GALFAN®

IMPROVED GALVANIZING

18th
LICENSEE MEETING PROCEEDINGS

October 4-5, 1993 • Hotel Schillerpark • Linz, Austria

Sponsored by:
International Lead Zinc Research Organization, Inc.
GALFAN Technical Resource Center
Research Triangle Park, NC • USA

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PAPERS, REPORTS AND DISCUSSIONS

Proceedings of the 18th Meeting

of the

GALFAN® LICENSEES

October 4 and 5, 1993

Kaufm. Vereinshaus Convention Center
Linz, Austria

Sponsored by:

ILZRO/Galfan Technical Resource Center
John L. Hostetler, Chairman

Conference Host:

Voest-Alpine Stahl Linz
Linz, Austria

18th Galfan Licensee Meeting
October 4 and 5, 1993
Linz, Austria

MEETING ATTENDEES

Name	Company	License
Aufderheide, Howard	Wheeling-Pittsburgh Steel Corp.	Sheet
Bent, Peter	Voest-Alpine	Sheet
Blankenship, M.	Kohler Coating Machinery	Supplier
Blondeau, Jean	SOLLAC	Sheet
Bluni, Scott	Lehigh University	Research
Bohunovsky, Otto	Treibacher	Supplier
Bourgeois,	Galvameuse	Sheet
Brugarolas, Juan	Procoat	Supplier
Capul, Anthony	Weirton Steel Corporation	Sheet
Celestin, A.	Weirton Steel Corporation	Sheet
Conde, K.	Procoat	Supplier
D'Hoore, Fernand	Bekaert	Wire
Dewitte, Marc	N.V. Bekaert	Wire
DuBois, M.	Cockerill Sambre	Sheet
Ellek, Steve	Weirton Steel Corporation	Sheet
Elser, Phillip	Indiana Steel & Wire	Wire
Faderl, Josef	Voest-Alpine	Sheet
Feron, S.	Cockerill Sambre	Sheet
Goodwin, Terry	British Steel Corporation	Sheet
Grimm, Russell	Wean Industries	Supplier
Havrda, Miroslav	ILZRO	-
Heiler, Hans	Thyssen Stahl	Sheet
Hennechart, Jean	SOLLAC-Mouzon	Sheet
Hogan, Joseph	ILZRO	-
Hostetler, John	ILZRO	-

Name	Company	License
Kösters, Kurt	Voest-Alpine	Sheet
Kwiecien, Jerzy	ILZRO	-
Lake, John	BHP	Wire
Lamberigts, M.	Centre de Recherches Metallurgiques	Res. Contr.
Lamesch, J.	Trefil ARBED	Wire
Lewandowski, Jorg	Krupp Hoesch Stahl	Sheet
Lynch, Richard	ILZRO	-
Malmgreen, John	Eastern Alloys	Alloy
Matthews, Austin	British Steel	Sheet
Messerly, Robert	Wean Industries	Supplier
Nabberfeld-Arnold, E.	Thyssen Stahl	Sheet
Nunninghoff, Rolf	Univ. Wuppertal/TrefilARBED	Wire
Paavilainen, Jorma	Rautaruukki Oy	Sheet
Pankert, Roger	Union Miniere	Alloy
Payne, Derek	Bridon Ropes	Wire
Pelini, L.	Cockerill Sambre	Sheet
Pimminger, Michael	Voest-Alpine	Sheet
Pirklbauer, Markus	Voest-Alpine	Sheet
Proskurkin, Eugene	ILZRO	-
Quarshie, R.	British Steel	Sheet
Ranck, T.	Ferro Technologies, Inc.	Supplier
Rendos, John	Wheeling-Pittsburgh Steel Corp.	Sheet
Rey, Giorgio	Wean Industries	Supplier
Taylor, Mike	Pasminco Europe	Alloy
Theillout, R.	Krupp Hoesch Stahl	Sheet
Wegria, Jean	Union Miniere	Alloy

Proceedings of
The 18th Galfan Licensee Meeting
Oct. 4 and 5, 1993
Linz, Austria

Explanation of the Proceedings

The papers and reports presented to the 18th Galfan Licensee Meeting are reproduced and published in this document. As is always the case, there were questions and answers following most of the presentations. These are not published because of the difficulty to transcribe and edit them. One benefit of attending the meeting that cannot be realized by simply reading the papers is the opportunity to question the presenter. All of the sessions were, however, recorded so that there is an audio record of all the presentations and the dialogue following. Each presentation (more or less) is on one side of a tape cassette. A copy of a tape side is available from GTRC at $20 each plus shipping.

Marcel Lamberigts presented information from ZM-285 Progress Report No. 28 *Galfan Outdoor Corrosion Performance.* Rather than reprint the report in these proceedings, a full copy of PR28 is attached.

A significant Galfan research project is under way at Lehigh University. It is not part of ZM-285, but is funded by several Galfan Licensee shareholders. We asked Scott Bluni, the primary investigator to present some of the general data discovered in this project with the hope that it will encourage other licensees to become shareholders.

18th Galfan® Licensee Meeting
October 4 and 5, 1993 — Linz, Austria

STATEMENT REGARDING CONFIDENTIALITY

Most of what is reported in these sessions will become public information but some must be considered *CONFIDENTIAL* and proprietary to ILZRO, a Galfan Licensee or a Specifier.

Every company here has agreed to terms in a *Confidentiality Agreement* with ILZRO and as such, is legally and ethically bound to receive any information from these sessions under the terms of that Agreement.

One of the reasons for this policy is to encourage a safe exchange of information whether it comes from formal papers and reports or causal question and answer discussions.

The Proceedings of these sessions shall therefore be considered as confidential material.

We live in an information society. This group certainly knows the value of good information. The Licensee Meeting is a tremendously effective forum for transferring information but we need to be sure the information, usually hard won, profits the licensed group first.

A Report to the Licensees
from the Galfan Technical Resource Center (GTRC)
at the 18th Licensee Meeting
Oct. 4 and 5, 1993
Linz, Austria

It seems like only last month we were meeting in Tokyo as the 17th Galfan Licensee Meeting. I have a theory about the passing of time which says, *"A unit of time seems to vary by its proportion to the total units lived"* and as I hear of my colleagues retiring with greater frequency every day, I am not surprised that a year no longer seems to be a long time.

Nevertheless, GTRC had an intensely busy year, and I will not try to recall all of the activities and projects we participated in but I can think of some that are significant in terms of results. They are:

• *Organization of the Galfan License and Technology Sales Dept.* GTRC's existing staff cannot adequately support licensees and at the same time promote *new* licenses which is the best way to expand Galfan into new regions and new applications. These are, however, objectives which must be achieved. We did, therefore, establish the Galfan License and Technology Sales Dept. and now have contracts with six qualified Sales Representatives in Eastern Europe, EEC Europe, India and Mexico/South America who will be promoting Galfan and recruiting new licensees in those areas. We hope to add another in China and possibly one in Southeast Asia. Some time had to be given to organize and negotiate the contracts but now that they are in place, GTRC's capabilities and presence have been multiplied several-fold.

• *The Galfan Product Manual.* In some ways this manual is a replacement for the 1988 manual but its emphasis is more on how to *engineer and specify* Galfan rather than how to *make* it. One thousand manuals were produced in the original edition which is designed to be registered to add future additions and revisions.

• *Development of Single-Dip Electroflux (SDEF) for wire.* The SDEF process is now operating on one strip and six tube lines. Continuing production on the tubing lines strongly suggest the process is ready for wire production. The key to successful SDEF, regardless of the form, is *adequate* cleaning so that the electro-deposition of the thin Zn layer is uniform and uncontaminated. SDEF makes Galfan a more attractive proposition to a potential wire licensee than the more expensive and more difficult two-pot double-dip process.

• *The Galfan Bath Management Task Force (GBMTF).* Nineteen Galfan producers and five alloy licensees have voluntarily joined the GBMTF which is chaired by Michelle Dubois, Cockerill-Sambre/Phenix Works. GBMTF's first project was to establish standards for sampling and assaying the Galfan bath. The group established the standards and GTRC developed the logistics and forms for a system to gather samples and get them to the assaying labs. Fifty convenient kits for containing, documenting and shipping the samples were provided to each member. The system is in use and holds promise of many advantages for the producers as well as Galfan in general. It is difficult for me to understand why any Galfan producer would not be enrolled as a member.

• *Organization of the 18th Licensee Meeting.* This meeting will introduce information concerning Galfan's outstanding performance and our continuing efforts to improve it even more. I take this opportunity to thank Kurt Kösters and others at Voest-Alpine Stahl Linz for all of the help and the work they have contributed to make this meeting a reality. I do hope this one proves to be the best we have had ever.

• *Galfan in Eastern Europe.* The countries in Eastern Europe and the C.I.S. countries represent a timely opportunity for Galfan. GTRC is about ready to announce the addition of a sheet licensee and to that in all likelihood, several wire licensees will be added in the near future. We have worked with Miroslav Havrda, formerly with the Czech research institute, SVUOM, for five years, mainly through Galfan seminars in Prague. In 1992, eight of the European Galfan licensees sponsored a booth at an exposition in Czechoslovakia and in 1993, GTRC exhibited in Protech '93 in Prague. We also presented papers at SVUOM's seminar and at the Slovak Galvanizers' annual meeting. Mr. Havrda will be directing the effort in Eastern Europe from Prague, including the Galfan License and Technology Sales Dept. work by Eugene Proskurkin in Ukraine and Jerzy Kwiecien in Poland.

• *Additional Licenses.* Seven continuous lines were licensed in the last year. They are (by company, country and type):

Australian Wire Industries	new	Australia	Wire
Bekaert-Tinsley	added	U.K	Wire
Florida Wire and Cable	re-instated	USA	Wire
ITT Higbie (Fulton Works line)	added	USA	Tube
Ningbo Fishery Wire Rope	new	China	Wire
Pilot Industries	new	USA	Tube
Weirton Steel (No. 5 line)	added	USA	Sheet

• *Malaysian Seminar.* GTRC, along with a number of qualified alloy and equipment suppliers, presented a Galfan Seminar in Kuala Lumpur for continuous strip galvanizers in southeast Asia. It has become the prototype of three seminars now scheduled for Beijing, Dnepropetrovsk, and Warsaw. We need to thank Federal Iron Works for their help with the seminar. GTRC has put a high priority on various kinds of Galfan seminars in 1994. A special optional meeting is scheduled for Tuesday night, Oct. 5 for those who are interested to learn more about them.

• *The Line Operating Manuals.* A universal version of a manual for each type continuous producer (sheet, wire and tube) was produced and is now a part of the Galfan technology for new licensees. Existing licensees may purchase them at US$ 100 each after Jan. 1, 1994. The *customized* version is the result of a joint effort between GTRC and the new licensee's representative to modify and expand the universal version so that it becomes a *detailed* Operator's Manual for the licensed line and becomes proprietary to GTRC and the licensee. The manuals will prevent many start-up problems and mistakes, assist in the training of operating personnel and identify standards and practices pertinent to the line.

That is a look at what is just past. Our future looks brighter than ever but we must be prepared to work harder and smarter if we are to realize Galfan's potential. I think each of us must commit to the idea that if we all make contributions to the *overall* promotion or improvement of Galfan, we will each benefit from the combined results. It is a form of synergism. *The total is more than the sum of its parts.* We face formidable competition and it promises to get more aggressive and focused as Galfan's performance and benefits become better known. If a licensee attempts to oppose it alone, even if he possesses know-how his other Galfan colleagues do not have, the odds are against him . By sharing our know-how, we are *all* the better off because we present more formidable opposition and our competitors cannot as easily keep us away from the buyers.

Projected (but subject to licensee support) GTRC activities in 1994 include:

- Produce and present Galfan Seminars
- Negotiate new licenses (20 on serious prospect list)
- Support Licensees
  GBMTF, Constant Improvement Program, Regional problems, distribute information
- Produce Galfan Pre-paint brochure
- Produce Galfan automotive application packet
- Establish comprehensive literature library
- Produce *Galfan Life Cycle Cost* software and system
- Produce 19th Galfan Licensee Meeting
- Continue promotion in new regions
  China, Eastern Europe, India, Mexico, South America
- Continue promotion in new applications
- Produce six *Galfan Exchange* newsletters
- Attend/participate in international galvanizing meetings

Our next meeting in West Point, New York, USA is only eight months away but it is already evident we will have more information and good news to exchange than this meeting's agenda. I hope to see you there.

Respectfully,

GALFAN TECHNICAL RESOURCE CENTER

John L. Hostetler, Director

Sept. 17, 1993

AGENDA

18th GALFAN LICENSEE MEETING
Oct. 4 and 5, 1993 Linz, Austria

Sunday, Oct. 3

14:00 Meeting of the Galfan License and Technology Sales Representatives
Hotel Schillerpark

16:00 Reception and Welcome Bar
Hotel Schillerpark Lounge

20:00 Brucknerfest Concert (London Philharmonic Orchestra)
Bruckner Hall

Monday, Oct. 4
Research Session
Kaufm. Vereinshaus Convention Center
Gallery Room

8:00 - 8:30 Registration and Introductions

8:30 - 8:40 Welcome
Kurt Kösters, Voest-Alpine Stahl Linz

8:40 - 9:00 Announcements, Instructions and Explanations
J.L. Hostetler, GTRC

9:00 - 9:25 Ten Year Atmospheric Corrosion Test Results of Galfan Coated Sheet
Yusuke Hirose, Ph.D., Nisshin Steel Co., Ltd.
Atmospheric corrosion characteristics of Galfan-coated steel sheet have been studied by using 10-year outdoor exposure test results. The Galfan-coated steel sheet has 2.1 to 2.3 times the corrosion resistance of regular galvanized steel in all the exposure atmospheres, which are better results than those of previously reported 7-year exposures. This is considered to be caused by the difference in the corrosion products. The corrosion products formed on the regular galvanized steel sheet consist of both zinc carbonate hydroxide and zinc oxide. The Galfan sheets, however, shows only Al-containing zinc carbonate hydroxide with low electrical conductivity covering the coating surface which reduces the corrosion rate.

9:40-10:05 Galfan Outdoor Exposure Corrosion Performance (PR28)

Marcel Lamberigts, C.R.M.

Long-term atmospheric corrosion panels corresponding to GALFAN, and reference classical galvanized, Aluzinc and aluminized industrial sheet products have been removed from three exposure sites of distinct severity in Belgium (Eupen, Liege and Ostend) for complete evaluation. Laboratory simulations test-pieces, characterized by aluminum contents spanning the GALFAN specified range and limited silicon additions, and which had been exposed in Liege for a similar period of time, were also part of the study.

Comparative evaluation was performed by scanning Auger surface microanalysis, transverse section scanning electron metallography with local X-EDS analysis, together with corrosion product and residual coating selective dissolution. The latter technique, which required the development of an original test procedure, made it possible to estimate coating weight losses, and corrosion product and residual coating chemistries, thus opening the way to coating system performance comparison, corrosion site aggressivity rating, and mechanism characterization.

Based on coating weight loss rates, it clearly appears that atmosphere global aggressivity is practically multiplied by a factor 2 from Eupen (rural) to Liege (industrial) and Ostend (marine). the mechanisms involved are however quite different, as is for instance evidenced by distinct surface aspects and corrosion product compositions.

On an average, GALFAN has been shown to be twice as corrosion-resistant as its pure zinc galvanized counterparts exposed at all three sites, although some scatter was of course observed in individual material behaviours. Corrosion may develop heterogeneously through classical galvanized coatings and push at places down to the substrate, depending on grain orientations, but zinc generally retains its effective cathodic power. This does not always seem to be the case with Galfan, for which traces of interfacial propagation have been detected in some specifications. Galfan corrosion at rural Eupen exposure site clearly improves with higher coating aluminum content, and corresponds to an average thickness loss rate of about 1 µm/year. The performance at industrial and marine sites is apparently more affected by total coating weight than by chemistry; it is characterized by an average thickness loss rate of about 2 µm/year.

10:15-10:30 Coffee Break

10:40-11:05 Corrosion and Forming Behaviour of Galfan vs. Lead-Free and Conventional Galvanizing

Marcus Pirklbauer, Voest-Alpine Stahl Linz, GmbH

Corrosion resistance of unpainted regular galvanized (Z-"Pb"), "lead-free" zinc coated (Z) and Galfan (ZA) coated steel sheet were investigated in laboratory salt spray and Kesternich tests. The influence of chromate passivation treatment on corrosion performance in these tests was also studied.

The difference in cracking behaviour (in an unpainted condition) depending on the type of metallic coating will be shown on the basis of an actual formed part (washing machine front panel). Equivalent results have been obtained for prepainted samples (typical coil coating paint system) using laboratory forming tests.

11:15-11:35 Pozen Type Electric Furnace with Ceramic Bath with Silicon Carbide Heating Elements Immersed in the Galfan Bath
Jerzy Kwiecien, M.Sc.Ing., Institute of Precision Mechanics
Construction specification and principle of working POZEN type furnaces designed and built in Poland and experience in its operation for 8 years of working in hot-dip aluminizing (8 tons Al capacity) and 2 years of working in hot-dip galvanizing (over 70 tons Zn capacity). Possibility to improve this type furnace for Galfan technology.

11:45-12:05 Mischmetal Master Alloy for Galfan
Otto Bohunovsky, Ph.D. Treibacher Chemische Werke AG
The valuable properties of Galfan are achieved by the addition of approx. 0.05% Mischmetal (MM). MM is an alloy of cerium and lanthanum and other rare earth metals, usually in proportion to the natural occurrence.

To overcome problems when dissolving MM in the Galfan alloy, a master alloy was developed with a melting point of 490°C (instead of 800°C for MM). This master alloy is available with either 25% or 50% La within the rare earth metals. Less than 1% of the MM produced worldwide is used for Galfan. Raw materials for MM production and other applications will be discussed.

12:15 Lunch *(Red Room)*

Monday Afternoon Research Session Gallery Room

13:30 Reconvene

13:40-14:15 The Development of Smooth Surface Galfan for Coil Coating
Scott T. Bluni, Lehigh University

I. Introduction and objectives
- A. To determine the relationship between Zn-Al eutectic and off-eutectic microstructures and the extent of denting.
- B. To determine the effect(s) of impurity elements on microstructure and denting.
- C. To determine the effects of solidification conditions on microstructure.

II. Surface defects sometimes found on Galfan coatings.
- A. Shrinkage
- B. Cracking
- C. Impurity Microsegregation

III. Proposed mechanism for denting and cracking

IV. Laboratory solidification experiments
- A. Galfan alloy ingot samples
  - 1. Surface defects found
- B. Pure Zn-Al alloy samples
  - 1. Surface defects found

V. Ongoing research
- A. Commercial Galfan characterization
  - 1. Relationships between coating microstructural characteristics and the extent of denting (no specifics)
- B. Relationship development between Zn-Al solidification microstructure and denting
  - 1. Alloys consisting of:
    - a. pure alloys having 93-98 wt% Zn
    - b. same alloys in (a) having controlled impurity additions
  - 2. Samples melted and re-solidified at various cooling rates
  - 3. Sample surfaces examined for frequency and depth of denting in order to determine relationship(s) between microstructure and surface characteristics
- C. Relationship development between solidification conditions and microstructure
  - 1. The roles of G, v and composition on the eutectic-dendritic transition
  - 2. Nucleation experiments
    - a. DSC experiments from liquid phase and 2-phase regions
  - 3. Growth experiments
    - a. Directional solidification experiments

VI. Summary

14:25-14:45 <u>Galfan's Efficient Galvanic Action Provides Excellent Corrosion Protection</u>

Marc Dewitte, N.V. Bekaert Co.

Starting from the knowledge and experience that zinc coatings offer a very good cathodic protection, all recent data confirm that Galfan exceeds this protection. Results of electrochemical and metallographic research are very helpful to understand the corrosion protection of the eutectic zinc-aluminum alloy layer on a steel base (sheet, tube or wire).

14:50-15:05 Coffee Break

15:10-15:25 <u>Comparing Resistance Welding Characteristics of Galfan Coated Sheet with Electrogalvanized and Regular Hot-Dip Galvanize</u>

Anil Nadkarni, SCM Metal Products

This paper compares the resistance welding characteristics of Galfan coated steel with electrogalvanized steel. Weldability lodes were developed using standard Cu-Cr electrodes and two types of GlidCop® Dispersion Strengthened Copper electrodes. Constant current weld life tests were also conducted. Sticking of the electrodes to the workpiece is a major problem when welding coated steels. Therefore, sticking behavior of the three electrode materials was studied. The GlidCop electrodes have superior resistance to sticking compared to Cu-Cr electrodes. Additionally, they have a wider weldability lobe which provides a much wider "window" for trouble-free welding without sticking. The weld lives showed some variability, but overall, the GlidCop electrodes showed longer life on Galfan coated steel.

15:35-15:55 New Developments in Protective Organic Coatings for Enhanced Galfan-coated Steel Performance

R. F. Lynch, and F. Rodellas, Procoat, S.L.

Recent developments in organic coatings, including hexavalent chromium-free formulations, offer new opportunities to further enhance the performance of Galfan steel. Two related water-based acrylic coatings have been developed and are now routinely used in production to enhance the performance of Galfan, regular galvanized, electrogalvanized, Galvalume and galvanneal. A separate treatment was specifically developed to prevent the formation of gray patina on Galfan.

Brugal GM-4 and N6 can be applied in-line on the galvanizing line using existing chemical treatment. The liquid product is flowed onto the sheet immediately before squeegee rolls and is then cured with an in-line dryer. Application can also be made by roll-coater, electrostatic spray or other means. Brugal T3MG is applied using a roll-coater. The ability to apply these ProCoat products economically on the coating line is a major factor contributing to the low cost of enhanced Galfan-coated steel performance.

16:05-16:20 Discussion of Galfan Sheet Characterization Program: a Review of C.R.M. Progress Report Nos. 26 and 27

Marcel Lamberigts, C.R.M.

Licensees have already received Progress Reports 26 and 27 which review this work. A presentation of PR26 was made last year but licensees have had no presentation of PR27. It is suggested you bring both reports with you because this session will be more of a discussion than a presentation. The reports do not disclose the source of the samples discussed. That same confidentiality will be maintained in this session.

J.L.H.

16.30 Dismissal

The following papers will be included in the Proceedings of this meeting but will not be presented orally.

Method for Metallographically Revealing Intermetallic Formation at Galfan/Steel Interfaces

Seth A. Eliot, Weirton Steel, now at Carnegie Mellon University

A technique has been presented to easily and quickly reveal Fe-Al-Zn compounds, formed at Galfan/steel interfaces during hot-dip Galfanizing, which are detrimental to material performance The material to be examined is mounted between copper spacers and ground on SiC papers, then polished with 6μm diamond. An optional picral preetch is then followed by a copper sulfate solution etch that interacts with the Galfan, steel and copper. Proper use of this technique should facilitate detection and identification of intermetallic phase a t the interface.

On-going Development of the Single-Dip Electroless Flux Process for Galfan-Coated Tube, Wire and Small Parts

Thomas Ranck, Ferro Technologies, Inc.

Monday Evening
(Spouses and children welcome)

18:00 Buses leave Hotel Schillerpark for St. Florian's Abbey

Tour of St. Florian's Abbey
This baroque Augustinian monastery, with its cathedral and church, built 1686-1750 is a perfect example of the period's architecture. The architects were: Carlo Carlone, Jacob Prandtauer and Gotthard Hayberger. Points of particular interest include: The Pilgrimage Church, gothic altar paintings by A. Altdorfer, the Anton Bruckner organ, the crypt of the composer Anton Bruckner, the Emperor's suite, Marble Hall and the art gallery

Reception (and Recognition Awards)

Dinner

Entertainment (Austrian music)

22:00 Buses return to the hotel

Tuesday Morning, Oct. 5
Reporting Session
Gallery Room

8:30 - 9:00 Worldwide Galfan Status Report
J.L. Hostetler, GTRC
Establishment of the Galfan License and Technology Sales Dept.
GTRC Galfan Seminars
New Regions: Australia, China, Eastern Europe, Mexico, South America
New Applications: Small parts, SDEF for wire, Batch-dip

9:00 - 9:15 Presentation of Galfan Pre-Paint Sheet Brochure
J.L. Hostetler, GTRC
Although a request to fund Project UZD-95 to produce a 16-page 4-color brochure "Pre-painted Galfan" has been submitted to the ILZRO Technical and Funding Committees, it is not likely to be approved without significant participation by Galfan Licensees. A description of the brochure with quoted costs to write the manuscript, produce the brochure, and print it will be presented. It is hoped discussion will result in enough subscriptions for the brochure to fund the project and make a quality brochure available to the Licensees at a very low per copy cost.

9:15 - 9:30 Report from Galfan Bath Management Task Force
Michelle Dubois, Cockerill Sambre/Phenix Works

9:30 - 10:15 Reports From Licensees

10:15 - 10:30 Report From NAGDA
Phillip C. Elser, President

10:30 Coffee Break

10:40-11:30 Sales and Marketing Session

Development of ASTM Life Cycle Cost Analyses
GTRC has developed computer software to compare the cost of Galfan corrugated roof and siding panels to regular galvanized. Some of the marketing organizations are using Life Cycle Cost Analysis to successfully promote their product. An existing ASTM Specification could be used as a model to develop comparison of any product or coating to Galfan. GTRC is prepared to design and produce the software for such a program if there is interest by the Licensees.

Cooperation between Licensees and GTRC
Literature
Samples for testing

Galfan Seminars

11:30 - 11:40 Plans for 1994 and 1995 Licensee Meetings
John Malmgreen, Eastern Alloys for the 19th meeting in West Point, NY.
J.L.Hostetler, GTRC, for the 20th meeting

11:40 - 12:30 Review, Final Announcements and Dismissal

12:30 Lunch *(Red Room)*
Presentation of Voest-Alpine Tour
Manfred Maschek, Voest-Alpine Stahl Linz

Tuesday Afternoon
VOEST-ALPINE PLANT TOUR

14:30 Buses leave Hotel Schillerpark for Voest-Alpine Plant

Tour of coating and paint lines at Voest-Alpine

16:45 Discussion and de-briefing at Voest-Alpine

17:15 Buffet at Voest-Alpine

18:00 Buses return to Hotel Schillerpark

Tuesday Evening
Hotel Schillerpark

19:00 (Optional) Galfan Seminars Planning Session

Meeting room to be announced

See the attachment "Galfan Seminars". This optional planning session is for those involved in Introductory Seminars and to discuss Regional Galfan Development Seminars. GTRC suggests that the Licensees or Regional Development Associations consider a Regional Galfan Licensees Seminar during the year 1994. This Licensee meeting is a good place to begin planning such seminars.

Wednesday Morning, Oct. 6
Hotel Schillerpark

8:00 - 10:00 Galfan Bath Management Task Force

Restricted to participating members or Licensees wanting to enroll.

M. Dubois, Cockerill-Sambre/Phenix

1. Review and discussion of new sampling and testing techniques.
2. Discussion: The need and method for stirring or agitating the Galfan bath, especially during non-operating periods.
3. Ford Motor Company's (North America) DOE program for Galfan baths management.
4. Other member concerns.

WELCOME
(Transcript)
Mr. Kurt Kosters

Good morning, gentlemen. It is a pleasure for me to welcome you all in the name of my company, Voest-Alpine Steel Linz to the 18th Galfan Licensee Meeting here in Linz.

As you maybe know, Linz is a highly industrialized city with approximately 200,000 inhabitants and acts as an economic factor for upper Austria. No longer only the iron and steel industry but also chemicals, pharmaceutics, machinery, construction, industrial engineering, textile and tobacco industry are also very important. After opening of the Rhine, the Danube is, as of September 1992, a powerful waterway between the North Sea and the Black Sea and it gives Linz an additional economic opportunity for the future. But Linz has also a historic tradition. It has a tradition in science and culture. Near to the castle of Linz, there is St. Martins church, probably the oldest original maintained church in Austria built in the 7th century. Linz got its municipal law in the year 1214. At the end of the 15th century, the old castle was completely rebuilt by emperor Frederick III of Hapsburg and Linz became the emperor's residence for some years.

During the baroque period in the 17th century, Linz received a fresh economic impetus. The first textile factory of Austria was founded in Linz in 1672. It was a great success for the city because more than 10,000 people got work there. A lot of baroque buildings and enlargement of the city was established at that period. 1832; the first horse trailway of the European continent between Linz and Budejovice (its in Bohemia) was opened. From 1612 to 1626, the famous astronomer Johannes Kepler worked and lived in Linz.

Our university which was founded in the year 1966 is named after him, Johannes Kepler University. 1824: the famous composer Anton Bruckner was born in a small village close to Linz. He was chief organist here in Linz at the old cathedral as well as the monastery in St. Florian which is about 15 km away from Linz. Today in the evening, we will make a guided tour through the Abbey. In memory of him, our concert hall is called Brucknerhaus and every Autumn we have an international concert festival named Brucknerfest. Some of us have the opportunity yesterday and Saturday evening to join a concert.

In 1898 the so called Vestling Berg, an electric adhesion tramway up to the 519 meter high Vestling barrack with slope of 10.5% was opened. Today it's still the steepest mountain tramway in Europe.

Gentlemen, I have tried to give you a short historic background of Linz and our culture. Perhaps based on this tradition some important technical inventions and achievements have been accomplished by our company. I want to remind you the LD process, the oxygen blowing steel process was developed 1952 in Linz and in 1953 our sister company in Donnevitz; it gets its name LD from Linz Donnevitz. Its still today the most important steel process all over the world. A new pig iron process for replacement of the coke oven blast furnace route the so called Core-X process is another technical and economic a very promising invention which has been developed in the past ten years after the technical application.

We have been the first company in Europe to install an in-line phosphating in our continuous galvanizing line No. 2 and are now able to produce pre-phosphated zinc as well as galvanneal and Galfan. So I am back to our topic of the meeting today. I hope we will have an interesting and stimulating meeting with good discussions for the further technical and economic development for Galfan. Tomorrow we have the honor to host you and show you our coating facilities, the galvanizing lines and the coil coating lines. At last, I want to thank John Hostetler and also all the other ILZRO people for organizing the meeting.

Thank you very much for your attention.

10/93

10-YEAR ATMOSPHERIC CORROSION TEST RESULT OF GALFAN COATED STEEL SHEET

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Abstract

Atmospheric corrosion characteristics of Galfan coated steel sheets have been studied by using 10 years of outdoor exposure test results.

Galfan coated steel sheets have 2.10 to 2.28 times better corrosion resistance of galvanized steel sheets in all the exposure atmospheres, which is a better level than those of the 7-year exposure test. This is considered to be caused by the difference in corrosion products. The corrosion products formed on the galvanized steel sheets consist of both zinc carbonate hydroxide and zinc oxide.

However, in the case of Galfan coated steel sheets, both zinc carbonate hydroxide and zinc aluminum carbonate hydroxide hydrate with low electrical conductivity cover the coating surface, which reduces the corrosion rate.

1. Introduction

Since May 1983, we have exposed "Galtite" (Nisshin's brand name of Galfan) for the purpose of investigating atmospheric corrosion characteristics compared with "Pentite B" (Nisshin's brand name of hot dip galvanized steel sheet), and have periodically inspected corrosion of the test panels. In June 1990, we already reported the results after 7 years of outdoor exposure. After another three years, we again investigated corrosion of Galtite compared with Pentite B. This report describes the results after 10 years of outdoor exposure.

2. Test panels and the exposure sites

2. 1. Test panels

Table 1 shows details of Pentite B and Galtite test panels. Shape and dimensions of them are shown in Fig. 1.

2. 2. Exposure test sites

Fig. 2 shows the locations where the test panels were exposed. We selected four types of exposure circumstances: rural site (Kiryu), industrial site (Amagasaki), severe marine site (Okinawa), and marine site (Choshi).

2. 3. Exposure test period

Approximately 10 years from May 1983 to February 1993.

3. Items investigated

3. 1. Surface appearance and cross-sectional micro-structure of the coated layer.

3. 2. Corrosion loss of the coated layer.

3. 3 Identification of corrosion products by X-ray diffraction techniques and X-ray micro-analysis.

4. Results and discussions

4. 1. Surface appearance and cross-sectional micro-structure of the coated layer

4.1.1. Surface appearance

Photos 1 and 2 show the surface appearance of each section of Pentite B after 10 years of outdoor exposure. Photos 3 and 4 show those of Galtite after 10 year exposure.

1) Flat area

On Pentite B, red rust has occurred at the cut edges in Amagasaki and Okinawa test panels. Especially, heavy red rust can be seen on the test panel at Okinawa. On Galtite, on the other hand, darkening has progressed on the flat areas at three sites, except Okinawa. Darkening on the Amagasaki exposed test panel has reached a remarkable level. In Okinawa, darkening has not been found and much white rust has been observed. On Galtite, red rust could not been found at any test site.

2) Cross-cut

On Pentite B, a little red rust has been found on the Okinawa site test panel. However, on Galtite, there has been no red rust on the cross-cut areas on any site test panel, and good condition has been maintained.

3) Drilled hole

On Pentite B, red rust was found at the drilled hole on the Amagasaki and Okinawa sites test panels. On Galtite, only a little white rust was found around the drilled holes at each site, and red rust could not be found.

4) Cut edge

On Pentite B, light red rust was found on the Kiryu and Amagasaki site test panels. Heavy red rust was found on the Okinawa site test panel. On the Choshi test panel, heavy white rust was found. But red rust could not be found. On the other hand, on Galtite, light rust was found on the Kiryu test panel, and the one at Amagasaki has darkened on the cut edge. On Galtite at Okinawa and Choshi, heavy white rust occurred on the cut edge, but red rust could not been found.

5) Bent area

On Pentite B, light red rust on the Amagasaki test panel, and heavy red rust on the Okinawa test panel were observed. On the Kiryu and Choshi test panels, only white rust

was observed, and red rust could not be found. On Galtite, only white rust was found, and no red rust was found at any site.

4.1.2. Cross-sectional micro-structure of the coated layer

Photos 5 and 6 show the cross-sectional structure of both Pentite B and Galtite respectively after 10-year outdoor exposure testing at each exposure test site.

1) Flat area

On the Okinawa site Pentite B test panel, the coated layer has almost been corroded, and partial corrosion of the base steel was also found. On the Amagasaki site test panel, the remaining coated layer has been quite minimal, though corrosion on the base steel could not be observed. On the other hand, with Galtite, a 10 to 12 μm coated layer has remained, even at the most severe Okinawa site. Thus, it is concluded that corrosion of Galtite is quite slow compared to that of Pentite B.

2) Cut edge

Pentite B lost much of the coated layer in the area of the cut edge at each exposure site. On the Amagasaki and Okinawa test panels, especially, the coated layer proximate to the cut edge has almost corroded, and corrosion on the base steel was observed. On the other hand, Galtite had some coated layer uncorroded even at Okinawa, and corrosion on the base steel was not found.

3) Bent area

The Kiryu and Choshi test panels of Pentite B maintained their coated layer. But, on the Amagasaki and Okinawa test panels of Pentite B, the coated layer was almost corroded out, and even the base steel was partially corroded. On Galtite, there was no corrosion of the base steel even on the Okinawa test panels, and coated layer has still been maintained.

4.2. Corrosion loss of coated layer

We summed up the relation between exposure period and corrosion loss of the coated layer and showed it in Fig. 3. Table 2 shows the corrosion loss level of the coated layer for both Pentite B and Galtite after 10 years of outdoor exposure. The corrosion loss level of 10 years exposure in Figure 3 is given by plotting the measured results of Table 2. The Pentite B test panel at Okinawa had already lost the coated layer after 10 years of exposure so that we could not plot the results for this case.

Fig. 3 shows that the average corrosion loss of Pentite B coating increased linearly with the lapse of exposure time at each site. On the other hand, the corrosion loss of Galtite increased parabolically at each site. So, little difference could be seen over a short exposure period between Pentite B and Galtite, and corrosion loss level between them deviates as the exposure period becomes longer, like 7 years and 10 years. The corrosion degree has been largest in Okinawa, and decreased in progressive order of Amagasaki, Choshi, and Kiryu.

Table 3 shows the corrosion resistance ratio of Galtite compared with Pentite B after 10 years of outdoor exposure at each site, based on Fig. 3. These figures are in the range of 2.10 to 2.28 depending on the exposure sites, which are larger than the results after 7 years of exposure testing.

The difference in atmospheric corrosion resistance between Pentite B and Galtite is assumed to be caused by the difference of corrosion products.

Figures 4 and 5 are X-ray diffraction patterns of corrosion products after 7 years of exposure in various atmospheres. The corrosion products on Pentite B were found to be composed of both zinc carbonate hydroxide and zinc oxide, irrespective of exposure atmospheres. But among the corrosion products on Galtite which were exposed in three different atmospheres (except the severe marine site), both zinc carbonate hydroxide and zinc aluminum carbonate hydroxide hydrate were found, but no zinc oxide was detected. It has been reported that the electrical conductivity of zinc carbonate hydroxide and basic salts is notably smaller than that of ZnO, and that the oxygen reduction of zinc at cathode site during corrosion is suppressed as these corrosion products cover the coating surface[1)]. Therefore, it can be understood that the corrosion rate of Galtite is reduced remarkably with exposure period when zinc carbonate hydroxide - with and without aluminum - having low electrical conductivity covers the whole coating surface, and that the aluminum in Galtite coating has a strong effect of stabilizing zinc carbonate hydroxide as a corrosion product.

5. Conclusion

We have investigated the corrosion of Pentite B and Galtite after outdoor exposure testing of approximately ten years from 1983 to 1993, under atmospheric variations of Kiryu, Amagasaki, Choshi, and Okinawa. Below are main results:

1) Pentite B had red rust proximate to the cut edge on the Amagasaki and Okinawa test panels. On the contrary, red rust could not be found on Galtite on any site test panel.

2) On Pentite B at Okinawa, the most severe environment, almost no coated layer remained and partial corrosion on the base steel was found. On the contrary, Galtite maintained a coated layer of 10 to 12 μm and the corrosion rate was very small compared with Pentite B.

3) The average corrosion loss of Pentite B coating increased linearly with the exposure period at each site. On the other hand, the corrosion loss of Galtite increased parabolically with the lapse of exposure time.

4) The corrosion resistance ratio of Galtite against Pentite B further increased in the 10-year outdoor exposure test compared with the 7-year exposure test at each site as follows:

• Kiryu (rural site)	:	2.10 (2.04)
• Amagasaki (industrial site)	:	2.28 (2.07)
• Okinawa (severe marine site)	:	—— (2.16)

• Choshi (marine site) : 2.19 (2.03)

Figures in parentheses indicate the results after 7-year outdoor exposure test.

Note: The corrosion resistance ratio of Pentite B in Okinawa could not be calculated since the coated layer was completely lost after 10 years of outdoor exposure.

5) The difference in atmospheric corrosion resistance between Pentite B and Galtite is assumed to be caused by the difference of corrosion products. The corrosion products formed on Pentite B consist of zinc carbonate hydroxide and zinc oxide. However, in the case of Galtite, both zinc carbonate hydroxide and zinc aluminum carbonate hydroxide hydrate with low electrical conductivity cover the coating surface, which reduces the corrosion rate.

The atmospheric exposure testing plan of Pentite B and Galtite was formerly scheduled to end after ten years. However, no red rust was observed for Galtite on any site test panel after ten years. Therefore, we will prolong the exposure testing for another ten years and continue the investigation on corrosion characteristics of Galtite.

Reference

1) Y. Miyoshi, J. Oka and S. Maeda, Trans ISIJ, 23, (1983), 974.

Table 1 Details of test panels.

Test panel	Thickness (mm)	Composition of coating (mass %)			Coating mass (g/m2)
		Al	Mg	M.M	
Pentite B (Galvanized)	0.35	0.23	tr.	tr.	160
Galtite (Galfan)	0.35	4.2	0.1	0.01	156

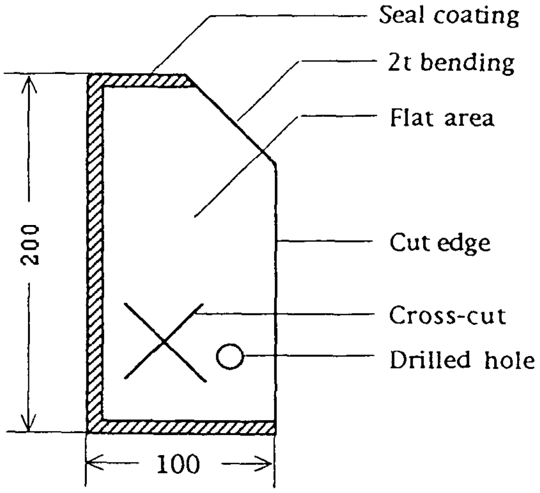


Fig. 1: Details and dimensions of the exposed test panel

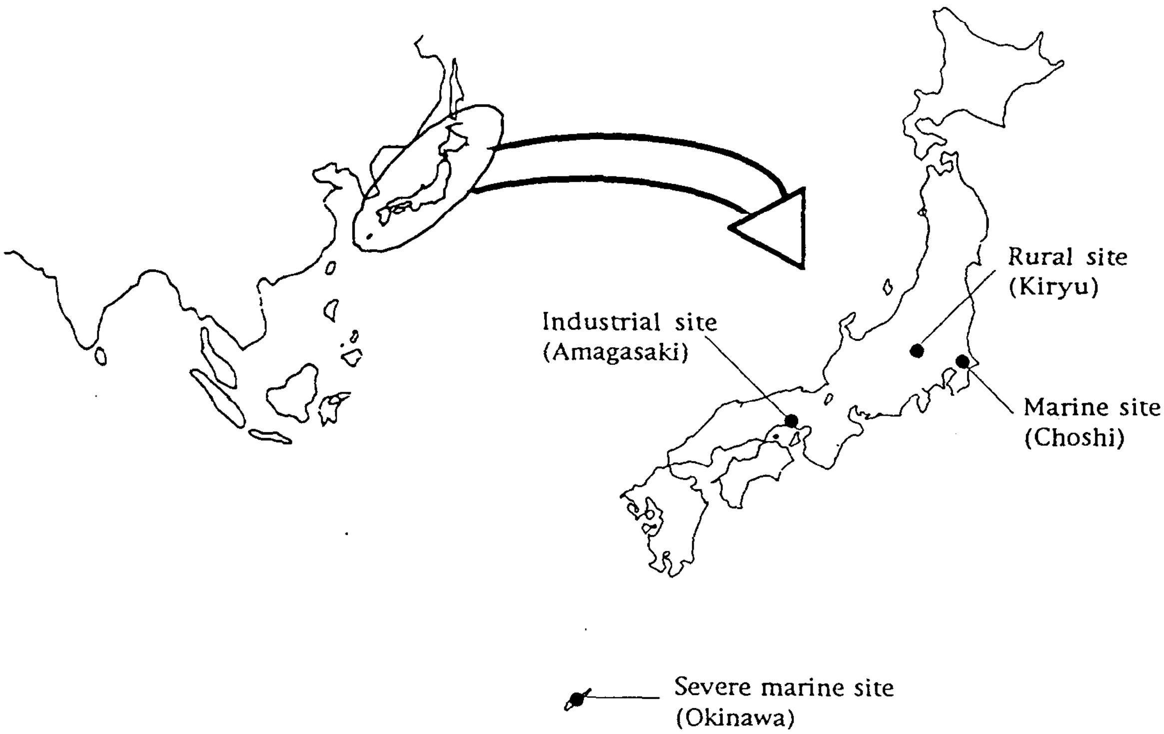


Fig. 2: Exposure sites in Japan

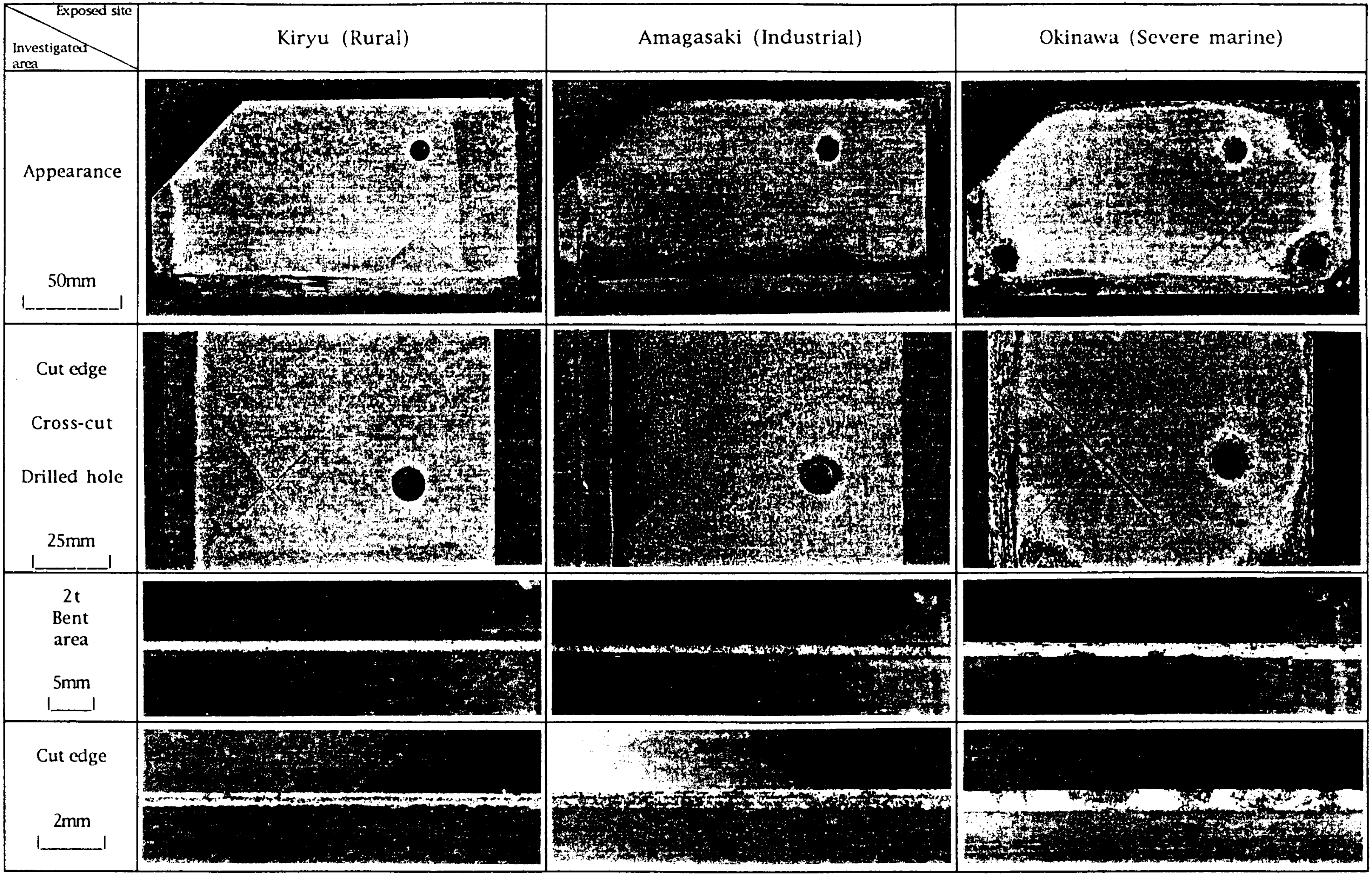


Photo 1. Pentite B after 10 years of outdoor exposure testing

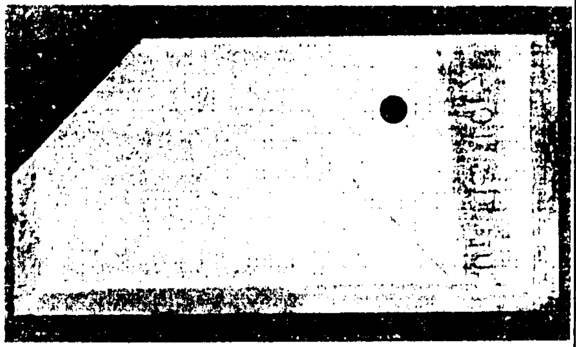
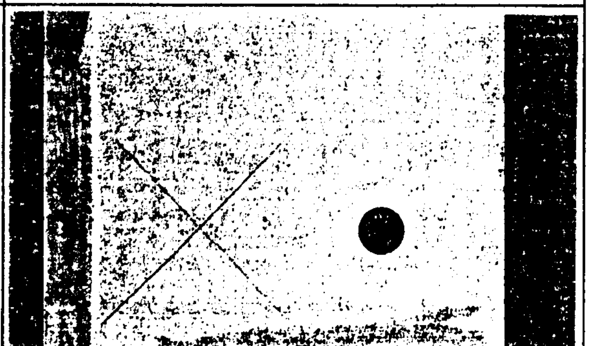
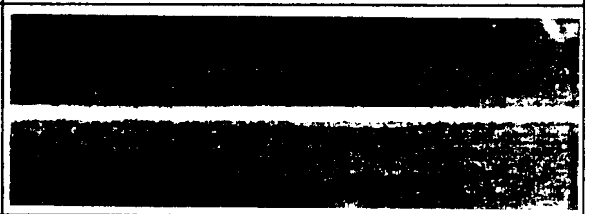
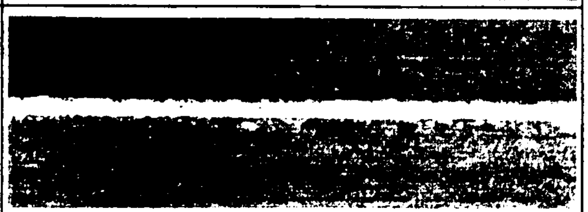
Investigated area \ Exposed site	Choshi (Marine)
Appearance 50mm	
Cut edge Cross-cut Drilled hole 25mm	
2t Bent area 5mm	
Cut edge area 2mm	

Photo 2. Pentite B after 10 years of outdoor exposure testing

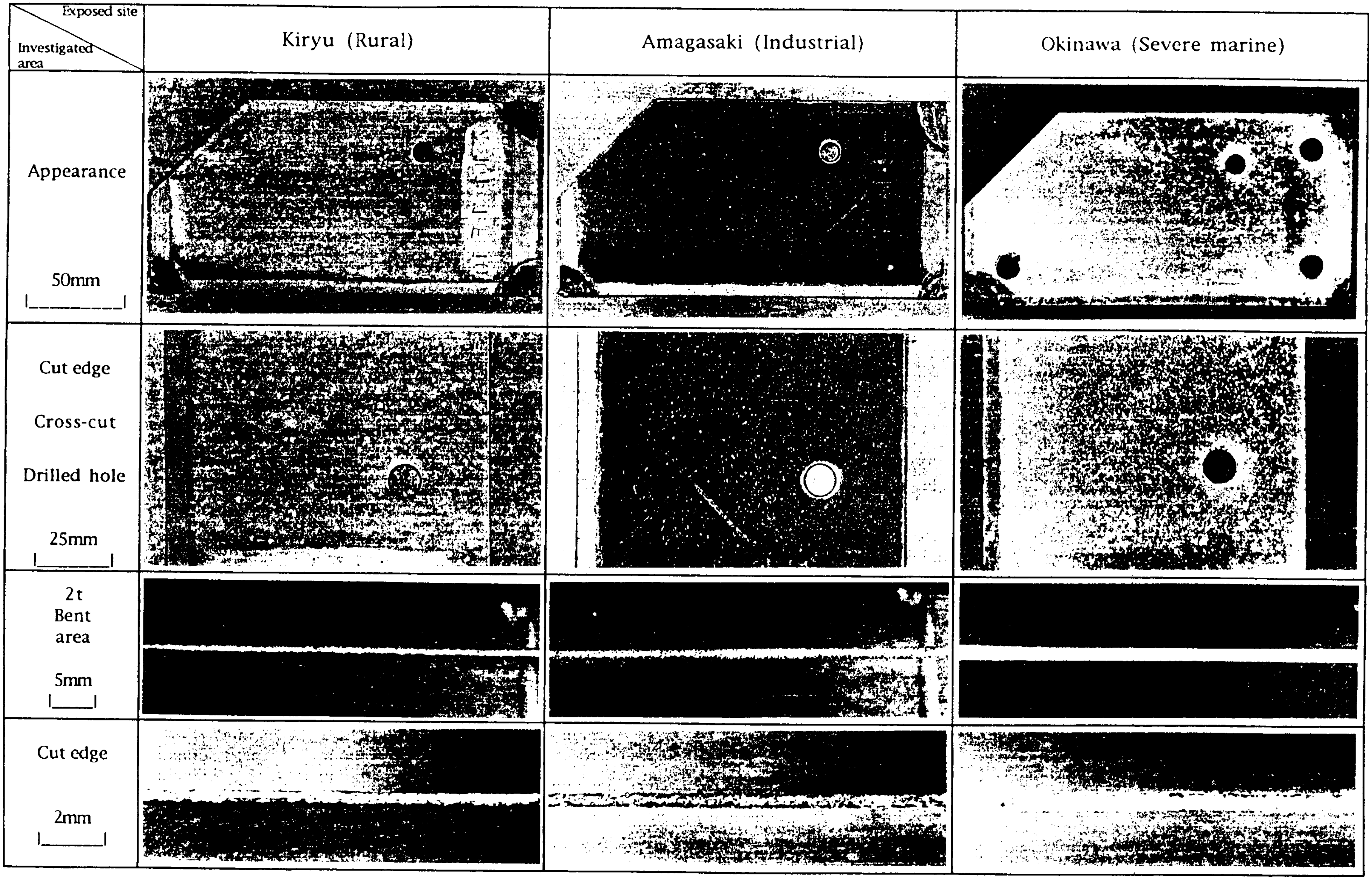


Photo 3. Galtite after 10 years of outdoor exposure testing

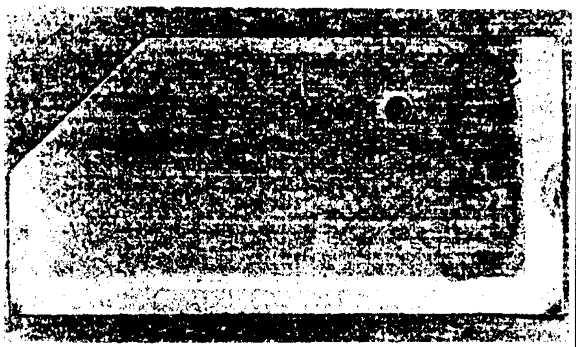
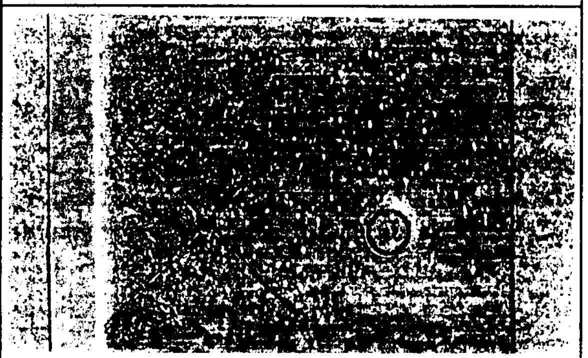
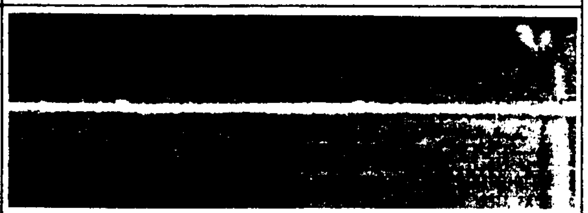
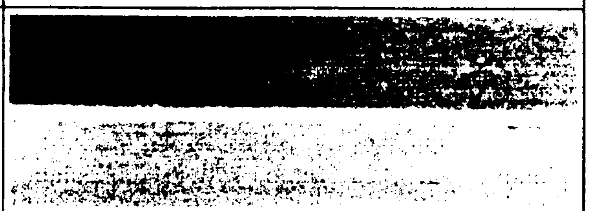
Exposed site / Investigated area	Choshi (Marine)
Appearance 50mm	
Cut edge Cross-cut Drilled hole 25mm	
2t Bent area 5mm	
Cut edge 2mm	

Photo 4. Galtite after 10 years of outdoor exposure testing

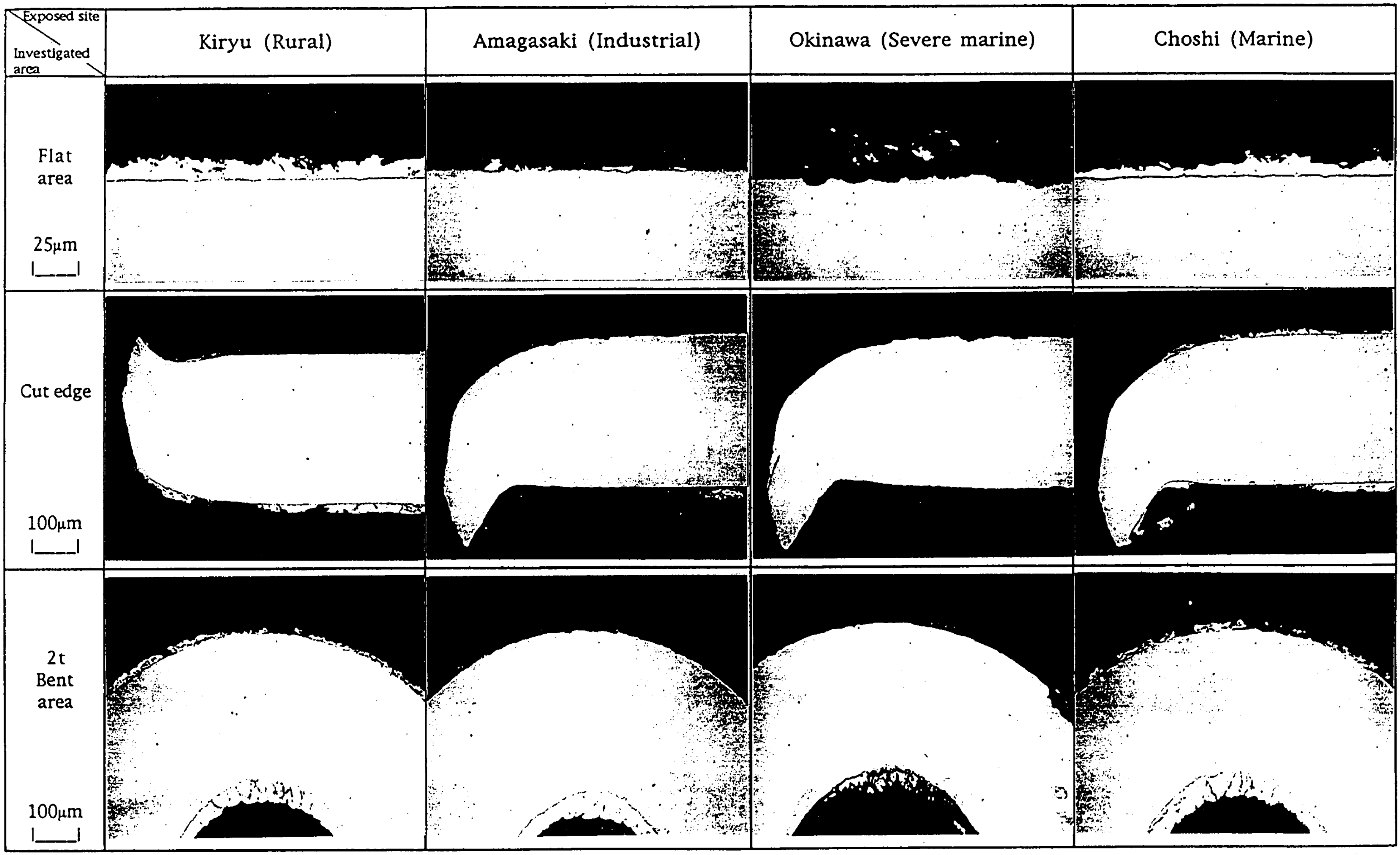


Photo 5. Cross-sectional micro-structure of Pentite B after 10 years of outdoor exposure testing

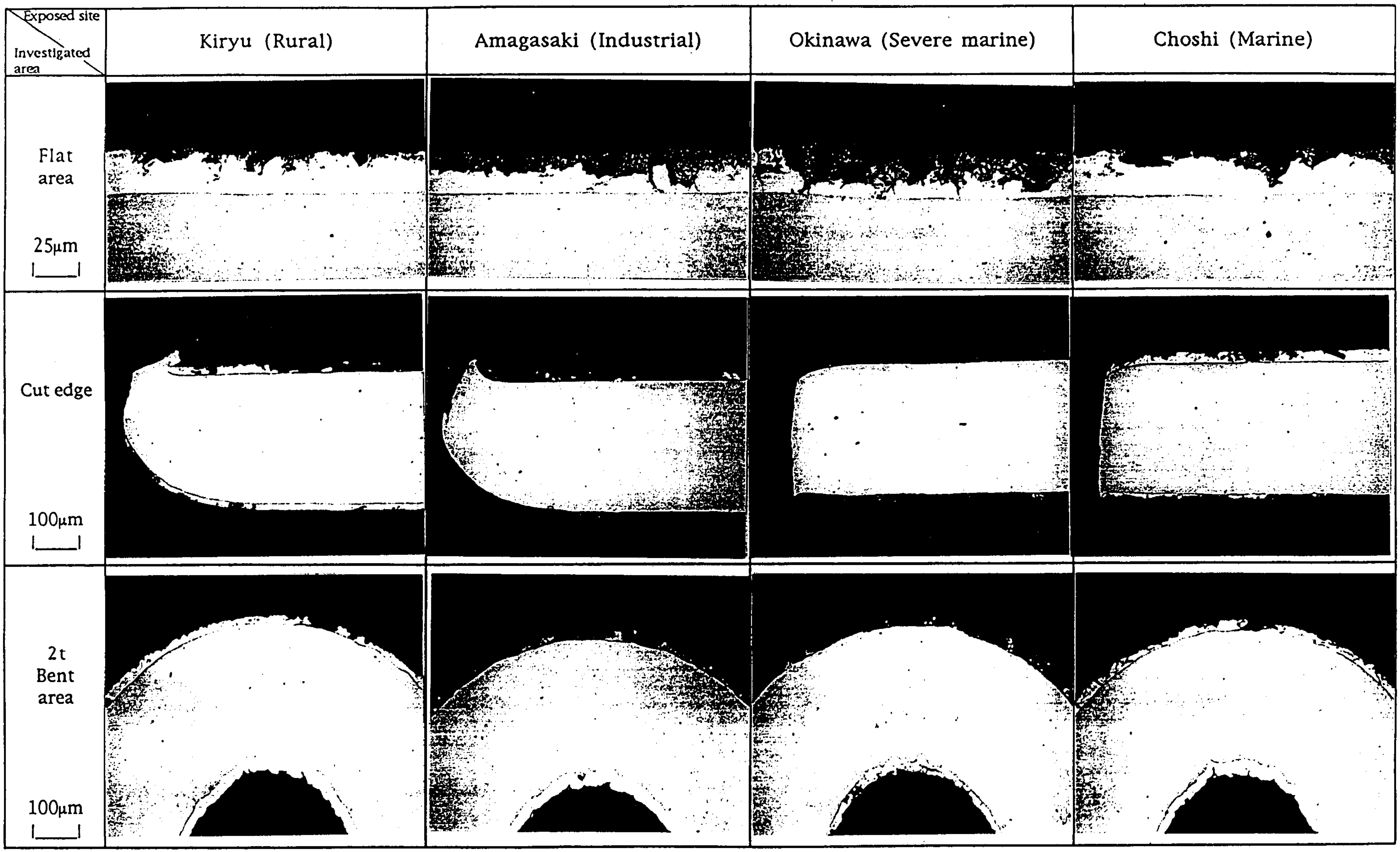


Photo 6. Cross-sectional micro-structure of Galtite after 10 years of outdoor exposure testing

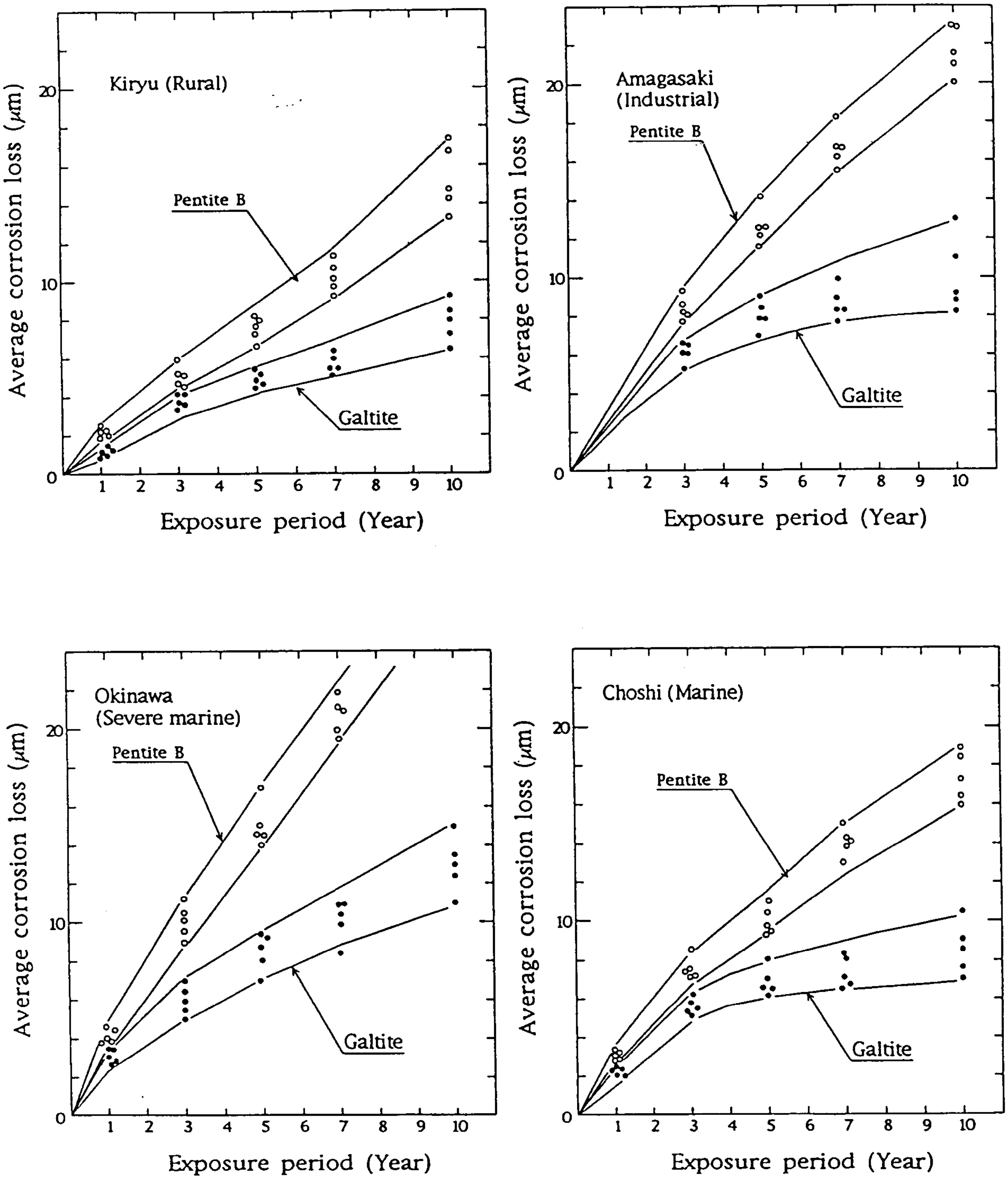


Fig. 3 Corrosion loss of coated layer after the atmospheric exposure test

Table 2: Corrosion loss of Pentite B and Galtite after the 10-year atmospheric exposure test (μm)

	Kiryu		Amagasaki		Okinawa		Choshi	
	Pentite B	Galtite	Pentite B	Galtite	Pentite B	Galtite	Pentite B	Galtite
1	17.0	8.0	22.5	9.0	-	15.0	16.5	10.5
2	14.0	9.0	20.0	13.0	-	13.5	18.5	7.0
3	13.0	7.0	21.0	11.0	-	11.0	19.0	8.5
4	16.5	6.2	21.5	8.8	-	12.5	17.5	7.5
5	14.5	7.8	22.5	8.2	-	13.0	16.0	9.0
X	15.0	7.6	21.5	10.0	-	13.0	17.5	8.5

Note 1: Corrosion loss measuring method of the coated layer

1) We inspected the cross-section at five points of flat area of the test panels using a microscope, and measured the remaining coating thickness at 20 points for each point. Then we averaged these values.

2) Corrosion loss of the coated layer is given by deducting the thickness of remaining coated layer from that of the coated layer before the test.

Note 2: No coated layer remained on Okinawa Pentite B test panel.

Table 3: Corrosion resistance ratio of Galtite against Pentite B

Exposure period / Exposure site	5 years	7 years	10 years
Kiryu	1.65	2.04	2.10
Amagasaki	1.70	2.07	2.28
Okinawa	1.80	2.16	-
Choshi	1.57	2.03	2.19

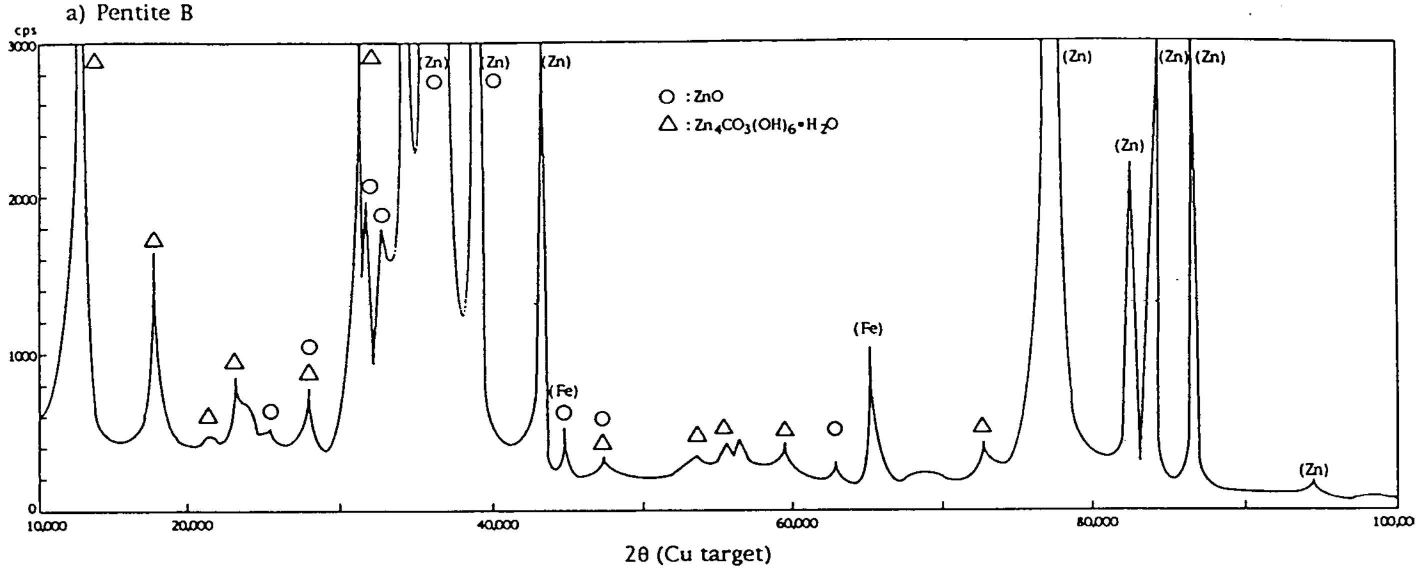
Note 1: Corrosion loss ratio was given by converting the average thickness of corrosion loss (μm) to the mass of corrosion loss (g/m^2).

Note 2: Density:

Pentite B --- 7.1

Galtite ------ 6.7

a) Pentite B



b) Galtite

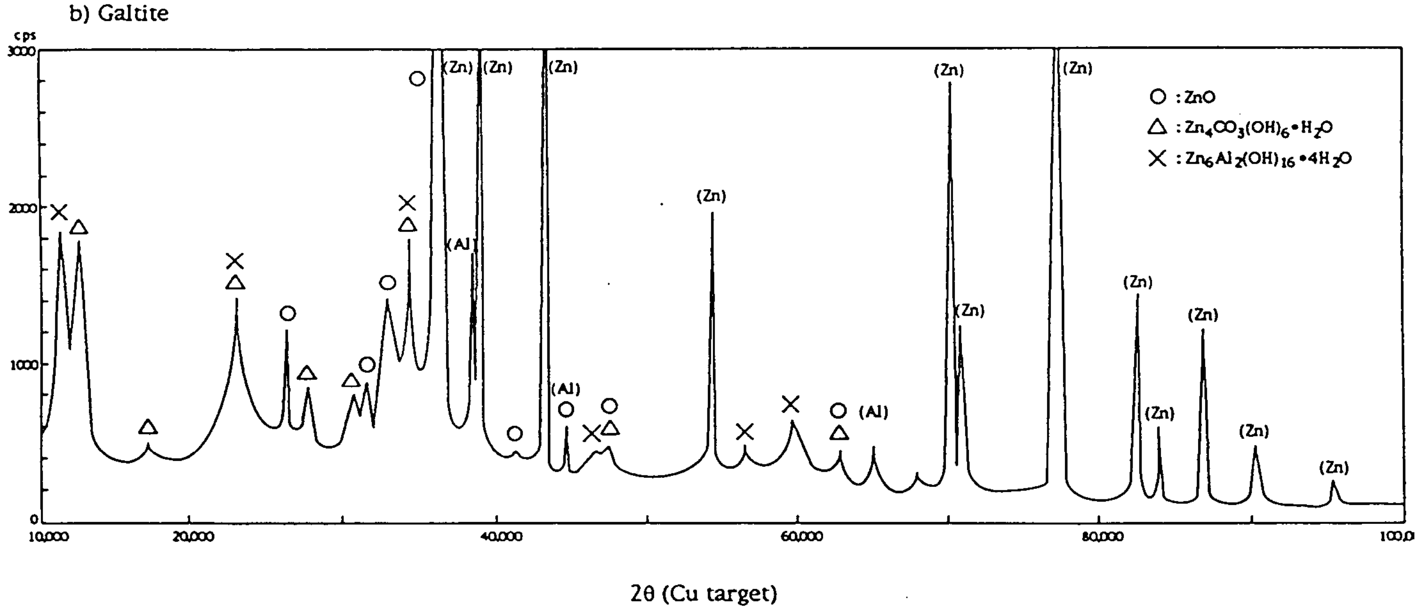
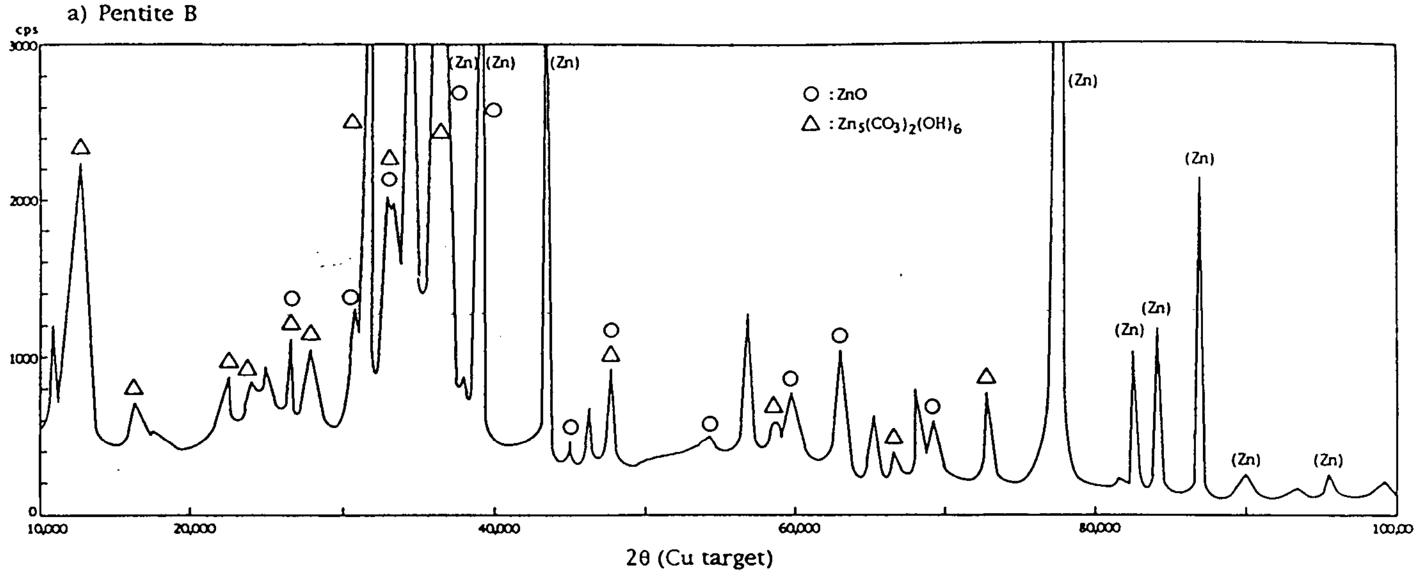


Fig. 4 Corrosion products on Pentite B and Galtite panels exposed for 7 years in Choshi (Marine site).

a) Pentite B



b) Galtite

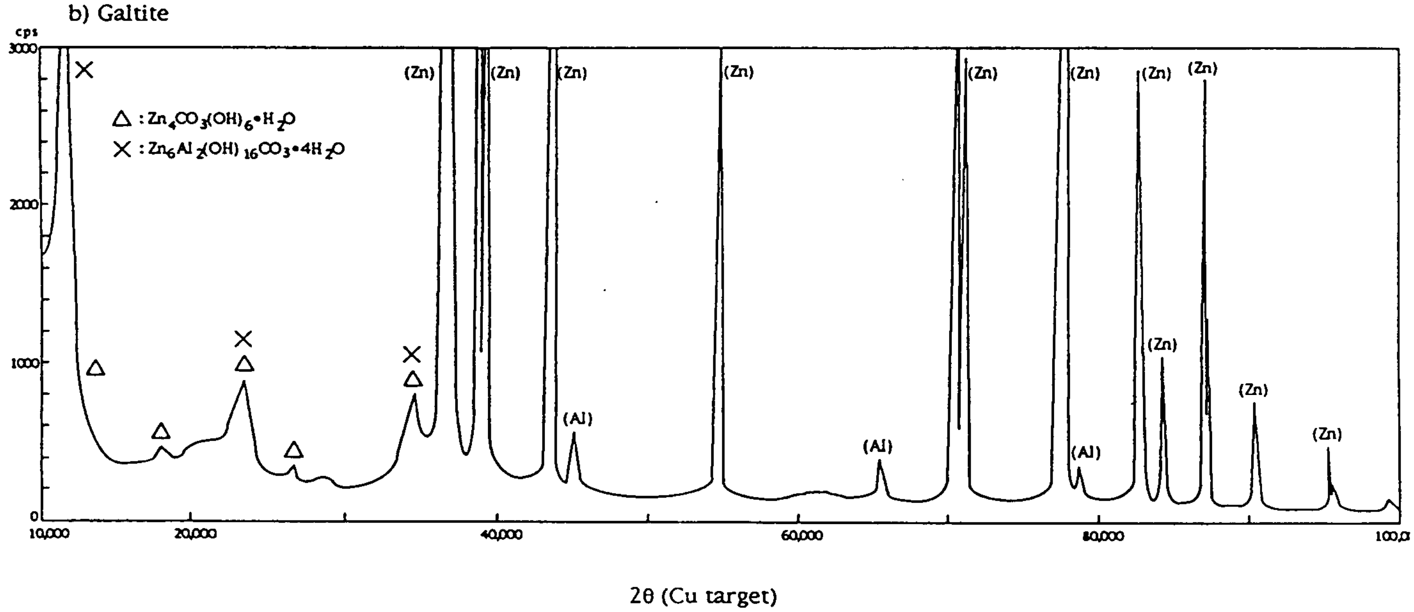


Fig. 5 Corrosion products on Pentite B and Galtite panels exposed for 7 years in Okinawa (Severe marine site).

Corrosion and Forming Behaviour of Galfan in Comparison to "Lead Free" and Conventional Zinc Coatings

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Abstract

Corrosion resistance of unpainted regular galvanised (Z-"Pb"), "lead free" zinc coated (Z) and Galfan (ZA) coated steel sheet was investigated in laboratory salt spray and Kesternich tests. The influence of chromate passivation treatment on corrosion performance in these tests was also studied.

The difference in cracking behaviour (in an unpainted condition) depending on the type of metallic coating will be shown on the basis of an actual formed part (washing machine front panel). Equivalent results habe been obtained for prepainted samples (typical coil coating paint system) using laboratory forming tests.

1. Introduction

A lot of different alloy layers based on zinc coated steel strip were coming up on stream during the last decades. Galfan is one of them. Due to the special (eutectic) coating composition of Galfan advantages in comparison to conventional zinc in cracking resp. forming behaviour of the coating have been raised and confirmed.

Also the corrosion behaviour in the bare condition is improved in comparison to zinc coated steel. In contrast to the Galvannealed-coating, the surface topographie and the hardness of the Galfan coating is quite similar to the conventional hot dip zinc coating. Beside the introduction of Galfan also a change in the production of conventional zinc coated strip occured, during the last decade. The lead content in the zinc has been reduced significantly from about 0.2 wt% down to less than 0.01 wt% on some hdg-lines.
Secondly on some lines a pre-cleaning section has been installed.

The aim of this paper is to compare the properties of conventional galvanized (Z-"Pb"), lead free (Z) zinc coated and Galfan (ZA) coated steel, regarding the corrosion behaviour and the forming behaviour.

2. Accelerated laboratory corrosion tests in bare conditions

2.1 Salt-Spray Test (DIN 50021)

It is well known that the corrosion resistance of Galfan – evaluated by using the salt spray test – is significantly higher in comparison to pure zinc.

The corrosion rate has been found to be three times less for Galfan (fig. 1). Conventional lead containing zinc coatings (Z-"Pb") and "lead-free" (Z) zinc coatings have practically identical corrosion rates! There is no influence of lead on the corrosion rate.

On the other hand the passivation treatment has to be taken into account. For chromate passivated Galfan- and zinc-coatings (about 15 mg/m^2 Cr) a corrosion resistance up to 50 % higher has been found in comparison to the oiled counterparts (fig. 2).

2.2 Kesternich-Test (DIN 50018 KFW 2.0 S)

The influence of the SO_2-concentration on the corrosion rate of zinc has been proved by Schikorr [1]. Zinc-carbonate can not be formed because in SO_2 containing acid environments the formation of zinc sulfates is preferenced. The soluble zinc sulfate is removed easily by rain resp. water ensuring high corrsoion rates.

In the laboratory corrosion test a wet atmosphere enriched with 0,67 vol% SO_2 has been adjusted. The time respectively number of cycles (one cycle = 24 h) to first red rust is evaluated. Analogous to the salt spray test a linear correlation between the coating weight and the corrosion resistance has been found. There was no difference between lead free and lead containing zinc coatings (fig. 3). About 30 % lower corrosion rates have been found for Galfan in comparison to zinc. The influence of the chromate passivation was negligible (fig. 4).

3. Cracking behaviour of the metallic coating in unpainted condition

An actual formed part (washing machine front panel) has been used to study the cracking behaviour of Galfan in comparison to "lead-free" and lead containing zinc coatings. Therefore steel sheets with equivalent sheet thickness (0.95 mm) and steel grades as well as different coating types have been produced (table 1).

Metallic coating type	*Coating thickness (µm)*	*Grain size (mm)*	*Bath Composition (%)*		*Steel grade*
			Al	Pb	
Z-"Pb"	10	0.5	0,192	0,084	FeP 06 G
Z	10	1.5	0,172	< 0,005	FeP 06 G
ZA	18	–	n.d.	n.d.	FeP 06 G

The formation of cracks has been evaluated on a special deep-drawn part of the formed blanks.

On the lead containing zinc coating only grain boundary cracks occured. For the Galfan and lead free zinc coating short cracks within the cells resp. grains have been observed.

The cross sections show that the form of the crack is quite similar for later ones (fig. 5). On Galfan more cracks have been found in comparison to lead free zinc. But the higher coating thickness for Galfan has to be taken into account.

The different cracking behaviour of the lead containing zinc coating can be explained by a different grain boundaries chemistry. Engberg et. al. have shown that lead is preferentially located at the grain boundaries [2]. In spite of the smaller grain size intercellular cracks have been found only for the lead containing zinc coating.

4. Cracking behaviour of prepainted, metallic coated steel sheets

The influence of metallic coated substrate on the forming behaviour of coil coated sheet metal has been investigated on the basis of laboratory samples regarding aging of the metallic coating and aging of the organic coating. Therefore substrate types according to table 2 have been available.

Metallic coating type	*Coating thickness (µm)*	*Sheet thickness (mm)*	*Bath Composition (%)*		*Steel grade*
			Al	Pb	
Z	10	0.7	0,160	< 0,005	FeP 06 G
ZA	7	0.5	n.d.	< 0,005	FeP 05 G

Both substrate types have been pretreated in the laboratory by using chromate treatment plus chromate rinse (standard coil coating pretreatment) and laboratory painted using a typical coil coating polyester two coat paint system.

Primer: Cr-containing polyesterprimer (5 µm dry film thickness)
Topcoat: White polyester topcoat (20 µm dry film thickness)

This paint system was chosen because its flexibility is not too high to cover the differences in cracking behaviour of the metallic coatings.

Application and curing conditions (peak metal temperature) have been kept constant for all substrate types.

4.1 Resistance to cracking on bending (ECCA T7)

Galfan is known as a very ductile type of metallic coating.
The tightest bends (T-values) without cracks in the organic coating (40 x magnification), applied 1 day before measurement, are shown in table 3.

Substrate	*T-value*
Z	1.5 T
ZA	1 T

Galfan showed even at the 0.5 T-bend only one crack. For the lead free zinc coated sample at the 1.0 T-bend more than one crack has been observed (fig. 6).

Unfortunately it was not possible to get comparable substrates for Z and ZA regarding metallic coating thickness and sheet thickness. With respect to the influence of metallic coating thickness on the cracking behaviour one would expect advantages for the Galfan sample. On the other hand the lower sheet thickness should at least equalize this advantage.

4.2 Resistance to cracking on rapid deformation (ECCA T5)

The test results confirm the advantages of Galfan in forming (table 4).

Substrate	*Maximum deformation energy (J) without cracks*	*Dome heights (mm)*
Z	16	3.5
ZA	≥ 20	5.5

Due to the lower sheet thickness the dome height for Galfan resulting from the deformation is significantly higher in comparison to the zinc-coating. This fact additionally points out the better cracking behaviour of Galfan.

4.3 Aging behaviour of metallic and organic coating

Both forming tests have also been carried out after 7 days, 33 days and 54 days storage in laboratory atmosphere on original organic coated test panels and on new pretreated and painted (1 day before testing date) samples.

No aging of substrat could be found even after 54 days. The original values have been measured on the new painted substrates.

Noticeable aging of the organic coating independent on the metallic coating type is shown in fig. 7 and fig. 8.

5. Summary

- For Galfan corrosion resistance 3 times higher has been found in comparison to zinc with the salt spray test. Lead free and lead containing zinc coatings have the same corrosion rates.
- The chromate passivation treatment leads to an up to 50 % higher corrosion resistance in the salt spray test.
- In SO_2-containing atmosphere the corrosion resistance of Galfan is about 30 % higher in comparison to zinc.
- The shape of the cracks observed at lead free zinc coatings and Galfan is quite similar.
- Regarding the cracking behaviour in prepainted condition advantages for Galfan in comparison to lead free zinc have been found.
- After 54 days storage at laboratory atmosphere no noticeable loss of formability of the metallic coatings occured.

References:

[1] Schikorr, G.
"Die Äquivalenz der atmosphärischen Korrosion von Zink und Nickel mit dem aus der Luft aufgenommenen Schwefeldioxid"
Metall, 15 (1961), p. 981-987

[2] G. Engberg; A. Haglund; S.E. Hörnström
"The influence of ageing on the properties of hot dip zinc coatings"
16th Biennal Congress 1990, IDDRG/Borlänge, p. 131

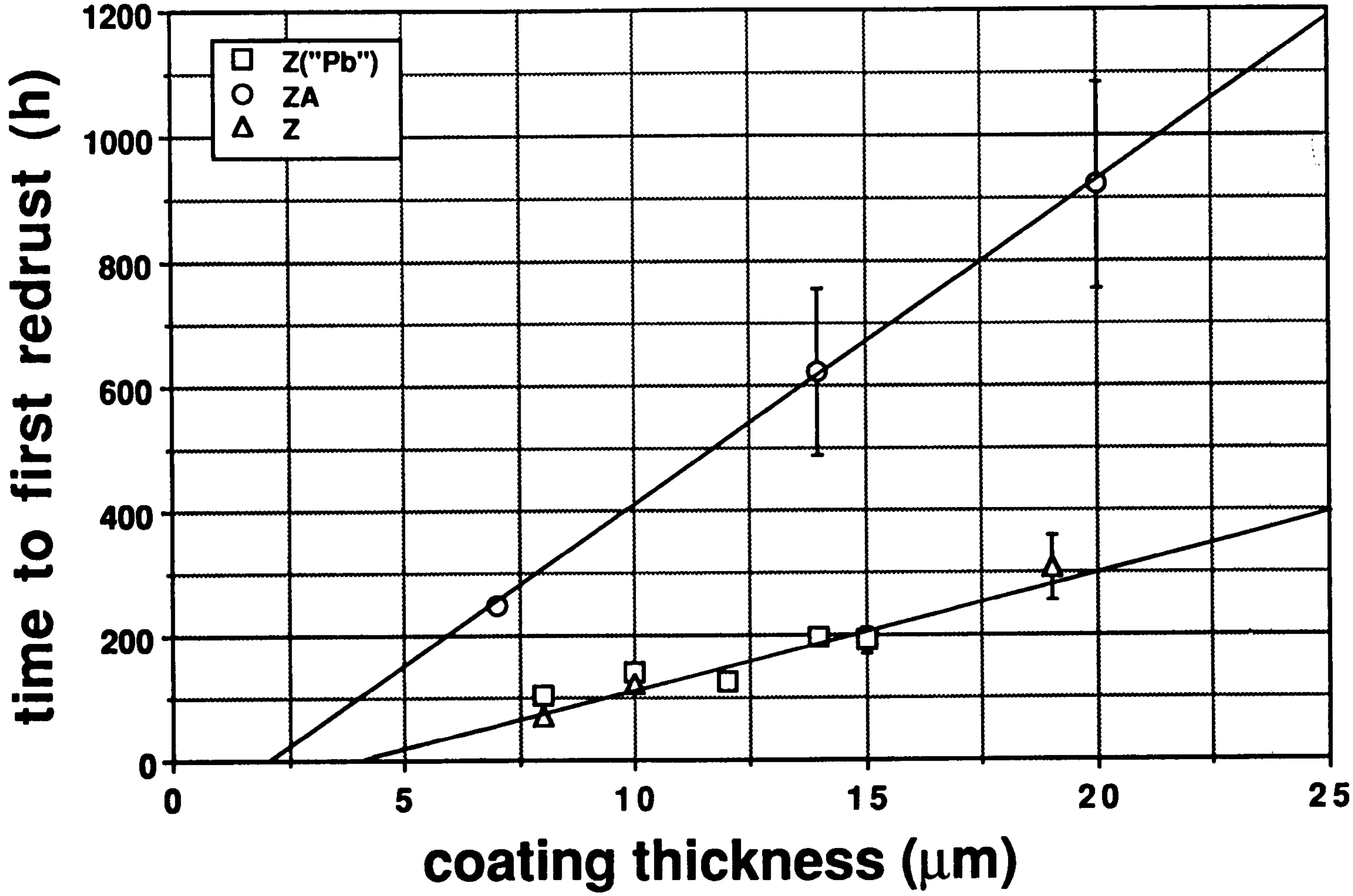


Fig. 1 Corrosion Behaviour of Different Coatings in the Salt Spray Test (DIN 50021)

VOEST-ALPINE STAHL LINZ

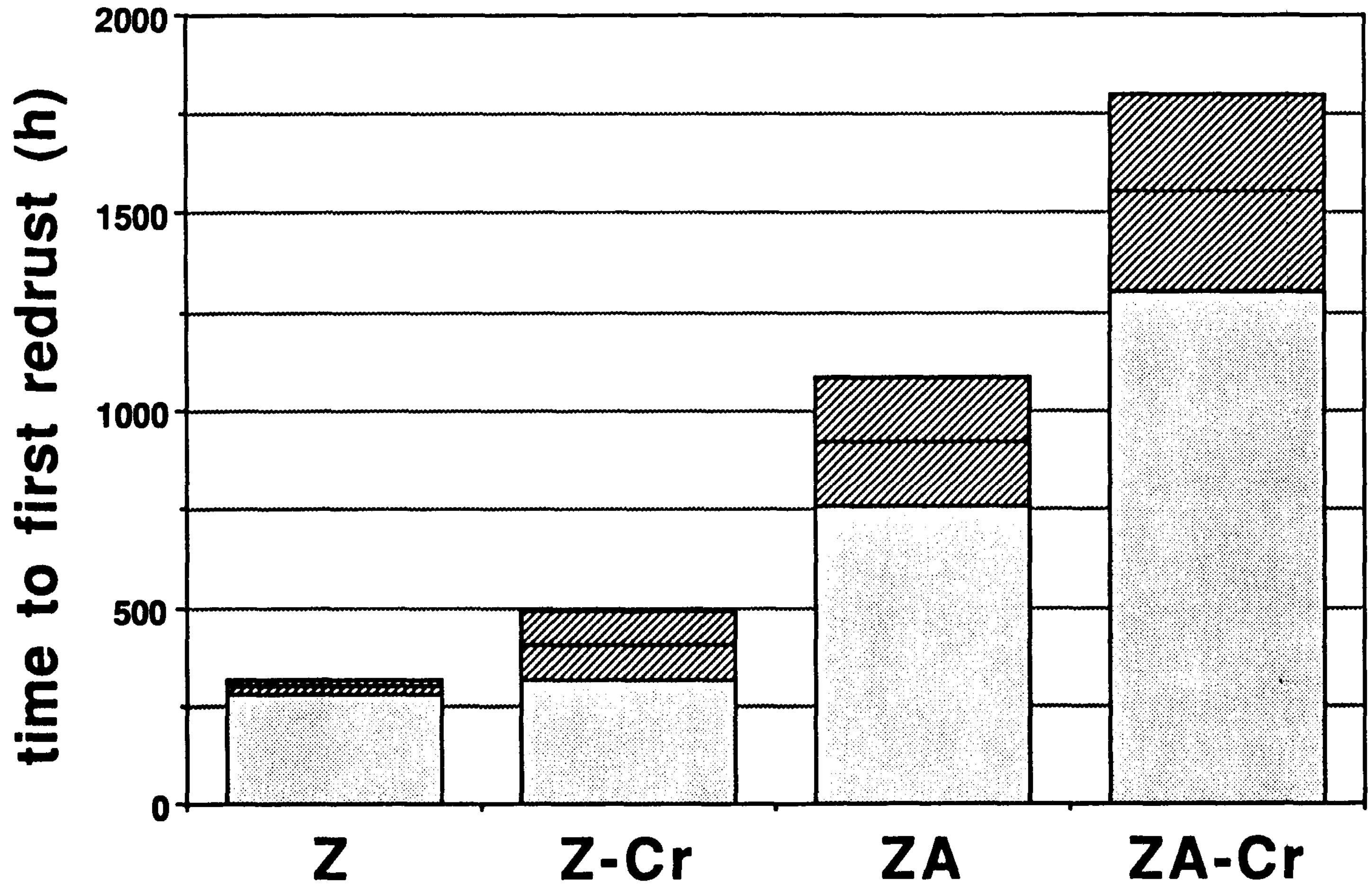


Fig. 2 Influence of the Chromat Passivation on the Corrosion Resistance of Different Coatings (coating thickness: 20 µm) in the Salt Spray Test (DIN 50021)

VOEST-ALPINE STAHL LINZ

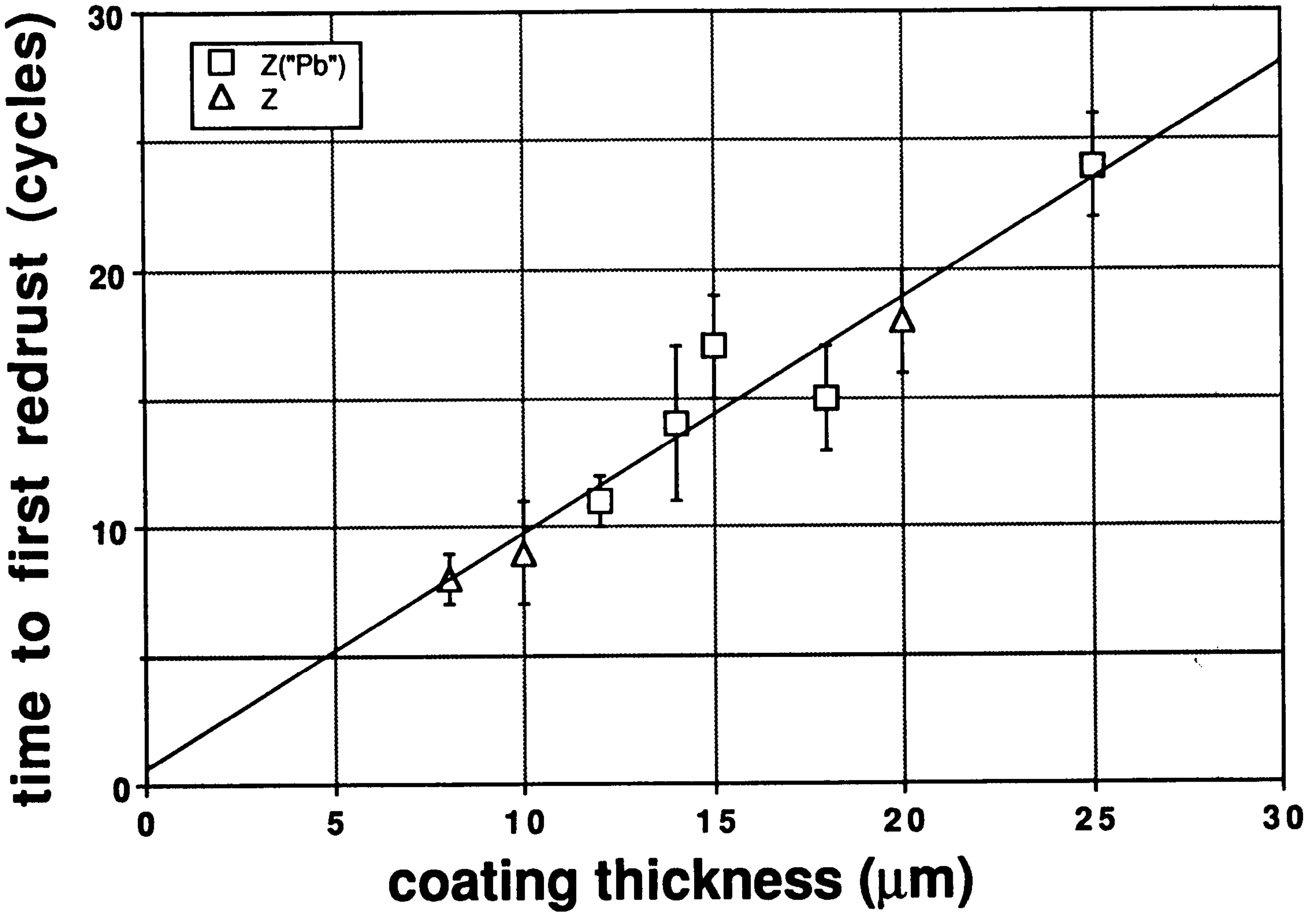


Fig. 3 **Corrosion Behaviour of Lead-free and Lead Containing Zinc Coatings in the "Kesternich-Test" (DIN 50018 KFW 2.0 S)**

VOEST-ALPINE STAHL LINZ

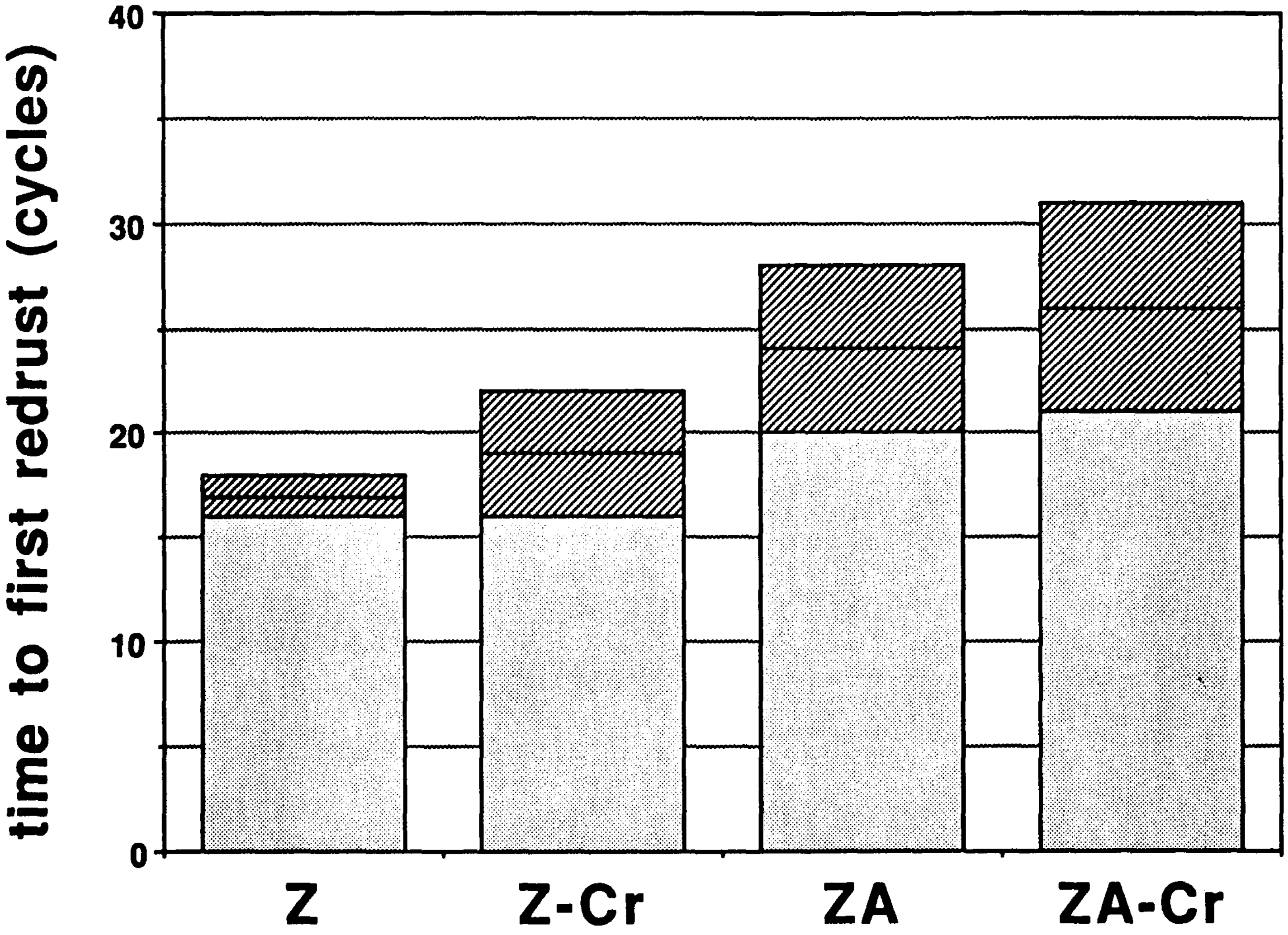
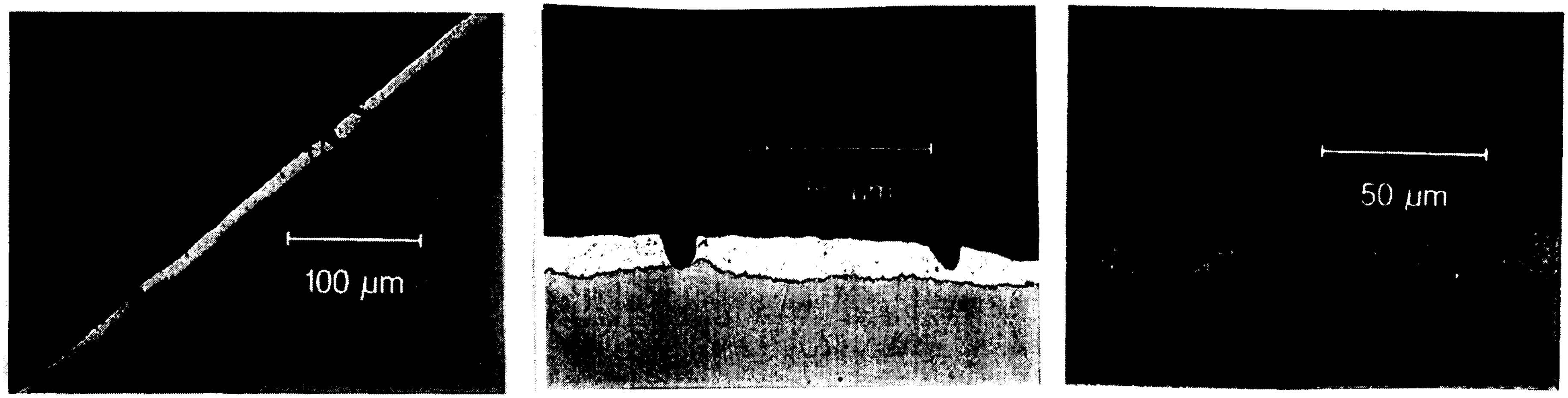


Fig. 4 Influence of the Chromat Passivation on the Corrosion Resistance of Different Coatings (coating thickness: 20 μm) in the "Kesternich-Test" (DIN 50018 KFW 2.0 S)

VOEST-ALPINE STAHL LINZ



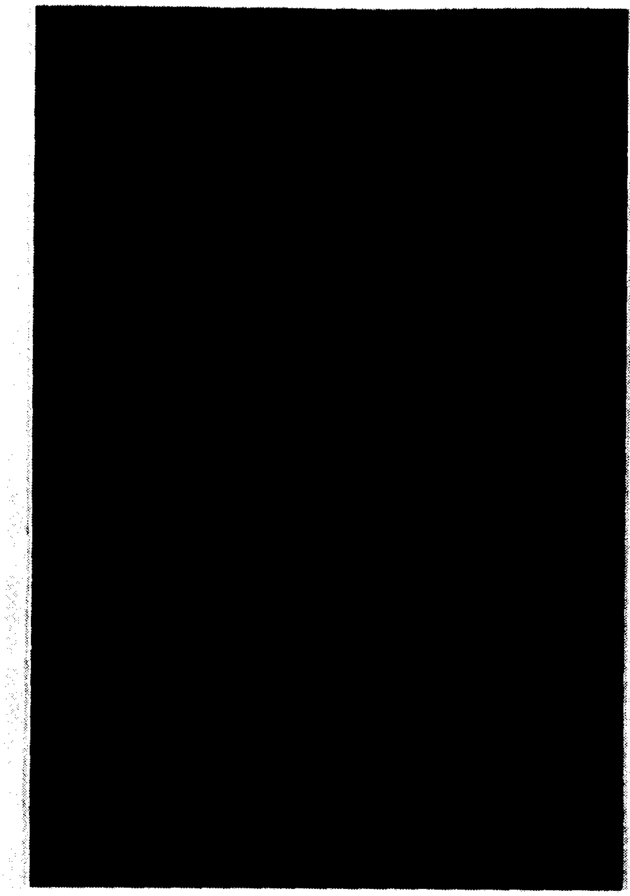
Z-"Pb" **Z** **ZA**

Fig. 5

Crack Formation of the Different Coating Types at a Special Deep Drawn Part

VOEST-ALPINE STAHL LINZ

Z



40 x
1 T (crackfree: 1.5 T)

ZA

40 x
0.5 t (crackfree: 1 T)

Fig. 6

Resistance to Cracking on Bending acc. to ECCA T7 (tested 1 day after organic coating)

VOEST-ALPINE STAHL LINZ

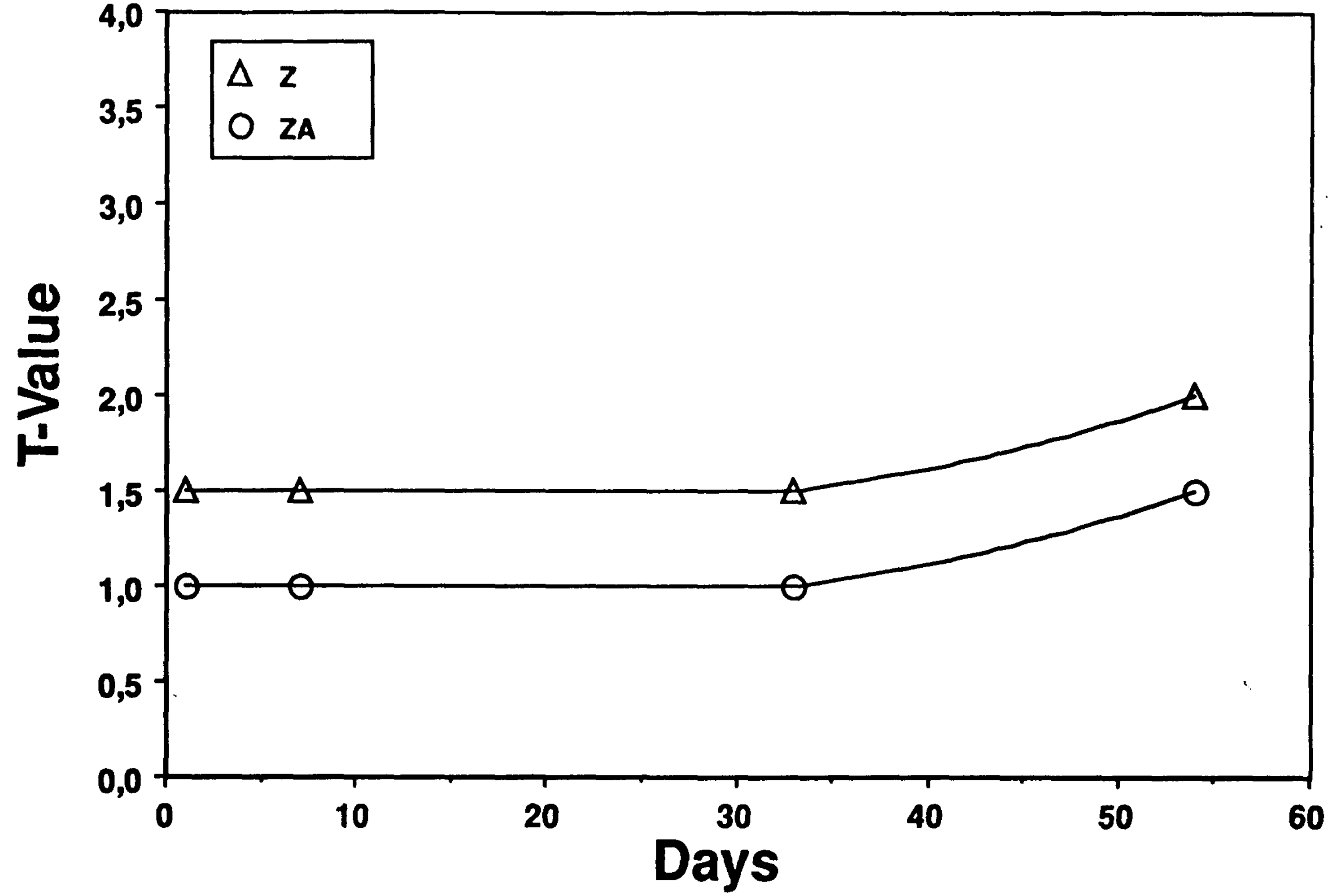


Fig. 7 Aging Behaviour of Organic Coated Z and ZA: Resistance to Cracking on Bending (ECCA T7)

VOEST-ALPINE STAHL LINZ

VOEST-ALPINE STAHL LINZ GMBH, FORSCHUNG, ENTWICKLUNG UND PRÜFTECHNIK

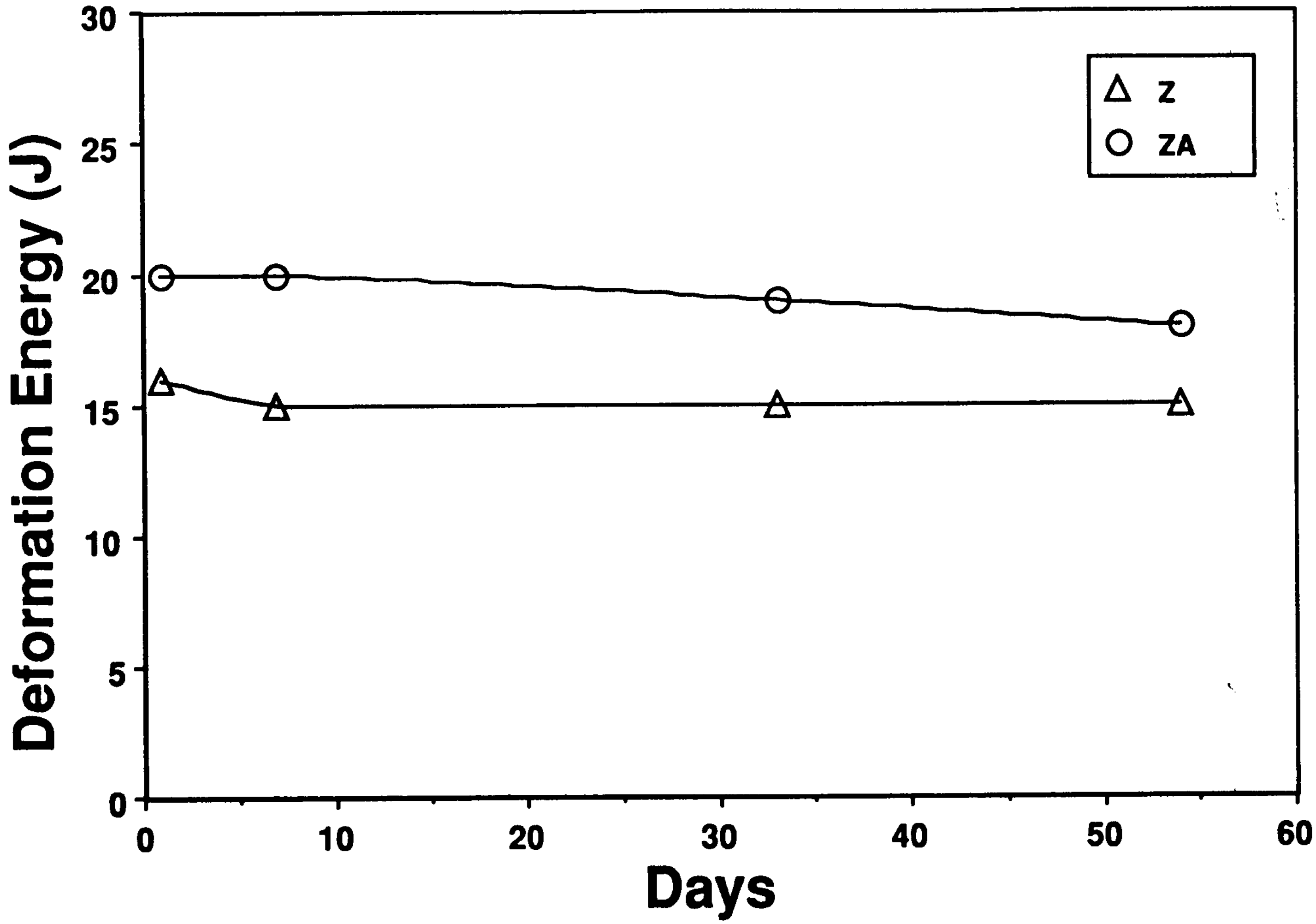


Fig. 8 Aging Behaviour of Organic Coated Z and ZA: Resistance to Cracking on Rapid Deformation (ECCA T5)

VOEST-ALPINE STAHL LINZ

VOEST-ALPINE STAHL LINZ GMBH, FORSCHUNG, ENTWICKLUNG UND PRUFTECHNIK

18th GALFAN License Meeting
Linz, Austria
October 4+6, 1993

POZEN - ELECTRIC TYPE FURNACE WITH CERAMIC BATH AND SILICON CARBIDE HEATING ELEMENTS DIRECTLY IMMERSED IN HOT-DIP METALLIZATION BATH.

by

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Abstract

A detail description of the construction of POZEN type furnaces and their operating principles have been presented. The new heating system relies upon the direct heating of the metal bath by electrodes made of SiC based material. Ceramic furnace lining is also an advantage. Technical and economical results after 8 years of application in hot-dip aluminizing as well as 2 years of galvanizing have been discussed.

Introduction

The original idea of the POZEN furnace dates back to 1977 - 1982 when a detail analysis of conventional hot-dip metallization processes and relevant facilities have been made. A special research program was focused on the actual construction of furnaces, their resistance against liquid metals such as zinc, aluminium and their alloys. The following goals have been considered to achieve:

- resistance against all known and applicable melted metals used in hot-dip processes,

- at least ten years of durability of ceramic walls of the pot,

- invention of the new heating system characterized by the maximum watt-hour efficiency.

The POZEN prototype have been designed and constructed in the late seventies by Dr Felicjan Biolik from "BIPROMET" - Katowice [1-3]. POZEN is the Polish abbreviation of the name Resistive Furnace with Immersed Heating Elements.

Construction and Operating Principle

The furnace consists of the steel pot isolated by ceramic furnace lining and covered by at least 85% Al_2O_3. The latter material is resistant against all melted metals applicable in hot-dip metallization processes.

New and unique heating system relies upon the direct heating of the metal bath. This is realized by specially designed heating elements built from ceramic material based on silicon carbide (SiC) and directly immersed in the bath.

The basic construction is illustrated in Fig.1. Resistance-heating elements in form of tube (see element 1 in Fig.1) are filled with liquid metal. The graphite electrode is inserted into the tube. The heat necessary to melt the metal in the bath and maintain the proper temperature of the melt is generated by wall of the heating element ((1) in Fig.1) as a result of the current flow. The source of this current flow is voltage applied across the electrode (2) (see Fig.1) inserted into the tube and another one immersed in the metal bath i.e. outside the heating element. Metal bath inside the pot is linked with grounded body of the furnace by means of graphite electrodes built in ceramic material of the furnace lining.
Due to semiconducting properties of the heating element, its resistance decreases while temperature of the liquid metal increases. At the same time current load of the element increases.

The resistance of particular heating elements depends on their production parameters and may vary, for instance, under nominal load and bath temperature 460°C for zinc and 720°C for aluminium one may obtain 0.3 - 1.5 Ohm. For certain load and bath temperature resistance as a function of time is constant. Ageing of heating elements is eliminated due to effective protection against the furnace atmosphere.

Power Supply and Control System

The power supply system of the furnace is shown in Fig.2. It is fed to AC three-phase network. The individual heating elements are supplied by phase voltage or delta voltage through a single-phase power regulator based on thyristors and a single-phase tapping transformer. Primary windings are star- or delta- linked, while the secondary windings are only star-linked. The zero point of the secondary winding is isolated and connected through the cable with grounded frame of the furnace. The phase voltage cable is applied directly to the electrode of the heating element.

The furnace control system is fully automated and comprises the following functions:

- control of bath temperature,
- power control of particular heating element,
- safety protections,
- measurements of power supply parameters,
- emergency signalling.

The power and control system of the POZEN furnace is shown in Fig.3. AC voltage from the supply transformer is decreased to 50 - 150 V by the power regulator and is supplied to the metal inside the heating element by means of the graphite electrode.

Heating element as a resistive element due to the current flow of approximately 100 - 500 A transfer heat to the metal bath through the whole contact area. This is the reason of the 95% efficiency of the heating system.

Starting of the Furnace

The first starting as well as starting after renovation of the furnace lining rely upon the preliminary melting of the metal in the operating bath and fitting of the heating elements inside the metal bath. Before mounting, these elements are heated in the additional starting furnace and they are filled by the liquid metal from the main operating pot. For the preliminary metal melting one may also use electric panel heaters equipped with resistance elements having load of 40 kW/m^2. The starting panels are supplied from the main unit and conveniently adapted for easy assembly and disassembly.

Advantages of the POZEN - Furnaces

Technological and economical advantages of the POZEN furnaces applied in the metallization processes are specially important in hot-dip aluminium as well as zinc-alumiunium processes. On the basis of actual informations obtained from industry i.e. hot-dip galvanizing and aluminizing companies one may assume the following advantages of the new heating system:

- high thermal efficiency of the heating system estimated of 95 - 97.5%,

- the lowest indexes of energy consumption; for instance, during Zn melting in 450°C an energy consumption index is 87.5 kWh/t,

- the lowest losses of the furnace during idle running; for instance power necessary to maintain of 1 ton of zinc at 480°C in furnace of 25 tons capacity is equal to 500 W, and 2500 W for aluminium being kept at 700°C,

- the lowest amount of melting losses in comparison with conventional furnaces, like inductive heating furnaces or heated by direct thermal radiation where high metal circulation in the former and overheating of the melted surface in the latter case causes significant metal losses; the amount of melting losses in inductive furnace in comparison with POZEN furnace at the same level of charge and surface of the pot is four times larger i.e. 1.6% and 0.4% respectively,

- in hot-dip galvanizing, decreased amount of so-called "hard zinc" in comparison with steel pot and lead elimination, which is applied in steel equipment,

- a choice of the shape and size of the pot (maximum depth 2.5 m),

- safety of work due to grounding of the metal bath,

- possibility of the replacement of heating element without interruption of the power supply,

- elimination of steel pots and additional stand-by furnace in hot-dip galvanizing process,

- applicability of the POZEN furnaces for all actually applied in practice hot-dip metallization processes also including GALFAN,

- possibility of development and practical applications in Poland and other countries hot-dip aluminizing process by non-continuous method in similar scope and efficiency as in galvanizing technology.

Samples of Applications

POZEN belong to new generation of furnaces appropriate for melting and maintaining in the liquid state of non-ferrous metals such as zinc, aliminium and their alloys. The new heating system has been developed in Poland in 1977-1982. During practical application this heating system was systematically improved in order to achieve optimum properties.

POZEN furnaces found an application in those cases, where ceramic pots are needed, for instance in baths more aggressive against steel then zinc. They have a recommendation of the Institute of Precision Mechanics for the application in hot-dip aluminizing process ALUZAN. POZEN type furnaces may have a successful application in GALFAN process as well, for instance in the continuous wire coating or pipes of small diameter and in the future in end products plating.

Several types of POZEN furnaces are actually in use in Poland. One of them is applied in the Institute of Precision Mechanics and since 1985 it operates continuously. The diagram of this furnace is shown in Fig. 4. This kind of furnace posses the following technical parameters:

- dimensions of the operating pot:
    * length (l) - 1500 mm
    * width (s) - 800 mm
    * height (h) - 1500 mm

- rated power - 60 kW

- weight of the aluminium bath - 8 tons

- temperature of the aluminium bath - 700 - 730 °C.

- the power at the idle period with covered bath surface
    * after 2 years of application - 18 kW
    * after 4 years of application - 22 kW
    * after 8 years of application - 28 kW

- amount of heating elements - 3

- effective efficiency - 150 kg/h

- durability of the heating element - approx. 6 months

The example presented in Fig.5 shows the furnace described above and sample of the driven well pipe being plated in this system.

Another model of POZEN 12r x 20 - z/Zn80 - 1.8 has been installed in "BIAVAR" plant in Białystok (see Fig.6). It is intended mainly to hot-dip galvanizing technology for electric water heaters. The application of this furnace allowed significant savings in energy consumption i.e. at least 30 - 40% in comparison with previously applied hot-dip galvanizing steel pot.

POZEN model 3r x 20 - z/Zn16 - 1.3 is in operation in "DUAL" - the producer of zinc coating on cast iron connectors in Radom.

Recently POZEN model 6r x 20 - z/Zn35 - 1.1 has been installed in "LINODRUT" in the plant of wires covered by Zn coating, located in Sosnowiec. This furnace is actually on starting. It is potential candidate for the first application of GALFAN technology in Poland.

The models of POZEN type furnaces along with short technical description is listed in Table 1.

References

1. Pl Patents No. 106380, 108821, 124892.

2. US Patents No.4158743, 4351057.

3. POZEN Electric Melting/Holding Furnace, Technical Information, POZEN Co., Katowice 1988.

4. Kwiecień J., Pasiak W., An Effective Method of Protecting Ferrous Alloy Products Against Different Kinds of Corrosion and High Temperature by Hot-Dip Aluminizing, Proceedings of U.K. Corrosion 87, Brighton, October 26-28, 1987.

5. Kwiecień J., Biolik F., Pasiak W., The Application of the POZEN Pot Furnace for Hot-Dip Aluminizing, Metaloznawstwo, Obróbka Cieplna, Inżynieria Powierzchni, Ed. IMP, No.99-100,1989.

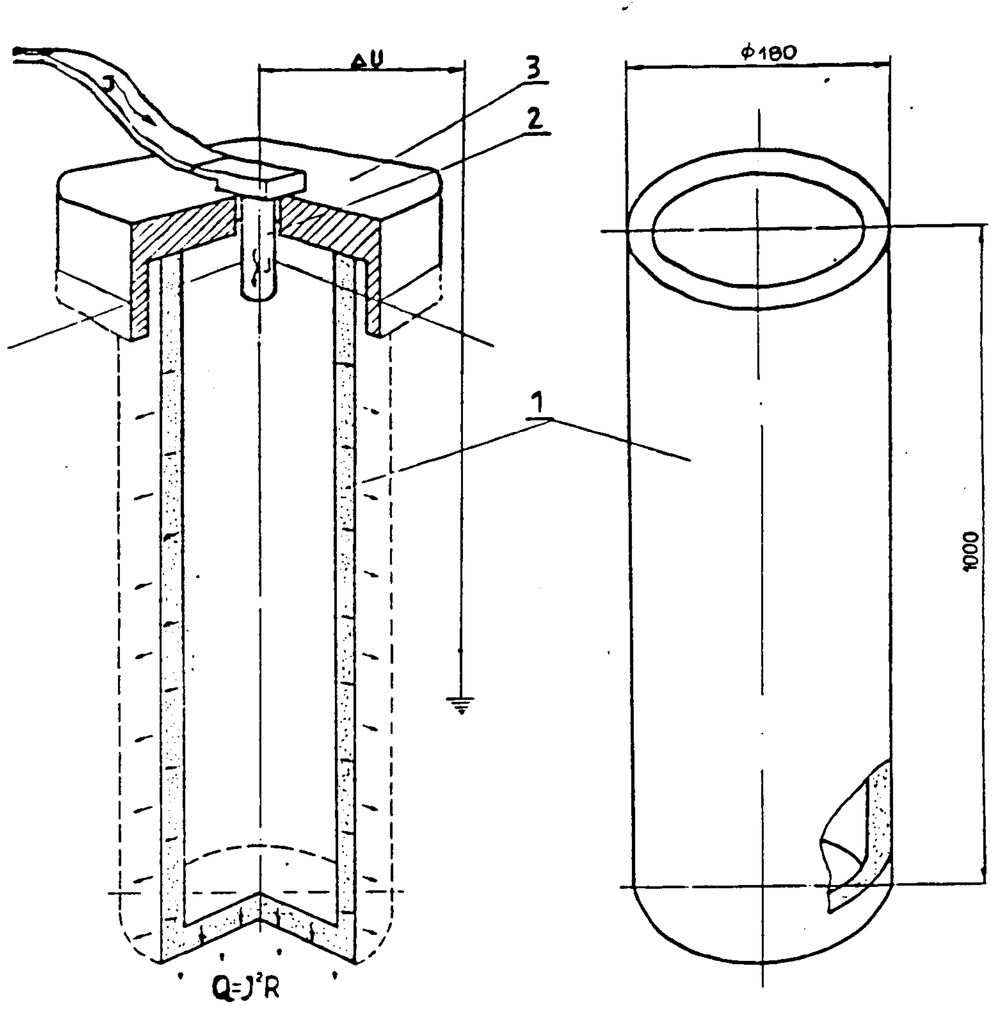

Fig.1. Diagram of the heating element.

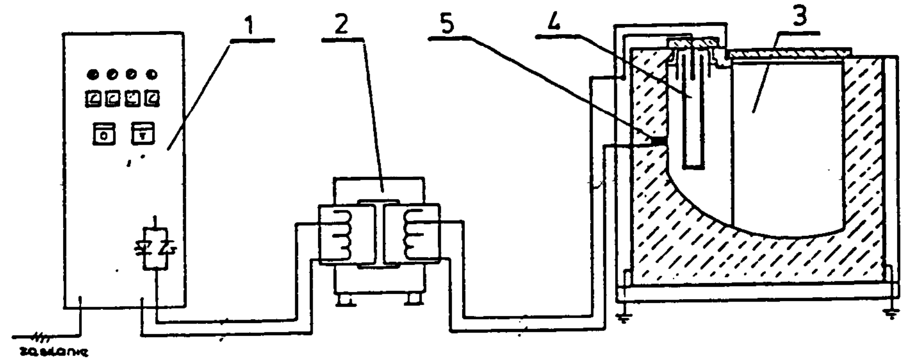

Fig. 2. Diagram of POZEN supply system.
1. control device,
2. tapping transformer,
3. furnace,
4. heating element,
5. grounded electrode.

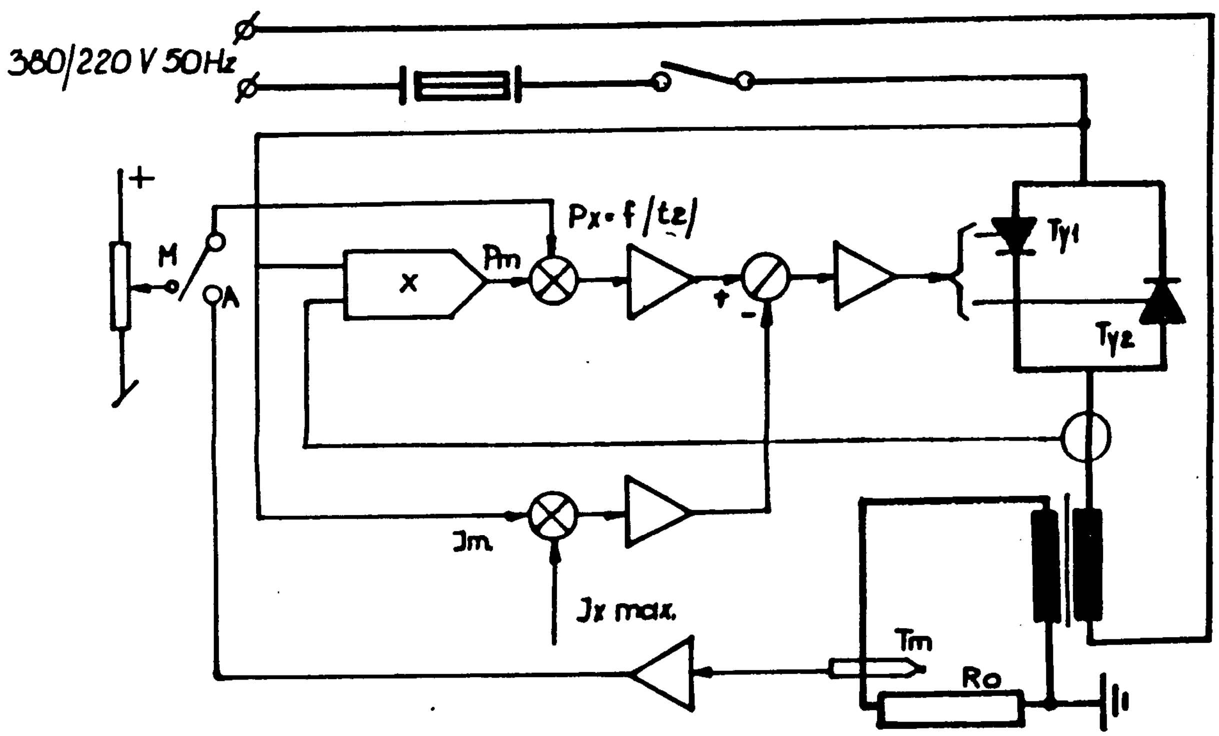

Fig.3. The circuit of the power and control system.
A - automatic control
B - manual control
R_o- resistance of the heating element.

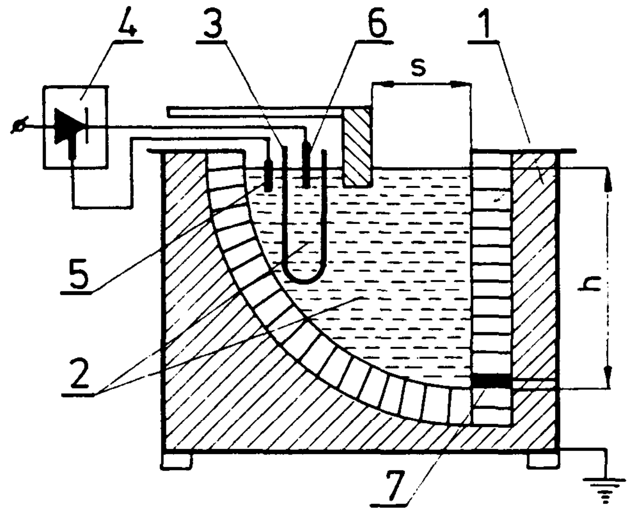

Fig.4. Diagram of the POZEN furnace installed in the Institute of Precision Mechanics (IMP).

1. ceramic pot,
2. aluminium bath,
3. heating element,
4. power controller,
5. thermocouple,
6. current supply electrode,
7. grounding electrode.

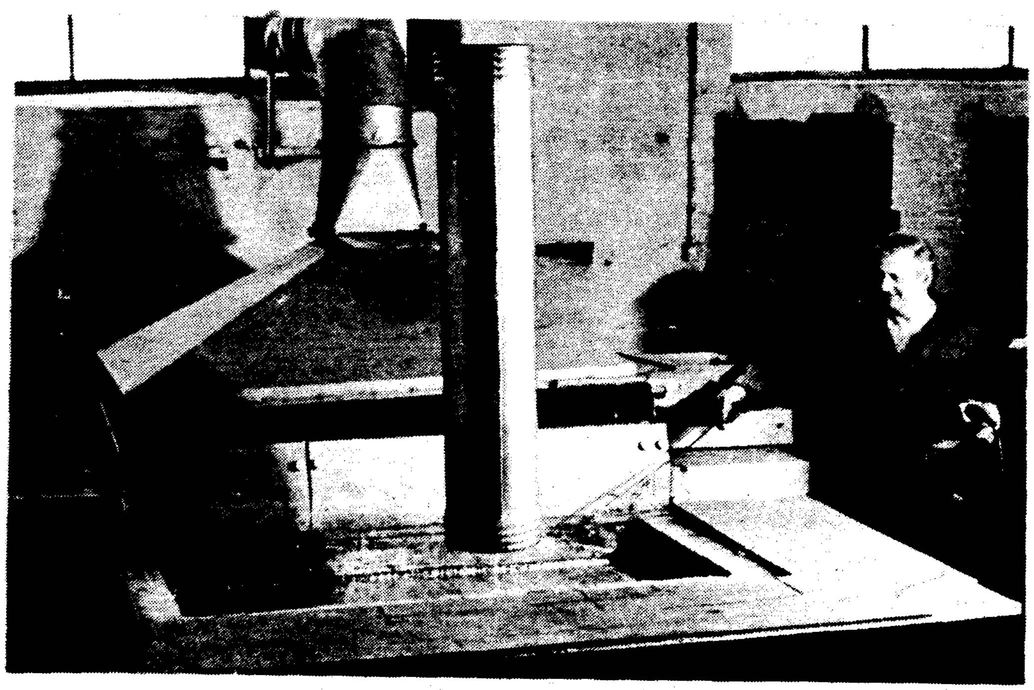

Fig.5. POZEN furnace, model 3r-z/Al8-1.5, at IMP.

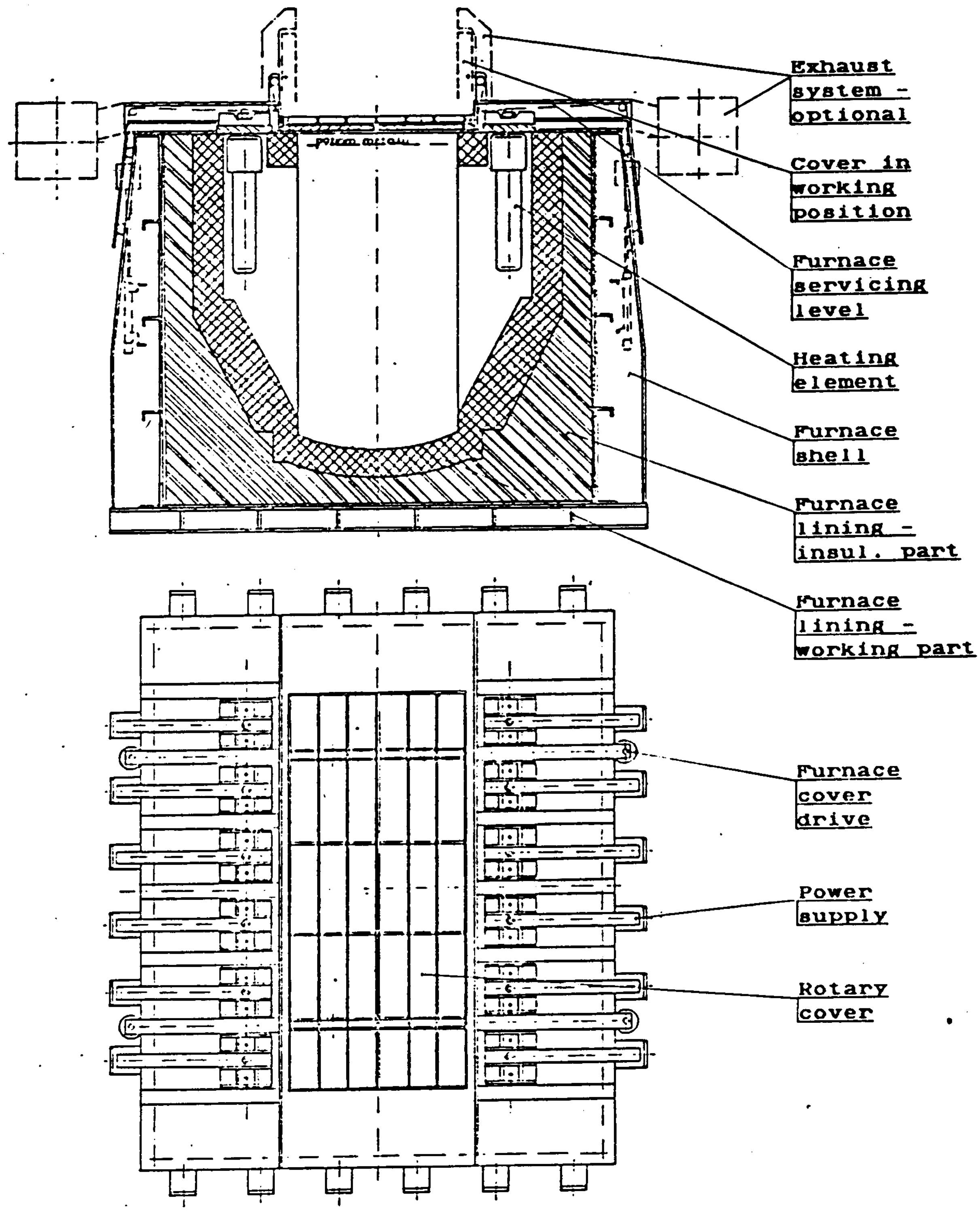

Fig.6. Diagram of the POZEN model 12r-z/Zn80-1.7, for hot-dip galvanizing, installed in "BIAVAR" plant in Białystok.

Table 1. Technical data of the POZEN furnaces.

Furnace Model	POZEN 2rx20-o/Al	POZEN 3rx20-z/Zn16-1.3	POZEN 3rx20-z/Al 8-1.5	POZEN 6rx20-z/Zn35-1.1	POZEN 6rx20-z/Al10-1.4
application	holding furnace	hot-dip galvanizing	hot-dip aluminizing	galvanizing of wires	hot-dip aluminizing
efficiency kg/h	100	500	200	850	400
dimensions of the working space, mm	710x305x1000	1270x810x1350	1620x810x1500	3360x920x1150	1620x810x1400
overall dimensions, mm	1290x1300x1630	2520x2630x2570	2880x2650x2730	4550x2750x2370	2880x3230x2490
weight of the metal bath, Mg	1.15	16	8	35	10
amount of heating elements, pieces	2	3	3	6	6
power rating, kW	40	60	60	120	120
idling power, kW	8	15	20	25	30

Table 1. Cont.

Furnace Model	POZEN 12x20-z/Zn80-1.8	POZEN 15rx20-z/Zn125-1.7	POZEN 15rx20/Al54-1.7	POZEN 24rx20/Al54-1.7	POZEN 36rx20-z/Al72-1.7
application	hot dip galvanizing	hot-dip galvanizing	hot-dip aluminizing	hot dip aluminizing	hot-dip aluminizing
efficiency kg/h	1200	1800	400	1400	1800
dimensions of the working space, mm	3800x1100x1800	4380x1500x1750	7000x1000x1700	7000x1000x1700	9000x1200x1700
overall dimensions, mm	5580x4300x3230	6140x4650x3290	8900x3600x2600	8900x4000x2600	10800x4100x2400
weight of the metal bath, Mg	81	125	54	54	72
amount of heating elements, pieces	12	15	15	24	36
power rating, kW	240	300	375	600	900
idling power, kW	30	40	105	125	132

18th Galfan Licensee Meeting
Linz, Austria
October 4-5, 1993

MISCHMETAL FOR GALFAN

Treibacher Chemische Werke AG
Auermet Division
Otto Bohunovsky

MISCHMETAL FOR GALFAN

The Galfan Alloy contains about 0,05 % Mischmetal (MM). This addition enhances the following qualities of Galfan:

- better Wetting
- better Formability
- better Corrosion Resistance
- better Adhesion of the cover

Therefore it should be useful to discuss Mischmetal. Mischmetal was first produced by the founder of TREIBACHER, Auer von Welsbach. Mischmetal is produced by molten salt electrolysis. It is the metallic form of the mixed Rare Earths. Rare Earths are a group of 14 chemical elements with a very similar chemical behaviour. The major constituents are Cerium and Lanthanum, followed by Neodymium and Praseodymium. The actual composition varies with the raw material used. Raw materials for Rare Earths are Monazite, Bastnaesite and the so called Ionic Ore. Here are some examples: (Table 1).

Rare Earth Distribution for different Rare Earth Ores

	Monazite	Bastnaesite	Ionic Ore
La2O3	24 %	27 %	30%
CeO2	47 %	50 %	7 %
Nd2O3	16 %	15 %	30 %
Pr6O11	4 %	5 %	7 %
Others	9 %	3 %	26 %

Overall, approximately 38,000 tpy of Rare Earth Oxydes have been produced in 1992 worldwide, equivalent to 31,500 tpy Rare Earth Metal content. The ores are treated chemically to give Rare Earth compounds. Most of this is being used as Rare Earth compounds and only minor portions are reduced to the metallic state. There are some important uses of individual Rare Earth Metals, mainly Samarium and Neodymium for Magnets. The biggest portion of Rare Earth metals is represented by Mischmetal however. Around 2,000 tpy of Mischmetal are produced world wide. The uses are:

- flints, mainly for disposable lighters
- removal of Sulphur in steel
- addition to Magnesium and Aluminium Alloys (grain refining)
- Galfan

Galfan is responsible for only a very small portion of Mischmetal use. Taking a figure of 450,000 tpy of Galfan coated steel and assuming that 5 % of the weight is Galfan, you arrive at 22,000 tpy of Galfan. If Mischmetal is contained at 0,05 %, this would would result in a total Mischmetal requirement of just 11 tpy. To TREIBACHER, as a Mischmetal producer, this is a very minor market. To you as Galfan users, it is important that Mischmetal supply should be no problem. Reserves of Rare Earth Minerals are plentiful. China is the country with the most reserves. Also capacity for treating Rare Earth Minerals and for electrolysis of Rare Earth compounds to give Mischmetal is sufficient.

Most uses of Mischmetal are based on the high affinity of Mischmetal to Oxygen and Sulphur. This represented a problem when dissolving Mischmetal in the Zn/5% Al-alloy, because Mischmetal melts only at approx. 800 °C and tended to burn before being dissolved. In order to overcome this problem, we introduced a Mischmetal-Alloy with 12 % by weight of Zn. This Master Alloy has a melting point of only 490 °C. The production of the Master Alloy is a strongly exothermic reaction. This is a further advantage of using the Master Alloy as compared to Mischmetal as such, because there is no danger of overheating. Dissolution of this Master Alloy in the Zn/5% Al-Alloy takes its time. One producer told me that he stirs the bath for 1,5 to 2 hours at 570 °C-580 °C to ensure that the Mischmetal is well dissolved. In the beginning of the use of this Master Alloy, we recommendet to submerge it into the bath, but apparently this is not necessary. Comments from Galfan Alloy producers would be welcome.

Some discussion has been going on, if Cerium and Lanthanum have different effercts. We have no data to show any differences. We supply Master Alloys with the following compositions of Rare Earths: (Table 2).

Analyses of Galfan Master Alloys

(RE = Rare Earth)

RE-metals	**88 %**
Zinc	**12 %**

RE-distribution

	La-rich	Ce-rich
Lanthanum (La)	55 %	25 %
Cerium (Ce)	32 %	50-55 %
Neodymium (Nd)	10 %	15 %
Praseodymium (Pr)	3 %	4-6 %

Some customers prefer one or the other. Sometimes two Grades of Master Alloy are blended to give a certain Ce:La ration. Here again your comments would be appreciated. Our comment is that the Ce-rich version costs less.

We have been told that analyses of Rare Earths in Galfan sometimes show unexpected results and a material balance sometimes is not possible. Our opinion is that Mischmetal would react with Oxygen and the Rare Earth Oxydes would go to the dross. This is one possibility why Mischmetal apparently is being lost. Also, it has been determined that Mischmetal solubility in the Galfan bath is below 0,01 weight percent at 450 °C and the surplus of Mischmetal is to be found in intermetallic compounds in the bottom dross.

On analytical procedures our experience is limited to the Master Alloy with 88 % Mischmetal and 12 % Zn. No experience is available for Galfan as such.

We dissolve the Master Alloy with concentrated Hydrochloric Acid and Hydrogen Peroxide. By this method also Rare Earth oxides will be dissolved. Rare Earths are determined in a borate bead by XFA after precipitation with Ammonium Chloride. Zinc is determined by AAS.

Also, we have been told that the analysis of Rare Earths in Galfan can be done with good results by emission spectrometry (in German: Gitterspectrograph) from a sample of the metal.

The effects of the Mischmetal addition to Galfan can be explained by grain refining. It is also likely that Mischmetal reduces the Oxygen content of the bath as well as the Nitrogen and Hydrogen content.

As a closing remark, let me say that as Mischmetal suppliers we have no own experience with Galfan, but we are glad to be here and learn something about this minor use of Mischmetal, however with a substantial growth potential.

TREIBACHER
CHEMISCHE WERKE

RARE EARTHS MASTERALLOY FOR GALFAN

1. For the usage of GALFAN–Alloy, Treibacher produces a special Rare Earth Masteralloy with Zinc.

2. Analysis (RE = Rare Earth):

RE – Metals	approx.	88 %
Zinc		12 %
Al	max.	0,11 %
Mg	max.	0,16 %
Si	max.	0,70 %
Fe	max.	0,15 %

Re – Distribution:

	La rich	Ce rich
La	55 %	approx. 25 %
Ce	32 %	50 – 55 %
Nd	10 %	approx. 15 %
Pr	3 %	4 – 6 %

Density: approx. 6,5 g/cm³

Melting temperature: 490°C

3. The Masteralloy is produced in bars or cubes

	shape	weight
bars	20 x 20 mm, up to 400 mm long	up to 1000 g
cubes	20 x 20 x 20 mm	approx. 50 g

Adresse: A-9330 Treibach-Althofen • Telefon (0 42 62) 505-0 · (0 42 62) 25 75-0 • Fax (0 42 62) 20 05 • Telex 42 24 27 tcwtr a
Banken: Creditanstalt-Bankverein Klagenfurt, Konto-Nr. 0981-33333/00, BLZ 11810 • Bank für Kärnten und Steiermark Klagenfurt, Konto-Nr. 100-362171, BLZ 17000 • GiroCredit Wien, Konto-Nr. 401-106-495/00/000, BLZ 20000 • Österreichische Postsparkasse Wien, Konto-Nr. 7900-347, BLZ 60000
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The Development of Smooth Surface GALFAN for Coil Coating Applications

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ABSTRACT

Commercial GALFAN samples have been characterized with the use of stereomicroscopy, scanning electron microscopy, quantitative x-ray spectroscopy, and quantitative image analysis techniques. Surface defects were sometimes observed in the form of shrinkage cavities and solidification cracks, both of which were found to occur at eutectic cell and nodule boundaries. Solidification experiments with the GALFAN alloy, and pure and impure Al-Zn eutectic and off-eutectic alloys, have provided insight into the causes of surface defects. By determining the solidification conditions necessary to produce desired microstructural characteristics, it is anticipated that the surface defects on GALFAN coatings can be minimized. The ongoing research program, which is designed to investigate the causes of surface defects and to develop a fundamental understanding of Al-Zn eutectic and off-eutectic solidification, is also described.

INTRODUCTION

As a hot dipped Zn-based coating containing 5wt% Al and up to 0.10% mischmetal, Galfan offers excellent corrosion resistance, formability, paintability, and cathodic edge protection.[1-4] As the phase diagram in Figure 1 indicates, the coating is expected to be primarily eutectic in nature, although the exact microstructure is influenced by processing conditions such as cooling rate. [5] Formability, which is superior to that of conventional galvanized steel sheet and wire,[1,3,4] can be attributed to the absence or limited formation of a brittle intermetallic layer at the coating/substrate interface, and the high fracture toughness of the largely eutectic coating structure.[2-5]

Although there are numerous uses for Galfan and the demand for this coating continues to increase, the appearance of these coatings is sometimes marred by surface defects. The exact cause of these defects has been unclear, but surface depressions have been associated with the boundaries between differently oriented eutectic cells. The purpose of this paper is to identify coating surface disorders and to propose mechanisms for the formation of such defects based on the characterization of coating microstructure and surface appearance.

EXPERIMENTAL METHODS

Commercially-produced Galfan was inspected with the use of conventional light optical microscopy (LOM) techniques, a JEOL 6300F high resolution scanning electron microscope (SEM) equipped with a LINK EXL energy-dispersive x-ray spectrometer (EDS), and a JEOL 733 SuperProbe electron probe microanalyzer (EPMA). A Zeiss confocal laser scanning microscope (LSM) was used to measure the depths of depressions on the coating surface. In order to examine the structure of proeutectic zinc dendrites, the coating surface was polished and then etched with a solution of $33H_2O$ - 67HCl. The etchant attacked the interdendritic eutectic material, leaving the dendritic structure available for observation.

In addition to commercial Galfan, a Zn-5% Al-mischmetal alloy ingot was sectioned into samples approximately 4mm x 4mm x 1mm for solidification experiments and subsequent characterization. The complete composition of the ingot is given in Table 1, which also shows that this composition is within specification as designated by ASTM B750. The samples were melted in alumina crucibles at approximately 400°C and resolidified in an Ar/5.1% H_2 atmosphere with the use of a hot stage in an Electroscan E30 Environmental SEM (ESEM). Cooling rates varied from 4.3 to 47.4°C/min. These solidification experiments were conducted in order to compare the resulting surface characteristics of the Galfan alloy, in the absence of a reactive substrate, with those of the commercial product.

RESULTS & DISCUSSION

A. Surface characterization of commercial Galfan

The GALFAN solidification process can be envisioned by inspection of the coating surface. When the surface is observed with the use of low-magnification stereomicroscopy and polarized light (Figure 2), eutectic cells can be seen to grow radially from a nucleation site until impingement occurs with an adjacent growing nodule. When etched to reveal the dendritic structure of the proeutectic zinc, it is seen that some of these dendrites serve as nucleation sites for the eutectic nodules. The remaining dendrites exist within eutectic nodules, and are encompassed by eutectic cells which grow around them as shown in Figure 3. This solidification sequence is in agreement with that suggested by Marder [7], as shown in Figure 4.

When the coating surface is observed with brightfield illumination, surface depressions, or "dents", seem to be arranged at grain boundaries as indicated in Figure 5. Such dents were found by LSM techniques to be typically 10-15μm deep relative to the highest adjacent points on the coating surface. It should be noted, however, that the depth of such dents will be obviously dependent on the thickness of the coating. since a dent cannot be deeper than the thickness of the coating itself. It can be concluded by inspection of Figures 2 and 5 that denting occurs only at eutectic nodule boundaries and triple points. One such area is shown in Figure 6, which shows a depression at the triple point and what appear to be cracks extending along the boundaries of the adjoining nodules. A higher magnification triple point image (Figure 7) further supports these observations.

B. Zn-5%Al-mischmetal alloy solidification

There are two results of interest from the Galfan alloy solidification laboratory experiments. The first is that cracking at eutectic nodule boundaries and the denting at triple points as sometimes found in commercial Galfan were successfully simulated. These phenomena can be seen in Figures 8 and 9, respectively. Because of these findings, it can be concluded that surface depressions may be influenced by, but are not a direct result of, substrate interactions. Therefore, the fundamental cause(s) of denting must be associated with the solidification of the alloy, regardless of whether it is applied as a steel sheet coating. The second finding is that impurity particles were often observed adjacent to nodule boundaries, as can be seen in Figure 8. These impurities were identified as lead by EDS techniques; no other impurities could be detected in these regions. The presence of these particles at nodule boundaries can be explained by the limited solubility of Pb in Zn and the monotectic transformation in the Zn-Pb system. Hence during the solidification process, Pb will be continuously rejected into the melt resulting in the segregation of impurity-rich, low melting point material to grain boundaries.

Since Pb segregation was found for the Zn-5%Al-mischmetal alloy, the EPMA was used to determine the Pb concentration across a surface region of commercial Galfan. The results are shown in Figure 10, which presents a micrograph of the coating surface used for analysis and a plot of the resultant Pb concentration data. The line superimposed on the micrograph represents the path over which concentration data was obtained, in 1μm intervals. By comparing the coating microstructure with the plot, which is drawn to scale, it can be seen that the Pb concentration at the triple point (indicated as "A") is approximately 0.3wt%, or 60 times the maximum allowable concentration as designated by ASTM B750 (see Table 1). Other Pb concentration spikes are noted at primary Zn dendrite / eutectic boundaries (indicated as "B"), also due to the limited solubility of Pb in Zn.

C. Mechanism for dent/crack formation

Using the information obtained from the commercial Galfan characterization and the Zn-5%Al-mischmetal solidification study, a mechanism for denting/cracking is proposed as schematically illustrated in Figure 11. During the solidification process, the liquid metal is quickly consumed due to the relatively large volume changes associated with the solidification of Zn and Al (4.7% and 6.5%, respectively). As a result, there will be a shortage of liquid between two (or three) adjacent growing eutectic nodules and upon impingement, the interface will be subsequently curved creating a surface depression. The dents often observed in Galfan are attributed to this phenomenon. In addition, because impurities such as Pb are continuously rejected into the melt during the solidification process, the resulting grain boundary areas should therefore be weak in comparison to the bulk coating. When stresses are induced from shrinkage due to any further solidification and/or cooling, cracking will occur within these weakened grain boundaries. This result can be observed in commercial Galfan as shown in Figure 7.

D. Ongoing research

The results discussed thus far have included observations which have been made during the course of a more inclusive research project on denting in GALFAN coatings and solidification in the Zn-rich portion of the Al-Zn system. A description of this project is now presented, but quantitative conclusions are not discussed since most of the findings are not yet complete.

The overall objectives of the research on GALFAN are to identify the factors which contribute to denting and to more fully understand the relationships between solidification, microstructure, and surface appearance for commercially-produced coatings. These objectives will be accomplished through a 3-part program as follows:

- <u>Part 1:</u> Quantitative commercial GALFAN characterization;
- <u>Part 2:</u> Relationship development between Al-Zn microstructure and the extent of denting; and
- <u>Part 3:</u> Relationship development between solidification conditions and Al-Zn microstructure.

Together, these parts will establish the relationships between processing, coating microstructure, and surface properties. If successful, research results will be used to alter line conditions to produce the optimal microstructures for smooth surface coatings. Each of these parts is described in some detail below.

Part 1: Quantitative commercial GALFAN characterization

Commercially produced coatings are characterized via quantitative image analysis techniques for eutectic nodule size, thickness, area% proeutectic zinc, and the size and shape of the proeutectic zinc dendrites. These coating microstructural characteristics, along with various processing conditions such as cooling rate, strip and bath temperature, skin pass reduction, and bath composition, will be related to the area% denting. Results will help determine the critical processing and microstructural parameters which are related to denting.

Part 2: Relationship development between Al-Zn microstructure and the extent of denting

Three types of materials are used for these experiments, namely i) pure eutectic and off-eutectic Al-Zn alloys, ii) the same alloys as in (i), but containing controlled impurity additions, and iii) GALFAN alloy. Samples of these alloys will be melted and solidified at various cooling rates, and subsequently examined for the frequency and depth of denting. Microstructural evaluation will be conducted with image analysis procedures in order to establish relationships between alloy composition, microstructure, and denting.

Part 3: Relationship development between solidification conditions and Al-Zn microstructure.

The roles of various solidification parameters, such as solidification rate, temperature gradient in the liquid, and nucleation and growth characteristics, will be defined for those alloys described for Part 2, above. A series of nucleation and growth experiments will be used to characterize solidification in the Al-Zn system. In nucleation experiments, samples will be heated into either the liquid phase or a 2-phase mixture wherein the proeutectic phase remains solid but the eutectic phase is molten. The subsequent cooling will be at a controlled rate, and the solidification events which occur will be recorded with the use of differential scanning calorimetry in order to determine the undercoolings required for the nucleation of proeutectic and eutectic phases. In growth experiments, samples will be directionally solidified at various growth rates and liquid temperature gradients via the zone-refining technique. Together, the nucleation and growth experiments will provide quantitative data on the eutectic-dendritic transition in the Al-Zn system. The results of this part will be used to determine how processing conditions can be used to control GALFAN coating microstructure.

CONCLUSIONS

1. Surface depressions which are sometimes found on the surface of Galfan coatings occur at eutectic nodule boundaries and triple points. The depths of these dents has been found to be on the order of 10-15μm below the highest regions on the coating surface in adjacent regions, although dent depths are obviously dependent on coating thickness.

2. The cracking at eutectic nodule boundaries and the denting at triple points often found in commercial Galfan was successfully reproduced by melting and solidifying small samples of Zn-5%Al-mischmetal alloy on a non-reactive substrate. Because of this, it can be concluded that surface depressions on Galfan coatings are not the result of substrate interactions, but are controlled by the solidification of the coating alloy.

3. Denting in Galfan coatings is believed to be the result of solidification shrinkage and is associated with subsequent cracking. This problem may be compounded by the grain boundary segregation of impurities, which can act to weaken the material in these regions to promote cracking upon the application of solidification and cooling stresses. In both the commercial Galfan product characterization and the Zn-5%Al-mischmetal solidification study, Pb was found to be segregated to regions adjacent to and within eutectic nodule boundaries.

4. Ongoing research on the characterization of commercially produced GALFAN and the solidification of Al-Zn eutectic and off-eutectic alloys will establish relationships between solidification (or processing) conditions, coating microstructure, and coating surface properties. The results of the study will be used to minimize or eliminate denting, but more importantly, such results can be used to improve product quality and reduce rejection rates due to a more fundamental understanding of the GALFAN product.

ACKNOWLEDGEMENTS

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LIST OF REFERENCES

1. S.F. Radtke and D.C. Herrschaft, Role of Misch Metal in Galvanizing with a Zn-5%Al Alloy, Journal of the Less Common Metals, 93:253-259 (1983).

2. S.J. Mäkimattila, On the Production Possibilities of a Deep-Drawing Quality, Zn-5%Al Coated Sheet Steel, Scandinavian Journal of Metallurgy, 15:224-232 (1986).

3. M.P. Roman, Proceedings of The International Conference on Zinc and Zinc Alloy Coated Steel Sheet (GALVATECH), Tokyo, The Iron and Steel Institute of Japan, 1989,p. 359.

4. S. Mathieu, F.E. Goodwin, and M. Lamberigts, Proceedings of the Third International Zinc Coated Sheet Conference (INTERGALVA), Barcelona, 1991.

5. M. Lamberigts, V. Leroy, and F.E. Goodwin, Proceedings of the Third International Zinc Coated Sheet Conference (INTERGALVA), Barcelona, 1991.

6. M.P. Roman and R.F. Lynch, Galfan Continues to Grow, Metal Bulletin Monthly, 222/6:50-55 (1989).

7. A.R. Marder, Proceedings of Zinc-Based Steel Coating Systems: Metallurgy and Performance, ed. by G. Krauss and D.K. Matlock, TMS, Pennsylvania, 1990.

Table 1: Chemical composition of the ingot used for solidification studies, and composition limits as designated by ASTM B750.

	Al	Ce+La	Fe	Pb	Cd	Sn
Ingot	4.90	0.055	0.016	0.0029	<0.001	<0.001
ASTM B750	4.7-6.2	0.03-0.1	0.075 (max)	0.005 (max)	0.005 (max)	0.002 (max)

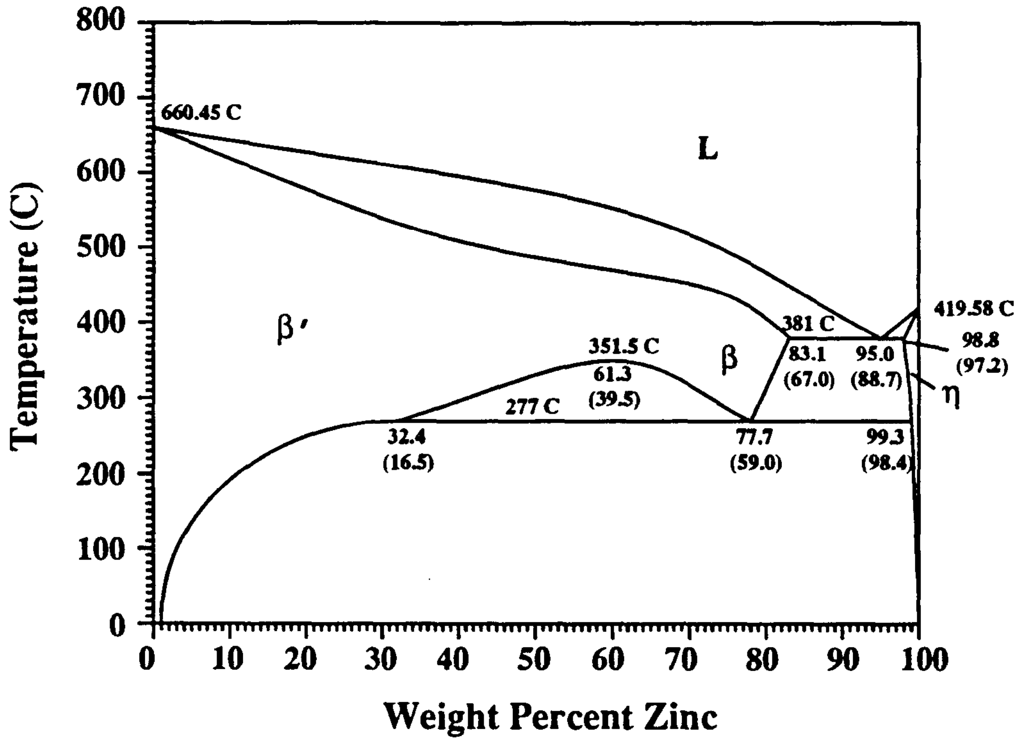


Figure 1. The Al-Zn equilibrium phase diagram.

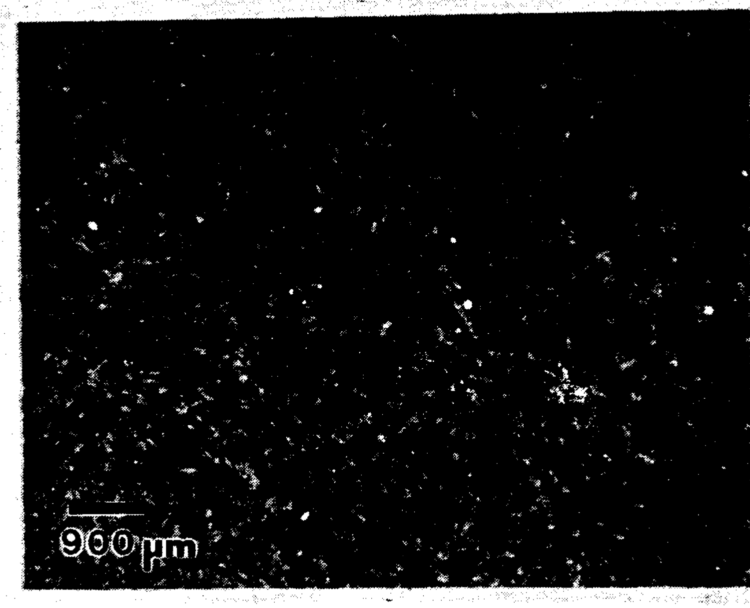


Figure 2. Galfan surface as observed with stereomicroscopy and polarized light.

Figure 3. Galfan surface etched to reveal the proeutectic zinc dendrite structure. The indicated dendrite serves as a nucleation site for the observed eutectic nodule.

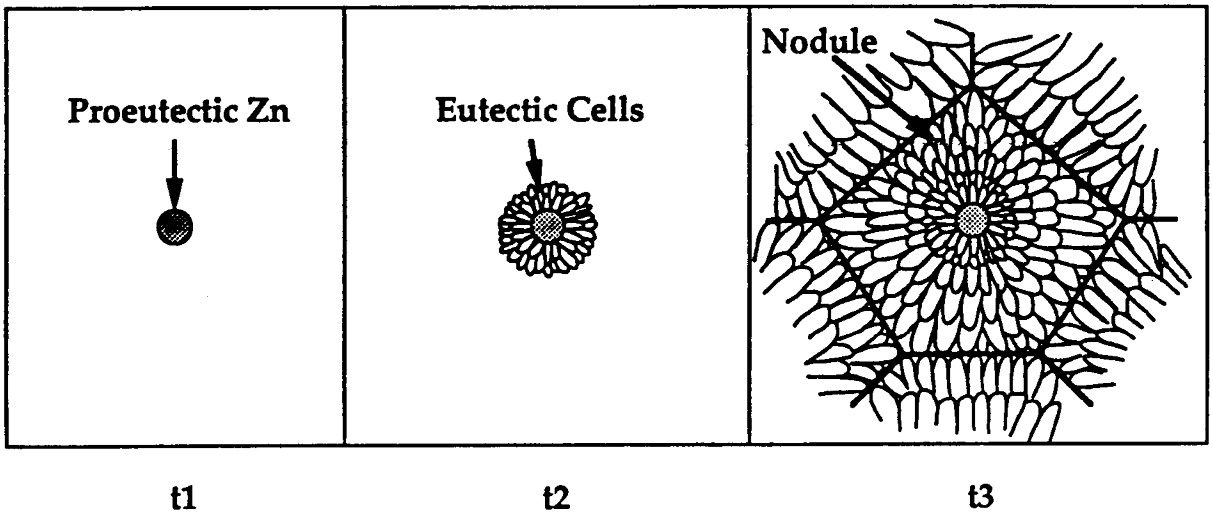


Figure 4. Schematic illustration of the Galfan solidification process (t1<t2<t3). (from [7])

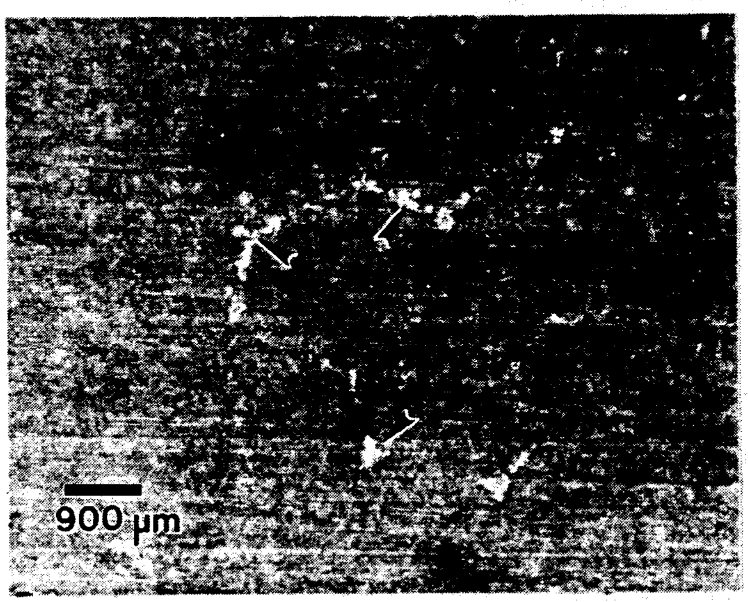


Figure 5. The same area as shown in Figure 2, as observed with brightfield illumination.

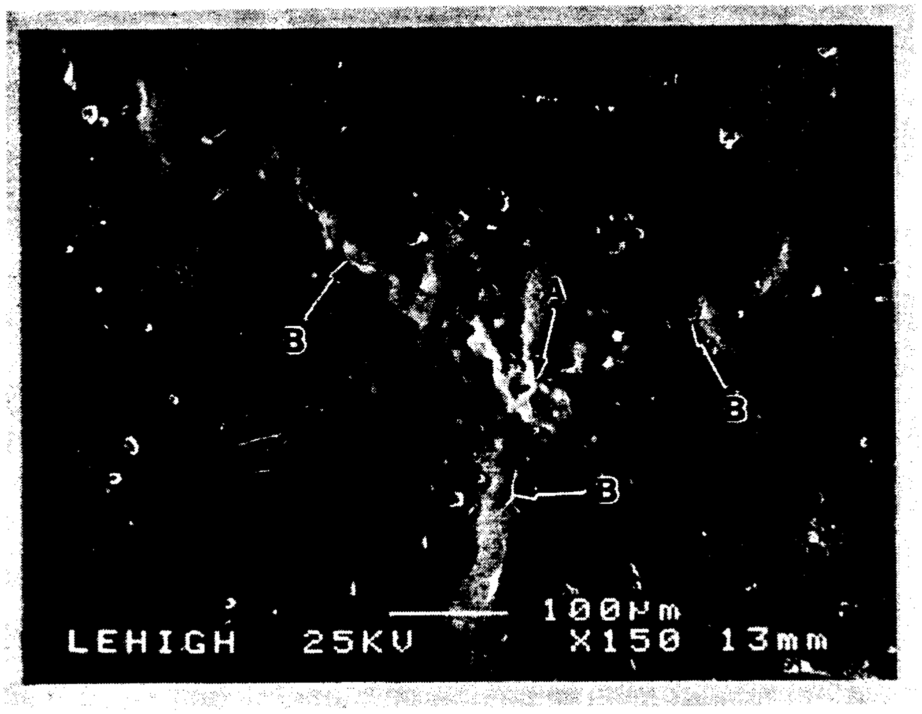


Figure 6. Galfan surface as viewed with an SEM. (A=triple point depression; B=cracks along nodule boundaries).

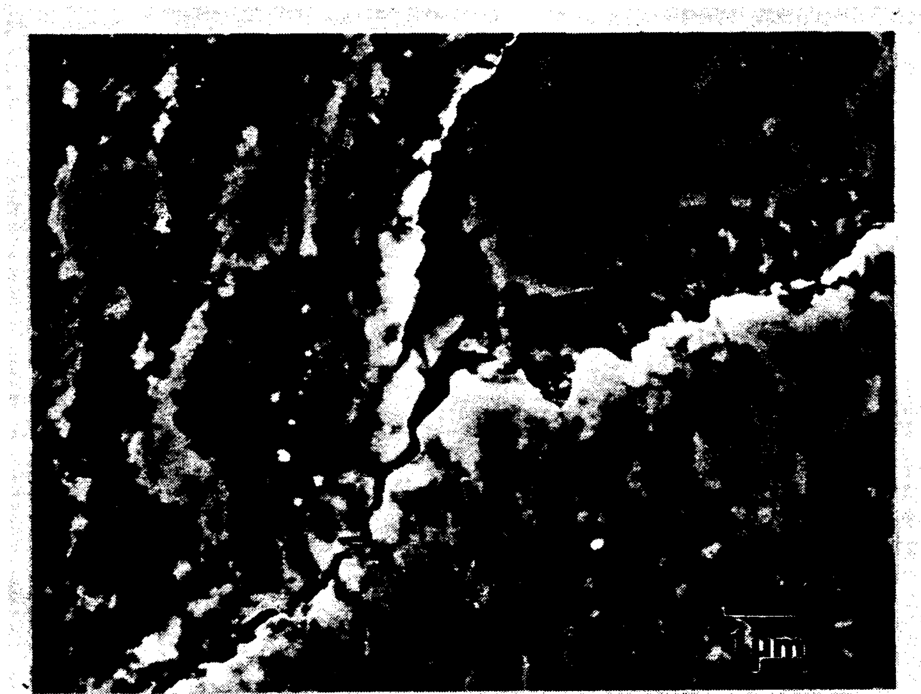


Figure 7. High magnification SEM micrograph of a eutectic nodule triple point on the surface of a Galfan sheet.

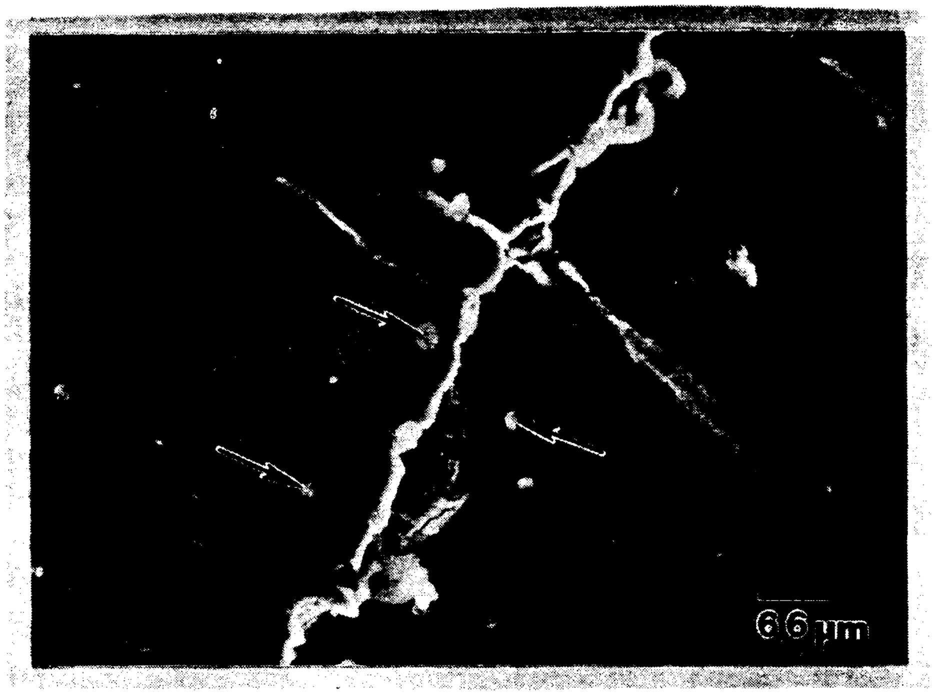


Figure 8. SEM micrograph showing cracking at eutectic nodule boundaries resulting from the solidification of Zn-5%Al-mischmetal alloy. Impurity particles are indicated.

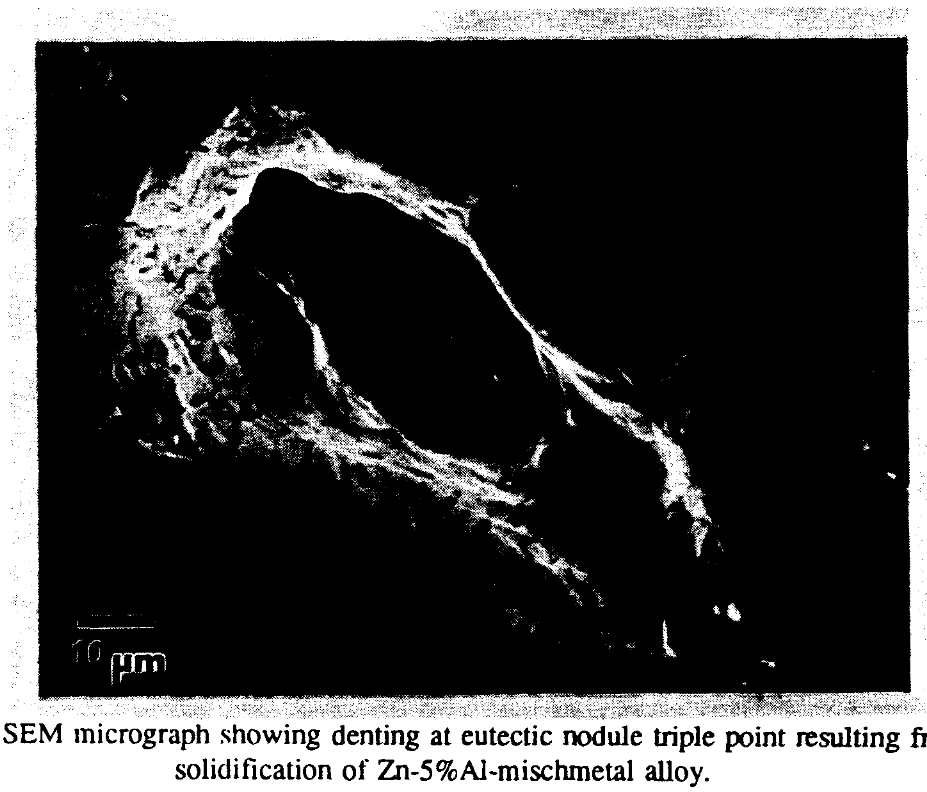


Figure 9. SEM micrograph showing denting at eutectic nodule triple point resulting from the solidification of Zn-5%Al-mischmetal alloy.

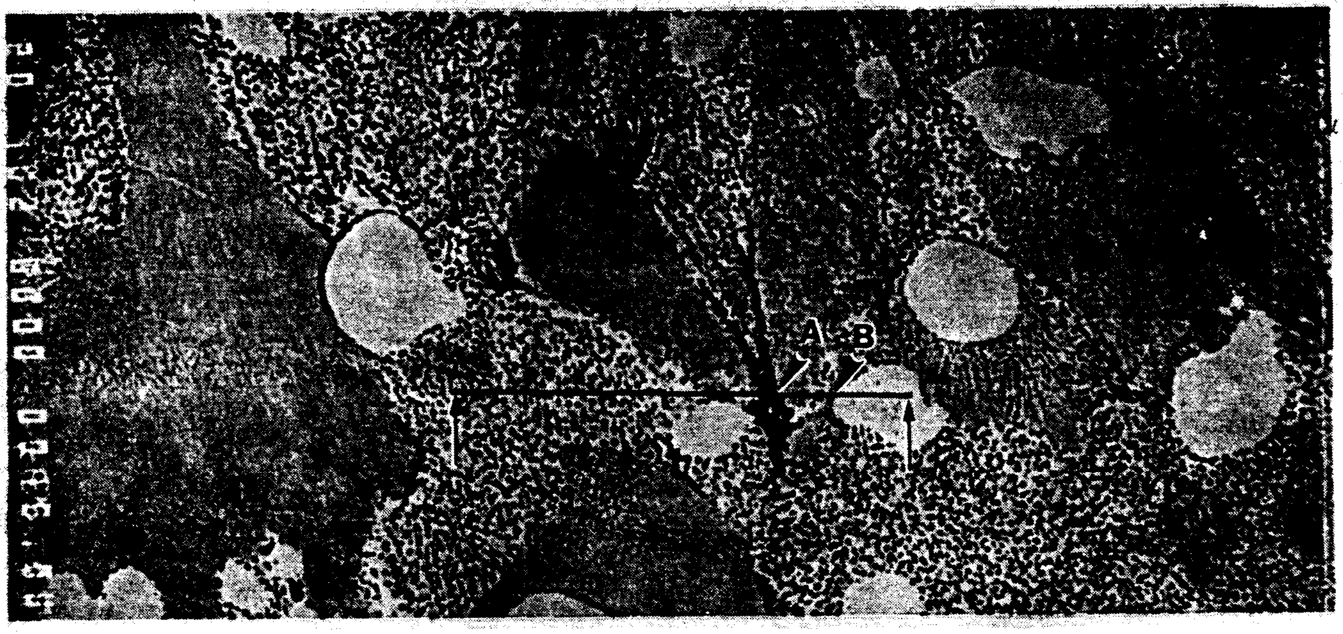
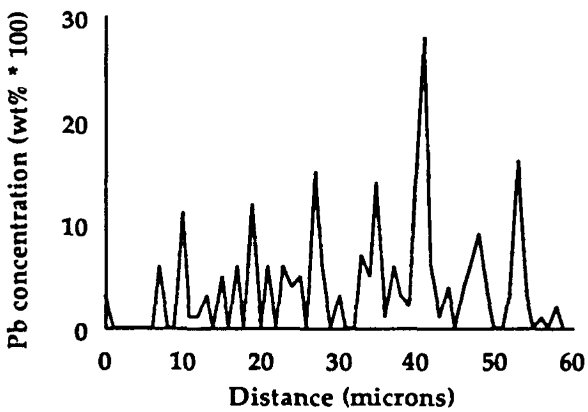


Figure 10. Polished Galfan surface (SEM) and associated Pb concentration profile. The line superimposed on the micrograph represents the path of EPMA analysis. (A=triple point; B=primary Zn dendrite)



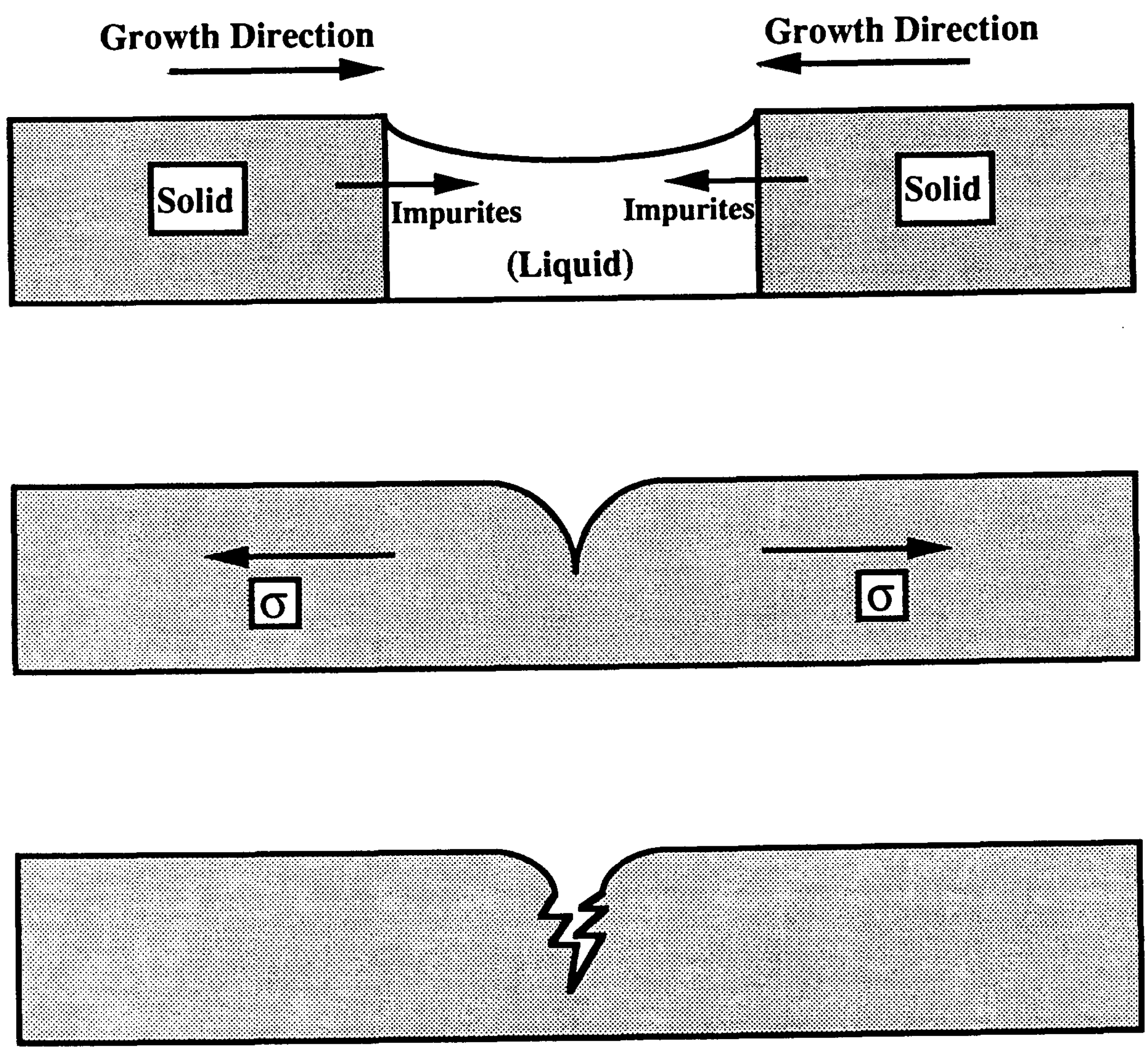


Figure 11. Schematic illustration of the proposed denting/cracking mechanism

GALFAN®'S EFFICIENT GALVANIC ACTION PROVIDES CORROSION PROTECTION

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GALFAN®'S EFFICIENT GALVANIC ACTION PROVIDES EXCELLENT CORROSION PROTECTION

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ABSTRACT

Starting from the knowledge and experience that zinc coatings offer a very good cathodic protection to steel, all recent data confirm that Galfan improves this. Results of electrochemical and metallographic research are very helpful to understand the corrosion protection of the eutectic Zinc-Aluminium coating on steel substrate (sheet, tube or wire).

INTRODUCTION

The excellent corrosion resistance performance of Galfan as a coating on steel substrates has been confirmed up to now, not only in laboratory corrosion tests, but also in field atmospheric environments in recent years.

The first goal of this paper is to update some recent corrosion test data on wires and wire products. However, the most important objective is to contribute to the understanding of the mechanism, whereby the addition of 5 percent (in weight) of Aluminium to the bulk of Zinc can ameliorate the corrosion protection by a factor 2 to 3 and can assure a more efficient galvanic protection to steel.

In line with the argued corrosion mechanism it makes us also understand how greases or analogous after-treatments on all galvanized objects (including Galfan) can hinder the galvanic protection and thus accelerate the rust formation of the steel substrates.

UPDATED CORROSION TEST RESULTS ON WIRES AND WIRE PRODUCTS

LABORATORY CORROSION TESTS

1. Salt spray test

The salt spray test is recognised as the most appropriate test for evaluating the expected corrosion protection of a coating. As a matter of fact, the accelerated corrosion action by salt water in this test cannot exactly represent the more complicated corrosion behaviour in real atmospheric conditions. However, when comparing different coatings as Zinc and its alloys, this rapid test can be very helpful to evaluate and to classify the resistance of one coating like Galfan versus an other coating like Zinc.

Test conditions :

- ASTM B 117 - DIN SS 50021.
- Conditions :
  - 100 % relative humidity
  - 35° C
  - 5 % NaCl (Sodiumchloride)
- Control : every 24 hours
- End of the test at 5 % red dust.

2. Kesternich test

The Kesternich test is based on the very corrosive action of SO_2. This test is oriented towards industrial environment applications.

Test conditions :

- DIN 50018 SFW 1,0 S.
- Conditions : 1 cycle
  - 8 hours
    - 40° C
    - 100 % relative humidity
    - 1 l SO_2 addition
  - 16 hours
    - Room temperature (18 - 28° C)
    - No SO_2 addition
    - Max. 75 % relative humidity
    - Complete water rinsing of the test room.
- End of the test at 5 % red rust.

3. Alternative immersion/emersion test in sea water

This test has been initiated for the investigations we have been following up regarding the corrosion action on fishing ropes in sea water. The test conditions are close to real application conditions, so that the observed phenomena and trends can be used to estimate the life expectation of fishing ropes, lobster trap cages or off-shore cables.

Test conditions :

- Composition of the sea water (DIN 50917) :

- NaCl	28 g/l
- $MgSO_4$ - 7 H_2O	7 g/l
- $MgCl_2$ - 6 H_2O	5
- $CaCl_2$	1,22
- $NaHCO_3$	0,2

- Daily cycle of immersion and emersion of the samples : 17 hours immersed
  2 hours emersed
  3 hours immersed
  2 hours emersed.

- End of the test at 5 % red rust.

CORROSION RESULTS FROM LABORATORY TESTS AND FROM OUTDOOR EXPOSURE

* Galfan coated and galvanized welded mesh products, as well for security fencing as for highway fencing, have been compared in their corrosion resistivity in the salt spray test and in the Kesternich test. (See tables 1 and 2).
  The comparative results are very much in favour of the Galfan coated samples, more so when taking into account the relatively lower coating weights for Galfan. A very positive aspect of the galvanic protection efficiency of Galfan is the rust prevention during the test, especially in the welded zones where the coating has visually disappeared.

* Galfan coated fishing ropes - as well finished products as strands or half-product wires - are resisting about 3 times longer than the corresponding galvanized samples. (Table 3).
  When the ropes or strands were greased, rust formation was observed earlier, both for the galvanized and for the Galfan coated strands. (See table 4 and fig. 1).

* From outdoor exposure follow-ups in real application conditions three different cases (tables 5, 6 and 7 and fig. 2 and 3) demonstrate very conclusively that Galfan is performing very well and can resist rust formation much longer than Zinc.

MECHANISM OF GALFAN'S EXCELLENT CORROSION PROTECTION

Electrochemical and metallographic research in combination with comparative corrosion tests on galvanized and Galfan coated steel wires have resulted in the following consecutive interpretation steps for the outstanding performance of Galfan coating as corrosion protection.

1st statement

The most effective corrosion resistance for a binary Zinc-Aluminium layer is reached when the alloy solidifies into a very fine eutectic structure without secondary phases or precipitates in the grain boundaries.
In fig. 4 and 5 the micrographic prints of Galfan can be compared with a zinc coating as shown in fig. 6.
It is important to focus attention on the fine eutectic microstructure of the Galfan coating. This microstructure consists of Al-rich and Zn-rich lamellae.

2nd statement

Aluminium and Oxygen surface enrichment are identified with the Scanning Auger Microprobe technique by analysing while sputtering the constituents into the bulk of a Galfan coating. See fig. 7.
The grey patina appearing very soon after some ageing time of the hot dipped coating is the hydratation and carbonation product of this Aluminium-rich outer surface film[1][2].

<u>3rd statement</u>

a) The difference in electrochemical corrosion behaviour between Zinc and Galfan is very spectacular. While Zinc and Galfan are measured in sea water with flushed oxygen on a quasi equal electropotential level (fig. 8), the gap in the current density between both protection layers during corrosion action (fig. 9) is representative for the much longer life expectation with Galfan as a coating.

b) When quantifying the coating weight loss in function of time interval during the salt spray test, a linear relationship is typical for Zinc while a parabolic path is typical for Galfan. See fig. 10.

c) Scanning Auger Microprobe analysis, this time on a corroded Galfan coated sample, shows the enrichment of Aluminium in the outer zone of the coating. See fig. 11.
This Aluminium enrichment is essential for understanding the decelerating corrosion shown in fig. 10.

4th statement

The most striking difference between Galfan and Zinc in corrosion behaviour, as well in laboratory corrosion tests as in atmospheric corrosion, is the residual coating thickness left on the steel substrate at the moment that red rust is detected. (See tables 6, 7 and especially 8).

With zinc coatings rusting occurs at a residual coating thickness of 15 to 20 μm. With similar Galfan coatings rusting occurs at a residual coating thickness of only 3 to 4 μm, that is when the Zinc-Aluminium outer layer is nearly completely consumed and only the intermetallic Zinc-Aluminium-Iron layer is left. (See table 8).

An explanation for these facts and figures has to be related with the more noble potential level of the intermetallic phase versus the less noble and thus more sacrificially corroding eutectic Galfan coating itself[3]. For galvanized wires, the similar galvanic potential difference between the Iron-Zinc alloy layers and the pure Zinc outer layer is much smaller, so that for galvanized products the corrosion can break through straight away towards the substrate.

Notwithstanding its lower thickness and its more noble electropotential, the galvanic protection of the Aluminium-Zinc-Iron interalloy layer continues to act as a real corrosion barrier for the underlying steel, since no rust at all is initiated earlier at the welds in welded mesh fabricated from "precoated" wires[4]. The high electric conductivity of Aluminium may be very helpful in this protective action.

5th statement

When cabling fishing ropes grease is applied. This grease film will not remain uniformly distributed over the surface of the filaments during the working conditions of a fishing rope. The corrosion action will therefore be dramatically accelerated at the ungreased spots. These spots will behave in a less noble way than large areas of the rope surface with grease. The unfavourable galvanic action along the rope surface will be superimposed on the normal corrosion behaviour described in the previous statements.

Potentiostatic analysis on greased versus non-greased fishing rope samples illustrates the pronounced difference in corrosion potential between both. (See fig. 12). The observation of earlier rust formation in salt spray and in sea water on greased galvanized as well as on greased Galfan coated samples (table 4 and fig. 1) was considered rather suspicious at an earlier stage. ("Sulphur contamination" was considered as "the weapon of crime"). With additional electrochemical research the unfavourable effect of grease on the corrosion protection can now be better understood. As far as the involved industrial applications are concerned, our observations and approach will contribute to adequate modifications.

CONCLUSIONS

In a more and more agressive atmospheric or industrial environment, Galfan coatings are demonstrating better corrosion protection efficiency than Zinc.

Trying to understand the corrosion phenomenon and the mechanism of protection is giving the best guarantee for continuous progress in product optimization.

REFERENCES

Ref. 1 The Nature of the Grey Patina on Galfan.
J. Lamesch, 2nd Galfan Meeting 1983.

Ref. 2 Dark Grey Patina developed on Galfan coated Steel Sheet.
Y. Hirose, 6th Galfan Meeting 1985.

Ref. 3 A New Generation of Corrosion Protective Coating.
M. Dewitte, A.P. Van Peteghem, E. Wettinck,
Wire Journal May 1990, pp. 30 - 40.

Ref. 4 A Corrosion Resistance Study of Post-welded Bezinal® (Galfan®) Coated Wires.
M. Dewitte, P. Lippens.
17th Galfan Licensee Meeting 1992.
Bibl. - New Galfan Technical Papers 92 - 006 - 16 pp.

Welded mesh as Security Fencing

1/2 " x 3" - 4mm wire diameter

	(After-) Galvanized	(Pre-) Bezinalized
Coating weight	543 g/m²	265 g/m²
Salt spray test (NaCl): Number of hours to 5% red rust	360 hours	768 hours
Kesternich test (SO_2): Number of cycles to 5% red rust	15 cycles	24 cycles

Table 1

Welded Mesh as Highway Fencing

2 " x 4" - 2,45mm wire diameter

	(After-) Galvanized	(Pre-) Bezinalized
Coating weight	355 g/m²	280 g/m²
Salt spray test (NaCl): Number of hours to 5% red rust	432 hours	> 1.100 hours
Kesternich test (SO_2): Number of cycles to 5% red rust	20 cycles	46 cycles

Table 2

Fishing Ropes - Strands - Wires

	Coating	Coating weight g/m²	Salt spray test resistance (in hrs) 5% red rust
1	Ropes: construction: core fabric cord + 6 x 7		
	Zinc	140 g/m²	216
	Bezinal	130 g/m²	1.272
2	Strands: 7 x 1		
	Zinc	167 g/m²	456
	Bezinal	150 g/m²	1.248
3	Strand Wire (before redrawing)		
	Zinc	410 - 436 g/m²	504
	Bezinal	420 - 434 g/m²	1.272

Table 3

Alternative immersion/emersion test in sea water

7 x 1 strand

Zinc: 230 g/m² no grease 5% rust after 453 days	Bezinal: 108 g/m² no grease 5% rust after > 558 days
Zinc: 230 g/m² grease 5% rust after 208 days	Bezinal: 108 g/m² grease 5% rust after 296 days

Table 4

Ursus as Highwway Fencing in Outdoor Exposure

6 year Atmospheric Corrosion at Ravensburg in Germany

- **240 g/m^2 residual coating weight left i.e. 75% of the original coating weight**
- **grey black patina but very smooth surface.**

Table 5

Motto

Outdoor exposure at the Belgian coast ('t Zwin Knokke)
6 year marine atmospheric corrosion

- **Bezinal coated samples** : Homogeneous dark patina
- **Galvanised samples** : Rust on many spots and extra rough tarnish surface.

		Residual Coating weight (g/m^2)					
Follow up Time (start in 1986)		17.11.87	16.12.88	05.12.89	12.12.90	12.12.91	12.12.92
Zinc	Line wire	282	263-274	151-330	87-216	48-146	25-72
	Barb wire	341	327-334	316-330	203-229	87-130	105-106
Bezinal	Line wire	228	229-231	227-232	153-170	139-158	141-152
	Barb wire	248	233-250	231-271	164	131-145	136-141

Table 6

In situ Exposure at Van Den Bergh, mink farm, Holland

Initial coating weight : **Zinc** : ± 300 g/m^2 (galvanized on welded mesh)
Bezinal : ± 280 g/m^2 (pre-Bezinal coating on wire and welded afterwards)

Results after 4 years of exposure at the mink netting farm:

	Zinc (g/m^2)	Bezinal (g/m^2)
Line Wire	39 - 0 - 108	132 - 148 - 122
Cross wire	0 - 13 - 9	108 - 135 - 135

Comments : The galvanized panel samples demonstrate 100% rust. The Bezinal panel samples are in good shape (dark, but smooth and clean).

Table 7

Residual coating thicknesses on salt spray test samples

Sample	Initial intermetallic layer in µm	Initial total layer in µm	Residual coating in µm
Low Carbon Wire			
Bezinal Coating	4 - 5	51 - 60	3
Zinc Coating	8 - 10	41 - 62	15
High Carbon Wire			
Bezinal Coating	4 - 5	44 - 48	4
Zinc Coating	6 - 10	64 - 78	20

Table 8

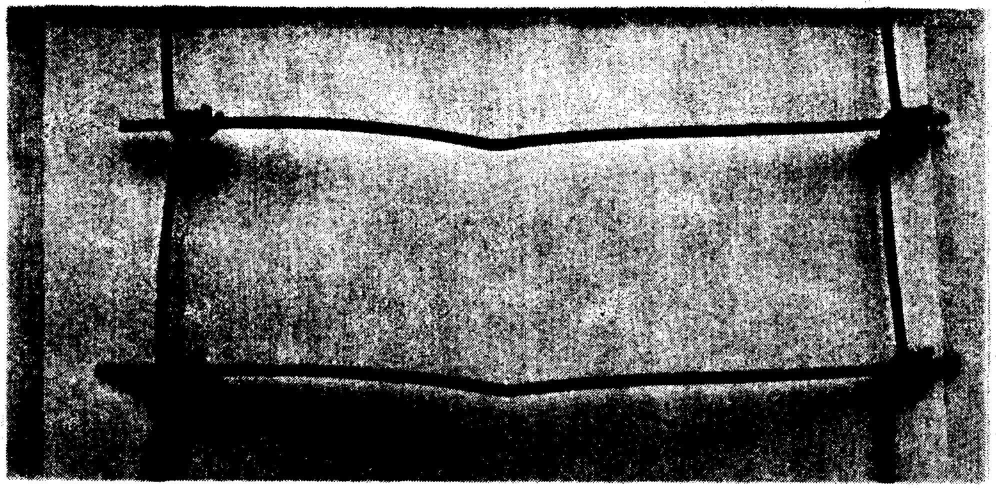

Fig.2 BEZINAL (GALFAN) coated fencing
6 Year outdoor exposure.

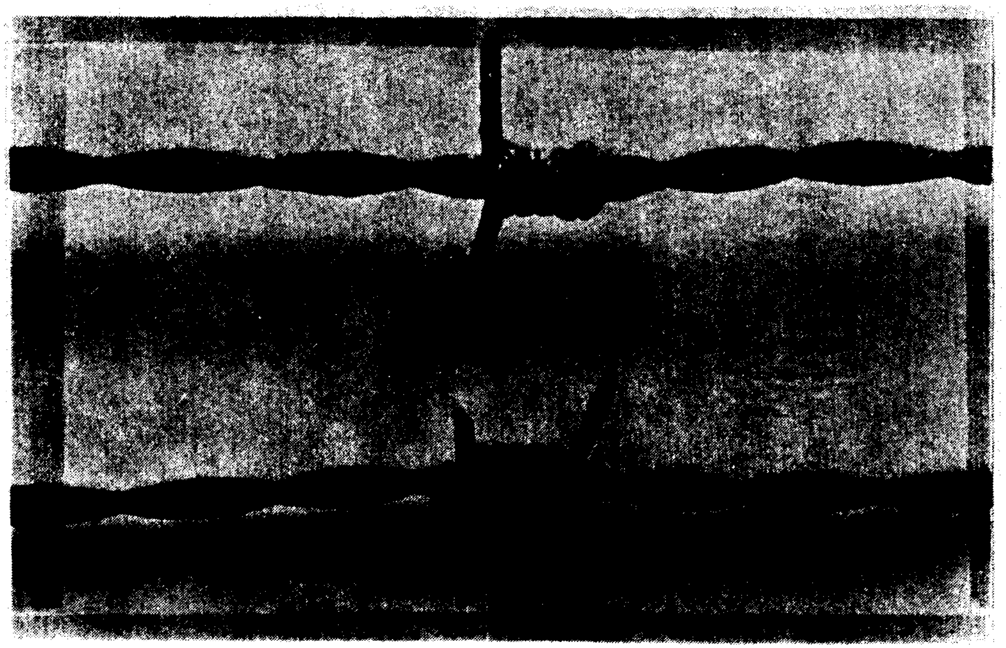

Fig.3 ZINC and BEZINAL (GALFAN) coated barbed wire
6 Year marine atmosphere corrosion.

Fig.1 ZINC and BEZINAL (GALFAN) coated wires
after 1416 hours Salt Spray

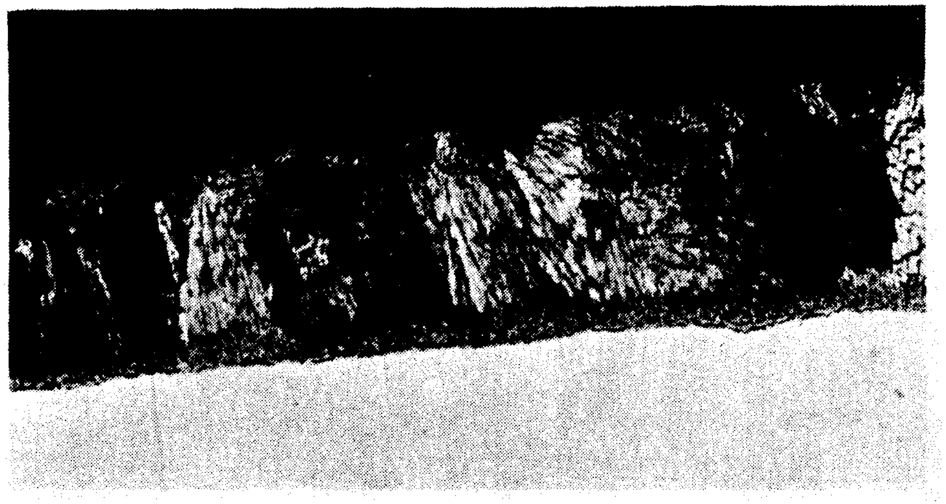

Fig.4 BEZINAL (GALFAN) coating.

Fig.5 EUTECTIC structure of BEZINAL (GALFAN) with corrosion front.

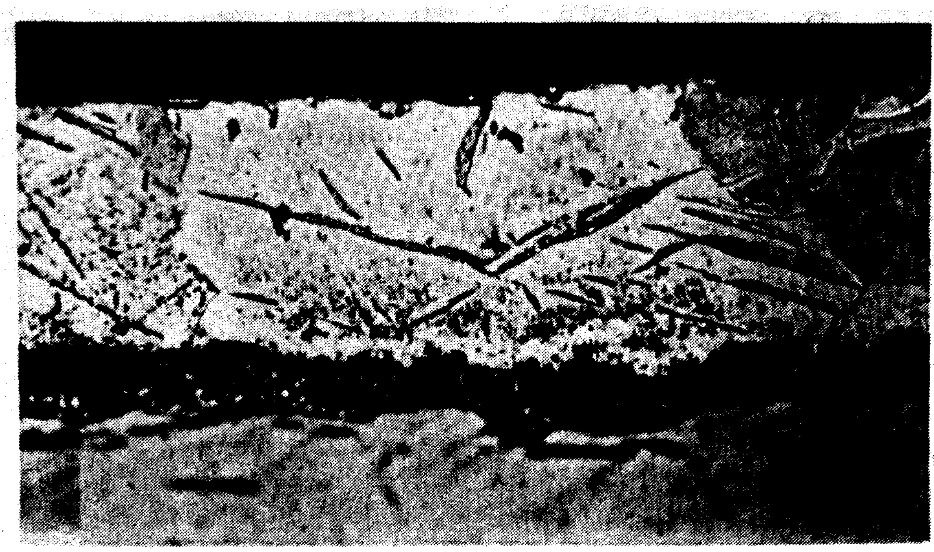

Fig.6 ZINC coating

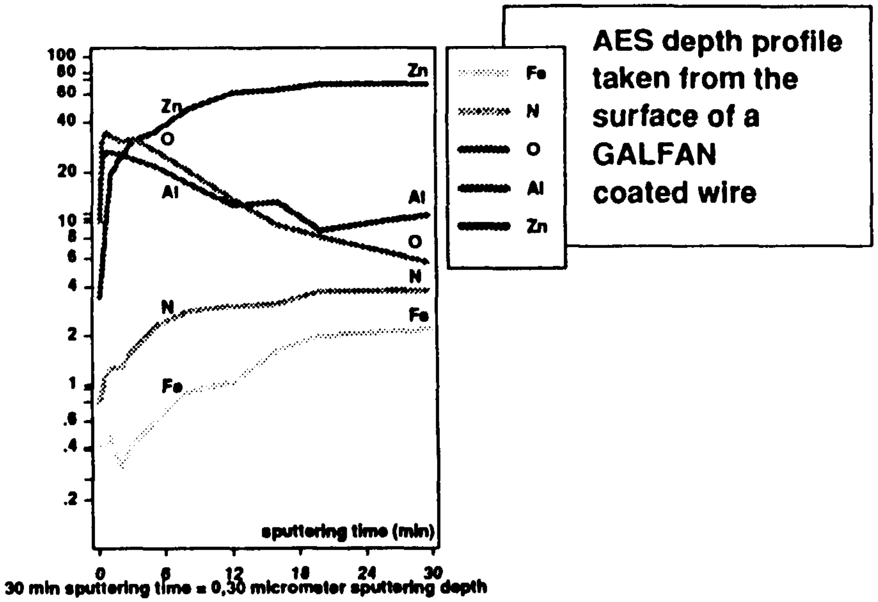

Fig 7

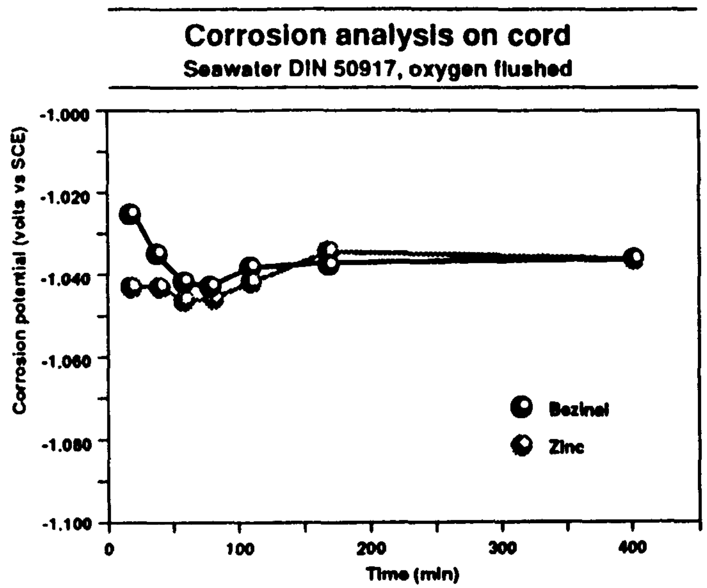

Fig 8

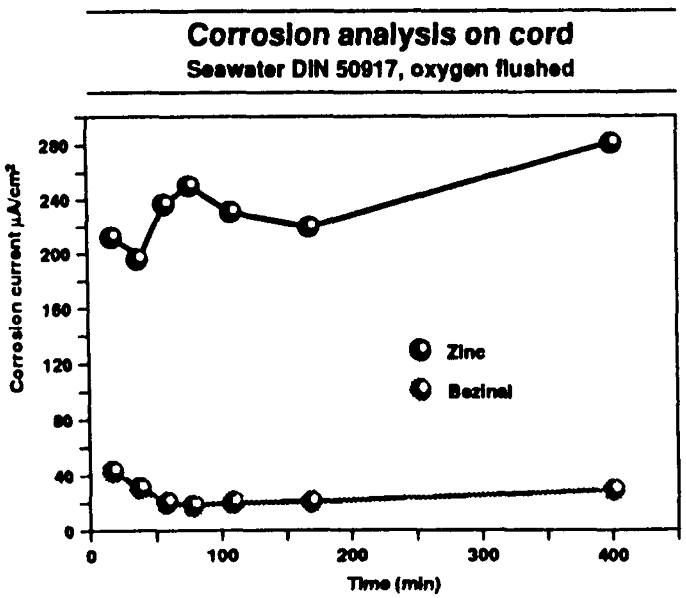

Fig 9

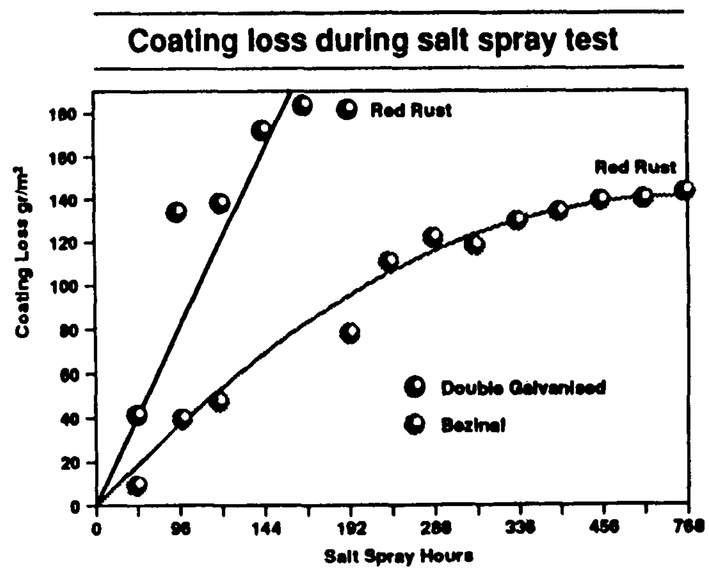

Fig 10

Al enrichment in the outer layers of a corroded Bezinal surface

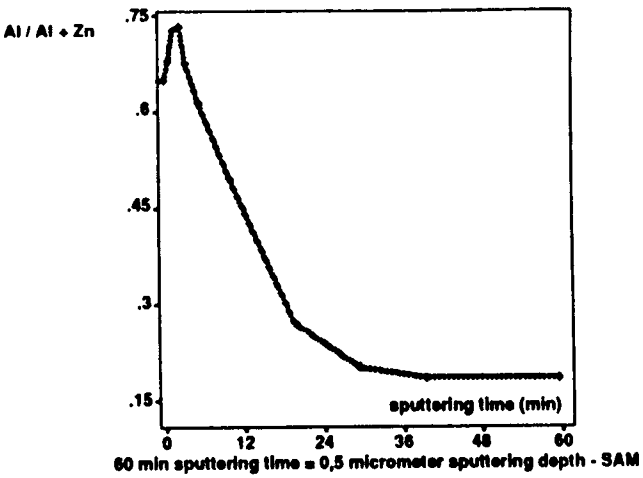

Fig 11

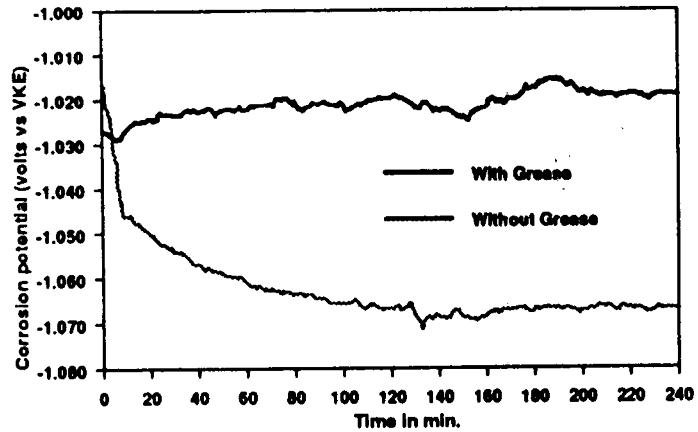

Fig 12

Comparison of Resistance Welding Characteristics: Galfan® vs. Electrogalvanized Steel

by

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ABSTRACT

This paper compares the resistance welding characteristics of Galfan® coated steel with Electrogalvanized steel. Weldability lobes were developed using standard Cu-Cr electrodes and two types of GlidCop® Dispersion Strengthened Copper electrodes. Sticking of the electrodes to the workpiece is a major problem when welding coated steels. Therefore, sticking behavior of the three electrode materials against the two steels was studied. Sticking data on hot dip galvanized steel was also developed. The GlidCop electrodes have superior resistance to sticking compared to Cu-Cr electrodes. Additionally, they have a wider weldability lobe which provides a much wider "window" for trouble-free welding without sticking. The weld lives showed some variability, but overall, the GlidCop electrodes showed longer life on Galfan and electrogalvanized steels.

INTRODUCTION

Resistance welding is the primary process used to assemble automobile body components because of its versatility and low cost. It lends itself well to automation and can tolerate more imprecise fits between the components to be welded than most other joining processes.

Use of zinc and zinc alloy coated steels for corrosion protection has been increasing worldwide over the past 15 years. Almost simultaneously, the automobile industry has been using more and more automation - robots, press welders, automatic welding controllers, etc. In the early days, welding of zinc coated steels was plagued with serious problems. The Cu-Cr welding electrodes predominantly used at that time had a tendency to stick to the zinc coated steels and pull off their adaptors. This required stoppage of the automated assembly lines for electrode replacement which seriously affected the productivity and increased the cost. Development of a new electrode material called GlidCop^{R}, an aluminum oxide particle dispersion strengthened copper which does not stick to zinc coated steel, problem. Another problem in welding zinc coated steels is much reduced electrode life compared to uncoated steel. The zinc alloys with the copper from the electrode and causes more rapid mushrooming, pitting, cracking, etc., and thus shortens electrode life.

Resistance weldability is one of the major selection criteria used by the automobile industry to qualify steels that can be used in cars and trucks. Weldability determination in this study included welding parameters required to produce a desired weld nugget size, electrode life and sticking behavior with commercially available welding electrodes. This paper compares the weldability of a Galfan coated steel with an electrogalvanized steel commonly used in automobile industry. The sticking data was also developed on a common hot dip galvanized steel. Cu-Cr and two types of GlidCop dispersion strengthened copper electrodes were used in this study.

TEST EQUIPMENT AND MATERIALS

The welding tests were done on a dual gun 2 x 70 KVA Taylor Winfield spot welder. Each gun is fired by an independent transformer and controlled by a separate Pertron ELF 2300 constant current programmable controller. Steel strips to be welded are fed to the welding guns by means of an air actuated hitch feed system capable of advancing the strips up to 50 times per minute. All tests were done in a single gun mode to simulate conditions described in the test standards used.

The steels used in this study were: 1) Weirkote Plus® Galfan®, hot dip Zn-5% Al/Mischmetal alloy coated .9 mm (.036") thick low carbon steel, AKDQ, GF-45, produced by Weirton Steel Corporation, and 2) Electrogalvanized (Zn) .8 mm (.032") thick low carbon steel, AKDQ, 70G70G, produced by National Steel Corporation. The sticking test was also done on hot dip galvanized (Zn) .94 mm (.037") thick low carbon steel, AKDQ, G-60, produced by National Steel Corporation.

The electrode materials tested were Cu-Cr RWMA Class 2, GlidCop AL-60 Class 20, and GlidCop AL-25. The electrodes were 16 mm (5/8") diameter female caps with a 45° truncated cone design similar to RWMA E nose. The weld face was flat and 6.4 mm (.25") in diameter.

PROCEDURES

1. Weldability Lobes

   Weldability lobe is the region on a weld current vs. weld time plot confined by two lines - see Figure-1. The lower end of the region is defined by a line which shows the currents required at different weld times to produce a weld nugget of a desired minimum size. The upper end of the region is defined by a line which shows the currents at different weld times where expulsion of liquid metal from the weld takes place. The best welding is done at conditions within this weldability lobe.

A weldability lobe was developed for each combination of steel and electrode material. For this test, the lobe width at 11 cycle weld time was determined rather than the entire lobe - see Figure-1. For each test, a new pair of electrodes was installed on the gun adaptor and the two electrodes were aligned and checked by means of carbon paper imprints. All steel strips were wiped with a dry cloth prior to welding to remove any excess oil or loose contaminants.

Welding test parameters, except for weld current, were held constant as shown in Table-1. The test was started at a weld current where no nugget formed; three hits were made at this level. The current was increased by 500 amps and three more hits were made. This was continued until a current level was reached where expulsion of liquid metal from the weld zone occurred. The welds at each current level were peeled and the weld nugget dimensions in directions longitudinal and transverse to the strip length were measured. The peel nugget diameters were calculated as the averages of these two dimensions. The lobe width was determined as the difference between the current required to produce a minimum nugget diameter of 5.6 mm (.22") and the current at which expulsion occurred.

2. <u>Electrode Life</u>

A constant current life test similar to Ford specification BA13-1 was used. The exceptions were electrode style (female vs. male caps) and weld face diameters [6.4 mm (.25") instead of 4.6 mm (.18")]. Steel strips 100 mm (4") wide x 2.4 m (8') long were used instead of 100 mm (4") x 300 mm (12") panels described in the Ford test.

From the weldability lobe experiments above, the weld current for a starting nugget size of 6.4 mm (.25") was selected. Peel tests were made on about the tenth weld of each test to verify the nuggets met a minimum 6.4 mm (.25") diameter. Once set-up size was confirmed, weld current was held constant throughout each test unless expulsion occurred after the electrode break-in period. In such cases the weld current was adjusted to eliminate expulsion. Peel tests were done at 250 weld intervals and the nugget sizes were measured. Carbon paper imprints of the electrode weld faces were also taken at each interval. This procedure was continued until the weld nugget size fell below the 5.6 mm (.22") minimum diameter. The electrode life was defined as the last 250 weld test point that produced satisfactory nuggets prior to the 250 weld increment that failed to meet the minimum weld nugget diameter.

3. Sticking Behavior

A test similar to the anti-sticking test described in the General Motors specification MDS-487 was used to compare the sticking behavior of the three types of electrodes on electrogalvanized, hot dip galvanized and Galfan steels described previously. The exceptions included electrode nose design (truncated "E" instead of pointed "A") and use of 100 mm (4") wide x 2.4 m (8') long steel strips instead of 25 mm (1") wide x 1.8 m (6') long strips.

The test parameters, except for the weld current, are shown in Table-2. The test electrodes were installed on appropriate adaptors and aligned. A carbon paper imprint of the electrode face was taken at the beginning of the test - it must show the full 6.4 mm (.25") electrode face diameter.

The weld current was increased in a stepwise fashion as shown in Table-3. The test was terminated after 150 welds or when the electrode stuck to the steel such that it pulled away from the adaptor or caused the strip feeder to jam. Two rows of welds, symmetrically placed [36 mm (1.4") apart], were made in this test. Four sets of tests were done on electrogalvanized and hot dip galvanized steels, but only two sets were on Galfan coated steel as the batch of material received for these tests ran out.

RESULTS AND DISCUSSION

1. Weldability Lobes

The weldability lobe data at 11 cycle weld time are shown in Table-4. For individual electrode materials the Galfan coated steel had lobes very similar to the lobes for electrogalvanized steel. Not only were the current levels similar, but the lobe widths were also similar.

Some differences were observed between electrode materials. For example, the lobe widths for the two types of GlidCop electrodes (AL-60 and AL-25) on both Galfan and electrogalvanized steels were wider (1000 amps) than the lobe widths for Cu-Cr electrodes (500 amps). This gives a little more latitude in selecting the welding current with GlidCop electrodes. A good welding practice should avoid expulsion because expulsion of liquid metal from the weld zone depletes the weld, thus reducing the nugget size and producing a weaker weld. Therefore, a current within the lobe width is recommended.

The lobe for GlidCop AL-25 was at a slightly higher welding current level than for AL-60 and Cu-Cr electrodes on both Galfan and electrogalvanized steels. This may be due to the higher conductivity of AL-25 and perhaps lower contact resistance between AL-25 and the steel which causes less heat generation at the surface and more heat has to be generated at the faying surface by using a higher weld current.

2. Electrode Life

The electrode life data from these tests are shown in Figures 2 and 3 and summarized in Table-5. Life tests generally show some inconsistencies, but overall, Galfan and electrogalvanized steel gave similar electrode lives.

Comparing the performance of the electrode materials, the two types of GlidCop electrodes gave somewhat longer life than Cu-Cr electrodes on both steels. The Cu-Cr electrodes produced identical number of welds (1250) on both steels. GlidCop AL-60 performed slightly better on electrogalvanized steel while AL-25 performed slightly better on Galfan. However, considering the normal variability observed in electrode life tests, the differences noted here are not to be construed as very significant. In earlier work it was found that the electrode shape had a more significant effect on electrode life than either the electrode material or the steel. Truncated cone design used in these tests generally showed longer electrode life than the other common RWMA designs used.

A look at the starting current and final current values in Table-5 shows that on electrogalvanized steel the current had to be lowered on all three electrode materials to avoid expulsion. Both GlidCop electrodes required a greater current adjustment than Cu-Cr electrodes. No such current adjustments were required on Galfan. It appears that the electrodes are "broken-in" and stabilized more quickly on Galfan than on electrogalvanized steel. This may have to do with the aluminum in the Galfan coating which also diffuses into the copper along with the zinc; thus conditioning the electrode quicker.

3. Sticking Behavior

The sticking data are presented in Figures-4, 5 and 6 and summarized in Table-6. The currents at which heavy sticking occurred (as defined previously) with the three electrode types are shown for each steel. The asterisk (*) indicates that the particular pair did not stick at the maximum current level of 19.5 K Amps used in these tests.

On all three steels GlidCop electrodes showed a clear superiority in sticking behavior over Cu-Cr electrodes. On Galfan and hot dip galvanized steels the GlidCop electrodes needed on average 3.5 to 5.0 K Amps higher current than Cu-Cr electrodes and many electrodes did not stick at all. On electrogalvanized steel the differences were less (1.5 to 2.5 K Amps). The reasons for this superiority are related to the nature of the Al_2O_3 particle dispersion in GlidCop. These include: 1) The particle size of Al_2O_3 in GlidCop is much finer (6 nm average) than the Cr particles in Cu-Cr electrodes (100 nm average). At the volume levels of Al_2O_3 particles in GlidCop, this equates to much greater surface coverage by the second phase particles than in Cu-Cr. For example, AL-25 electrodes have about 20 times more surface coverage than Cu-Cr electrodes while AL-60 electrodes have about 45 times more surface coverage. 2) The liquid zinc does not wet or bond to Al_2O_3 particles, and therefore they provide sites for separation of the electrode from the steel during retraction. 3) The Al_2O_3 particles are thermally stable and do not grow in size when exposed to the high temperatures involved in welding. The Cr particles in Cu-Cr, on the other hand, grow due to overaging and thus lose their effectiveness.

The significance of the above sticking data is that in Cu-Cr electrodes the sticking currents are very close to the weldability lobes. This means that the welding must be done in a narrow "window" - see Figures-7 and 8. Even when the current is controlled within the lobe width there is enough variability in the steel and the Cu-Cr electrodes to cause sporadic sticking in the field. GlidCop electrodes provide a wide window for welding, and sticking is never a problem.

The test used here artificially raises the sticking currents because it starts at low current levels and gradually increases the current, thus giving the electrodes a chance to be "conditioned" and build a layer of oxide. The sticking currents on a fresh electrode would be much lower, and therefore, in reality the welding window is even narrower than shown in Figures-7 and 8.

GlidCop electrodes are widely used in the automobile industry to weld electrogalvanized and hot dip galvanized steels because of their superior sticking resistance. Their wide welding "window" allows considerable latitude in the welding parameters that can be used, i.e., they are more forgiving than Cu-Cr electrodes. The data presented in this paper shows that the same holds true in welding Galfan coated steel. Therefore, use of GlidCop electrodes should be recommended for welding this steel.

CONCLUSIONS

Following conclusions are drawn from this study:

1. Galfan coated steel can be welded under very similar conditions to those used to weld electrogalvanized steel. The weldability lobes for the two steels are very similar in terms of welding currents and the lobe widths.

2. GlidCop electrodes have wider lobe widths than Cu-Cr electrodes on both types of steel.

3. The electrode lives on Galfan coated steel are similar to those on electrogalvanized steel.

4. GlidCop electrodes gave longer electrode lives than Cu-Cr electrodes on both types of steel.

5. GlidCop electrodes have far superior sticking resistance than Cu-Cr electrodes on Galfan, electrogalvanized and hot dip galvanized steels. They provide a wider welding window which allows trouble free welding.

6. GlidCop electrodes should be recommended for welding Galfan coated steels.

Table-1

Weld Test Parameters

Weldability Lobe and Electrode Life Tests

Weld Force:	200 kgf	450 lbs.
Min. Nugget Dia.:	5.6 mm	.22 in.
Start Nugget Dia.:	6.4 mm	.25 in.
Weld Spacing, Centers:	38.1 mm	1.5 in.
Squeeze Time:	25 Cycles	
Weld Time:	11 Cycles	
Hold Time:	5 Cycles	
Off Time:	79 Cycles	
Weld Rate, Per Minute:	30 Welds	
Water Flow, Per Minute: at 75°F +/- 5°F	5.7 l	1.5 Gal.

Note: 60 cycle, single phase, AC current

Table-2

Weld Test Parameters

Sticking Behavior Test

Weld Force:	275 kgf	600 lbs.
Weld Spacing, Centers:	22 mm	.875 in.
Squeeze Time:	25 Cycles	
Weld Time:	15 Cycles	
Hold Time:	1 Cycle	
Off Time:	79 Cycles	
Weld Rate, Per Minute:	30 Welds	
Water Flow, Per Minute: at 75°F +/- 5°F	2 l	.5 Gal.

Note: 60 cycle, single phase, AC current

Table-3

Weld Current Schedule

Sticking Behavior Test

Weld Number	Weld Current
1-15	10.5-11.0
16-30	11.5-12.0
31-45	12.5-13.0
46-60	13.5-14.0
61-75	14.5-15.0
76-90	15.5-16.0
91-105	16.5-17.0
106-120	17.5-18.0
121-135	18.5-19.0
136-150	19.5-20.0

Table-4

Weldability Lobe Data

Steel	Electrode	Lobe Characteristics		
		Min. Nugget Current (K Amps)	Expulsion Current (K Amps)	Lobe Width (K Amps)
Galfan	GlidCop® AL-60	12.5	13.5	1.0
Galfan	GlidCop® AL-25	13.0	14.0	1.0
Galfan	Cu-Cr	12.5	13.0	0.5
EG	GlidCop® AL-60	12.5	13.5	1.0
EG	GlidCop® AL-25	13.5	14.5	1.0
EG	Cu-Cr	12.5	13.0	0.5

Table-5

Electrode Life Data

Steel	Electrode	Lobe Characteristics		
		Start Current (K Amps)	Final Current (K Amps)	Electrode Life (No. of Welds)
Galfan	GlidCop® AL-60	13.0	13.0	1500
Galfan	GlidCop® AL-25	13.0	13.0	2000
Galfan	Cu-Cr	12.2	12.2	1250
EG	GlidCop® AL-60	12.5	11.5	2000
EG	GlidCop® AL-25	14.0	12.5	1500
EG	Cu-Cr	12.5	12.3	1250

Table-6

Sticking Behavior Data

Steel	Electrode	Average Sticking Current (K Amps)
Galfan	GlidCop® AL-60	18.5*
Galfan	GlidCop® AL-25	19.5*
Galfan	Cu-Cr	15.0
EG	GlidCop® AL-60	17.5
EG	GlidCop® AL-25	16.5
EG	Cu-Cr	15.0
HDG	GlidCop® AL-60	19.5*
HDG	GlidCop® AL-25	18.3
HDG	Cu-Cr	14.5

Note: * Indicates one or more pairs did not stick at max. current of 19.5 K Amps.

Figure-1: Weldability Lobe

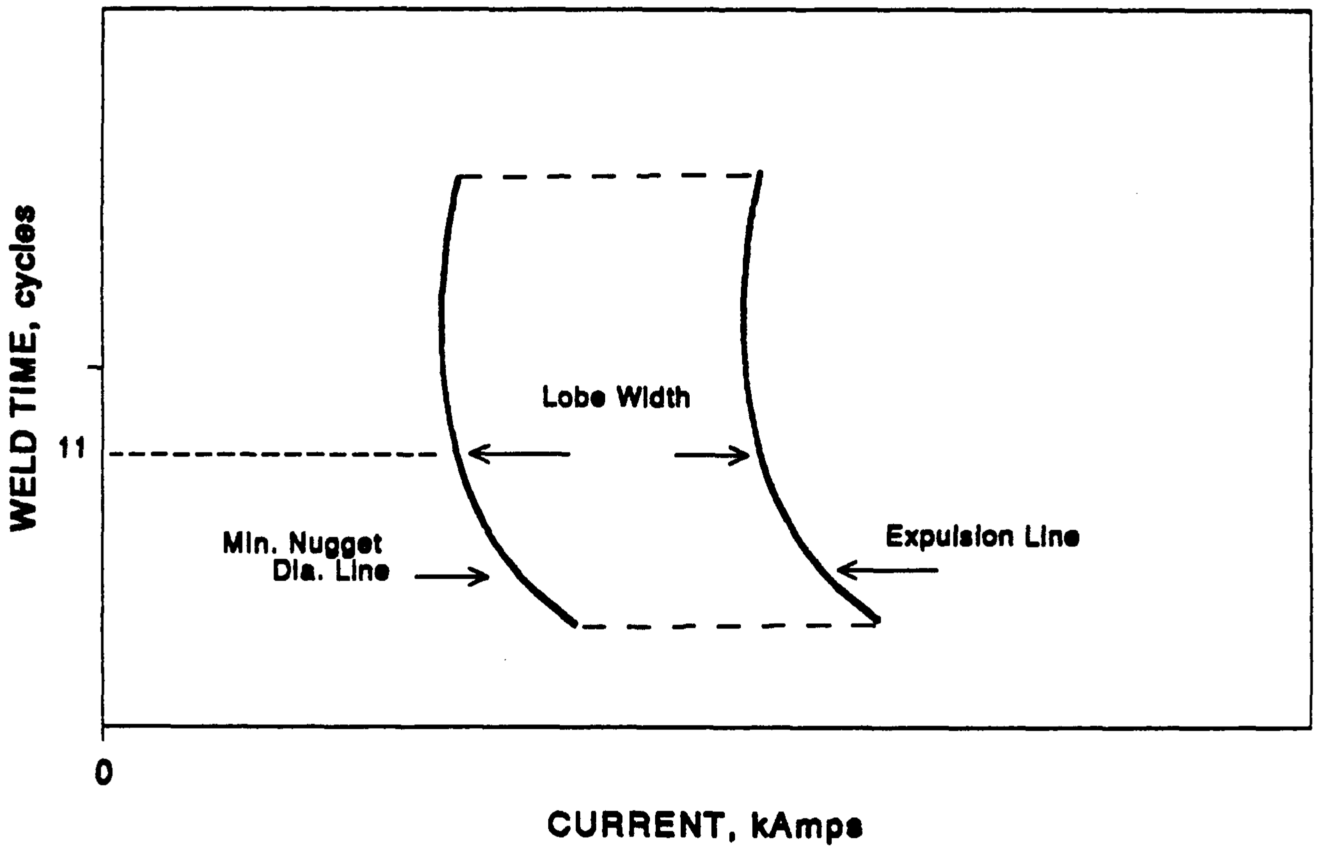


Figure-2: Electrode Life on Galfan Steel

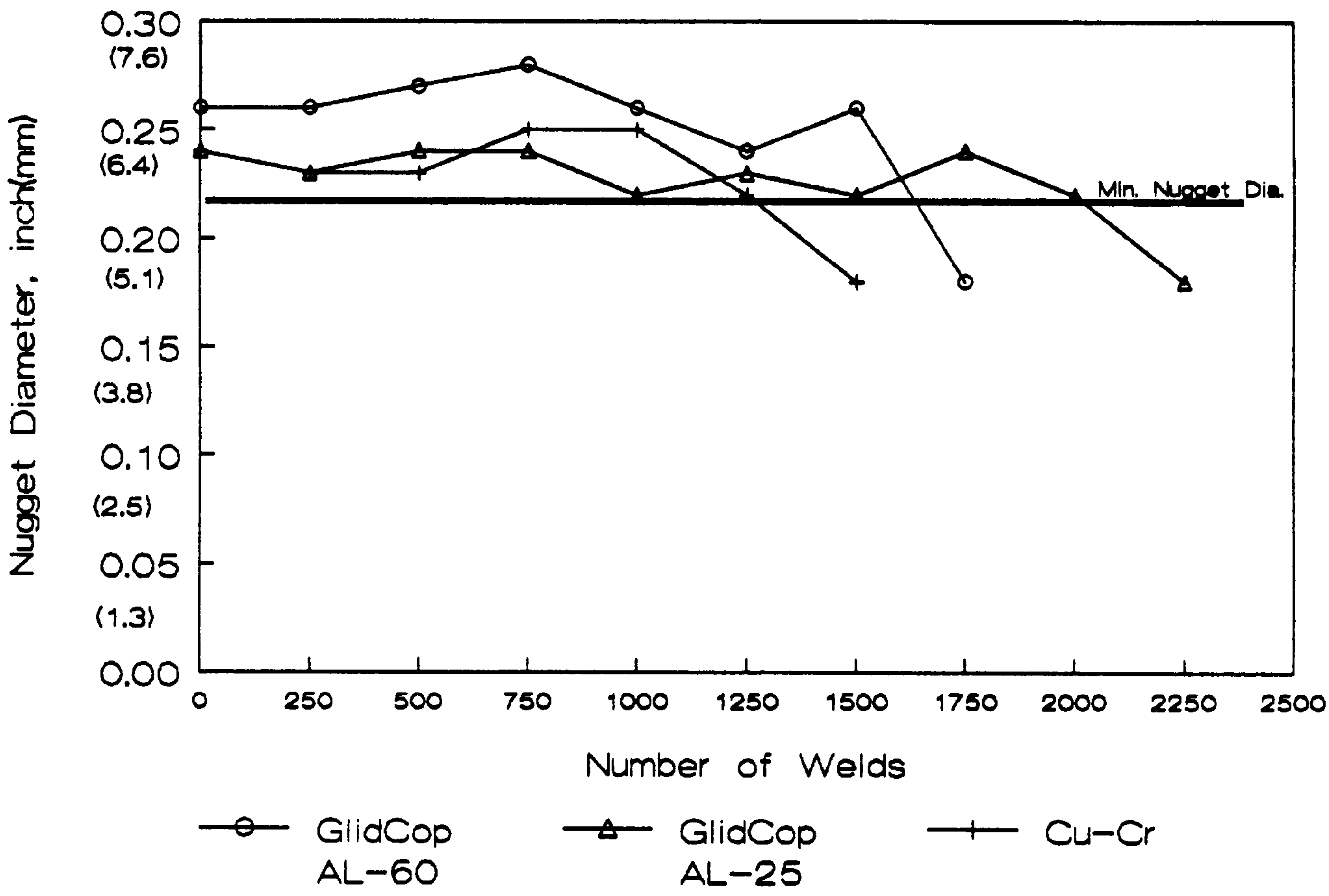


Figure-3: Electrode Life on Electrogalvanized Steel

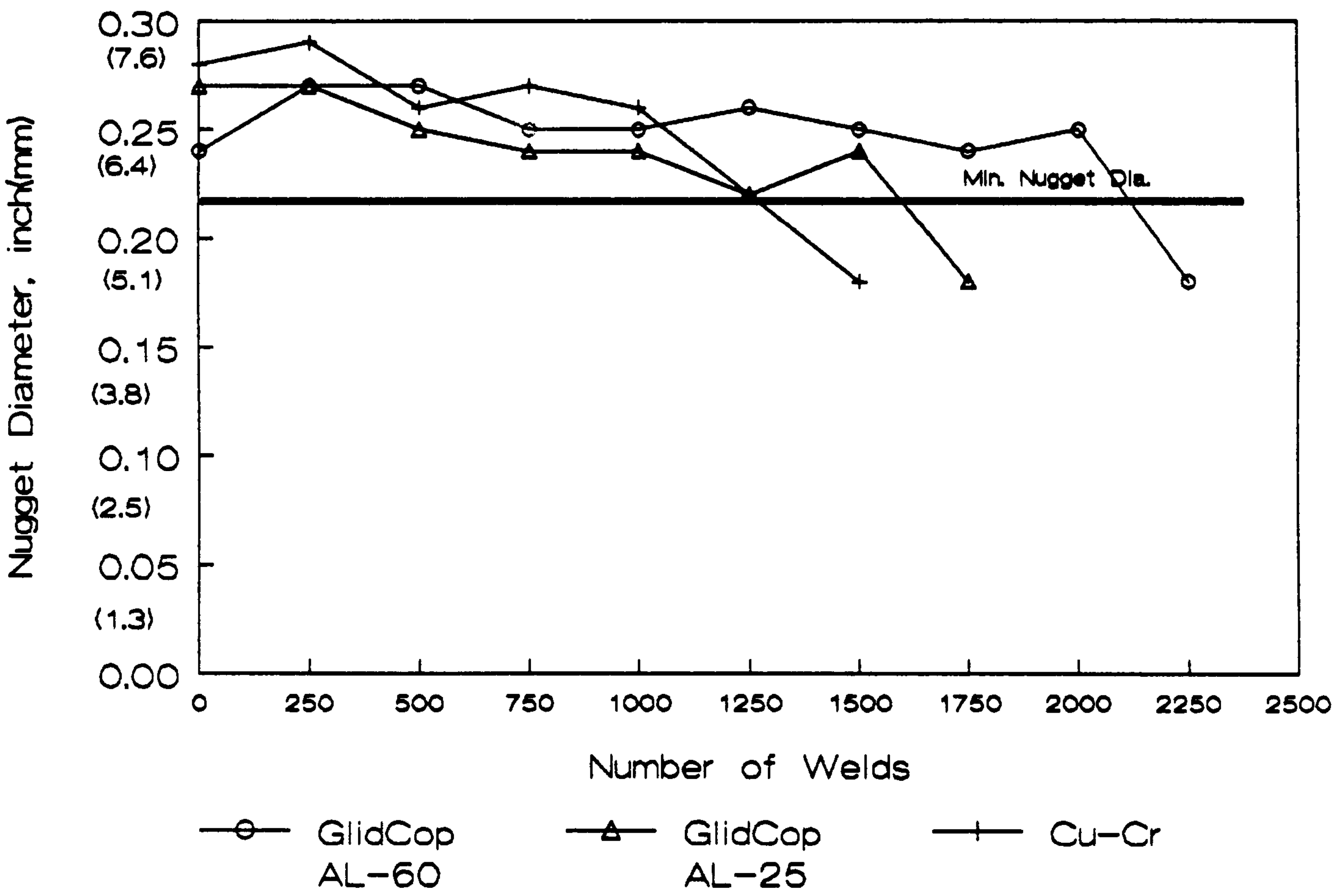
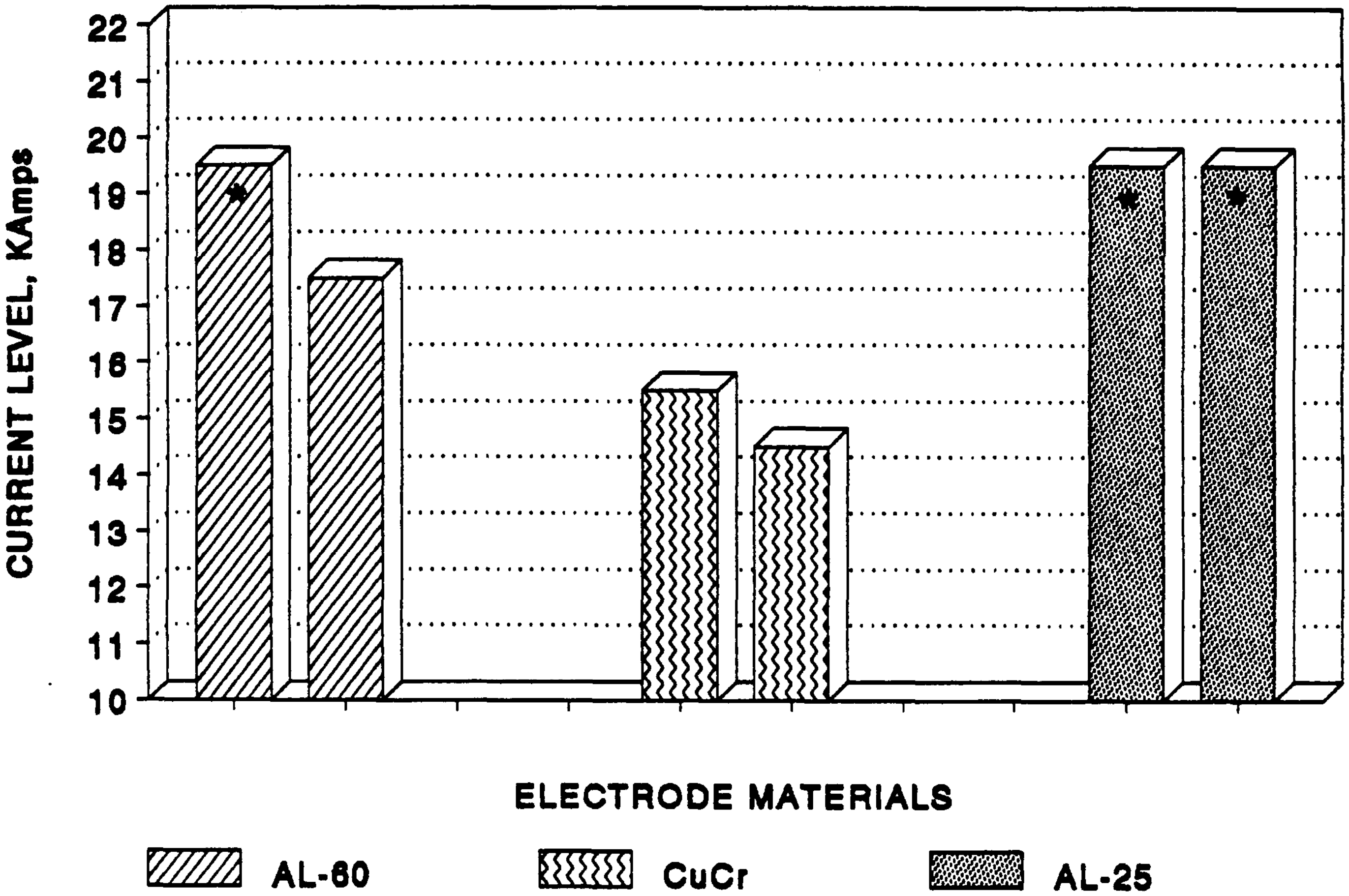


Figure-4: Sticking Behavior on Galfan Steel



* DIDN'T STICK TEST STOPPED 19.5 kAmps

Figure-5: Sticking Behavior on Electrogalvanized Steel

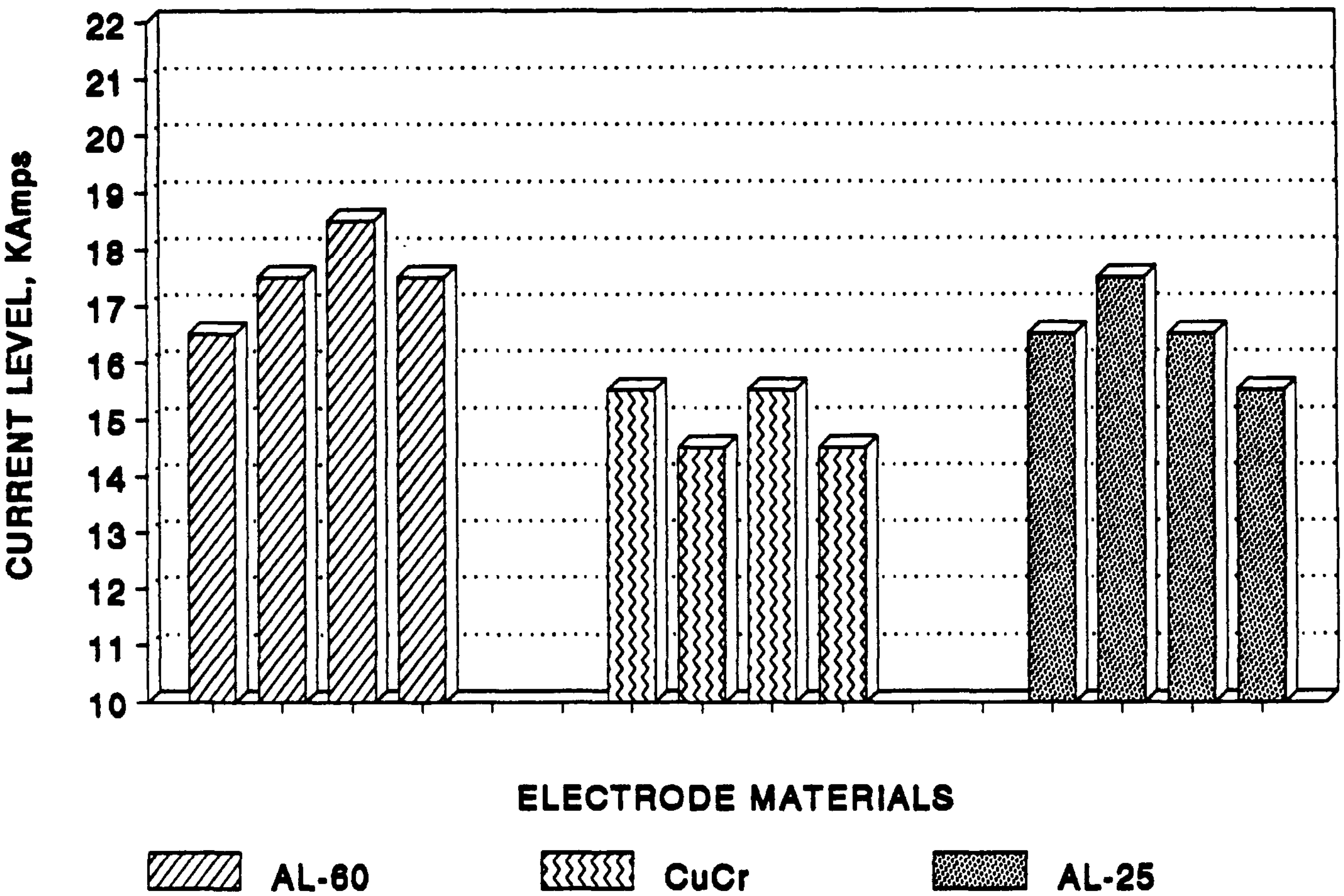


Figure-6: Sticking Behavior on Hot Dip Galvanized Steel

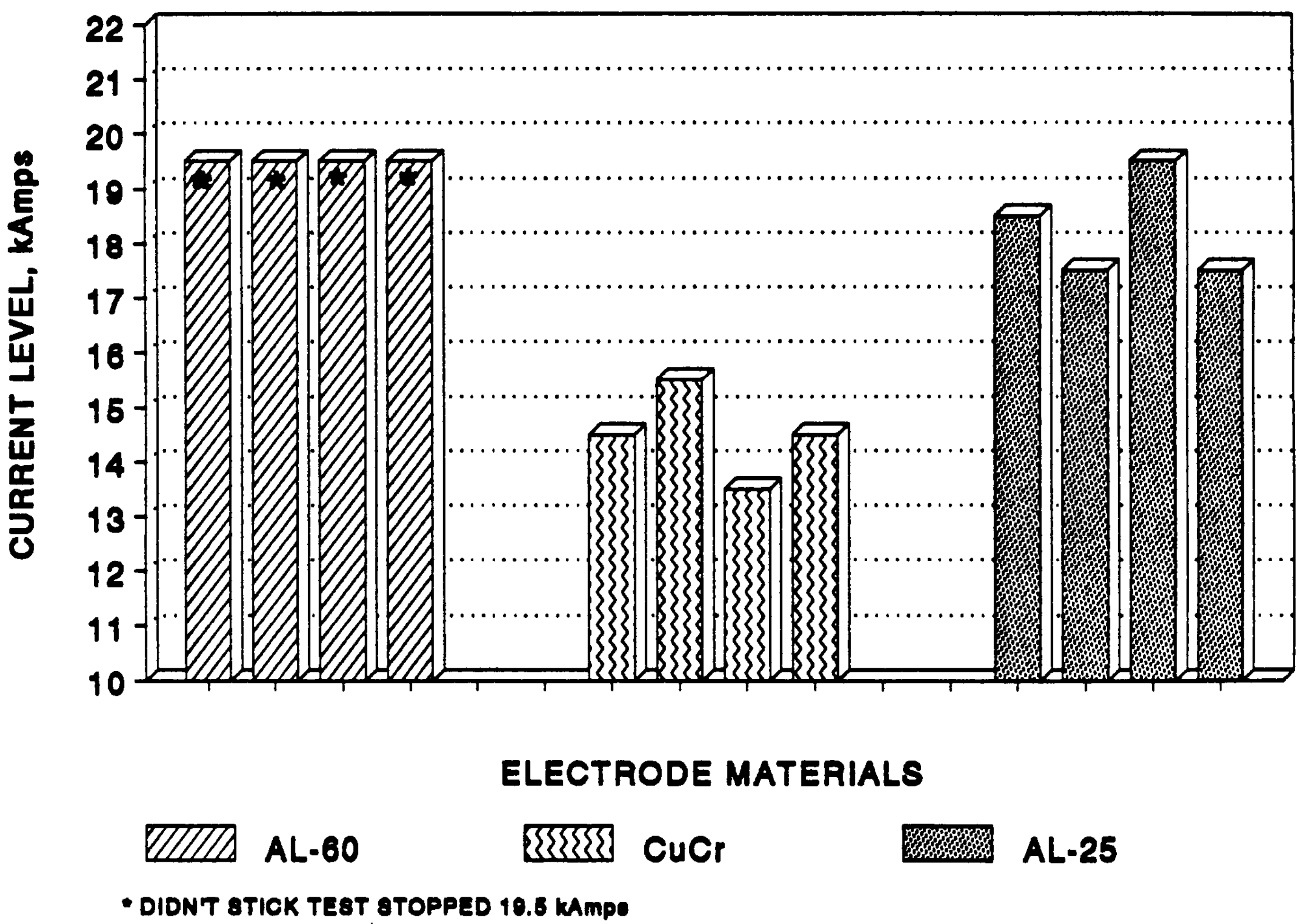


Figure-7: Welding Window for Galfan Steel

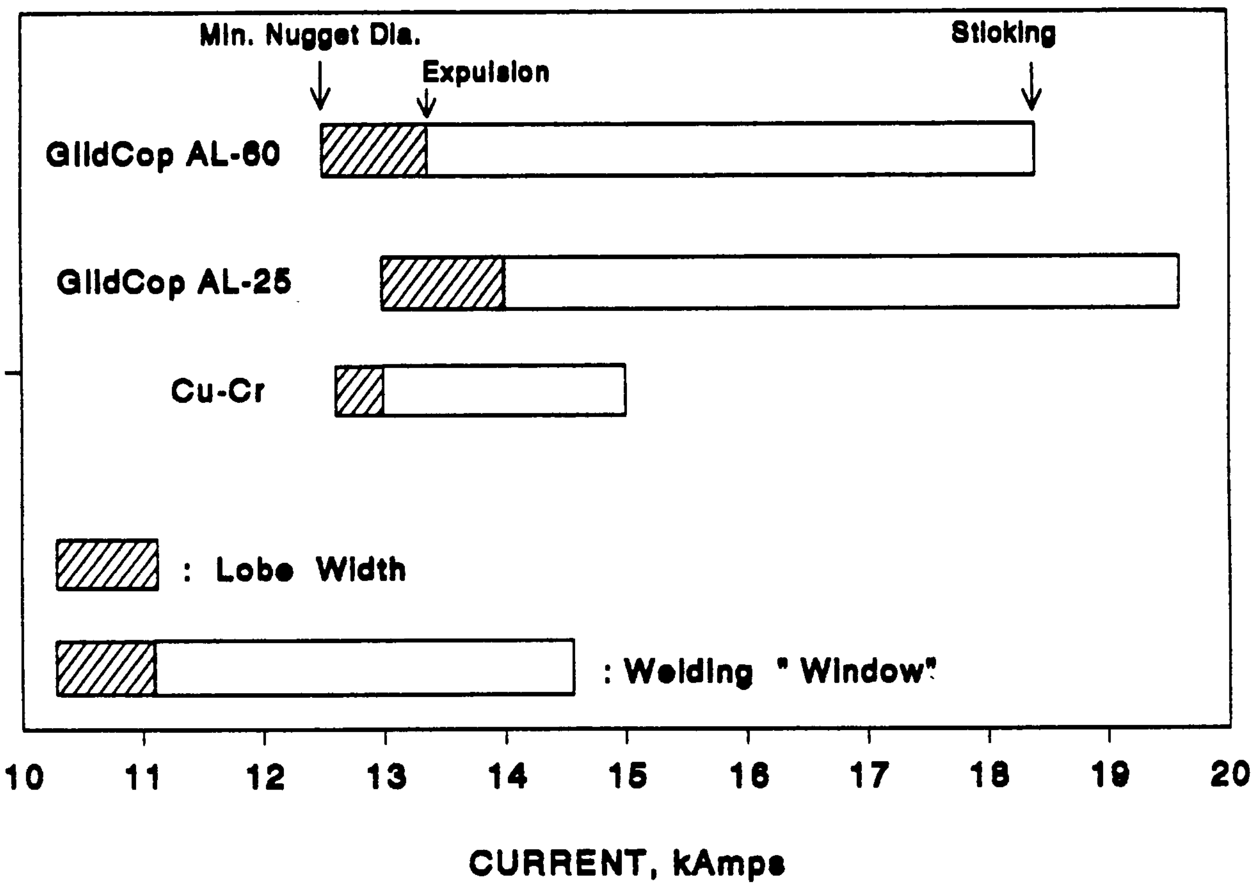
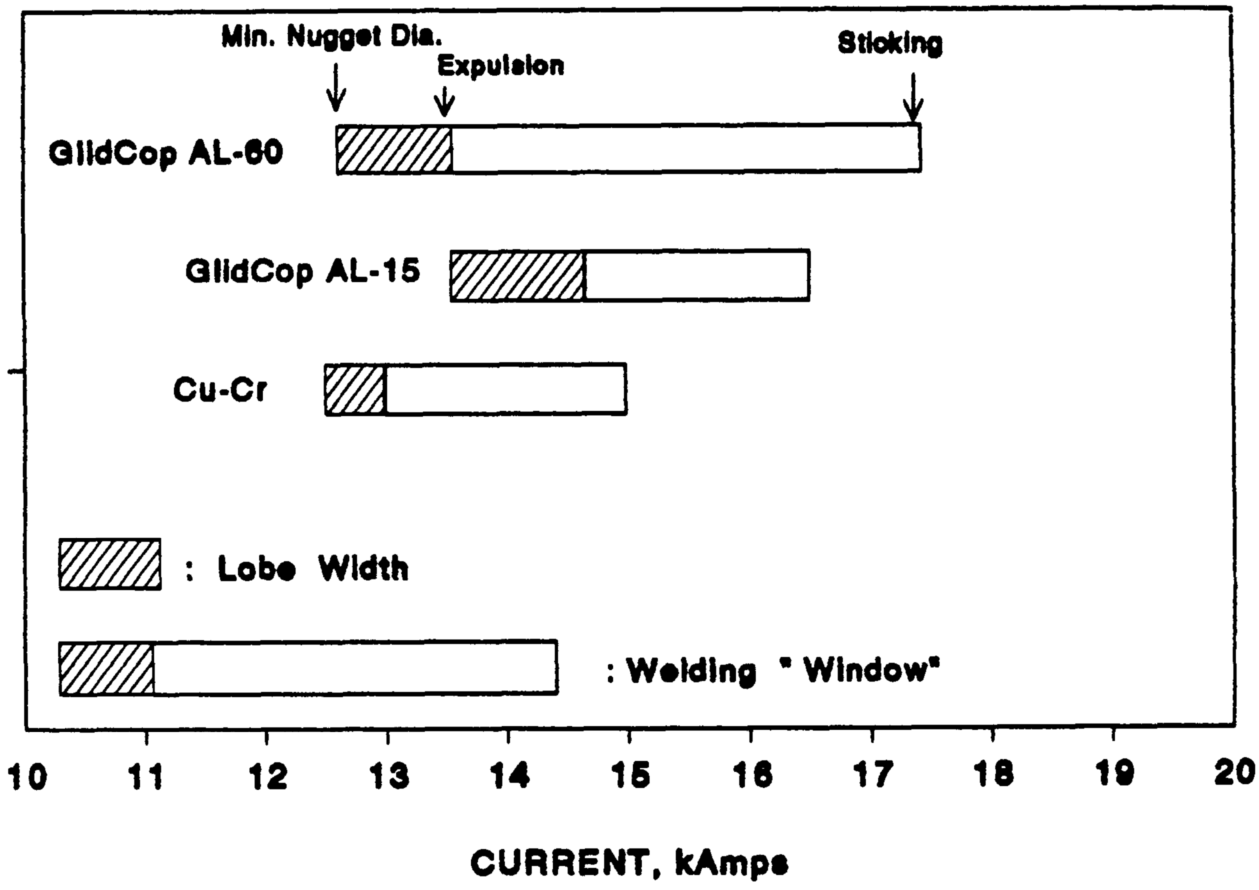


Figure-8: Welding Window for Electrogalvanized Steel



New Developments in Protective Organic Coatings for Enhanced Galfan Steel Performance

by

Richard F. Lynch, Lynch & Associates, Inc. and
Federico Rodellas, ProCoat, S. L.

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New Developments in Protective Organic Coatings for Enhanced Galfan Steel Performance

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Federico Rodellas, ProCoat, S. L.

ABSTRACT

Recent developments in organic coatings, including hexavalent chromium free formulations, offer new opportunities to further enhance the performance of Galfan and other coated steels. Two related water based acrylic coatings have been developed and are now routinely used in production to enhance the performance of Galfan, hot-dip galvanized, electrogalvanized and Galvalume. A separate treatment was specifically developed to prevent the formation of gray patina on Galfan.

Brugal GM-3, GM-4 and GM-5 are acrylic films containing a small amount of chromium that provides additional corrosion resistance, resistance to storage stain, intrinsic lubricity, cost effective easy application, and other benefits. It extends corrosion resistance even after temper rolling, allows roll forming without the use of oils or other lubricants thus eliminating residual oils on roofing and other products, and can be coil coated or post painted. The product is also available in tinted versions in a variety of colors. They have been used in regular production in Europe since 1989 on galvanized, Galfan and Galvalume. Highly successful production trials have just been completed in North America with GM-4RF, a version containing additional lubricant for severe roll forming and drawing operations. Applications are in construction, appliance and related markets.

Brugal N` 6 is a closely related product to Brugal GM-4 formulated without hexavalent chromium after user request. It provides the same basic performance properties as Brugal GM-4 but contains only small amounts of trivalent chromium. A related product without chromium is under development.

Brugal T3MG was developed specifically at the request of the Galfan community to prevent the formation of gray patina. It is a clear coating without hexavalent chromium and provides an additional anticorrosion barrier.

Brugal 65 is a dry film lubricant providing temporary corrosion protection, extensive lubrication, with easy and complete removal for use in automotive stamping and related applications.

Brugal GM-43, GM-4, GM-5, N` 6 and 65 can be applied in the steel mill using existing chemical treatment equipment. Application can also be by roll coater (coil coating) or by electrostatic spray. Brugal T3MG is applied using a roll coater. The ability to apply these ProCoat products economically in line is a major factor contributing to the low cost of enhanced Galfan and other coated steel performance.

INTRODUCTION

The performance of metallic coated steels can be further enhanced through the use of organic coatings to create a hybrid coating system, imparting additional desirable properties to the finished product. Beyond this, the processing of the steel into the final shape can be facilitated and achieved at a lower cost through the use of organic coatings.

Traditionally, the surface of galvanized, Galfan and other coated steels has been passivated through the use of a chromate treatment, often intended primarily to prevent the formation of storage stain. Separate from this, pre-treatments are applied to prepare a surface for coil coating to insure satisfactory adhesion. Now, recent developments in organic coatings offer new opportunities to further enhance the performance of Galfan and other coated steels, produced as sheet, wire and tube.

Customer needs include: storage stain resistance, long term corrosion protection, enhanced formability, reduced flaking and powdering, retention of an attractive appearance, versatility and low cost. A problem is that certain applications have more stringent requirements than can be satisfied solely by a metallic coated product, even one with the impressive performance characteristics of Galfan. In such cases something extra is needed.

At the same time, coating line operators have a set of requirements necessary for an organic coating to be reasonable to use on a continuing basis including: straight forward application method, utilization of existing equipment, ease of operation, good control, limited maintenance, versatility, no waste disposal, and low cost. In other words, the coating should be relatively trouble free to apply and not be cost prohibitive.

ProCoat has developed a family of technically unique products which satisfy both of these diverse sets of requirements. These water based acrylic coatings are versatile and user friendly. They have proven themselves in continuing production in Europe since 1989, with use now starting in North America. Acceptance and customer specification have been achieved in the construction, automotive, appliance and other industries, with use both bare and as painted.

ProCoat has developed four major types of acrylic coating products for use on Galfan:

* <u>Brugal GM-3, GM-4, GM-5 and N` 6</u> - Permanent protective coatings which maintain an attractive appearance, exhibit intrinsic lubricating properties, are available in attractive color tints, and can be coil coated.

* <u>Brugal GM-6</u> - A pre-treatment for coil coating which provides excellent bonding to the substrate and imparts flexibility and better corrosion resistance to the painted product.

* <u>Brugal T3MG</u> - A permanent protective coating specifically developed to prevent the formation of gray patina on bare Galfan.

* Brugal 65 is a dry film lubricant providing temporary corrosion protection, extensive lubrication, with easy and complete removal for use in automotive stamping and related applications.

These coatings will be discussed in turn including details on performance properties and comments on commercial applications. Then means of applying these products on existing production equipment will be described.

PRODUCT CHARACTERISTICS

Brugal GM-3, GM-4, and GM-5

These acrylic films provide a broad range of capabilities to add to those of the underlying metallic coated steel. These benefits include resistance to storage stain, additional corrosion resistance, retention of an attractive appearance, intrinsic lubricity, reduced flaking and powdering, versatility, low cost and easy application. Greater end-use applications are possible because the coating is weldable, paintable and fingerprint resistant.

Brugal GM-3 was designed for use primarily on wire, tube and piece parts. Brugal GM-4 is a closely related version specifically intended for use on sheet products. Both of these products provide a clear coating.

Brugal GM-5 was developed to impart attractive translucent color tints to the product surface. The product is available in blue, green, red, gold, black and other custom colors. These colored versions are used to both prove an attractive low cost alternative to a painted surface and to provide color identification for specific products. For example, wire product has been color coded to help distinguish one product from another after shipping and storage.

Corrosion Resistance

These unique coatings form a protective barrier film which is intimately bonded to the underlying metallic coating by a passivation layer formed immediately by the phosochromates in the coating as it dries. Thus protection is provided both by the chromium inhibited acrylic film and the underlying passified surface.

Testing in a steel company laboratory showed a major synergistic benefit for Brugal GM-4 on GF60 Galfan (180g/m^2), with significantly increased resistance in salt spray exposure compared to the improvement achieved with conventional galvanized steel. After 500 hours of exposure to 5% neutral salt fog in accordance with ASTM Test method B117, the Galfan surface was described as looking as though it was never in salt fog. Exposure for 1000 hours gave excellent results. Parallel testing of Brugal GM-5 in five colors gave results nearly as good as with clear Brugal GM-4 with all ranked as excellent. Testing in a separate laboratory showed the start of white rust at 450+ hours with 1000 hours to the initiation of red rust. Thus the remarkable corrosion resistance of bare Galfan can be further extended by the use of these acrylic films while at the same time maintaining an attractive surface appearance.

Forming

These acrylic coatings have an intrinsic lubricity which greatly enhances formability. This characteristic allows more severe deformation without the use of lubricating oil, although lubricants can be employed if desired. Versions with additional lubricants added (Brugal GM-4L and Brugal GM-4RF) have been perfected to further extend the ability to carry out severe forming operations without damage to the product.

Recent North American production line trials with difficult Galvalume roofing profiles achieved full success without the use of oil, thus eliminating a major safety concern as workmen will not be in danger of slipping and falling from roofing panels carrying a residual oil film. Because the film is flexible, corrosion resistance is extended even after temper rolling, as demonstrated by another North American steel company.

Appearance

The bright appearance of all substrates is maintained for long periods with the use of these coatings on hot-dip galvanized, electrogalvanized and Galvalume. With Galfan, GM-4L and GM-4RF maintain the initial gloss with a somewhat darker shade developing under the bright surface appearance.

Painted Product

These products are highly suited for factory painting, post painting, and coil coating applications. Investigation of painted product after OT bends revealed the absence of visible cracks which will lead to an improvement in painted product performance as well. Galfan treated with clear GM-4 is routinely factory painted using both liquid and powder paint systems. One application under development will be for door and window frames which will be fabricated and protected using a colored Brugal GM-5 film which will also serve as the base for post painting in the field after the building has been constructed.

To enable Brugal GM-4 to be immediately coil coated, a simple treatment sequence was developed at customer request to prepare the surface. The coil is cleaned on-line using normal equipment with an alkaline cleaner and then Scotchbrite brushed and washed. This treatment removes the acrylic coating but retains some of the passivation layer. Then the normal pre-treatment, primer, and top coat sequence can be carried out. Alternate higher performance, proprietary pre-treatments can also be employed. This capability allows the same coating, Brugal GM-4, to be applied to all material produced on a coating line whether it is to be used bare or painted, or whether it is a straight zinc or an alloy coating. In this way there can be a great simplification and cost savings in both production and inventory control.

End-Use Applications

Brugal GM-4 is used commercially on Galfan, hot-dip galvanized, electrogalvanized and Galvalume substrates, with production experience dating back to 1989. Commercial production is in France, Germany, Italy, Luxembourg, Spain and the United Kingdom, with testing and line trials underway in many other countries.

Earliest uses were in the construction industry. For example, long experience has been developed with bare Galvalume building panels for roofing and siding shipped to the Middle East and Far East from Europe. The use of Brugal GM-4 eliminated past problems with storage and transit abrasion stain enabling the product to reach the use location undamaged. Now customers specify Brugal GM-4 as a product requirement to insure satisfaction. Other similar construction applications utilize Brugal GM-4 on hot-dip galvanized where an attractive bright appearance is also maintained.

Brugal GM-4 is used on electrogalvanized to eliminate the need for phosphating before painting, achieving a cost reduction. Likewise it is used on stainless steel before powder painting to avoid rust in architectural applications.

The appliance industry is using Brugal GM-4 on bare Galfan for enhanced corrosion resistance in harsh detergent environments. Brugal GM-4 is also being successfully used prior to powder and liquid painting operations. Parts are merely cleaned using alkaline cleaners (pH = 11) and halogenated solvents after forming. This simplified process is an important benefit to the customer.

Another use is for electrical control cabinets which are fabricated from Galfan coated with Brugal GM-4 and then used painted on one side. The Brugal GM-4 coating provides protection on the unpainted surface.

An application is under development which will allow users to achieve both cost savings and better performance by substituting Galfan plus Brugal GM-4 plus cleaning before application of a two coat acrylic finish instead of the old system of cold rolled steel which was cleaned, phosphated, passivated, and anodic E-coated before application of the acrylic finish.

Testing is underway in the automotive industry for the use of clear Brugal GM-4 on Galfan tubing and black Brugal GM-5 for fuel related and other corrosive applications.

Environmental Features

There is increasing worldwide concern for environmental safety, especially with regard to the use of chromium. A major advantage of these ProCoat products is that they are "dried in place" with no need for rinsing nor spent product discard. Theoretically, all liquid coating that is brought into the plant can be applied to the product and dried in line with the excess returned to the storage reservoir for reuse, with new material added as required. This eliminates the problems of routine disposal of rinse water or spent product.

Although Brugal GM-3, GM-4 and GM-5 contain chromium, virtually all hexavalent chromium is converted to safe trivalent chromium upon curing. This is evidenced by a change in color from greenish-yellow to clear during the curing process which is fully complete within two days. Further, even this trivalent chromium is tied up in the acrylic film as demonstrated by leaching tests. Thus, these products are able to be used without danger of releasing the small amount of chromium that is present to the environment.

Brugal N` 6

Despite the low amount of chromium in Brugal GM-4 and the fact that it is converted from the hexavalent to the trivalent form upon curing, there is a concern that governmental regulations could prohibit the use of products containing hexavalent chromium or eventually any chromium at all. Because of such concerns on the part of customers, Brugal N` 6 was developed as a product closely related to Brugal GM-4 but containing only low amounts of trivalent chromium. Brugal N' 6 provides the same basic performance properties as Brugal GM-4 including paintability. Continuing evaluation is demonstrating the effectiveness of this new product. A related product without chromium is under development.

Brugal GM-6

Brugal GM-6 is a pre-treatment used before coil coating or powder painting. It forms a dry film on the metal substrate which is a mix of an insoluble chromate complex and an organic polymer. This film is applied without the need for rinsing and provides an excellent bond to the metal substrate thus improving the adhesion of the top coat system. The acrylic polymer contributes to the higher flexibility of the film and better corrosion resistance of the complete paint system.

Brugal T3MG

This product was developed at the specific request of the Galfan community to prevent the formation of gray patina. It is a clear coating without hexavalent chromium that prevents blackening of the Galfan surface and additionally provides an excellent anticorrosion barrier.

Laboratory evaluation by humidity cabinet exposure in 98% relative humidity at 49 C revealed no color change nor evidence of white rust after 250 hour. Likewise, there was no color change after 500 hours at 98% relative humidity and 40 C and only slight darkening after 3000 hours, with less than 10% white rust after 500 hours and 20% after 3000 hours. Salt spray exposure resulted in the first evidence of white rust after 48 hours. Adhesion was 100% in cross hatch, Ericksen draw and bend testing.

Outdoor exposure by CRM in an urban atmosphere for 14 months confirmed the success of Brugal T3MG in preventing the formation of a gray patina on minimum spangle, skin passed Galfan. The residual reflectance was 90% upon application of Brugal T3MG and remained at 84% brightness after 14 months exposure after reaching a plateau at 6 months. In contrast, untreated Galfan had an initial 100% brightness value but quickly decreased to 61% after 2 months and only 53% after 6 months which was unacceptable. Clearly T3MG provides a solution to the problem of gray patina formation on Galfan.

Brugal 65

Brugal 65 is a chromium free, dry film lubricant designed for the international automotive industry which also provides temporary corrosion protection.

Characteristics

Its intrinsic lubricating properties normally allow automotive stamping operations without the use of oil or other lubricants. Temporary corrosion protection, generally required for periods of up to 6 months, is amply provided. Standard alkaline cleaners completely and easily remove Brugal 65 with complete removal being less difficult than for standard oils. When oils are employed along with Brugal 65 for additional lubricity, they are also more easily removed because of the underlying Brugal 65. Welding is readily accomplished and Brugal 65 is compatible with bonding adhesives. These properties have been thoroughly evaluated by extensive testing and evaluation by European and North American automobile producers.

End-Use Applications

Following extensive field tests, Renault of Spain approved production use of Brugal 65 in 1989. Examples of large components in production use are: rear quarter panels, upper plenums, outer headlight heads, rear hatches, and van doors. Major benefits included reduced flaking and powdering, less required die cleaning, ability to use greater holddown pressure, better in process corrosion protection, and better and easier cleaning resulting in fewer paint defects. Numerous other European car companies are currently considering production use including: Fiat, Renault/France, Jaguar (UK), PSA (Peugeot-Citroen), and Mercedes (Spain). Testing in the U.S. has been very positive and on-going evaluation is underway.

APPLICATION METHODS

A major advantage of these ProCoat products is their versatility and relative low cost of application. They have been designed and formulated to be applied using existing production equipment, in many cases on the metallic coating line. Brugal GM-3, GM-4, GM-5, N` 6, and 65 can be applied by at least three methods: (1) squeezing roller, (2) immersion, and (3) roll coater including coil coating. Brugal 65 can also be applied electrostaticly. Application is followed by hot air drying to cure the coating. Brugal GM-6 and T3MG are applied by roll coater followed by hot air drying, either on the metallic coating line or on a separate coil coating line.

Squeezing Roller Application

The use of squeezing rollers to apply these products has a proven production history. It is a relatively low cost means of application, which lowers the cost compared to alternate systems. Most frequently, a pre-existing chemical treatment system can be easily modified for this purpose, Figure 1.

In operation the product is flowed onto the top surface of the sheet, allowing the excess to overflow into a lower catch basin which in turn feeds the lower squeezing roll. Roller hardness and pressure control the wet film thickness, as does the solution dilution. Rollers are usually flat and constructed of Neoprene or Hypalon with a 65 degree Shore hardness. A vertical strip arrangement can also be employed. Drying is accomplished by a convenient method to remove the residual water from the coating layer which also initiates curing of the polymer.

Good coating thickness control is obtained by this method. For example, long term mill experience coating electrogalvanized steel with Brugal 65 has resulted in coatings of $1.5\ g/m^2 \pm 0.3\ g/m^2$.

Immersion Application

This method for application of Brugal GM-3, GM-4, GM-5, 65 and T3MG involves the use of an immersion tank and a sinking roller system prior to the use of squeezing rollers to even and level the coating. The balance of the application and drying procedures are similar to those for squeezing roller application.

Electrostatic Application

Normal electrostatic application of Brugal 65 is possible. Any overspray or excess material can be recycled just as in other application methods. A smooth continuous layer must be achieved by process control before drying by any of the usual methods. It should be noted that special electrostatic methods exist that do not allow the use of Brugal 65 because it is a water based coating.

Roll Coating/Coil Coating Application

Standard roll coating procedures are used to apply all of these coatings. With a standard two roller unit, the applicator roll is normally smooth Neoprene with a 45-50 degree Shore hardness and operates in a reverse direction to that of the strip. The pick-up roll is typically a non-driven, stainless steel, grooved roll with 64-100 grooves/cm^2 and a pit depth of 200 microns. Ceramic rolls are also employed. Line speeds of up to 50-60 mpm are been used. Flat rolls can also be used but the solution must be prepared at a greater concentration to compensate for the lesser wet film thickness.

Curing of the Coating

Drying and curing take place in line following application. Essentially drying and curing take place in one step as the water is removed from the wet film and the film is cured to achieve its final characteristics. A number of drying systems have been effectively employed, by themselves or in combination: (1) hot air blast, (2) infrared or catalytic infrared, and (3) induction.

Drying time and temperature need to be sufficient to remove the water in the wet film and promote curing. Effective air flow is important to carry off the water vapor. Actual time of drying depends on line speed, with a lower temperature satisfactory if there is adequate time at temperature. Each product has somewhat different drying requirements:

For all application methods except coil coating, a peak metal temperatures of 80-90 C (175-195 F) is satisfactory, generally corresponding to a hot air temperature of 120 C (248 F). A peak metal temperature of 150 C (302 F) is needed in coil coating. Temperature and time parameters will, of course, increase when a greater film thickness is applied.

Coating Thickness Determination

Typical coating thicknesses are 1.0-1.5 g/m^2. However, depending on the intended application and the product in use, thicknesses as low as 0.5 g/m^2 and as high as 2.5 g/m^2 are employed. A coating of 1.0 g/m^2 corresponds to one micron in thickness.

Two methods are normally used to determine coating thickness. All of these coatings except Brugal 65 contain chromium. This allows a Portaspec or similar instrument to be used which is calibrated against standards for known coating thickness supplied by ProCoat. The coating thickness can be quickly determined using this procedure. Alternately, the weigh-strip-weigh method is employed.

SUMMARY

ProCoat has developed a family of acrylic coatings which can significantly enhance the performance of metallic coated steels including Galfan. Together, these hybrid coating systems can effectively meet increasingly more demanding customer requirements for storage stain resistance, longer corrosion protection, retention of an attractive appearance, greater formability without lubricants, versatility and low cost.

At the same time, these coatings have been designed to be user friendly and relatively easy to apply on existing hot-dip, electro, or coil coating lines. Application methods are straight forward and can utilize existing equipment, with good control, limited maintenance, no waste disposal and low cost. Further they are suitable for use on all products produced on a given line.

Different coatings provide different features, such as:

* Permanent protection and maintenance of an attractive appearance including color tints, with intrinsic lubricity, and the ability to be coil coated - Brugal GM-3, GM-4, GM-5 and N` 6.

* High performance, economical coil coating pre-treatment - Brugal GM-6.

* Prevention of gray patina formation on Galfan with added corrosion protection - Brugal T3MG.

* Dry film lubricant for automotive stamping plant operations which is easily and completely removed and provides temporary corrosion protection - Brugal 65.

Together these products offer great potential for producers of coated sheet, wire and tube to: solve chronic customer complaints, achieve enhanced product performance, extend the use potential of their product lines, and do so in an economical way with production proven technology.

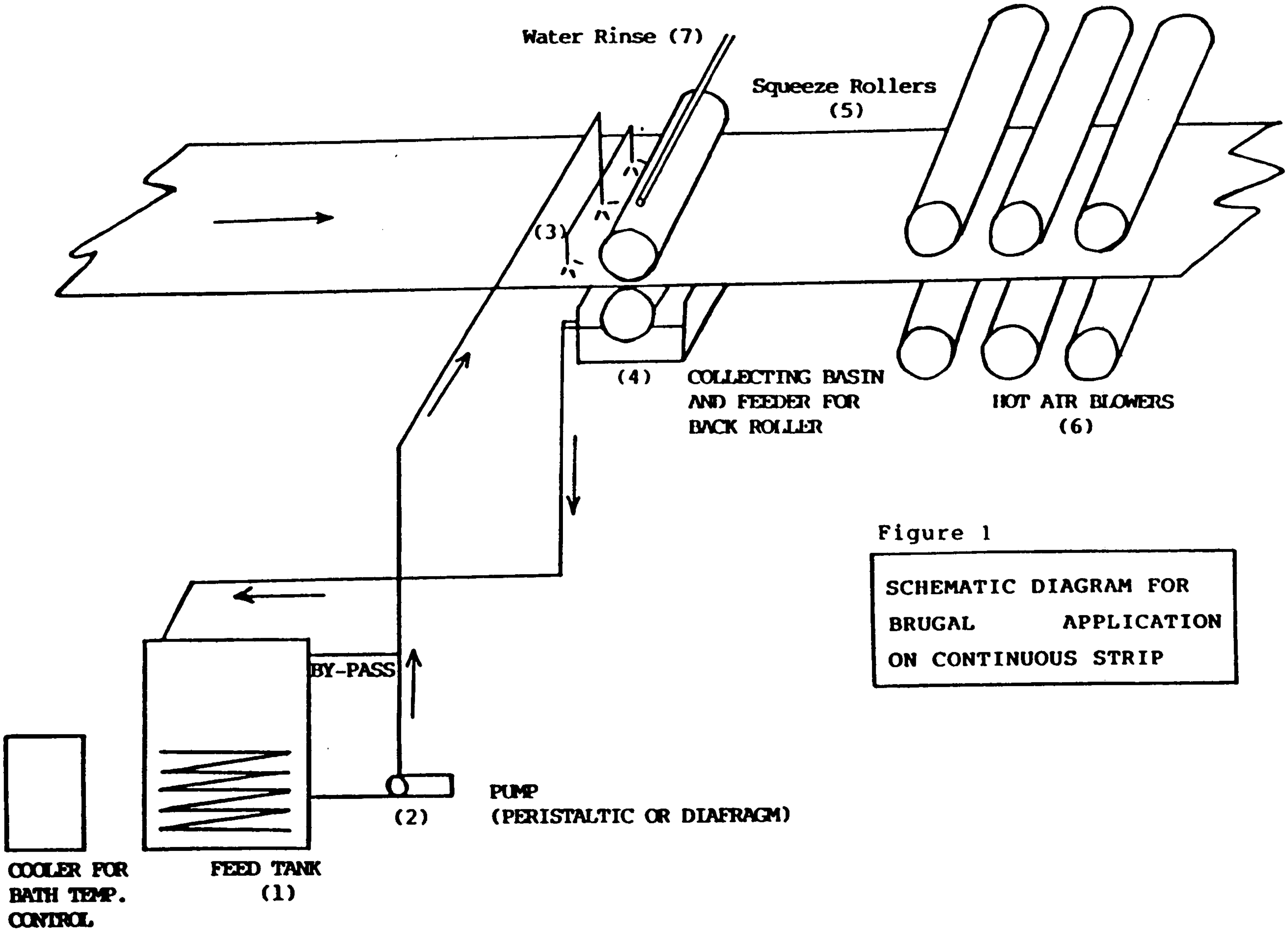

Figure 1

SCHEMATIC DIAGRAM FOR BRUGAL APPLICATION ON CONTINUOUS STRIP

Method for Metallographically Revealing Intermetallic Formation at Galfan/Steel Interfaces

Seth A. Eliot*
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INTRODUCTION

Galfan is a 95% Zn, 5% Al-mischmetal alloy (approximately 0.08% mischmetal, consisting primarily of La and Ce) developed over 11 years ago [1] as a coating for low carbon sheet steel. Such coatings of Galfan are more formable and corrosion resistant than standard galvanized coatings for low carbon sheet steel. Galfan coated sheet steel is produced via a continuous hot-dip process (Galfanizing) that requires careful control of operating parameters. Any deviation in such may result in the formation of intermetallics at the steel/Galfan interface [2]. These intermetallics are Fe-Al-Zn compounds of the form Fe_2Al_5-Zn_x, which grow into both the steel substrate and the Galfan coating [3]. These intermetallics are detrimental to both formability and corrosion resistance. The mischmetal addition is thought to play a role in the prevention of intermetallic formation by its effect on the wetting of the steel by the molten coating [4]. Surface pretreatment of the steel is also important [3] for the same reason. Work on other Zn-Al coatings of near eutectic composition without mischmetal shows a thin Fe-Al-Zn layer acting as an inhibitor to protruding intermetallic growth [5, 6]. Breakdown of this layer can occur because of elevated bath temperature [5], excessive aluminum content in the bath [5, 6], and long dip times [5, 6]. Extended immersion time in the bath has been verified as causing intermetallic growth in Galfan (*with* mischmetal) as well [3].

To establish the optimum operating parameters for production of Galfan-coated steel, it became necessary to identify material having intermetallic growth and the nature of such growth. The purpose of this article is to describe a metallographic method that clearly reveals these intermetallics.

METHOD AND RESULTS

The material examined was low carbon sheet steel after continuous hot-dip Galfanizing. The nominal temperature of the Galfan bath for this process is 465°C. Samples procured for this work were those processed at conditions sufficiently different than the norm so as to form intermetallics. Materials with coating thickness between 0.015mm and 0.050mm were examined. All samples illustrated in this report were pack mounted using copper spacer material and ground on silicon carbide papers through 180, 240, 320, 400, and 600 grit. A water rinse, an ethyl alcohol rinse, and hot air drying followed each step. The material was then polished with 6μm diamond on a napless cotton cloth

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and cleaned in ethyl alcohol. Pack mounts, consisting of alternate layers of specimen and spacer material secured by a clamp, are a useful means of preparing multiple sheet specimens simultaneously. Care should be taken to maintain the direction of grinding transverse to the coating/substrate interface, with 180° rotation between papers.

Material prepared by this method is shown in Fig. 1. Intermetallic "bursts" in the unetched material [Fig. 1(a)], as designated by arrows, are difficult to distinguish from the steel substrate. Use of a 4% picral etch [Fig. 1(b)] reveals the coating structure but does not help distinguish the intermetallic.

A new etchant was sought to better delineate the intermetallic phases. The samples from Fig. 1(a) (unetched) and Fig. 1(b) (picral etched) were immersed, face up, in a mixture of 100ml distilled water, 0.5g hydrated copper sulfate ($CuSO_4 \cdot 5H_2O$), and three drops of glycerin to promote wetting. Immersion continued until the copper spacers turned an even dark brown, and the steel substrate appeared an even tan brown. The sample was thoroughly rinsed in running water, rinsed with ethyl alcohol, and then blown dry in hot air.

It was found that the aqueous copper sulfate solution worked in conjunction with the copper spacer material in the pack mount to cause coloration of the steel substrate and Galfan coating, but not the Fe-Al-Zn intermetallic phases (Fig. 2). The Galfan that was

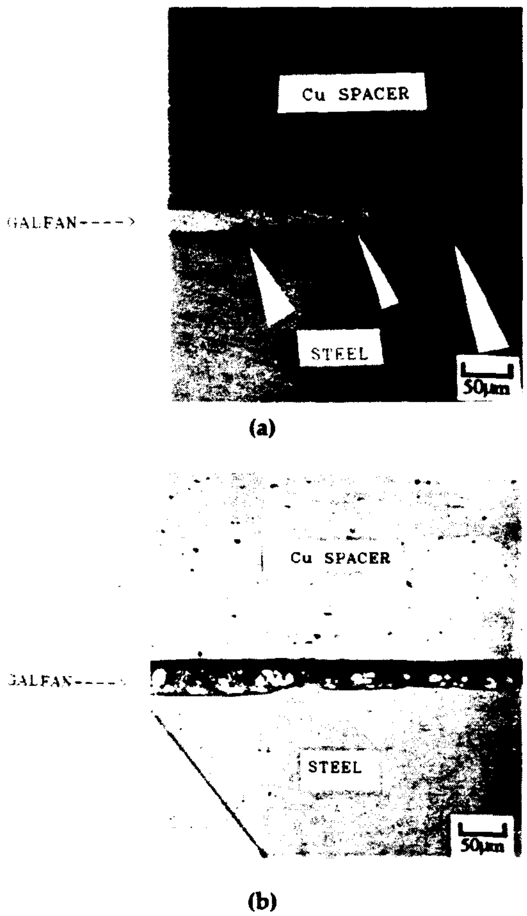

FIG. 1. Conventionally prepared material; intermetallics indicated by arrowheads: (a) Unetched; (b) Etched with 4% picral solution.

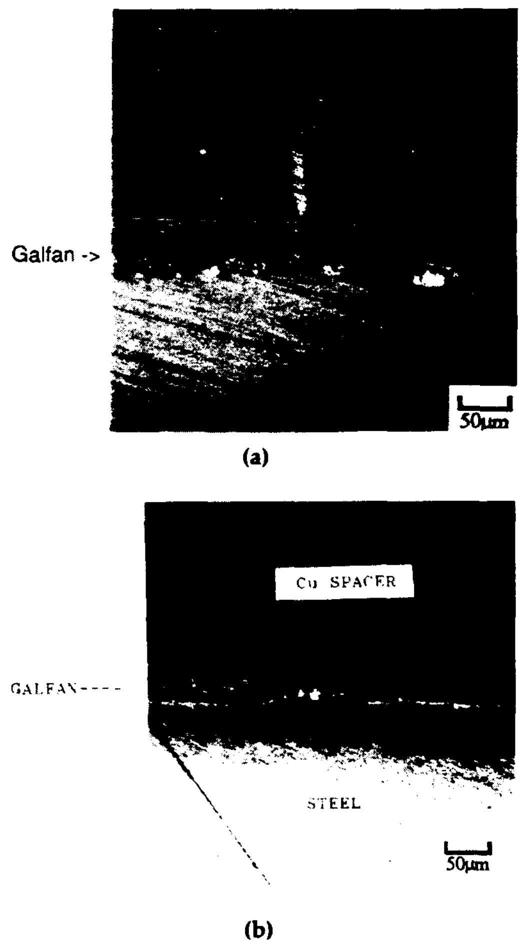

FIG. 2. (a) and (b) correspond to (a) and (b) of Fig. 1, except for an additional etch in $CuSO_4$ solution. Intermetallics are the lighter phase at Galfan/steel interface.

etched in 4% picral prior to the copper sulfate solution [Fig. 2(b)] still shows the microstructure in the Galfan itself, but the intermetallics now appear clearly separate from the surrounding material, ranging in color from white to light brown. The results indicate that a picral preetch followed by the copper sulfate etch reveals the intermetallic and coating structures simultaneously. Such a preparation is better illustrated in Fig. 3. The microstructure here consists of a Zn-rich phase (black globules), a eutectic Zn-Al phase (gray), and intermetallic (light gray-white).

In addition, a particular intermetallic burst may grow primarily into the steel, thus occluding detection under conventional metallographic processing. The copper sulfate solution etch is useful for detecting this morphology also (Fig. 4).

SUMMARY

A technique has been presented to easily and quickly reveal Fe-Al-Zn compounds, formed at Galfan/steel interfaces during hot-dip Galfanizing, which are detrimental to material performance. The material to be examined is mounted between copper spacers and ground on SiC papers, then polished with 6μm diamond. An optional picral preetch is then followed by a copper sulfate solution etch that interacts with the Galfan, steel, and copper. Proper use of this technique should facilitate detection and identification of intermetallic phase at the interface.

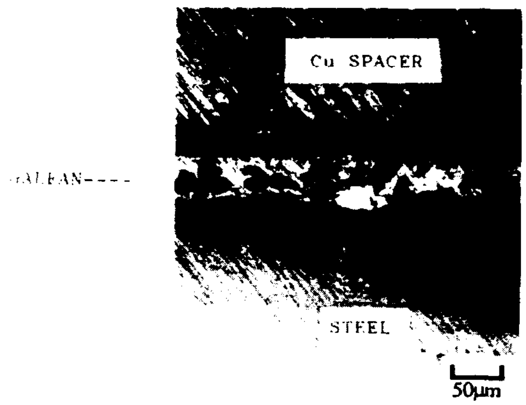

FIG. 3. Galfan with 4% picral solution preetch, followed by $CuSO_4$ solution etch showing coating microstructure as well as intermetallic.

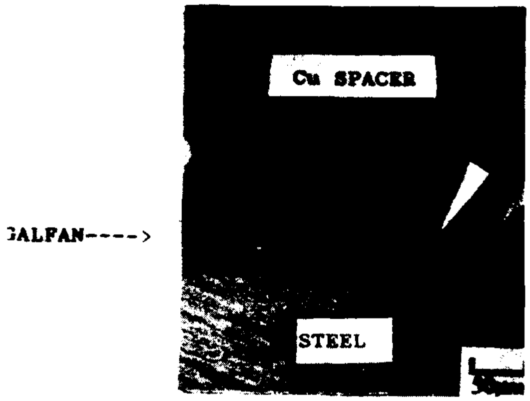

FIG. 4. Arrowheads indicate "nonprotruding" intermetallic growths, easily detectable using $CuSO_4$ solution etch.

The author thanks Mr. J. Sinsel of Weirton Steel and Dr. W. Garrison of Carnegie Mellon for their cooperation and help in his study.

References

1. J. Pelerin, B. Bramaud, J. F. Nouville, D. Coutsouradis, D. C. Herrschaft, and S. F. Radtke, *Galfan: A New Zinc-Aluminum Coating (Part I)*, Proc. 13th Int. Galvanizing Conf., London (1982).
2. D. G. Hudok, Metallographic Evaluation of Galfan Coating from First WSX Galfan Run, Weirton Steel Corporation, Weirton, WV (internal report, sheet mill quality assurance department) (May 13, 1986).
3. Z. W. Chen, J. T. Gregory, and R. M. Sharp, *The Formation and Growth of Intermetallic Phases During Galfanising of Low Carbon Steel at 450°C*, 18th Australasian Chemical Engineering Conf., Auckland, New Zealand (1990).
4. R. F. Lynch, Hot-dip Galvanising alloys, *JOM* 39:39–41 (1987).
5. A. R. P. Ghuman and J. I. Goldstein, Reaction mechanisms for the coatings formed during the hot dipping of iron in 0 to 10 pct Al-Zn baths at 450° and 700°C, *Met. Trans.* 2:2903–2914 (1971).
6. P. G. Caceres, C. A. Hotham, J. A. Spittle, and R. D. Jones, Mechanisms of formation and growth of intermetallic layer during hot dipping of iron in Zn-3 Al and Zn-6 Al baths, *Mater. Sci. Tech.* 2:871–877 (1986).

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GALFAN
BATH MANAGEMENT
TASK FORCE

PURPOSE

TO DEFINE: Sampling

Analytical Methods to Measure

- Al content with ± 0.05% max
- La, Ce content ± 5 ppm max

OBJECTIVE

Control Al composition
of the Galfan bath at ± 0.1%

GBMTF

MEMBERS

as of Oct. 4, 1993

ALLOY	SHEET	WIRE	TUBE
Union Miniere	Cockerill Sambre	Bekaert	Handy and Harman
Mitsubishi Materials	Thyssen Stahl	TrefilARBED	Higbee Automotive Newlex
Pasminco	Sollac	Trefilunion	Higbie Automotive Fulton
Eastern Alloys	Sumitomo Metal Ind.	Australian Wire Ind.	Bundy Tube (2) lines
Big River	Yodogawa		Arc Tube
	Weirton Steel		
	Wheeling-Pittsburgh Steel		

GBMTF PROGRESS REPORT

TECHNICAL

- Sampling Method Defined and Documented
- Map of Laboratory-Licensee Developed
- Sample Collection/Shipping Kit Developed

NEXT STEP

- Statistical Analysis of the Results

WELCOME
TO
VOEST - ALPINE
STAHL LINZ WORKS

VOEST-ALPINE STAHL LINZ GmbH

LINZ WORKS:

- Integrated metallurgical plant complex
- Area approx. 6,5 km² with own plant harbour
- Annual sales: appr. 16,5 bn AS
- Staff : appr. 10.000 employees
- Main products:

  Hot rolled steel
  Cold rolled steel
  Metallic coated steel (THERVAGAL®, GRAVIGAL®)
  Organic coated steel (COLOFER®)
  Heavy plates and clad plates
  Forge and foundry products
  Coking plant products

	CGL No. 1	CGL No. 2	EGL
Start up (revamping)	1973 (1978, 1985)	1991	1985 (1987, 1989)
Capacity (tons/yr)	218.000	210.000	190.000
Max. Strip velocity (m/min)	100	150	90
Strip dimensions (mm) **Width** **Thickness**	600 - 1520 0,6 - 2,5 (3,0)	750 - 1600 0,35 - 1,5	700 - 1600 0,5 - 1,5
Coating systems	**Z** (Thervagal®Zn, also pronounced spangle)	**Z** (Thervagal®Zn) **ZA** (Thervagal®ZnAl) **ZF** (Thervagal®ZnFe)	**Z** (Gravigal®Zn) **ZNE** (Gravigal®ZnNi) **Durasteel** (via CCL) (Gravigal®DS)
Post treatment variants: **C: chromate passivated** **P: phosphated** **O: oiled**	O C, CO	O C, CO P, PO	O C,CO P, PC, PO, PCO

galfan2.pre

GMQ
Thervagal
1993-10-04

Metallic Coating Lines at VOEST -ALPINE STAHL LINZ GmbH
Main Technical Data

VOEST-ALPINE STAHL LINZ

Main technical features of CGL No. 2

- Chemical cleaning section
  (alkaline spray – brush – electrolytic cleaning – brush – cascade rinsing)

- Vertical furnace with direct fired heating section
  (Selas type)

- Hot bridle-roll

- Two interchangeable ceramic pots
  (pure zinc without lead – Galfan)

- Coating with 3-roll system and air knife with changeable blades

- Hot coating mass gauge, traversing cold coating mass gauges for zinc-coating, prototype XRF-gauge for zinc-iron coating

- Moveable induction type galvannealing unit

- 4-high skin pass unit

- In-line phosphating section
  (activation – phosphating – cascade rinsing)

NISSHIN STEEL IS FIRST LICENSEE TO PRODUCE 1,000,000 TONS OF GALFAN PRODUCT

SPECIAL AWARD ACCEPTED BY DR. HIROSE

St. Florian's Abbey, just outside Linz, Austria, was the scene for the main social affair connected with the 18th Galfan Licensee meeting. The tour and a superb meal with authentic Austrian music in the background made real hits with the 74 guests including, for the first time, eight delegates' wives.

A special reception honoring the occasion of the first single licensee's production of 1,000,000 tons of Galfan product preceded the dinner. John Hostetler, Director of ILZRO's Galfan Technical Resource Center is shown presenting Nisshin Steel Co., Ltd's Dr. Yusuke Hirose the award plaque commemorating this first ever achievement.

Nisshin Steel is one of the early producers of Galfan sheet. About 95% of their Galfan products are used in the building industry. Nisshin's pre-painted Galfan sheet is offered in 16 standard colors and is guaranteed to be rust-free for ten years. Most of Nisshin's Galfan is heavy-gauge unpainted sheet for structural components. Their 10-year production record shows dramatic and consistent increases each year with the cumulative total now at 1,000,000 metric tons.

In addition to recognizing Nisshin's production record, the award also honored Dr. Hirose's work in basic and applied research. Many of the past Proceedings of Licensee Meetings include reports of Dr. Hirose's work. The Ten Year Outdoor Exposure Report in these Proceedings is sure to be one of the most popular and useful in the promotion of unpainted Galfan.

GALFAN
Pre-paint Brochure

Background

About one-half of the Galfan-coated strip produced since 1984 has been pre-painted. Galfan pre-painted sheet has performed well compared to other coated products. Both accelerated tests and long-term exposures generally show Galfan pre-paint exceeding the performance of regular hot-dip galvanizing for corrosion resistance and formability, and out-performing other coatings for formability and edge creep. Galfan's good characteristics match the primary requirements for pre-painted sheet very well, regardless of whether the application is automotive, general, architectural or appliances.

A Preferred Coating

Roll-coaters prefer Galfan over Galvalume because Galfan uses the same standard pre-treatments commonly used for regular galvanizing pre-paint . Galfan can be used to meet many different specifications because it is compatible with many different primers and top-coat systems. Galfan's eutectic microstructure allows its performance to be uniformly related to its thickness. There is no minimum thickness where it cannot be used..

Galfan pre-painted sheet has found its "niche" in the flat-rolled steel market. Strong growth forecasts for pre-paint sheet make it an attractive growth product with good *profit potential.* Its unique combination of characteristics make it a product which *answers the needs* of many applications not now using zinc coatings and its improved performance makes it a *strategic* product for galvanizers. .

Status of Galfan Pre-paint

Galfan pre-paint has demonstrated its superior performance. It needs now to be *promoted* as a better pre-paint sheet. The decision makers selecting pre-paint sheet, whether it be for an international metal building manufacturer, an architect or a small general contractor buying from a service center, needs to have access to easy to understand, convincing and believable information.

Although some many Galfan Licensees have produced attractive product catalogs and literature, general information now available to specifiers, fabricators, etc. does not provide a sound comprehensive evaluation of Galfan's performance compared to other hot-dip coatings. Lack of adequate basic data encourages comparisons of unequals, resulting in claims and counter-claims by the different product sponsors.

The contradictory performance claims are the results of differences in coating weights, pretreatments, primer and top-coat types and thicknesses, etc. Less than optimum systems are being compared. These unsound comparisons are inevitable and will tend to continue.

The best defense against this confusion is an attractive presentation of sound basic competitive data. ILZRO, GTRC and Galfan licensees should work together to develop a common base of shared data to unequivocally establish the performance of Galfan pre-paint in various environments and to compare that with the performanceof competitive pre-painted systems.

The Proposed Brochure

The proposal is to professionally produce an appealing 16-page four-color brochure which presents a comprehensive story of Galfan pre-paint. An outline of the manuscript to be produced by Glen Bush, a well-known strip coating research scientist, formerly with National Steel Corp., now a consultant in private practice, follows. The story-line will emphasize and illustrate the *benefits* of Galfan pre-paint.

- *Outside front cover* — 1
    - Montage of drawings
- *What is Galfan* — 2-3
    - Description
    - Production
- *Advantages of Galfan* — 4-5
    - Corrosion Resistance
    - Formability
    - Paint adhesion
    - Compatibility with different paint systems
- *Painting* — 6-7
    - Generally describe processes
        - Coil coating
        - Cleaning
        - Pretreatments
        - Primers
        - Topcoats

The Cost

Estimates for the cost of the different phases required to produce such a brochure were solicited. The phases and cost for each are as follows:

Manusript and development of material	US$ 6,000
Creative art and photography (Badertscher)	10,000
Printing 10,000 in four-color	15,000
Total estimated cost to produce the brochure	31,000

The project was submitted to ILZRO as Project UZD-95 with a request for $25,000 funding . It is not likely that the request will be approved, but they may approve partial funding (probably 50%). If the project is to proceed, licensees must underwrite the balance of the cost by subscribing to purchase the 10,000 pieces at US$ 2 each. If you are a Galfan sheet producer, please give careful consideration to subscribing for 500 or 1000 pieces. If you decide to purchase a supply, please fill out the form below and fax it to GTRC before Nov. 1, 1993.

We would expect the brochures to be available in November, 1994, assuming that ILZRO funds a portion and the 10,000 copies are subscribed for by the Licensees.

GALFAN PRE-PAINT 4-COLOR BROCHURE SUBSCRIPTION FORM

To: Galfan Technical Resource Center
Att: Janice Adkinson
Please reserve [ ] 500 [ ] 1,000 [ ] ______ copies of the proposed 4-color Galfan Pre-paint brochure for our company at US$ 2 each.

Company: ______________________________

Shipping Address ______________________________

City ______________ State ________ Zip ________

Phone ______________ Fax ______________

By: (name) ______________________________

Date ________

GALFAN SEMINARS

A major part of GTRCs effort in 1994 will be committed to creating and presenting GALFAN SEMINARS. These one-day and two-day programs seem to be the most effective and efficient media for transfering the growing Galfan technology and information to those who need it for improving quality or productivity or who are interested in using, specifying or designing Galfan products. GTRC is prepared to present three different types of seminars.

The Introductory Galfan Seminar

This is a regional meeting with a two-day agenda led by the GTRC Director, for continuous galvanizers who are potential Galfan producers. It discusses Galfan's features and benefits as they apply to sheet, wire and tube and then explains production processes and license requirements.

This seminar includes active participation of alloy and equipment suppliers and is held under the sponsorship of a research institution, zinc development association or governmental agency. It is designed to be held in a hotel with good room accomodations and meeting facilities.

Three such seminars are already scheduled; Beijing, China, Nov. 15-16, 1993, (Central Metallurgical Research Institute); Kiev, Ukraine, Apr. 11-12, 1994, (State Scientific Research Tube Institute (VNITI); and Warsaw, Poland, Apr. 14-15, 1994 (Institute of Precision Mechanics (PMI).

Introductory seminars shall be funded as follows:

Meeting facilities and materials	GTRC Budget
Materials	GTRC Budget
Events; lunch, dinner, refreshments, etc.	Suppliers
Local hosting expenses	Host
Director's travel and maintenance	GTRC Budget

Income: None

The New Galfan Licensee Seminar

A one-day program led by the GTRC Director for a new Galfan licensee's personnel involved in engineering, management, marketing, operating, production, QC, sales, testing, etc. related to Galfan products.

The logistics of the seminar's place and facilities shall be arranged by the licensee. The licensee's customized Galfan Line Operating Manual will be used extensively to make the seminar uniquely the licensee's.

New Licensee Seminars are funded from an allowance for technical services in the license fee.

The Regional Galfan Licensee Seminar

A one-day or two-day program led by the GTRC Director to discuss current technology and regional problems, specifications, market trends, etc. with Galfan licensees in a region.

The agenda and restrictions, if any, for this seminar shall be the result of co-operative planning by GTRC and the regional Galfan Development Assoc., or a committee of licensees' representatives. This seminar, for all intents and purposes, replaces the closed operating sessions at the annual international licensee meeting.

Regional Galfan Development Seminars shall be funded from registration fees, typically US$ 75-150 per attendee with discounted prices for multiple registrations from one licensee.

Galfan Seminars are not designed to take the place of the yearly Licensee meeting which shall primarily present *new research and development* information from research investigators to the Licensees. The Galfan Seminars are designed to introduce or explain *technology and technical know-how* to those who can improve the quality, productivity or use of Galfan.

CRM REPORT

(Transcript)

Marcel Lamberigts

I would just like to tell you about our concern regarding the future steps that we should take in terms of Galfan research. We at CRM are very concerned about where to go from here with Galfan and I think that what we should all bear in mind is the need to extend the market share which Galfan can claim for its own benefit. There's a whole field which so far has not been cornered which is cosmetic corrosion. When you say cosmetic corrosion you're talking automotive applications with the huge automotive market. To introduce my point, I would like to share with you some information that CRM has accumulated in another frame work which is ECFE research.

You cannot compare cosmetic corrosion resistance from one coating system to another unless everything in the processing chain is kept identical. I mean to say we need the phosphating treatment to be the same, we need the passivation and chromating treatment to be the same, we need the paint system also to be the same. And that was done in fact on a series of coating systems which are symbolized on the graph there. HD of course stands for hot dip galvanized. The numbers defined refer to the coating thickness, 8 microns in this particular case. GA stands for galvanneal. Again, 8 micron thickness coating system. GF is Galfan and in this particular case it was 18 microns in thickness. AZ is Aluzinc or Galvalume. EZ is electro-zinc coating and ZN is zinc nickel coating. Now, how do we assess cosmetic corrosion resistance in this particular case. What we do is have all the panels painted under the same conditions, then we scribe them down to the steel substrate with scribes of various widths. We then exposed those scribed panels to atmospheric corrosion and various conditions. One of those can be to mount the panels on frames which are borne by an actual automobile circling the same circuit everyday of the year. The panels are never washed and they are removed from the frame periodically for them to be evaluated. We also have exposure stations at different places in Belgium where you would expect deicing salts to be thrown onto the panels and perhaps effect their corrosion behavior.

Having said that, the evaluation is made by assessing how wide the pre-damage is so we measure the widths over which blistering has taken place. We subtract from that total width the width of the scribe itself. The diagram that is shown on the screen now gives the evolution of creep damage it is blistering with as a function of time. What I would like you to notice is that in this particular condition, Galvalume is not good at all - that we knew before hand because for it to be very effective, Galvalume must not be wounded in any way. As far as its galvanic or cathodic protection, it is almost nonexistent. You wouldn't expect it to provide effective protection once the coating has been wounded by the scribe. That's why the evolution of creep width with time is so dramatic. Now all the other coatings are not much better. What I would like you to notice is that Galfan out-performs them all. That is very important. It is somewhat better than hot dip and definitely better than electro-zinc, galvanneal or zinc-nickel. So that is an observation which we should take full advantage of.

Now, what type of application should we look at. We have measured the creep width at various stations, various mountings on the car and always Galfan comes up first. So that's something which is very clearly established. It is the best coating alloy around for that particular application. Having said that, what you think is to introduce Galfan in car body components rather outer components or non-visible parts. If you wanted to be introduced as a physical car body component, you first have to get rid of the denting problem which Scott Bluni told us about yesterday. I think this piece of work should be carried on as a research project just because of that. It would also presumably open new doors for Galfan to expand its market share.

There is another problem which hasn't been considered here. It is the problem of phosphating the Galfan-coated material. As you may well know in the automotive industry, what they do is use fluoride-containing tri-cationic phosphating baths which people think would get polluted with aluminum should Galfan be treated in those lines which by the way have also to treat classically galvanized components. What they say is that in our lifetime never would an aluminum-containing protective alloy be introduced in our protection. And when I say they, I mean Mercedes-Benz in Germany.

We wanted this sort of research work to be introduced at the last ILZRO Technical Committee Meeting until we got the bad news from Mercedes-Benz that they would not like this sort of an alloy to be introduced. It is only later that some west European steelmaker company with which we cooperate very closely having heard of Galfan said *"Look, why not challenge this apparently final opinion that was given by Mercedes-Benz and why not have a research work carried on that would prove clearly that this pollution problem doesn't exist because the opinion put forward by Mercedes-Benz has not been substantiated in any way by anything else other than their deep conviction. And if good and reliable technical evidence could be offered to which there is no danger whatsoever of polluting the phosphating bath, that would open the way to new market shares; not only visible parts because if we go there we have to get rid of the denting problem but also non-visible parts such as floors in cars. These are presumably parts where the outstanding corrosion resistance of Galfan would be most needed."*

So, let me put to you that an additional field of research work should be investigated - the sooner the better. And we suggest that CRM could carry out that piece of work perhaps in direct cooperation with a major European steelmaker.

This is what I wanted you to get as message. Galfan has not covered all of its ground and I heard John in the morning to tell you about tubes, wires, about building applications, appliances, but I am sure that provided the right steps are taken at the right time, the automotive market should be also open to Galfan.

Capul: Are you surprised that the galvanize was positioned ahead of the electrolytic and the galvanneal coatings in your creep study? A lot of money is being bet by the automotive companies in North America that that's not true. That will surprise a lot of people in the United States.

Lamberigts: Perhaps but they are wrong to be surprised, because as I told you, the test conditions are such that the panels are scribed down to the substrate and Galvalume would never offer any significant cathodic protection. It has been a consistent observation in our previous research in which this diagram is taken from. Galvalume behaved much worst than the zinc base coatings.

Lamesch: Mr. Lamberigts, do you remember the pretreatment you did on the Galvalume?

Lamberigts: Well, as I said, all specimens were surface treated under the same conditions at CRM, and was the same phosphating and chromating treatment for all of the specimens.

Lamesch: It was not a very interesting thing to do because each of those metal coatings have their own optimal pretreatment and primer system.

Lamberigts: It may be a good thought - yes.

Matthews: I'm just a little confused. As far as I'm concerned, when we talk about the automobile industry, we talk about penetration and cosmetic corrosions. You were speaking specifically about cosmetic corrosion there and there has been a lot of work done on standard testing, etc. Have you compared your results with the information that has been produced by ECSC projects, by major projects of the car companies and in most of the work that has been done, they try to keep the same coating weight. Your Galfan coating was pretty heavy compared with the others.

Lamberigts: You mentioned an ECSC source. I told you that the data I showed you came from that piece of work which we are part of. That's one point. Another point is that we try to normalize the results to bring them back to a typical 10 micron thickness and the vertical scale in the diagram in fact contains a factor that was $\frac{t}{10}$ where t represented the coating thickness of the particular specimen considered. So, although it may not be that simple, we tried to introduce some degree of correction for coating thickness.

Matthews: If you are talking about cosmetic corrosion, that means outside body parts, along with that goes direct optical image (DOI). I'm also aware of that necessary things in the steel plant to get the required finish were the products that you use equal to a full finish as one would expect to go to the auto industry and if so how do you get your Galfan to that state please.

Lamberigts: That is the point which I wanted to address when I said that before Galfan could be considered for outer panels in the automotive industry, they must first get rid of the denting problem or else distinction of image (DOI) will never be good enough. But provided the Lehigh University research work is carried out to its conclusion and provided a good and reliable technical solution is found, I expect that it would be a good step forward. What I would like to concentrate my attention on is non-visible parts perhaps which could take advantage of Galfan's outstanding corrosion resistance, and that also implies that the phosphating bath pollution problem has been turned around.

Matthews: I quite agree with you in the non-visible parts the opportunity but it no longer becomes cosmetic. It then becomes perforation. Your work was about cosmetic.

Lamberigts: Right.

Hostetler: I'd like to call attention to some information being presented by Sumitomo several years ago. I also remember some information from the Swedish Corrosion Institute at Galvatech '91 that clearly confirms what Mr. Lamberigts shows. I don't think there has ever been any question that Galfan would serve as an ideal corrosion resistant and paint adhesion system. The problem has been DOI and the perception of the welding difficulties. It would not take much courage to say that if we can cure the denting problem and use nitrogen finish, that Galfan could not become a surface that is comparable to what's being used today. There's still a lot of technology involved there, but it certainly doesn't take what I would call a giant leap of faith to think that it could be accomplished. I was not surprised at the results of that graph, because we've seen similar results before.

Matthews: I'm not denying the results of the graph or that Galfan is an excellent corrosion resistant material that has been proven. I was arguing about the use of cosmetic corrosion - if it's going to be used for underbody - it's just not on - that's my point. There is no argument that Galfan is a very superior corrosion resistant material.

Lamberigts: I totally agree with you but the point that we wanted to make was that before the automotive industry can be convinced that Galfan can be used for body components, you have to proceed step by step. Today, its a final no but I think if we could improve it progressively, and provided that the drawbacks of Galfan's surface are being removed, then perhaps it would be an open door to a much larger market share - that's all I wanted to say. The final aim should be outer body parts but let us proceed carefully and let us first look at non-visible parts.

Terry Goodwin: I'm a little confused now. We seem to propose a research program to address a problem with the Western European luxury car manufacturers when earlier you were talking about exploiting the relatively low technological base of car manufacturers in India, China etc. Has anybody talked to the Chinese for example, about the problems of them pretreating Galfan in that car manufacturer?

Hostetler: In the two or three meetings and exhibitions in Czech and Slovakia, I came into contact with automotive people. Granted that one of them was a truck manufacturer - not a Lexus or a Mercedes, but clearly they have some interest in knowing whether or not Galfan can be applied to outer skin. The other one was a bus manufacturer; again, I don't know how critical DOI might be but I suspect not as critical as Cadillac or Audi. So, we may be talking about levels of sophistication or requirement here, but if the possibility exists, that market is so attractive that I would hope that we wouldn't say well let's leave that for someone else. If Galfan can make a contribution, then I think we should pursue it. The strong swing to hot dip coatings instead of electrogalvanize opens the door for Galfan. Surely one or more Galfan licensees will take advantage of the opportunity.

M. Taylor: Can I just make a comment about this proposal to look at the effects on Galfan on contact with this pretreatment system in the car industry. Are we trying to do too much. Is this something that the suppliers of pretreatment systems to the car industry should be telling us - the car industry rather than us doing it for them. They are experts in what their pretreatment system can do whereas we would spend a lot of money doing what they may be already able to do for us.

Hostetler: Yes. Good point, I hope we will not be trapped into particular patterns just because things have been done a certain way in the past. Clearly, we are in an economic and competitive situation that is different. It has never been quite this way before, so we may have to look for different ways of accomplishing our objectives and maybe it is in working in consortiums with other people If we become part of a prepaint system, regardless of whether its on a building product or automobile product, it is a *system* and has to be looked at as a system, so others are involved in that system and maybe others need to be involved in how we approach and research it.

10/93

GALFAN® Status GTRC Report
(Transcript)

John L. Hostetler

I would ask you if you haven't already done so to refer to the report in front of the Agenda and Program paper. I will not elaborate on what is already there concerning last year's activities. I wrote this primarily as a report of the activities that we have been involved with at GTRC. I am more concerned about 1994 and I'm also concerned, of course, as to whether you agree that these are the things we need to spend our time, efforts and resources on.

Galfan Seminars

Much of our effort next year needs to be devoted to producing and putting on Galfan seminars. I'm sure there will be more, but we already see three different kinds of seminars and are prepared to present any one of those three. The first one is what we call the Introductory Seminar and would be the kind of seminar that would be put on in China, South America, or a new region where Galfan has not been introduced before. We've done a couple of these and they have worked out very well. It is not a one-shot program — the seminar is the first of a continuing step of activities that are needed in order to fully develop the atmosphere and climate to get people seriously interested in licenses and in using Galfan coated products.

The second kind is new and is what I call the Regional Development Seminar. It is increasingly difficult to present all the information in a quick one, two or even three day international session. There are some things that may be very interesting and maybe even critical for one region that would have little interest or no application in another. One way to handle that effectively is to use regional development meetings. These will probably be more oriented to marketing and sales than this meeting but would certainly include research and technical information that needs to be transferred.

The third kind that we see being helpful happens when we establish a new licensee. I know that this may be difficult for existing licensees to appreciate because the first reaction may be *"You didn't do that for me, why should I be interested in having you do that for somebody else?"* But the justification is the fact that any failure, any bad start-up, any introduction of bad Galfan product into the marketplace is obviously going to have a negative influence on everybody's Galfan activities, so it is in all of our interests to make sure that when a new licensee starts into production, that their start-up is as good as it can possibly be. That means giving him the technology and the know-how the rest of us may have gained through blood, sweat and tears, but I think it is to our best interest. So, part of that effort would be to hold a one or possibly two-day seminar with the new licensees' personnel from various departments - research, production, engineering, quality control, sales marketing - to make sure that all of the information that they might be interested in and available is accurately transferred.

We will be meeting tonight at 7:00 p.m. in the Enns Meeting Room in the Schillerpark Hotel on the second floor. Any who are interested in helping to set up a schedule or to talk about the seminar ideas are invited to attend. We already have a number of seminars scheduled for next year. I would particularly like to see the alloy suppliers and the equipment suppliers attend that meeting for involvement with the introductory seminars. European licensees who agree that the regional idea is a good one, should attend to help us in making plans. North America already has a development association in place and I am sure if we did any kind of seminar it would be under the auspices of the North American Galfan Development Association.

New Licensees

It would appear that in 1994, we are going to add many new licensees. We currently have 22 companies around the world that I would call serious potential license candidates. Most of those are in new regions but some are in the existing maturing regions. Most of those will be handled by the new Galfan License and Technology Sales Representatives, and some will probably not be negotiated before we meet again, but some will be. So, some of our effort has to be devoted to following up and to supporting the efforts of the license sales representatives.

Technical Support of Licensees

Still, the number one task given to the Galfan Technical Resource Center is to support the existing licensees but I sometimes find it a difficult to know exactly how to do that. In some cases we are not really equipped to deliver the technical support that you need. In some cases it would appear a licensee may not use the support that might come through GTRC, but in many cases we have given good technical support. The kind of technical support GTRC is best able to deliver to you is the kind that can come through a regional organization or on a regional basis. I want to fulfill that part of the mandate given to GTRC but I need better feedback on just how you expect GTRC can provide technical support to you. We did institute the Constant Improvement Manual and I still think that's a good program. It obviously has to be implemented to a much greater degree than what it is right now. Even though we have an improved galvanizing alloy and an improved system, it must be constantly improved to stay abreast of other developments and I know that the idea contained in that concept of *sharing know-how and information* is going to benefit all of us. We need to get past the idea that giving away an idea on how to do something better is giving the business away. It is the same idea that works in many things, *that those who improve the total are going to benefit individually*. Developing Galfan will be so much easier if everybody agrees to share and participate.

Automotive

One of the things that we see in the new regions is the potential for automotive application. I don't think anyone has seriously thought about exposed body parts in North America, in Europe, or in Japan so far. I do however, think there are parts of the world where the automotive application is possible because the requirements are not quite as demanding and the methods for welding and so forth are a little easier for us to slip into. One of the things we do want to do is collect all the information we possibly can for automotive applications and put a portfolio of that information together for use in East Europe, China and India. That's not to say that it couldn't be used in some cases for automotive type applications in North America, Europe and Japan.

Galfan Database

We also need to establish a database for information concerning Galfan. We are not prepared at this point to establish an electronic database but we can do the next best thing — to print out a comprehensive list of abstracts or summaries of papers and articles concerning Galfan. Every once in a while, somebody will call me and say *"Did you see this article on Galfan ?"* We may not have because it didn't happen to be in any of the magazines or journals that our library scans. We do have a wealth of information and will try to expand that, but more importantly, document it so that we have a record of what is available. It is another project that seems simple, but I'm finding that it takes time.

We shall continue to promote Galfan in the new regions, Australia, China, Eastern Europe and the former USSR countries, India and Latin America. Those all appear to be good markets for Galfan and the timing appears to be right for us to present Galfan and make the initial efforts to get the licensees established. We will also continue the promotion of new applications for Galfan, especially large usage applications like roofing and highway guardrails.

What is the bottom line for the Galfan effort? If I were an alloy producer, I might look at tons of alloy that are sold as a result of these efforts. It might be a little difficult for me to get excited about Galfan wire or tube because it doesn't produce the tonnage that sheet does. But on the other hand, we certainly see that the reputation, identification, recognition and acceptance of Galfan products these other smaller applications produce does the entire Galfan community a lot of good. We will also look for more applications where Galfan can be successful where regular galvanizing cannot.

One of the next areas that we see using Galfan for the first time is the large diameter tubing. Practically all the automotive tubing in North America is being Galfan-coated. The next step will be the larger diameter tubing such as would be used for fence support systems, for electrical conduit, for irrigation piping, for any number of applications. By larger I would mean from 15 mm up to 100 mm and there are many of those coating lines around the world that can be modified relatively easily to do Galfan. I think its one of those cases where it just takes one, especially if it's from one of the leading tubing coaters, to start the process — the rest will follow.

New Processes

We are spending time to develop the single-dip electroflux wire process and the reason for that is simply that we think Galfan will become a lot more attractive to wire producers with the single-dip process. The double-dip is doing an excellent job. All the Galfan wire produced to date has been produced by that process. It is performing beautifully and there is certainly nothing wrong with it, but it is more investment intensive, it is more difficult to operate and in some cases there just simply is not enough floor space in the plant for the two-pot system. So we think its important to develop the single-dip process for wire.

We have already mentioned the batch dip process. Professor Nunninghoff and others, have been making Galfan parts with the double-dip system but we don't think that it will be attractive commercially because of its complexity and cost. We think a single-dip process is absolutely necessary. A number of people particularly in Southeast Asia have developed systems and processes that have successfully produced Galfan batch-dip coated parts in commercial or industrial settings. But, these processes use something that, in our estimation, is not industrially practical. Either the fluxes have alcohol in them or the window of operating tolerances is too tight — something is always making it an unrealistic process. The process we're developing would be industrially practical because it is similar to what the batch-dip galvanizers are already using.

Dubois: I would like some comments regarding the development of Galfan in the very far countries, I mean China and perhaps South America. The reason is you know that the spangle appearance of galvanized is usually highly desired because those panels are found in very simple markets. The way they recognize galvanize is based on the spangle, and the coating weight is also evaluated on the spangle size so I would like you to give some comments about the feeling of those people interested in Galfan, how are they planning to promote the finished sheet.

Hostetler: For the most part, the interest in Galfan is coming from galvanizers who want a better prepaint product, although we just talked to a prospective licensee last week who is primarily looking for a construction product that would be unpainted. I don't think they even raised the question about spangle size, but they were concerned about the patina. That's the exception rather than the rule. More typical is the new licensee, Federal Iron Works in Kuala Lumpur in Malaysia, who is clearly interested in Galfan is as a substrate for prepaint product. They have built a new paint line and a new CGL galvanizing line to offer a premium product based on Galfan prepaint to their market.

The interest in wire is mainly for ropes but I would suspect that once they know what the other applications of Galfan wire will be, that we'll see some serious development in those other areas. The thing behind inquiries is the need for better fishing ropes, better mining ropes or they need better wire cables of some sort. The news about Galfan is getting around. I'm not sure how some inquiries learn about Galfan. Some of them are initially directed to CRM, so they've obviously seen something or heard something that was generated by CRM. Some of them are what I call "fishing expeditions" they are really just looking for information. By the time they come into contact with us on the telephone or by fax some of them know quite a bit about Galfan's applications and what they want to do with it. What they don't know is what they have to do with their processing line in order to make Galfan.

Dubois: I had another remark. I don't know if its time now to talk about that or if it is for marketing session. I would like to hear how we attack the problem of coating weight and microns (weight and thickness). They are not the same and as we are indeed selling corrosion resistance for certain time, all the advantages are in Galfan but due to government regulation rules or standards, we have to supply the same g/m^2 as regular galvanize.

Hostetler: It's really a complicated one and I am not going to be offering an immediate solution to that. Part of it has to do with specifications. Do we go along and let ASTM and other spec-writing agencies simply write us in as an alternative to regular galvanize, or do we take the more difficult route to get a specification written specifically for Galfan? I know that a lot of specifications are being rewritten right now and we may be too late to influence them. When I first began to work for GTRC, it seemed like everybody wanted to use half as much Galfan as regular galvanize and thereby reduce the cost of the product. I do not hear that so much any more and in our promotion of Galfan, we are trying to show the major benefit is longer life - not just equaling the life by using half as much but doubling or tripling the life of the life cycle cost application.

One of the things we should talk about is the idea of the life cycle cost system which a number of the people who are selling corrosion protection on various kinds of steel applications are using to good advantage. There is even an ASTM specification covering how you use the cost of the original system and so forth to develop these comparisons. It looks like an excellent way to promote Galfan. We did do some work a year and a half ago which Andy Celestin and Phil Elser used to show comparisons of cost for Galfan-coated product vs. regular galvanized coated products to demonstrate even though one may pay a premium for the Galfan product now, over 50 years time one saves a lot of money. Whether that can become an effective tool for the sales and marketing people, I really can't answer for sure, but we can develop the technical information and software that you need to support it.

Capul: It appears to me that the wire people are one up on the sheet people. The paper that Dr. Dewitte gave yesterday had some excellent data comparing lighter Galfan coatings on wire with heavier regular galvanizing showing the lighter Galfan coatings are every bit as good if not better. We don't have that in sheet. Some of the samples that have been submitted in sheets are now too old. They were made when we were infants in Galfan and they really don't represent the product quality made today. In my opinion, we need new material tested g/m^2 , one against the other, to see at what coating weight Galfan gets better.

Hostetler: There are still a lot of unanswered questions and I think we need to continue a lot of different research efforts but I also want to suggest that we now have enough information that we can be a lot more aggressive and much bolder in our promotion of Galfan then we generally are. That's not to take away from the promotional activities the licensees have been involved in, but certainly we have been very cautious. I think that was wise until we had enough confidence from enough evidence to justify that confidence. I think we now have more than enough evidence to justify it and we really need to become more aggressive in our promotion of Galfan's use.

Matthews: I think that you didn't really truly answer the question that Mr. Dubois raised. I think it's very very important and terribly naive of anyone around this table to think that large places such as China, India and other areas which are not really reliant upon sophisticated color coated lines but are really looking at standard galvanizing's corrosion protection being synonymous with the spangle itself. I think you underestimate one thing and that is a major education and training program for the people to understand what Galfan is. When we go into these areas, although they are large markets and they may not be very sophisticated, they have it in their mind they know what galvanize is, so I think you will have to have to set up some real education and training programs because once these people put Galfan in their warehouses and the spangle-less Galfan patina comes, they'll really wonder what is going on. So I really think you need to address that and I do agree with Michelle on it.

Hostetler: We have received a lot of help particularly in the new region from equipment suppliers and I will ask Russ Grimm to comment here. Part of the reason for going to China with a seminar is that we know of at least four new world-class galvanizing lines that are in the stages of being bid or being built. I think I'm correct in that everyone of these has two pots and the only question left is what's going to go into that second pot — Galvalume or Galfan. And the same thing is true in India, and I'm not so sure that's the case in South America but certainly in China and India that's what's driving them. They may be making quantum leaps in terms of galvanizing technology if you look at what they have now and what they will have two or three years from now. I don't know how difficult its going to be for them to make that quantum leap but the fact is that's what they're looking at. They're aiming to make world-class products.

Grimm: They want dual purpose lines and what they have to do is decide *"Should we go to Galvalume or Galfan?" "What's the best application for our market or segment of the market that we're going to attack."* So, what we (Galfan) have to do is make the comparisons with Galvalume. What are the advantages and what applications should Galfan be used for or what should we stay away from and let Galvalume produce? What Tony Capul is saying is correct. They want to know. Does the Galfan GF40 compare with the regular galvanize G90 or how does it compare with the same amount of coating on Galvalume. What they're looking for is that cost per ton or the cost to produce that and the ROI. Galvalume's done a good job - they offer a twenty year guarantee. What we're facing is competition with Galvalume to be the second coating.

Dubois: Regarding the corrosion resistance, I re-make the comment I made yesterday. I think we should change a little bit of the way of evaluation. I know its more difficult, but corrosion in flat panel is meaningless. We have to look mainly for the benefits and advantages of Galfan for edge protection and zero-T bends.

<u>Hostetler:</u> I agree. As you walk around the city or look out over the roofs, its not the flat areas that generally are the problem. It's where someone drove a nail in or cut a piece off or something that's causing stain to run down the flat portion. We come back to the fact that Galfan has three major attributes. It is more corrosion resistant than regular galvanize, it is more formable than any other zinc-aluminum alloy coating that is presently in use, and it is more paintable than Galvalume. When you can combine two or more of those features, it's difficult for me to imagine how anybody could beat Galfan out of the business. So I think we can arm ourselves with more ammunition if we go after the applications where at least two of those three major attributes being of real value and where they apply.

19th Licensee Meeting

Part of next year's work, of course, will be to put on the 19th Licensee Meeting and we will talk a little more about that later.

NAGDA REPORT
(Transcript)

by Phil Elser, President

NAGDA, the North American Galfan Development Association, was formed in 1991 and for the first two years, Andy Celestin was the President. We have grown slightly during this period of time. We started out with 25 members, of which 9 were producers, 16 were associate members. We currently have 27 members; 10 producers and 17 associate members. Of the regular members, 5 are alloy producers, 2 are sheet producers, 1 is wire and 2 are tubing producers. The associate members consist of suppliers of equipment, coatings, chemicals, ILZRO and as of this past year, we have 2 of the end-users of Galfan products in our association.

The Board consists of 7 members, a wire producer, 2 sheet producers who are represented here - Andy Celestin and Howard Audferheide, a tubing producer who is our Secretary/Treasurer - he is not at our meeting, Glen Nishimura of Noranda and John Hostetler of GTRC and Tom Ranck of Ferro Technologies. Five of those members are here today and we have 3 others so we have a total of 8 NAGDA companies represented at this meeting.

Our last meeting was held in May at which time we had a general membership meeting and our three active committees also met. Those committees consist of Marketing, chaired by Glen Nishimura, Technical Application, chaired by Bob Goodhart of Weirton, and Technical Process, chaired by Tom Ranck of Ferro Technologies.

First, I'll talk about the Marketing Committee. The first thing that they're doing is to establish a library of all previous Galfan articles and papers. John mentioned earlier that GTRC is assisting in that. Also, in our Marketing Committee, all of the Galfan producers exchanged their marketing literature. It was also decided that we are going to reprint the Galfan brochure. The initial 10,000 copies that were printed have all been distributed, so we are going to have another 5,000 printed. I assume that most of you have seen one of these. If you haven't, I have a few copies with me. Another project under the Marketing Committee — We have hired an organization called CITE to answer our 800 telephone to handle inquiries for Galfan in North America. They record that information and send them a letter and literature. That list is sent monthly to Glen Nishimura who will then talk to individual sheet, wire, or tubing producers about the inquiry. CITE then makes a follow-up call within 30 days.

One of the most important things that the Marketing Committee is doing is to produce four slide presentations by the end of the year. One will be generic, to cover Galfan and the benefits of Galfan that could be presented to any audience, one customized for sheet, one for wire and one for tubing.

The next item that we discussed is the revision of the ZI-sheet *"How does Galfan compare to other coatings?"* We are updating those particular tables to be current with each product. There will be one for sheet, wire, and tubing because not all producers compete against the same coatings that are listed in the table. We also have presentations planned by members of our Marketing Committee, The Metalcon Show in October which will be Andy Celestin; the 1994 SAE Meeting a paper presented of Galfan vs. electrogalvanized on tubing which will be presented by Bill Regan and John Hostetler; in June of 94, a presentation by Don Mossgrove of Weirton at the CIS show which is the Construction Specifiers.

The Marketing Committee sets priorities for the technical committees. The Technical Application Committee also met and had each Galfan producer fill out a product availability sheet which includes size range, thickness, diameter, coating weights, the type of steels used, the coating finish and the applicable specifications for the products. The second thing that they did was to set priorities and collect information to support marketing. In this we found that we need data on Galfan corrosion resistance in soil and concrete. Weirton completed a two-year study and it was decided there was more information needed, so a five-year study was proposed to ILZRO but was not funded so NAGDA voted to fund the first year in the amount of about $27,000. We have had eight major contributors with $5,000 each from Weirton, Wheeling-Pittsburgh, NAGDA and GTRC and $2,500 each from Cominco and Noranda and $1,000 each from Eastern Alloys and Indiana Steel & Wire. NAGDA suppliers also pledged some support. That project will evaluate regular galvanize with five unpainted Galfan, three prepainted Galfan samples and two fence posts. Altogether, there will be 270 samples buried at these sites; Montreal, Quebec, Weirton, West Virginia, and Wilmington, Delaware. The plan is to retrieve a series of samples at different time intervals of six months, one year, two years, three years, etc. through five years.

Other things are being considered by the committee. The first and highest priority after the soil and concrete study is the corrosion resistance, looking at the galvanic protection comparisons, behavior of Galfan in contact with other materials, the formability of Galfan for sheet, tubing and wire, and the joining weldability of Galfan.

Our other committee that met was the Technical Process Committee. Their current work is on improving the cleaning of steel prior to Galfan coating which has also been mentioned before. It is a very definite consideration that needs to be taken care of for a single dip process.

Our next meetings will be in November of this year. Our intentions are to try to hold two meetings a year.

10/93