Engineering In Zinc, Today's Answer

The Advantages of zinc casting alloys

TODAY'S ZINC CASTING ALLOYS are strong, durable and cost effective engineering materials. Their mechanical properties compete with and often exceed those of cast aluminum, magnesium, bronze, plastics and most cast irons. These characteristics, together with their superior finishing capabilities, and choice of casting processes make zinc alloys the unquestioned material choice for the 1990's, because they'll save you time and money:

- **Assembly operations are reduced.** Entire assemblies can be cast as a single unit, eliminating the need for expensive manual assembly operations.
- **Less material is required.** Zinc's superior casting fluidity, strength and stiffness permits the design of thin wall sections for reduced weight and material cost savings.
- **Machining operations are reduced.** Due to the superior net-shape casting capability of zinc alloys, machining can be eliminated or drastically reduced.
- **Faster production and extended tool life.** Die casting production rates for zinc are much faster than for aluminum, or magnesium. Coupled with a tool life often exceeding 1 million parts, tooling and machine usage charges are dramatically reduced.
- **Eliminate bearings and bushings.** Zinc's excellent bearing and wear properties allow greater design flexibility and reduce secondary fabrication costs by eliminating small bushings and wear inserts.
- **Choice of low, medium and high production.** A variety of casting processes are available to economically manufacture any size and quantity required.

Alloys Tailored to meet your needs: General Purpose and Special High Strength Alloys.

ZAMAK alloys are the standard general purpose die casting alloys, exhibiting an excellent combination of cost, strength, ductility, impact strength and finishing characteristics. They are the designers first choice when considering die casting.

ZA alloys are a family of new high strength zinc-aluminum engineering materials. They exhibit the highest yield strengths of all conventionally die cast materials and have superior high temperature performance compared to the ZAMAK alloys. They also offer bearing and wear characteristics superior to conventional bronze bearings.

While the ZAMAK alloys are mainly die casting alloys, the entire ZA family can be used for sand, permanent mold and die casting, as well as in centrifugal, investment, plaster, and continuous casting.

The ZA alloys differ from the ZAMAK alloys mainly in terms of their higher aluminum content. The numerical digits (8, 12 and 27) represent their respective approximate weight percentages of aluminum.

ZA alloys are specialty materials and therefore are not as universally available as the ZAMAK alloys. When die cast, only ZA-8 can be "hot-chamber" cast which is the most cost efficient and flexible die casting process. ZA-12 and ZA-27 must be "cold-chamber" die cast similar to aluminum alloys.

Major Alloy Characteristics

ZAMAK 2: This is the strongest and hardest ZAMAK alloy. Generally die cast, it is occasionally employed for gravity casting. ZAMAK 2 is not widely used.

ZAMAK 3: This is the most used general purpose zinc die casting alloy, providing an excellent combination of strength, ductility, and impact strength. It also provides excellent plating and finishing characteristics. This alloy is the designers first choice for die casting applications.

ZAMAK 5: ZAMAK 5 should be considered when moderately greater hardness, strength and creep resistance is required over ZAMAK 3.

ZAMAK 7: This is a high purity form of ZAMAK 3 with similar mechanical properties. However, ZAMAK 7 has higher ductility (for forming and bending operations) and the highest casting fluidity of the ZAMAK family.

ZA-8: This should be the first choice when considering die casting the ZA family, due to its cost effective hot chamber castability. ZA-8 provides improved performance characteristics over the ZAMAK alloys. Plating and finishing characteristics are similar. ZA-8 can also be sand or permanent mold cast.

ZA-12: This is the preferred alloy for permanent mold applications although it can also be cold-chamber die cast with excellent results. It combines low temperature melting efficiency and thin wall capabilities with premium mechanical properties. ZA-12 should be used when switching from cast iron or permanent molded aluminum. ZA-12 can usually be poured directly into molds designed for aluminum and brass.

ZA-27: Components requiring optimum strength, hardness and light weight should be specified using ZA-27. With over double the yield strength of die cast A380 aluminum and 25% lighter than ZAMAK 3, this is definitely the high performance member of the group. ZA-27 also offers excellent bearing properties comparable to those of aluminum-bronze.

Photo: ZA-27, die cast. Motorcycle oil filter adapter. ZAMAK 3, die cast. Cordless screwdriver utilizes unit to size, zero draft single gear housing. ZAMAK 3, die cast. Chrome plated seat belt buckle offers good looks and high strength.

ALLOY COMPOSITION	% Weight of Main Alloying Elements			
	Al	Cu	Mg	Zn
ZAMAK 2	3.9–4.3	2.6	.025–.05	balance
ZAMAK 3	3.9–4.3	.1 max.	.025–.05	balance
ZAMAK 5	3.9–4.3	.75–1.25	.03–.06	balance
ZAMAK 7	3.9–4.3	.1 max.	.01–.02	balance
Conforms to ASTM B240				
ZA-8	8.2–8.8	.8–1.3	.02–.03	balance
ZA-12	10.8–11.5	.5–1.2	.02–.03	balance
ZA-27	25.5–28.0	2.0–2.5	.012–.02	balance
Conforms to ASTM B669				

Material properties that help solve today's engineering problems.

Strength
ZA alloys deliver the highest tensile strength among the most widely used non-ferrous alloys and match or exceed that of most cast irons.

Yield strength is a major ZA alloy attribute reaching 55,000 psi for ZA-27, that's more than twice that of A380 die cast aluminum, and significantly higher than the strongest plastics. Even ZAMAK 3, the most common alloy has a significant yield strength advantage over A380 aluminum, showing 3 times greater elongation, while maintaining greater hardness and higher stiffness.

Rigidity
Zinc alloys are rigid engineering materials. Their elastic moduli are greater than those of aluminum and magnesium alloys and an order of magnitude greater than those of engineering plastics. This, combined with their high strength allows the volume of individual castings to be markedly reduced, saving space and weight.

Toughness and Ductility
High impact strength and good ductility are qualities of zinc alloys that are rarely found in most other casting alloys. Ductility is important for bending and crimping in post-casting assembly operations, while impact strength provides performance in rough environments. Fracture toughness is also greater than for most aluminum alloys and cast irons.

Hardness
ZAMAK alloys provide high hardness and abrasion and wear resistance. Optimum hardness is provided by the ZA family whose Brinell Hardness ranges from 95 to 122 when die cast. These values are much higher than the 70 to 85 BHN displayed by aluminum alloys, and much higher than the hardness values of engineered plastics. Along with high hardness, ZA alloys also exhibit excellent abrasion and wear resistance.

Conductivity
As zinc alloys conduct both heat and electricity, they can be used for heat dissipating devices such as heat sinks. Zinc's excellent casting fluidity permits thinner fin and cooling pin design to better dissipate heat. Zinc's excellent electrical conductivity also provides good EMI, RFI and ESD shielding.

Non-sparking and non-magnetic
Aluminum alloys can generate a spark when struck with a rusty iron component. All zinc alloys except ZA-27 are classified as "non-sparking" and are the perfect low-cost alternative to bronze in potentially explosive environments.

Zinc's non-magnetic properties are ideal for use in electronics and other applications where delicate moving parts are subject to magnetic disturbances.

Fatigue Strength
This measure of a material's ability to withstand cyclic loading is an important design criterion. Both the ZAMAK and ZA alloys have high fatigue strengths.

Design (Creep) Stress
The allowable design stress, or resistance to creep, at room temperature of ZA alloys is far better than for all but the most esoteric engineering plastics. The room temperature design stress of die cast ZA-27, for example, is 10,000 psi (stress required for creep of 1% in 100,000 hours). This property allows ZA alloys to be used in applications subject to significant static loading. However, permissible design stress drops with increasing temperature and a careful review of all constant load applications at temperature is required to determine the suitability of zinc alloys.

Pressure Tightness
Soundness of castings is largely related to product design, tooling layout and process control. Die cast ZAMAKs, ZA-8 and ZA-12 are often used for pressure tight applications. For sand and permanent mold casting ZA-12 is the preferred material. All zinc alloys solidify into a dense strong matrix with excellent pressure tightness.

Damping Capacity
All of the ZAMAK and ZA alloys have excellent damping capacity. At 20°C, ZA-27, the highest damping zinc alloy, has nearly ten times greater damping capacity than A380 aluminum or mild steel. At 100°C damping capacity increases and all of the zinc alloys become "HIDAMETS" (high damping metals) and have a damping capacity greater than that of grey cast iron. This property makes zinc alloys the perfect choice for housings where vibration absorption is required.

Corrosion Resistance
Zinc has excellent corrosion resistance under normal atmospheric conditions, and in many aqueous, industrial and petroleum environments. Corrosion resistance can be enhanced by such treatments as plating, chromating, painting and zinc anodizing.

Photo: ZA-27 die cast. Front axle tube for 4WD truck provides high strength and excellent stability.

Engineering characteristics that answer your most critical needs.

Accuracy
Generally zinc die casting tolerances are superior to those of aluminum and magnesium die castings. Zinc die casting can produce repeatability of less than ±0.001" for small components, often rivalling machining tolerances. Few other processes can easily achieve the same net shape performance. Many components are die cast to net shape and require no further machining.

Machinability
In general zinc alloys machine rapidly, with minimal tool wear. Machining rates often rival those of free machining brass, and can be three times faster than for cast iron. Ease of machining and elimination of tool breakage problems often influences the selection of ZAMAK and ZA alloys over competitive materials.

Thin Wall Capability
Exceptional casting fluidity is displayed by all ZAMAK and ZA alloys, which provides superior thin-wall castability, regardless of the casting process employed. Wall thicknesses of .025 inches (.65mm) for die casting and .090 inches (2.3mm) for permanent mold casting are being produced. This thin-wall capability results in smaller, lighter, low cost components.

Zero Draft Angle Castability
Draft angle is the taper on the surface of a die required to facilitate removal of the cast part from the die cavity. In general zinc alloys can be die cast with less draft angle than competitive materials. In fact, zinc components can sometimes be cast with zero draft angles. This is usually not possible with aluminum or magnesium alloys. Zero internal draft permits net shape manufacturing resulting in lower cost production.

Dimensional Stability
The ZAMAK alloys, ZA-8 and ZA-12 have excellent dimensional stability characteristics. ZA-27, however, may require a stabilization heat treatment to minimize aging effects where exceptional tolerances are required.

Joining
Zinc alloys can be welded using MIG and TIG welding methods and brazed using special zinc filler rods. Welding is normally not an economical joining method for zinc die castings due to the high production volumes involved. Normally, mechanical devices are used for joining, however, flaring, riveting and crimping techniques are common low cost joining methods.

Temperature Limitations
The low melting temperatures of zinc alloys are an energy-saving advantage for foundrymen, however this also causes some loss of strength and hardness at moderately elevated temperatures. Plastic deformation or creep can occur with these alloys when they are stressed at less than their yield stress for extended time periods at elevated temperatures. In general, applications which are above 250 degrees F or under high constant stress should be avoided. Moderately stressed parts at ambient temperatures up to 150 degrees F are best suited for ZAMAK and ZA alloys (see design stress).

Main photo: ZAMAK 3 die cast. Thin walls, high accuracy, and dimensional stability make zinc alloy the perfect choice for this 4 barrel carburetor.

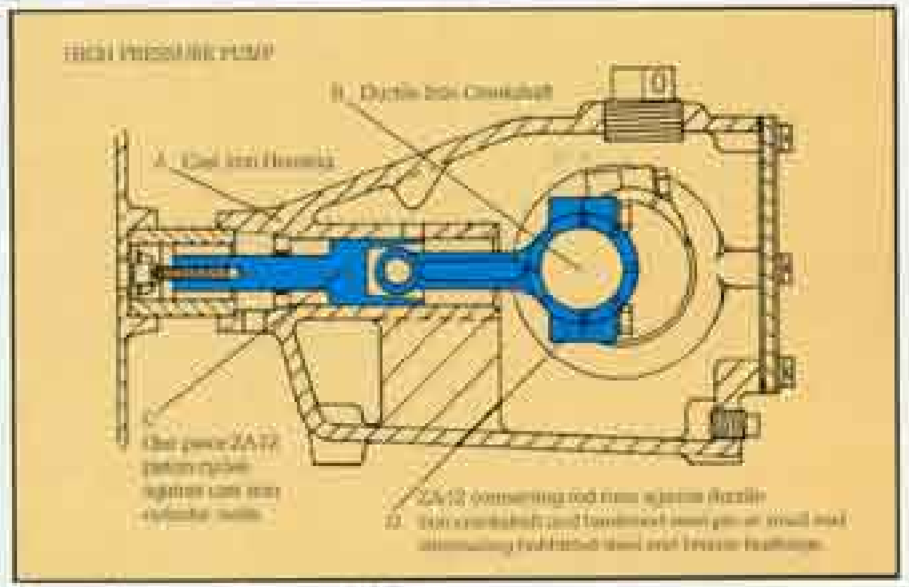
Inset photo: ZA-12 graphite permanent mold cast. Machined satellite dish component.

Superior bearing properties ensure built-in reliability.

All zinc alloys, particularly ZA-12 and ZA-27 demonstrate excellent bearing and wear resistance qualities thanks to their high hardness and natural lubricity characteristics. ZA alloy bearings should be considered wherever bronze bearings are currently being specified. They generally operate best in lubricated, high load, low speed applications under moderate temperature conditions, however they have also been successfully used in high speed, low load applications.

ZA alloys are increasingly being used as direct substitutes for larger bronze industrial bushings and bearings since they cost less and are up to 43% lighter.

For smaller components, zinc's natural lubricity may contribute to lower secondary fabrication costs by eliminating small bushings and wear inserts, thus allowing greater design flexibility.



Schematic of components shown in inset photo

Main photo: ZA-12, sand cast. Large journal bearing takes advantage of low cost sand casting method and provides superior performance.
Inset photo: ZA-12, permanent mold cast. Connecting rod and piston for high pressure pump utilize ZA-12's excellent bearing and wear properties as well as high strength.

A variety of high quality surface finishes is another major advantage.

Electro-Plating

Zinc die castings offer excellent plating characteristics. Electro-plating is generally a multi-layered coating consisting of one or two copper layers, one or two layers of nickel, and a final layer of chromium, brass, gold, or any other platable metal. Chromium plating is the most popular decorative finish when corrosion and high abrasion resistance are required.

Chrome plating adheres best to the ZAMAK alloys and ZA-8 followed by ZA-12. Chrome plating of ZA-27 is possible but more difficult due to the need to treat ZA-27 like an aluminum casting. Processes which provide a smooth, dense outer skin such as pressure die casting and permanent mold casting are preferred when plating is being considered.

Chromates

Chromating is a low-cost chemical treatment that provides additional corrosion protection against "white rust". This form of zinc corrosion is caused by prolonged exposure to damp conditions. Chromate finishes are produced by simple dip methods which deposit a thin chromate coating. Chromate coatings are often applied to instrument, military and automotive components where low cost resistance to moisture is required. These coatings normally have a bronze tone or metallic lustre depending on the process used.

Phosphates

Phosphate coatings are primarily used to provide a good base for painting or powder coating.

Anodizing

A special zinc anodizing treatment is available for zinc castings. This coating is completely different than that for aluminum alloys. Zinc anodizing is a functional coating providing maximum corrosion resistance in atmospheric and marine environments.

Since the process uniformly coats deep recesses and threaded areas, anodized zinc alloy castings can serve as an economical alternative when replacing traditional brass, bronze and stainless steel components.

Polishing and Brushing

Conventional high lustre polishing or brush finishing techniques can produce appearances similar to chrome plating or stainless steel. When lacquered, these finishes are suitable for decorative interior applications.

Painting

All zinc alloys form an excellent base for paints. To aid paint adhesion, phosphate or chromate pretreatments are often employed. Zinc alloys can also be electrostatically painted.

Powder Coatings

Powder coating involves electrostatic spraying of the zinc castings with an epoxy or polyester powder. The parts are then immediately oven cured for a hard durable finish. The result is an even, inexpensive, corrosion resistant plastic coating. Powder coatings are available in a wide range of colours.

Main photo: ZA-27, die cast. Painted, cast-to-size winch component.
ZAMAK 3, die cast. Chrome plated finish provides a beautiful, quality finish and excellent corrosion resistance.
Inset photos, top: ZAMAK 3, die cast. Chromated gears.
Bottom: ZAMAK 3, die cast. Powder coating provides the fan housing with a tough and durable finish, available in a wide range of colours.

Casting versatility leads to further savings.

Die Casting

This is the most efficient process for high volume precision casting, producing the best tolerances and rapid production rates, but having high initial tooling costs.

Die casting should be considered for components requiring a production run of at least 10,000 pieces. All tolerances depend on part size and complexity, however tolerances of ±0.001" are common. Hot chamber die casting cycle rates range from roughly 150 parts per hour for large components to over 2000 per hour for small ones.

The ZAMAK alloys and ZA-8 can be used in a "hot chamber" die casting machine, while ZA-12 and ZA-27 must be "cold chamber" die cast like the aluminum alloys. The hot chamber process offers faster cycle times, resulting in lower production costs.

Due to the low melting temperatures of zinc alloys, dies for zinc parts last longer, often 3–4 times longer than the same dies when used for casting aluminum alloys.

Permanent Mold Casting

ZA-8 and ZA-12 are generally considered for permanent mold applications. Permanent mold casting has traditionally been done using steel or cast iron molds, but is now also performed in graphite molds. Permanent mold casting often competes with sand casting by providing tighter tolerances and a smoother surface finish which can reduce machining operations.

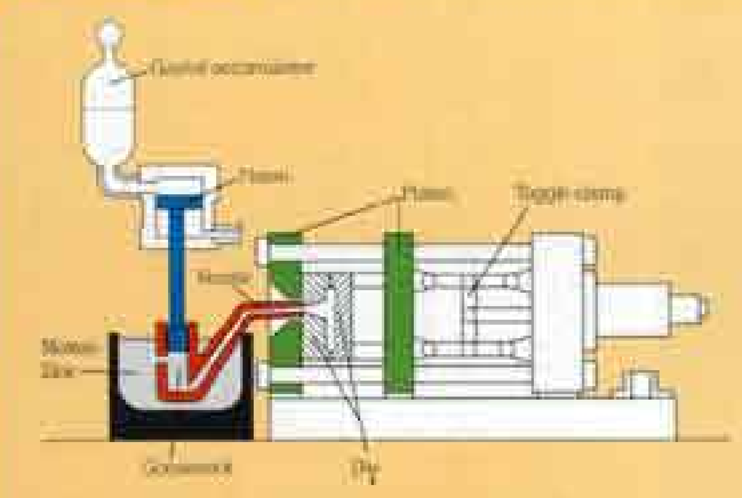
Ferrous permanent molds designed for aluminum alloys are generally suitable for casting zinc alloys. However, due to the superior casting fluidity of zinc, thinner sections can be cast. This process is well suited for medium production runs of 500–10,000 pieces. Ferrous permanent mold casting has great flexibility in terms of part size, ranging from ounces up to 100 lbs.

Graphite permanent mold casting offers some distinct advantages over metal tooling. Improved tolerances, lower tooling costs, and a superior surface finish are all benefits of the graphite mold process. Drawbacks are, limited component size, complexity and coring.

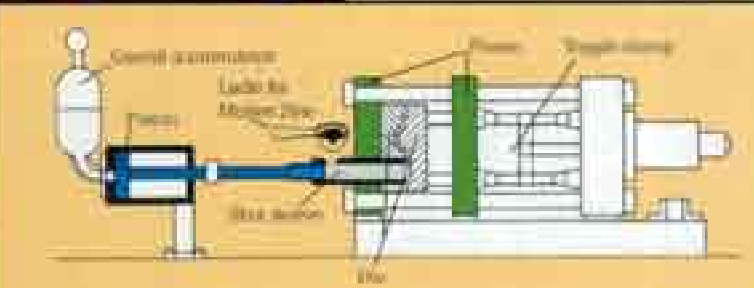
Sand Casting

All the ZA alloys are suitable for sand casting, however, ZA-12 is the most popular. Sand casting offers the greatest design flexibility in terms of size, complexity and quantity requirements. Tooling costs are generally low, therefore facilitating low volume production. However, surface smoothness and tolerance capabilities are limited, usually requiring machining.

Photo: ZA-27 die cast. Automatic gear changer housing for bicycle.



Principal components of a hot chamber die casting machine



Principal components of a cold chamber die casting machine

COMPETITIVE PERFORMANCE CHART. ZINC ALLOY CASTINGS MEASURE UP.

ALLOY PROPERTY		ZINC														ALUMINUM			MAGNESIUM	[illegible]		IRON	
		[illegible]	[illegible]	[illegible]	[illegible]	ZA-8**			ZA-12***			ZA-27***				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Die Cast	Die Cast	Die Cast	Die Cast	Sand Cast	Perm Mold	Die Cast	Sand Cast	Perm Mold	Die Cast	Sand Cast	Sand Cast HT*	Perm Mold	Die Cast	Die Cast	Sand Cast	Sand Cast	Die Cast	[illegible]	[illegible]	[illegible]	[illegible]
MECHANICAL																							
Ultimate Tensile Strength	psi x 10³ MPa	52 359	41 283	48 331	41 283	38 263	35 240	54 374	43 290	48 328	59 404	61 421	46 318	64 441	62 426	47 324	27 186	33 228	34 234	35 241	37 255	31 214	50 345
Yield Strength 0.2% Offset	psi x 10³ MPa	NA	32 221	33 228	NA	29 198	30 208	42 290	31 211	39 268	46 320	54 371	37 257	55 379	54 371	24 165	18 124	24 165	23 159	18 124	17 117	18 124	32 221
Elongation (% in 2")		7	10	7	13	1.7	1.3	8	1.5	2.2	6	4.6	8.4	2.5	2.5	3.5	2	3.5	3	20	30	nil	10
Young's Modulus	psi x 10⁶ MPa x 10³	≥12.4 ≥85.5	≥12.4 ≥85.5	≥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	11.3 77.9	11.3 77.9	10.3 71.0	10.7 73.8	10.5 72.4	6.5 44.8	14.5 100	12.0 82.7	13-16 89.6	25 172.4
Torsional Modulus	psi x 10⁶ MPa x 10³	NA	NA	NA	NA	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	4.3 29.6	4.3 29.6	3.9 26.9	4.0 27.6	3.9 26.9	2.4 16.5	NA	NA	NA	9.3 64.1
Shear Strength	psi x 10³ MPa	46 317	31 214	38 262	31 214	NA	35 241	40 275	37 253	≥35 241	43 296	42 292	33 225	NA	47 325	27 186	22 152	26 179	20 138	NA	NA	43 296	45 310
Hardness (Brinell)		100	82	91	80	85	87	103	94	89	100	113	96	114	119	80	70	70	63	65	60	170-229	110-155
Impact Strength	ft-lb J	35 47	43 58	48 65	43 58	15 20	NA	31 42	19 25	NA	21 29	35 48	43 58	NA	9 13	3 4	4 5	8 11	2.7 3.7	6 8	11 15	nil	40-65 54-88
Fatigue Strength Rotary Bend (5 x 10⁸ cycles)	psi x 10³ MPa	8.5 58.6	6.9 47.6	8.2 56.5	6.8 46.9	NA	7.5 51.7	15 103	15 103	NA	17 117	25 172	15 103	NA	21 145	20 138	10 69	8.5 58.6	14 97	16 110	11 76	14 97	28 193
Compressive Yield Strength 0.1% Offset	psi x 10³ MPa	93 641	60 414	87 600	60 414	29 199	31 210	37 252	33 230	34 234	39 269	48 330	37 257	NA	52 359	NA	19 131	25 172	23 159	46 317	37.5 259	109 752	NA
PHYSICAL																							
Density	lb/in³ kg/m³	0.24 6600	0.24 6600	0.24 6700	0.24 6600	0.227 6300			0.218 6030			0.181 5000				0.098 2713	0.101 2796	0.097 2685	0.066 1827	0.322 8913	0.308 8512	0.25 6920	0.26 7196
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			708-903 375-484				1000-1100 538-593	960-1130 516-604	1035-1135 557-613	875-1105 468-596	1570-1700 854-927	1670-1850 910-1010	>2150 >1177	>2250 >1232
Electrical Conductivity (% IACS)		25	27	26	27	27.7			28.3			29.7				27	27	39	NA	12	15	NA	8
Thermal Conductivity	Btu/ft hr °F W/m K	60.5 104.7	65.3 113.0	62.9 108.9	65.3 113.0	66.3 114.7			67.1 116.1			72.5 125.5				55.6 96.2	65.5 113.4	87 151	41.8 72.3	34 59	41.8 72	28-30 48-52	NA
Coef. of Thermal Expansion (68-212°F)	μin/in °F x 10⁻⁶ μm/m °C x 10⁻⁶	15.4 27.7	15.2 27.4	15.2 27.4	15.2 27.4	12.9 23.2			13.4 24.2			14.4 26.0				11.8 21.2	11.9 21.4	11.9 21.4	14 25.2	10 18	10 18	6.7 12.1	6.6 11.9
Pattern Shrinkage (in/in of casting)		0.006	0.006	0.006	0.006	0.010		0.007	0.012		0.0075	0.013			0.008	0.006	NA	NA	NA	0.018	0.016	0.010	0.010

*3 hrs at 610°F and furnace cooled. 10mm unnotched Charpy. 1/4 in unnotched Charpy. at 1/2% elong. Izod. notched Charpy. compression strength. at 10% permanent set. NA – Not Available.

**Complies with ASTM specification B86

***Complies with ASTM specification B669