Gravity-Cast Zinc Alloys Find Acceptance

Zinc alloys traditionally have been associated with the diecasting process. During the last four years, however, a new family of zinc alloys has been developed that lends itself to sand and permanent mold casting. This article describes their advantages and disadvantages and looks at some current applications.

By WILLIAM MIHAICHUK / Eastern Alloys Inc, Maybrook. N Y

Reprinted from FOUNDRY MANAGEMENT & TECHNOLOGY
December 1980

For further information on ZA zinc casting alloys contact:

eastern alloys, inc.
BOX Q, MAYBROOK, N.Y. 12543 (845) 427-2151

Gravity-Cast Zinc Alloys Find **Acceptance**

Zinc alloys traditionally have been associated with the diecasting process. During the last four years, however, a new family of zinc alloys has been developed that lends itself to sand and permanent mold casting. This article describes their advantages and disadvantages and looks at some current applications.

By WILLIAM MIHAICHUK / Eastern Alloys Inc., Maybrook, N. Y.

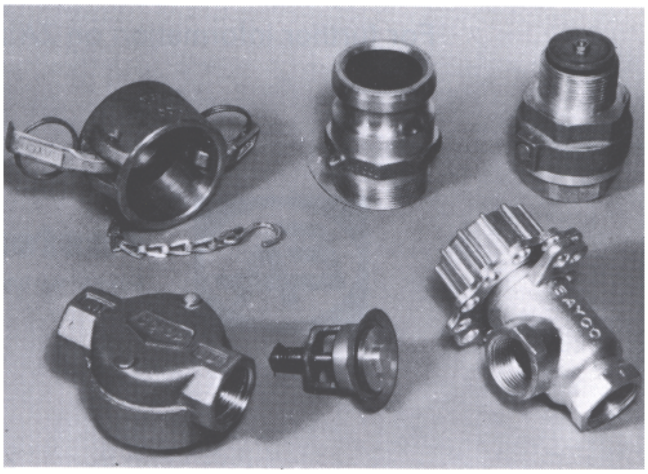
SINCE THE EARLY '7Os, the first of a subsequent family of high-strength zinc-based alloys for nonferrous sand and permanent mold foundries has been available. The family of alloys is receiving attention because casting buyers are specifying them for a wide range of industrial products.

These alloys are radically different from zinc diecasting alloys. They contain higher percentages of aluminum (up to 27%) with minor alloying ingredients of copper and magnesium. Casting buyers appreciate their strength, hardness, pressure tightness, bearings, and wear-resistant properties and easy machining. Nonferrous foundries like these alloys because they usually mean new business and can be handled and cast easily.

Mechanical properties and chemical compositions of these materials are listed in an accompanying table. The alloys have been identified as Zn-12, Zn-27, and Zn-8 which are the nomenclatures recently proposed by the Zinc Institute. The numerical digits (12, 27 and 8) represent the approximate percentage by weight of aluminum, which is the major alloying ingredient to zinc.

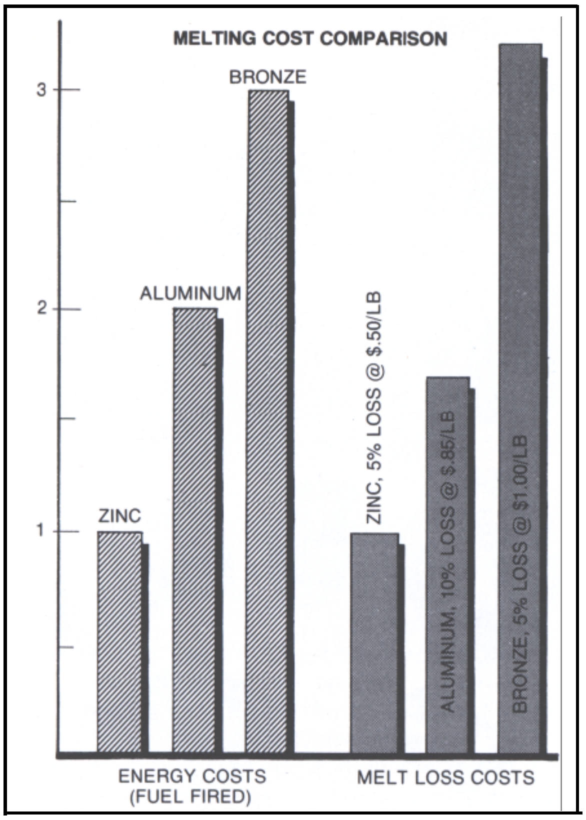
Before 1976, a relatively small number of American foundries employed zinc. That situation has changed with the development of Zn-27 and Zn-8 by Noranda Research Centre, Pointe Claire, Quebec, Canada, and with the emergence of a concerted effort by zinc companies to develop zinc foundry applications. Various trade names are now being used internationally in the promotion of these new products. Most incorporate the same numerical digits, but with different prefixes that indicate the producer.

Melting Zinc Alloys—Foundries usually give zinc alloys high marks for cutting energy bills while reducing melting pollution. They provide low melting temperatures (a com-

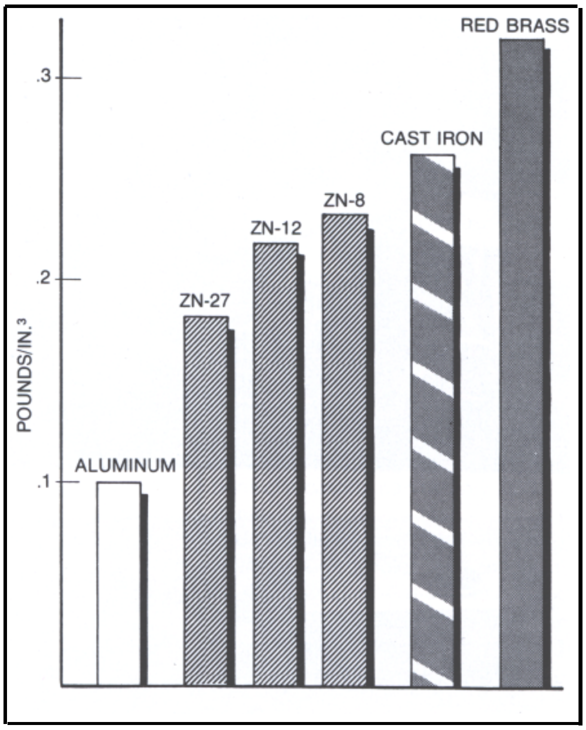


Zn-12 sandcast fuel-dispensing products include coupler components, fuel nozzle check valve, and poppet and gasoline storage tank angle valve, all of which take advantage of the material's excellent pressure tightness. Courtesy Bay Bronze Industries Ltd.

Large conduit elbow fittings are sandcast of Zn-12. Courtesy Lion Head Cast Products.



Comparison of melting costs for zinc, aluminum, and bronze shows fuel-fired energy costs, top, and melt loss costs, bottom, per unit volume of metal cast. Figures are based on approximations from foundries using zinc alloys, with zinc 1 on the scale.



Density of various cast metals ranges from 1 lb/in.^{3} for aluminum to more than .3 Iblin.^{3} for red brass.

Typical Properties of Various Cast Metals

	Zn-12		Zn-27		Zn-8		Bronze (85-5-5-5)	Aluminum (356-T6)	Cast Iron (Class 30)
	Sand	Perm Mold	Sand	Sand Ht*	Sand	Perm Mold	Sand	Sand	Sand
Tensile Strength, psi x 10^3	40-45	45-50	58-64	45-47	36-40	32-37	37	33	30-34
Yield Strength, psi x 10^3, .2% offset	30	31	53	37	28	30	17	24	—
Elongation, % in 2 in.	1-3	1-3	3-6	8-11	1-2	1-2	30	3.5	—
Hardness, BHN	105-120	105-125	110-120	90-100	90-100	85-90	50-65	70	179+
Young's Modulus, psi x 10^6	12	12	10.9	10.9	12.4	12.4	13.5	10.5	13
Density, lb/cu in.	.218	.218	.181	.181	.23	.23	.318	.097	.26
Melting Range, F	710-780	710-780	708-903	708-903	707-759	707-759	1570-1849	1076-1130	2100+
Electrical Conductivity, % IACS	28.3	28.3	29.7	29.7	27.7	27.7	15	40	—
Nominal Composition	11 Al, .75 Cu .02 Mg, bal Zn		27 Al, 2.2 Cu, .015 Mg, bal Zn		8.4 Al, 1 Cu, .02 Mg, bal Zn		—	—	—

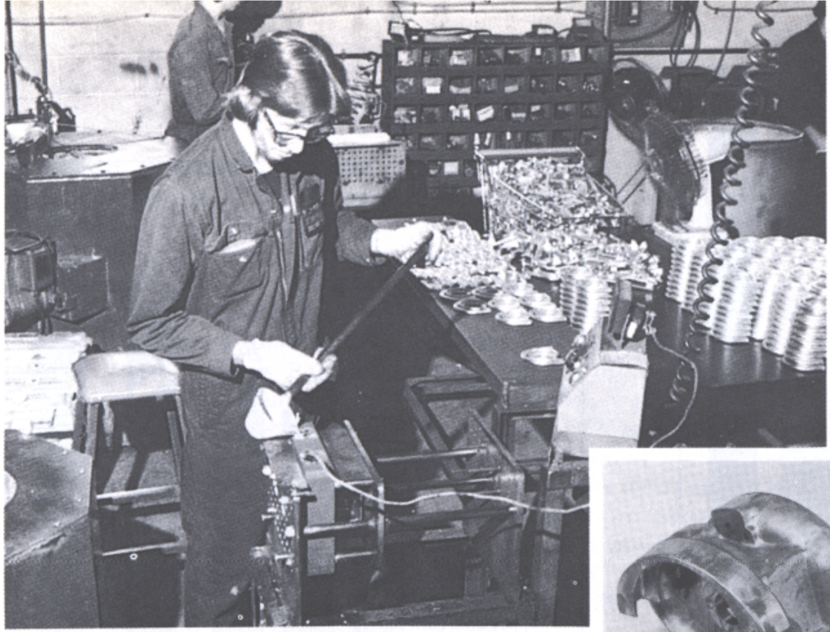
*Heat Treatment—3 hr at 610 F and slow furnace cool.

bined range of 707-903 F), that results in melting cost savings.

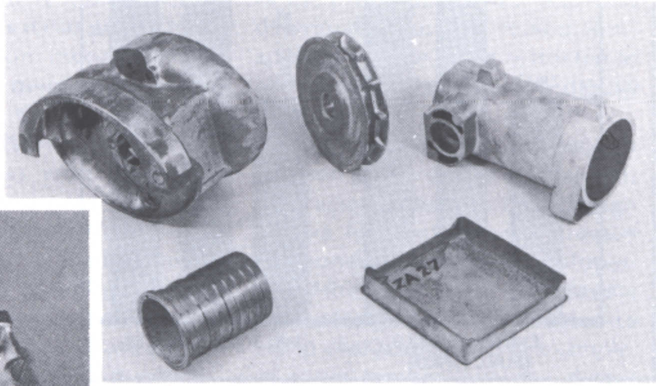
Dave Thompson, Thompson Foundry, Union Hill, N.Y., says "Zinc foundry alloys really melt fast. It takes us 40 to 45 minutes to melt a crucible of bronze (No. 50 crucible, 180 lb of bronze), but zinc takes just 15 minutes." Thompson uses kerosene-fired crucible melting furnaces. Another advantage of low-temperature melting is extended crucible life.

Zinc alloys melt virtually fume free. The zinc fuming that occurs during brass and bronze melting does not occur with these alloys because the melting and casting temperatures are several hundred degrees below the fuming point of zinc. Zinc's vaporization temperature is 1,665 F, whereas the alloys seldom are cast above 1,100 F. Secondary melting treatments such as degassing or fluxing are not required, even when returns are recycled.

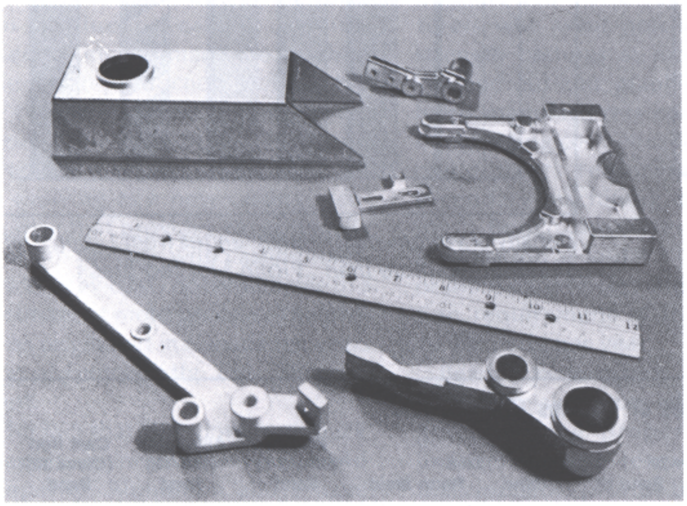
Handling is a straightforward matter of melting, skimming, and pouring. The only melting precautions required are to prevent overheating and to use a separate crucible for zinc alloys-never a crucible that previously has held brass or bronze since lead and tin are serious contaminants. Melting in iron pots also should be avoided because zinc attacks iron and will cause melt contamination. All fer-



Zn-12 graphite permanent mold casting is poured at Fantom Mfg. Ltd. Ejector platen insures that parts are ejected off the die accurately. Die cycling is controlled thermostatically.



Left to right, permanent molded parts made in England are, top row, chain pulley block, chain wheel, and explosionproof light housing, all Zn-12, and bottom, Zn-12 hose fitting and Zn-27 cover. Courtesy Brock Metal Co.



These Zn-12 graphite permanent mold castings made at Graph/cast Inc. provide excellent as-cast finish and tolerances of ±.005 in or better on critical dimensions.

rous utensils should be coated with a refractory.

Sandcast Zinc - Zn-12 and Zn-27 are the recommended sand foundry alloys. Zn-12 is the best performing sand casting alloy and can be used with patterns and matchplates designed for aluminum, bronze, and cast iron, usually with only minor modifications to gating and risering.

Nonferrous sand foundries that have tried the alloys have found them compatible with their sand system, although fine sand systems definitely are preferred. Zinc's fluidity can replicate fine mold detail, but will tend to penetrate coarse sand systems such as those found in most ferrous shops.

Lion Head Cast Products, Bridgeport, Conn., is a ten-man sand foundry that is particularly suited for zinc because of its sand system. It produces castings with exceptionally smooth finish and tolerances of ±.015 in. for castings up to 6 in. and ±0.25 in. for castings 6 to 12 in.

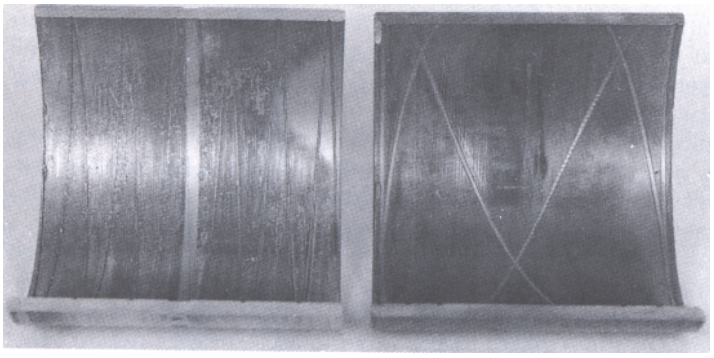
"We use an 00 Albany sand system," explains Dennis Kulish, president. "Zinc gives us exceptional finish and fluidity. It's easy to pour and we like its low temperatures," he says. Kulish uses a gas-fired 400-lb-capacity aluminum bale-out furnace for most of his melting.

"It takes us about 1½ hr to melt 1,000 lb of zinc. A full pot of aluminum takes us 20 minutes longer. In our 30-lb aluminum crucible, zinc melts about twice as fast as aluminum," says Kulish. The melt loss with zinc is limited to skimmings and is only 4-5%, or roughly half that of primary 319 aluminum.

Kulish adds, "most of our castings require shell cores. We use a 1½% resin mix and get good shakeout properties."

Underside Shrinkage - Zinc sand casting is not all simplicity, however. Unique to zinc is underside shrinkage, a spongy surface defect that occurs only on the drag side of zinc castings. Its cause is related directly to poor feeding characteristics of wide-freezing-range alloys. Zn-27 is particularly prone to this defect.

For this reason, all important surfaces should be kept in the cope. Underside shrinkage is controlled through proper risering and use of chills and insulated risers. Casting layout also is important. For example, a flat plate is best cast on its edge, thus reducing drag surface area and minimizing underside



Sectioned scoop tram bushings after 4,100 hr of actual service, SAE-600 bronze bushing on left, zinc on right. Courtesy Texasgulf Inc.

shrinkage.

Core removal also can be a concern. Because zinc is cast at low temperatures, insufficient binder or resin breakdown occurs, resulting in poor shakeout. Best shell core removal is achieved with thin shell cores with resin content kept as low as possible. Intricate internal cores with very small core removal openings are most difficult to shake out. Wide, open-ended cores usually are removed easily by shot blasting.

Occasionally, hot tears develop at heavy-thin section transitions or at sharp radiuses. Increasing the radiuses or using ribs or tapered sections usually resolves these situations. Extra venting also is recommended to preclude air entrapment porosity.

Bay Bronze Industries, Ltd., in Winnipeg, Man., Canada, probably has as much experience with zinc as any other sand foundry. It has been casting Zn-12 for nine years in its modern, 145-man sand and permanent mold operation. The plant uses a No. 100 crucible pushout furnace to melt zinc and bronze.

"Melting aluminum with our electric furnace is inefficient," says Gunther Mathwig, foundry foreman, "but zinc works fine. It takes 15 min at half power to melt zinc. The same volume of bronze (300 lb) takes 20 min at full power. In fact, with zinc we can work so that we have one man melting and one man pouring, making for maximum efficiency."

Another foundry advantage of zinc's low temperature is better sand control. Bay Bronze has an automatic sand system to complement its automatic matchplate molding machine and jolt squeezers.

"We don't have to make any additions to our sand because there is little if any burnout. Sand returns to the muller much cooler, making moisture control easier," says Mathwig. Bay Bronze uses an AFS 115 GFN silica sand system with 2½% moisture, 55 permeability, and 16-psi green strength. The sand system is reported to provide a good finish for zinc castings as well as for aluminum and bronze alloys.

Mathwig observes, "Zinc is by far the preferred alloy for melting, but I would give aluminum the edge when it comes to castability. Zinc's fluidity is great, but feeding of isolated heavy sections gives us trouble because of underside shrinkage. Casting of relatively even-walled parts, however, is easy." Bay Bronze uses the same gating systems for zinc and aluminum. The same matchplates are incorporated for both in some of their casting requirements.

Permanent Mold Casting Zn-8 and Zn-12 are the preferred materials for casting in ferrous permanent molds. Zn-8 is employed for permanent mold castings only when platability is of maximum importance. Zn-12 is used for general-purpose engineered castings when maximum strength and dimensional stability are needed. Both alloys offer excellent fluidity for thin-walled intricate shapes.

In the UK, permanent mold cast-

DESIGN CONSIDERATIONS FOR ZINC GRAPHITE PERMANENT MOLD CASTING

Dimensional tolerances - These tolerances are suggested for critical dimensions only: first inch, ±.005 in.; additional inches, ±.002 ipi; across parting line, add ±.005 in. Closer tolerances can be held if required. All inside radiuses (fillets), .02-.03 in, minimum.

Wall thickness - A prevailing wall thickness of .10 in. would be the minimum for a shallow, 4 by 4-in. casting. Larger parts require up to about .180-in. walls, and small sections of a casting can be only ,060 in. thick.

Cored holes and draft - If 2-deg draft is allowed, holes of all sizes can be cored to 3 or 4 diameters deep. Holes to be cored normally must be oriented perpendicular to the parting line unless they are "on" the parting line. Nominal draft requirement is 2 deg all over, with ½ deg external and 1 deg internal minimum requirements.

Side or side-action cores- Similarly to diecasting, auxiliary die components can be incorporated to form undercuts and other complex shapes not possible with a two-piece mold. These parts of the mold must be withdrawn before the mold is opened to allow ejection of the part. Slide features will increase mold cost compared to that of a simple, two-piece mold.

Ejector pin marks - The impression of the faces of the mold ejector pins will appear on one side of the casting, just as in diecasting or injection molding. Important surfaces and practical locations for these necessary marks should be specified, as well as whether the pins should be "in" or "raised."

Parting line - The parting line will appear on the part as a raised bead approximately .015 in. wide by .010 in. high. It normally will be on a sidewall, not on an edge, to facilitate gating and minimize flashing and sharp edges, and will be removed by the degating operation whenever the gate appears.

Lettering and artwork - The process can reproduce fine lettering and artwork, preferably as raised graphics. If lettering cannot protrude above the surface, a sunken pad with raised letters is used.

ing of zinc is the dominant casting method, advises Mike Barber, assistant general manager, Brock Metals Ltd., Staffordshire, England, an alloy supplier. "We've found that Zn-12 is the preferred alloy in gravity diecast shops (permanent mold) in the UK," says Barber. "They use exactly the same mold designs that they are accustomed to with aluminum. The only difference appears to be a somewhat longer cycle time for larger zinc castings."

Graphite Permanent Molds — Although graphite permanent mold casting is not new, zinc is revolutionizing the use of graphite dies for production casting requirements. Zinc has made the graphite die a high-production tool capable of casting in excess of 25,000 shots from a single mold. The zinc graphite permanent mold process is evolving as a new casting technology that provides exceptionally smooth finishes with casting tolerances previously not obtainable in a permanent mold process. The process originated in Canada ten years ago at Fantom Mfg. Ltd., Thorold, Ont.

The fact that zinc does not attack graphite is one reason for mold longevity. Aluminum alloys have been tried in the process, but higher casting temperatures and the abrasive nature of aluminum cause premature die deterioration. With zinc, die surfaces usually are sprayed with a graphitic aerosol mold release. Refractory coatings are used only in the runner system to promote feeding, thus avoiding dimensional surface finish inconsistencies associated with the heavy refractory coatings used on iron dies.

Because graphite conducts heat rapidly, casting cycle times are reduced compared to those used with iron molds. In addition, machining of graphite dies is easier and faster than that of iron, and tooling cost for graphite dies is usually less than for iron. On the other hand, graphite permanent mold castings are limited to parts under 10 lb and presently are restricted to casting sizes of approximately 12x14x7 in. Although bench hand molding is being done, the new process uses dies mounted on a simple, semiautomatic machine that incorporates an ejector system in the opening cycle. Accurate part removal is necessary to prevent chipping or fracturing the graphite.

Graphicast, Inc., West Peterborough, N.H., was the first job shop in the USA to set up a zinc graphite permanent mold operation. In two years it has grown to a 10-man operation incorporating complete mold building capabilities. Les Bunch, Graphicast president, states, "We're having our greatest success with machine builders and instrument manufacturers who want precision, high-strength castings at modest cost. We find our zinc graphite process helps manufacturers control costs by providing cosmetically attractive components requiring minimal secondary machining and finishing." Bunch describes a typical graphite job as under 3 lb with two or more cored holes and a production requirement of from 500 to 10,000 parts per year.

Bearing Performance — A feature of the zinc-aluminum alloys is their good bearing properties. Preliminary bearing research shows that zinc alloys provide bearing and wear performance equivalent to SAE 660 up to 250 F. The zinc industry through ILZRO (International Lead Zinc Research Organization) has under way an in-depth bearing property evaluation for Zn-12 and Zn-27 at Battelle Research, Columbus, Ohio, to identify technical guidelines for future applications. In the meantime, most zinc bearing applications are being investigated and specified via prototyping and field testing.

Texasgulf Inc., Stamford, Conn., is a supplier of zinc foundry alloys that has been conducting bearing tests for the last two years at the company's mining operations. Ken Altorfer, manager of business development, states, "There is a big market for these zinc alloys as bearings. We've demonstrated to ourselves that zinc can stand up extremely well in arduous bearing applications and that substantial cost savings can be appreciated without sacrificing bearing performance. In most of our tests, zinc has outperformed the traditional bronze bearing."

Limitations — Just as low casting temperature is a key foundry advantage for zinc alloys, there are major limitations as to how high a temperature the alloys can be used at. At moderately high temperatures, properties of the materials deteriorate. For this reason most applications are being restricted to operating conditions below 200-250 F.

Highly loaded and continuously stressed parts require special consideration. The limiting design criteria for continuously stressed components are the creep properties of the alloys. Zn-27 provides the best elevated temperature and creep characteristics. For example, at room temperature the design creep strength of Zn-27 sand casting is approximately 10,000 psi, which is triple the creep strength of conventional No. 3 zinc diecasting alloy and Zn-12. At 200 F, however, Zn-27's creep strength is 3,000 psi, or about the same as that of a zinc diecasting at room temperature

Manufacturing Cost — In terms of present foundry costs, zinc alloys offer the lowest handling and melting costs available. Zinc alloys are not much more expensive than aluminum. As-cast strengths of zinc are superior to those of heat treated 356T6 aluminum, and material costs are about the same when T6 heat treatment costs are included.

Ray Hohenwarter, vice president of manufacturing, Schmitts Aluminum Foundry Inc., Allentown, Pa., explains, "Volume for volume, our melting energy costs and melt losses for zinc are half those of aluminum. Right now, our combined metal and melting costs for 356 aluminum, excluding fluxing and degassing costs, are $1.04 for a typical 1-lb sand casting. The same part, by volume, averages $1.17 in zinc. If we add 20 cents per pound for aluminum T6 heat treating, you can see that zinc becomes less expensive since it normally doesn't require heat treating. If thinner sections can be designed for zinc to take advantage of higher strengths, then the new alloys probably are more competitive."

Hohenwarter adds that his zinc crucible (No. 600 oil-fired dipout) lasts at least four times longer than his aluminum-melting crucibles.

In terms of secondary manufacturing cost, fast, trouble-free machining is a big plus for zinc. In addition, the alloys are less likely to warp or distort during casting or machining. Some manufacturers claim that freedom from distortion, fast machinability, and long machine tool life are more important than casting price. In many instances, casting buyers are paying a premium for zinc castings and picking up overall cost reductions in lower machining and finishing costs. Zinc alloys have no skin effects, inclusions or hard spots to plague machinability.

Pressure tightness is another advantage. Several years ago Bay Bronze switched a red brass gasoline storage tank angle valve to Zn-12. The 2-in.-diam angle valve (1 lb in zinc) was sandcast with wall sections of around 1/8 in., subsequently machined to .075-.l00in. thick. Pressure testing to 75 psi for leakage occurred after machining. With 85-5-5-5 red brass, 5-10% were leakers, but with Zn-12 the same valve, with the same matchplate, eliminated leakers.

The Future for Zinc - In the long run, zinc's energy-saving melting and cleanliness will promote these alloys. The graphite permanent mold process holds great future promise. There now are eight zinc graphite shops in North America, four each in the USA and Canada.

Once on-going zinc bearing research has identified operating parameters for the alloys, zinc will expand into bearing markets because of its modest cost. The alloys have been semicontinuously cast and centrifugally cast without pollution.

Zinc's real buyer appeal is the combined effect of good properties, a choice of casting processes, modest alloy cost and low manufacturing costs. Growth of zinc applications depends on the demonstration of all these advantages to casting buyers and their manufacturing and technical people.