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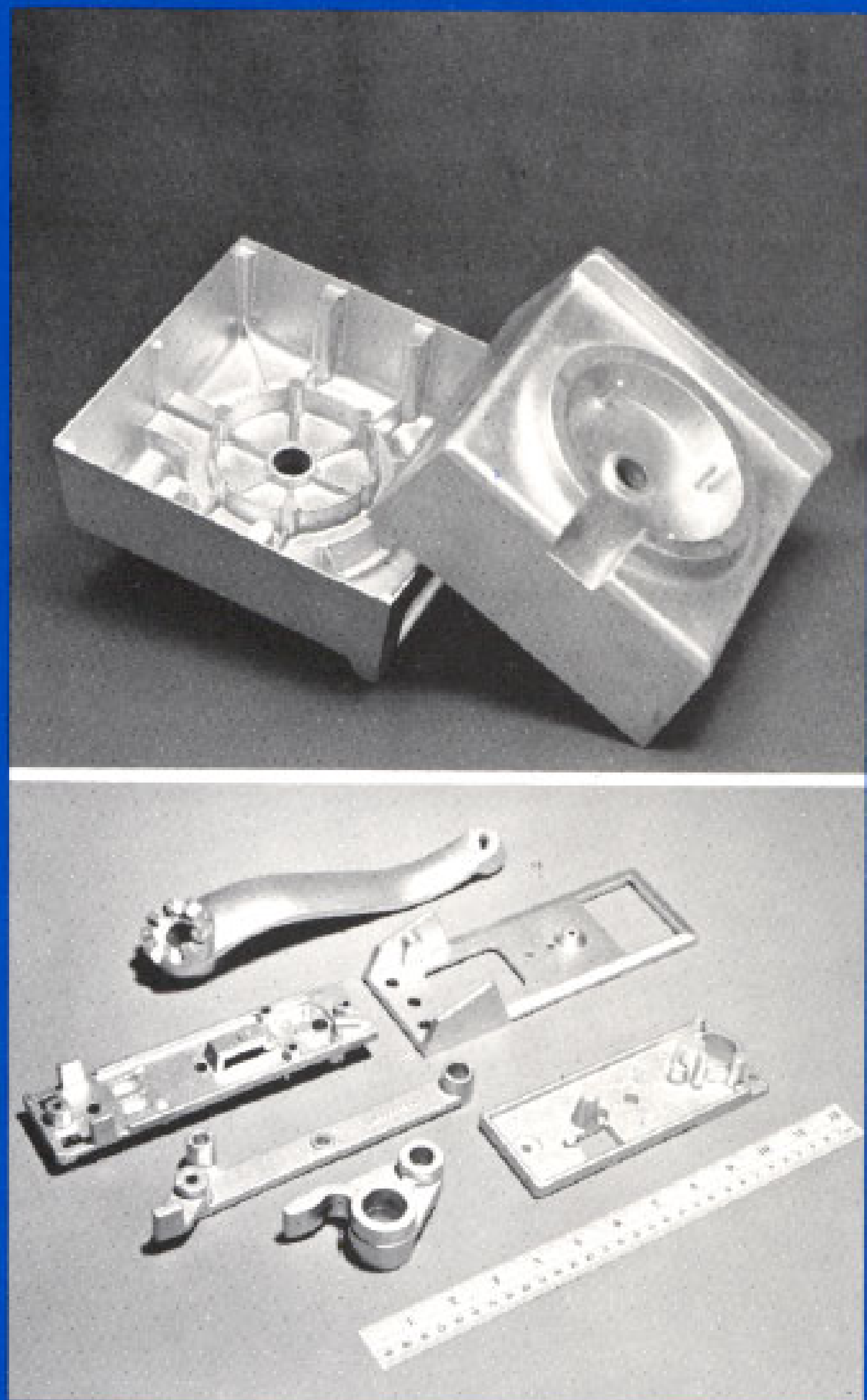
ZA®
CASTING ALLOYS
FOR GRAVITY AND PRESSURE DIE CASTING



ZA CASTING ALLOYS

ZA® casting alloys are a family of new high strength zinc-aluminum engineering materials. They were developed as general purpose casting alloys and are now being used in sand and permanent mold casting, die casting, and the new graphite mold process, as well as investment, centrifugal, plaster and rubber mold casting.

The ZA alloys are alternative alloys which compete with and replace such materials as cast iron, bronze, aluminum, plastics and steel fabrications. They feature clean, low-temperature, energy-saving melting, excellent castability, high strengths, and bearing properties equivalent and often superior to standard bronze bearings.

There are three ZA casting alloys, ZA-8, ZA-12 and ZA-27. The alloys are zinc based and contain high aluminum contents with minor alloying elements being copper and magnesium. The numerical digits (8, 12 and 27) represent the approximate percentage of aluminum in each. It is this fact, along with improved properties and wider casting process choice, which distinguishes ZA from standard zinc "ZAMAK" die casting alloys. High aluminum content is the reason the ZA family are called "zinc-aluminum" alloys.

This brochure is intended as a ZA alloy property summary and process selection guide for designers and materials specifiers. Please note that detailed technical data sheets are available on the many subjects briefly discussed in this brochure (see available Case Histories and Technical Bulletins on back page.)

Cover Photos
Top: Thin wall ZA sandcast housing.
Bottom: Examples of new graphite mold process (Instrument & machine parts.)

COMPARISON OF TYPICAL CASTING ALLOY PRO

ALLOY			
	ZA-8		
MECHNICAL PROPERTIES	SAND CAST	PERM MOLD	DIE CAST
ULTIMATE TENSILE STRENGTH (psi X 10^3)	36-40	32-37	54
YIELD STRENGTH 0.2% Offset (psi X 10^3	28	29	42
ELONGATION (% in 2")	1-2	1-2	6-10
YOUNG'S MODULUS (psi X 10^6)	—	12.4	—
SHEAR STRENGTH (psi X 10^3)	—	35	40
HARDNESS (BRINELL)	82-88	85-90	95-110
IMPACT STRENGTH (ft-lb)	$13\text{-}18^A$	—	31^B
FATIGUE STRENGTH ROTORY BEND (psi X 10^3) (5 X 10^8 cycles)	—	7.5	15
COMPRESSIVE YIELD STRENGTH (psi X 10^3)	29^H	31^H	37
PHYSICAL PROPERTIES			
DENSITY (lb/cu in)		0.227	
MELTING RANGE (°F)		707-759	
ELECTRICAL CONDUCTIVITY (% IACS)		27.7	
THERMAL CONDUCTIVITY (BTU/ft.•hr•°F)		66.3	
COEF. OF THERMAL EXPANSION (68-212°F) (u in/in/°F)		12.9	
PATTERN SHRINKAGE		1/8 in/ft	.007 in/in

1 & 2. Die cast ZA-12 lawn tractor steering-column support bearing replaced expensive steel fabrication. Column now rides directly against ZA casting with minimal wear. Eliminated the need for spherical bearing.

3. Commercial blender features thin-wall ZA-12 sand cast base. (Also see front cover.) ZA's superior casting fluidity provided smooth finish and 0.094" wall sections.

4. Thin-wall (0.090") ZA-12 permanent mold castings for check cancelling machines.

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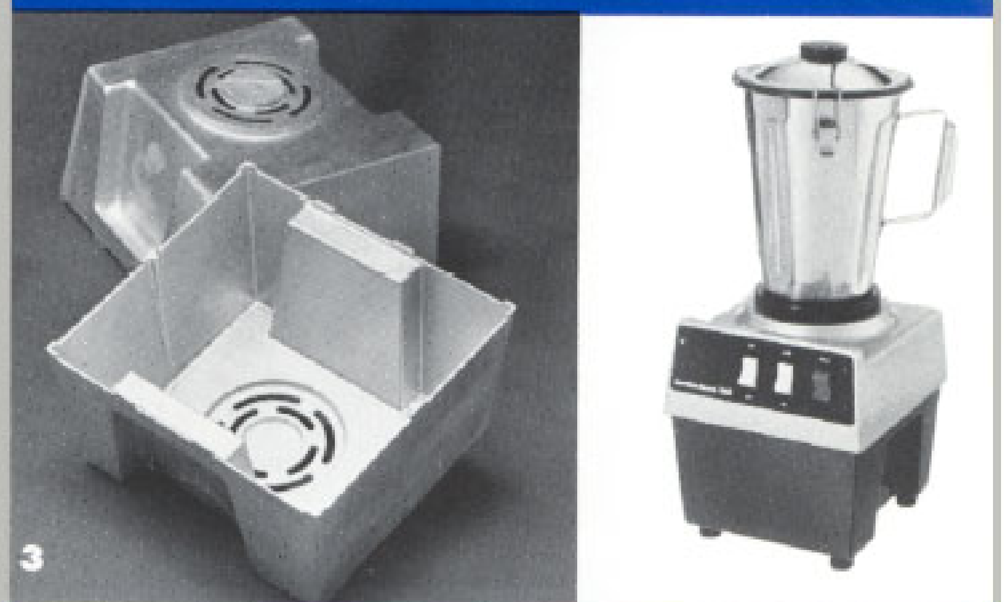
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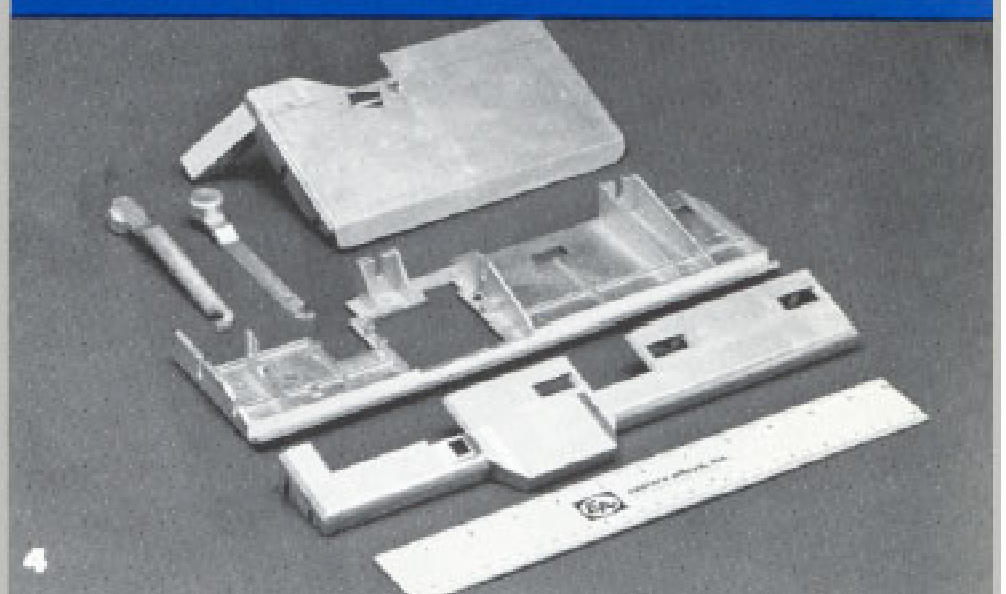
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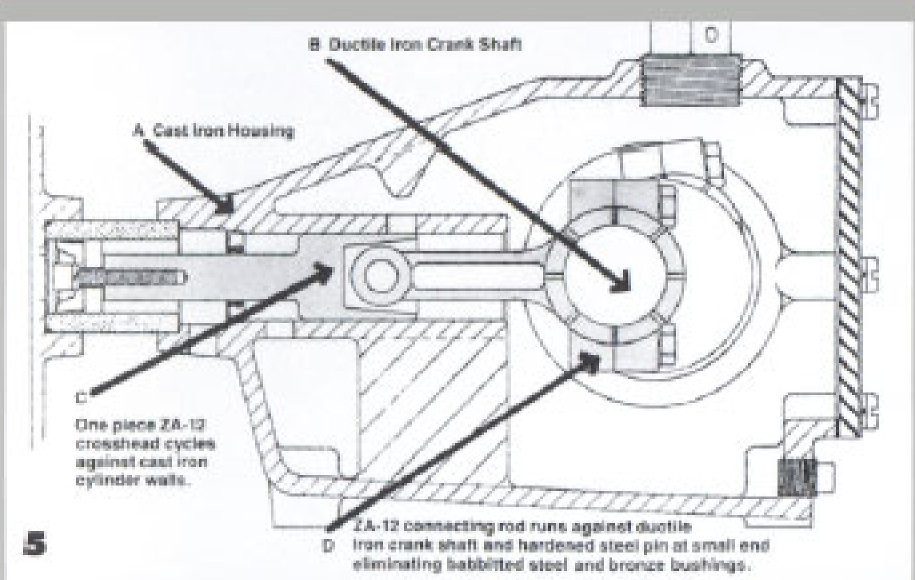
PERTIES

ZINC							ALUMINUM			BRASS/BRONZE			IRON	
ZA-12			ZA-27			No. 3 ZINC DIE CAST ALLOY (AG-40A)	380	319	356-T6	SAE 660 C93200	SAE 40 C83600	SAE 64 C93700	CLASS 30	32510 MALLEABLE IRON
SAND CAST	PERM MOLD	DIE CAST	SAND CAST	SAND CAST HT*	DIE CAST		DIE CAST	SAND CAST	SAND CAST	SAND CAST	SAND CAST	SAND CAST	CAST IRON	
40-46	45-50	58	58-64	45-47	61	41	47	27	33	35	37	35	31	50
30	30	46	53	37	53	—	24	18	24	18^C	17^C	18^C	18	32
1-3	1-3	4-7	3-6	8-11	1-3	10	2	3.5	3.5	20	30	20	—	10
12	—	—	10.9	11.5	—	—	10.3	10.7	10.5	14.5	13.5	11	13-16	25
37	—	43	42	33	47	31	27	22	26	—	—	—	43	45
90-105	90-105	95-115	110-120	90-110	105-125	82	75	70	70	65	60	60	170-269	110-156
19^A	—	21^B	35^A	43^A	9^B	43^B	3^A	4^A	8^A	6^D	11^E	11^E	—	$40\text{-}65^A$
15	—	—	25	15	21	6.9	20	10	8.5	16	11	13	14	28
33^H	34^H	39	48^H	37^H	52	60^F	—	19	25	46^G	37.5^G	47^G	109^F	—
0.218			0.181			0.24	0.098	0.101	0.097	0.322	0.318	0.32	0.25	0.26
710-810			708-903			718-728	1000-1100	960-1120	1035-1135	1570-1790	1570-1850	1403-1705	>2150	·2250
28.3			29.7			27	27	27	39	12	15	10	—	6
67.1			72.5			65.3	55.6	65.5	87	34	41.6	27.1	28-30	—
13.4			14.4			15.2	11.6	11.9	11.9	10	10	10.3	6.7	6.6
1/8 in/ft		0.0075 in/in	5/32 in/ft		0.008 in/in	0.006 in/in	0.006 in/in			7/32 in/ft	3/16 in/ft	1/8 in/ft	1/8 in/ft	1/8 in/ft

A-10mm unnotched Charpy
B-¼ in unnotched Charpy
C-at ½% elong
D-Izod
E-notched Charpy
F-compressive strength
G-0.1 in. set per in.
H-0.1% offset
* 3 hrs. at 610°F & furnace cool.

ZA Properties developed by the International Lead Zinc Research Organization, New York, NY and, the Noranda Research Centre, Pointe Claire, Quebec, Canada.



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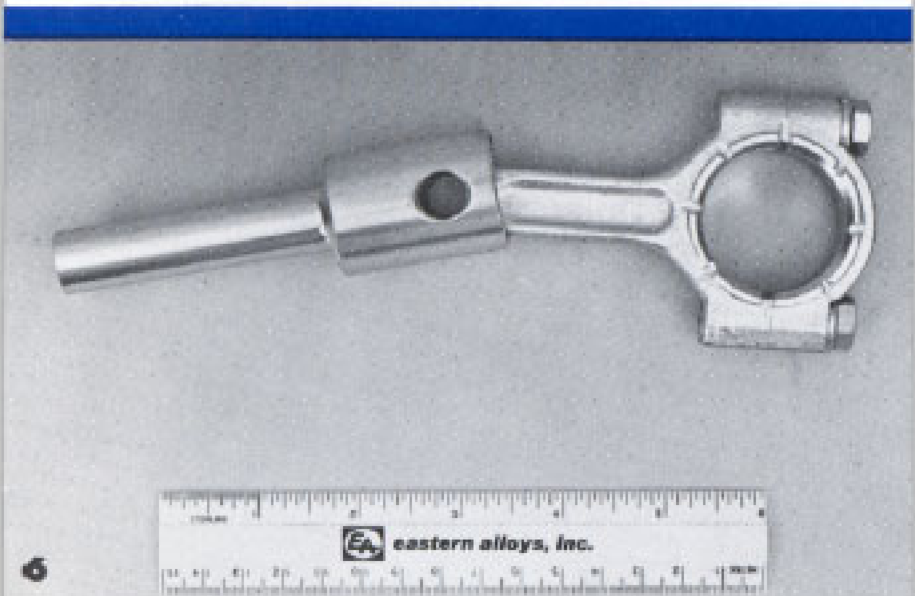

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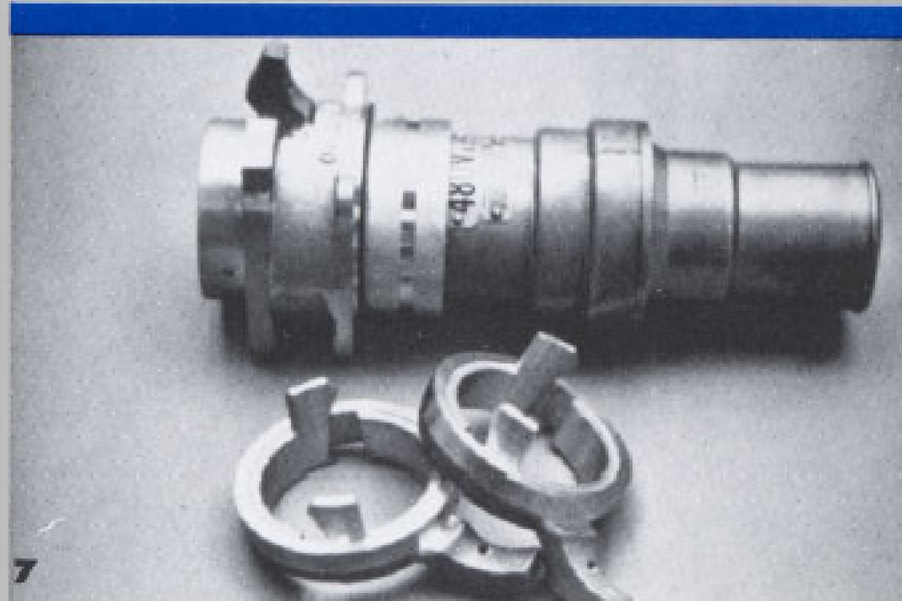
COMPOSITION

ZA Alloys conform to ASTM ingot specification B669-84.

	U.N.S. No.	% Wt. of Main Alloying Elements: Al	Cu	Mg	Zn
ZA-8	(Z25630)	8.0-8.8	0.8-1.3	0.015-0.030	Balance
ZA-12	(Z35630)	10.5-11.5	0.5-1.25	0.015-0.030	Balance
ZA-27	(Z25840)	25-28	2.0-2.5	0.010-0.020	Balance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5 & 6. Schematic of car wash pump featuring ZA-12 connecting rod and cross head. Eliminated connecting rod bearings and chrome-plated steel cross head design. Components cycle at 550 RPM.

7. Marine electrical coupler assembly contains ZA-27 casting shown in foreground. ZA-27 doubled the strength of critical ear lug sections and replaced 356-T6 aluminum sand castings.

DESIGN FEATURES

Strength & Hardness: ZA alloys possess high tensile strength and hardness. which make them suitable as alternative materials to cast iron, bronze. aluminum and steel fabrications. Strengths range up to 64,000 psi depending upon alloy and process selection.

Bearing and Wear Resistant Properties: ZA alloys have inherent bearing properties and are being used as direct substitutes for larger bronze industrial bushings and bearings. ZA alloys are substantially lower in cost than bronze and up to 43% lighter. For smaller components, ZA's natural lubricity may permit the elimination of small bushings and wear inserts, thus lowering secondary fabrication costs The alloys can replace aluminum or hard coat anodized aluminum parts because of ZA's superior galling and wear resistance. In some cases, cast iron parts have been converted to ZA because of similar wear resistant properties.

Machining: ZA alloys machine rapidly, with minimal tool wear. Machining rates are often equivalent to free machining brass and can be three times faster than for cast iron. Ease of machining and elimination of tool breakage problems have often influenced ZA alloy selection over cast iron

Non-Sparking: Aluminum alloy components. when struck with rusty iron or steel, can generate a hot exothermic reaction which can cause an explosion of flammable gas, air mixtures. ZA-8 and ZA-12 are recommended as non-sparking alloys for mine, marine or other potentially hazardous locations. Copper base alloys are also non-sparking: however, ZA alloys are lower cost and lighter.

Pressure-Tightness: Sand and permanent mold cast ZA-12 components can be considered where pressure-tightness is important Gravity cast ZA-12 has demonstrated good pressure tightness for such applications as oil and gasoline valves.

Corrosion Resistance: ZA materials possess good corrosion resistance under atmospheric conditions, and in various aqueous solutions and industrial and petroleum products. Corrosion resistance of the ZA materials is similar to common grades of aluminum. Surface treatments such as chromating, plating. painting and zinc aodizing (see below] provide additional corrosion protection.

Finishing: ZA materials can be polished to a bright lustrous chrome-like finish which can be lacquered for longevity. Plating, chromating and painting are other conventional finishes that can be applied. Zinc anodizing is a special finish (not to be confused with aluminum anodizing) recommended for marine atmospheres or for aggressive environments. The green ceramic-like coating is nonconductive and is particularly resistant to salt water

Material Cost: Although the cost/lb. of each ZA alloy differs. the actual metal cost (cost/unit volume) for each alloy is nearly identical. Therefore, there is no significant cost advantage for selecting one ZA alloy over another. ZA alloys are only slightly higher in cost than standard zinc die casting alloys. They are substantially lower in cost than bronze alloy. but higher than aluminums and cast iron.

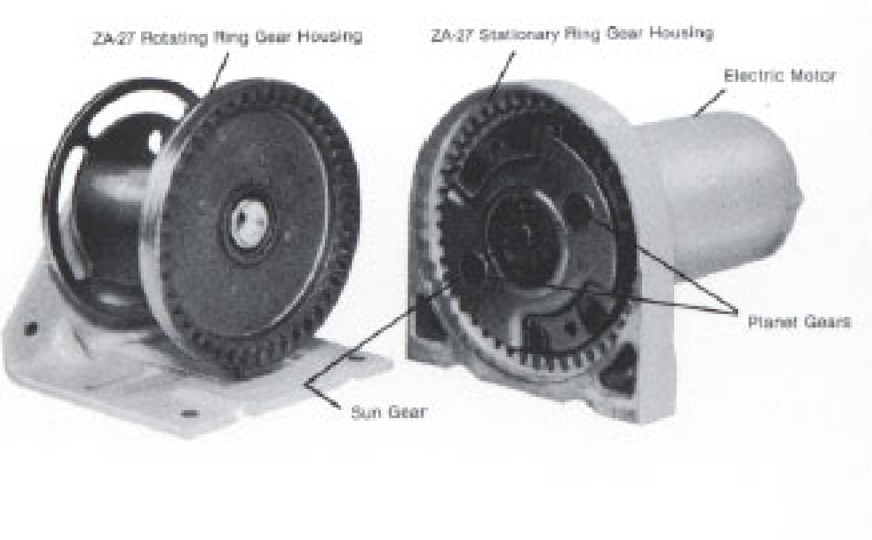
Metal cost, however, is often of secondary importance when considering ZA. ZA's near-net-shape processing options allow for cast-to-size shapes, thus eliminating or reducing secondary machining and processing costs. These reductions can significantly outweigh metal cost considerations In addition, ZA's fast, easy machining can often compensate for material cost differences.

Dimensional Stability: Dimensional change due to residual stress or metallurgical instabilities can result in change of critical dimensions in many alloy systems. Fortunately, residual stresses in ZA alloy are usually minimal due to low casting temperatures. Dimensional change upon aging (metallurgical instabilities), however, is an important consideration. ZA-12 offers the best dimensional stability after aging. ZA-27, on the other hand, can grow up to 0.12% when aged at elevated temperatures (200^0 F.) However, ZA-27 can be given a stabilization heat treatment (12 hrs at 480^0 F.) to minimize aging effects. Aging characteristics of ZA-8 are similar to ZA-12. Detailed aging data is available upon request.

Temperature Limitations: A design limitation of ZA alloys is their use at elevated temperatures. ZA's low melting point is an energy saving advantage for foundrymen. However, at moderately elevated temperatures, strength and hardness decrease. The ZA alloys are subject to plastic deformation (creep) when stressed at elevated temperatures. In general. applications which are above 200^0 F and under high constant stress should be avoided. Moderately stressed parts at ambient temperature up to 120^0 F are best suited for ZA alloys For detailed information on criteria for designing with ZA alloys, particularly at elevated temperatures, please request Eastern's "Design Stress Considerations for ZA Alloys".

1. Recreational winch features two ZA-27 die cast ring gears which were 2½ times stronger than aluminum die castings.

2. ZA-12 printing press idler bearing run at 1000-1500 rpm provided 4 times the life of SAE 660 Bronze in conjunction with major cost savings.



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ALLOY SELECTION

Numerous factors influence material selection. Most important are mechanical properties, choice of casting process, secondary machining and finishing characteristics, corrosion resistance and material and manufacturing costs. Described are the general design features of the ZA alloy family and their differences, which can influence material selection.

COMPARISON RATINGS	ZA-8	ZA-12	ZA-27
SAND CASTABILITY	G	E	F
PERM. MOLDABILITY	E	E	F
DIE CASTABILITY	E	G	G
STRENGTH	G	G	E
DUCTILITY	G	G	G
BEARING WEAR	G	E	E
MACHINABILITY	E	E	E
PRESSURE TIGHTNESS	G	E	F
PLATING	E	G	F
ZINC ANODIZING	E	E	E
CHROMATING	E	G	F
PAINTING	E	E	E
DIMENSIONAL STABILITY	G	E	F

E-Excellent G-Good F-Fair

GENERAL COMMENTS

ZA-8

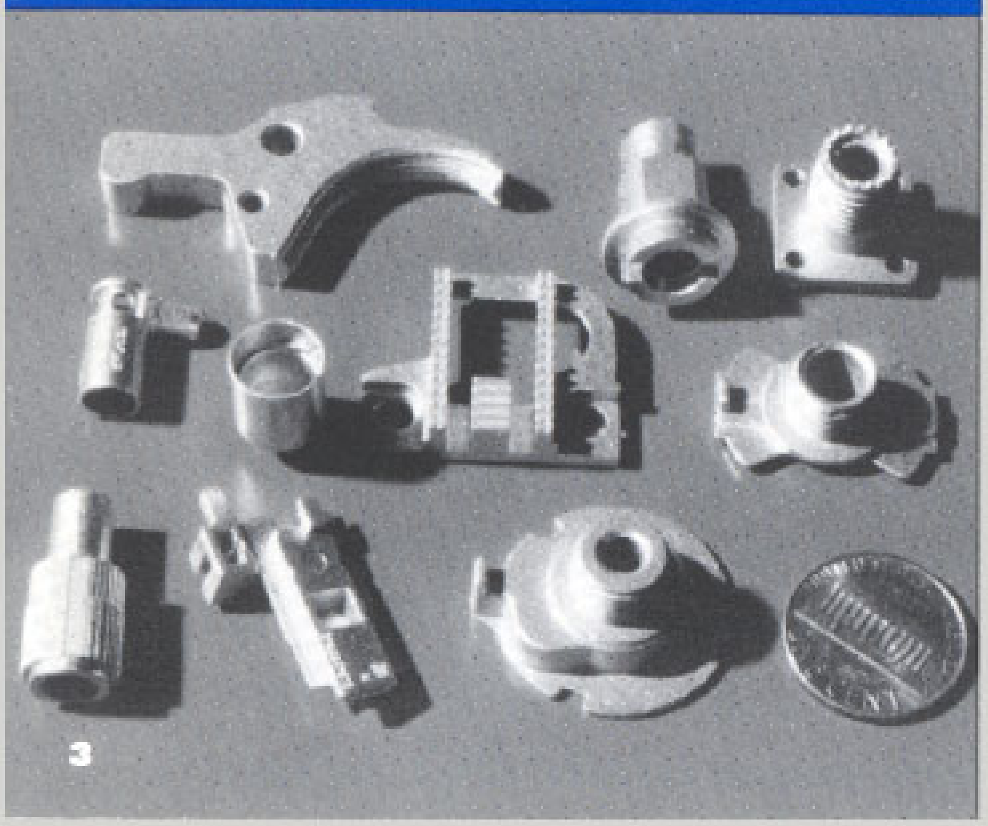
Offers best plating and finishing characteristics and good permanent mold characteristics. Can be hot chamber die cast with improved strength, hardness and creep properties compared to conventional zinc ZAMAK die casting alloys. Major application area is expected to be for die casting where improved properties over ZAMAK's are required, particularly performance at elevated temperatures.

ZA-12

A first choice when considering ZA alloys. An excellent alternate to cast iron, bronze, aluminum and fabrications. ZA-12 provides the best gravity casting capabilities, particularly for sand, permanent mold and the new graphite process. Die castability (cold chamber) is somewhat easier than ZA-27. Offers best pressure tightness using gravity casting methods and best dimensional stability of all ZA alloys. Provides good bearing properties. Best fabrication characteristics for heavy-walled section gravity casting. Can be plated and readily chromated.

ZA-27

Recommended when highest mechanical properties are needed. Best properties but difficult to gravity cast in heavy sections. Preferred for even sections under 3/8". In general, good die castability (cold chamber) but more difficult than ZA-12 die casting. Offers excellent bearing properties but may require stabilization heat treatment for dimensional stability. Difficult to chrome plate. Special foundry and casting procedures may be necessary with this alloy, particularly for heavy sections.



3. Miniature ZA -8 die castings. ZA-8 provides strength, hardness and creep property improvements over standard zinc die casting alloys and can employ existing dies.

4. ZA-12 sand cast cone crusher liner (several hundred pounds) replaced bronze at lower cost with similar bearing and wear performance.

PROCESS SELECTION

A key benefit of ZA alloys is the choice of casting processes available. For example, cast iron and bronzes are normally sand cast, which usually requires extensive machining to obtain final tolerances. Most of the described processes (see chart) offer cast-to-size accuracy which can reduce or entirely eliminate machining and secondary operations.

Proper process selection requires a basic understanding of tooling and manufacturing cost differences as well as the quantity suitable for each process. Complexity of design will also influence process

CASTING PROCESS CHART

CASTING PROCESS	RECOMMENDED ZA ALLOY ZA-8	ZA-12	ZA-27	TYPICAL QUANTITY RANGE	RELATIVE TOOLING COSTS	RELATIVE PART COSTS	TYPICAL TOLERANCES
DIE CASTING: Molten metal is injected under pressure into hardened steel dies, often water cooled. Part ejected for gate removal with trim dies. Process can be automated with robots. Listed are three variations of the process.							
HOT CHAMBER: Plunger injection system submerged in holding furnace which is an integral part of the machine. Results in automated injection, and greater efficiency than cold chamber process. Primarily used with standard zinc die casting alloys.	E	NR	NR	+20,000	1	5	±0.0015"/" Add ±0.001" to ±0.015" across parting line
COLD CHAMBER: Metal must be ladeled from separate furnace into machine for injection. Primarily used with aluminum alloys.	E	E	G	+20,000	1	5	±0.002"/" Add ±0.001 to ±0.015 across parting line
MINIATURE: Specialized version of hot chamber process for very small castings only. Extremely efficient process using batch process tumbling or vibrating technique or in-mold degating. Primarily used with standard zinc die casting alloys.	E	NR	NR	+25,000	2	5	±0.001"/" Add ±0.003 across parting line
GRAPHITE MOLD: Manual gravity pour of molten metal into molds machined from solid graphite and mounted on semi-automatic machines. Parts ejected for manual trimming. Similar to permanent mold casting, but no need for refractory mold coatings.	F	E	F	300-15,000	4	3-4	First inch: ±0.005" Additional inches: ±0.002" Add ±0.005" across parting line
PERMANENT MOLD: Manual gravity pour of metal into machined ferrous dies requiring protective coatings. Parts ejected for manual trimming. Can employ sand/shell cores for complex internal designs. A specialized process can employ low pressure molten metal assist during casting (Low Pressure Permanent Mold Casting).	E	E	F	500-10,000	2-3	3	Basic ±0.015" Add ±0.002"/" Add ±0.010" to ±0.030" across parting line
SAND CASTING: Tempered sand is packed onto wood or metal pattern halves, removed from pattern, assembled with or without cores, and metal is poured into resultant cavities. Various core materials can be used. Molds broken to remove castings. Specialized binders now in use can improve tolerances and surface finish.	G	E	F	Any quantity	4-5	3-4	Basic ±1/32" to 6" Add ±0.003" for each additional inch
PLASTER MOLD: Plaster slurry is poured onto pattern halves, allowed to set, then mold is removed from pattern, baked, assembled, and metal is poured into resultant cavity. Molds broken to remove castings.	G	G	F	1-250	4	1	±0.005" Over 2" add ±0.002"/" Add 0.010" across parting line

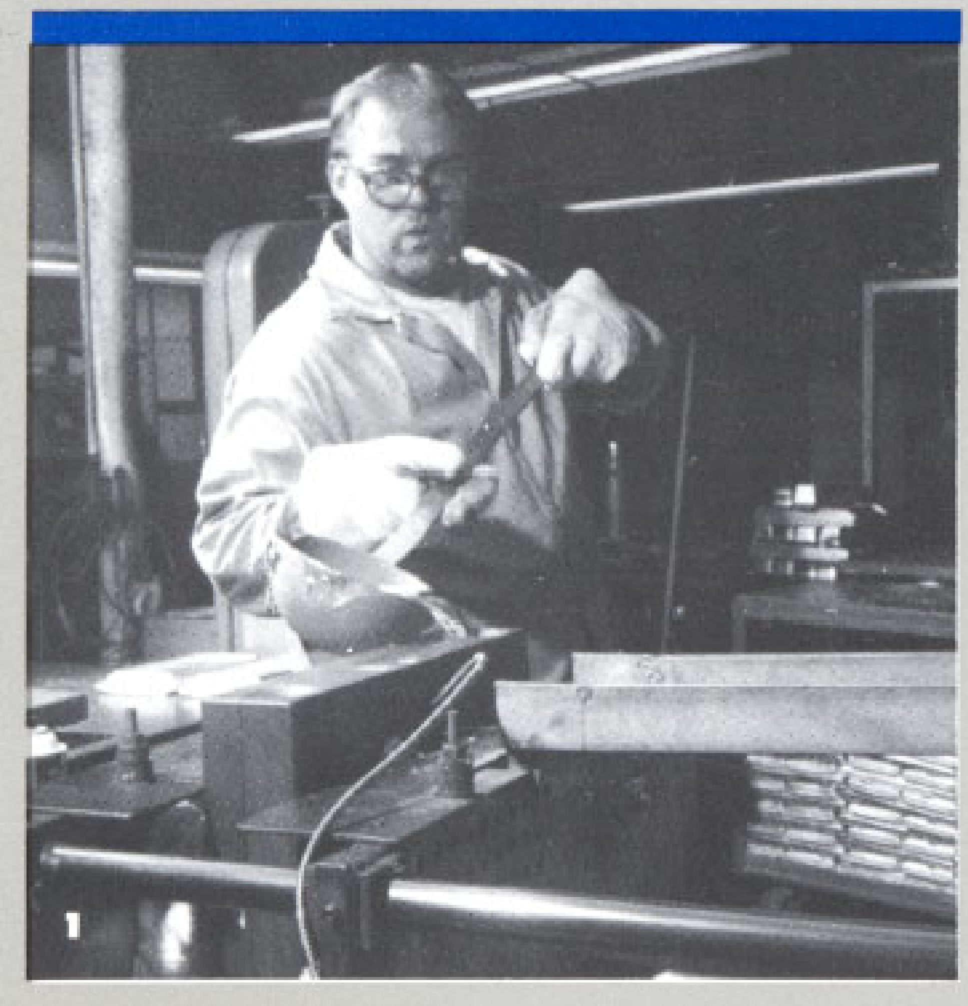
E - Excellent G - Good F - Fair NR - Not Recommended 1 - Most expensive / most design freedom 5 - Least expensive / least design freedom

New graphite mold process uses ZA alloys for precision casting.

1. Metal being poured into graphite mold.

2. Solidified casting being extracted from the die. Note exterior gating system which must be trimmed.

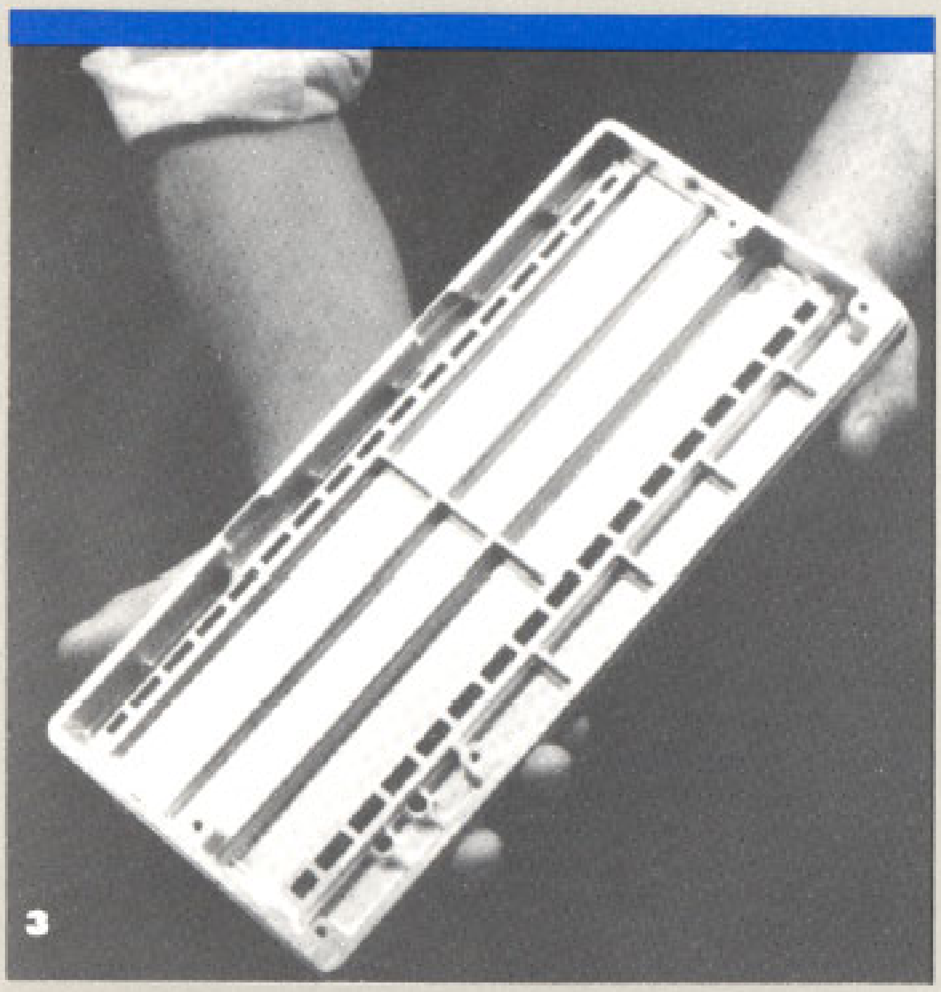
3. Trimmed casting. Note excellent detail and finish. Graphite mold casting is a new process offering excellent precision at low cost for low-medium volume requirements.



selection. The chart is intended as a general guide to help designers evaluate alloys and possible casting processes.

Only the most common casting methods are described. Ceramic, rubber, investment and centrifugal casting are other casting processes which employ ZA alloys. Eastern Alloys can be consulted to review potential ZA applications and which casting process(es) may be best suited.

MINIMUM DRAFT REQUIRED	NOMINAL MINIMUM WALLS	SURFACE FINISH	SIZE RANGE	DESIGN FREEDOM	COMMENTS
½° to 2°	0.025" to 0.040"	32-63 RMS	Not normally over 2 sq. ft.	5	Most efficient process for high volume precision casting, typically 20,000-50,000+ pieces. Best tolerances, rapid production but high initial tooling costs. Internal porosity can be encountered due to entrapped air. Cold chamber ZA-12 and ZA-27 can be used with aluminum die casting machines and dies but require special refractory melting equipment. ZA-27 prone to solidification shrinkage. Hot chamber casting is usually more efficient than cold chamber. Die life of zinc and ZA dies will be considerably longer than for aluminum alloy. Superior fluidity of zinc and ZA alloys results in greater thin-wall capabilities and tighter tolerances than for aluminum. Miniature die casting preferred for very small intricate zinc castings. Tolerances listed for cold chamber are typical for casting of aluminum while those for miniature and hot chamber are typical for zinc die casting alloys. Tolerances for ZA die casting can be considered similar to standard zinc die casting. Note that ZA-8 is suitable for hot chamber casting.
1° to 3°	0.030" to 0.060"	32-63 RMS	Not normally over 2 sq. ft.	5	
¼° TO 2°	0.020"	32-63 RMS	Less than 4½ sq. in. surface area	4	
External: ½° Internal: 1°	0.125" To 0.06" for Small areas	63-125 RMS	One ounce to 10 pounds (Up to 12" X 14" X 7" deep)	4	Combines modest tooling costs with good precision and surface detail. Ideal for low-medium production runs (several thousand/yr. typical). Often selected over die casting for low run applications due to lower tooling costs. Limited mainly to smaller "hand sized" parts normally under 5 lbs. of shallow designs with even wall sections (⅛" typical). Competes with permanent mold casting and sand casting by offering improved tolerances, finish and elimination of secondary machining. Relatively few sources for this new process. Not normally used with shell or sand cores for internal cored designs.
External: 2° Internal: 2° (4° desirable)	.1875" to 0.100" for small areas	150-250 RMS	Ounces to 100 lbs.	3	Similar to but offers greater design freedom than graphite mold casting. Particularly suited for larger parts. Can incorporate shell or sand cores for intricate internal designs. Iron permanent molds withstand considerable abuse compared with graphite and last longer. Tooling designed for aluminum can use ZA alloys. ZA-8 and ZA-12 alloys preferred and can cast thinner sections than aluminum or graphite process (0.100" possible). Tooling cost usually slightly higher than for graphite molds.
1° to 5° cores: 1° to 1½°	0.125" to 0.250"	150-350 RMS	Ounces to any size	1	Sand casting is the most common casting process available. Offers widest choice of casting design freedom in terms of casting size and quantity range. ZA-12 preferred alloy. Tooling cost usually low. A first choice for a few castings or low volume production (under 500 pieces) but suitable for any quantity, even very high production using automatic molding equipment. Tolerance capabilities limited, therefore secondary machining usually rerquired. Finish can be improved with special facing sands. Finish depends upon sand systems, which can vary considerably from one foundry to the next. Thinner than normal sections (0.100 inch range) can be sand cast with ZA alloys due to high fluidity characteristics. Use of cores common. Variations of sand process include CO_2 and air-set sand systems which employ ZA alloys.
External: 0° to ½° Internal: ½° to 2°	0.070"	63-125 RMS	Normally up to 500 sq. in.	2	Provides high dimensional accuracy, smooth finish and intricacy. High processing costs, however, limit consideration to volumes usually under 250 pieces. An excellent method for intricate castings. Often used to prototype die castings.



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PROTOTYPING

Prototyping of ZA components can be accomplished using several methods. Prototyping is often desirable to test product performance prior to investment in production tooling. This is particularly true for high tooling cost processes such as die casting. In many instances, prototypes machined from ingot or sample bar may be adequate. For complex shapes, a gravity casting method is usually employed. Sand casting is the least costly prototype method; however, when greater precision is needed, plaster mold casting can be used. Graphite mold casting and permanent mold casting are also considerations when higher pre-production quantities are needed. Where tooling presently exists for a part under consideration in ZA, it is usually possible to make ZA parts from the tooling. This has been done with sand, permanent mold and die casting tooling.

Prototyping may require compromises in terms of properties and tolerances obtained from samples made compared to actual production casting. Properties will vary with process selection (see property chart). It is best, therefore, to review your specific prototype needs with Eastern Alloys for the most economical methods available to suit your quantity and tolerance requirements.

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Eastern Alloys are specialists in the manufacture of zinc alloys which are marketed under Eastern's Eazall trade name.

Products include alloys for the casting, plating and metal coating industries.

ZA TECHNICAL BULLETINS

Eastern Alloys has a full complement of case histories and technical literature to aid designers and material specifiers. Write and ask for them. They include:

Design Stress Considerations for ZA Alloys
ZA-12 Foundry Data
Foundry Core Guidelines for ZA Alloys
Die Casting Guidelines for ZA-12 and ZA-27 Alloys
ZA-8 Hot Chamber Die Casting Guidelines
ZA Alloy Machining Guidelines
Corrosion Resistance of ZA Alloys
ZA Bearing Design Guidelines
Plating ZA Alloys
Chromating ZA Alloys

ZA APPLICATIONS AND TECHNICAL ASSISTANCE

Competent technical assistance is available. Call or send us drawings for confidential value analysis of potential ZA applications. We will advise on ZA alloy selection, processing and ZA casting sources near you. Eastern maintains a technical staff and laboratory to conduct metallurgical evaluations for ZA product development. ZA technical seminars for groups of engineers, designers and purchasing staff are also available.

AFFILIATIONS

Because professional and trade organizations help industry make progress and stay profitable, Eastern Alloys maintains an interest and is active in these Organizations.

NADCA, North American Die Casting Association
AFS, American Foundrymen's Society
ILZRO, International Lead Zinc Research Organization
FEF. Foundry Education Foundation
IZAA, Independent Zinc Alloyers Association

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. It is the user's responsibility to determine suitability and fitness of application, preferably through independent prototype testing and field evaluation programs by users. Eastern Alloys limited warranty provides only that its products will meet its chemical specifications. There is no warranty of merchantability or fitness for use, nor any other warranty other expressed or implied. Eastern Alloys will not be liable for incidental or consequential damages of any kind resulting from misapplication or failure of castings produced from the alloys.

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COMPARISON OF TYPICAL CASTING ALLOY PROPERTIES

ALLOY	ZINC										ALUMINUM			BRASS/BRONZE			IRON	
	ZA-8			ZA-12			ZA-27			No. 3 ZINC DIE CAST ALLOY (AG-40A)	380	319	356-T6	SAE 660 C93200	SAE 40 C83600	SAE 64 C93700	CLASS 30 CAST IRON	32510 MALLEABLE IRON
MECHNICAL PROPERTIES	SAND CAST	PERM MOLD	DIE CAST	SAND CAST	PERM MOLD	DIE CAST	SAND CAST	SAND CAST HT*	DIE CAST		DIE CAST	SAND CAST	SAND CAST	SAND CAST	SAND CAST	SAND CAST		
ULTIMATE TENSILE STRENGTH (psi X 10^3)	36-40	32-37	54	40-46	45-50	58	58-64	45-47	61	41	47	27	33	35	37	35	31	50
YIELD STRENGTH 0.2% Offset (psi X 10^3)	28	29	42	30	30	46	53	37	53	—	24	18	24	18[C]	17[C]	18[C]	18	32
ELONGATION (% in 2")	1-2	1-2	6-10	1-3	1-3	4-7	3-6	8-11	1-3	10	2	3.5	3.5	20	30	20	—	10
YOUNG'S MODULUS (psi X 10^6)	—	12.4	—	12	—	—	10.9	11.5	—	—	10.3	10.7	10.5	14.5	13.5	11	13-16	25
SHEAR STRENGTH (psi X 10^3)	—	35	40	37	—	43	42	33	47	31	27	22	25	—	—	—	43	45
HARDNESS (BRINELL)	82-88	85-90	95-110	90-105	90-105	95-115	110-120	90-110	105-125	82	75	70	70	65	60	60	170-209	110-156
IMPACT STRENGTH (ft-lb)	13-18[A]	—	31[B]	19[A]	—	21[B]	35[A]	43[A]	9[B]	43[B]	3[A]	4[A]	8[A]	6[D]	11[E]	11[E]	—	40-65[A]
FATIGUE STRENGTH ROTORY BEND (psi X 10^3) (5 X 10^8 cycles)	—	7.5	15	15	—	—	25	15	21	6.9	20	10	8.5	16	11	13	14	28
COMPRESSIVE YIELD STRENGTH (psi X 10^3)	29[H]	31[H]	37	33[H]	34[H]	39	48[H]	37[H]	52	60[F]	—	19	25	46[G]	37.5[G]	47[G]	109[F]	—
PHYSICAL PROPERTIES																		
DENSITY (lb/cu in)	0.227			0.218			0.181			0.24	0.098	0.101	0.097	0.322	0.318	0.32	0.25	0.26
MELTING RANGE (°F)	707-759			710-810			708-903			718-728	1000-1100	960-1120	1035-1135	1570-1790	1570-1850	1403-1705	>2150	>2250
ELECTRICAL CONDUCTIVITY (% IACS)	27.7			28.3			29.7			27	27	27	39	12	15	10	—	6
THERMAL CONDUCTIVITY (BTU/ft.•hr•°F)	66.3			67.1			72.5			65.3	55.6	65.5	87	34	41.6	27.1	28-30	—
COEF. OF THERMAL EXPANSION (68-212°F) (μ in/in/°F)	12.9			13.4			14.4			15.2	11.6	11.9	11.9	10	10	10.3	6.7	6.6
PATTERN SHRINKAGE	1/8 in/ft		.007 in/in	1/8 in/ft		0.0075 in/in	5/32 in/ft		0.008 in/in	0.006 in/in	0.006 in/in			7/32 in/ft	3/16 in/ft	1/8 in/ft	1/8 in/ft	1/8 in/ft