LIA15997

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4 P.M. Thursday, April 29, 1965

ZINC RESEARCH - FORMULA FOR INDUSTRY PROGRESS

by

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The ability to plan ahead is perhaps the most important executive function in directing an industry or a corporation and contributes most to ultimate success. Unfortunately, it is also the greatest intangible when blueprinting an industry program. But in today's burgeoning technology, adequate planning is the catalyst for progress or even survival. It has lost its visionary connotation; instead it is a necessary ingredient in day-to-day management.

Industry planning requires a careful, painstaking study of many factors and critical self-evaluation. The planner must take into account the present and future state of the industry based on its strengths and weaknesses. These involve the technical capabilities of the product, potential new developments, marketing programs, even the mental attitude of personnel. This same evaluation must be applied to the competition to chart probable long range economic positions and threats. It is here that the true ability to plan ahead can be introduced to improve the industry for the future. It is not always enough that the financial position of the industry progresses. With effective planning this improvement must be related to changes in both the economy and the competition. It must also contain a large element of technical advancement for protection against the future.

(Presented at the 47th Annual Meeting of the American Zinc Institute, Inc.
Chicago, Illinois, April 29, 1965)

major contribution will be in alloy developments. Better alloys provide improved castability, physical properties, and smoother surfaces for subsequent finishing and plating operations. Zamak 7 is considered by many to be a valuable alloy with improved castability and finish; characteristics which yield economies through higher production rates and reduced finishing costs. For certain applications, particularly in those subject to elevated temperatures, zinc suffers from deformation under load. A portion of our research program is devoted to developing die casting alloys with improved creep resistance. Originally developed as a wrought alloy, the zinc-copper-titanium alloy, with certain modifications, is showing improved performance in this vital area. Because of zinc's overall excellent castability, plus this improvement in creep, we believe that a portion of the market we have lost in certain areas can be regained.

A critical portion of the die casting operation is the design of casting dies. In a joint program with the American Foundrymen's Society Training and Research Institute and the Die Casting Research Foundation of the American Die Casting Institute, an excellent study has been conducted to evaluate metal flow characteristics in die casting dies and the proper design of gates. This study, which has resulted in an excellent motion picture film will, we believe, be a significant contribution to the die designer. It should serve as a practical guide for better die design with subsequent improvements in physical properties and surface finishes of die cast components.

Tinted water was introduced into transparent plastic dies and photographed by high-speed cameras to trace flow patterns at high velocities. Such parameters as fluid flow in the gate and die cavity and the influence of coring, venting and gating were studied. We have learned a great deal from this program on improved design of casting die components to reduce turbulence and gas pockets to produce sound castings with better properties and finishes. Fig 3, for example, shows one experimental arrangement for evaluating the effect of gate design on fluid flow.

One factor not investigated in the ILZRO program, but which should be considered, is the effect of vacuum on the die casting operation. Many so-called vacuum die casting systems do not provide an adequate vacuum and hence the full potential benefits are not realized. Another important point is the high cost of manufacturing die casting dies. This initial tooling outlay sets a lower limit on production runs which are economical. If electroformed dies can be proved satisfactory from a technical standpoint, they will certainly contribute to the overall economy of the die casting operation. Because of the beneficial characteristics inherent in the process, surface finish and surface quality should be enhanced. Through a cooperative program, production runs will be conducted with the dies to show their overall performance and their application to the casting of metals.

Preparation for Plating - The latest threat on the horizon for plated zinc die castings is plated plastics. The plastic industry claims that it can produce parts at a much lower cost than plated zinc die castings. However, they are making certain assumptions concerned with this second cost center, Preparation for Finishing (Fig.4). They claim that their components, in contrast with zinc die castings, do not have to be buffed prior to plating. It is quite likely that the buffing operation can be eliminated on small plastic parts. However, it is extremely debatable that this advantage extends to large plastic sections. Shrinkage and other thermal effects can cause surface deformation which may require adjustments.

On the other hand, there is every likelihood that we can further narrow any gap by greatly reducing normal costs encountered in plating preparation and, in other cases, entirely eliminate them. It is known that with proper care of die casting dies, and improvement in casting operations, by the use of carefully maintained dies, buffing can, in many instances, be eliminated. Perhaps electroformed dies can also contribute significantly to surface improvement and thereby eliminate preparation for plating. However, there are other methods which certainly could greatly reduce the cost of preparation for plating. These include mechanical preparations, such as tumbling with abrasives, improved buffing techniques and the employment of pore-filling and leveling plating baths. Bright acid copper has been found extremely effective for leveling off irregularities which increase finishing costs and cause premature corrosion. Much of our research effort during the coming year will certainly be focused on these areas because of the potential cost and quality benefits. Concerning plating (Fig. 5), the participation of ILZRO, the plating supply houses, as well as the automotive industry, in what has become a very well known cooperative effort, has greatly contributed to the outstanding performance of plated zinc die castings to meet today's severe service conditions. The great advances have been duplex nickel, crack-free chromium, and microcracked chromium. These employed individually, or as part of a total system, can provide outstanding performance with greatly extended service life.

In outdoor exposure testing programs at static sites, on tugboats (Fig. 6) and automobiles, microcracked chromium, with a continuous network of cracks, proved to be the most effective system. Only about ten per cent of several microcracked chromium over bright nickel plating systems, applied up to five years ago on automobiles, showed excessive corrosion. Many refinements have been introduced, such as applying a cathodic dichromate treatment after plating. This technique further improves corrosion resistance by depositing a protective oxide coating over chromium plate. The test panel, shown at the left in Fig. 7, exhibits excellent resistance to a chloride atmosphere after this treatment.

However, these improvements have been gained at a moderate increase in the cost of plating. Actually, this cost increase is marginal when compared with the significant improvements which have been made. However, a portion of our continuing work in the plating area is to maintain the same level of performance, but at the same time significantly reduce costs. I would like to repeat again that these improvements in plating are not due solely to our own research efforts, but to the major contributions of the plating supply houses, the automotive and appliance manufacturers, plus ILZRO research. The annual plating seminars which we have held recognize the outstanding cooperation of these groups. Certainly progress would not have been realized if we had not had the cooperation of all of these groups.

A completed automotive or appliance part represents an entire system, comprising the metal, casting operation, the preparation for plating, and plating. Each of these factors, as we have previously discussed, are critical segments of the total component system. All are important since they determine final part cost and the competitive position of zinc in the die casting market. Screening the die casting program in toto, it is obvious that we have gone back over each of the steps to contribute cost and performance advantages for the system. We must meet the challenge of the prime competitive materials -- plastics and aluminum -- promptly and forcibly. Every possible approach to better our position must be considered since this market is vital to the economic health of our entire industry. We believe that this systems approach will yield success for us in maintaining this market.

However, there are other improvements that can be made though alternate finishes for zinc die castings. They may offer basic decorative appeal or contribute to improved performance of die castings subjected to severe environmental corrosive conditions. In the past, we have discussed at length developments in anodizing. Last year at this time, we announced that three new finishes had been introduced as part of the family of anodized coatings. These offer a higher order of corrosion and abrasion resistance than the original APCF coating, plus additional colors. Fig.8 illustrates the results of exposure for from 50 to 442 hours in 5% salt spray for parts as cast, with a chromate conversion coating and anodized by the APCF process.

We hope in the not too distant future to announce the award of an exclusive license to an important commercial organization which will market and service this process domestically as well as internationally. Field evaluation of the anodized coatings show definitely superior performance where abrasion resistance or corrosion resistance is required. Typical anodized parts are shown in Fig. 9. Parts which have been anodized, and in some cases field tested, include: washing machine pump casings and impellers, automotive window crank assemblies, door latch housings, automobile generator pulleys, bolts for pipe lines, gears and a host of others.

There are also painted finishes, organic in nature, which provide an alternative to plated die castings where cost and color are deciding factors. Significant improvements have been made in finishes compatible with zinc; however, additional work remains to develop a totally satisfactory clear finishing system. Pigmented polymer coatings show excellent corrosion resistance as well as decorative appeal for zinc die castings. And, finally progress has been made in providing adherent paint systems for plated zinc die castings to round out their total styling appeal.

In planning ahead for zinc's continued position in the die casting industry, we feel we have left none of the important steps untouched in our zeal to produce a superior product which offers high performance through the key attributes of quality plus economy. We certainly have reached major milestones in each of the areas mentioned above. If the same degree of success continues in our total program, we sincerely believe that zinc will remain the quality competitive material in the die casting industry.

Galvanized Steel

There is probably no coating for steel which provides such excellent protection at such a relatively low cost as does zinc. Despite its excellent performance, the steel industry and others are looking at a variety of systems to protect steel which do not include zinc. Organic coatings, aluminized steel, electrophoretic coating systems, and alloyed steels are all being promoted as providing corrosion protection suitable for a wide range of environmental service conditions. But none of these are galvanized steels. With this wide and growing series of alternate coatings for steel, we must continue our research activities on our own, as well as in cooperation with the steel industry, to improve quality, performance, decorative appeal, and widen applications for coated ferrous products. In reviewing the galvanizing process, one technique which we have investigated has proved economically sound and has resulted in a unique product. This is our process for cladding steel with particulate zinc, either in Prime Western grades or in a range of alloys which could not be applied to steel except through the particulate metallurgy process. The advantages include a wide range of alloy systems with varying corrosion performance, one-side clad galvanized steel, and thicker coatings with longer life and improved ductility. Several organizations have checked out the preliminary work we have conducted and agree with our findings. We believe that ultimately this will find important commercial application because of its unique capabilities.

In the field of alloys for galvanizing, our research in conjunction with the Canadian Lead and Zinc Research Committee at the Mines Branch in Canada has led to new alloys for hot dip galvanizing. These new alloy systems have reduced the sensitivity of the high strength low alloy steels to zinc attack, with the formation of heavy, rough coatings significantly reduced. Surface finish is improved through the suppression of iron-zinc alloy outbursts. These new hot dip galvanizing alloys should provide a universal galvanizing bath which will permit a uniform zinc coating to be achieved, not only on the high strength, low alloy steels but also on assemblies of mixed steels. Advantages will include: better appearance, improved performance and closer control of coating thickness. If the pilot trials prove to be as successful as the laboratory tests, this should be one of the most significant contributions which has been made to hot dip galvanizing. In the field of applications, our program on resistance welding of galvanized sheet for automotive and appliance manufacturing has proved significant. Research results are contributing to improved welding practices for many of the automotive manufacturers and will serve as a standard reference for the galvanizing industry and users of galvanized products. Several definitive papers have been prepared and widely circulated to provide technical assistance to fabricators employing our materials. In addition, a complete resistance welding manual will soon be completed for use as a guide by the development associations.

Another manual is being prepared by IIZRO on the joining of galvanized products by other welding techniques such as gas, arc, consumable and non-consumable welding techniques. However, further data are needed, and we hope to have additional research initiated in the not too distant future. This new emphasis will be on the welding of heavy structurals and plate coated by hot dip galvanizing, organic and inorganic zinc rich paints and by metallizing. This new research is essential to enhance the economic and technical merit of joining galvanized products. Last year an important program on the bolting of heavy galvanized structurals was initiated to provide structural engineers with design criteria to enable them to fully utilize galvanized components which will provide long service life with little or no maintenance. The rapidly increasing cost of maintenance had been an important incentive for specifying galvanized structures which are essentially maintenance-free. However, in certain instances, a lack of adequate design criteria for bolted structures has prevented engineers from using zinc coated members. Definitive results from this investigation, should open up an important new market for the industry.

One of our older programs which is now yielding vital data is our investigation of the use of galvanized reinforcement for concrete. This includes prestressed structures as well as structures subject to highly corrosive atmospheres, such as on bridge decks, marine piers, marine structures, abbutments, and other

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structures subject to marine environments, or attack by chlorides in the building sand or road salts. Maintenance of reinforced concrete structures is extremely costly and difficult to accomplish. Fig. 10 illustrates cracking of concrete piles under stress which will lead to aggravated corrosion of the reinforcement rods. A relatively slight investment in galvanized reinforcement is more than justified in view of the long life which can be realized through the use of these materials. In other types of structures composed of concrete footings, foundations, porches, ledges, and the like, where galvanized elements are imbedded in concrete, there has, for many years, been resistance to a fully galvanized component. The member imbedded in the concrete has usually been masked during the galvanizing operation, increasing the cost of the galvanized component and at the same time producing a weak interface subject to quite serious corrosion. Our research has shown that the bond strength between concrete and galvanized reinforcement or galvanized structural members, is at least equivalent to or better than that of bare steel. This will certainly improve the economics as well as extend the potential use of galvanized guard rails, towers, and the like.

The program is receiving wide response in the United States and Europe. Bulletins are being translated and reproduced in many languages. At the present time, full-scale field programs are being planned in conjunction with state and federal agencies. All of this work will call attention to the efficacy of galvanized reinforcement to provide long life at low cost.

Bond tests, summarized in Fig. 11, show the amount of slip between black iron and galvanized reinforcing bars and the concrete at different levels of bond stress. In the first group, it can be seen that at stress levels up to failure, the galvanized bar performance is superior to the black bar, as the amount of slip at a given bond stress level is less for a galvanized bar than for a black bar. All three specimens with the black bars failed before the bond stress of 500 psi was reached. Only one of the three specimens with galvanized bars failed before this stress level was reached. The average slip in the other two specimens, as shown in the slide, are seen not to be excessive. These conditions were similar for the second group. In the third group, performance for both bars is similar. In group IV, galvanized is superior.

Corrosion tests have also been conducted. Under similar exposure to corrosive conditions, concrete test prisms cracked earlier, more rapidly, and more extensively with black steel as compared with galvanized steel reinforcement.

The emphasis on decorative finishes, plus the desire to significantly increase service life through the application of paint films, has led to a demand for painting systems compatible with galvanized steel. The inherent advantage of these combined protective systems is that total system life reflects a far greater increase than would be realized by adding the individual protective life span of each coating.

Certainly there are problems in achieving adequate adherance to galvanized surfaces. Because of these problems, and our desire to enhance the ability to apply these decorative finishes, we are initiating a two-phase program. One part of the program consists of a fundamental investigation of the surface of galvanized coatings plus an analysis of service conditions where paint adherance has been poor. This will help to identify the unique conditions under which such failure occurs. The second phase is an applied program evaluating commercial materials, and paints which are reported to be uniquely adapted to galvanized coatings. This will develop data on systems which are mutually compatible. Our research to date has shown that many of the conventional materials suffer from a lack of uniformity and that many paint systems are inadequate. We believe that this effort will be of value to the galvanizers in developing surface treatment which will be more favorable to the application of paint as well as to the manufacturer of paint systems to develop coatings which will meet performance requirements. We feel this is one of our most important programs in galvanizing, and its importance to galvanizing parallels the importance of the plating research program to the die casting market.

One area where significant progress has been made in the past year is in porcelain enamels for galvanized steel. Naturally, the enamels are compatible only with galvannealed type systems where the coating has been entirely converted to the intermetallic compound. This results in lower vapor pressure of zinc with resulting ability to apply low melting enamels. Fortunately, for our program, the porcelain enamels most suitable to galvannealed steel are lead-based enamels, and we are indeed fortunate to find a system which makes effective use of the two metals to their mutual enhancement. These coatings have a reasonably wide range of colors, good adherance, and should provide decorative appeal and long life. In the event of damage to the outer porcelain layer, extensive corrosion products will not develop due to cathodic protection by the zinc. This prevents the continuing and catastrophic failure to the enameled coating which would occur with uncoated iron. Again, we believe that this will have significant promise for enlarging the markets for galvanized products in the future.

Wrought Zinc

It has long been our belief that the market for wrought zinc products will ultimately grow to a level approaching that for die casting and galvanized steel. However, much remains to be done not only in improvement of properties, but also in improved fabricating techniques for wrought zinc. Wrought zinc offers compelling advantages: excellent ductility, corrosion resistance, platability, paintability, solderability, and weldability. Combined with relative low cost, this material becomes a vital adjunct to zinc die castings so that wrought zinc sheet and extrusions, together with die castings, can provide compatability not only from the standpoint of corrosion, but uniform color match and flexibility for the designer.

During the past year we have made significant progress with the 12% aluminum alloy which was originally developed as a die casting alloy. It has also shown promise as a wrought material. This alloy, as extruded or as a rolled material, has very good machinability not only in conventional machining operations, but also in automatic screw machines. for operations conducted on automatic screw machines such as forming, box tool turning, drilling, thread rolling, die threading, cutoff, knurling and flaming. Typical screw machine parts and rolled bar stock are shown in Fig. 12. Operations include drilling, turning, and threading. In addition, the 12% aluminum alloy has excellent ability to be extruded and properties of the material, shown in Fig. 13, are excellent. Because of the economics of a zinc screw machine product, plus its good machining and physical characteristics, we believe a substantial market can be developed.

The 12% aluminum alloy also shows retention of properties despite the cooling rates which may be encountered. This suggested its potential not only as a die casting alloy but for permanent mold and sand casting. The sand casting alloy has evidenced very good properties as shown in Fig. 14. The material has good stability, can be plated readily, and has very good corrosion resistance. However, purity of the alloy must be maintained at a high level and lead must be excluded as a tramp element during the casting operations if corrosion resistance is to be maintained. This means, of course, that the basis metal for the casting must be special high grade zinc. We believe that there are many small production runs of components, which cannot be die cast but which may be cast in zinc or in other metals for prototypes and for limited production runs. This alloy should prove excellent for these applications. The automobile rear window frame (Fig. 15), for example, was cast in plaster molds for mock-up trials. Following casting, the material was buffed and plated with excellent results. The alloy will be useful for such trials and for limited production runs where the total quantity required is insufficient to justify the expense of die casting dies.

At the inception of our ILZRO research program, it was proposed that wrought zinc products could be produced from particulate materials. Fig. 16 depicts the production operation which was contemplated. It consists of the production of particulate zinc, the direct rolling of these particles into sheet, and such subsequent finishing operations as are required to produce material in the necessary gages. During the past year and a half, supporting members of ILZRO have produced particulate zinc. Their results confirmed our estimate of the low cost of production as well as the ease of production and the ability to produce a range of alloy compositions. These materials have been subsequently readily compacted to produce wrought products. Our research program at the University of British Columbia has shown that a new range of alloy systems, offering improved physical properties and creep resistance, could be produced via the particulate metallurgy process. With each of the steps of the process carried out, the future of this technique for zinc should be assured. It is most gratifying to note the number of our companies who are participating in these various steps and have confirmed our original contention that this technique holds promise for the industry. We have long felt that this process would make available wrought zinc materials with the lowest possible capital investment in a range of alloys which could not be produced by any other technique and at low production cost. It also has the significant advantage that scrap is readily utilized and converted again into saleable products. We believe that this process will contribute a great deal to the future success of wrought zinc products. # Zinc organometallic research has made significant strides during the past year. A wide range of new compounds with stable zinc carbon bonds have been produced which should provide a new series of compounds for industrial application. A review of Harvey Brown's "Zinc Oxide Rediscovered" will unveil the wide utility of zinc oxide and related compounds as fungistats, mildestats, photosensitive materials, semi-conductors, plus a host of other applications. The exciting possibility of zinc organometallic compounds, enhanced by the chemistry of the zinc atom itself, combined with the amplifying characteristics of the organic part of the molecule, should open new areas and applications for these materials. With the rapid progress being made, we believe that, late this year or early next year, we can initiate a pilot program for the production of sample materials to be distributed to a variety of industries for evaluation as agricultural chemicals, textile treatments, and paint components. Despite the warnings that the high electropositivity of zinc would preclude the possibility of producing stable compounds, it has been possible to synthesise such compounds which we believe can have important commercial application. Such are the fruits of research and the satisfaction that comes with doing the near impossible. This program in itself certainly proves that research done by competent, imaginative and creative individuals in suitably equipped facilities can produce outstanding technical and potentially fruitful economic success. With the critical self-appraisal which the industry, its consumers and associates have made, it has been possible to plan a long range program not only to support new ventures, but to improve existing products. While we cannot guarantee that every phase of the program will achieve success, nevertheless, we believe that through this cooperative effort, we have truly planned ahead for the future economic well being of our industry. We believe the course we have charted will run true and that exciting and successful future achievements lie ahead arising from our research effort.