7.0	2.2	4.3	8.0	2.5	11.0	5.5	5.3	14.7	2.8	2.5	6.0	2.8	0.8	1.0
Brinell hardness	101.0	76.0	82.0	109.0	86.0	91.0	126.0	88.0	103.0	130.0	93.0	100.0	138.0	98.0	119.0	115.0	115.0	131.5	117.5	120.0

Table notes: 1.) Data for the Zamak and ZA alloys extraced from Paper No. G-T89-091 (15th International Die Casting Congress & Exposition). 2.) Data for ACuZinc 5 extracted from the "ACuZinc Reference Manual". 3.) Data for EZAC collected through internal research and testing. 4.) Properties are an average value of 1" and 4" diameter bars. (except for ACuzinc 5, which values are an average of 3/4" and 4" dia bars).

Contact Eastern Alloys' to discuss prototyping EZAC, the die casting industry's strongest alloy. With improved creep resistance, strength and hardness, this alloy offers die casters opportunities to convert parts to zinc from more costly materials. Also with exceptional fluidity, EZAC has been cast as thin as 0.0075 inch (see Eastern's thin wall business card below).



For the majority of applications, using the same con-cast alloy to prototype for a die casting is sufficient; however, some properties such as creep resistance or ductility may not be as similar. In these cases, please call us for other solutions to your prototyping needs.

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EASTERN'S EAZALL™ LOGO APPEARS ON STANDARD BARS. IT'S A GUARANTEE OF CONSISTENT QUALITY AND PRODUCT PERFORMANCE.

TECHNICAL ASSISTANCE

Eastern Alloys, Inc. is the largest specialized zinc alloy supplier in North America and provides complete technical assistance. Product design, material and process selection, defect analysis, and prototyping assistance is available. This brochure is one of many technical bulletins available from Eastern to help material specifiers better understand the design and technical capabilities of zinc alloys. Should you have a question about the suitability of any of the alloys listed, please call us for immediate attention to your request.

LIMITED WARRANTY

While the technical information and suggestions for use contained herein are believed to be accurate and reliable, nothing stated in this bulletin is to be taken as a warranty either expressed or implied. Eastern Alloys will not be liable for incidental or consequential damages of any kind resulting from application or failure of castings and products made from these alloys. It is the alloy user's responsibility to determine suitability of application, preferably through proper prototype testing and field evaluation programs. Eastern Alloys' limited warranty provides only that its products will meet its chemical specification.

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