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METALLURGICAL EXAMINATION OF GALVANIZED TRANSMISSION TOWER SAMPLES

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Metallurgical examination of galvanized transmission tower samples revealed that the variable galvanizing behaviour of the parts was related to the nature and degree of attack of the steel base in the coating process. Recommendations for the production of acceptable coatings are offered.

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INTRODUCTION

In connection with the hot-dip galvanizing research being conducted by the Physical Metallurgy Division under the auspices of the Canadian Zinc Research and Development Committee, three samples of galvanized transmission tower steel were submitted by Mr. A. R. Cook, American Zinc Institute, Inc., with a request for metallurgical examination of the parts (letter of October 29, 1962). The samples were received on November 9, 1962.

Specific information was required on the reason for the very heavy coating developed on one of the samples (angle section) despite the fact that all three had been pretreated and galvanized at the same time. Comments on the coating microstructures reproduced in submitted photomicrographs was also requested as well as on the influence of the tin and aluminum concentrations that had been found on analysis of the galvanizing bath. The bath composition determined spectrographically was given as follows: 0.002% Al, 0.06% Sn, 0.01% Cu, 0.01% Fe, 0.5% Pb, 0.01% Cd, balance - zinc.

CHEMICAL COMPOSITION

The chemical composition of the steel base materials as reported by the Analytical Chemistry Subdivision of the Mineral Sciences Division, Mines Branch, is given in Table 1. It can be seen that the limited composition requirements of the relevant specifications are met. The rod and angle section materials appear to be semi-killed steels, whereas the plate composition suggests a capped or rimming grade. From the low silicon and phosphorus content in all cases it is apparent that steel composition was not a significant factor contributing to the variable galvanizing behaviour reported.

TABLE 1

Chemical Composition

	C, %	Mn, %	Si, %	S, %	P, %
* Plate, Sample P_1	0.28	0.48	trace	0.049	0.010
* Rod, Sample R_1	0.19	0.43	0.05	0.036	0.007
** Angle section, Sample S_1	0.21	0.53	0.08	0.025	0.013
* ASTM A7-61T	-	-	-	0.063 max	0.05 max
** ASTM A36-61T	0.32 max	-	-	0.063 "	0.05 "

METALLOGRAPHIC EXAMINATION

Because of the etching treatment applied, interpretation of the submitted photomicrographs illustrating the galvanized coating microstructures was difficult. For this reason, specimens from the samples provided were polished and examined metallographically. Typical coating microstructures found are reproduced in Figure 1.

The microstructure of the coating on the plate material, Sample P_1, was found to be most representative of a so-called normal galvanized coating. The characteristic layer development of iron-zinc alloy phases was present as shown in Figure 1 (a) and the coating was uniformly thick at about 0.004 in. (2.4 oz/sq ft) over the section examined. The coating on the rod material, Sample R_1, showed similar areas of uniform iron-zinc alloy growth which, however, were occasionally broken by zeta phase bursts extending outwards into the zinc layer as a loosened mass of crystals. Such formations as well as non-uniform iron-zinc alloy growth at notches and other steel surface irregularities apparently contributed to heavier zinc drag-out and a thicker coating averaging around 0.0055 in. (3.3 oz/sq ft). These features are illustrated in Figure 1 (b).

A typical area showing the very heavy coating at about 0.011 in. (6.6 oz/sq ft) developed on the angle section, Sample S_1, is reproduced in Figure 1 (c). It can be seen that extremely active localized reaction with the steel base has occurred leading to the formation of a highly exaggerated outburst of fine zeta crystals, bounded on either side by much larger crystals of the same phase. In the affected area, the delta phase originally formed at the steel surface has disappeared, presumably having been transformed to zeta. An indication of the more active nature of this steel is also provided by the thickness of the delta phase patches which remained intact as in Figure 1 (c). In the section examined, numerous sites of aggressive attack such as illustrated were found and the resulting excessive dispersions of iron-zinc crystals embedded in a zinc matrix thus accounts for the very thick coating developed on the angle section.

Interference by the galvanized coating prevented satisfactory etching of the steel microstructure adjacent to the coating and additional microsections were polished after removal of the coating. Microscopic examination revealed evidence of a decarburized surface rim on the plate material. The negligible amount of pearlite phase in this rim is shown in Figure 2 (a). In the angle section, a surface rim was absent and the pearlite distribution was essentially unaltered across the section as illustrated in Figure 2 (b). The microstructure at and near the surface of the rod represented an intermediate condition, but was more similar to that of the angle. These structure variations are apparently related to original processing of the steels and/or the working and finishing operations in fabrication of the end products.

DISCUSSION

The variable galvanizing behaviour of the samples submitted was found to be associated with very aggressive localized zinc attack of the angle section material, and of the rod material to a lesser extent. Observed variations in steel base microstructure appear to be of some significance in explaining this abnormal behaviour since it is known that a pearlitic structure is much more aggressively attacked than a decarburized surface by molten zinc. However, steel microstructure is not necessarily the only factor involved. Localized attack of the type encountered can occur in sporadic fashion on otherwise "normal" surfaces that would be expected to yield a uniform coating comparable to that in Figure 1 (a). The effects of such factors as local work hardening, surface roughness, steel composition and bath temperature on the initiation of heavy, general or localized steel attack by zinc are well established. Much less is known about sporadic local attack occurring for no obvious reason and this apparently involves a complex mechanism.

From a recent investigation, Harvey(1) offers an explanation based on local concentration of impurity in the steel base which leads to instability in the delta phase and to its eventual transformation by the reaction delta + zinc → zeta. Because of the explosive nature of the growth at this stage, a compact zeta layer cannot form and rapid local attack of the steel proceeds unhindered. This explanation does not consider the possible influence of other factors including the microstructure of the steel base and surface chemistry of the reacting surface. Study of the effects of these and related variables on the galvanizing process as well as further information on the chemistry of the iron-zinc phases and reactions is required for a better understanding of the phenomena in question.

From the practical standpoint, it is suggested that acceptable coatings could be produced on the aggressive angle section material by application of closer control of the pretreatment and galvanizing operations. Minimum pickling, combined with a short dipping time and low bath temperature should be effective in reducing the incidence of excessively thick coatings. For this and related types of products, pre-galvanizing annealing treatments to produce a less reactive surface would probably be uneconomic but could be expected to provide a more satisfactory solution.

Information was requested on the possible influence of tin and aluminum present in the bath in which the plate, rod and angle section samples were galvanized. From information available in the literature and from prior work carried out at these laboratories it can be stated that the concentrations quoted, i.e., 0.002% Al and 0.06% Sn would not be expected to have any adverse effect on the formation or corrosion resistance of the coatings.

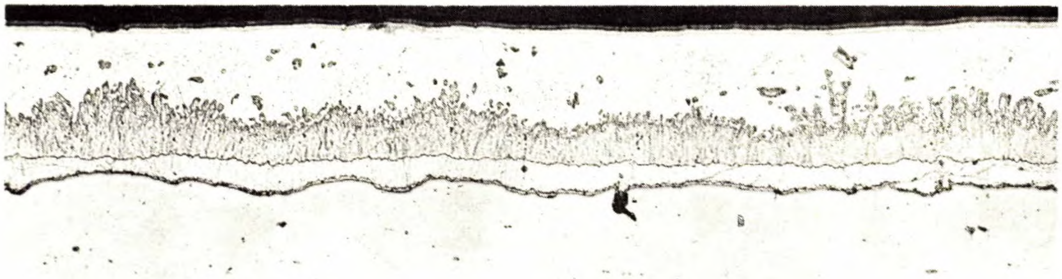
CONCLUSIONS

The very thick galvanized coating developed on the angle section submitted was found to be related to aggressive localized attack of this material in the coating process. The microstructure of the steel base appeared to be a contributing factor but, because of the complex nature of the phenomena involved, this cannot be considered solely responsible for the observed behaviour. Stricter control of the pretreatment and galvanizing operations should enable production of acceptable coatings on such material.

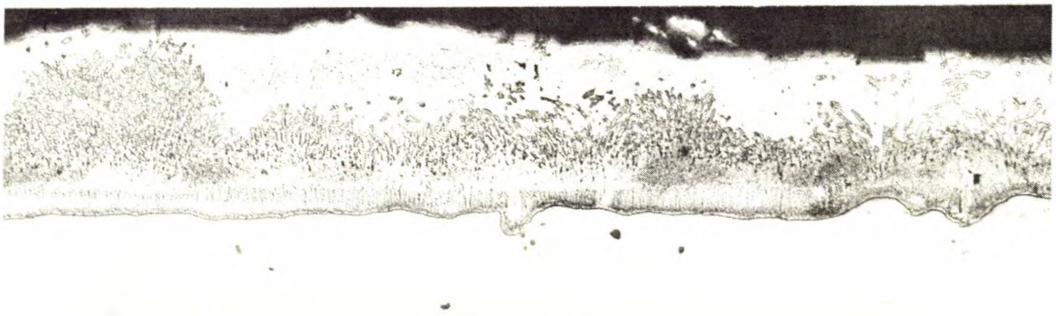
No detrimental effects can be expected from the presence of 0.002% Al and 0.06% Sn in the galvanizing bath.

REFERENCE

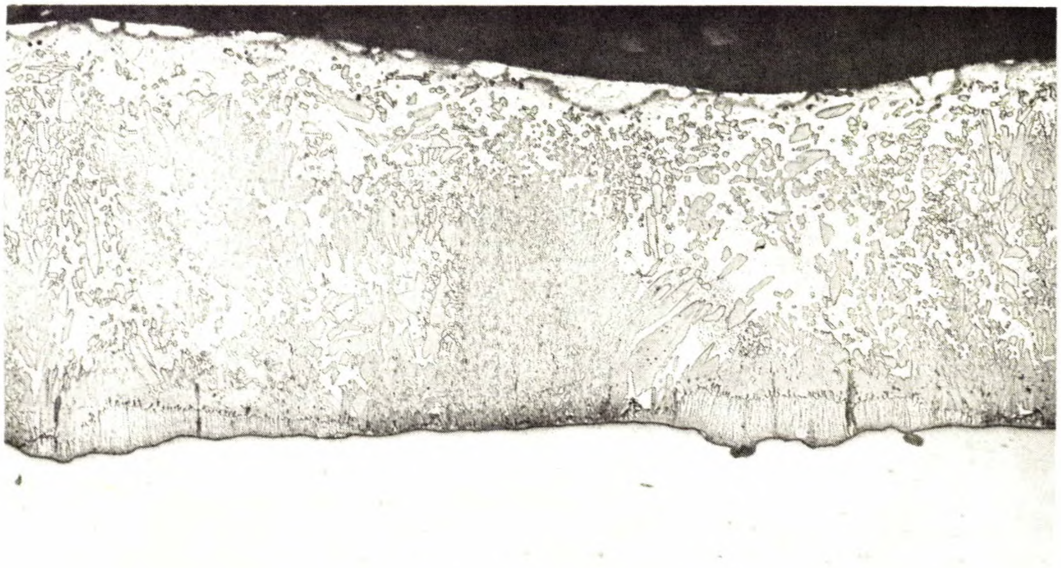
1. G. J. Harvey - "Some Kinetic Features of Galvanizing" - J. Australian Inst. Metals, <u>7</u>, 17-26 (Feb. 1962).



(a) Plate, Sample P_1



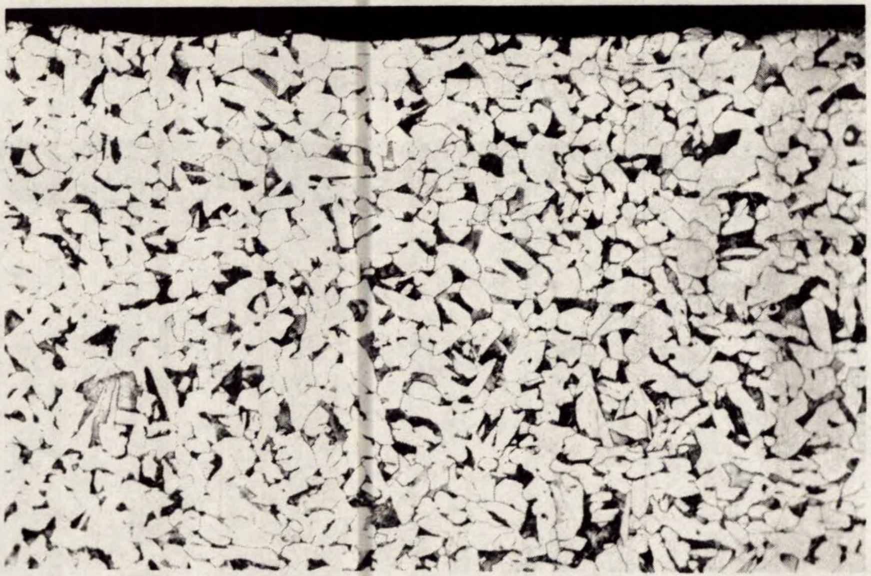
(b) Rod, Sample R_1



(c) Angle section, Sample S_1

Figure 1. Typical microstructures of galvanized coatings on samples indicated. Picral etch X200.

(a) Plate, Sample P_1



(b) Angle section, Sample S_1

Figure 2. Steel base microstructures of samples indicated showing surface decarburization of plate sample (a) and uniform pearlite distribution through to surface in angle section (b). Nital etch X150.