INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.

GALFAN TECHNICAL RESOURCE CENTER

MEMORANDUM

TO: GALFAN Process Licensees
GALFAN Alloy Licensees
GALFAN Technical Resource Center Sponsors
GALFAN Suppliers
Dr. Richard F. Lynch, ILZRO Consultant
Dr. D. Coutsouradis, C.R.M.
Mr. J.J. Hogan, Brailsford Wire

FROM: Marshall P. Roman, Director
GALFAN Technical Resource Center

DATE: March 16, 1989

SUBJECT: Minutes of the Thirteenth GALFAN Licensees Meeting
Tokyo/Osaka, Japan, 9-12 January 1989

Enclosed please find the subject minutes. These minutes do include brief summaries of the plant tours of Nisshin Steel (Ichikawa Works) and Sumitomo Metal Industries (Wakayama Works).

Total GALFAN production tonnage for 1988 (all products - sheet, wire, and tube) was approximately 145,000 metric tons. The forecast for 1989 is approximately 200,000 metric tons. This figure should be noted to be a minimum number; several licensees have indicated that their production could be higher than noted. On a cumulative basis, the half-million ton milestone should be achieved sometime this year.

Please note that a major announcement for the next Licensee Meeting in Helsinki, 5-7 July 1989, was mailed several weeks ago. Please contact me if you have not yet received any information.

MPR/ja

Encls.

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION INC.

GALFAN TECHNICAL RESOURCE CENTER

VISIT REPORT

DATE: January 9, 1989

VISIT TO: Nisshin Steel Company, Ltd.
Ichikawa Works

TOUR ATTENDEES:
Ayoub, C. - CRM
Baker, A. - New Zealand Steel
Bourgeois, P. - Galvameuse
Brinsky, J. - Weirton Steel
Capul, T. - Weirton Steel
Celestin, A. - Weirton Steel
Choi, J-W - POSCO
Coutsouradis, D. - CRM
Fujiwara, S. - Sumitomo
Fukuoka, T. - Mitsui Mining & Smelting
Furuichi, S. - NKK
Goodwin, F. - ILZRO
Hatano, Y. - Nippon Denro Mfg. Co.
Hirose, Y. - Nisshin Steel Co.
Hook, G. - New Zealand Steel
Hosoya, G. - Yodogawa Steel
Hubert, R. - Arbed
Inoue, H. - Dowa Mining
Komatsu, Y. - Sumitomo Metal
Kosaka, K. - NKK
Kubota, - Nisshin Steel Company
Lynch, R. - ILZRO Consultant
Maruyama, A. - Sumitomo Metal Industries
Maschek, M. - Voest-Alpine
Mishima, I. - NKK
Moreau, A. - Galvameuse
Moriyama, K. - Sumitomo Metal Mining
Nishimura, G. - Noranda
Nitta, S. - Yodogawa Steel
Ohori, M. - Kawasaki Steel
Pelerin, J. - Phenix Works
Pimminger, M. - Voest-Alpine
Polard, V. - Phenix Works
Rhi, J-Y - POSCO
Roman, M. - ILZRO
Sakai, H. - Kobe Steel

Ichikawa Works Plant Tour - Visit Report contd
Continuation of Plant Tour Attendees:

Shimada, Y. - Sumitomo Metal
Shijima, S. - Kawatetsu Galvanizing
Shono, K. - Dowa Mining
Sippola, P. - Rasmet
Sugimoto, K. - Maruichi Steel Tube
Sugimoto, S. - Mitsui Mining & Smelting
Suzuki, T. - Nippon Denro Mfg. Co.
Szydlik, A. - Stahlwerke Peine-Salzgitter
Tajiri, Y. - NKK
Tomita, T. - Maruichi Steel Tube
Yoshii, F. - Yodogawa Steel
Yoshimura, Y. - Maruichi Steel Tube

SUBJECT: Plant Tour - Thirteenth GALFAN Sheet Licensees Meeting

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Prior to the actual tour of the Ichikawa Works, Mr. Kubota, General Manager of Ichikawa Works gave a brief introduction to Nisshin Steel and Ichikawa Works. He began by noting the 1988 tonnage for GALFAN which was 40,000 tons and there was an increase planned for 1989. GALFAN at Ichikawa/Nisshin is called "GALTITE," the registered trademark for Nisshin Steel.

Mr. Kubota noted that the first production of GALFAN at Nisshin was done in the R&D labs in March of 1983 after a June 1982 licensing. GALFAN was then run first on pilot trials at Nisshin's Sakai Works in June of 1983. Production was then switched over to Ichikawa Works. It was noted that the first commercial production of GALFAN on the Ichikawa No. 3 CGL was in July of 1987. Note that Nisshin Steel is now licensed to run GALFAN on both No. 2 and No. 3 lines at Ichikawa Works. Mr. Kubota gave a quick explanation of the pot switch-over systems for the GALFAN/galvanize switch-over. He noted that on the No. 2 CGL, Nisshin uses the air-bearing (levitation) method to switch main pots, whereas on No. 3 CGL pure zinc is pumped out into a holding pot, GALFAN is pumped in and vice versa.

The group was then bussed to the No. 3 CGL where, at the time, Nisshin was making their galvanneal product. Throughout the tour, Nisshin representatives were present to answer questions, but due to the noise, most of the questions were saved for after lunch. Also, the No. 3 paint line was toured, where Nisshin also paints their galvanized and GALFAN product. It was noted that Nisshin uses a variety of the standard galvanizing pretreatments and also a variety of standard topcoats for galvanized products.

After lunch, Mr. Kubota, assisted by Mr. Furukawa (Manager of Technical Section, Ichikawa Works) answered a variety of questions regarding GALFAN at Nisshin.

MPR/ja

"NISSHIN STEEL - ICHIKAWA WORKS"

LINE SPECIFICATIONS

No. 2CGL

Type	Selas
Thickness	1.2 — 6.0mm
Width	710 — 1230mm
Line Speed	55m/min. (max.)
Capacity	28,000tons/month

No. 3CGL

Type	Sendzimir
Thickness	0.27 — 2.3mm
Width	630 — 1250mm
Line Speed	180m/min. (max.)
Capacity	27,000tons/month

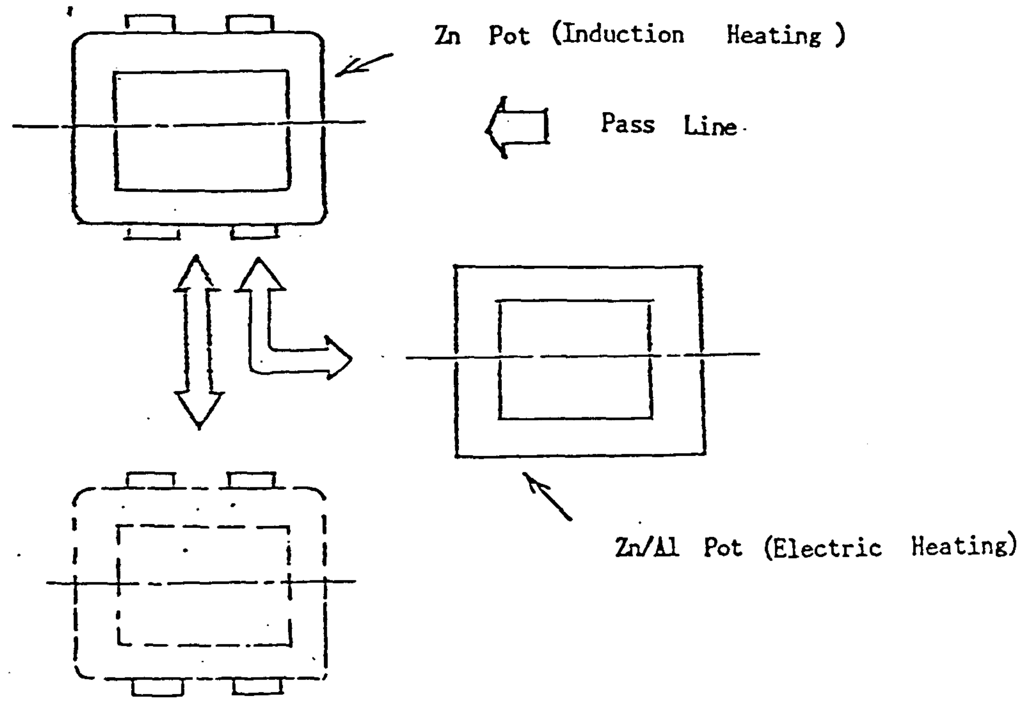
No. 1CCL

Type	2—Coat 2—Bake
Thickness	0.27 — 1.0mm
Width	610 — 1036mm
Line Speed	55m/min. (max.)
Capacity	5,500tons/month

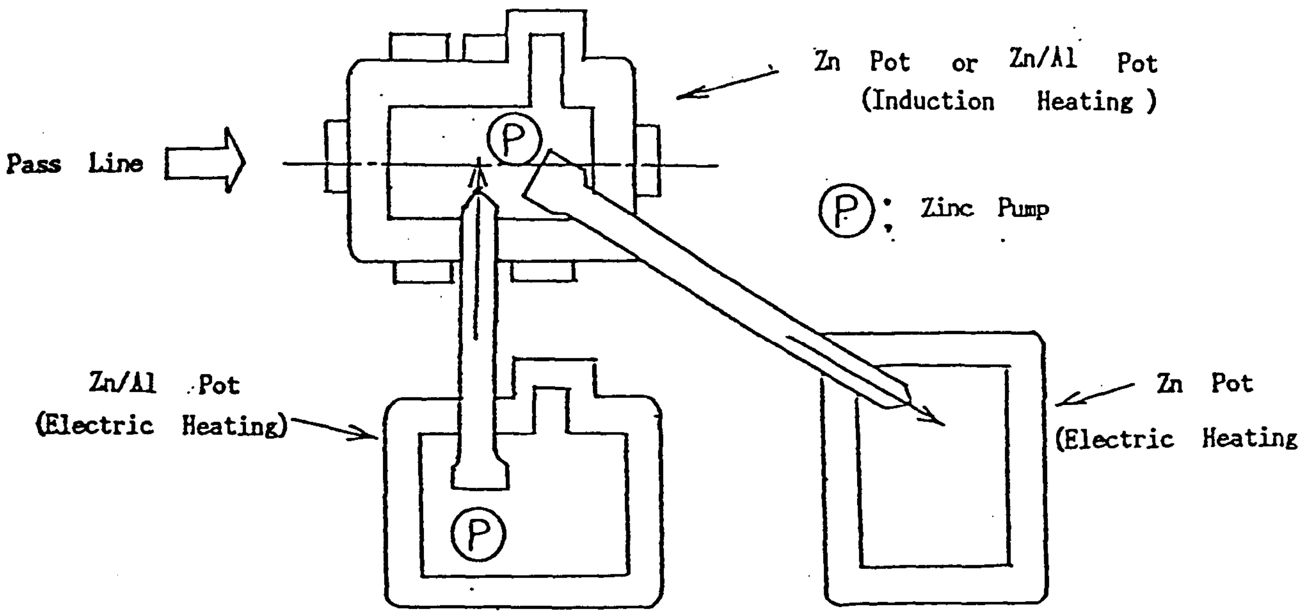
No. 2CCL

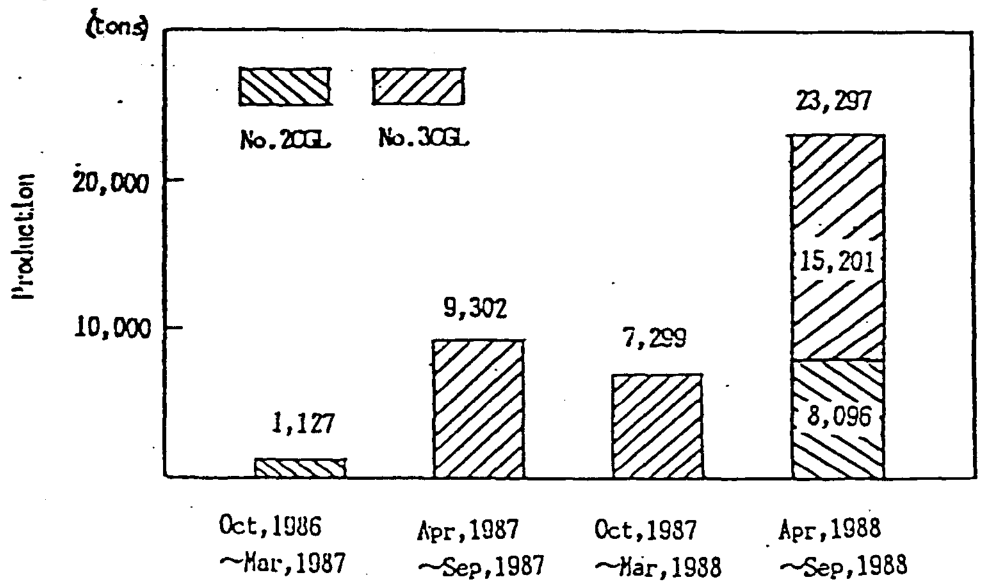
Type	2—Coat 2—Bake
Thickness	0.27 — 1.6mm
Width	610 — 1250mm
Line Speed	77m/min. (max.)
Capacity	6,300tons/month

No, 2CGL

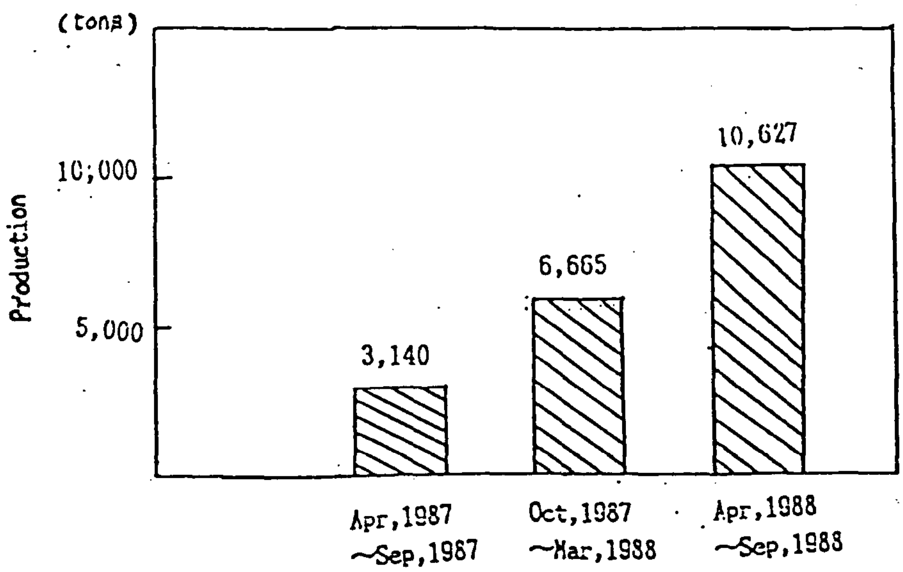


No, 3CGL





Production Of "Galtite" Steel Sheet



Production Of Paint—Coated "Galtite" Steel Sheet

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.

GALFAN TECHNICAL RESOURCE CENTER

VISIT REPORT

DATE: January 10, 1989

VISIT TO: Sumitomo Metal Industries - Wakayama Works Plant Tour

TOUR ATTENDEES:
Andoh, Y. - NKK
Ayoub, C. - CRM
Baker, A. - New Zealand Steel
Bourgeois, P. - Galvameuse
Brinsky, J. - Weirton Steel
Burgarolas, J. - PROCOAT
Capul, T. - Weirton Steel
Celestin, A. - Weirton Steel
Choi, J-W, POSCO
Coutsouradis, D. - CRM
Fukuoka, T. - Mitsui Mining & Smelting
Funahashi, T. - Sumitomo Metal
Furukawa, K. - Nisshin Steel
Goodwin, F. - ILZRO
Hatano, Y. - Nippon Denro Mfg.
Hook, G. - New Zealand Steel
Hubert, R. - Arbed
Inoue, H. - Dowa Mining
Lynch, R. - ILZRO Consultant
Maruyama, A., Sumitomo Metal Industries
Maschek, M. - Voest-Alpine
Mishima, I. - NKK
Moreau, A. - Galvameuse
Nakamura, H. - Kobe Steel
Nishimura, G. - Noranda
Nitta, S. - Yodogawa Steel
Ohori, M. - Kawasaki
Pelerin, J. - Phenix Works
Pimminger, M. - Voest-Alpine
Polard, V. - Phenix Works
Rhi, J-Y, POSCO
Rodellas, F. - PROCOAT
Roman, M. - ILZRO
Sempels, R. - Vieille-Montagne
Shijima, S. - Kawatetsu
Shono, K. - Dowa Mining
Sippola, P. - Rasmet

Tour Attendees Continued

Sugimoto, K. - Maruichi Steel Tube
Sugimoto, S. - Mitsui Mining & Smelting
Suzuki, T. - Nippon Denro Mfg. Co.
Szydlik, A. - Stahlwerke Peine-Salzgitter
Tajiri, Y. - NKK
Takusari, K. - Kawatetsu Galvanizing
Tomita, T. - Maruichi Steel Tube
Watanabe, T. - Mitsui Mining & Smelting
Yoshimura, Y. - Maruichi Steel Tube
Yoshino, S. - Nisshin Steel

SUBJECT: Thirteenth GALFAN Sheet Licensees Meeting Tour

The Wakayama Works (near Osaka) of Sumitomo Metal Industries was toured this date. Prior to the actual plant tour, a short introductory meeting was held. Dr. Hoboh of Sumitomo conducted this brief introduction. He noted that Sumitomo was licensed in 1985 for GALFAN and began commercial production in 1986. Sumitomo now produces GALFAN every month at a rate of about 1,000 tons per month or about 12,000 tons per year, for prefabricated housing uses in the bare state and roofing/siding in the painted state.

There was a thirty-minute movie introduction, reviewing the Sumitomo Wakayama Works.

After the movie, Mr. Maruyama (technical section-Wakayama Works) presented some overheads which outlined GALFAN production at the plant. These overheads are reproduced in the appendices of the minutes. Briefly, the first overhead noted on a bar chart the tonnage campaigns, the second overhead noted the breakdown of production for GALFAN at Sumitomo (62% is bare chromated material - all approximately 1.4 mm gauge and the other 38% is painted material, broken down to 21% less than .35 mm gauge, and finally the other 17% greater than .35 mm gauge). The next overhead noted that all material was temper passed or skin passed. Also noted there the bath composition, coating weight, bath temperatures, strip inlet temperature, and annealing temperature. The other overheads noted the production capabilities of No. 2 CGL as well as a schematic drawing of the No. 2 CGL.

The tour itself was very informative. Participants were allowed to wonder (within reason) extensively, asking questions at all times. Sumitomo was producing GALFAN at that time. The group congregated for quite a while around the GALFAN pot, asking many questions at that point. At the exit end, bare and painted samples were available for inspection as well as galvanized and GALFAN coils in the warehouse area. There were also scrap samples available that most participants examined closely.

Visit Report - Sumitomo Metal Industries
Wakayama Works Plant Tour
January 10, 1989

After lunch, there was an extensive question and answer period. Some of the highlights are as noted. It was noted that Sumitomo does not use any magnesium additions to the GALFAN alloy. Dr. Hoboh noted that such use was being considered for future experimentation. Dr. Hoboh noted that perhaps a level of 0.05% would be used for experimental purposes. Also noted was the fact that Sumitomo used to produce hot roll material for structural building members which has since been replaced by GALFAN. Also noted was the fact that Sumitomo uses the one main pot for GALFAN/galvanizing. They pump out the main pot into a holding pot of pure zinc. From a GALFAN holding pot, GALFAN alloy is pumped into the main pot and vice versa. The main pot is ceramic, the holding pots are stainless steel. When not in use, the molten GALFAN is allowed to freeze. It was noted that Sumitomo underwinds the finished product at the exit end. This was explained to be standard operating practice. It was thought that it was being done to put the best surface on the top. Dr. Hoboh noted that any spangle differential is due to coating weight differences from top to bottom. He noted that this is characteristic of both GALFAN and galvanized product.

It was noted that Sumitomo produces about 10% full hard material and Dr. Hoboh noted that specific presentation on their problems with that would be presented at the Thursday, January 12th, Operating Session.

There was then a series of individual questions which are now summarized. Mr. Capul of Weirton Steel asked if any work on the growth of an iron-zinc alloy layer was done at Sumitomo, specifically regarding alloy burst for deep drawn applications. Dr. Hoboh responded that Sumitomo had some experience with that phenomenon and noted that the formability is not as good. Dr. Hoboh also noted that since most of their GALFAN is produced at 4.2% aluminum, there was no experience on this phenomenon at 5.0% aluminum. Mr. Hook asked about bath temperature control. Dr. Hoboh responded that there was no pot cooling device but their product mix is well balanced and does not overheat the pot. Mr. Hook also asked what was the heaviest coating weight for GALFAN. Dr. Hoboh responded 270 grams per square meter maximum. Mr. Capul asked if there was any coating edge buildup problem on heavy gauge material. Mr. Hoboh responded that there was a similar problem to that of galvanized but is prevented with GALFAN using a bowtie profile on their air knives. The bowtie profile was noted to be spacing of 1.6 mm on the edges and 0.7 mm at the center. The question was asked about the barrier around the GALFAN pot. Dr. Hoboh noted that it was for noise prevention. Another question was asked about the potential use for nitrogen wiping and Mr. Hoboh indicated that there were no plans do to so at Sumitomo.

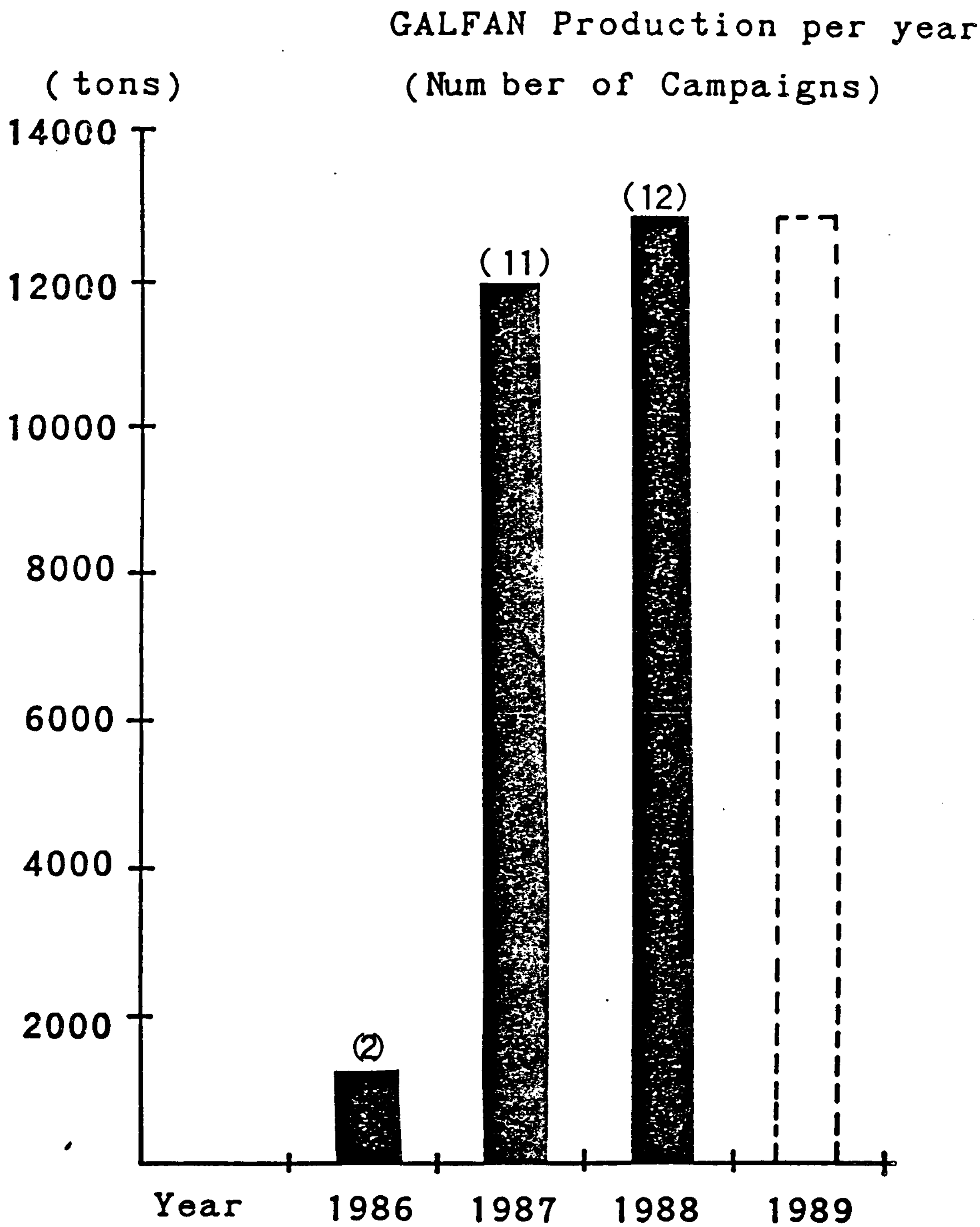
Mr. Pimminger asked what type of chemical treatment was used for GALFAN. Dr. Hoboh noted that conventional chromates were used with GALFAN and galvanize.

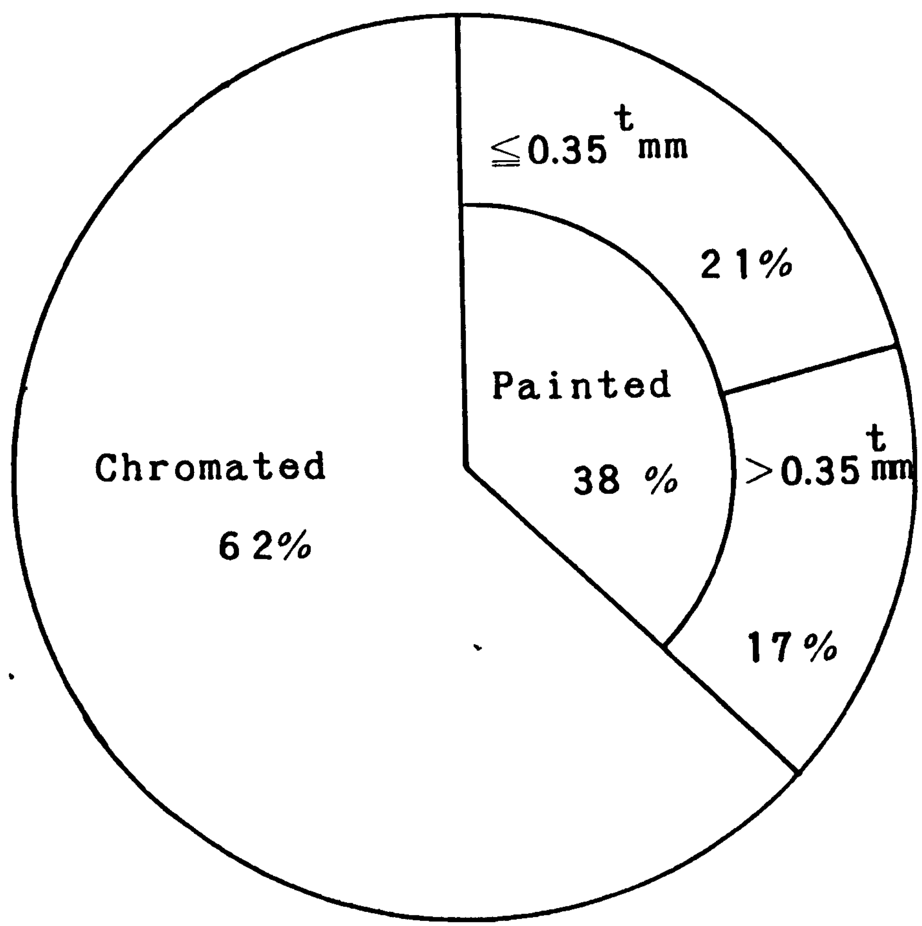
Dr. Hoboh brought up the subject of gray patina, noting that it was not a problem for their painted product, and it was not a problem for their bare GALFAN in their metal products because it is not visible. He does anticipate that it could be a problem as the market grows for GALFAN and Sumitomo aims for markets for exposed bare material.

Dr. Goodwin noted that the forecast for 1989 matched the actual production of 1988 and asked if that was due to capacity or demand. Dr. Hoboh noted it was mostly due to capacity, i.e. their line time is very limited. Dr. Lynch asked what type of paint systems were used for GALFAN and galvanized. Dr. Hoboh noted that the same systems used for both GALFAN and galvanized at Sumitomo were phosphate-based. Mr. Shijima asked about the aluminum content, noting that he saw that Sumitomo currently uses 4.2% aluminum. Dr. Hoboh responded saying that Sumitomo started out using GALFAN at the CRM recommended level of 5.2% aluminum, whereupon they saw many grain boundary dents. After two or three campaigns, Sumitomo dropped the aluminum down to its present 4.2% aluminum level. Mr. Sugimoto of Mitsui asked how Sumitomo addresses or solves the problem of alloy layer growth. Dr. Hoboh noted that temperature control of the incoming strip is controlled in order to control this problem. Mr. Hook, asked about the change-over time of GALFAN to galvanized and back. Dr. Hoboh responded that pumping actually takes one hour, but the total time for switch-over is about two shifts, normally done during scheduled maintenance downturns. Mr. Hook asked about how Sumitomo preserves their atmospheric furnace when changing from GALFAN to galvanized and back. Dr. Hoboh noted that Sumitomo uses a nitrogen air blast and they do not shut down their radiant tubes. Part of their downtime is involved in re-establishing their hydrogen nitrogen atmosphere after using pure nitrogen. Mr. Hook asked what the satisfactory dewpoint was. Dr. Hoboh responded approximately -35°C.

At this time, the question and answer period was concluded since time was growing short. Mr. Roman thanked Mr. Hoboh and Mr. Maruyama, and Mr. Hagiwara (Assistant General Manager, Wakayama Works) for their hospitality and gracious for opening up their plant to all the attendees.

MPR/ja


GALFAN Production per year
(Number of Campaigns)
(tons)
14000
12000
10000
8000
6000
4000
2000
(2)
(11)
(12)
Year
1986
1987
1988
1989


Chromated
62%
Painted
38 %
≦0.35t mm
21%
>0.35t mm
17%

	Painted	Chromated
·Annealing Temp.	720℃	720℃
·Strip Inlet Temp.	550~620℃	460℃
·Bath Temp.	460℃	440℃
·Coating Weight	180~275 g/m^2	120g/m^2
·Bath Composition		
Al	4.2%	
Pb	<0.005%	
Fe	0.02%	
La	0.003%	
Ce	0.008%	
·Skinpassing	Skinpassed	

No. 2 CGL

- Production Capacity : 12,000 T/M
- Entry Coil Dimensions

  Gauge : 0.25 to 3.20 mm

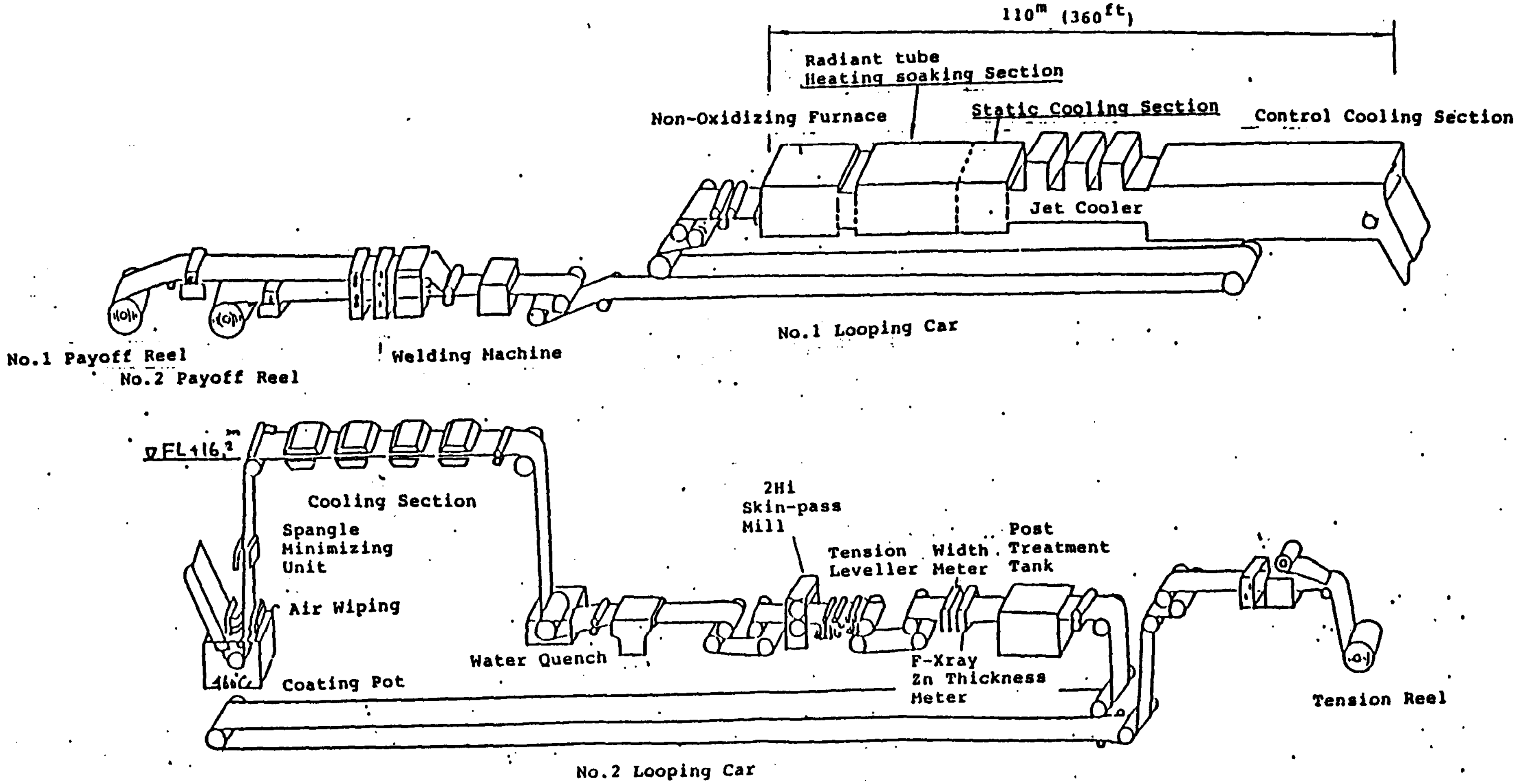
  Width : 610 to 1230 mm

  Weight (max.):33Ton
- Product

  Galvanized – Normal Spangle

  Galvanized – Minimized Spangle

  Galfan
- Line Speed : 110mpm max.



110m (360ft)
Radiant tube
Heating soaking Section
Non-Oxidizing Furnace
Static Cooling Section
Control Cooling Section
Jet Cooler
No.1 Looping Car
No.1 Payoff Reel
No.2 Payoff Reel
Welding Machine
▽FL+16.2m
Cooling Section
Spangle
Minimizing
Unit
Air Wiping
Coating Pot
460°C
Water Quench
2Hi
Skin-pass
Mill
Tension
Leveller
Width
Meter
Post
Treatment
Tank
F-Xray
Zn Thickness
Meter
Tension Reel
No.2 Looping Car

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.

GALFAN TECHNICAL RESOURCE CENTER

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MINUTES OF THE THIRTEENTH GALFAN SHEET LICENSEES MEETING

Royal Hotel
Osaka, Japan

January 11, 1989

ATTENDANCE

Name	Company
Ayoub, C.	CRM
Baker, A.	New Zealand Steel
Bourgeois, P.	Galvameuse
Brinsky, J.	Weirton Steel
Brugarolas, J.	PROCOAT, S.A.
Capul, T.	Weirton Steel
Celestin, A.	Weirton Steel
Choi, Jae-Wan	POSCO
Coutsouradis, D.	CRM
Furukawa, K.	Nisshin Steel
Goodwin, F.	ILZRO
Gotoh, H.	Mitsui Mining & Smelting Co.
Hatano, Y.	Nippon Denro Mfg. Co., Ltd.
Hirano, M.	Mitsubishi Metal
Hiromatsu, M.	Kobe Steel
Hirose, Y.	Nisshin Steel
Hoboh, Y.	Sumitomo Metal Industries Ltd.
Hook, G.	New Zealand Steel
Hosoya, G.	Yodogawa Steel
Hubert, R.	ARBED
Inoue, H.	Dowa Mining Co., Ltd.
Ito, F.	Maruichi Steel Tube
Kamio, S.	Mitsubishi Metal
Kusubashi, H.	Sumitomo Metal Mining Co., Ltd.
Lynch, R.	ILZRO Consultant
Maruyama, A.	Sumitomo Metal Industries Ltd.
Maschek, M.	Voest Alpine Stahl Linz
McAuliffe, J.H.	ZALAS
Moreau, A.	GALVAMEUSE
Moriwaki, Y.	Sumitomo Metal Ind.
Nishimura, G.	Noranda
Nomura, S.	Kobe Steel
Ogura, A.	Yodogawa Steel
Ohori, M.	Kawasaki Steel
Pelerin, J.	Phenix Works
Pimminger, M.	Voest Alpine Stahl Linz

Attendees Continued:

Name	Company
Polard, V.	Phenix Works
Rhi, Jae-Young	POSCO
Rodellas, F.	PROCOAT, S.A.
Roman, M.	ILZRO
Sempels, R.	Vieille-Montagne
Shijima, S.	Kawatetsu Galvanizing Corp.
Shiota, T.	Sumitomo Metal Ind.
Shono, K.	Dowa Mining Co., Ltd.
Sippola, P.	Rasmet
Sugimoto, K.	Maruichi Steel Tube Ltd.
Suzuki, T.	Nippon Denro Mfg. Co. Ltd.
Szydlik, A.	Stahlwerke Peine-Salzgitter
Tajiri, Y.	NKK
Takusari, K.	Kawatetsu Galvanizing Corp.
Watanabe, T.	Mitsui Mining & Smelting
Yoshimura, Y.	Maruichi Steel Tube
Yoshino, S.	Nisshin Steel

MEETING CONVENED

Mr. M.P. Roman, Director of the GALFAN Technical Resource Center, welcomed all the attendees to Osaka. He made note of and thanked both Nisshin Steel and Sumitomo for their hospitality and courtesy the previous two days tours. Mr. Roman then welcomed the newest GALFAN licensees. They are Voest Alpine Stahl, GmbH (Austria), Kobe Steel Limited, Maruichi Steel Tube Limited, and a second licensed GALFAN line for Nisshin Steel (Japan). Mr. Roman identified the second licensed line to be at the Sakai Works (it was later ascertained that both Nisshin GALFAN lines will be at the Nisshin Ichikawa Works. Nisshin Steel will run GALFAN on a No. 2 and 3 galvanizing lines). Mr. Roman then introduced Dr. F.E. Goodwin who would chair the Research Session of the GALFAN Licensees Meeting.

Dr. Goodwin welcomed all and noted that with respect to GALFAN research, the GALFAN licensees are now funding greater than 50% of the ongoing research and development. Dr. Goodwin asked all the attendees to individually stand up and introduce themselves and Mr. Roman passed the attendance roster around.

RESEARCH SESSION

Dr. Goodwin introduced Mr. Camille Ayoub of CRM who presented the ZM-285 GALFAN research work. The entire text of Mr. Ayoub's report with the reproductions of slides and figures is attached to the appendix.

Questions were asked with respect to the anodic dissolution method for measuring weight loss. Dr. Goodwin noted that all three major coatings (galvanized, Galvalume, and GALFAN) are all electrochemically different. He continued noting that the anodic dissolution method is very good for comparing GALFAN to GALFAN and GALFAN to galvanized. He asked Mr. Ayoub if this was useful. Mr. Ayoub replied that he thought that it was only good for comparing GALFAN to GALFAN, and GALFAN to galvanized. Galvalume could not be properly treated with this method. Mr. Polard just wanted to know what was the lead content in the GALFAN with lead. Mr. Ayoub replied that it was 140 ppm (0.014%). Mr. Pimminger (Voest-Alpine) asked Mr. Ayoub how he analyzed the aluminum-rich dissolved powder. Mr. Ayoub replied that he used atomic absorption. Mr. Pimminger continued by asking if there was any effect, if there was the presence of an intermetallic alloy layer. Mr. Ayoub replied that there was no effect, he can dissolve the zinc and aluminum without dissolving the iron due to each elements characteristic electric potential. Dr. Goodwin added that you can adjust the potential for the most anodic of elements presence which would be zinc and aluminum.

Mr. Ayoub wanted to clarify the effect of microstructure and results, noting that the eutectic microstructure of GALFAN yielded the best corrosion resistance. Mr. Sempels of Vieille-Montagne noted that the anodic dissolution method was developed by Vieille-Montagne and added that one reason it is ineffective for Galvalume is that there is a polarization of aluminum at high percentages of aluminum. (Galvalume has 55% aluminum). Dr. Lynch noted that the anodic dissolution method should be verified at least by another laboratory to add credence to its validity. Mr. Capul (Weirton Steel) noted that he saw that there were temper rolled samples and asked how they were minimized. Mr. Ayoub responded that all the temper rolled samples were minimized by standard methods but he could not expound any further on it because they are commercial samples and he did not have a total history on process conditions, only of what the samples actually consisted. Mr. Capul continued noting that he saw that the temper rolled and then spangled GALFAN was superior to the other samples in an industrial atmosphere. Mr. Ayoub added that this should be expected because minimized samples often have the optimal eutectic microstructure. Dr. Goodwin closed the questions on anodic dissolution by asking all the attendees if anyone else had tried to use anodic dissolution. There was no response.

These questions were raised about the discussion on the effect of aluminum content on corrosion resistance. Dr. Goodwin started by noting Mr. Ayoub's good work and asked if Mr. Ayoub had any recommendations. Mr. Ayoub replied that for unpainted GALFAN, one should produce GALFAN at the eutectic point of 5.2% aluminum as long as the grain boundary dents are of no concern. He added that the performance would be better if the product was chromated. Mr. Polard commended Mr. Ayoub for his work with the aluminum content. He did ask Mr. Ayoub to please explain the abbreviations used in his slide presentations. Mr. Ayoub responded that the SD was a 4.16% aluminum, SB was 4.54% aluminum, SC was 5.1% aluminum. Mr. Ayoub also added that the given results were in microns of thickness loss.

Dr. Goodwin thanked Mr. Ayoub for his presentation regarding the corrosion resistance of deformed GALFAN and galvanized. Mr. Nishimura (Noranda Sales) commended Mr. Ayoub for his work and asked for recommendations on optimum aluminum content. Mr. Ayoub noted that he saw his best results on GALFAN in the range of 4.7-5.2% aluminum.

The following questions/comments were with regard to the post annealing of GALFAN studies. Mr. Capul noted that it was unfair to compare chromated post annealed GALFAN to chromated galvanized (no post anneal) with regard to corrosion resistance. Mr. Capul continued noting that the comparison should be made with like samples, noting that the post annealing will burn off the chemical treatment or chromate. Mr. Ayoub noted that he would try to secure like samples for future studies. Mr. Kusubashi (Sumitomo) noted the recrystallization and grain coarsening was dependent upon temperature. He asked if Mr. Ayoub could vary the temperature of the post anneal. Mr. Ayoub responded that such temperature variation may not be possible. Normally, GALFAN coated steel is post annealed to improve the substrate and such temperatures are usually set, making a variation impossible. CRM did take samples where possible, just to study the effect on the coating. Again, the post annealing is done for the substrate (whereas post annealed Galvalume is done for the coating). Mr. Ayoub also noted that attendees should refer to their minutes of the GALFAN meeting in Naples where Dr. Makimallitila presented some post annealing work. Mr. Nishimura noted that post annealing of GALFAN had been studied and presented in Naples (6/88) and Reims (1/88). Mr. Nishimura continued noting that it seems to be quite well known that post annealing has a detrimental effect on GALFAN. He wondered if such studies should be continued. Mr. Ayoub noted that he would recommend an I-F (interstitial-free) substrate to avoid the need for post annealing. Dr. Goodwin added that the study of the effects of post annealing of GALFAN is not a high priority for continued study.

As there were no more questions, Dr. Goodwin thanked Mr. Ayoub for his very thorough presentation on GALFAN research.

ADHESIVE BONDING OF ZINC COATED SHEET STEELS

Dr. Goodwin reported on research which has recently been completed at ILZRO under ZM-343, "Adhesive Bonding of Zinc Coated Sheet Steels." Steel coatings tested with various adhesives in this program were an iron-zinc-galvannealed coating, iron-zinc electroplate, pure zinc electroplate, hot dip ultrasmooth, and GALFAN. The GALFAN coating had a composition of 5.4% aluminum. Both tensile shear and peel samples were made using these coatings for five adhesives. These were acrylic tape, low-bake one part epoxy, two-part epoxy, induction cure one-part epoxy, and one-part epoxy. The gap size was constant at .13 mm (.005 inches). Glass beads were used as spacers. The coating surfaces were either ultrasonically cleaned in acetone, or coated with a controlled amount of one of two lubricants after this cleaning. Nalco 6925 mill oil commonly used in stamping, or WD-40 spray lubricant was used. It was found that these lubricants always lowered the strengths of the adhesive bond compared to the ultrasonically cleaned condition. Some of the adhesives had solvents in them to break up oil, but this still did not give them enough advantage compared to the clean surface. It was found that the joints contaminated with spray lubricant had higher strengths than joints contaminated with mill oil. The acrylic tape was applied as is at room temperature. The low bake epoxy was cured at 250°F for thirty minutes. Two part epoxy was cured at 350°F for twenty minutes followed by 315°F for sixty minutes. The induction curable epoxy and the one part epoxy were both cured at 350°F for thirty minutes. Conclusions from mechanical testing results of samples prepared as-is was that the induction cured epoxy had the highest strengths in all steels except iron-zinc electrogalvanized. The tensile shear strengths for epoxies fell between 6.9-20 MPa (1,000-2,000 psi). Peel strengths for epoxies fell between .7-1.7 MPa (100-250 psi) except for pure zinc electrogalvanized bonded with induction curable epoxy which had a strength of 5.5 MPa (800 psi). Peel strengths for acrylic tape fell between 0.09-.23 MPa (13-35 psi). Tensile shear strengths for acrylic tape averaged 0.7 MPa (100 psi).

Corrosion testing of adhesively bonded joints with these coatings was done using the salt spray test for 0, 5, 10, and 20 days. The hot dip galvanneal and pure zinc electrogalvanized coating showed red rust immediately. The acrylic tape and two-part epoxy had the most corrosion encroachment into the joint. Induction cured epoxy showed much more encroachment then low bake or induction cured epoxies. Results on corrosion testing were that tensile shear strengths in all cases increased with salt spray testing up to 5 to 10 days. The causes for this increase was either a curing phenomenon or an increase in area and roughness of substrate with corrosion exposure. Peel strengths did not increase with corrosion testing. All tensile shear strengths decreased after 10 to 20 days corrosion exposure. The strengths of adhesives on GALFAN and iron-zinc electrogalvanized decreased less than the free zinc coated steels.

In order to improve strengths of adhesively bonded joints, spot welds can be used through the joints. It was found that successful welds could be made with a squeeze time of 60 cycles, followed by a weld time of 12 cycles, followed by a hold time of 10 cycles. Weld force used was 500 pounds for a standard class to anodes electrode. This uses a copper chromium alloy. A 30 kva spot welding machine was used. It was found that the current range for a good weld was 11,000 to 14,000 amps. The presence of adhesive for most coatings usually expands the current range making welding easier. Tensile shear strengths increased only with spot welding and induction cured epoxy together. In all their cases, the strength dropped. The welding lobes for GALFAN were shown to be rather wide. The lower end of the lobe was typically at 13,000 amps with the upper end 17,000 amps. This was valid for weld times of 8 to 20 cycles. The spacing between these welding range curves narrowed to around 2 killoamps when various types of adhesives were used. By contrast, the welding lobes for normal galvanized steel widen from 2 to about 3 killoamps when adhesive was added.

Dr. Goodwin noted that the results from this project were now available in a final report which was available from ILZRO.

Mr. Brinsky (Weirton Steel) asked if it was O.K. to compare weld lobes with different coatings. Dr. Goodwin responded that it was commonly done and is actually the subject of extensive ILZRO research. Mr. Capul asked what the aluminum percentage of GALFAN was. Dr. Goodwin responded it was 5.4% aluminum supplied by Weirton Steel. Dr. Goodwin indicated that the study could be continued, varying aluminum contents for GALFAN. As there were no more questions, Dr. Goodwin introduced Mr. Shiota of Sumitomo.

REPORT ON CORROSION RESISTANCE OF PAINTED GALFAN

Mr. Shiota presented his report on long-term outdoor exposure (5-years) on painted GALFAN and painted galvanized materials. The text of Mr. Shiota's report is reproduced in its entirety in the appendix. Mr. Shiota concluded that the painted GALFAN was superior to painted galvanized, with respect to overall corrosion resistance. This includes results on deformed samples as well as edge creep corrosion evaluations.

Dr. Goodwin commended Mr. Shiota on his work, noting that he gave an excellent report. Mr. Nishimura asked Mr. Shiota if the exposure was to continue. Mr. Shiota noted that the exposure had been discontinued after issuance of this report. Dr. Goodwin noted that it may be beneficial for all companies to lengthen their exposure tests to verify warranties. Mr. Sempels asked what the aluminum percentage was and Mr. Shiota noted that Sumitomo had obtained the material from another source because they were not producing GALFAN at the time; so he is not absolutely sure, but thinks it was approximately 4.5% aluminum. As there were no more questions, Dr. Goodwin introduced Mr. Rodellas of PROCOAT.

PROCOAT REPORT

Mr. Rodellas noted that PROCOAT has been heavily involved with galvanized and zinc alloy protective coatings for steel. Specifically, the work with GALFAN has been mostly aimed at the prevention of gray patina. Mr. Rodellas noted that PROCOAT, in order to continue and expand their work, would like to find out what some of the needs were for GALFAN licensees. He circulated a questionnaire asking for response so that PROCOAT could use it as a guideline for further work. He also handed out brochures. The questionnaire is reproduced in the appendix of these minutes. There were no questions, so Dr. Goodwin continued by reintroducing Dr. Hoboh of Sumitomo.

SUMITOMO BROCHURE TRANSLATION

Dr. Hoboh provided the English translations for the all-Japanese brochure which was handed out during the Sumitomo Wakayama Works Plant Tour of Tuesday, January 10th. Those translations are listed, page by page, figure by figure, in the appendix.

Dr. Goodwin opened the floor to any other licensees reports. There were no responses, so he introduced Mr. Roman.

PAINTABILITY REPORT-REQUEST FOR INPUT

Mr. Roman noted that he was compiling data for a report on GALFAN paintability to be issued at the next licensees meeting in Helsinki. He noted Mr. Shiota's excellent work at Sumitomo and asked if all licensees could continue their input or make input in order to facilitate a wider range of available data for this report.

Minutes of the Thirteenth
GALFAN Sheet Licensees Meeting
January 11,1989

MARKETING SESSION

Mr. Roman, who chaired the meeting, started out with a presentation on the Patent and Trademark Estate for GALFAN.

PATENT/TRADEMARK REPORT

Mr. Roman summarized the current state of the patent, the state for GALFAN, followed by a listing of the newest grants of trademark by country. These reports are reproduced in the appendix to these minutes. The highlight was Mr. Roman's reporting that the issuance of a patent for GALFAN in Japan was imminent. The Japanese patent examiner apparently had allowed all but one claim on the patent, and it was the opinion of the ILZRO corporate patent attorneys that this issue would be clarified shortly with no problems, so again, the Japanese GALFAN patent should be issued soon. Mr. Roman also noted that with respect to the Japanese trademark for GALFAN, ILZRO had applied for trademark protection for GALFAN under Classification No. 7. ILZRO already has trademark protection for GALFAN under Classification No. 6.

Dr. Hirose (Nisshin Steel) asked Mr. Roman to repeat and clarify the information given on the Japanese patent. Mr. Roman did so, noting that the Japanese patent for GALFAN was applied for in 1981. Request for examination was registered in 1982, and the Japanese Patent Office has not acted upon it until just recently. Actually, due to requests from Japanese producers at the Reims meeting of January 1988, ILZRO had asked their corporate attorneys to see if action could be expedited. Now the Japanese patent examine had examined the ILZRO patent application and had granted all the claims but one. The specific claim is not exactly known, but the ILZRO corporate patent attorneys noted that it is more of a "red tape" holdup.

STANDARDS AND SPECIFICATIONS

Dr. Lynch made a brief presentation on the current standards and specifications for GALFAN available in North America. A listing of those specifications is reproduced in the appendix to these minutes. The highlights were that the ingot specification ASTM B-750 has been revised to allow lower aluminum. It was 4.7% aluminum, it is now 4.2% aluminum, so the specification is now listed as ASTM B-750-88. Dr. Lynch noted that there were some minor modifications for some of the wire and wire strand specifications. Dr. Lynch also noted that the sheet specification ASTM A-875/A-875M has been modified for type 1 (zinc aluminum mischmetal i.e. GALFAN) and type 2 (zinc aluminum magnesium i.e. Superzinc). Dr. Lynch noted that there are currently fencing standards under consideration. He also noted the existence of other specifications in private industry such as independent Ford specifications, etc.

Mr. Szydlik (SALMAX) noted the existence of DVV specifications (not DIN) for GALFAN in West Germany.

Dr. Hirose commented on the Japanese standard JISI, noting that for the zinc-5% aluminum systems for coated steel sheets, mischmetal and magnesium are not fixed and are dependent on negotiations with customers.

Mr. Hook (New Zealand Steel) noted that the antimony specification is listed as 0.002% maximum, and asked for comments. Mr. Roman noted that he had received a request from Dr. Norm Clark of New Zealand Steel to examine that same subject because apparently deleterious effects of antimony are not noted until 0.02% antimony. Dr. Lynch added that the change in antimonies being considered for the ASTM specification. Mr. Hook asked if any of the Japanese producers could list what the typical antimony levels were as seen in normal production in Japan. Dr. Hoboh responded that Sumitomo had no experience because it is not analyzed but he feels it was very low in their galvanizing bath and therefore would be extremely low in GALFAN. Mr. Brinsky added that licensees may want to consider changing the iron specification. Dr. Lynch noted it is known that there are compositional changes from ingot to bath to coating (e.g. mischmetal). Dr. Lynch noted that perhaps there should be a survey or questionnaire regarding the subject of compositional changes from ingot to bath to coating circulated by the GALFAN Technical Resource Center. Mr. Roman replied that that could be easily accomplished. Mr. Ayoub noted that the lanthanum and cerium levels are fixed by their solubility in the molten bath and that they are not easily detected. Dr. Goodwin added that also when detecting mischmetal, it is not possible to distinguish between the pure metallic stage oxide and zinc or aluminum mischmetal alloys.

NEEDS OF LICENSEES TO BE ADDRESSED BY GALFAN TRC

Mr. Roman addressed the group, noting that there has been a lack of contact by some licensees to the GALFAN Technical Resource Center. Mr. Roman wanted to be sure that it is known that the GALFAN Technical Resource Center exists to serve the licensees and can be very effective as a focal-point for information exchange. Mr. Roman noted that in many cases, an answer to a request can be usually immediately addressed or perhaps a source that may know the answer may be contacted. Mr. Roman noted that in some cases licensees have come to him as a last resort and apparently were pleasantly surprised at the speed of a response. So again, Mr. Roman reiterated that the GALFAN Technical Resource Center may be under-utilized and licensees should be aware of its potential for their use.

Mr. Raymond Sempels of Vieille-Montagne, Belgium, representing the European Zinc Institute had some comments regarding the GALFAN Technical Resource Center and the development of the market for GALFAN in Europe. Mr. Sempels began his comments with a notation that the image of GALFAN in Europe is good. He felt that GALFAN is now at a crucial point of development. Companies involved in the production or use of GALFAN must determine where GALFAN is good and how it is best profitable. Mr. Sempels noted that the goals of EZI regarding GALFAN are as follows: Where can EZI promote GALFAN i.e. what are the best market areas to "attack," or where are the resources of EZI best applied for the promotion of GALFAN. Also needed is a better market intelligence. The needs of customers must be determined so that intelligent recommendations can be made for the product. Mr. Sempels noted that he felt the GALFAN Technical Resource Center (with its worldwide contacts) should set up some kind of GALFAN marketing strategy. He noted the GALFAN Technical Resource Center should have a role in gathering market information, i.e. where GALFAN is and could be used and why. Mr. Sempels felt that a very important program would be to develop case histories for the successful application of GALFAN. Such cases would be a strong help for further development of GALFAN.

Overall, EZI is promoting GALFAN as one of the "Four G's," GALFAN, galvanized, Galvalume, and electrogalvanized. The EZI is promoting all coatings that use zinc. It is the position of EZI that all coatings utilizing zinc deserve its attention.

Dr. Goodwin noted that he agreed with all of Mr. Sempels points and felt that some kind of market intelligence is required and necessary for all worldwide markets for GALFAN. Such worldwide market intelligence would be the most efficient way to apply the available resources for the promotion of GALFAN.

REGIONAL REPORTS

Weirton Steel Report

Mr. Roman introduced Mr. Andy Celestin of Weirton Steel Corporation who made a short presentation on GALFAN at Weirton Steel. Mr. Celestin started out by noting that Weirton Steel is the only producer of GALFAN sheet in North America. Such status is extremely restrictive to the development of GALFAN in Mr. Celestin's marketplace. Mr. Celestin continued by noting that in 1988, Weirton Steel made 15,000 tons of GALFAN in ten campaigns. He noted that it was less GALFAN than Weirton had desired to produce. He continued by noting that Weirton Steel started GALFAN production in December of 1985 and had just finished its 19th GALFAN campaign and they have produced to date a cumulative total of 25,000 tons of GALFAN. Mr. Celestin noted that for 1989, Weirton Steel forecasts twelve campaigns for

GALFAN (once per month) with a total production ranging from 20,000-25,000 tons. Weirton Steel alternates their GALFAN production between a heavy gauge and light gauge line. Weirton Steel has also come out with new promotional literature (e.g. small handout type of brochure with GALFAN coupons for examination). Mr. Celestin continued by noting that the first advertising brochure for Weirton Steel GALFAN came out in 1985 with a very limited amount of information, depending mostly on results from Europe and Japan. In 1988, Weirton Steel put out a new brochure. He noted that it has much more definitive information such as the five-year outdoor exposure data, formability data, and many pictures and case histories. Mr. Celestin noticed that anyone that asked for a copy would have one sent to them.

Mr. Celestin continued by repeating that Weirton Steel is the only sheet GALFAN producer in the North American region. He noted that Weirton Steel GALFAN is limited not by capacity but by customer acceptance of the product. In North America, customers prefer more than one supplier and do not want to be single-sourced. Mr. Celestin noted that Weirton is working with Hoesch Stahl to help satisfy some of those customers who hesitate to purchase GALFAN from only one supplier. Mr. Celestin noted that if necessary, he can work with other GALFAN suppliers for importation into the U.S. of GALFAN so that he can have multiple sources for GALFAN customers.

Mr. Celestin continued by noting that Mr. Sempels of the EZI mentioned the "Four G's," however in the United States there is an extremely strong Galvalume effort by BIEC, which is restrictive to the marketing of GALFAN. Mr. Celestin noted that in an attempt to counteract some of that Galvalume effort, Weirton Steel has developed a subsidiary to assist other companies in the initiation of GALFAN production. Mr. Celestin offered the services of Weirton Steel to any company there.

Mr. Celestin continued by noting some new uses for GALFAN. (Note that in the Pittsburgh minutes 5/87 and Reims minutes 1/88 Mr. Celestin listed GALFAN end uses in detail). In the automotive market, Weirton is developing a market for deep drawn automotive parts, especially so for Ford Motor Company. He also noted that there was some indirect supply to all the "Big Three" automakers. In the HVAC market, Mr. Celestin noted that the painted panels for air conditioner use is developing and should become a big market. With regard to painted roofing, currently that market is small in the U.S.A., (less than 2% of the roofs in the U.S.A. are metal). Mr. Celestin sees that market as the huge potential area for GALFAN as well as GALFAN painted and/or bare accessory items. Mr. Celestin continued by noting that GALFAN has replaced aluminum in some electronic air cleaners for furnaces (bare). Due to the rising price of aluminum, GALFAN was accepted as a substitutional product. A surprise market for Weirton is the use of GALFAN for toaster ovens. Initially, Weirton Steel had not approached that market due to the uncertainty of the performance of GALFAN in the environment of high temperatures. However, the toaster ovens are working at 550°F with no problems. Some other end uses were clothes dryer cylinders, ice chests in walk-in freezers, as well as some deep drawn motor housings.

Dr. Coutsouradis (CRM) noted that for roofing (industrial, commercial, residential), it is normally produced from Galvalume, so why are customers considering GALFAN? Mr. Celestin noted that in his opinion, Galvalume is an excellent substrate for use in the bare, low slope applications, whereas GALFAN is extremely well suited to applications in painted and high visibility areas. Mr. Sempels noted that he has seen some applications noted by Mr. Celestin where formability is the major parameter or selling point. Mr. Sempels wondered if compared to galvanized steel, is the selection of GALFAN due to product performance or price. Mr. Celestin noted that the selection of GALFAN is normally for performance. Normally, this gets Weirton a premium for GALFAN because it is sold as on performance expectations (i.e.,. superior corrosion resistance, superior formability, superior paintability). Mr. Celestin noted that in the U.S. galvanized and Galvalume are selling for the same price. Mr. Celestin also noted that Weirton Steel did not try to switch customers to GALFAN if they are currently happy with their galvanized product. Dr. Hoboh noted that in roofing, painted GALFAN performs better than painted Galvalume. Dr. Hoboh asked Mr. Celestin what he felt was the weak point of painted Galvalume. Mr. Celestin replied that Weirton Steel feels that the problem with painted Galvalume is the propensity for edge creep corrosion. Dr. Hoboh asked Mr. Celestin what type of pretreatment is used for painted Galvalume in the U.S. Mr. Celestin responded that he was not exactly sure, but felt it was probably some type of chromate. Mr. Celestin repeated the opinion that he felt painted GALFAN is best suited for high slope, highly formed roofing applications. Dr. Coutsouradis asked if Mr. Celestin could define some specific markets for GALFAN applications. Mr. Celestin responded that it was tough to estimate such markets because they are in the process of creating them. For example, he feels the roofing market is a potential market of 2 million tons per year.

NORTH AMERICAN MARKET DEVELOPMENT REPORT

Mr. Roman introduced Dr. Richard Lynch who gave a marketing presentation on GALFAN development in North America. Dr. Lynch began his presentation by noting his current function as a consultant to ILZRO for the development of GALFAN in North America. Dr. Lynch made his presentation using overhead transparencies which are reproduced in the appendix to these minutes.

After Dr. Lynch's presentation, Mr. Polard asked what the production of GALFAN was in North America. Dr. Lynch repeated the Weirton Steel production of 15,000 tons in 1988 and estimated Gregory Galvanizing of Canton, Ohio to have produced 2,000 tons in 1988 (it was later learned that Gregory had only produced 500-600 tons, however not noted in the presentation was the production by Arc Tube of Canada at approximately 1,500 tons of GALFAN tubing). So, in North America, there is an approach to a 20,000 ton per year mark (including imports). Dr. Lynch felt that the potential for GALFAN production and consumption in North America is in the 100,000's of tons per year and that depends very much so on the eventual startup of a second sheet producer. Dr. Coutsouradis asked about the spot weldability of GALFAN, noting that he was wondering what do end users need (i.e. what type of tests must GALFAN pass in order for it to be accepted as a weldable product). Dr. Lynch noted that almost formal requirements for welding of GALFAN conform to the Ford specification to the 2,000 spot weld minimum prior to redress. Dr. Lynch repeated the fact that Weirton Steel has been developing (with ILZRO, Edison Welding Institute, MIT) the upsloping technique to always exceed the 2,000 spot weld minimum. Otherwise, it is too early to know what auto manufacturers may require. Dr. Lynch noted that in North America, the automotive market has been very heavily geared towards electrogalvanized product for the past five years and is only now beginning to look at other materials.

EUROPEAN ZINC INSTITUTE PRESENTATION

Mr. Roman introduced Mr. Sempels of Vieille-Montagne, representing EZI. Mr. Sempels started by noting that what the position regarding GALFAN by EZI is and what work has been done by EZI for the promotion of GALFAN. Mr. Sempels noted that EZI is a supporter of GALFAN research projects, as well as the GALFAN Technical Resource Center. As he had stated previously, the zinc industry should establish a positive image for GALFAN and he felt that steel companies should have a larger, more active role in such promotion. On the promotional side, Mr. Sempels noted that he had had good responses from the GALFAN brochure but better response through the issuance of Press Releases on GALFAN. He felt that the Press Releases were an excellent tool for the promotion of GALFAN.

A second step is the need for more active promotion by the steel companies and EZI stands ready to help such steel companies in their promotion. He added that EZI would decide in 1989 the extent of this type of activity.

Mr. Sempels noted some of the work done by EZI on GALFAN. He noted that Mr. Alan Stoneman of ZDA-London had presented a GALFAN paper in Plovdiv, Bulgaria last year. The large project now ongoing sponsored by EZI is the development of GALFAN in eastern Europe. EZI has Mr. Frank Porter (formerly of the ZDA-London) working on this project for them. Initially there was an effort to promote GALFAN in Czechoslovakia. That effort is now aimed towards the U.S.S.R. and Poland. Mr. Sempels noted that Mr. Porter, Mr. Roman, Dr. Coutsouradis, and Mr. Pesonen of Outokumpu Oy are going to the Soviet Union for active promotion of GALFAN in February. He also added that there is a galvanizers conference in May of 1989 to which Mr. Porter will probably go.

Mr. Sempels concluded by noting that through better market intelligence, EZI can best serve all markets with promotion of GALFAN and all "Four G's."

PRODUCTION FIGURES AND FORECASTS

Mr. Roman started this part of the meeting by noting that he was just going to go around the table to each producer to ascertain their 1988 production of GALFAN, as well as the plans for production in 1989.

Yodogawa

Dr. Hoboh noted again that the production in 1988 was 12,000 tons and that is the forecast for 1989 - 12,000 tons. Most of the product is prepainted for roofing applications and there are also some bare applications for structural members.

Nisshin Steel

Mr. Furukawa noted that in 1988 Nisshin Steel had made 43,000 tons of GALFAN. He noted that the breakdown was 15,000 tons on No. 2 CGL and 28,000 tons on No. 3 CGL. He noted that in 1989 the forecast is for 59,000 tons minimum production of GALFAN. The planned breakdown was for 26,000 on No. 2 CGL, and 33,000 tons on No. 3CGL. He noted that this figure may go up.

Kawasaki-Kawatetsu Galvanizing

The production for 1988 that Kawatetsu was 13,000 tons of GALFAN. The forecast for 1989 is 12,000-13,000 tons. Most of the product is painted (95% minimum) for construction applications.

Sumitomo Metal Industries

Dr. Hoboh repeated the figures given in the previous day's tour. They are 1988 production tonnage of 12,000, with a forecast for 12,000 tons in 1989. Dr. Hoboh added that the vast majority of this material is for painting. The product breakdown is noted in the visit report to Sumitomo's Wakayama Works.

NKK Corporation

Only recently licensed, (December 1987) NKK had made two trials of GALFAN, one in November and one in December, with only several hundred tons produced. All that material is being tested and evaluated-none is being sold commercially. There is no set tonnage figure established for 1989. It is likely that there may be another trial in February.

Kobe Steel

Kobe Steel, only licensed on December 20, 1988, is in the process of evaluating GALFAN at this time and it is too soon to come up with production figures.

Maruichi Steel Tube

Maruichi, only licensed on December 22, 1988, is also just evaluating GALFAN. Maruichi is building a new galvanizing line to be commissioned in late 1989 at which time they will implement the use of GALFAN.

Weirton Steel

Mr. Celestin repeated the figures of 15,000 tons produced in 1988 with planned production of 25,000 tons in 1989.

Gregory Galvanizing

Dr. Lynch thought that Gregory had produced 2,000 tons of GALFAN in 1988 and it is likely they will produce the same in 1989. (It was later learned that Gregory had produced only 600 tons in 1988 - the forecast for 1989 should be for no more than 1,000 tons).

Arc Tube

Mr. Roman reported that Arc Tube had produced 1,500 GALFAN in 1988 with a planned production of 2,000 tons in 1989. Arc Tube is supplying Ford Motor Company with GALFAN tubing for all Fords built in North America.

Indiana Steel and Wire

Mr. Roman reported that Indiana Steel and Wire had produced an unspecified amount of GALFAN wire for experimental purposes in 1988. He noted that he would expect ISW to become a commercial producer of GALFAN sometime in 1989 but no tonnage could be quoted at this time.

ARBED

ARBED produced 4,100 tons of GALFAN wire in 1988 with plans to produce 4,500 tons in 1989. Dr. Hubert noted that the majority of applications were for the vineyard and agricultural industries.

Phenix Works (Galvameuse)

Mr. Polard indicated that Phenix had produced no GALFAN in 1988, with no plans for production in 1989. It is possible that Phenix Works may initiate trials at the end of 1989, but for the time being, there is no capacity for the implementation of GALFAN. If and when Phenix does initiate GALFAN production, Mr. Polard felt that most of the product would be for painted applications.

SALMAX (Stahlwerke Peine-Salzgitter)

Mr. Szdylik indicated that SALMAX had made two campaigns of GALFAN in 1988, one with 700 tons and the other was approximately 500 tons. In 1989 they hope to produce 2,000 tons of GALFAN in three campaigns.

Hoesch Stahl

Mr. Roman reported that Hoesch Stahl had produced 32,000 tons of GALFAN in 1988 with a forecast production figure of approximately 35,000 tons for 1989.

Voest-Alpine Stahl

Mr. Maschek and Mr. Pimminger reported that Voest-Alpine, only licensed in November of 1988, will start GALFAN production sometime in 1990. They are building a new line, utilizing the two pot technology system.

Rautaruukki Oy

Mr. Sippola of RASMET, speaking for Rautaruukki had made 2,000 tons of GALFAN in 1988 an they hope to produce a 10,000 ton campaign in March. If that campaign is working successfully, they hope to go into continuous GALFAN production with a capacity for 100,000 tons per year.

New Zealand Steel

Mr. Hook noted that there had been no GALFAN production in 1988 at New Zealand Steel. He noted that New Zealand Steel hopes to produce some GALFAN in December, possibly. It is very dependent upon the status of the company which is in the process of being sold.

Galvanor-Ziegler

Mr. Roman reported that Galvanor Ziegler had produced 2,000 tons of GALFAN in 1988 and had forecast 5,000 tons for 1989. (Note that Galvanor-Ziegler "hosted" the January 1988 GALFAN Meeting in Reims, France.)

ICMI

Mr. Roman reported that there had been no GALFAN production in 1988 in Naples, however it was forecast that there should be 5,000 tons of GALFAN produced in 1989. (Note that ICMI "Hosted" the June 1988 GALFAN Licensee Meeting in Naples, Italy.)

Trefilunion Lens

Mr. Roman estimated that approximately 4,000 tons of GALFAN wire had been produced in 1988 and estimated that production may be in the range of 5,000 tons for 1989. (Note that the forecast for 1988 production from the "Reims" minutes - January 1988 was 2,500 tons. A more realistic estimation of 1989 production is probably 3000 tons.)

FFM

Mr. Roman reported that there had been no production in 1988 of GALFAN by FFM and no plans to produce any GALFAN in 1989. FFM's galvanizing lines have only recently been restarted after major rebuilding and they are quite booked-out.

Bekaert

Mr. Roman reported that Bekaert produced approximately 2,500 tons of wire in 1988 with a forecast for approximately 3,000 tons in 1989.

ENSIDESA

Mr. Roman reported that ENSIDESA had produced no GALFAN in 1988 but were planning initial production trials in the range of 2,000-3,000 tons in 1989.

SCHEDULE FOR NEXT MEETING - JULY 1989

Mr. Roman, prior to concluding the meeting, noted that the July 1989 GALFAN Licensee Meeting will be a joint Sheet-Wire/Tube Meeting to be held at the Hesperia Hotel in Helsinki, Finland, highlighted by a tour of the Hameenlinna Works of Rautaruukki Oy. A copy of the pertinent hotel information with a tentative schedule is attached to the minutes appendix. Mr. Roman reiterated the importance of registering early to avoid confusion. The dates for the meeting at July 5,6, and 7, 1989 (Wednesday, Thursday, Friday).

At this point in time, no site has been chosen for a January 1990 meeting.

CONCLUSION

Mr. Roman noted that prior to the actual conclusion, that the operators session of the next day has been restricted for the first time to only active producers of GALFAN. Mr. Roman noted that he did this in order to solicit a more open atmosphere in the meeting. Mr. Roman noted that he had observed the Operating Session to become mostly a listing of tonnage, gauges, widths, coating weights, etc. and felt that a restriction of the meeting would allow the operators to be more open i.e. "roll up their sleeves" and get down to the business of galvanizing and GALFAN. Mr. Roman noted that depending on the success of the next day's meeting, the meeting in Helsinki may or may not be restricted.

Mr. Roman began to conclude the meeting by reviewing the days meeting as well as the previous two days tours at Nisshin Steel-Ichikawa and Sumitomo-Wakayama. Mr. Roman thanked the respective companies for their hospitality and openness in conducting the tours, noting that a successful meeting always has a good plant tour (or two plant tours in this case) to attract attendees. Mr. Roman also thanked Mitsui Mining & Smelting (especially Mr. T. Fukuoka) for all their assistance in the organization of the meeting. Mr. Roman thanked all the attendees for all their input which made the meeting very successful and concluded the meeting at 1700 hours.

MPR/ja

Attachments

13TH GALFAN SHEET LICENSEES MEETING

OSAKA - JANUARY 1989

C. AYOUB

Comments on the slides

S 2 - *This presentation completes the results given during the former Galfan meeting in Naples, in that first the anodic dissolution method for weight loss determination is more thoroughly presented. The second subject deals with the corrosion resistance of Galfan coatings with different Al contents. The third subject is about the corrosion resistance of bent coatings.*

In formability, only bending has been tested up to now. In this presentation, elongation and stretching are discussed.

Concerning post-annealed Galfan coatings, their corrosion resistance and formability were compared to normal Galfan and Galvanized.

S 3 - *The anodic dissolution method is justified by these curves giving, for outdoor exposed industrial Galfan coatings, the weight loss related to the dipping time in a CrO_3 solution 80 gr/l, for 2 temperatures. We notice that these weight losses increase continuously with time.*

S 4 - *In the case of galvanized coatings, the tendency is to reach a constant value after 10 min of immersion.*

S 5 - *This slide gives the principles of the method, which consists in applying a constant current to the sample (WE) via a Pt counterelectrode (CE), and to record V(t). The electrolyte is an acetic buffer (pH 5.3) deaerated with N_2 bubbles.*

If i is $< i_{crit}$, Zn and Al will be dissolved separately and the curve V(t) will give 2 plateaux each of it being characteristic of the dissolution of 1 element. In case $i > i_{crit}$, both elements will be polarized (and thus dissolved) simultaneaously and erronated results are obtained.

The dissolution periods of each element are used by Faraday's law in order to calculate the weight of uncorroded material.

N.B. : It should be specified that only dissolution of uncorroded metals is a current consumer reaction. The dissolution of oxides is achieved by reaction with hydronium ions and do not consume current.

S 6 - *For the accuracy sake of this method, it was important to check if Faraday's law effectively matches with reality. Therefore, anodic dissolution of uncorroded Galfan coatings were performed, and samplings were achieved at times (S5) a, b, c and d, and the Zn and Al contents analyzed.*

The results prove that : - the analytical and theoretical values are quite comparable; - In b, only 0.5 % Al are dissolved and are balanced by the zinc which is subsequently dissolved with the Al (0.02 meq).

At the end of the trial, 3.5 % Al were dissolved; however when taking into account the weight of the disaggregated material remaining on the WE (2 mg), we notice that we reach 5.0 % Al.

S 7 - *This method has been systematically applied to the samples involved in the long term exposure program. Here are presented 2 examples which show how to estimate the dissolution periods of Zn and Al. Also are indicated the remaining weights.*

S 8 - *Based on these curves, this slide gives the details of the estimation of the total weight of uncorroded material.*

S 8'- *Considering the samples involved in the long term outdoor exposure program, after 3 years of exposure in 4 different sites.*

S 9 - *The application of anodic dissolution gave the following results, determined for both exposed and unexposed faces, thus giving a mean value.*

S 10 - *According to the initial characteristics of the exposed panels, we were able to investigate the influence of some process parameters on the outdoor corrosion resistance, ...*

The comparison of Galvanized and Galfan shows a thickness loss ratio ranging between 2.0 and 3.8.

S 11 - *This slide gives a better view of the influence of each of the process parameters on the thickness loss. We notice that these effects depend greatly on the exposure site, as shown by the next slide.*

S 12 - *We notice that the effects of chromation and microstructure are the most important in the marine sites, whereas the effects of minimization and presence of Pb were dominant in the industrial and rural sites.*

S.a - *The influence of the Al content (in Galfan coating) on the corrosion resistance is investigated through different testing methods.*

S.b - *First, polarization measurements, performed in an aerated 0.5 M neutral NaCl solution. We notice that these curves show that the 5.0 % Galfan presents a higher corrosion resistance than that of 4.0 and 4.6 % Al.*

S.c - *From these curves, the following parameters were estimated :* i_{corr}, R_P *(Stern-Geary),* i_{Pl}, *cath slope,* $i_{-1.5V}$, τ.

Sd & Se - *Give the values of these parameters. In both cases (regul/min spangle coating), we notice the improvement of* R_P, *corresponding to a decrease of* i_{corr}. *Also the decrease of* E_{corr} *is significant as well as the evolution of* τ.

S.f - *It would also be interesting to check the polarization behavior in other corrosive media.*

S 13 - *Accelerated tests have been performed on Galfan coated sheets, coming from the simulation equipment. Four Al contents and 2 cooling rates were investigated through a 10 ppm accelerated test.*

S 14 - *The evaluation has been performed through cross-sectional microscopy after 3 weeks and 5 weeks of exposure.*

We notice that the slowly cooled 4.0 % Al Galfan is severely corroded.

S 15 - *Whereas the rapidly cooled 4.0 % Al Galfan exhibited a significantly higher corrosion resistance, but still shows a high concentration of local corrosion due to the significant amount of Zn-rich globules.*

S 16 - *A similar behavior is shown by the slowly cooled 4.6 % Al Galfan, which is severely corroded after 5 weeks of exposure.*

S 17 - *The rapidly cooled 4.6 % Al Galfan leads to narrower pits although few deeper and larger pits are stil present.*

S 18 - *The slowly cooled 4.9 % Al Galfan shows a more homogeneous corrosion evolution which could be comparable to that of eutectic Galfan.*

S 19 - *The rapidly cooled 4.9 % Al Galfan behaves similarly to the eutectic Galfan. We notice that only intercellular corrosion is present. The general corrosion is highly homogeneous.*

S 20 - *The same comments could be stated with respect to both slowly and rapidly cooled eutectic Galfan.*

S 21 - *A third program investigating the influence of the Al content deals with industrial coated sheets where mainly SB and SC are the most comparable samples.*

S 22 - *Corrosion progress data from bare edges are given after 3 increasing exposure periods in a 10 ppm SO_2 atmosphere. Data are standardized for an initial thickness of 20 μM. We notice that the difference of progress data between SB and SC increases at higher exposure periods.*

S 23 - *A microscopy examination of the samples exposed 20 weeks showed that the 4.0 % Galfan is severely corroded, exhibiting locally a complete corrosion of the coating.*

S 24 - *A better resistance is exhibited by the 4.6 % Al Galfan which is stil showing locally a pitting corrosion around primary phases.*

S 25 - *Whereas an excellent behavior is shown by the eutectic alloy, which exhibited generally a homogeneous corrosion evolution, with some few intercellular corrosion.*

A case of local corrosion was observed, and is due to the presence of a zinc-rich globule and that of a nearby zone containing Al-rich nodules.

S 26 - *Corrosion resistance has also been tested through outdoor exposure in 3 different sites. Thickness loss data after 1 year of exposure gave significant differences between the eutectic Galfan and the others, even in the rural site.*

S 27 - *Standardized corrosion progress data from bare edges evidences the considerable advantage of an eutectic alloy.*

S 28 - *A cross-sectional microscopy study evidenced the harmful consequences caused by the presence of Zn-rich globules, here pointed out by arrows. It is clear that a severe interphase corrosion is generated by the presence of these phases, which are quite numerous in the case of a 4.1 % Al Galfan.*

S 29 - *A similar but attenuated interphase corrosion is shown by the 4.5 % Al Galfan.*

S 30 - *An excellent behavior is exhibited by the eutectic Galfan, except some cases of intercellular corrosion and, to a much lower extent, very few cases of corrosion of zones containing Al-rich nodules.*

S 31 - *In the industrial site, the 4.0 % Al Galfan showed the same interphase corrosion as in the severe marine site.*

S 32 - *This was also the case for the 4.5 % Al, which showed some local attacks due to Zn-rich globules, whereas the eutectic Galfan showed an excellent corrosion resistance.*

S 33 - *The same problem was encountered in the rural site by the 4.0 % Al Galfan.*

S 33'- *We also notice that even if generally the eutectic alloy proved to be excellent, the microscopy examination showed that an interphase corrosion occurred at the vicinity of a primary phase.*

S 34 - *Surface SEM examinations, of the same samples, were also performed after 1 year of outdoor exposure. The aim of this investigation was twofold.*

- *First to check the surface aspect corresponding to the corrosion of different phases that are mainly : eutectic phase, primary phase and Al-rich nodules containing phase.*

- *Second to analyse qualitatively the corrosion products of each of these phases considering the exposure site where they come from, and the Al content of the investigated Galfan coating.*

The coating here-considered is the eutectic alloy after 1 year of exposure in the severe marine site. An overview as well as a detailed view are given of the general corrosion of this coating. It is remarkable that the Cl peak is comparable to the basic line whereas the S peak is very small.

S 35 - *The presence of some Zn-rich globules in the grain boundaries leads to local attack and formation of Zn chloride or Zn oxychloride. The detail of one of these corroded phases shows that we still at the first step of corrosion because the corroded area is superficial. A SEM spectrum of these pellets demonstrates that we are in presence of a corroded primary phase because of the absence of Al. It is also interesting to notice the importance of the Cl and S peaks compared to those of the eutectic phase in S 34.*

S 36 - *This SEM picture illustrates the first stage of an interphase corrosion occurring at the separation area between a Zn-rich globule and the surrounding eutectic phase. A SEM spectrum in the corroded eutectic area (arrow) evidenced the absence of Cl.*

S 37 - *In the case of eutectic alloys, we have demonstrated many times that Al-rich containing zones are the principal cause of local corrosion. Such areas are like that shown in this slide. In our case, this area is close to a primary phase as proven by the SEM spectrum of phase Y (in D). The SEM spectrum of phase X gave no Cl but only S and a high Al peak.*

S 38 - *Considering the case of the 4.0 % Al Galfan after 1 year of exposure in the severe marine site, we notice that the Zn-rich phases are at different stages of corrosion.*

These SEM pictures illustrate the first stages of corrosion of primary phases the concentration of which is very high. This corroded state is proven by the SEM spectrum in C. Besides, it is remarkable that a Cl peak is also exhibited by the surrounding eutectic phase as shown by the SEM spect. in (D), whereas it has never been the case in 5.2 % Al Galfan.

S 39 - *Here is illustrated an advanced stage of corrosion of a primary phase, as proven by the Al X-ray image and the SEM spect. within the holes.*

S 40 - *These zones have been frequently observed on the surface of the 4.0 % Al Galfan, as illustrated by these SEM pictures and their respective SEM spectra.*

S 41 - *This slide evidences once more that the Cl present in the corroded primary phase extends to the surrounding eutectic phase.*

S 42 - *After 1 year of exposure in an industrial site, this slide gives a typical illustration of the deleterious consequences of the presence of a Zn-rich globule. The comparison of the SEM spectra shows that the S content of the primary phase is much greater than that shown by the corroded eutectic.*

S 43 - *The SEM spectrum corresponding to the general corrosion of eutectic phase gives a very low peak of S, whereas this S peak is greater in the case of zones containing Al-rich nodules (see the Al peak).*

S 44 - We also noticed the presence of encrusted Iron particles (Y in (A)). Some of these particles created locally microcells, thus leading to local corrosion of the coating as shown by the SEM spectrum in (D).

S 45 - The general state of the surface of the 5.2 % Al Galfan showed to be mildly corroded (SEM spect. in C). As in the severe marine site, the only cause of local corrosion is to be attributed to areas containing Al-rich nodules. In this case, we notice that the S peak is more important.

S 46 - After 5 years of exposure in an industrial site, the same characteristics were observed, but at an advanced stage.

First considering the Iron encrusting, illustrated by the white particles in the SEM pictures and the SEM spect. of these particles (in C).

S 47 - Second, the local corrosion of primary phase, as proven by the Al X-ray image (in D). Its S X-ray image proves that the corrosion kinetics of Zn is much greater than that of eutectic. Also with the SEM spect., we can say that the coating encloses locally a very high concentration of corroding species.

S 48 - This is an example of the last stage of corrosion of a primary phase. We are in presence of a hole which is permanently filled with electrolyte which is retained by the high degree of porosity of this area. This site could be easily considered as being permanently anodic.

S 49 - The local corrosion generated at a grain boundary dent seems to have a limited effect. This is proven by the comparison of the SEM spectrum within the dent to that performed in an Al-rich nodules containing zone.

S 49'- As to conclude this chapter, we can state that the presence of Zn-rich globules (and more specifically for hypoeutectic alloys) leads to several deleterious consequences which decrease, to a certain extent, the corrosion resistance of Galfan. ...

However, we must keep in mind that anodic dissolution data, after 1 year of outdoor exposure, proved that this effect is relatively limited and that the difference with Galvanized remains high.

S 50 - *Another program in corrosion resistance deals with bent Galfan and Galvanized coatings. Two steel grades (0.8 and 1.2 mm) and 2 coating thicknesses (15 and 20 µm) were tested. The samples were industrially coated.*

The investigation was achieved by exposing the panels in a 10 ppm SO_2 atmosphere. Three folding angles were performed. The results are given in time to appearance of 5 to 10 % of red rust at the folding ...

S 51 /

S 51'- *Illustrate the state of OT bent Galfan coatings after 140 days of exposure (except ZA3). The OT bent Galvanized resisted 25 to 28 days to red rust (according to their initial thickness).*

S 52 - *The influence of the Al content on the formability has already been tested through bending tests. In this presentation, tensile stress and stretching are investigated.*

Industrial Galfan coated sheets are used. According to the initial characteristics, SB and SC are more comparable because they have similar characteristics whereas SD (4.1 % Al) has a lower coating thickness and is mildly skin-passed. Galvanized and 55Al-Zn coatings were also tested for comparison.

S 52'- *Considering the tensile stress with an elongation of 20 %(*), we notice that the 4.0 % Al Galfan exhibits a severe cracking at the grain boundaries, these cracks propagating all along these boundaries.*

At a higher magnification, we notice that many failures occurred at the area separating the primary phases and the eutectic alloy, and that these cracks are very deep.

(*) The direction of the elongation is given by that of the arrow.

S 53 - *A similar behavior, but to a lower extent, was exhibited by the 4.5 % Al Galfan which showed also some cracks within the grains.*

S 54 - *No cracks were shown by the eutectic alloy at the boundaries, whereas the cracks within the grains are superficial, very tiny, and do not propagate.*

S 55 - *The normal spangle Galvanized shows deep cracks at most of the grain boundaries, and also a network of small cracks within the grains (length = 50 µm), which are normal to the direction of the elongation.*

S 56 - *The minimized spangle Galvanized was more severely cracked, first at the grain boundaries (the number of which is greater than that in the former case);*

S 57 - *and second within the grains where cracks could be seen propagating in several directions, these cracks extending on several 100 of µm. At a higher magnification, we notice that the coating is nearly peeling.*

S 58 - *For an elongation of 15 %, the 55Al-Zn coating shows a lower cracking density compared to Galvanized coatings. However, these cracks when generated propagate rapidly with an increasing elongation.*

S 59 - *The stretching operation is illustrated in this slide. The edges of the sample are fixed, and the dashed lines illustrate the increasing degrees of deformation of the sample, the stress being applied vertically by the punch. The investigated deformed area is that at the folding which has been submitted to a stretching stress.*

S 60 - *The surface SEM investigation gave the same results regarding the 4.0 % Al Galfan, that are deep cracks propagating all along the grain boundaries, these cracks could be partly due to the failure of adherence occurring between the eutectic phase and Zn-rich globules concentrating at grain boundaries.*

S 61 - *Failures at grain boundaries are much less concerned in the case of 4.6 % Al Galfan which shows some cracks (more or less deep) within the grains. Their density is relatively low but their mean dimension (length) is rather high.*

We also notice the deleterious consequences, of a locally high skin pass degree, on the formability of Galfan. Despite this fact, the generated crack dit not propagate.

S 62 - *Very few superficial and tiny cracks occurred in the stretched eutectic Galfan. Here also, a local decrease of the formability was noticed in a hardly temper-rolled area. Thus, we can conclude that the 5.2 % Al Galfan provides the best formability regardless the considered type of deformation, and that the more hypoeutectic a Galfan is, the more its formability is deteriorated. However, it is a matter of fact that even 4.0 % Al Galfan are still showing a much higher formability than Galvanized coatings.*

S 63 - *This slide shows that the cracks density is very high reaching a near-peeling stage. Apart the high brittleness in grain boundaries, we notice within the grains, the formation of 2 networks of parallel cracks, which are normal to each others.*

S 64 - *This slide gives another illustration of the 2 networks of cracks.*

S 65 - *Similar failure characteristics were observed for the minimum spangle Galvanized.*

S 66 - *55Al-Zn showed a better behavior than Galvanized. Its failure characteristics being similar to that observed in tensile stress, which are relatively few cracks which propagate on a broad length.*

S 67 - *The third and last chapter deals with bringing data about the corrosion resistance of post-annealed Galfan coated sheets, and also to test their formability with tensile stress and stretching operations.*

This slide gives the initial characteristics of the post-annealed samples. Al contents correspond to normal values. Two categories can be discerned : coatings with respectively a high and a low coarsening degree.

S 68 - *The corrosion resistance was investigated through a 3 weeks exposure in a 10 ppm SO_2 atmosphere. Non post-annealed Galfan, Galvanized and 55Al-Zn coatings were also used as reference material. No data were provided for Galvanized becuuse some visible red rust spots could be seen on the sample.*

The anodic dissolution data evidenced that the thickness loss increase was of 50 % for the low coarsened microstructures, and of 80 to 90 % for the high coarsened microstructures.

S 69 - *These cross-sectional microstructures show the corrosion evolution in the reference materials : ZA1 = 4.2 % Al, ZA2 and ZA4 = 4.6 % Al and 55 Al-Zn, to be compared*

S 70 - *to post-annealed Galfan. It is clear that corrosion evolves through the Al-rich phases, which could be considered as anodic sites in the Zn matrix. Obviously the corrosion resistance of Galfan is seriously affected as also confirmed by the thickness loss data.*

The difference between low coarsened microstructures,

S 71 - *and high coarsened microstructures is made clear by these pictures.*

S 72 - *Despite this deterioration of the corrosion resistance, these coatings are still better than conventional Galvanized.*

S 73 - *The formability of the low coarsened post-annealed Galfan proved to remain similar to that of normal eutectic Galfan, when submitted to tensile stress.*

S 74 - *But showed some deterioration when submitted to stretching.*

S 75 - *As expected, a sharp decrease of the formability was observed with the high coarsened post-annealed coatings, when being stretched. This result confirms what was already observed with bending tests.*

THIRTEENTH GALFAN SHEET LICENSEES MEETING

CORROSION RESISTANCE - FORMABILITY

PRESENTED BY CRM

OSAKA - JANUARY 1989

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1. CORROSION RESISTANCE

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1.2. INFLUENCE OF THE AL CONTENT AND OF THE COOLING RATE ON THE CORROSION RESISTANCE OF GALFAN.

1.3. CORROSION RESISTANCE OF BENT GALVANIZED AND GALFAN COATED SHEETS.

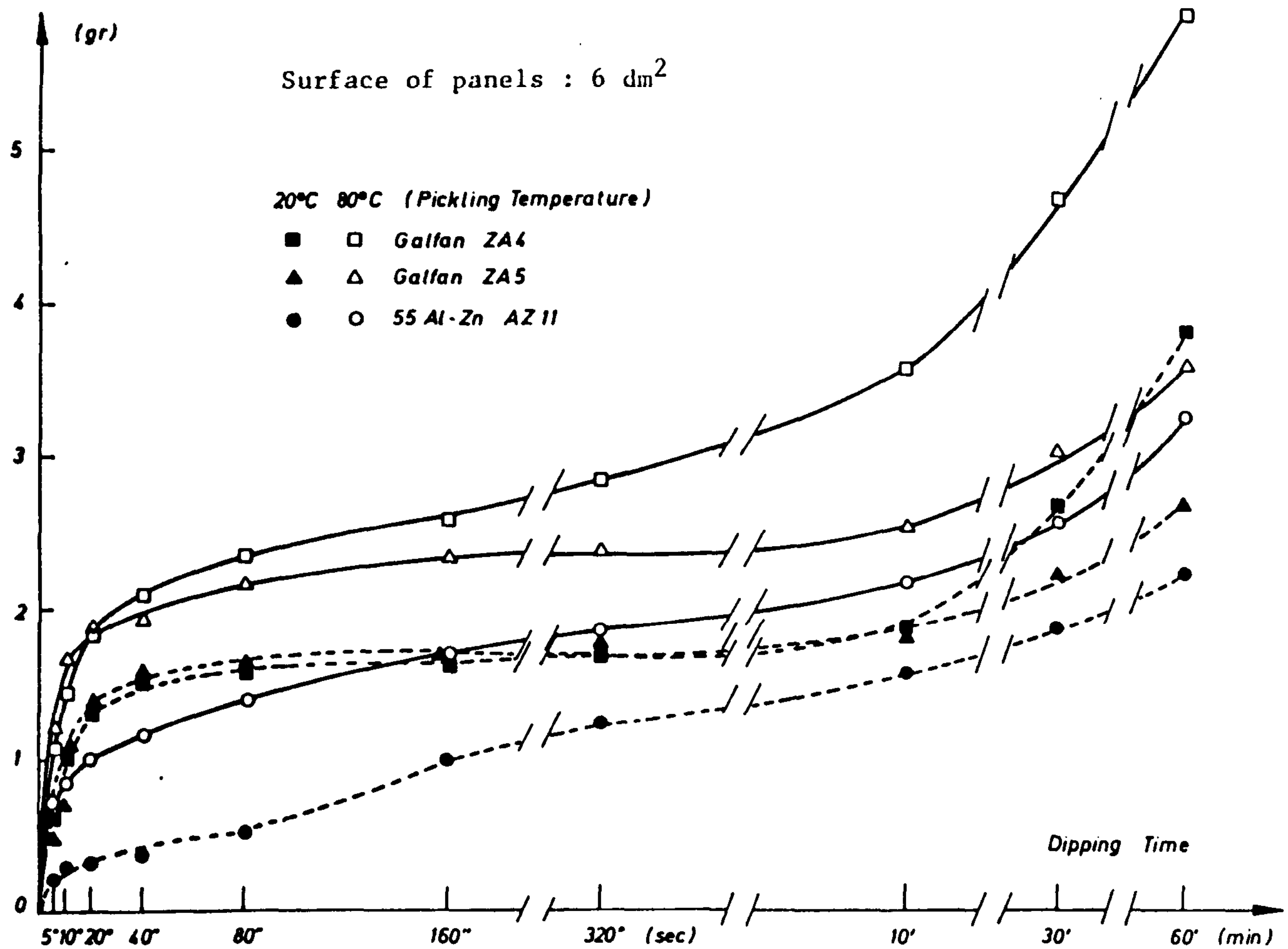
1.4. INFLUENCE OF BATCH POST-ANNEALING ON THE CORROSION RESISTANCE OF GALFAN COATINGS.

2. FORMABILITY

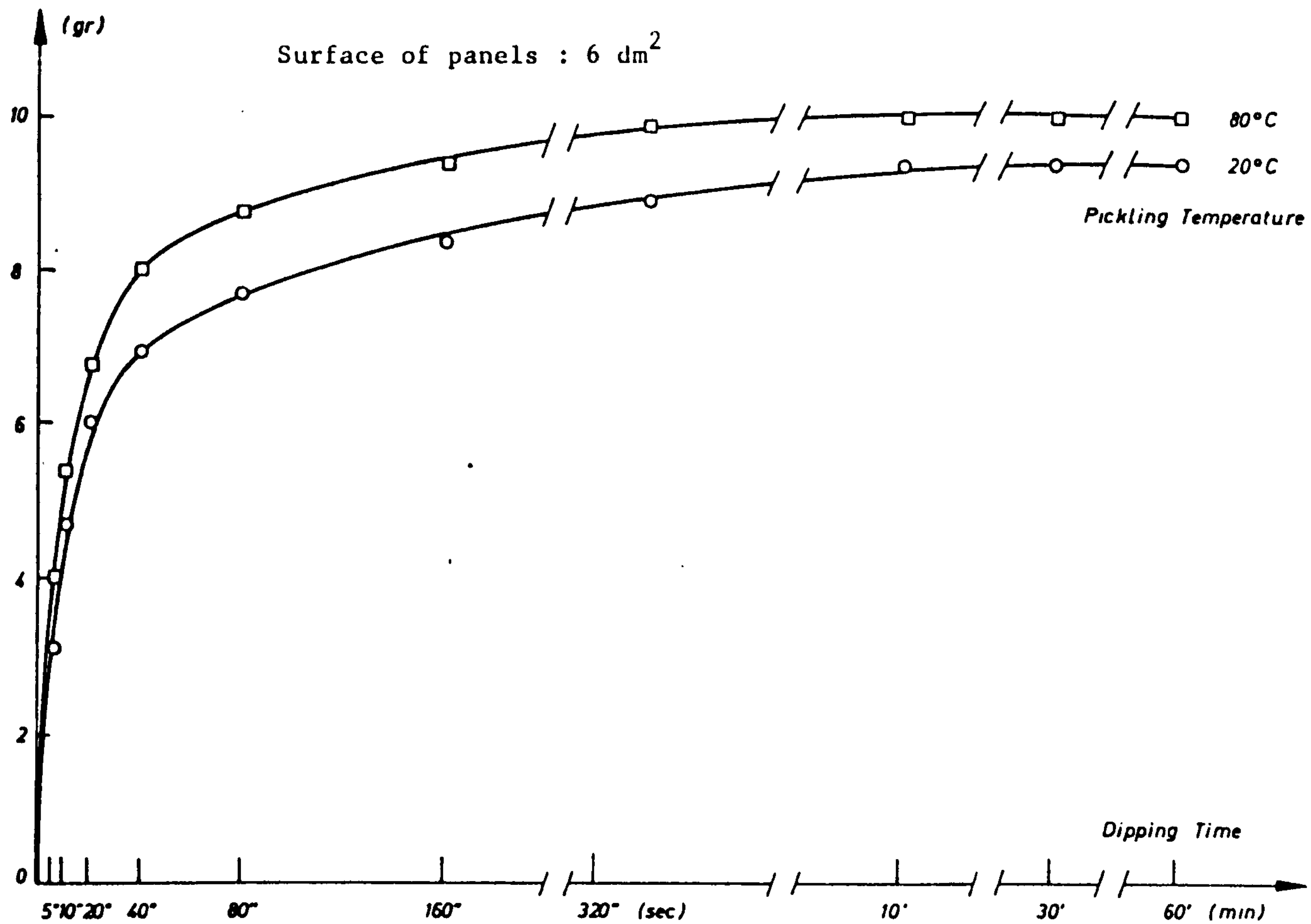
2.1. INFLUENCE OF THE AL CONTENT. DEFORMATIONS ARE EXPANSION AND [redacted]. STRETCHING.

2.2. INFLUENCE OF BATCH POST-ANNEALING. SAME DEFORMATIONS AS IN 2.1.

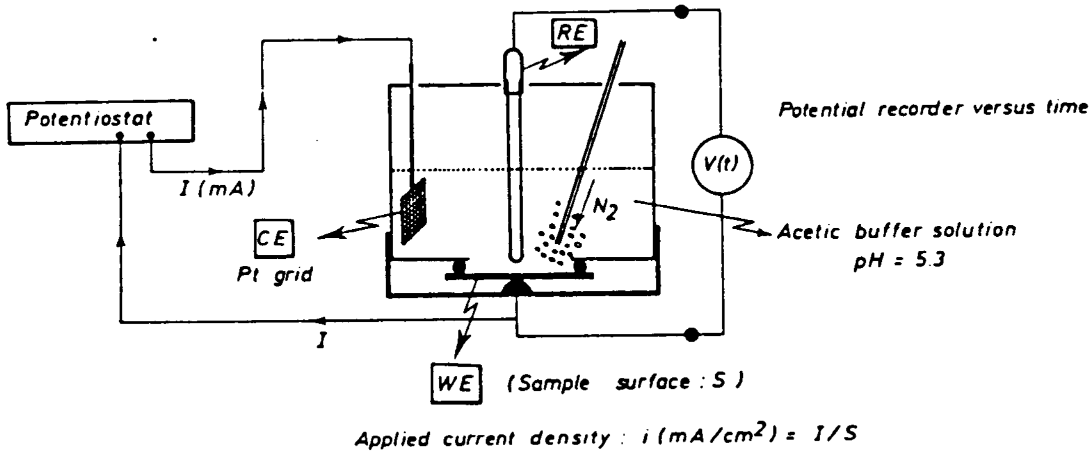
WEIGHT LOSS DETERMINATION USING THE ANDERSON-REINHARD METHOD (CrO_3 80gr/l)
INFLUENCE OF DIPPING TIME ON THE WEIGHT LOSS OF GALFAN AND 55Al-Zn COATINGS .
SAMPLES HAVE BEEN 3 YEARS OUTDOOR EXPOSED IN A SEVERE MARINE SITE .

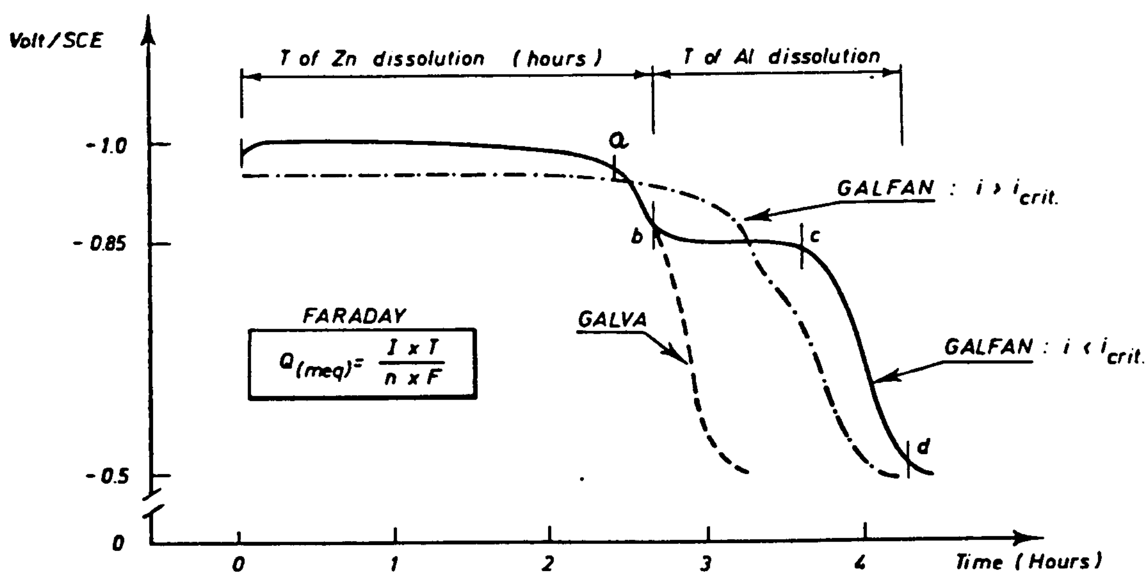


WEIGHT LOSS DETERMINATION USING THE ANDERSON-REINHARD METHOD (CrO_3 80 gr/1).
INFLUENCE OF DIPPING TIME ON THE WEIGHT LOSS OF GALVANIZED (Z9) COATING .
SAMPLES HAVE BEEN 3 YEARS OUTDOOR EXPOSED IN A SEVERE MARINE SITE .



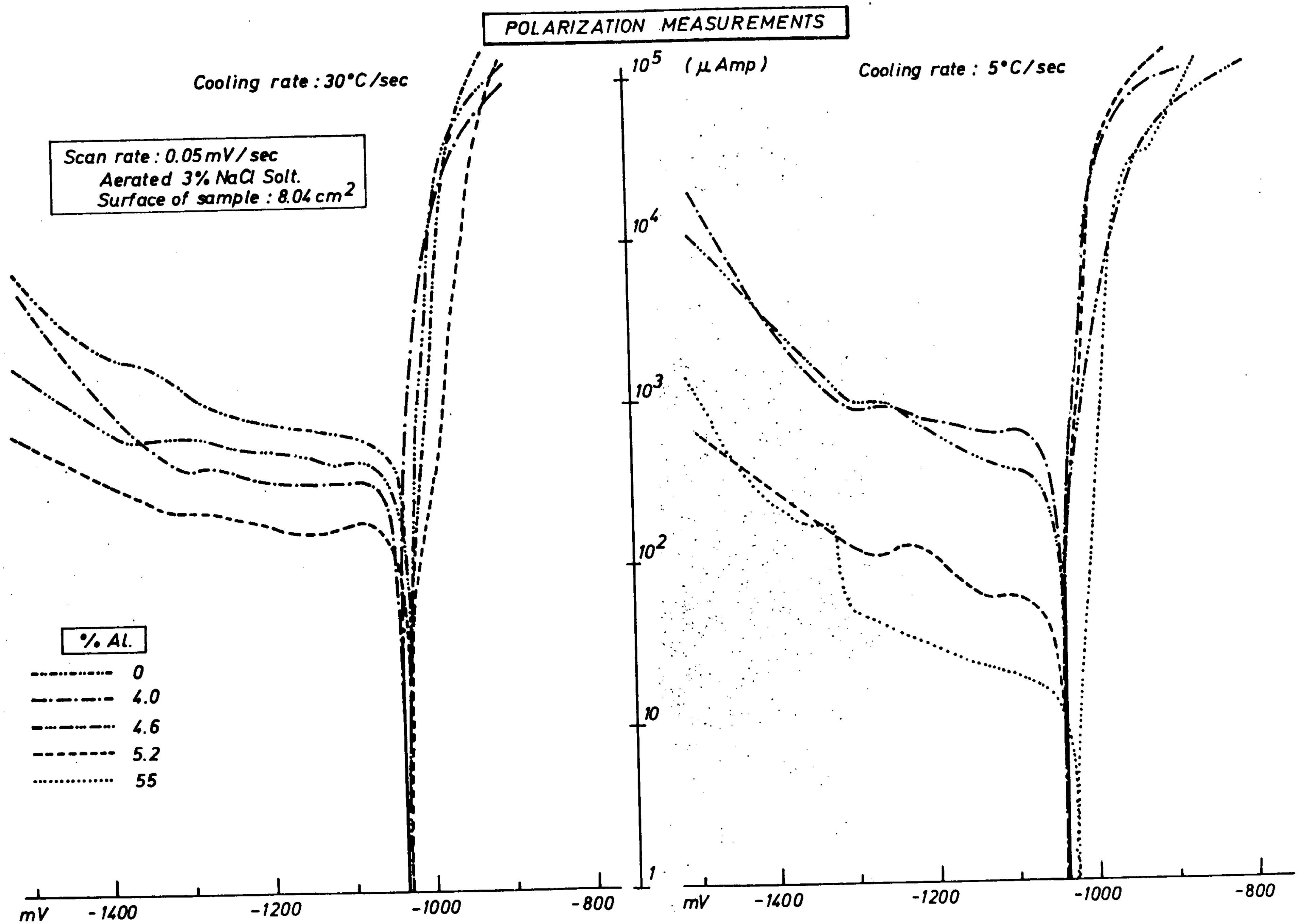
ANODIC DISSOLUTION - PRINCIPLE AND APPLICATION





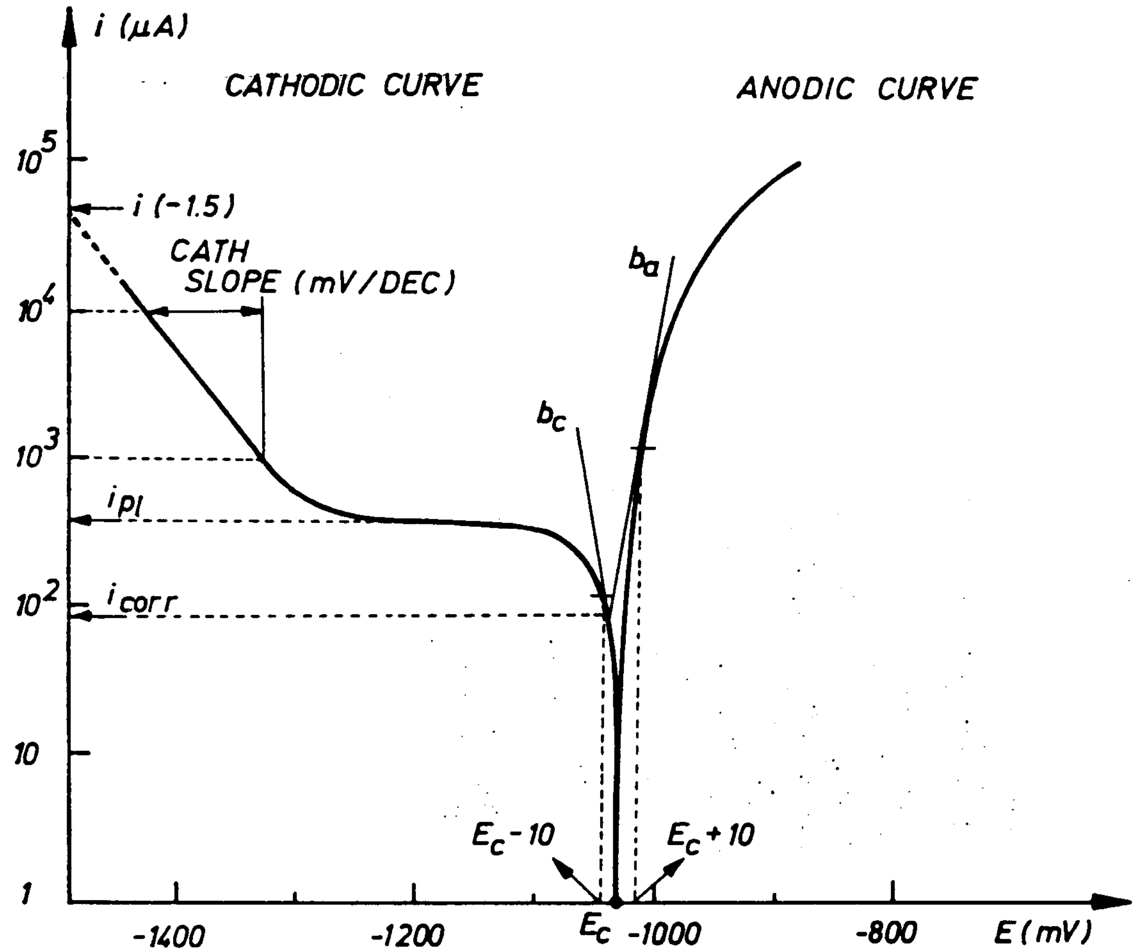
INFLUENCE OF THE AL CONTENT OF GALFAN COATINGS ON ITS CORROSION RESISTANCE

1. POLARIZATION MEASUREMENTS IN AN AERATED 0.5 M (3% W) NEUTRAL NACL SOLUTION.
2. A 5 WEEKS EXPOSURE OF SIMULATED GALFAN COATED SHEETS IN A 10 PPM SO_2 ATMOSPHERE.
3. A 20 WEEKS EXPOSURE OF INDUSTRIAL GALFAN COATED SHEETS IN A 10 PPM SO_2 ATMOSPHERE.
4. 1 YEAR OF OUTDOOR EXPOSURE OF INDUSTRIAL GALFAN COATED SHEETS IN 3 SITES.


POLARIZATION MEASUREMENTS
Cooling rate : 30°C/sec
Scan rate : 0.05 mV/sec
Aerated 3% NaCl Solt.
Surface of sample : 8.04 cm2
% Al.
0
4.0
4.6
5.2
55
10^5
(μ Amp)
10^4
10^3
10^2
10
1
Cooling rate : 5°C/sec
mV
-1400
-1200
-1000
-800

POLARIZATION MEASUREMENTS

DETERMINATION OF ELECTROCHEMICAL PARAMETERS



STERN - GEARY :
(Rp in $\Omega.cm^2$)

$$R_p = \frac{b_a \times b_c}{2.3 \times i_{corr} \times (b_a + b_c)}$$

PASSIVATION EFFICIENCY :
(τ in %)

$$\tau = 100 \times \frac{(i^{\circ}_{corr} - i_{corr})}{i^{\circ}_{corr}}$$

i°_{corr} : CORR. CURR. DENSITY OF REF. COAT.

CORROSION RESISTANCE OF ZN-BASE COATINGS. INFLUENCE OF THE AL CONTENT.
RESULTS FROM POLARIZATION MEASUREMENTS. CASE OF REGULAR SPANGLE COATINGS.

AL (%)	$-E_{CORR}$ (MV)	I_{CORR} ($\mu A/CM^2$)	RP ($\Omega.CM^2$)	I_{PL} ($\mu A/CM^2$)	CATH SLOPE (MV/DEC)	$I_{-1.5}$ (MA/CM^2)	τ (%)
0 (2)	1040	18.7	270	190	100	875	0
4.0	1050	12.5	300	88	112	2.5	33.2
4.6	1040	6.3	565	70 (1)	190	1.25	66.3
5.2	1037	2.0	2610	8.8 (1)	275	0.08	89.3
5.0	1030	0.81	6320	3.1 (1)	100	0.13	95.7

(1) MEAN VALUE
(2) ELECTPOGALVA

CORROSION RESISTANCE OF ZN-BASE COATINGS. INFLUENCE OF THE AL CONTENT.
RESULTS FROM POLARIZATION MEASUREMENTS. CASE OF MINIMIZED SPANGLE COATINGS.

AL (%)	$-E_{CORR}$ (MV)	I_{CORR} (μA/CM²)	RP(1) (Ω.CM²)	I_{PL} (2) (μA/CM²)	CATH SLOPE (MV/DEC)	$I_{-1.5}$ (MA/CM²)	τ (%)
0(3)	1040	18.7	270	100	190	875	0
4.0	1040	15.8	370	44	170	622	16
4.6	1035	12.5	250	68	300	200	33.2
5.2	1037	5.0	1242	25	390	88	73.3

(1) EQUATION OF STERN AND GEARY
(2) CATHODIC CURRENT AT THE PASSIVATION PLATEAU
(3) ELECTROGALVA

NEXT POLARIZATION MEASUREMENTS

1. MILDER MARINE MEDIUM (0.05 M AERATED NACL SOLUTION). CHECK THE EVOLUTION OF THE ANODIC CURVE.

2. SIMULATION OF AN INDUSTRIAL MEDIUM. SOLUTION IS AN AERATED NEUTRAL 0.05 M NA_2SO_4.

3. SIMULATION OF A RURAL MEDIUM. SOLUTION IS AN AERATED CO_2 SATURATED DEIONIZED WATER.

ANODIC DISSOLUTION METHOD. COMPARISON OF THE THEORETICAL AND ANALYTICAL RESULTS

$Q_{th} = 0.747 \times t$ (hours)

SAMPLING REFERENCE (Fig. 65)	DISSOLUTION TIME (min)	ANALYTICAL RESULTS				FARADAY'S LAW
		Q_{Zn} (meq/300ml)	Q_{Al} (meq/300ml)	$Q_{an,tot}$ (meq/300ml)	Dissolved Al(*) (% w)	$Q_{th,tot}$ (meq/300ml)
a	200	2.485	0.032	2.517	0.35	2.49
b	242	3.02	0.058	3.06	0.53	3.01
c	262	3.10	0.230	3.33	2.04	3.26
d	280	3.12	0.392	3.512	3.34	3.49

Weight of disaggregated metallic powder : 2 mg ⟶ 90 % Al = 1.8 mgr
⟶ 10 % Zn = 0.2 mgr

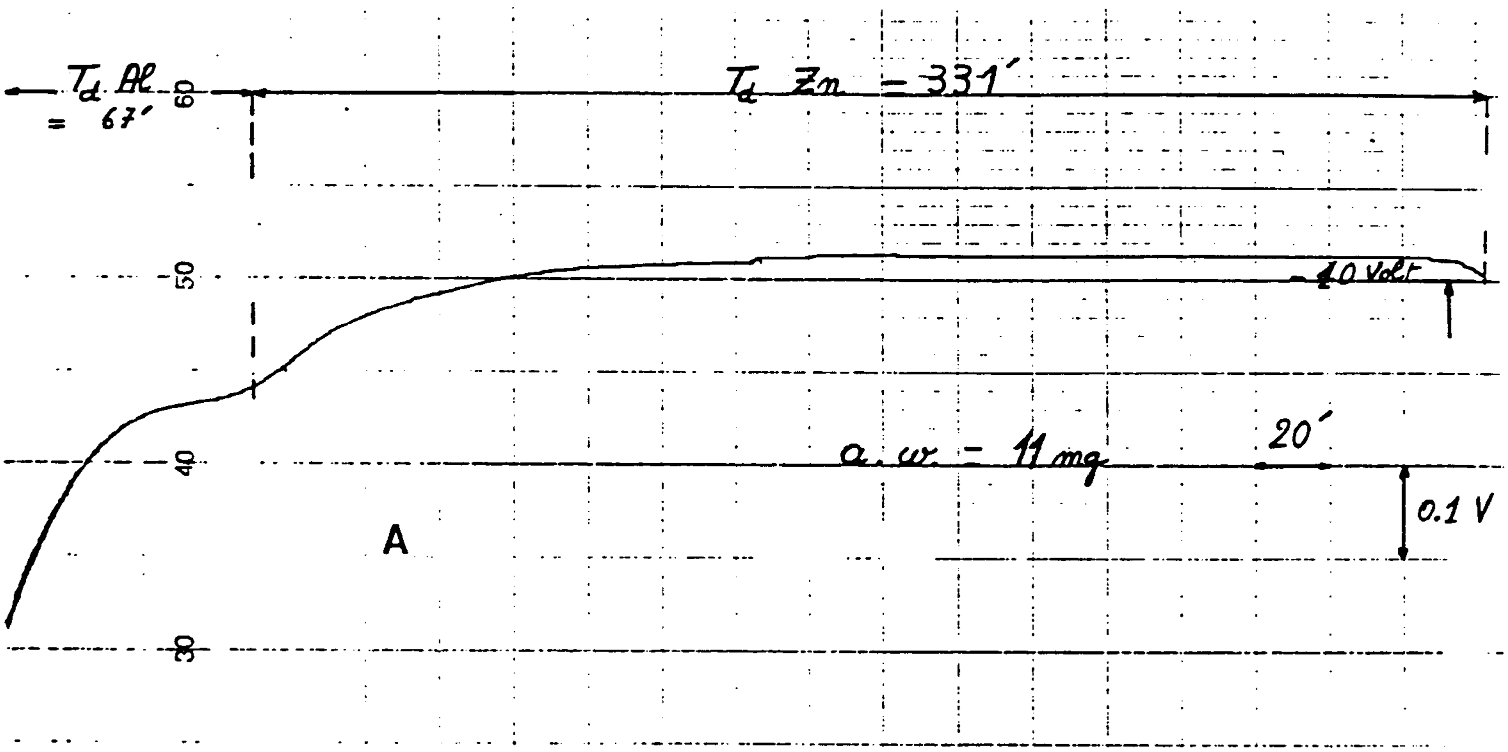
⟶ weight % Al in the coating : $\dfrac{(0.392 \times 9) + 1.8}{(0.392 \times 9) + (3.12 \times 32.7 + 0.2)} = 5.04\ \%\ w$

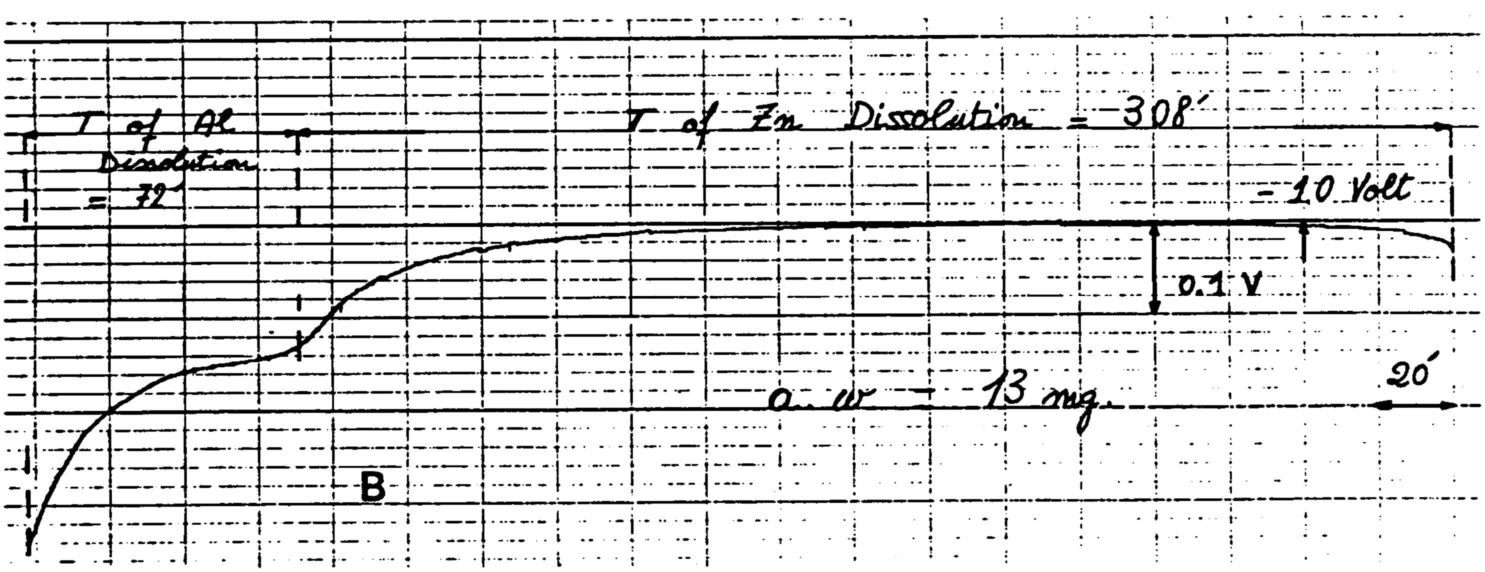
(*) Dissolved Al = $\dfrac{Q_{Al} \times 9}{(Q_{Al} \times 9) + (Q_{Zn} \times 32.7)}$

WEIGHT LOSS DETERMINATION BY THE USE OF ANODIC DISSOLUTION.

POTENTIAL-TIME PLOT (i = 2.5 mA/cm^2 , S = 8.04 cm^2) .

a) GALFAN ZA5 , UNEXPOSED FACE.
b) GALFAN ZA7 , EXPOSED FACE.





ANODIC DISSOLUTION; THICKNESS LOSS DETERMINATION
BY THE APPLICATION OF FARADAY'S LAW (EQUATION 12)
NUMERICAL ILLUSTRATION

	ZA7 (NF)(*)	ZA7 (EF)(*)	Comments
t_d Zn (min)	331	308	Dissolution time of Zn
Q_{th} Zn (meq)	4.120	3.835	$Q_{Zn} = 0.747 \times \frac{t\ (min)}{60}$
Weight Zn (gr/m^2)	167.6	156.0	$W_{Zn} = \frac{Q_{Zn}}{0.804} \times 32.7$
t_d Al (min)	67	72	Dissolution time of Al
Q_{th} Al (meq)	0.834	0.896	$Q = 0.747 \times \frac{t\ (min)}{60}$
Weight Al (gr/m^2)	9.34	10.03	$W_{Al} = \frac{Q_{Zn}}{0.804} \times 9$
Dissolved Weight (gr/m^2)	176.94	166.03	$W_d = W_{Zn} + W_{Al}$
Remaining Weight (gr/m^2)	13.68	16.17	$W_r = \frac{a.w}{0.804}$
Total Uncorroded Weight (gr/m^2)	190.6	182.2	$W_T = W_d + W_r$
Equivalent Uncorroded Coating thickness (microns)	28.9	27.6	$Th = \frac{W_T}{6.6}$

(*) NF/EF : Non exposed face / Exposed face

CHARACTERISTICS OF COATINGS USED IN THE LONG TERM ATMOSPHERIC EXPOSURE PROGRAM
INITIATED IN EARLY 1985

N°	COATING	THICKNESS (µm)	STEEL GAGE	CHROMIUM (+/-)	COMMENTS (1)
ZA3 (2)	GALFAN	20	0.70	-	S.M
ZA4	GALFAN	18	1.00	+	S.M
ZA5	GALFAN	26	1.00	+	S.M
ZA6	GALFAN	20	2.35	-	S.M
ZA7	GALFAN	30	0.60	-	N
ZA8	GALFAN	25	0.60	+	N
Z 9	GALVANIZED	22	0.70	+	N
AZ11	ALUZINC	20	0.63	+	S

(1) Note : M/N : Minimized/Normal spangle   S : Temper rolled

(2) ZA3 : 3.8 % Al, 140 ppm Pb

ANODIC DISSOLUTION. THICKNESS LOSS DATA (microns) AFTER 3 YEARS OF OUTDOOR EXPOSURE

EXPOSURE SITES

SAMPLES	SEVERE MARINE			MARINE			INDUSTRIAL			RURAL		
	EF(*)	NF(*)	MV(*)	EF	NF	MV	EF	NF	MV	EF	NF	MV
ZA3	9.5	7.2	8.4	9.0	4.5	6.8	9.0	4.5	6.7	3.7	6.3	5.0
ZA5	6.6	6.5	6.6	6.3	4.9	5.6	5.0	1.0	3.0	2.8	0.4	1.6
ZA6	7.5	6.7	7.1	5.6	4.8	5.2	5.2	2.7	4.0	3.0	1.4	2.2
ZA7	8.3	6.3	7.3	7.0	5.0	6.0	5.5	5.3	5.4	4.0	3.0	3.5
ZA8	6.5	1.5	4.0	5.0	0.6	2.8	3.3	1.5	2.4	2.0	0.3	1.2
Z 9	10.0	15.3	12.7	12.6	3.0	7.8	10.4	6.9	8.7	6.0	3.0	4.5
AZ11(**)	-	-	3.5	-	-	2.0	-	-	1.1	-	-	0.8

(*) EF/NF/MV : EXPOSED FACE / NON EXPOSED FACE / MEAN VALUE

(**) ANDERSON-REINHARD

CORROSION RESISTANCE OF GALVANIZED AND GALFAN COATINGS AFTER 3 YEARS OF OUTDOOR EXPOSURE : INFLUENCE OF PROCESS AND PRODUCT PARAMETERS ON THE THICKNESS LOSS OF THE EXPOSED COATINGS.

		EXPOSURE SITES			
EFFECT OF	COMPARED COATINGS[1] WORSE BEST	SEVERE MARINE (µm)	MARINE (µm)	INDUSTRIAL (µm)	RURAL (µm)
CHROMATION	ZA6 - ZA8 (Cr(-) VS Cr(+))	3.1	2.4	1.6	1.0
MINIMIZATION	ZA7 - ZA6 (RS VS MS)	0.1	0.8	1.4	1.3
MICROSTRUCTURE	ZA5 - ZA8 (Coarse VS fine eutec.)	2.6	2.8	0.6	0.4
PRESENCE OF PB	ZA3 - ZA6 (Pb(+) VS Pb(-))	1.3	1.6	2.7	2.8
COATING[2]	Z 9 / ZA8[2] Dimensionless	3.2	2.8	3.6	3.8
	Z 9 / ZA5 Dimensionless	2.0	1.4	3.0	2.8

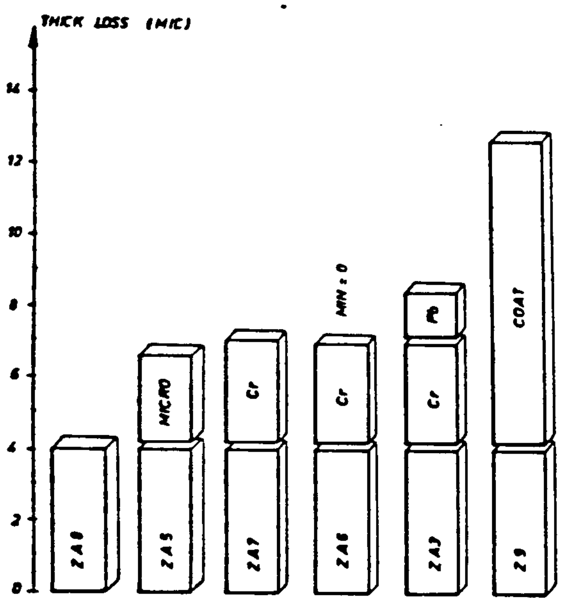
(1) The first four effects are expressed by the difference (in microns) between the mean values of the thickness losses (table 4) of the compared coatings.

(2) The coating effect is evaluated by the ratio between the mean values of the thickness losses (table 4) of the compared coatings. These yields are non-dimensional values.

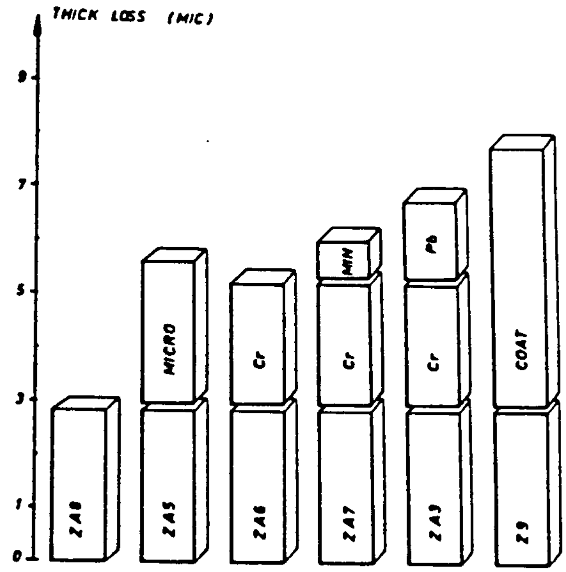
3 YEARS OF OUTDOOR EXPOSURE

RESULTS FROM ANODIC DISSOLUTION

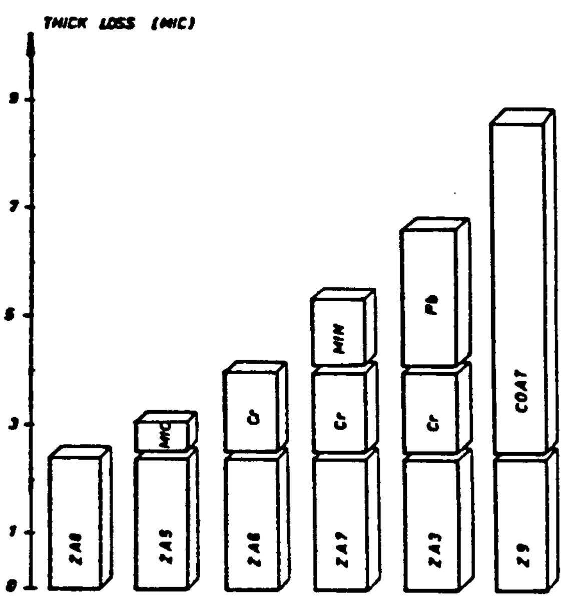
SEVERE MARINE SITE



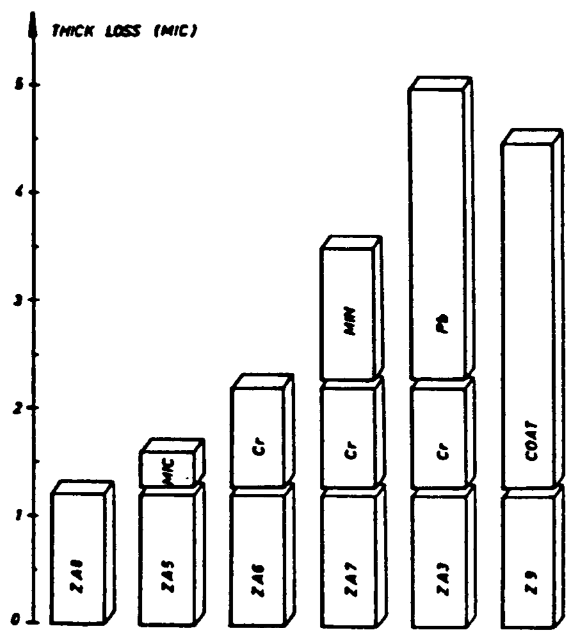
MARINE SITE



INDUSTRIAL SITE



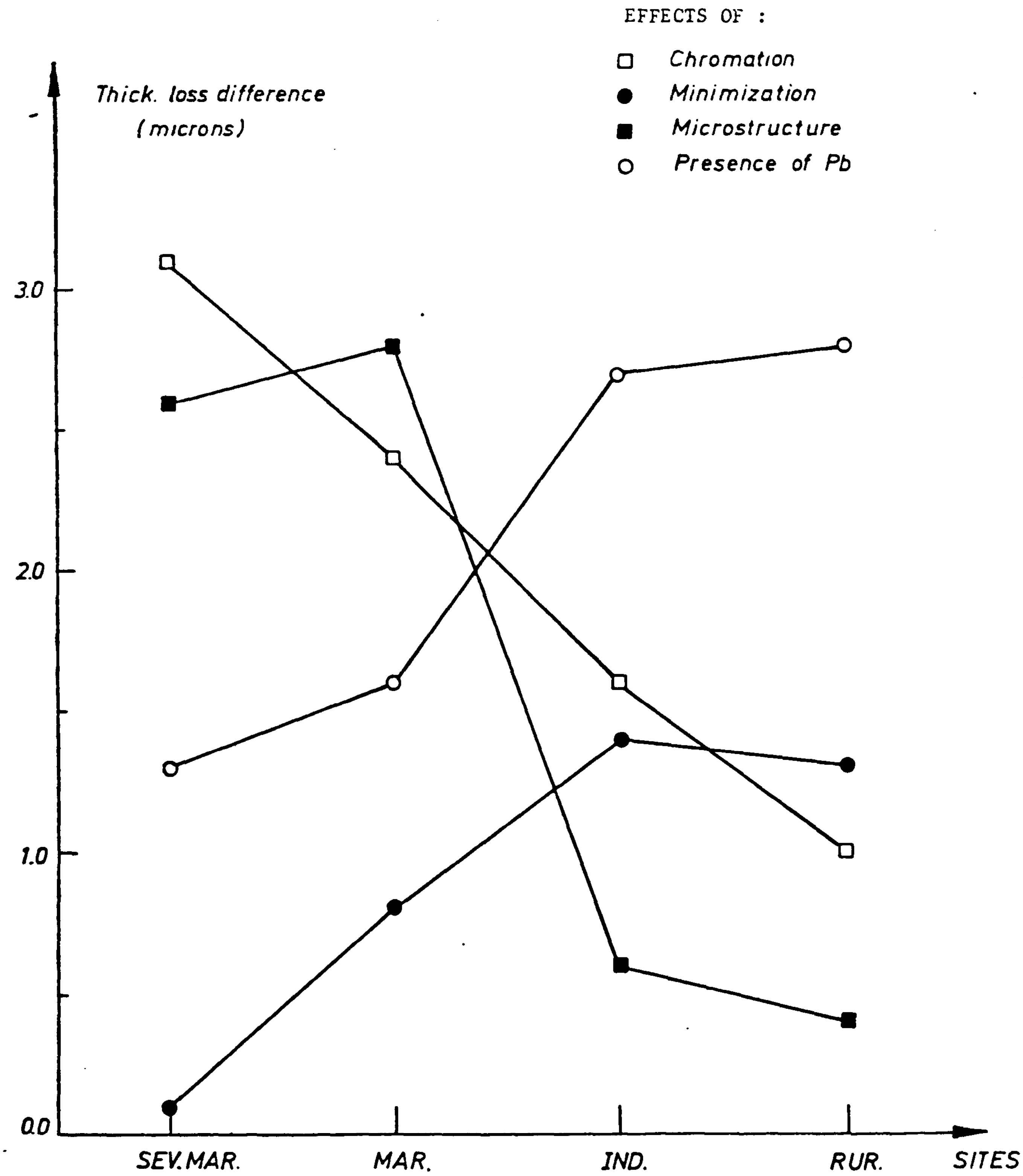
RURAL SITE



3 YEARS OF OUTDOOR EXPOSURE .

COMPARISON OF HTICKNESS LOSS DATA (DATA FROM TABLE 5) .

INFLUENCE OF PROCESS/PRODUCT PARAMETERS FOR EACH EXPOSURE SITE .



INFLUENCE OF THE AL CONTENT AND OF THE COOLING RATE ON THE CORROSION RESISTANCE OF GALFAN COATINGS

- SAMPLES FROM THE CRM'S SIMULATION EQUIPMENT
- SIMULATION CONDITIONS :

  TEMP. STRIP AT THE ENTRY : 500°C
  TEMP. OF THE GALFAN BATH : 470°C

- ATMOSPHERE : N_2 - 5 % H_2
- PARAMETERS INVESTIGATED :

  ——› AL (%) : 4.0, 4.6, 4.9, 5.2
  ——› COOL. RATE (°C/SEC) : 5, 30

- TESTING PROCEDURE : EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE

  EVALUATION THROUGH CROSS-SECTIONAL MICROSCOPY.

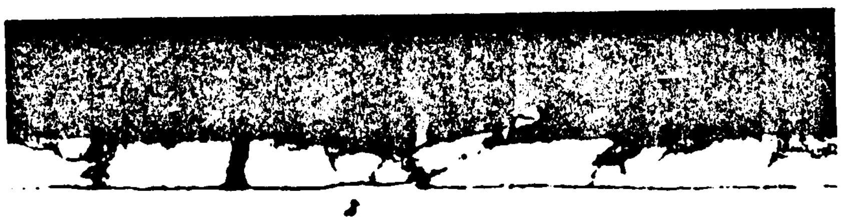
17

AL : 4.0 %

COOL. RATE : 5°C/SEC

3 WEEKS

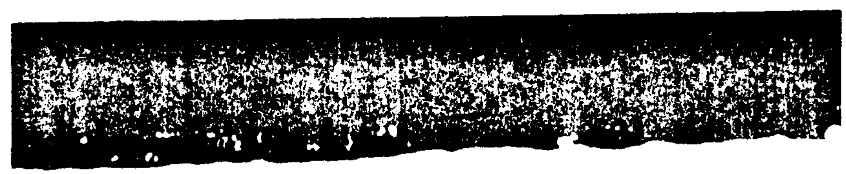
5 WEEKS



A. (250X) 088/190/3

C. (250X) 088/190/13

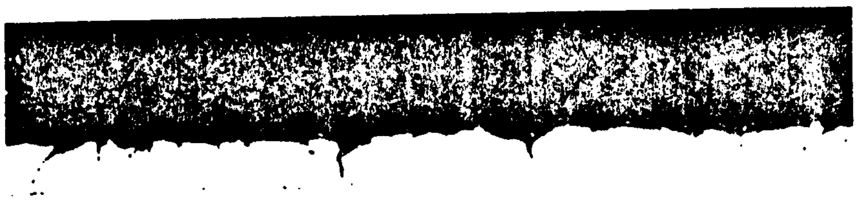
B. (250X) 088/190/2



D. (250X) 088/190/14

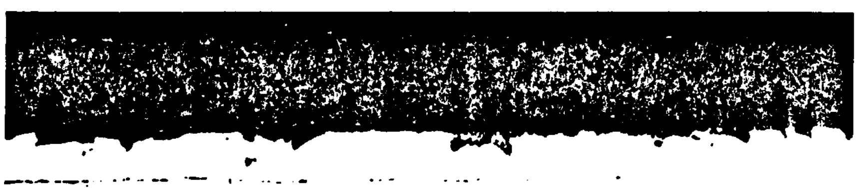
AL : 4.0 %   COOL. RATE : 30°C/SEC

3 WEEKS   5 WEEKS

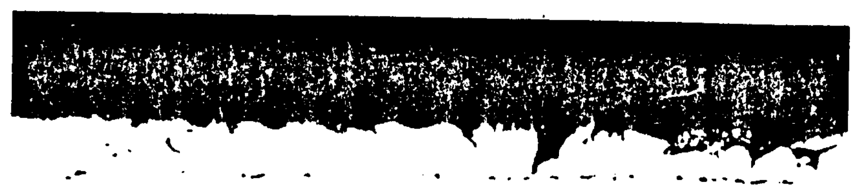


A.   (250X)   088/190/23

C.   (400X)   088/190/32



B.   (250X)   088/190/24



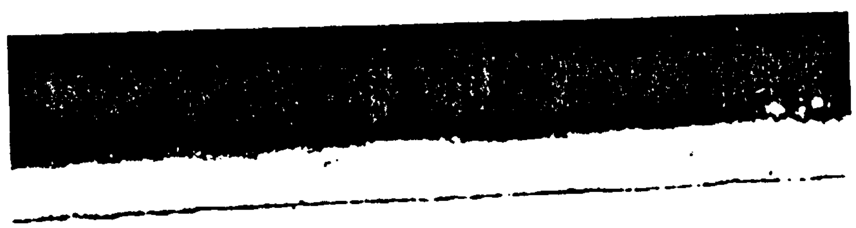
D.   (400X)   088/190/33

AL : 4.6 %

COOL. RATE : 5°C/SEC

3 WEEKS

5 WEEKS



A. (400X) 088/190/6

C. (400X) 088/190/18

B. (250X) 088/190/4,5 (400X)

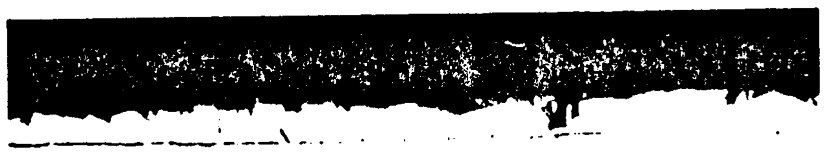
D. (250X) 088/190/16

AL : 4.6 %

COOL. RATE : 30°C/SEC

3 WEEKS

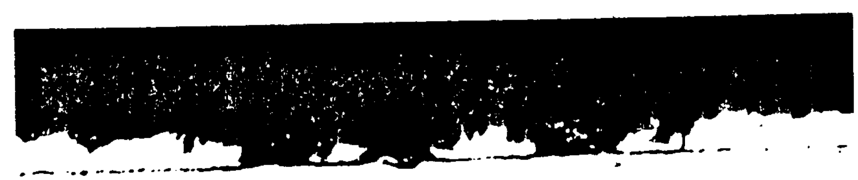
5 WEEKS



A. (250X) 088/190/25

C. (400X) 088/190/35

B. (250X) 088/190/26



D. (250X) 088/190/34

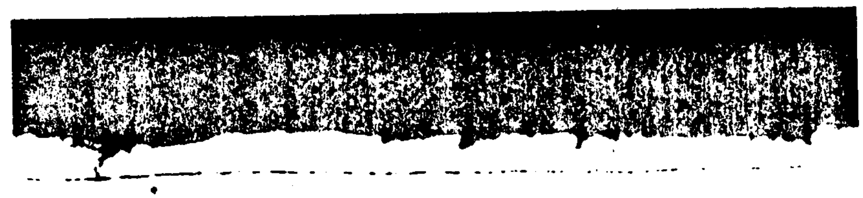
AL : 4.9 %

COOL. RATE : 5°C/SEC

3 WEEKS

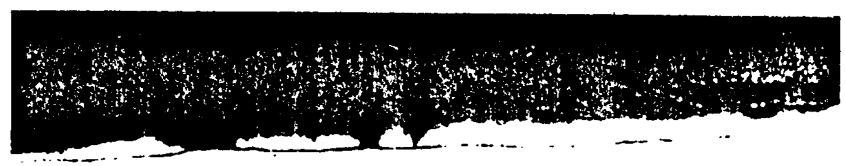
5 WEEKS

A. (400X) 088/190/7



C. (250X) 088/190/19

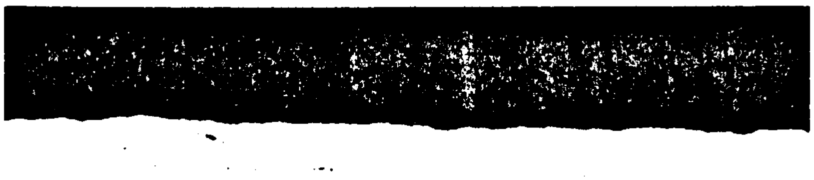
B. (400X) 088/190/9



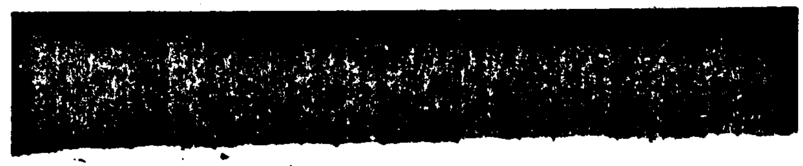
D. (250X) 088/190/20

AL : 4.9 %　　COOL. RATE : 30°C/SEC

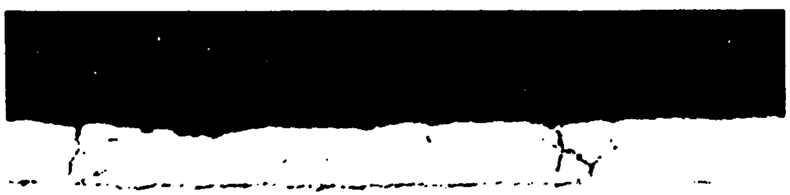
3 WEEKS　　5 WEEKS



A. (250X) 088/190/28



C. (250X) 088/190/36

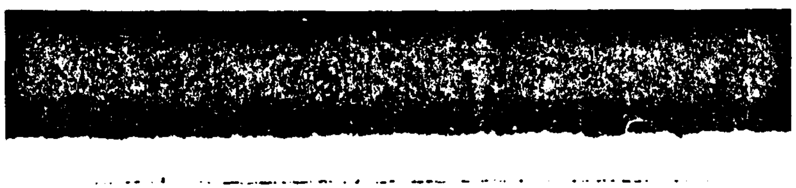


B. (400X) 088/190/27

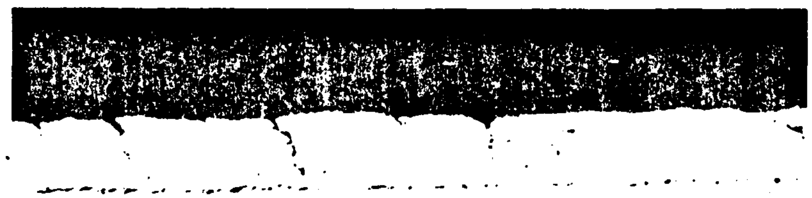
AL : 5.2 %

COOL. RATE 5°C/SEC

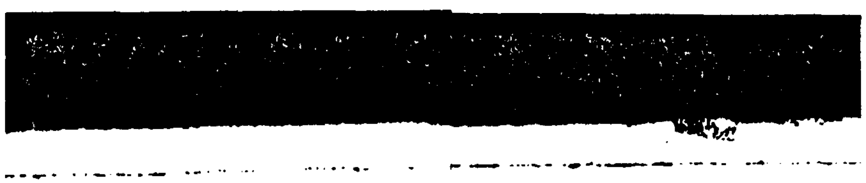
30°C/SEC



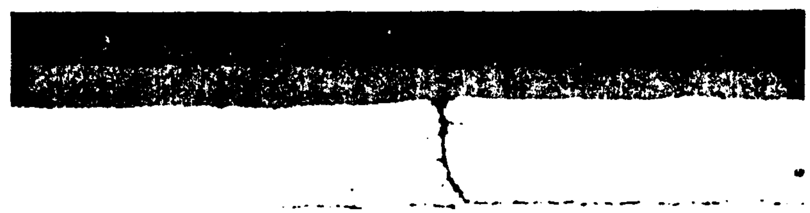
A. 3 WEEKS (250X) 088/190/10



C. 3 WEEKS (400X) 088/190/30



B. 5 WEEKS (250X) 088/190/21,22



D. 5 WEEKS (500X) 088/190/39

CORROSION RESISTANCE OF INDUSTRIAL GALFAN COATINGS;
INFLUENCE OF ALUMINIUM CONTENT
INITIAL CHARACTERISTICS OF GALFAN COATINGS.

REF	STEEL GAGE (MM)	INITIAL THICK (µM)	SPANGLE (R/M)(*)	AL (%)	FE (%)	SKP (H/S)(*)
SD	0.80	14-17	M	4.16	0.10	S
SB	0.42	25	R	4.50	0.12	H
SC	0.38	22	R	5.14	0.11	H

(*) NOTES : - R/M IS REGULAR/MINIMUM SPANGLE
- H/S IS HARD/SOFT SKIN-PASS
- PB CONTENT IS 0.008 %

INFLUENCE OF THE AL CONTENT OF GALFAN
ON ITS CATHODIC PROTECTION

TEST : EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE

DATA : PROGRESS OF CORROSION (µM) FROM BARE EDGES (*)

REF.	AL (%)	INITIAL THICK. (µM)	EXPOSURE PERIODS (WEEKS) 3 (µM)	10 (µM)	20 (µM)
SD	4.16	18	1900	2400	2740
SB	4.50	22	500	1000	1400
SC	5.14	22	480	600	880

(*) DATA ARE STANDARDIZED FOR AN INITIAL THICKNESS OF 20 µM.

GALFAN SD : 4.16 % AL

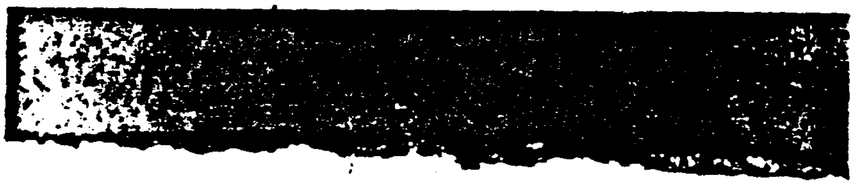
20 WEEKS OF EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE

A. (400X)

088/218/26

B. (400X)

088/218/25



C. (400X)

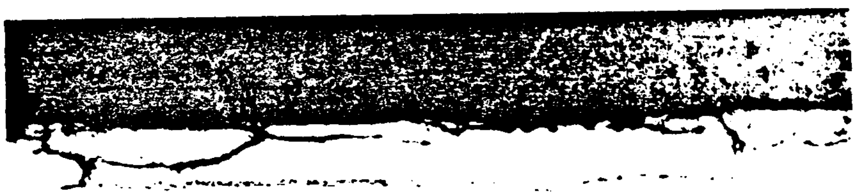
088/218/27

GALFAN SB : 4.50 % AL

20 WEEKS OF EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE

A. (400X)

088/218/21



B. (400X)

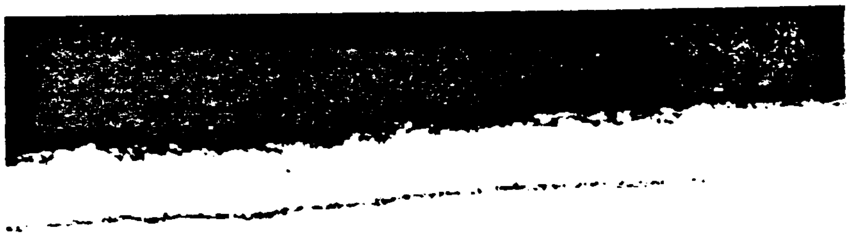
088/218/19

C. (400X)

088/218/20

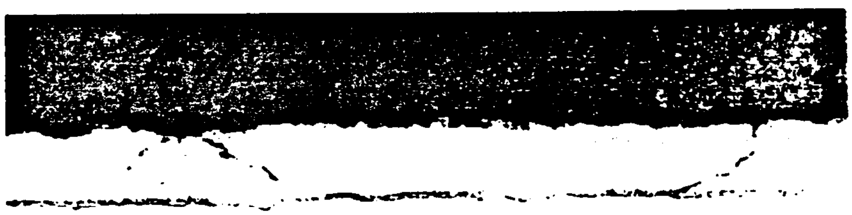
GALFAN SC : 5.14 % AL

20 WEEKS OF EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE



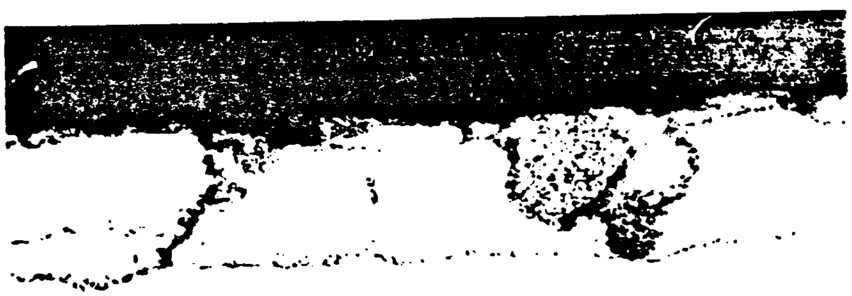
A. (400X)

088/218/22



B. (400X)

088/218/24



C. (800X)

088/218/23

CORROSION RESISTANCE OF GALFAN COATINGS. INFLUENCE OF THE AL CONTENT.
RESULTS FROM ANODIC DISSOLUTION AFTER 1 YEAR OF OUTDOOR EXPOSURE.

REF. OF SAMPLES	EXPOSURE SITES								
	SEVERE MARINE			INDUSTRIAL			RURAL		
	EF	NF	MV	EF	NF	MV	EF	NF	MV
SD	5.0	3.2	4.1	2.5	1.3	1.9	2.2	1.0	1.6
SB	4.6	3.0	3.8	2.9	1.0	1.9	2.0	0.2	1.1
SC	4.0	2.6	3.3	2.3	0.7	1.5	1.5	0.2	0.85

INFLUENCE OF THE AL CONTENT OF GALFAN ON ITS CATHODIC PROTECTION

TEST : 1 YEAR OF OUTDOOR EXPOSURE

DATA : PROGRESS OF CORROSION (μM) FROM BARE EDGES (*)

REF.	AL (%)	INITIAL THICK. (μM)	EXPOSURE SITES SEV. MAR. (μM)	INDUSTRIAL (μM)	RURAL (μM)
SD	4.16	18	900	720	360
SB	4.50	22	440	50	0
SC	5.14	22	50	0	0

(*) DATA ARE STANDARDIZED FOR AN INITIAL THICKNESS OF 20 μM.

GALFAN SD

1 YEAR OF EXPOSURE. SEVERE MARINE SITE

A. (800X)

088/255/8

B. (500X)

088/255/10

C. (800X)

088/255/9

GALFAN SB

1 YEAR OF EXPOSURE. SEVERE MARINE SITE

A. (250X)

088/255/1

B. (800X)

088/255/3

C. (500X)

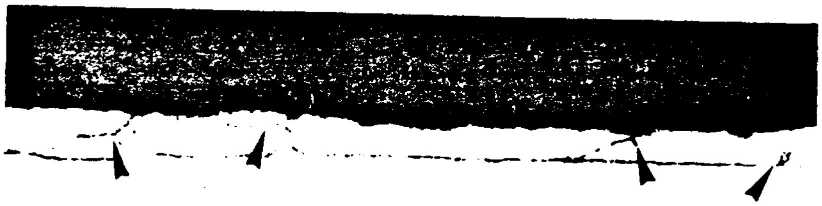
088/255/2

GALFAN SC

1 YEAR OF EXPOSURE. SEVERE MARINE SITE

A. (250X)

088/255/5



B. (320X)

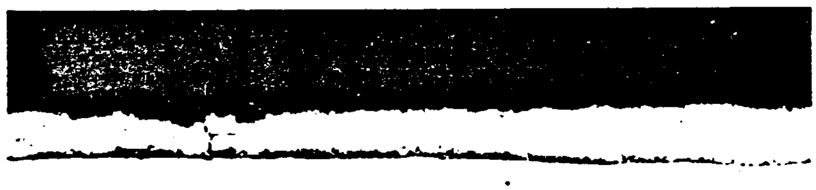
088/255/6

C. (800X)

088/255/7

GALFAN SD

1 YEAR OF EXPOSURE. INDUSTRIAL SITE

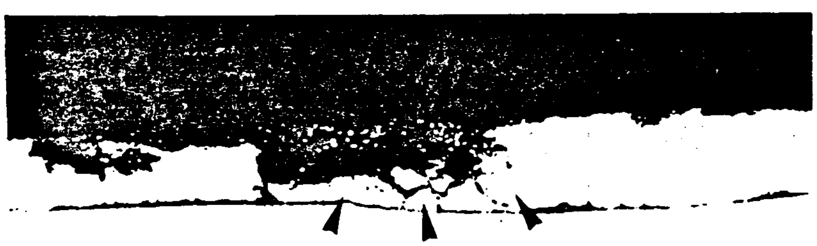


A. (400X)

088/255/19

B. (400X)

088/255/17

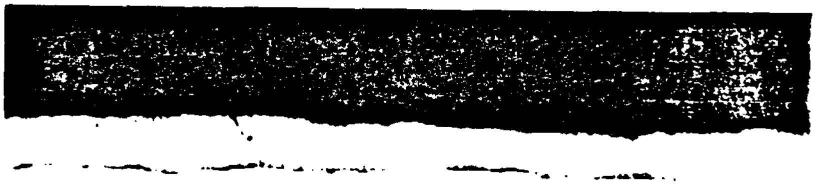


C. (625X)

088/255/18

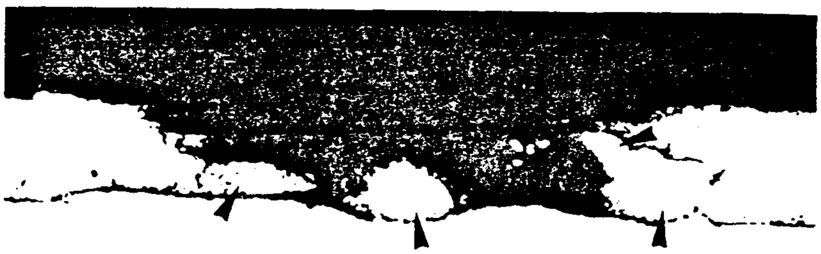
GALFAN SB AND SC

1 YEAR OF EXPOSURE. INDUSTRIAL SITE



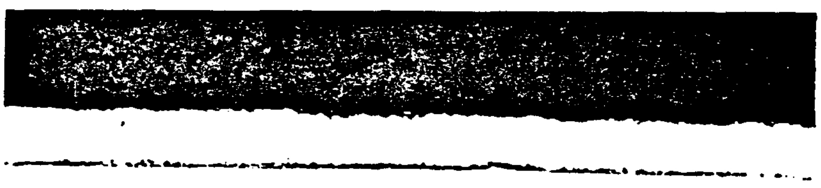
A. SB
(400X)

088/255/13



B. SB
(800X)

088/255/12

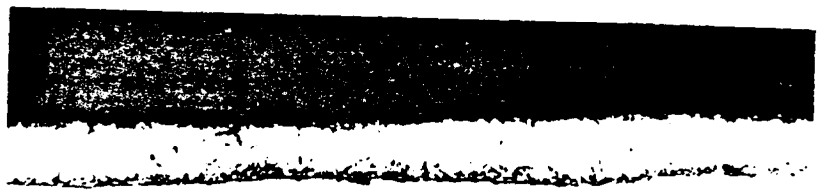


C. SC
(400X)

088/255/15

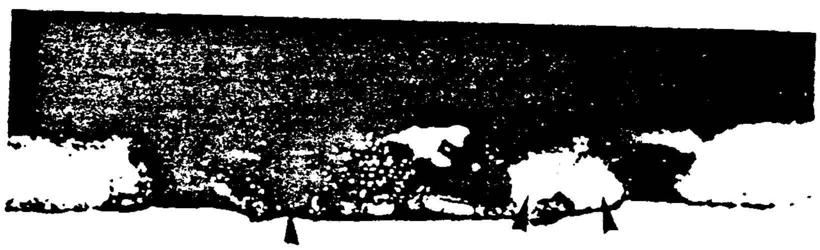
GALFAN SD

1 YEAR OF EXPOSURE. RURAL SITE



A. (400X)

088/255/29



B. (625X)

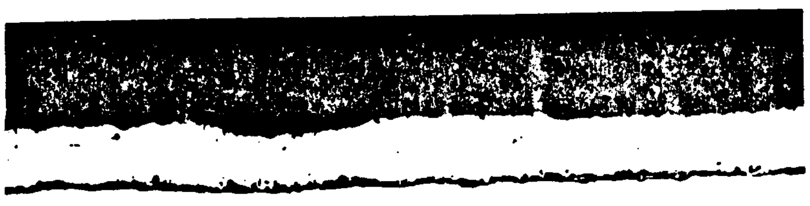
088/255/27

C. (625X)

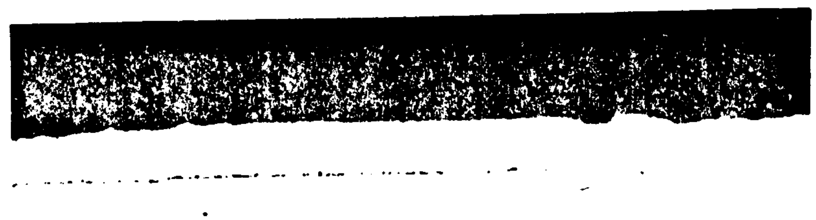
088/255/28

GALFAN SB AND SC

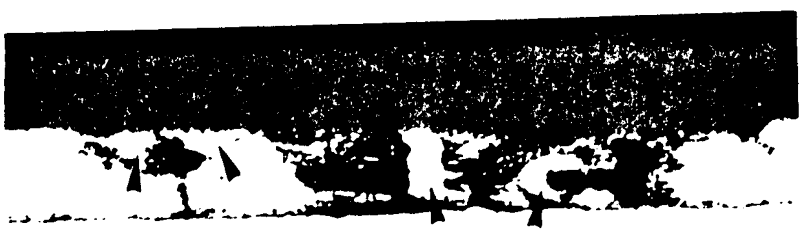
1 YEAR OF EXPOSURE. RURAL SITE



A. SB (400X) 088/255/23



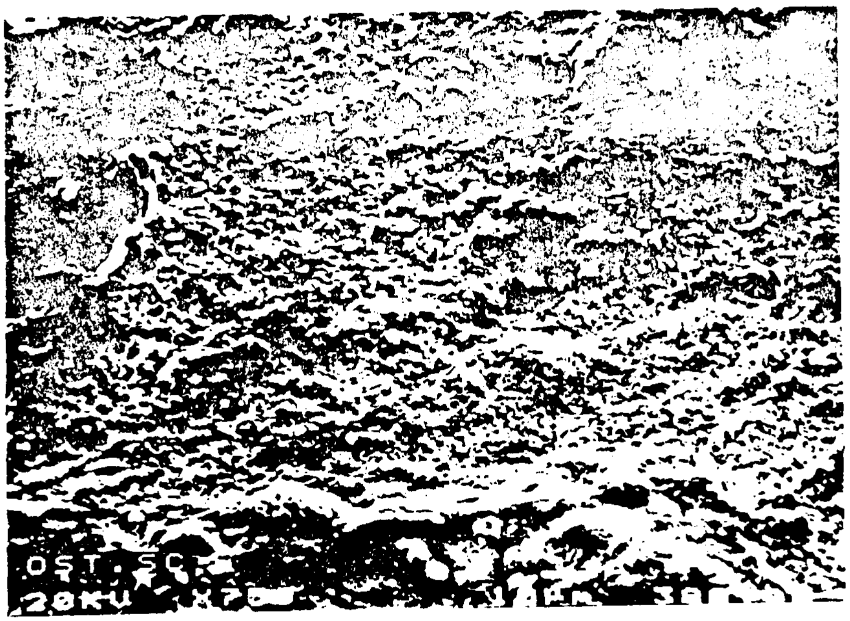
C. SC (250X) 088/255/25



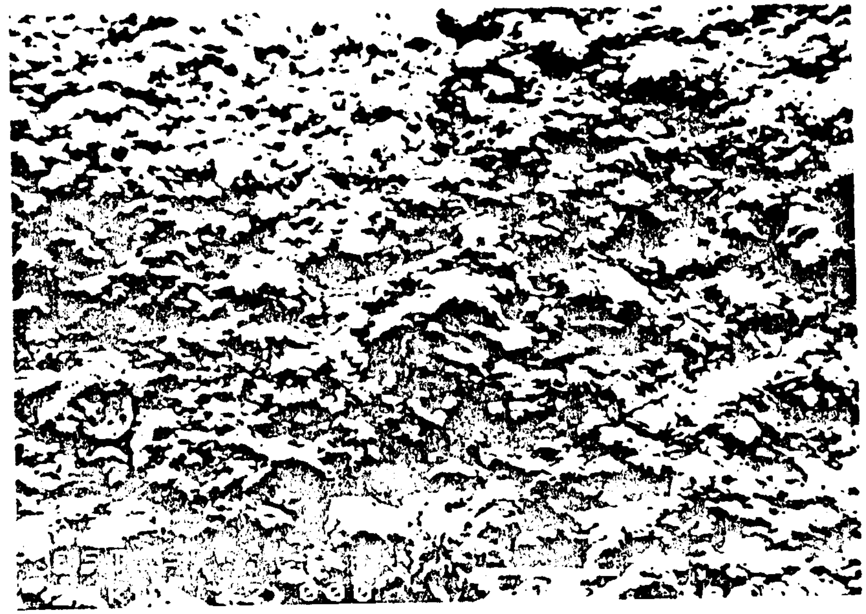
B. SB (625X) 088/255/20

D. SC (800X) 088/255/26

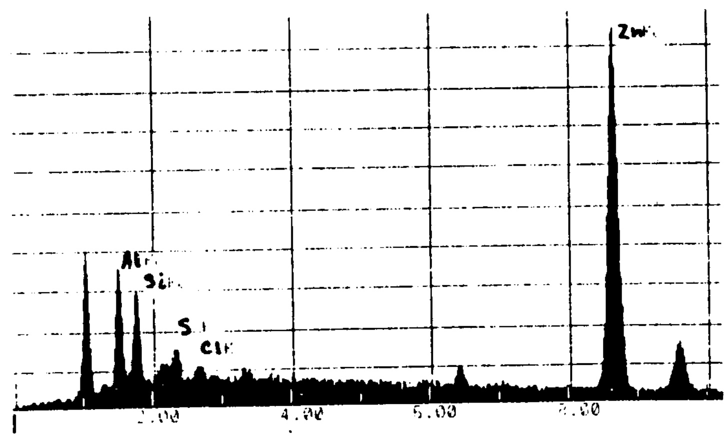
- GALFAN SC (5.1 % AL)
- 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE
- GENERAL CORROSION



A. (750X) 88/270/24



B. DETAILED VIEW (2000X) 88/270/21

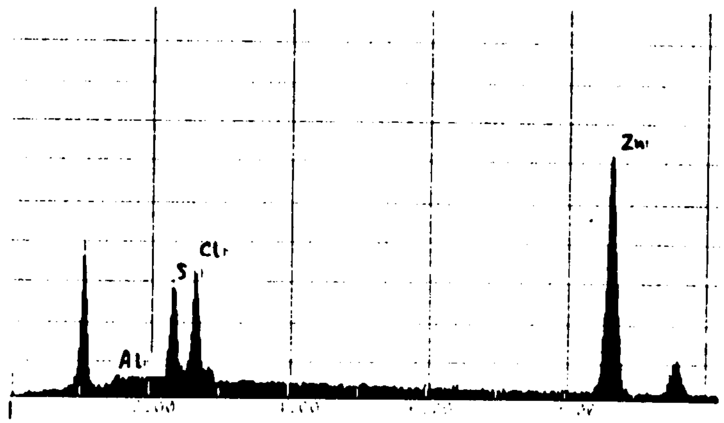


C. SEM SPECTRUM OF (B)

- GALFAN SC (5.1 % AL)
- 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE
- LOCAL CORROSION IN THE GRAIN BOUNDARIES : SUPERFICIAL PELLET SHAPED CORROSION COMPOUNDS OF ZN

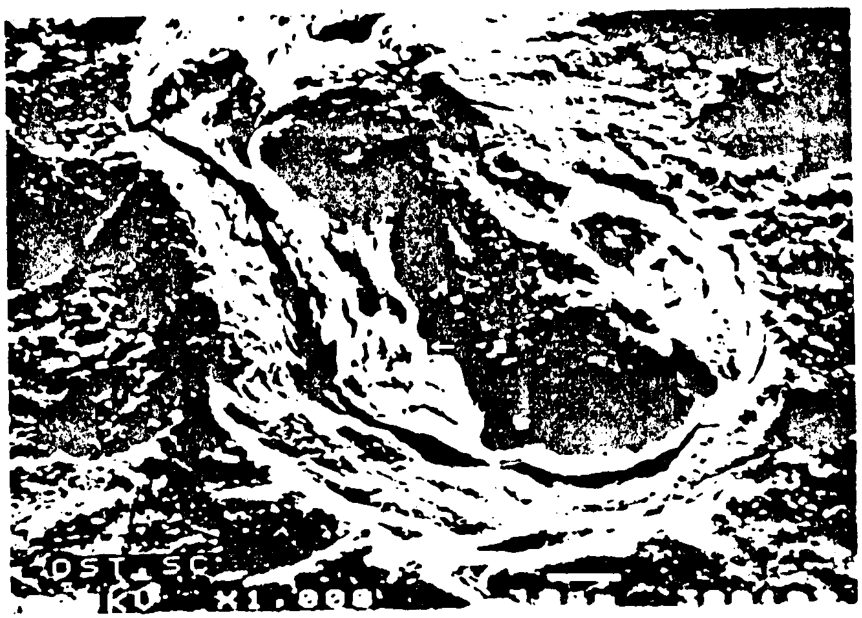
A. (2000X) 88/270/20

B. DETAILED VIEW OF (A), (3500X) 88/270/17

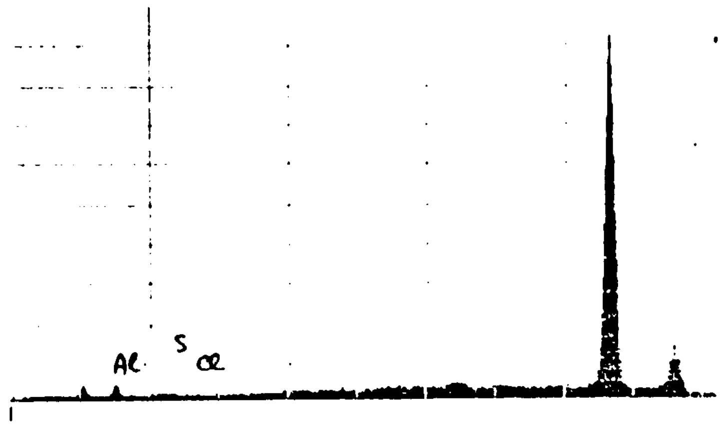


C. SEM SPECTRUM OF PELLETS IN (B)

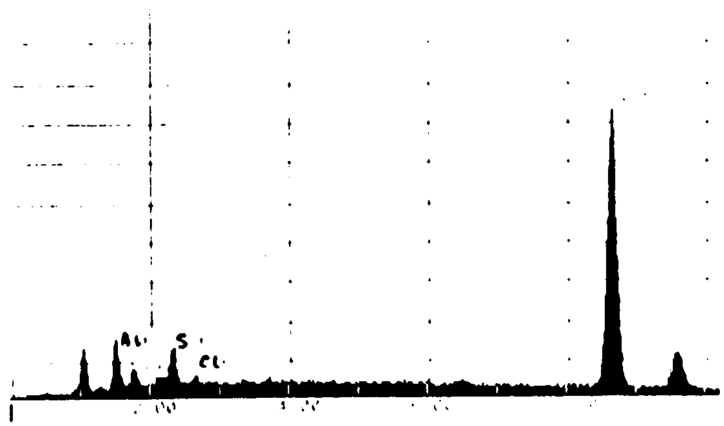
- GALFAN SC (5.1 % AL)
- 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE
- INTERPHASE (ZN-RICH GLOBULE/EUTECTIC) CORROSION



A. (1000X) 88/270/23



B. SEM SPECT. OF ZONE X IN (A)

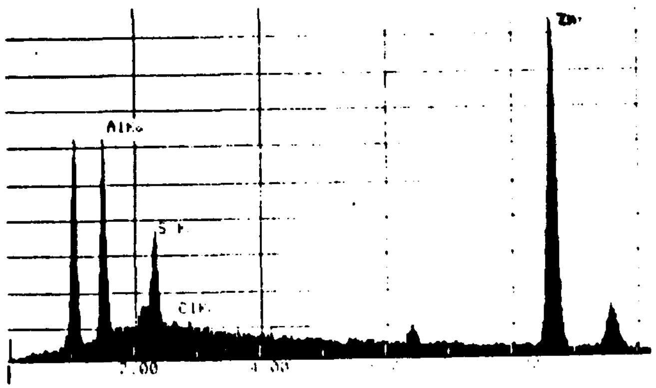


C. SEM SPECT. AT THE ARROW IN (A)

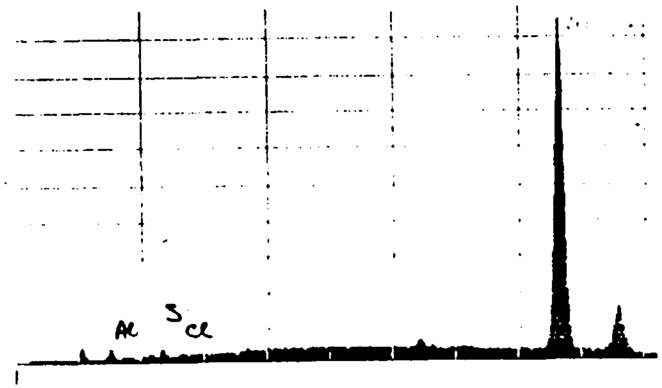
GALFAN SC (5.1 % AL). 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE.
LOCAL CORROSION OF A ZONE CONTAINING AL-RICH NODULES, CLOSE TO A PRIMARY PHASE.

A. (500X) 88/270/19

B. DETAIL OF (A), (1500X) 88/270/18



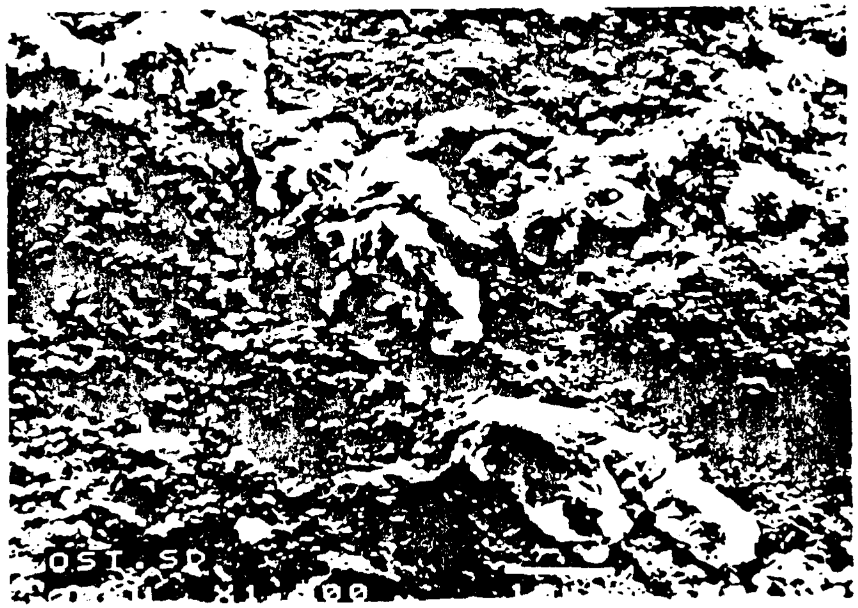
C. SEM SPECT. OF ZONE X IN (B)



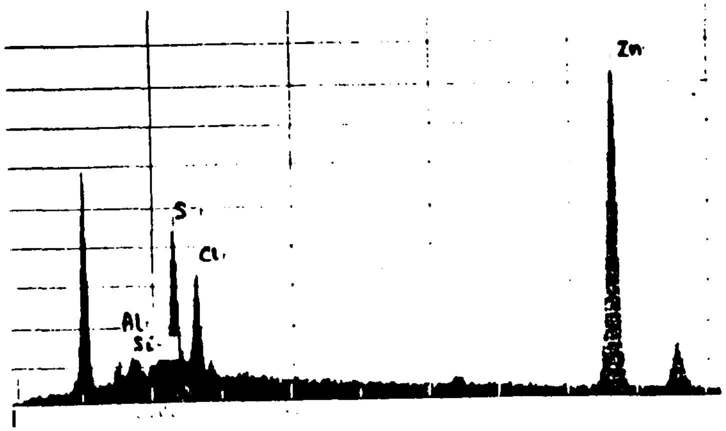
D. SEM SPECT. OF ZONE Y IN (B)

GALFAN SD (4.1 % AL). 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE.
GENERAL CORROSION OF EUTECTIC AND ZN-RICH PHASES.

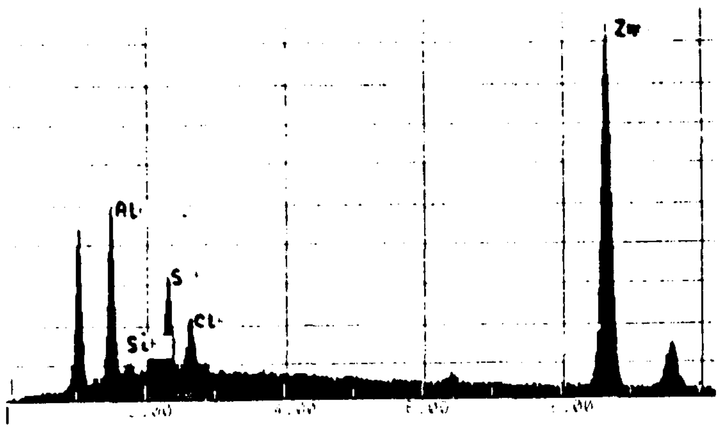
A. (1500X) 88/270/5



B. (1500X) 88/270/11



C. SEM SPECT. OF ZONE X

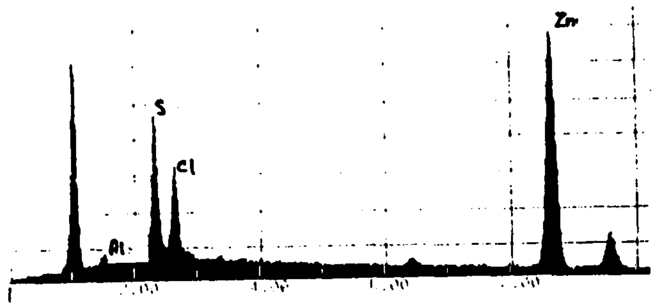


D. SEM SPECT. OF ZONE Y (GENERAL CORROSION)

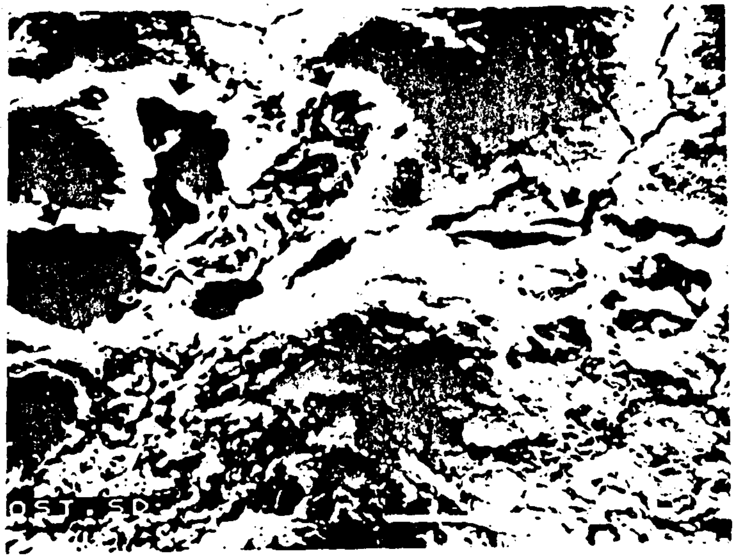
GALFAN SD (4.1 % AL)

1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE

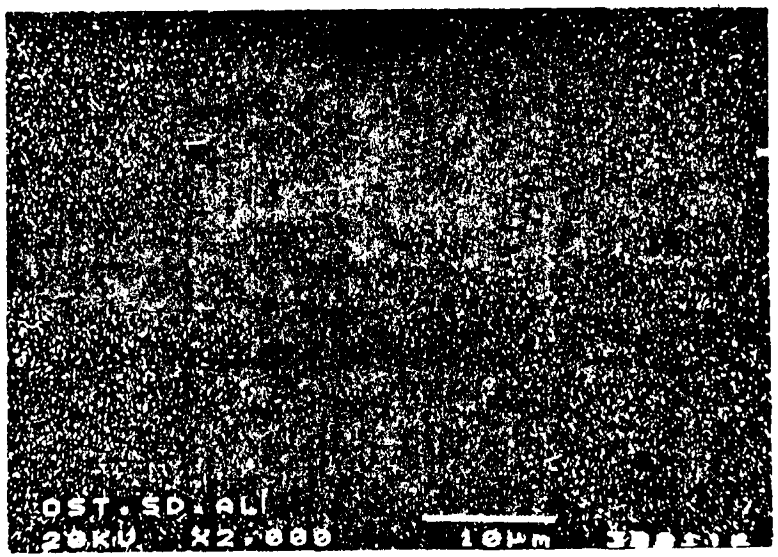
CORROSION OF PRIMARY PHASE



B. SEM SPECT. IN A HOLE (ARROWS)

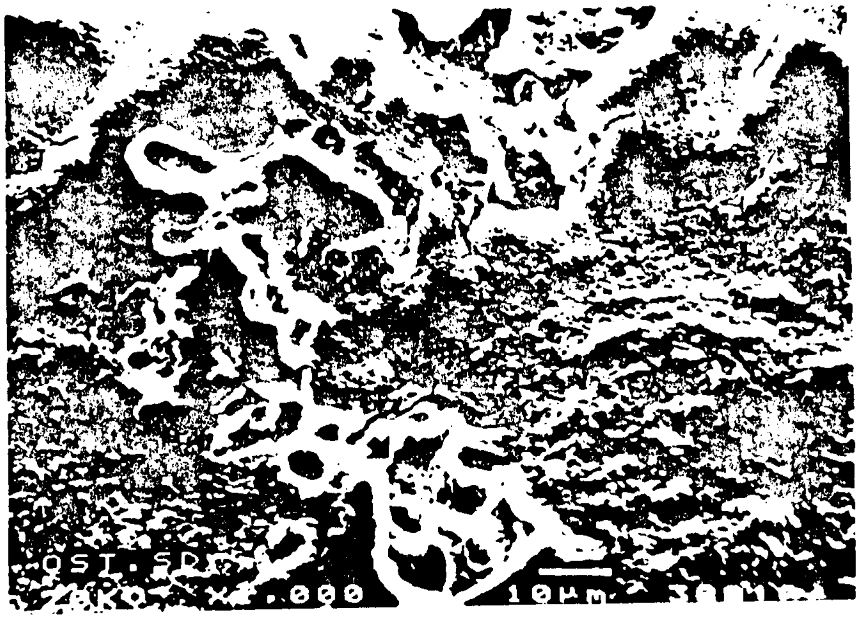


A. (2000X) 88/270/15



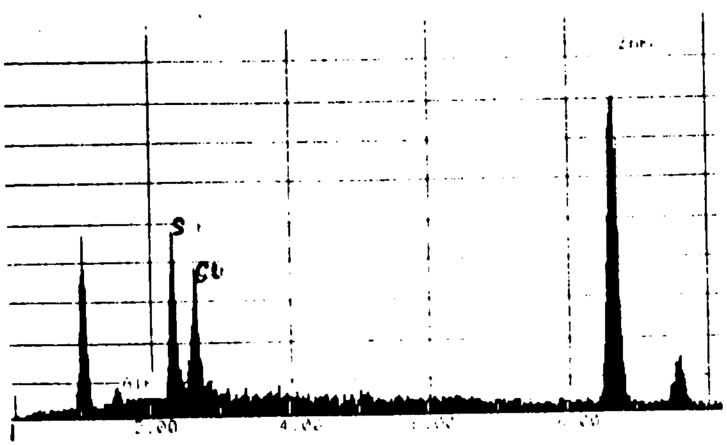
C. (2000X) 88/270/16

GALFAN SD (4.1 % AL). 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE.
CORROSION OF PRIMARY PHASE.

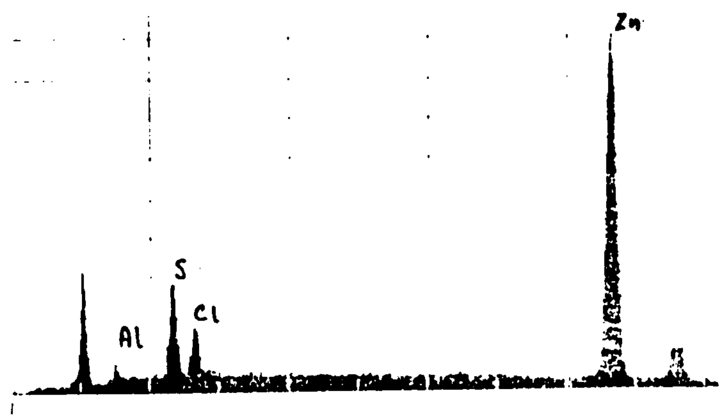


A. (1000X) 88/270/4

B. (1500X) 88/270/3

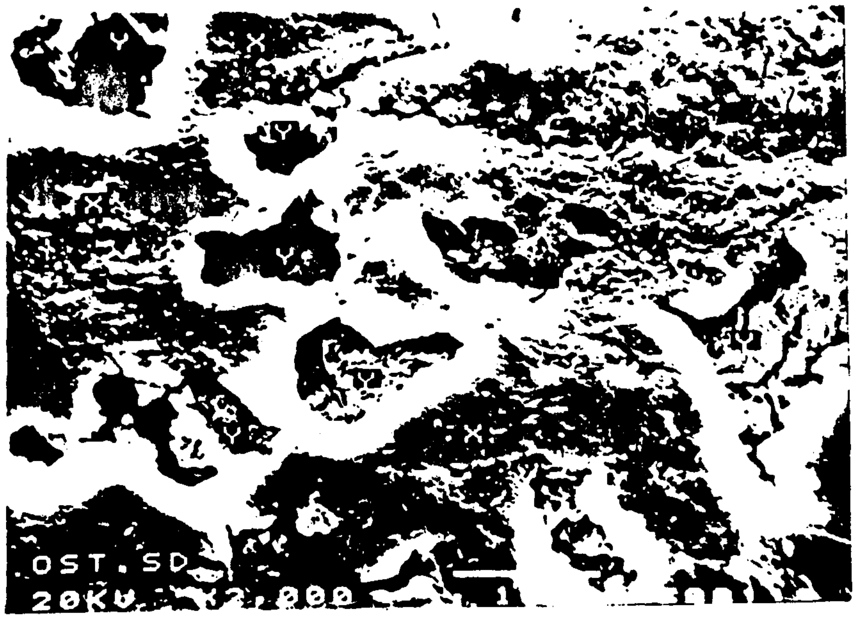


C. SEM SPECT. IN A HOLE (ARROW IN A)

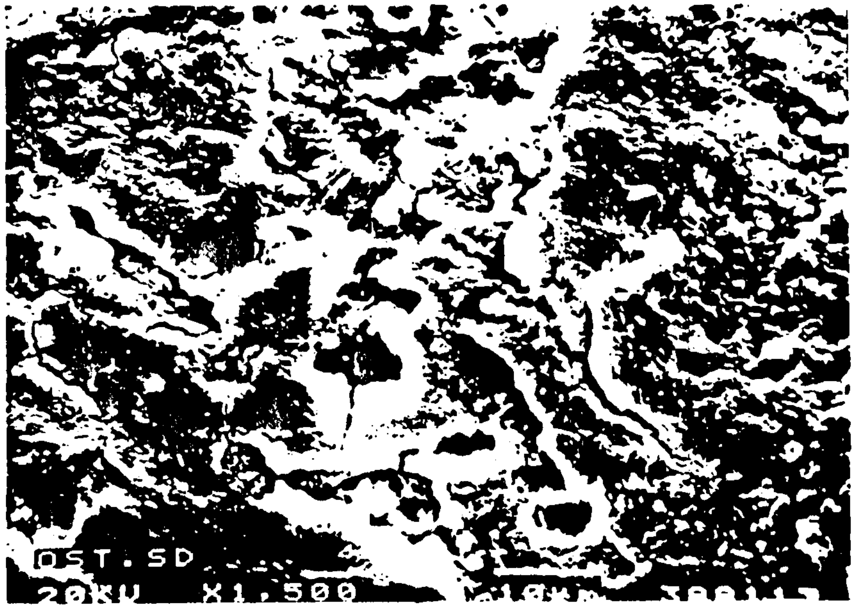


D. SEM SPECT. IN A HOLE (ARROW IN B)

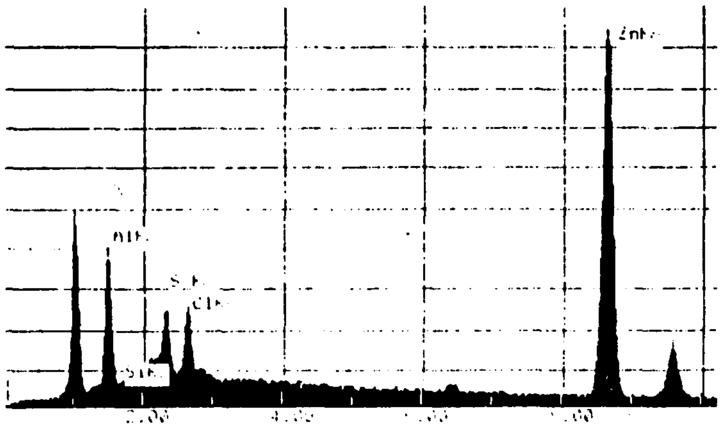
GALFAN SD (4.1 % AL). 1 YEAR OF OUTDOOR EXPOSURE IN A SEVERE MARINE SITE.
CORROSION OF PRIMARY PHASE AND ITS SURROUNDING AREAS.



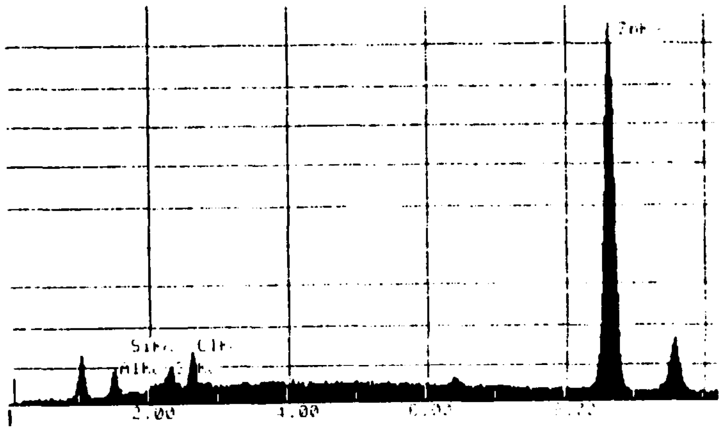
A. (2000X) 88/270/12



B. (2000X) 88/270/13



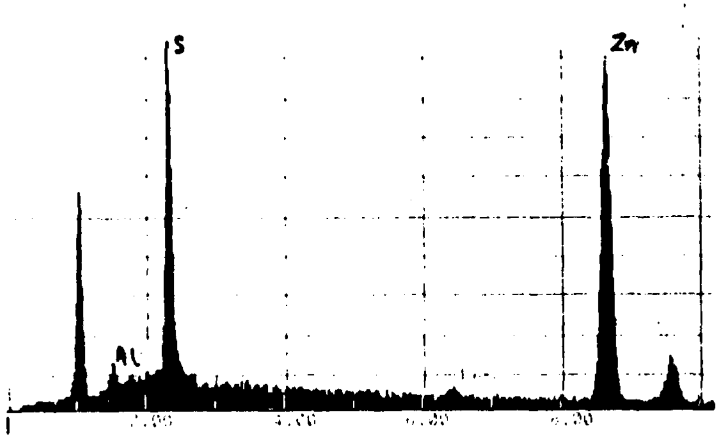
C. SEM SPECT. OF ZONES X



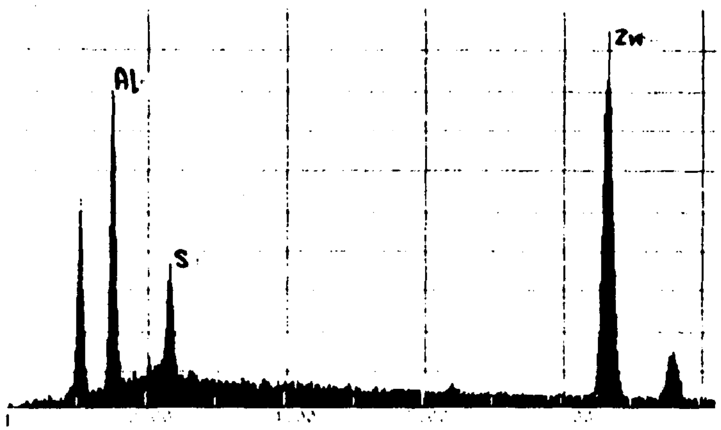
D. SEM SPECT. OF ZONES Y

GALFAN SD (4.1% AL). 1 YEAR OF EXPOSURE IN AN INDUSTRIAL SITE.
CORROSION OF A ZN-RICH GLOBULE (X), AND OF THE SURROUNDING EUTECTIC PHASE.

A. (2000X) 88/311/2



B. SEM. SPECT. OF ZONE X

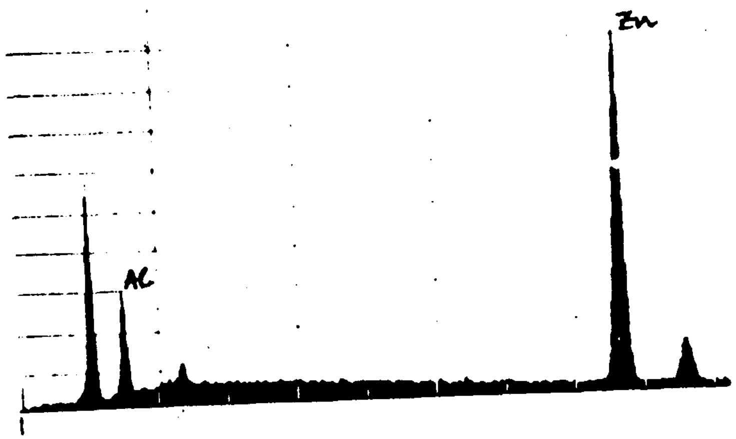


C. SEM. SPECT. OF ZONE Y

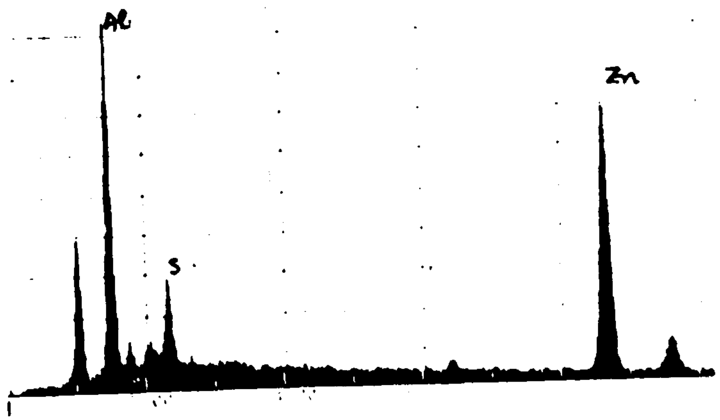
GALFAN SD (4.1 % AL). 1 YEAR OF EXPOSURE IN AN INDUSTRIAL SITE.

A. (750X) GENERAL CORROS. 88/311/5

B. (1500X) AL-RICH NODULES 88/311/5



C. SEM SPECT. IN (A)

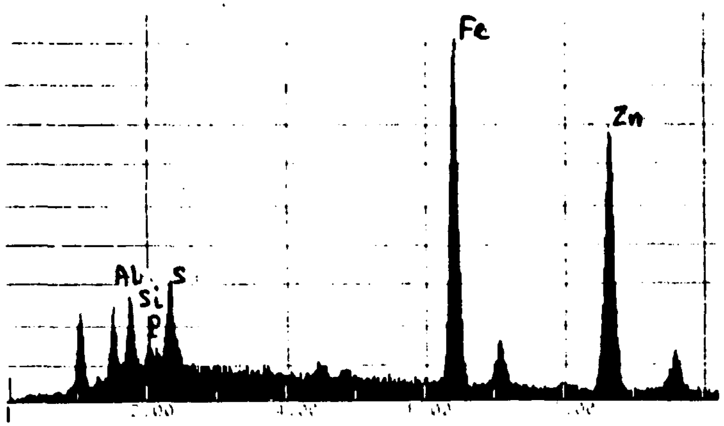


D. SEM SPECT. IN (B)

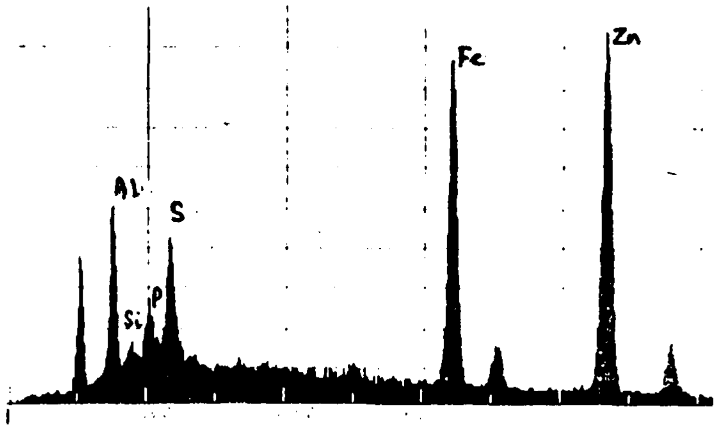
GALFAN SD (4.1 % AL). 1 YEAR OF EXPOSURE IN AN INDUSTRIAL SITE.

A. (1500X) SURFACE ENCRUSTING 88/311/1

B. (3500X) SURFACE ENCRUSTING 88/311/4

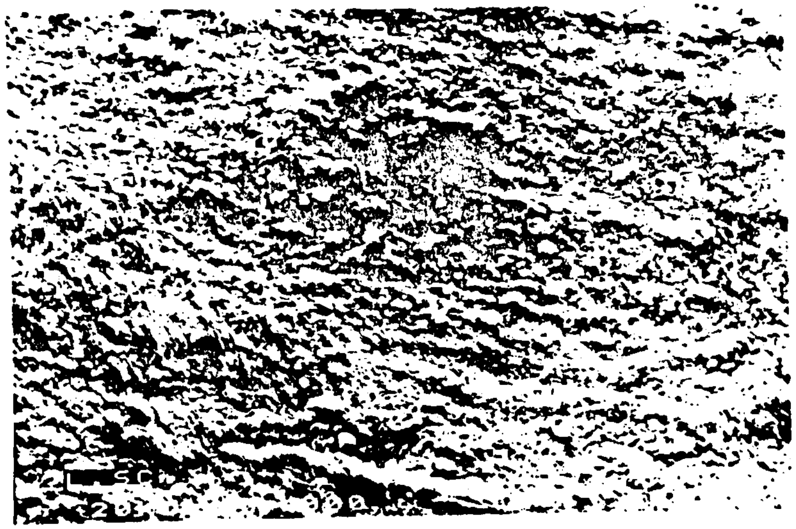


C. SEM SPECT. OF ZONES Y IN (A)

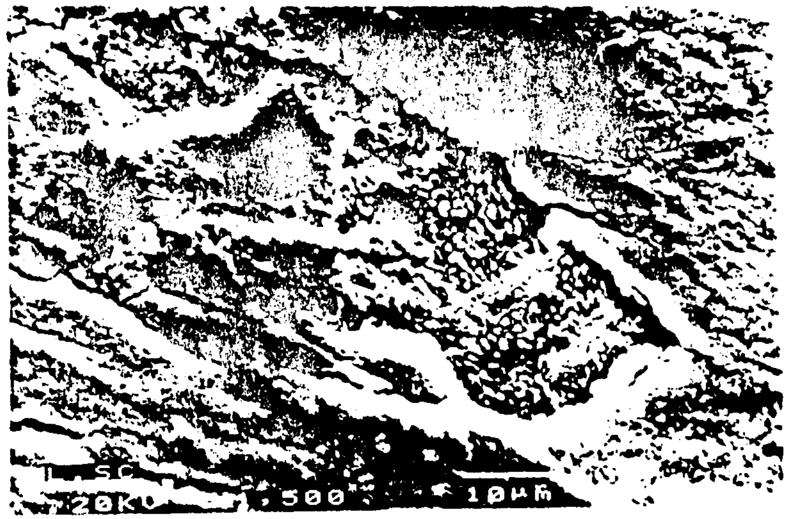


D. SEM SPECT. OF ZONES X AND Y IN (B)

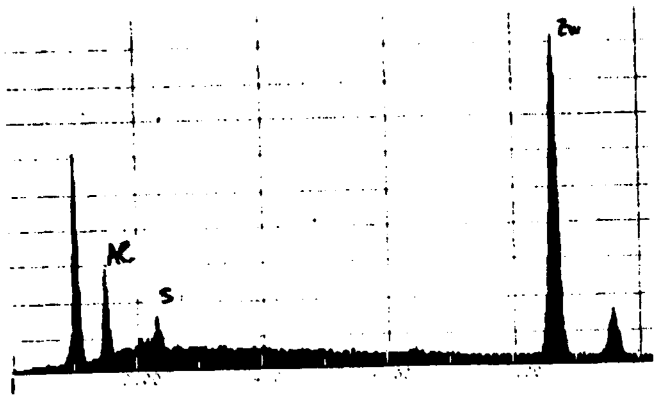
GALFAN SC (5.2 % AL). 1 YEAR OF EXPOSURE IN AN INDUSTRIAL SITE.



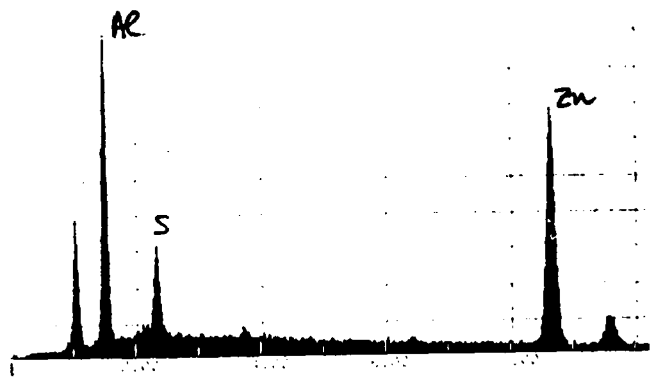
A. (1000X) GENERAL CORROS. 88/311/8



B. (1500X) AL-RICH NODULES 88/311/7

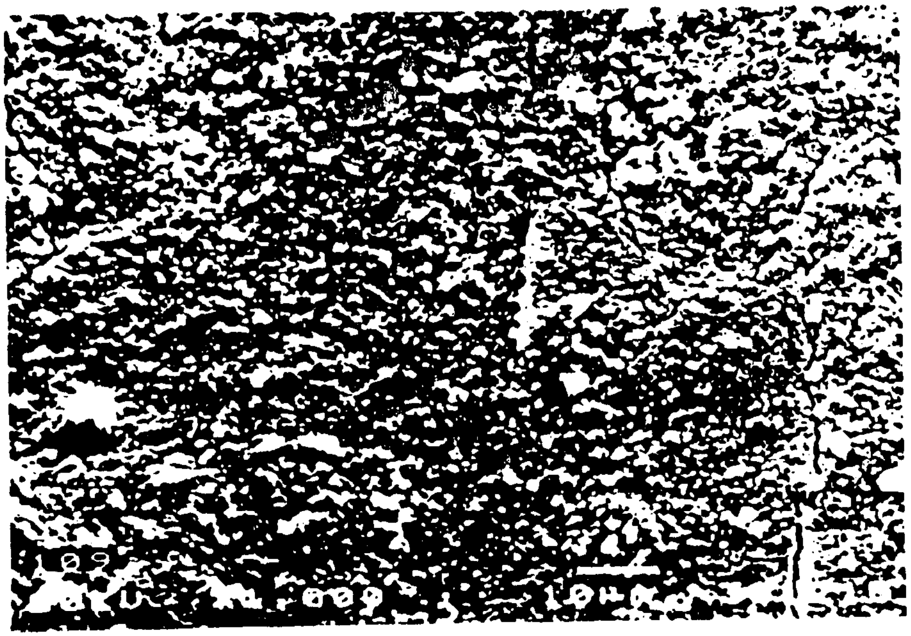


C. SEM SPECT. IN (A)

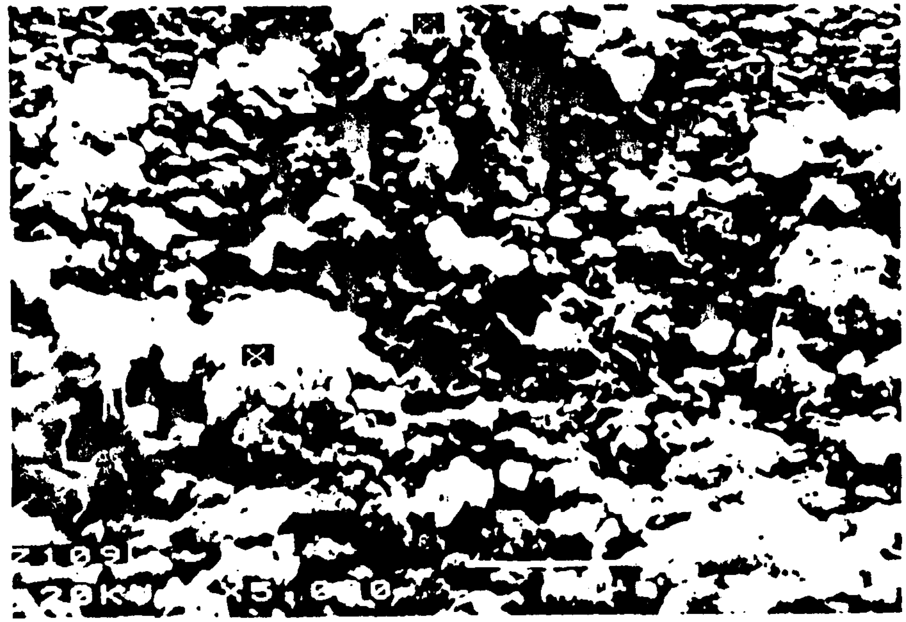


D. SEM SPECT. IN (B)

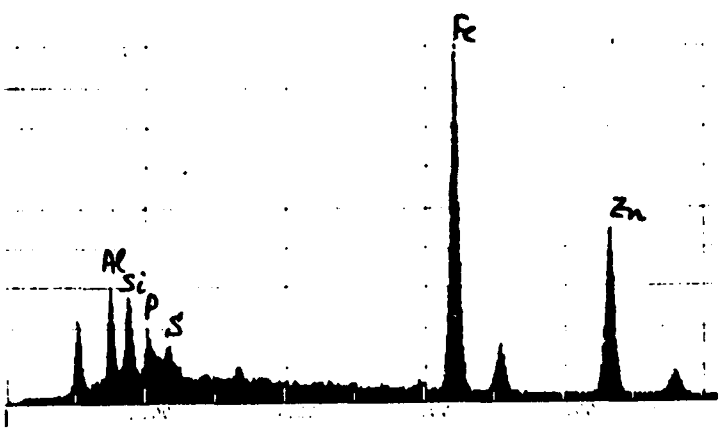
INDUSTRIAL CHROMATED GALFAN. 5 YEARS OF OUTDOOR EXPOSURE IN AN INDUSTRIAL SITE.



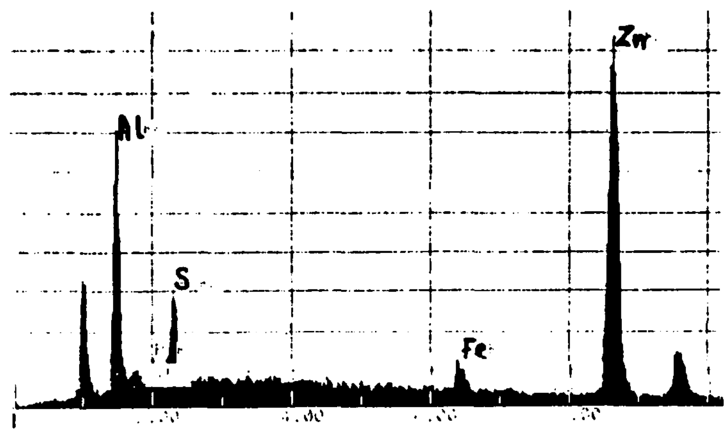
A. GENERAL CORROS., OVERVIEW (1000X) 88/298/15



B. DETAIL VIEW OF (A), (5000X) 88/298/05

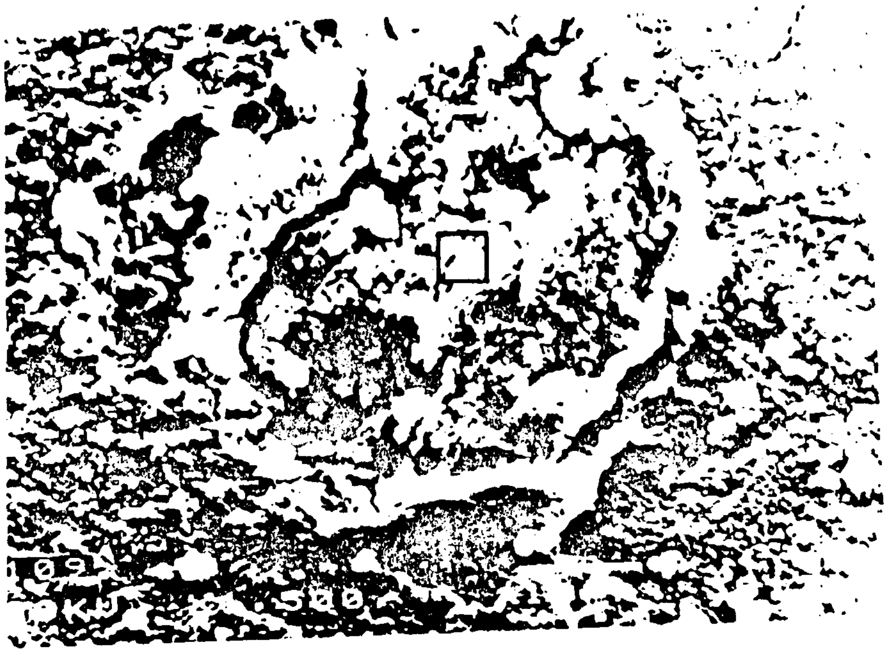


C. SEM SPECT. OF ZONES X IN (B)

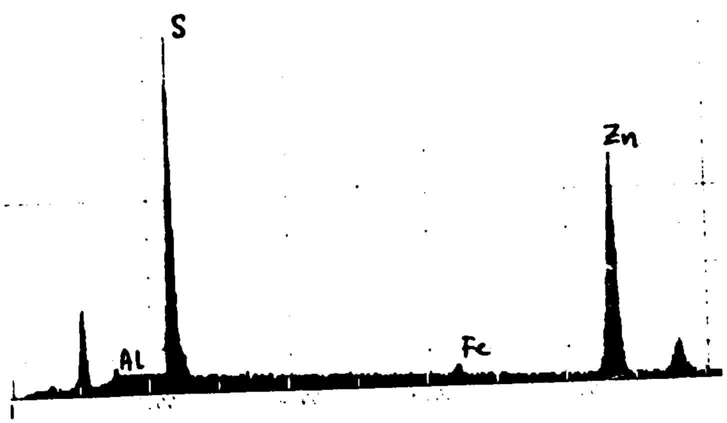


D. SEM SPECT. OF ZONES Y IN (B)

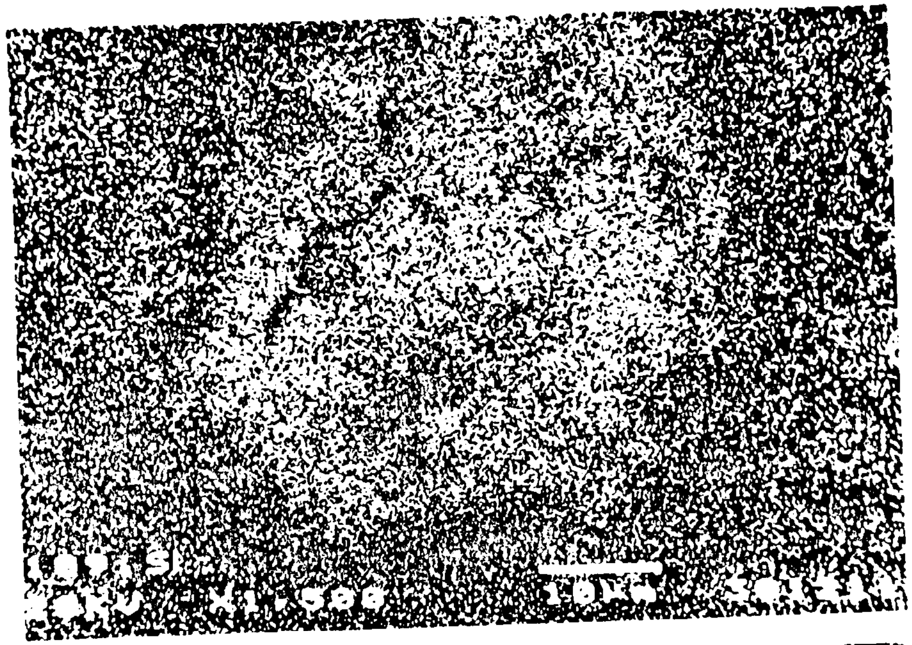
INDUSTRIAL CHROMATED GALFAN. 5 YEARS OF OUTDOOR EXPOSURE IN AN INDUSTRIAL SITE.



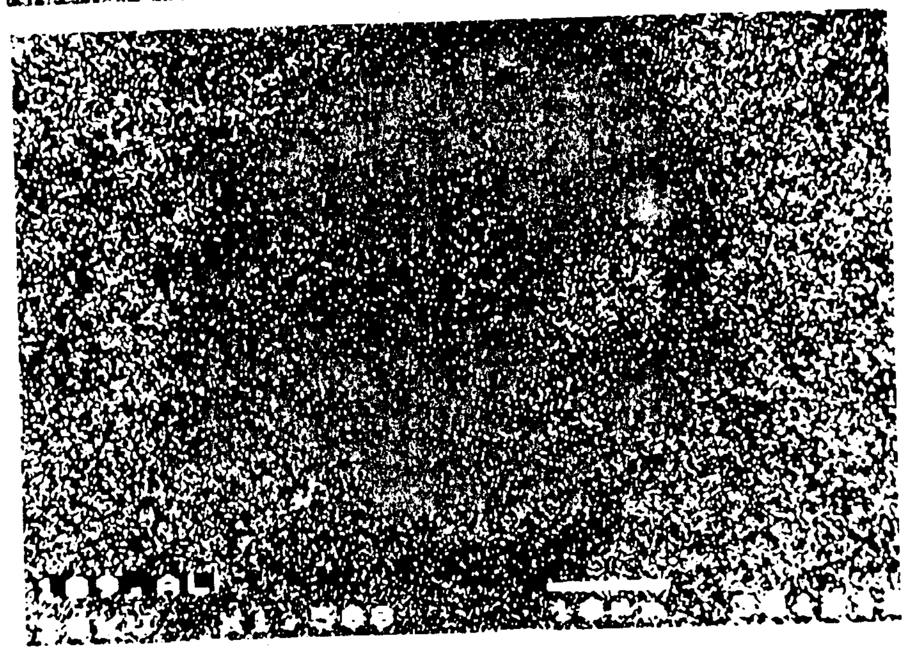
A. LOCAL CORROSION OF ZN-RICH PHASE
A,C,D CORRESPOND TO 88/289/10,11,12



B. SEM SPECT. OF THE CORRODED AREA IN (A)

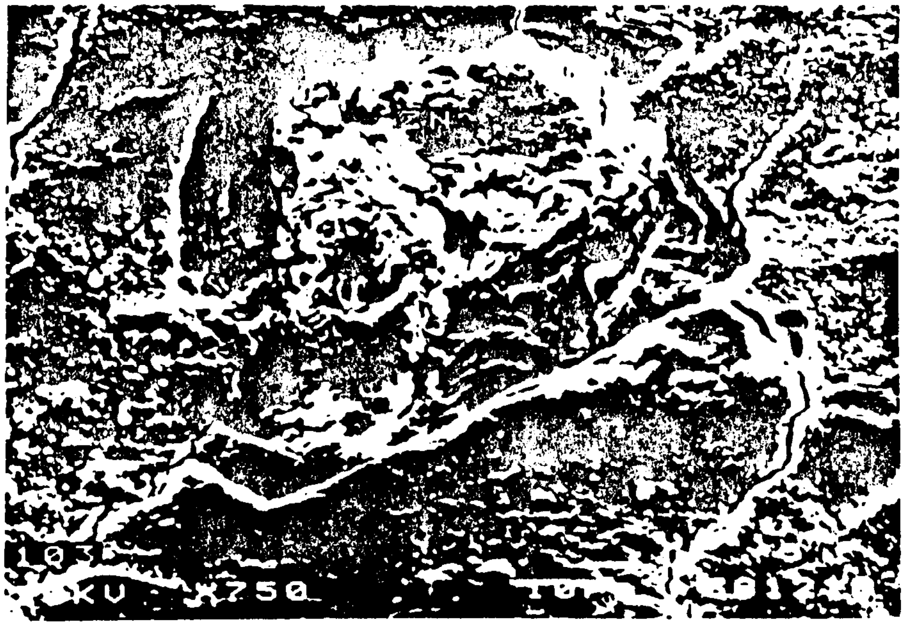


C

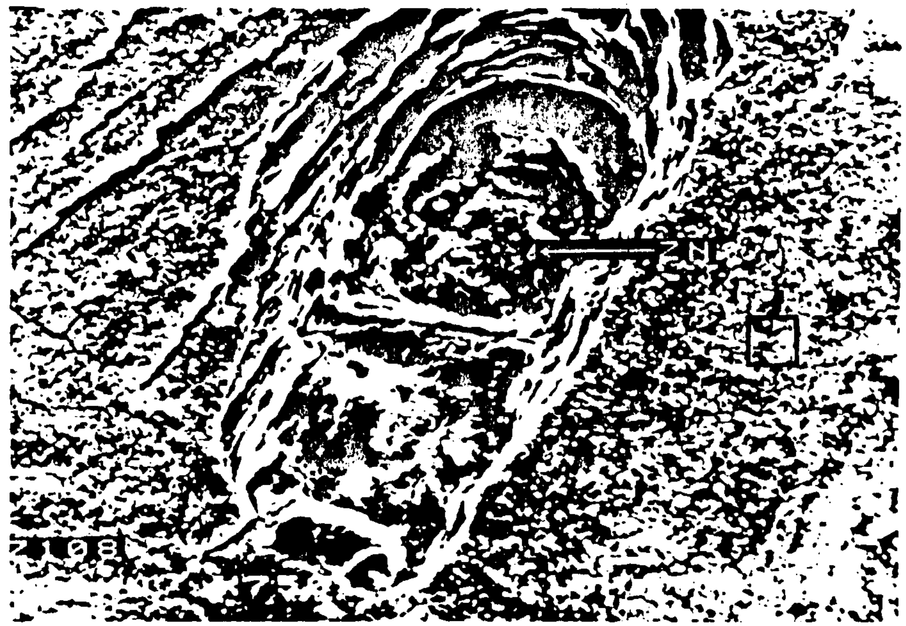


D

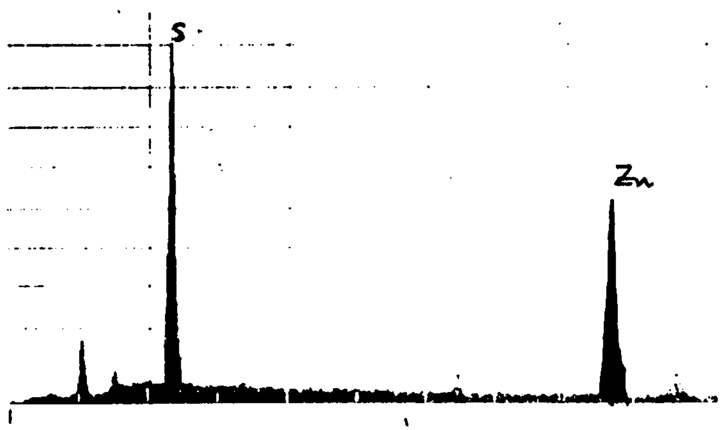
INDUSTRIAL UNCHROMATED GALFAN. 5 YEARS OF OUTDOOR EXPOSURE IN AN INDUSTRIAL SITE.



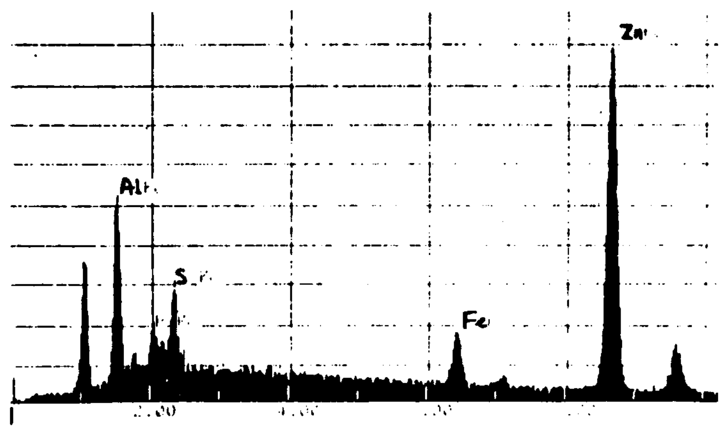
A. FIRST STEP OF CORROSION OF A PRIMARY PHASE (750X) 88/289/18



B. ADVANCED CORROSION OF A PRIMARY PHASE (750X) 88/289/21



C. SEM SPECT. OF CORRODED AREAS IN (A) AND (B)

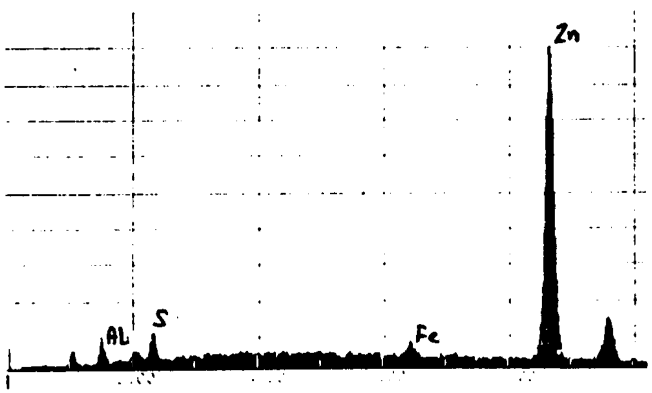


D. GENERAL CORROSION. SEM SPECT. IN A WINDOW (B)

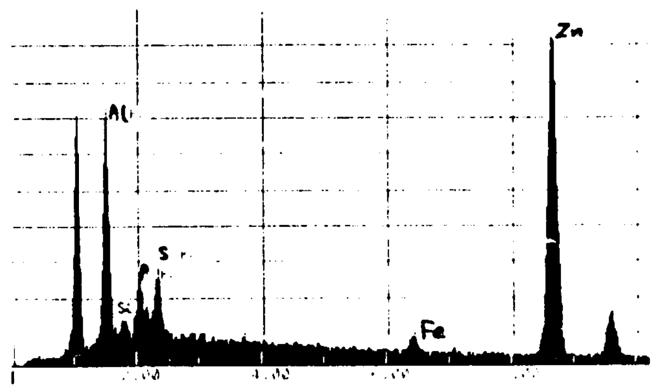
INDUSTRIAL CHROMATED GALFAN. 5 YEARS OF OUTDOOR EXPOSURE IN AN INDUSTRIAL SITE.

A. CORROSION AT A DENT, (1500X) 88/289/13

B. CORROSION OF AN AL-RICH NODULES CONTAINING ZONE, (750X) 88/289/14



C. SEM SPECT. IN THE DENT IN (A)



D. SEM SPECT. IN THE CORRODED AREA IN (B)

CORROSION RESISTANCE OF BENT GALVANIZED AND GALFAN COATED SHEETS IN A 10 PPM SO_2 ATMOSPHERE. INFLUENCE OF STEEL GAGE AND COATING THICKNESS.

REF (ZA/Z)	INITIAL THICK (µM)	STEEL GAGE (MM)	AL (%)	TIME TO APPEARANCE OF 5 TO 10% RED RUST AT THE FOLDING (DAYS) 90°	135°	180°
ZA1	15	0.8	4.2	(*)	(*)	(*)
ZA2	20	0.8	4.6	(*)	(*)	(*)
ZA3	15	1.2	4.6	131	(*)	83
ZA4	23	1.2	4.7	(*)	(*)	(*)
Z1	15	0.8	0.2	45	45	25
Z2	20	0.8	0.2	39	36	28
Z3	15	1.2	0.2	100	53	25
Z4	20	1.2	0.2	130	85	28

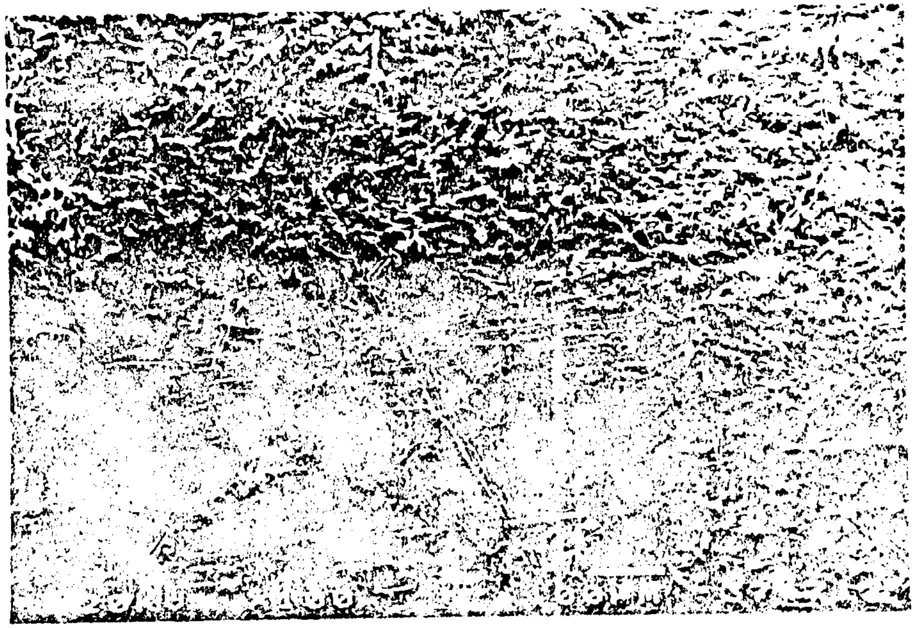
(*) TIME IS > 140 DAYS

NOTE : ALL THE SAMPLES ARE CHROMATED

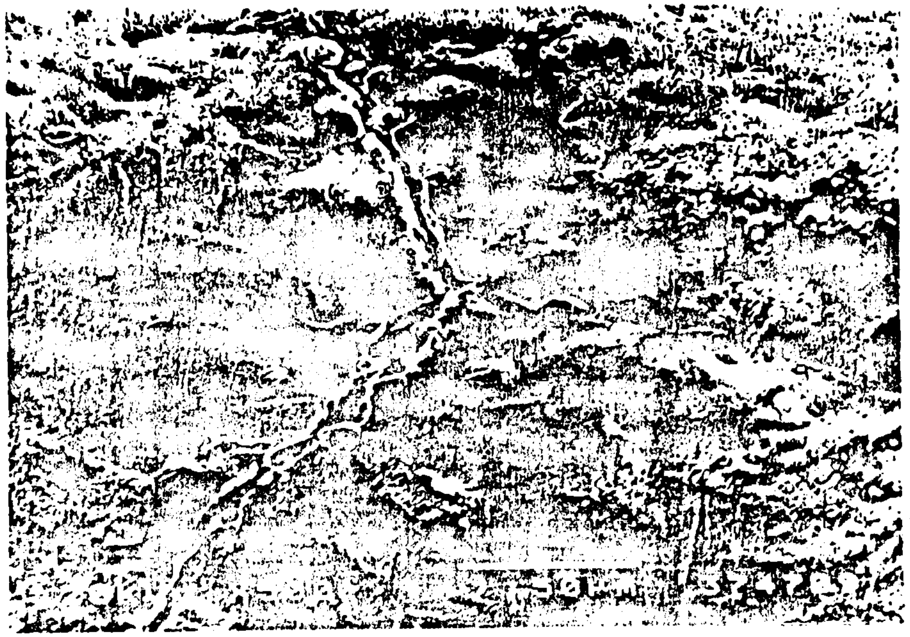
- FORMABILITY OF GALFAN COATINGS

- EXPANSION (20%) OF GALFAN SD (4.1% AL)

- INTENSIVE CRACKING AT THE GRAIN BOUNDARIES WHERE BRITTLENESS ORIGINATES AT THE ZN-RICH GLOBULES/EUTECTIC INTERPHASE AREA



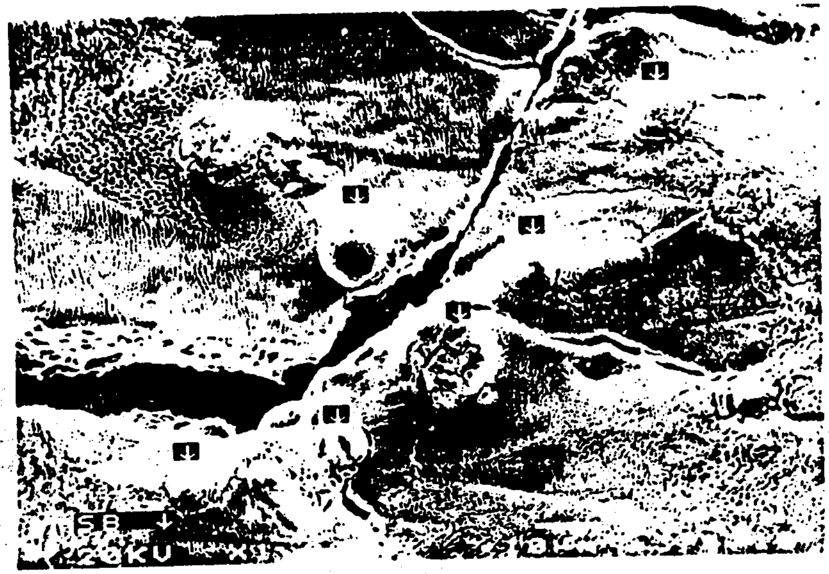
A. (100X) 88/185/12



B. (500X) 88/185/9

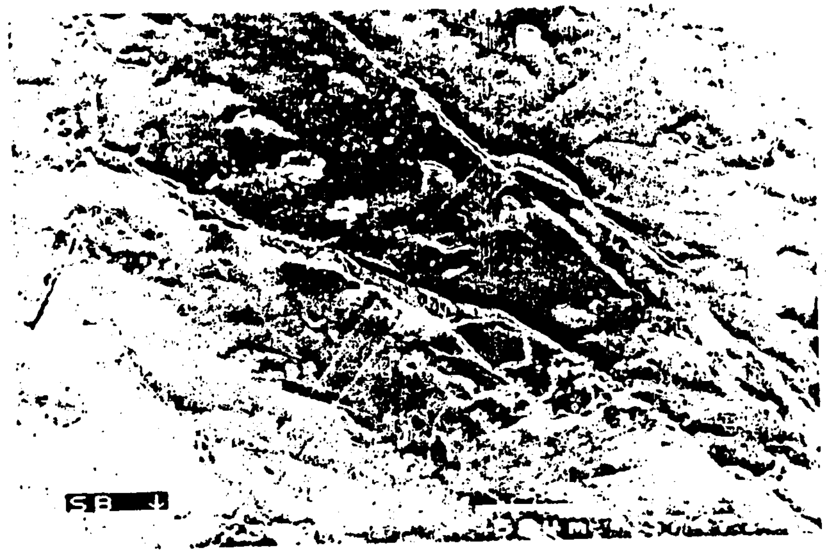
C. (1000X) 88/185/11

- FORMABILITY OF GALFAN COATINGS
- EXPANSION (20%) OF GALFAN SB (4.5% AL)
- FEW CRACKS AT THE GRAIN BOUNDARIES AND SOME CRACKS FORMED WITHIN THE GRAINS



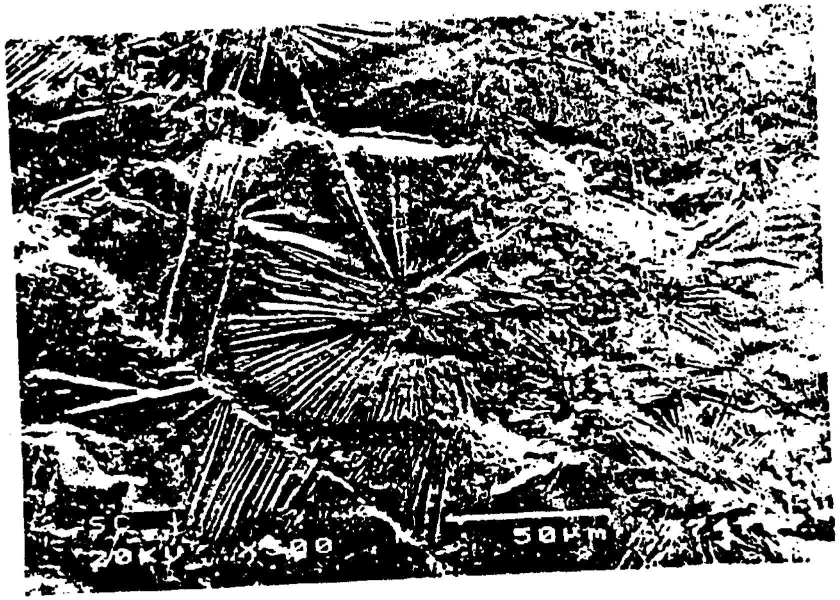
A. (1000X) 88/185/18

B. (500X) 88/185/20

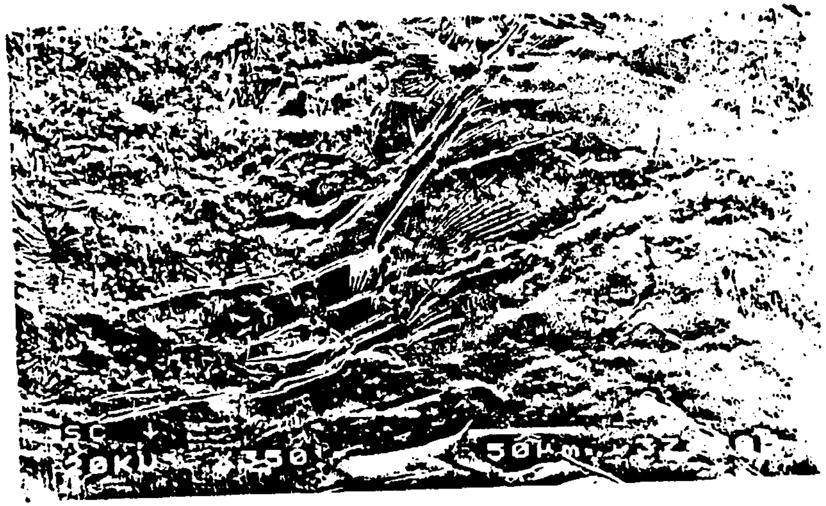


C. (350X) 88/185/17

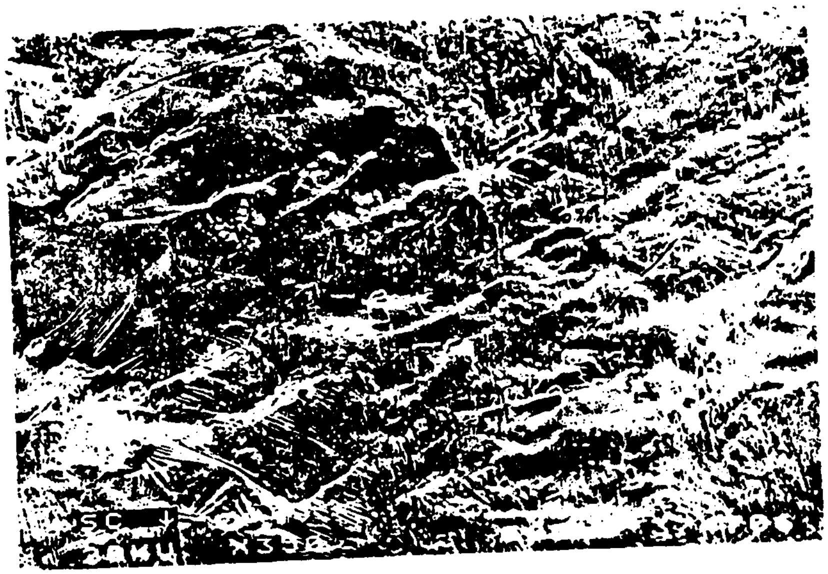
- FORMABILITY OF GALFAN COATINGS
- EXPANSION (20%) OF GALFAN SC (5.1% AL)
- NO CRACKS AT THE GRAIN BOUNDARIES. TINY CRACKS ARE SPREAD OUT OVER THE COATING.



A. (500X) 88/185/7

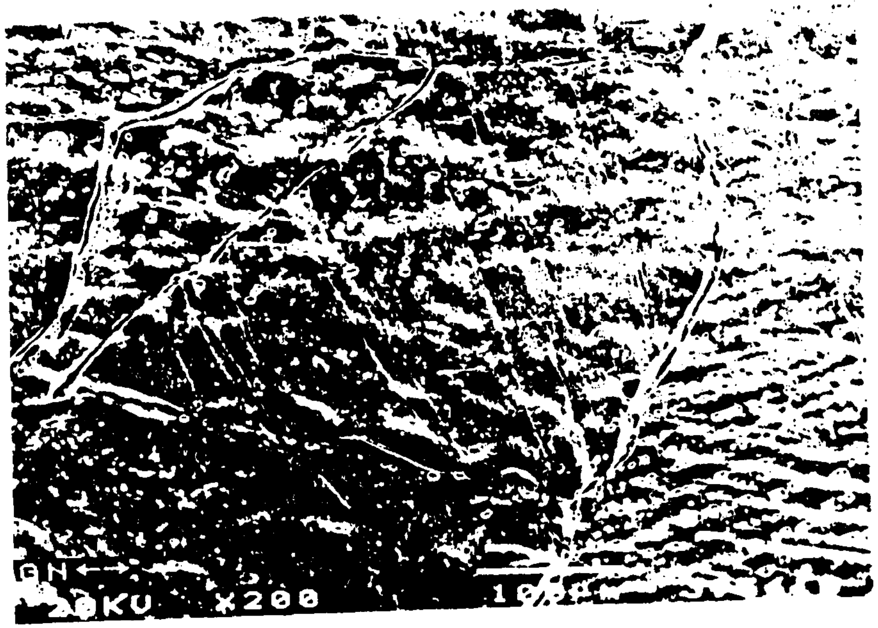


B. (350X) 88/185/5



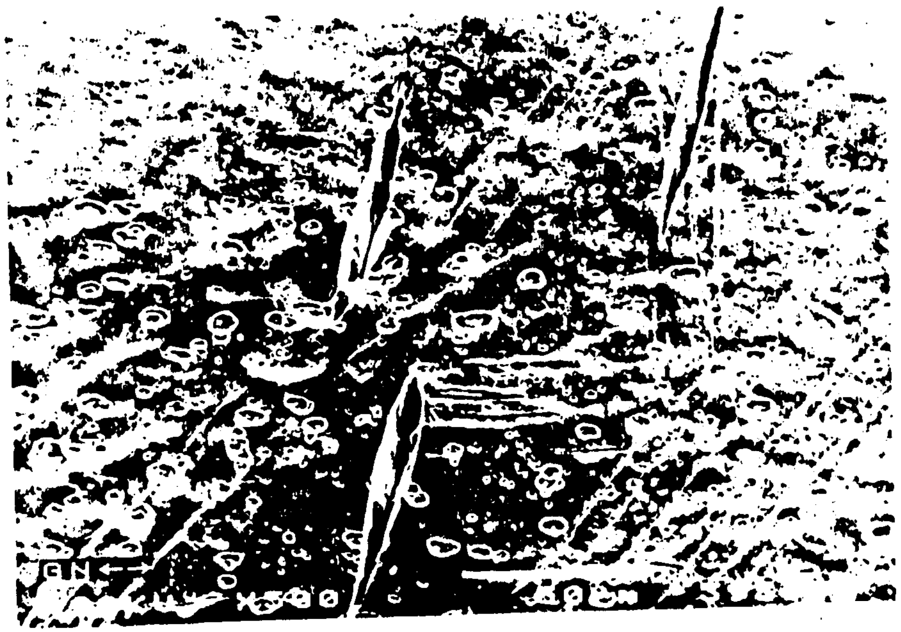
C. (350X) 88/185/6

- FORMABILITY OF NORMAL SPANGLE GALVANIZED COATING
- EXPANSION (20%). INITIAL THICK.: 20 μm
- INTENSE CRACKING AT THE GRAIN BOUNDARIES. CRACKS OF RESTRICTED DIMENSIONS WITHIN THE GRAINS.



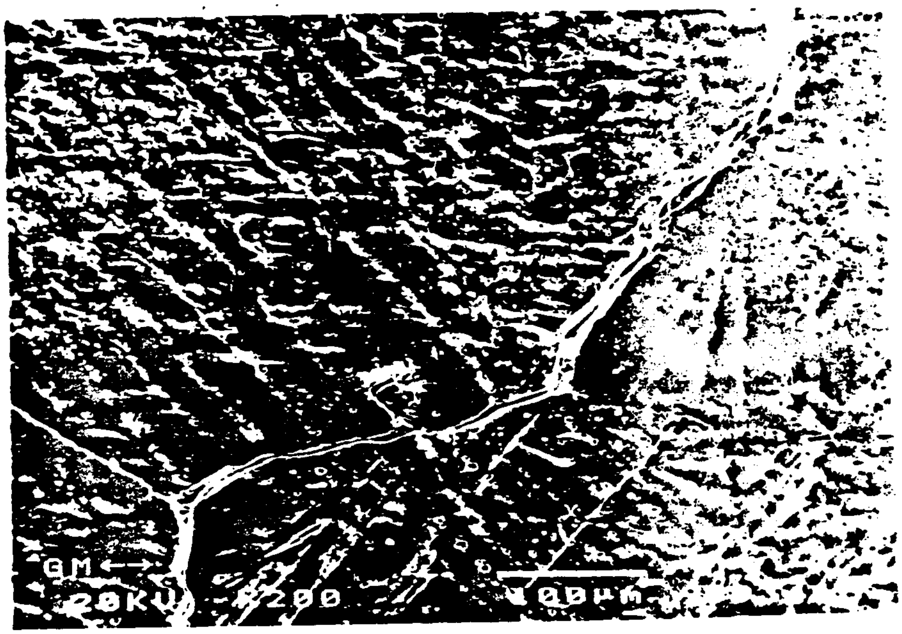
A. (200X) 88/302/10

B. (500X) 88/302/11



C. (500X) 88/302/12

- FORMABILITY OF A MINIMIZED GALVANIZED COATING
- EXPANSION OF 20%. INITIAL THICK.: 20 μm
- INTENSIVE CRACKING AT THE GRAIN BOUNDARIES



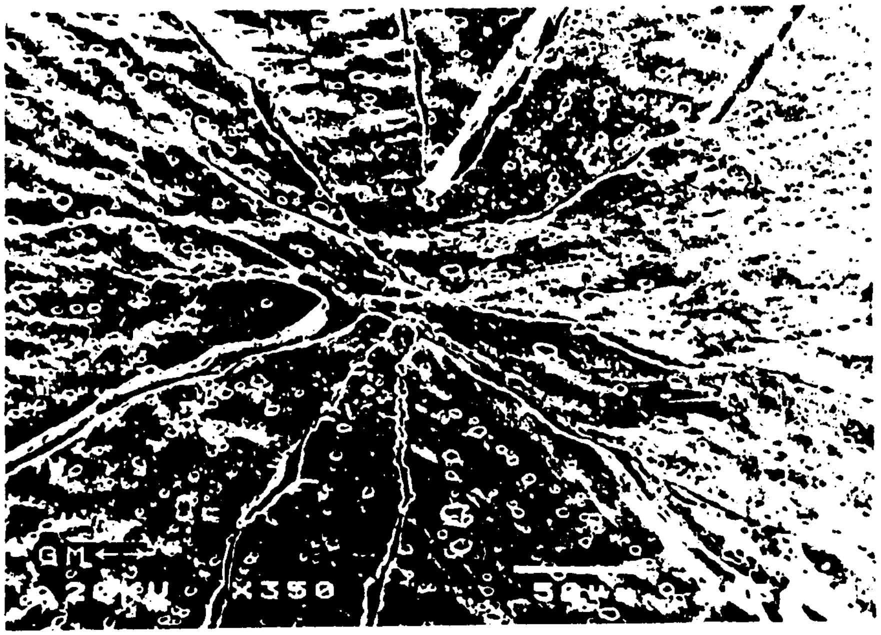
A. (200X)

88/302/15

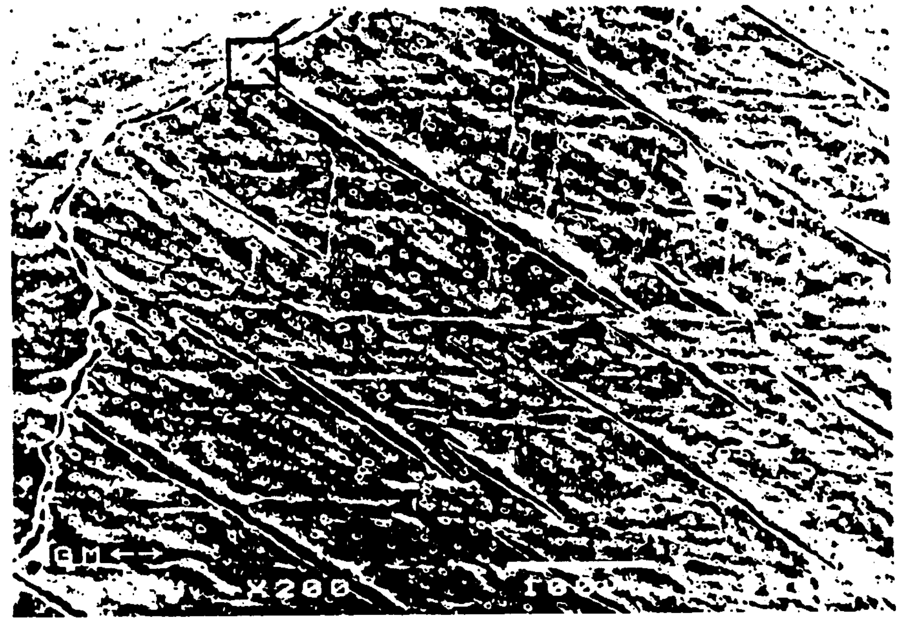
B. (350X)

88/302/16

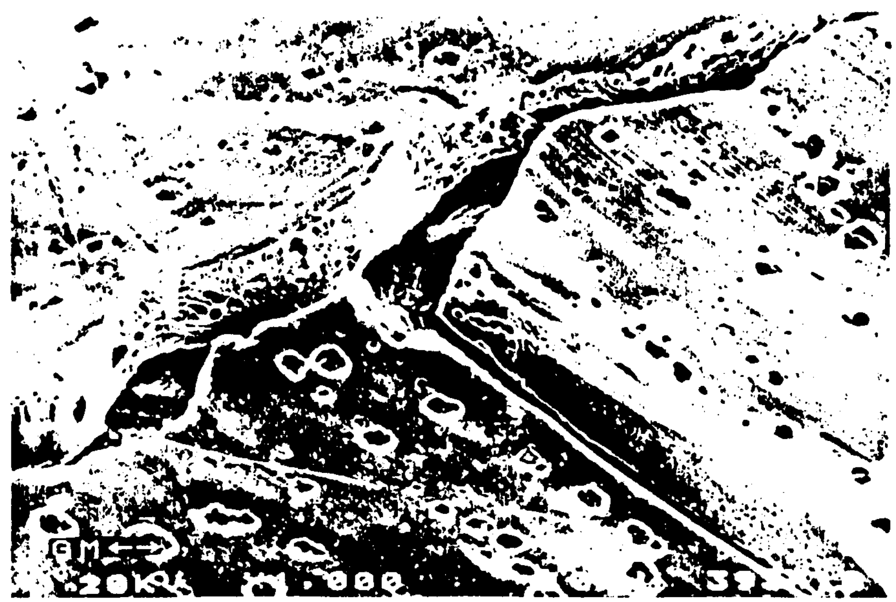
- FORMABILITY OF A MINIMIZED GALVANIZED COATING
- EXPANSION OF 20%. INITIAL THICK.: 20 μm
- CRACKING WITHIN GRAINS



A. (350X) 88/302/20

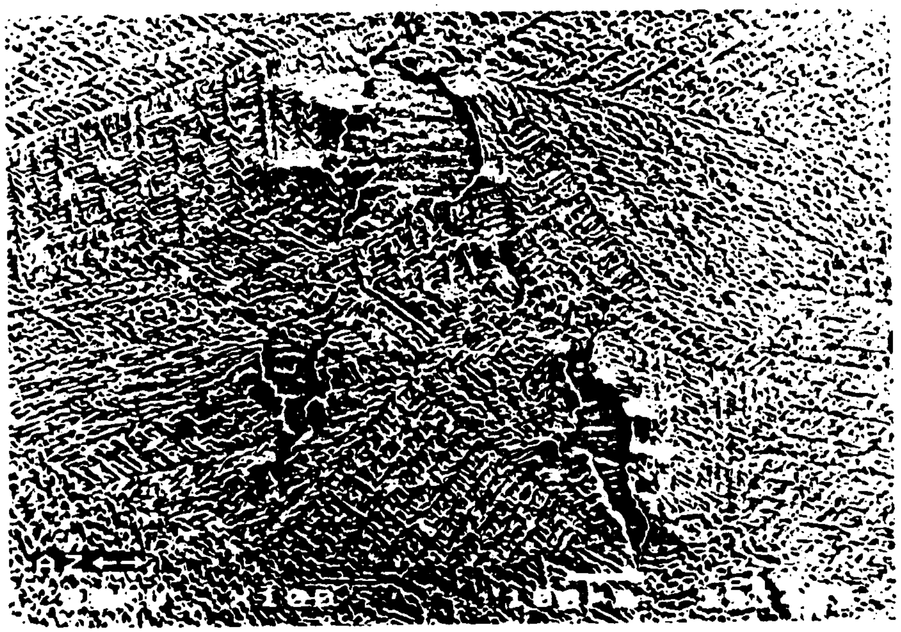


B. (200X) 88/302/17

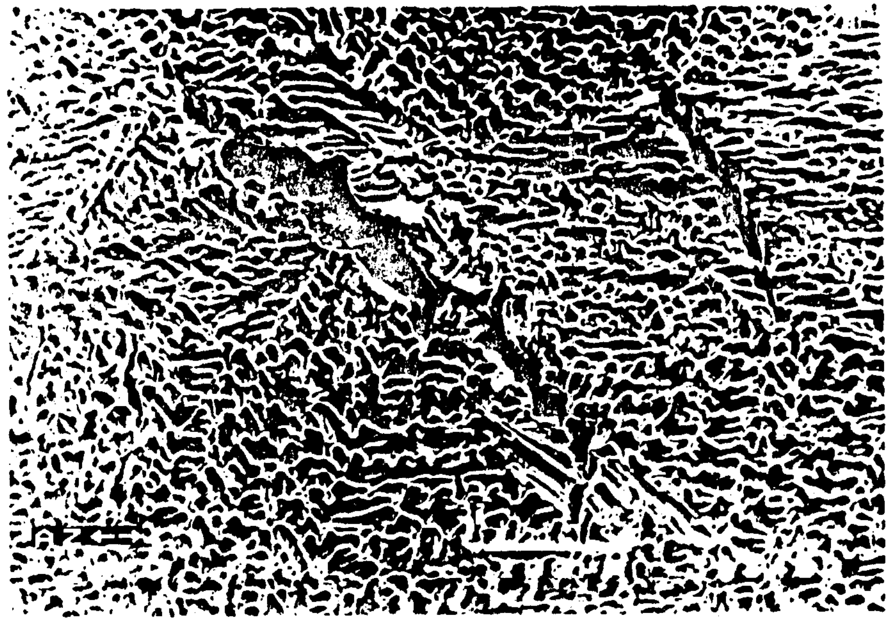


C. (1000X), DETAIL OF (B) 88/302/18

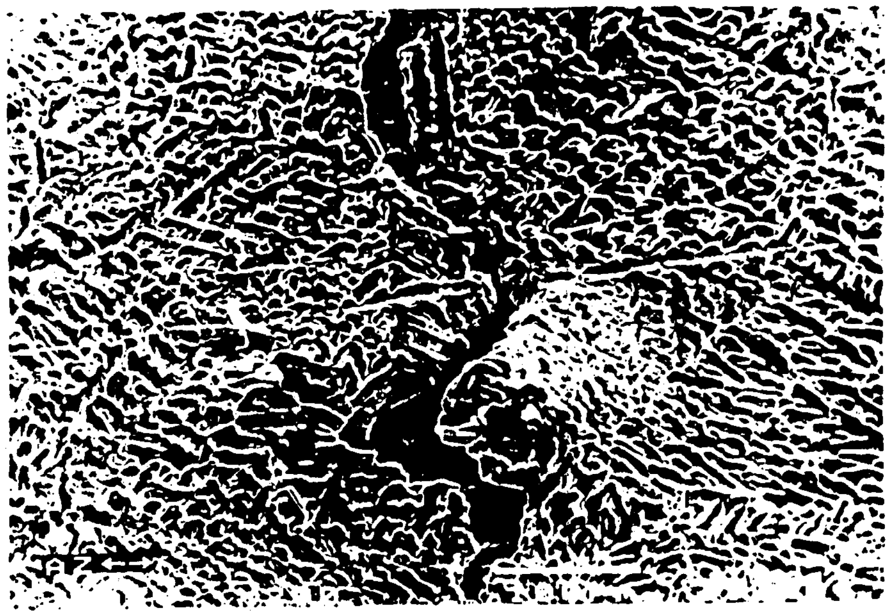
- FORMABILITY OF 55 AL-ZN COATINGS (23µM)
- EXPANSION OF 15%
- NUMBER OF CRACKS IS RELATIVELY LOW, BUT THESE CRACKS, ONCE GENERATED, PROPAGATE WHEN THE DEFORMATION IS INCREASED



A. (100X) 88/302/9

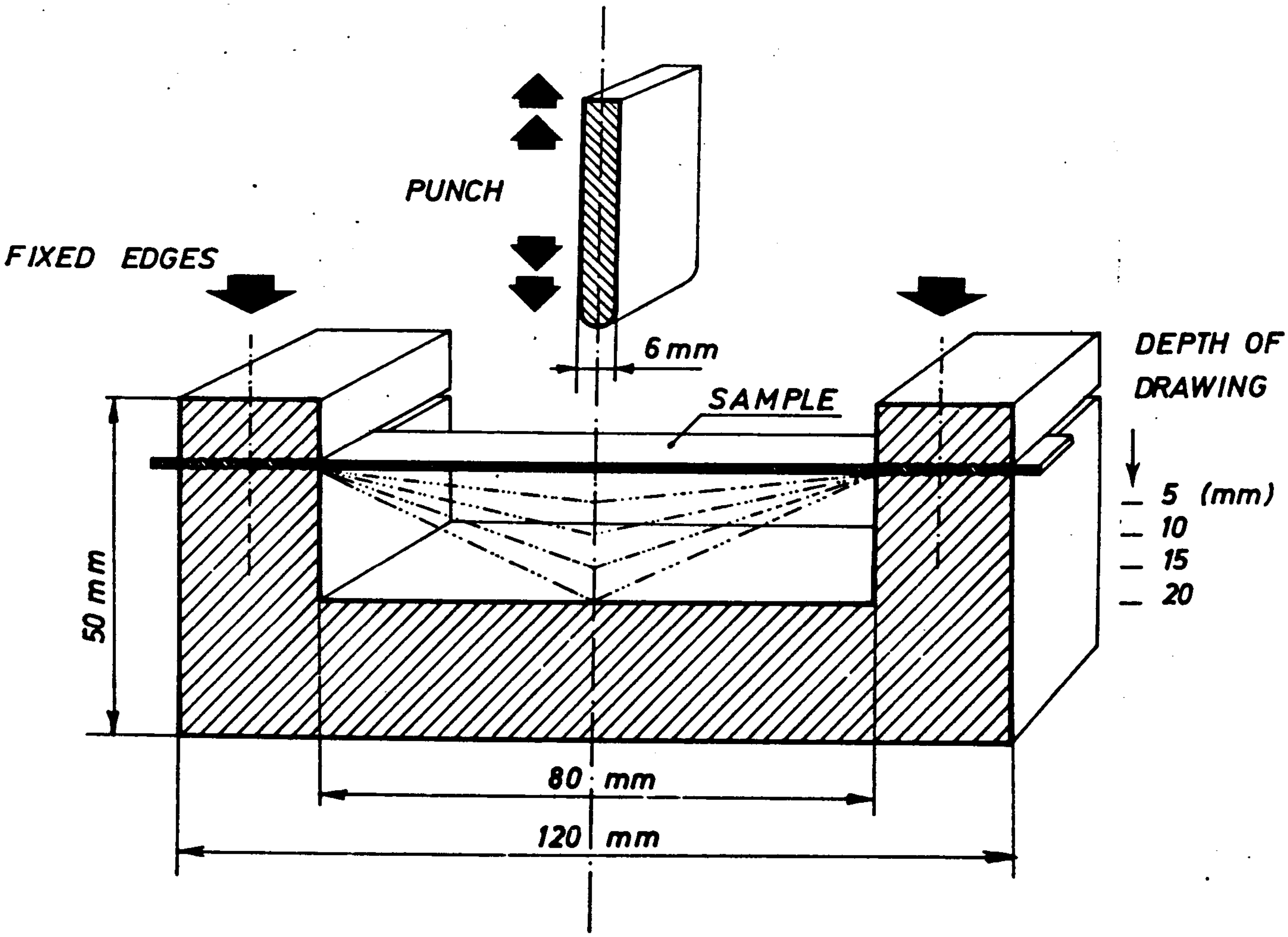


B. (200X) 88/302/2



C. (200X) 88/302/4

STRETCHING TEST



Sample -110-130 x-10-25 mm

FORMABILITY OF GALFAN SD (4.1% AL)

STRETCHING.

· INTENSIVE CRACKING AT THE GRAIN BOUNDARIES WHERE BRITTLENESS ORIGINATES AT THE ZN-RICH/EUTECTIC INTERPHASE AREA

A. (500X) 88/286/8

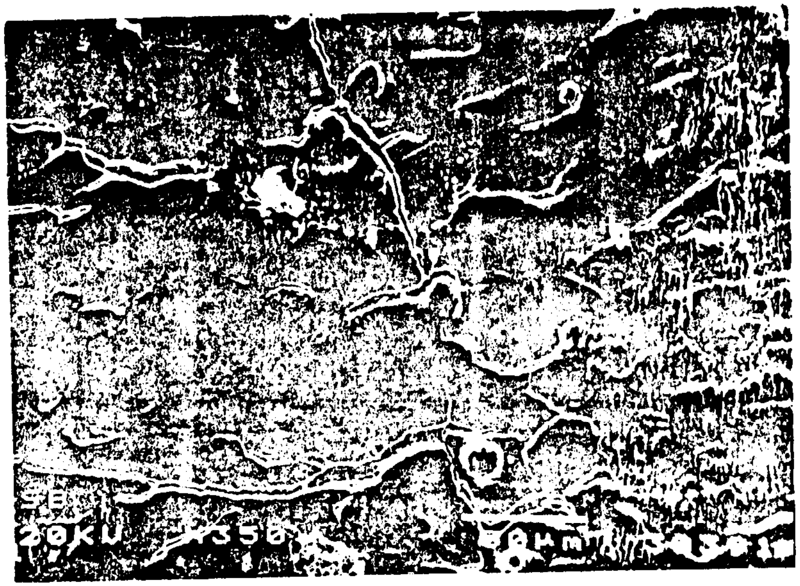
B. (1000X) 88/286/4

C. (1500X) 88/286/5

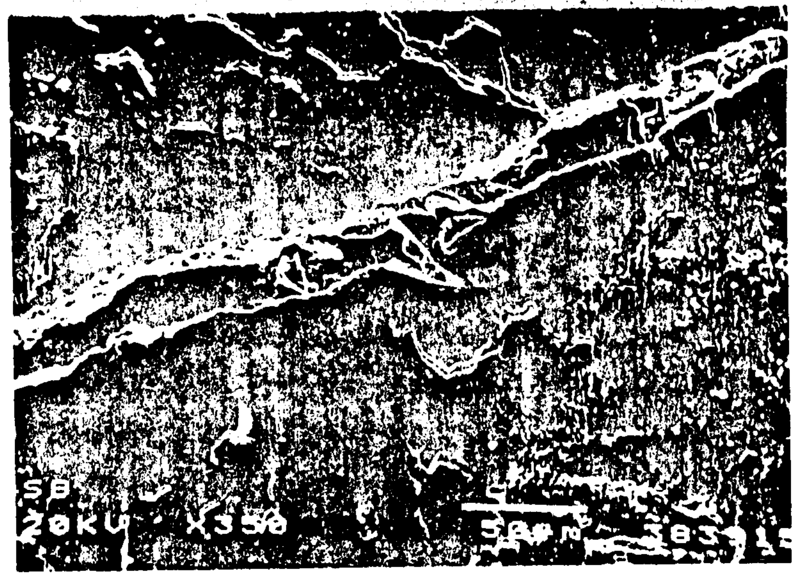
- FORMABILITY OF GALFAN SB (4.5% AL)

-

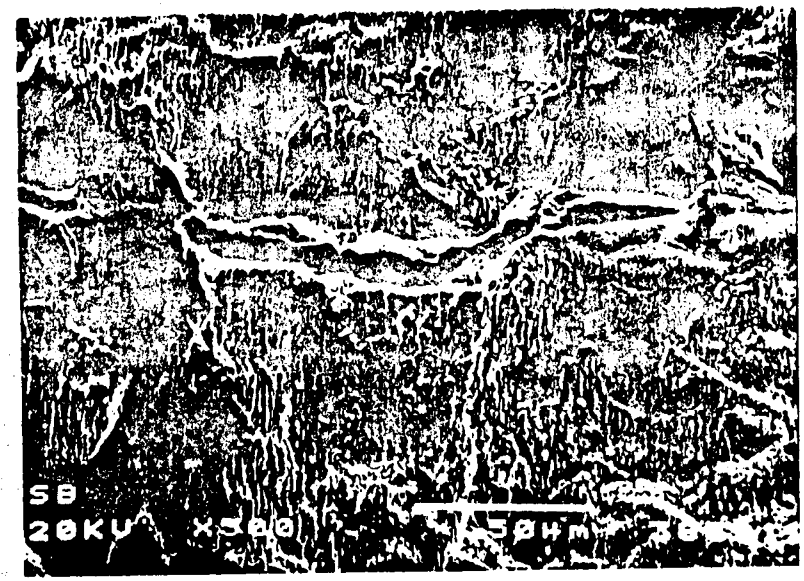
- MODERATE CRACKING AT THE GRAIN BOUNDARIES (A), BUT SOME PROPAGATING CRACKS WITHIN THE GRAINS (B), AND LOCAL BRITTLENESS INDUCED BY A HARD SKIN-PASS



A. (350X) 88/286/14



B. (350X) 88/286/15



C. (500X) 88/286/12

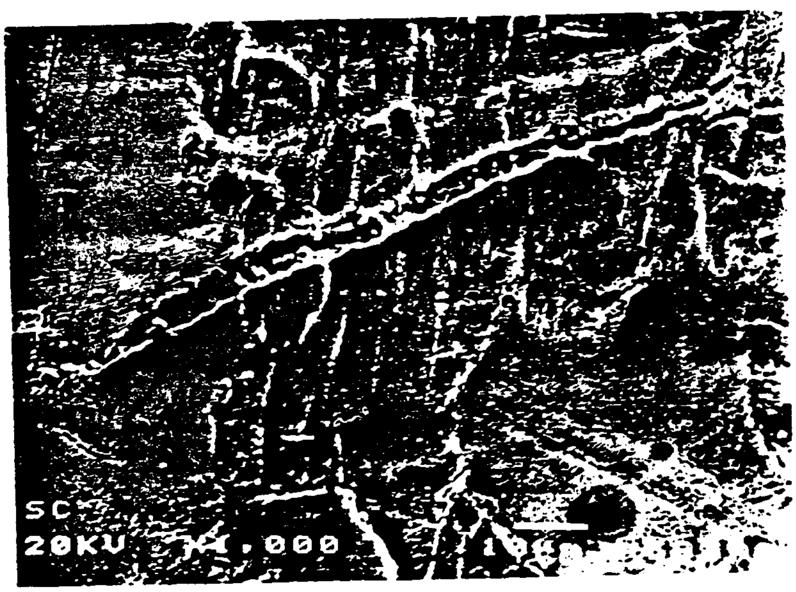
- FORMABILITY OF GALFAN SC (5.1% AL)

-

- (A) NO CRACKS AT GRAIN BOUNDARIES. LIMITED CRACKING WITHIN THE GRAINS WITHOUT ANY PROPAGATION.
  (B) LIMITED CRACKING ORIGINATING IN A SKIN-PASSED AREA.

A. (750X)

88/286/9

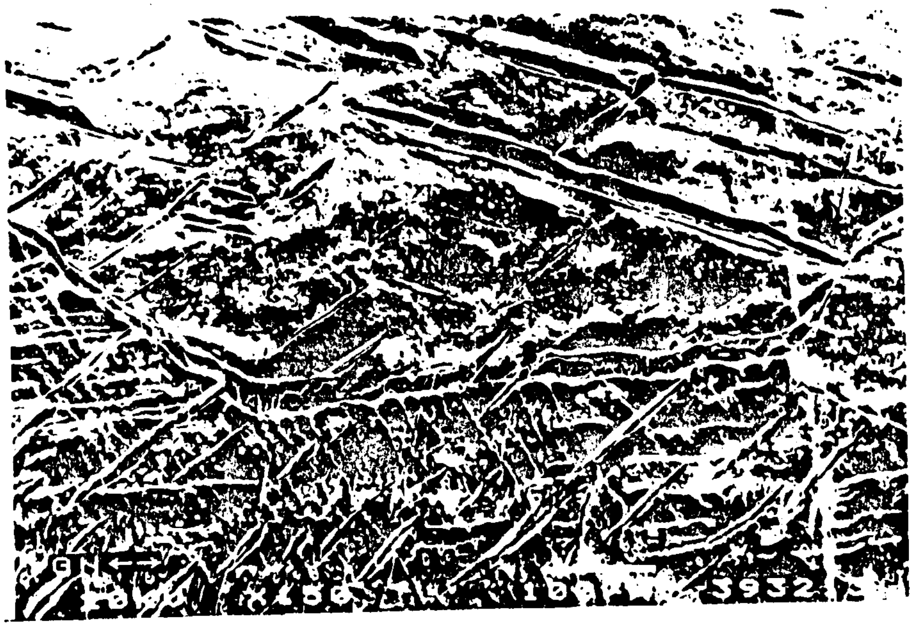


B. (1000X)

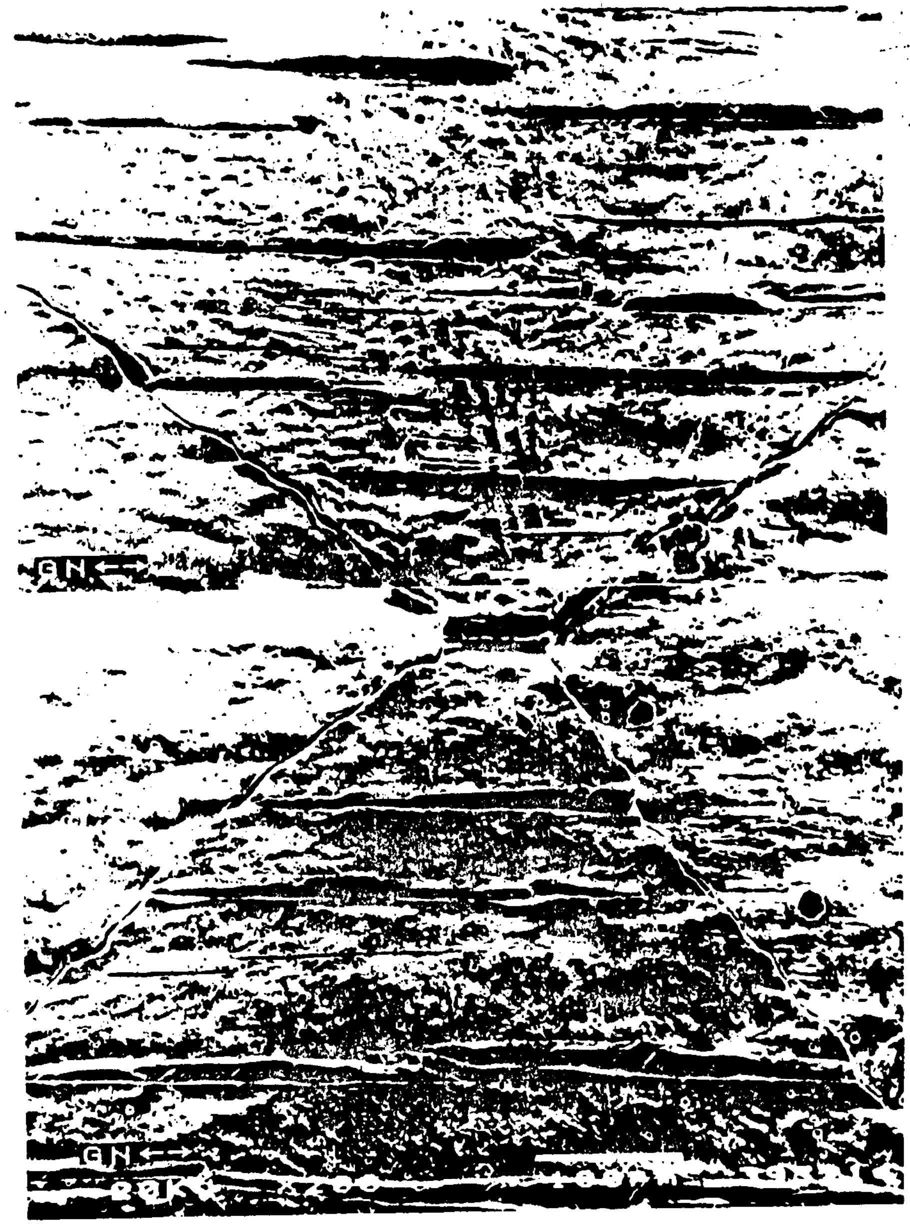
88/286/11

- FORMABILITY OF NORMAL SPANGLE GALVANIZED COATING (20μM)

- INTENSE CRACKING AT GRAIN BOUNDARIES AND INTERIOR. NETWORKS OF CRACKS ARE ALONG TWO DIRECTIONS.



A. (150X) 88/301/13



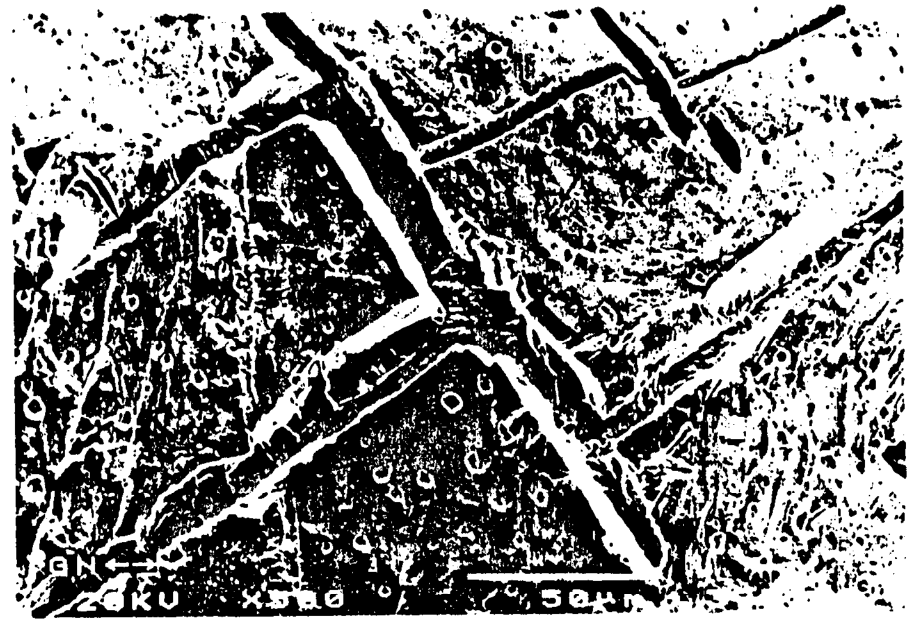
B. (200X) 88/301/15

- FORMABILITY OF NORMAL SPANGLE GALVANIZED COATING (20µM)

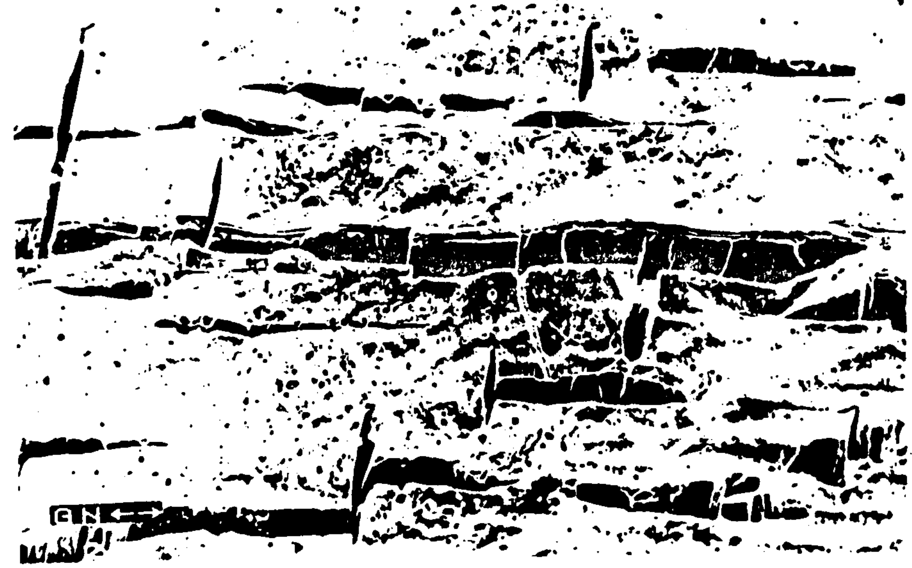
-

- ILLUSTRATION OF TWO DIRECTIONS CRACKS.

A. (150X) 88/301/19



B. (500X) 88/301/20



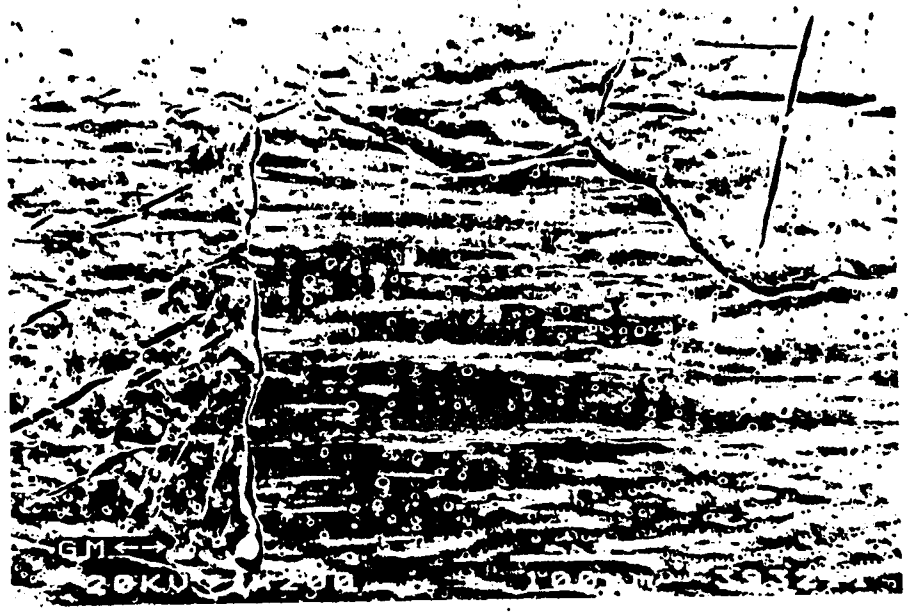
C. (350X) 88/301/16

- FORMABILITY OF A MINIMIZED GALVANIZED COATING (20μm)

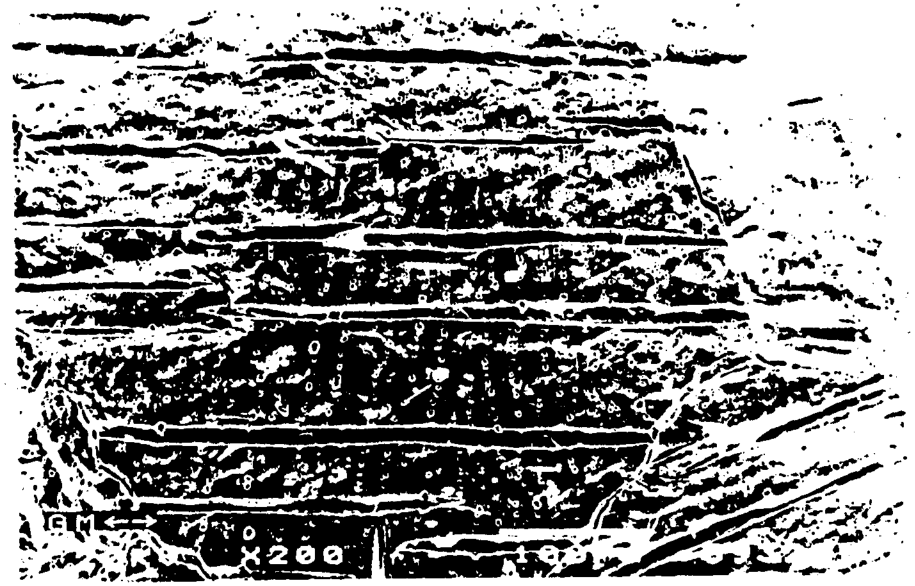
-

- INTENSE CRACKING AT THE BOUNDARIES AND NETWORKS OF PARALLEL CRACKS WITHIN 50% OF THE GRAINS. VERY FEW CRACKS NORMAL TO THE AXIS OF DEFORMATION.

A. (200X) 88/301/12



B. (200X) 88/301/11

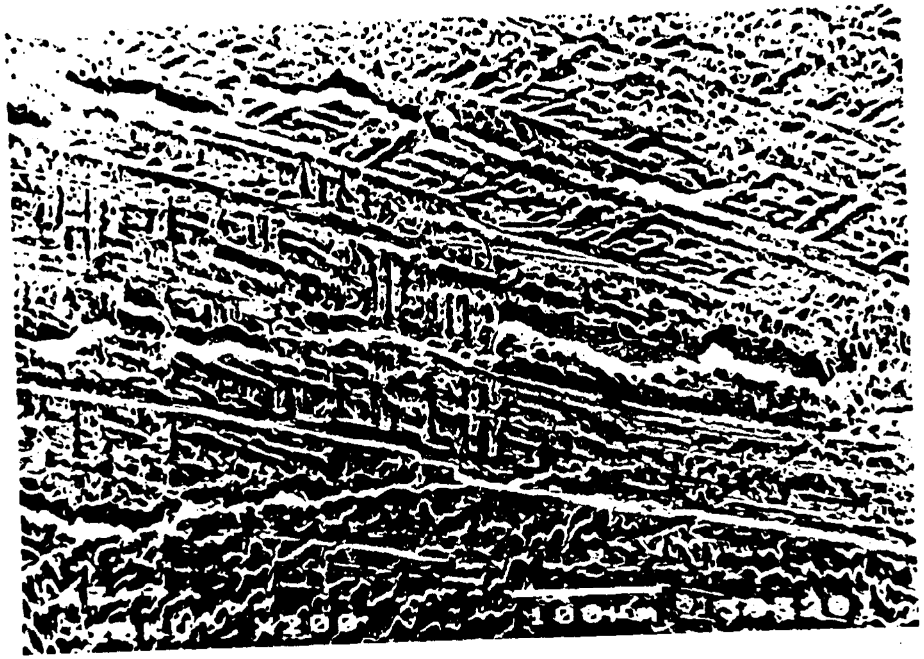


C. (200X) 88/301/7

- FORMABILITY OF 55 AL-ZN COATING (23µM)

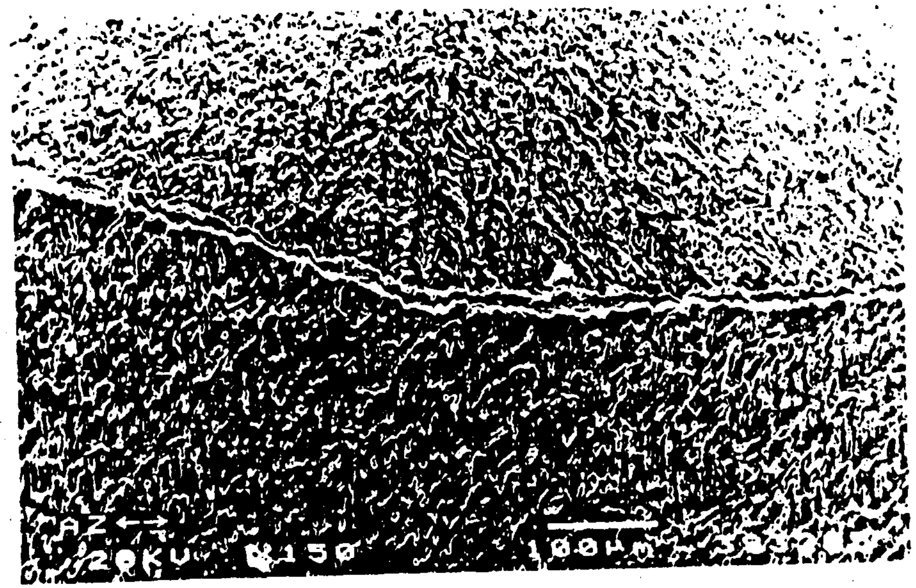
-

- MODERATE NUMBER OF CRACKS, BUT PROPAGATE OVER SEVERAL HUNDREDS OF MICRONS



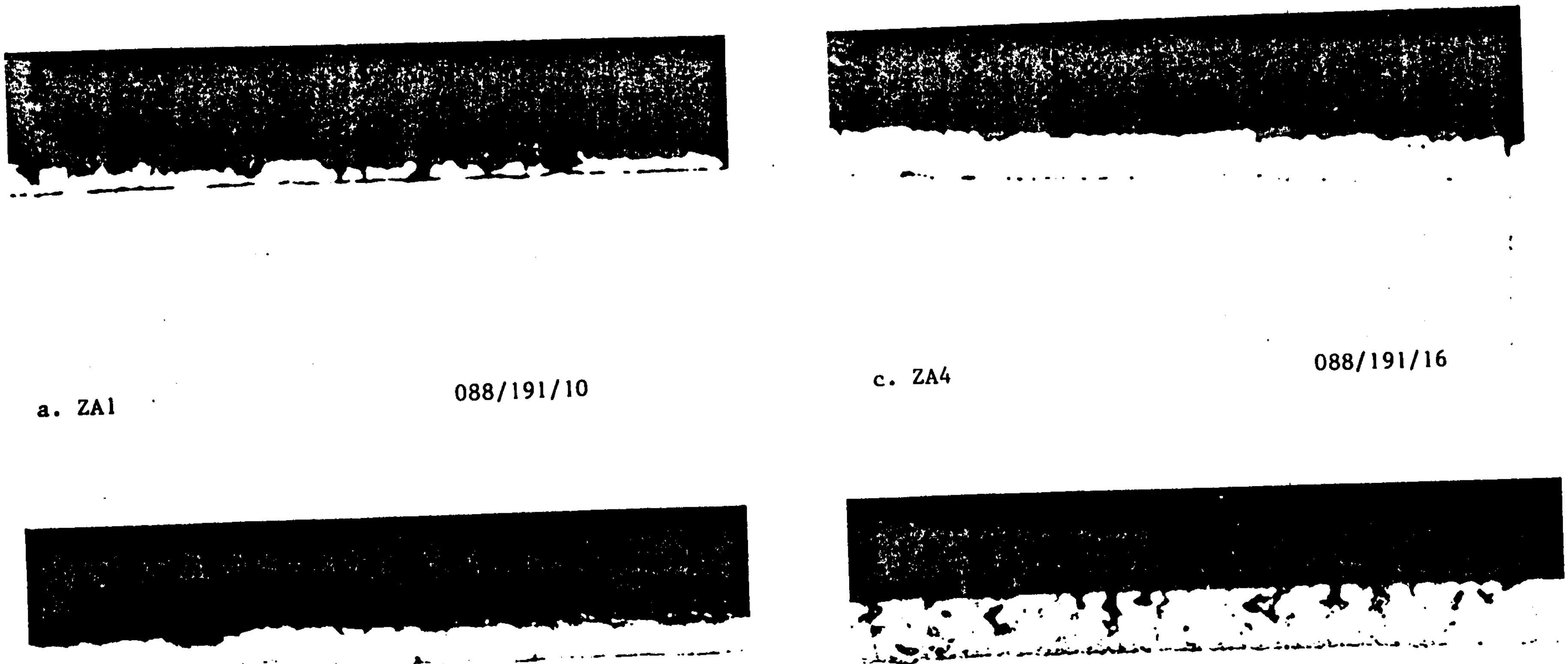
A. (200X) 88/301/1

B. (200X) 88/301/2



C. (150X) 88/301/5

FIGURE 70 : CROSS-SECTIONAL MICROSTRUCTURES (MAGN.250X) OF NON POST-ANNEALED GALFAN (TABLE 14) AND 55AL-ZN COATINGS,AFTER 3 WEEKS OF EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE.



a. ZA1 088/191/10

c. ZA4 088/191/16

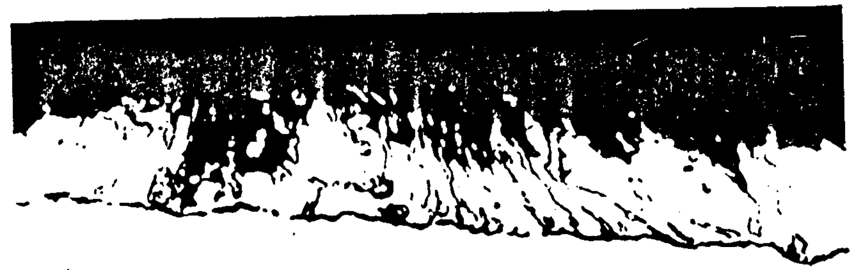
b. ZA2 088/191/14

d. 55AL-ZN 088/191/29

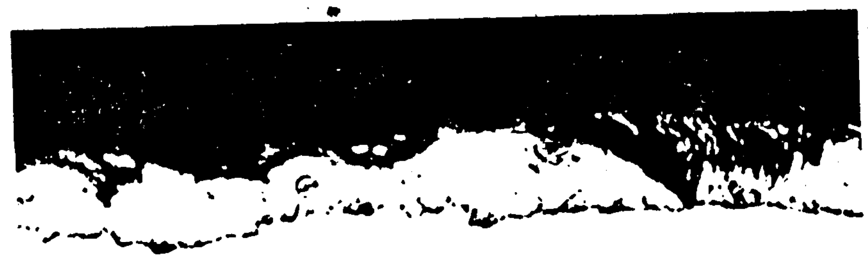
FIGURE 71 : CROSS-SECTIONAL MICROSTRUCTURES OF POST-ANNEALED GALFAN COATINGS, AFTER 3 WEEKS OF EXPOSURE IN A 10 PPM SO_2 ATMOSPHERE. a to d) LOW COARSENING DEGREE OF GALFAN'S MICROSTRUCTURE.

a. (800X) 088/191/30

b. (800X) 088/191/32

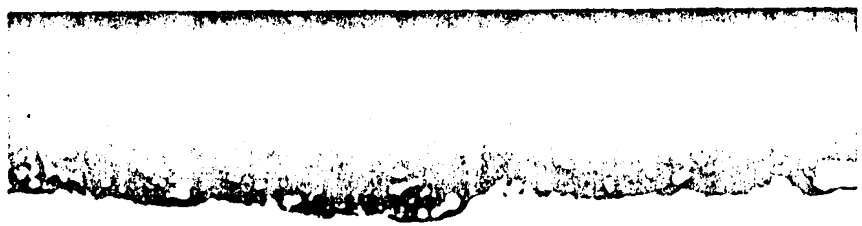


c. (800X) 088/191/31



d. (500X) 088/191/24

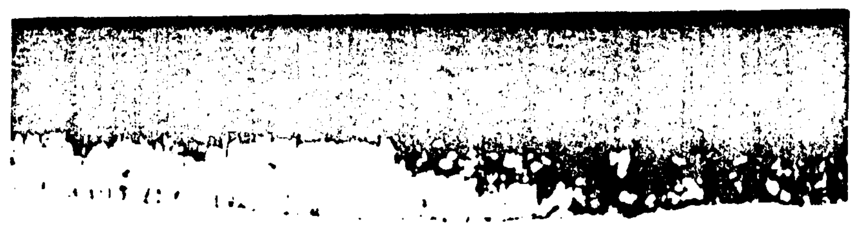
FIGURE 71 (CONTINUED) : e to h) HIGH COARSENING DEGREE OF GALFAN'S MICROSTRUCTURE.



e. (500X) 088/191/17

g. (400X) 088/191/27

f. (800X) 088/191/18

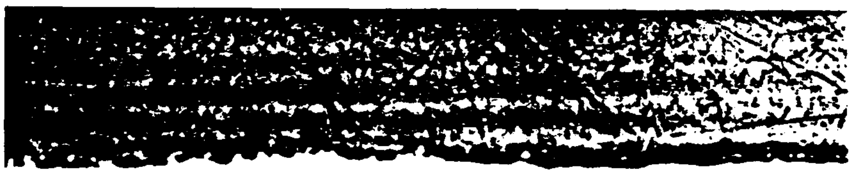


h. (500X) 088/191/26

FIGURE 69 : CROSS-SECTIONAL MICROSTRUCTURES OF GALVANIZED COATED SHEETS, EXPOSED 3 WEEKS IN A 10 PPM SO_2 ATMOSPHERE.

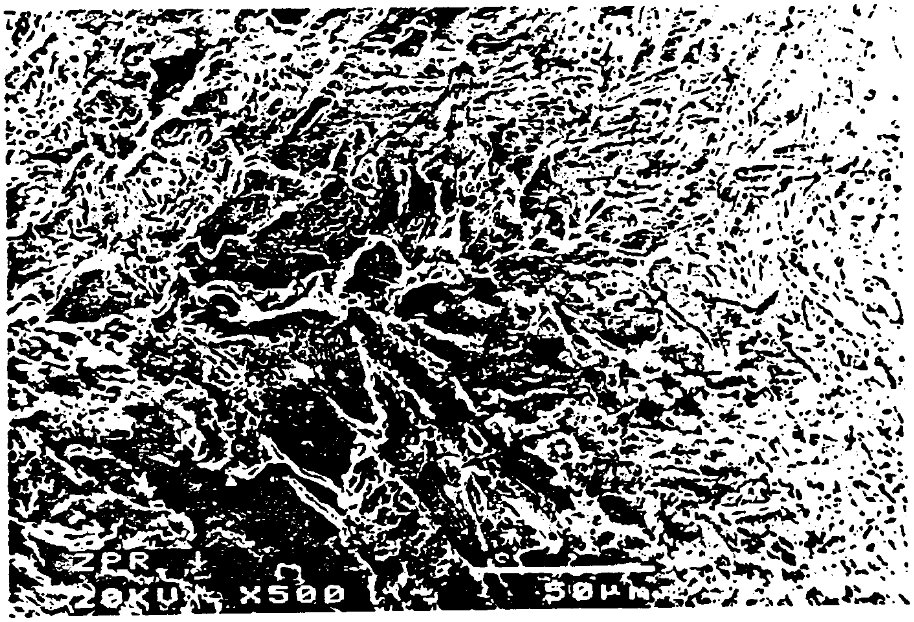
a. Z1 (250X) 088/191/1

b. Z2 (400X) 088/191/4



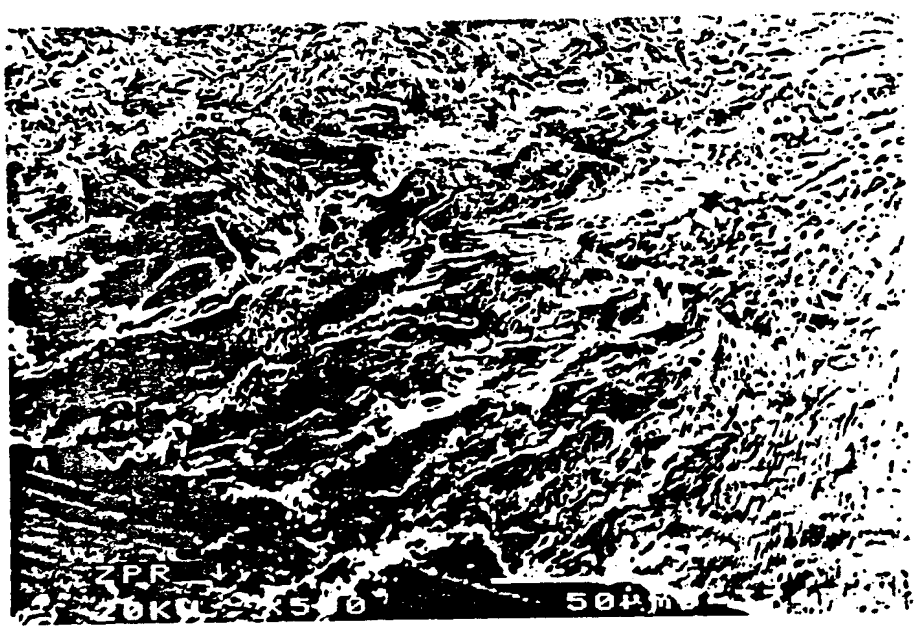
c. Z4 (250X) 088/191/7

- FORMABILITY OF POST-ANNEALED GALFAN COATED SHEETS
- LOW COARSENING DEGREE
- EXPANSION (17%). GOOD BEHAVIOR.



A. (500X)

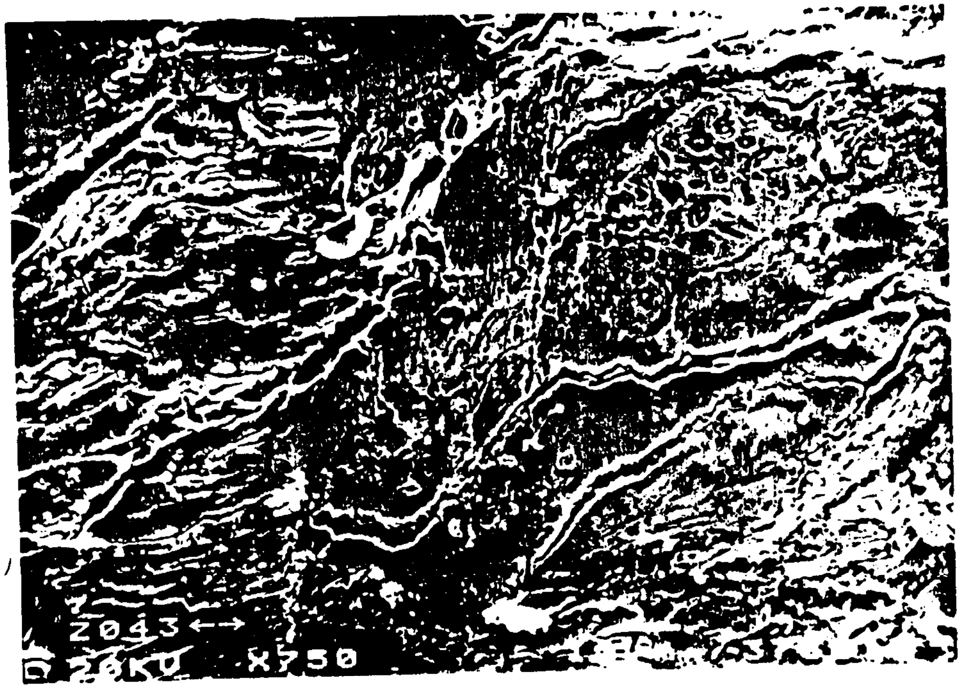
88/185/3



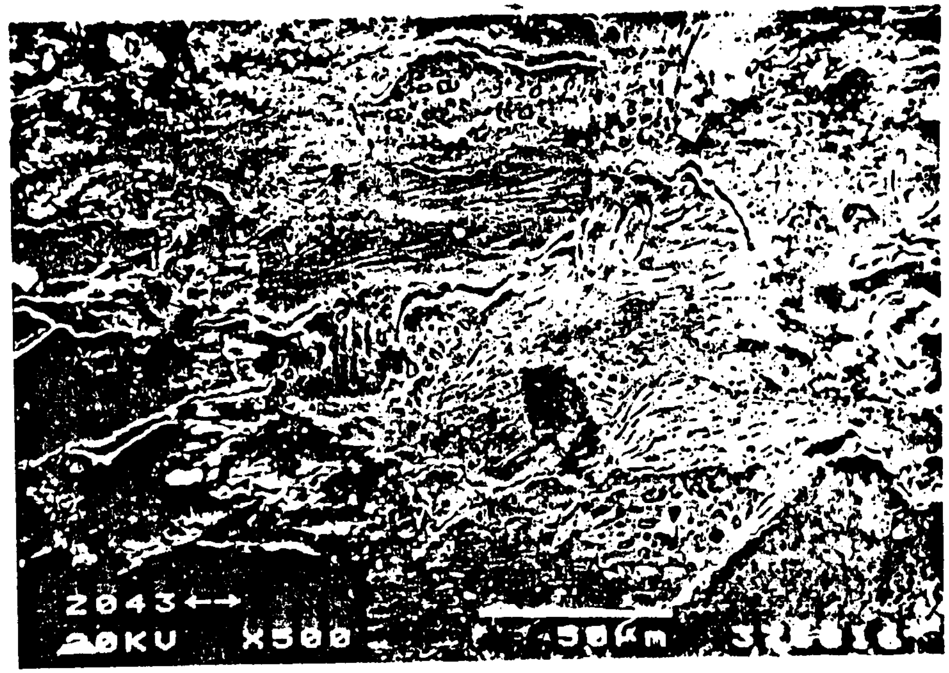
B. (500X)

88/185/4

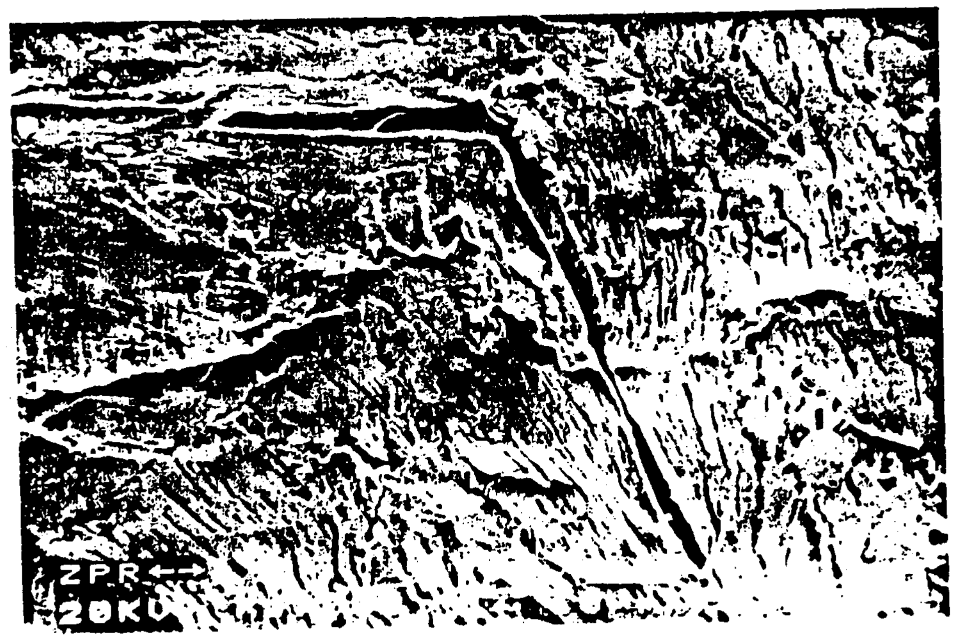
- FORMABILITY OF POST-ANNEALED GALFAN
- LOW COARSENING DEGREE
- DEEP DRAWING



A. (750X) 88/291/15



B. (500X) 88/291/16

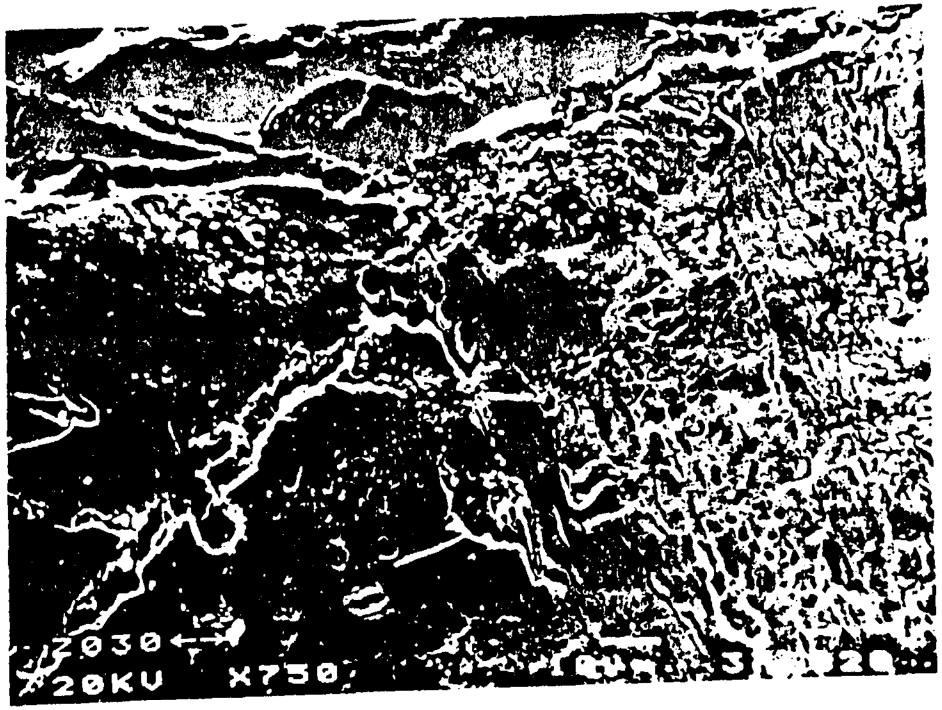


C. (1000X) 88/291/14

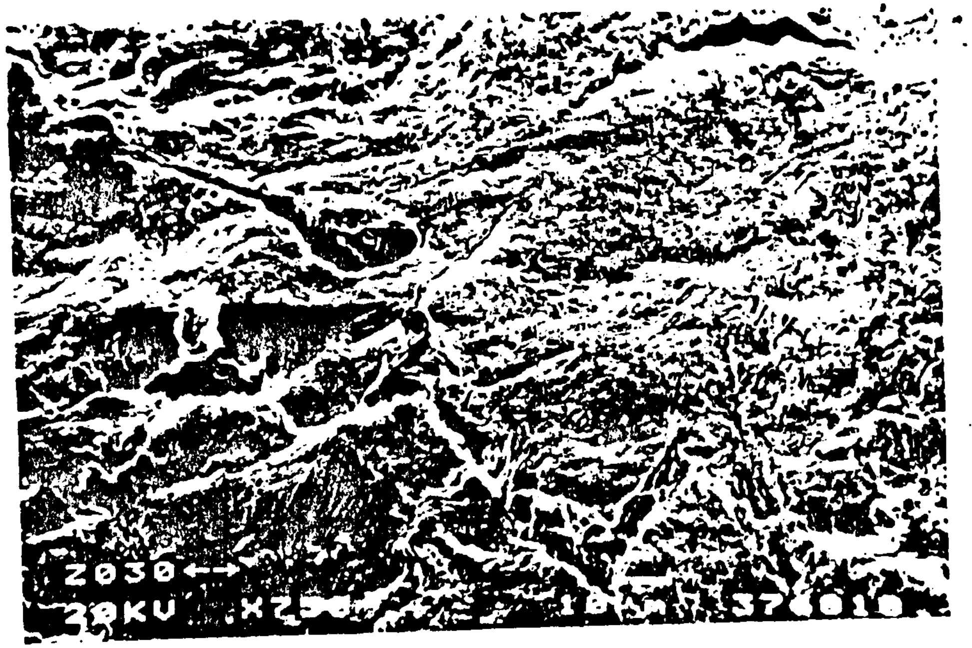
- FORMABILITY OF POST-ANNEALED GALFAN

- HIGH COARSENING DEGREE

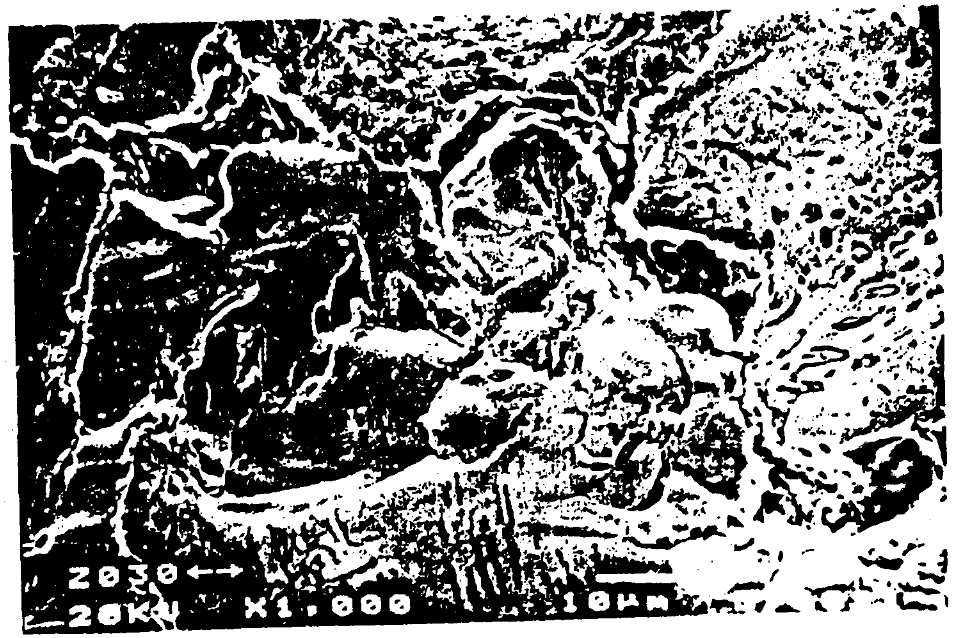
- DEEP DRAWING



A. (750X) 88/291/20



B. (750X) 88/291/18



C. (1000X) 88/291/21

CORROSION RESISTANCE OF PREPAINTED GALFAN

T. Shiota, C. Shiotani, and Y. Hoboh
Sumitomo Metal Industries, Ltd.

January 11, 1989

Osaka, Japan

CORROSION RESISTANCE OF PREPAINTED GALFAN

Toshiaki Shiota, Chitoshi Shiotani, and Yoshihiko Hoboh
Sumitomo Metal Industries, Ltd.

INTRODUCTION

Prepainted Galfan through the years has been proved to show superior corrosion resistance to prepainted galvanized steel sheet by many external exposure tests.

We have carried out several accelerated exposure tests together with outdoor exposures. Although salt spray test is one of the most popular accelerated tests, it is said not to simulate outdoor exposure tests very well. Therefore, we have introduced some cycle corrosion tests to simulate outdoor exposure. Light irradiation is included in one of the cycle corrosion tests.

EXPERIMENTAL

Materials

A 0.5mm thick Galfan steel sheet(GF) with coating weight of 250g/m^2 and a 0.5mm thick galvanized steel sheet(GI) with coating weight of 250g/m^2 were used as substrates.

For both steel sheets, hosphatizing was followed by a chromate rinse as pretreatment. On primer painted both substrates, oil-free polyester top coat was applied. Film thickness of the primer was 3μm and that of the top coat was 10μm. Test panels were painted in our coil coating line.

Corrosion tests

Salt spray test(SST), dry and wet cycle test(D&W), and humidity test(HT) were carried out as conventional accelerated exposure tests. Two cycle corrosion tests(CCT) were proposed to simulate outdoor exposures. Among the steps in one of the CCT is included light irradiation by a xenon lamp with wave length distribution very simslar to solar radiation.

The test conditions are as follows:

SST: Spraying 5% NaCl solution at 35°C

D&W: →Immersion in 5% NaCl solution at 35°C (1h)
↓
Hot air drying at 50°C (1h)

HT: 95% relative humidity at 50°C

CCT(I): →SST (2h)
↓
Hot air drying at 50°C (16h)
↓
HT (6h)
1 cycle = 24h

CCT(II): →Immersion in 0.5% NaCl solution (0.5h)
↓
80% R.H. at 60°C (4.25h) ┐
↓
Dew falling (0.5h) — Xenon lamp irradiation ($3kw/m^2$)
↓
80% R.H. at 60°C (4.25h) ┘
↓
Dew falling (0.5h)
↓
Chilling to -10°C (2h)
1 cycle = 12h

The outdoor exposure test was carried out for five years in three locations: Okinawa, a severe marine environment with high humidity and temperature; Naoetsu, a mild marine environment; Amagasaki, an industrial environment.

Flat and bended test panels were subjected to exposure. Bending includes 2T and 10T hand bending and roll forming for roofing. As coated metal films cracks at 3 or 4T bending, the 2T-bended test panel must have cracks on the substrate surface. The corrosion behavior at flat areas, cut edges, and bended portions were observed.

RESULTS AND DISCUSSION

Conventional accelerated exposure tests

In Figure 1 are shown the corrosion resistance of prepainted GF (PGL) and GI (PGI) at flat areas after 140 days exposure. Many blisters were observed on PGI in SST and HT. However, PGF exhibited littie blister. A considerable amount of rust was formed on PGI in D&W, whereas a little amount of rust appeared on PGF. At flat areas, PGF showed far greater corrosion resistance than PGI in every corrosion test.

Figure 2 illustrates the results at cut edge after 140 days exposure. Although the maximum width of edge creep of PGF was nearly equal to that of PGI by SST, it was less than that of PGI by D&W and HT.

Larger edge creep and greater amount of white rust were observed in SST compared with other tests. In addition, the edge creep of PGF by SST showed unusual shape. Therefore, SST is not estimated to simulate outdoor exposure very well. SST provides too much edge creep and white rust formation at cut edge.

Corrosion resistance at bended portion of PGF were excellent compared with PGI irrespective of test method or degree of bending as demonstrated in Figure 3.

Cycle corrosion tests (CCT)

The corrosion resistance at bended portion by roll forming were studied by CCT(I). Large amount of white rust and a little red rust were observed at bended portion of PGI after 258 days exposure, whereas only a little white rust was formed on PGF.

Corrosion resistance at flat area and cut edge were examined by CCT(II) including xenon lamp irradiation. PGF showed superior resistance to PGI at cut edge as well as at flat area after 80 cycles (40 days) as shown in Figures 4 and 5. In PGI, red rust was formed in spite of relatively less amount of white rust.

The results by CCT well corresponded with conventional accelerated exposure tests, proving much superior corrosion resistance of PGF to PGI except edge creep in SST.

Outdoor exposure test

The maximum width of edge creep of PGF was smaller than that of PGI by outdoor exposure test at Okinawa as illustratd in Figure 6. At the other locations, the difference between PGF and PGI was not clear.

Rust formation at flat area was only observed on PGF in Okinawa.

In conclusion, the corrosion resistance of PGF was proved to be superior to PGI by five-year outdoor exposure test, as well as accelerated exposure tests.

Among accelerated exposure tests, CCT(II) exhibited the most similar result to outdoor exposure.

CONCLUSION

1) PGF exhibits greater corrosion resistance than PGI at flat area and bended portion in any accelerated and outdoor exposure test.

2) Edge creep of PGF was superior to that of PGI in every accelerated and outdoor exposure test except SST. SST is not estimated to simulate outdoor exposure very well, because it provides too much edge creep and white rust formation at cut edge.

3) Among the accelerated tests, CCT(II) including xenon lamp irradiation exhibited the most similar result to outdoor exposure.

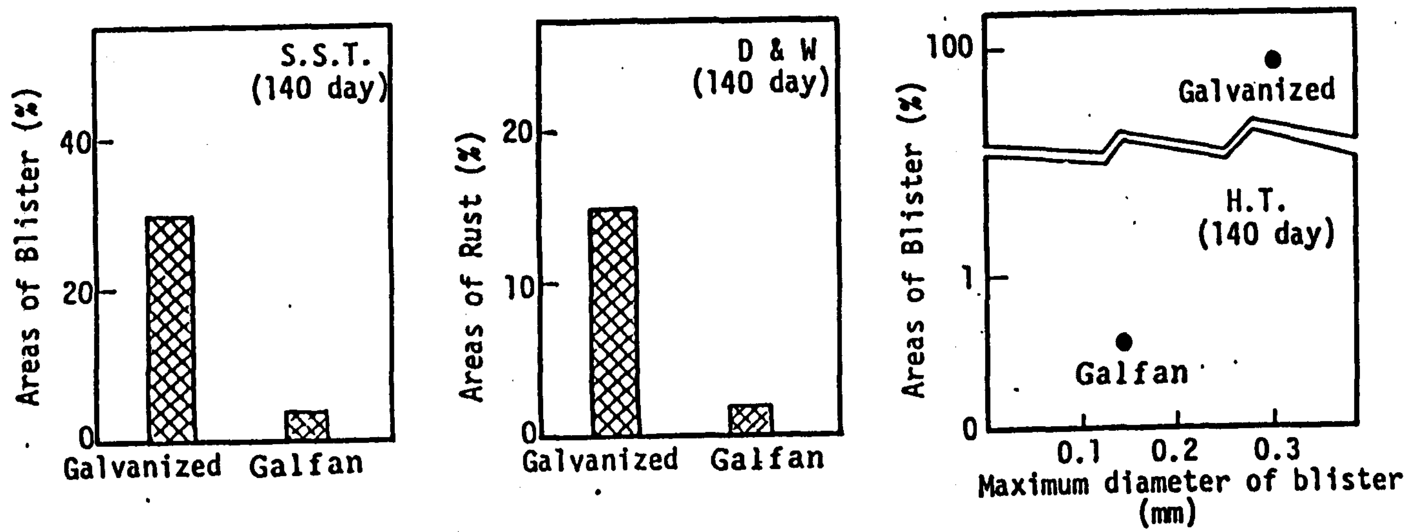


Fig. 1 Corrosion resistance of prepainted Galfan and Galvanized(Flat Areas)

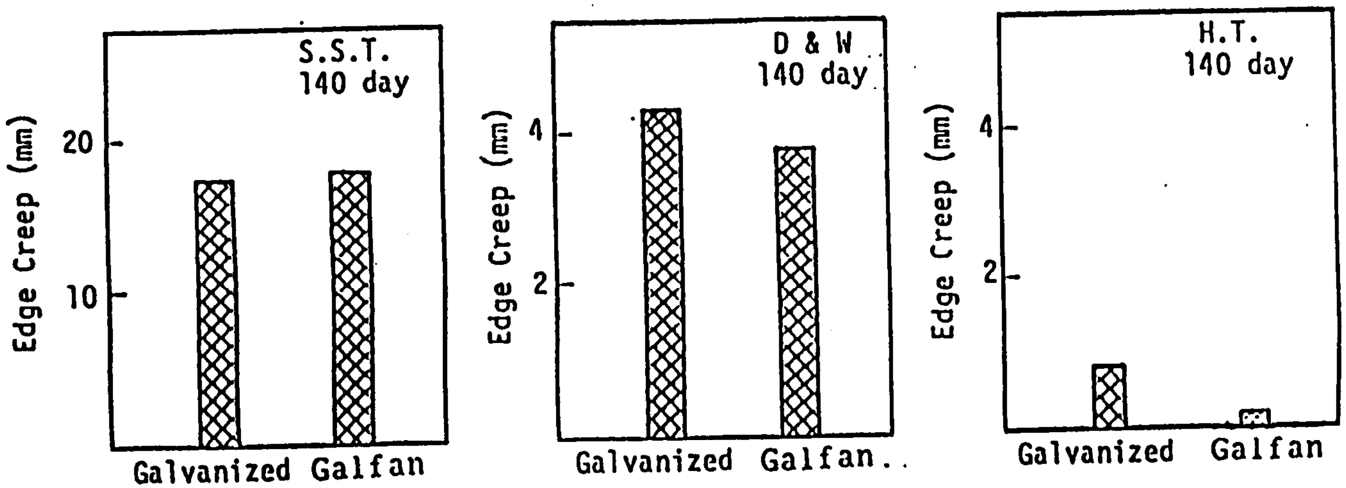


Fig. 2 Corrosion resistance of prepainted Galfan and Galvanized
(Cut Edge)

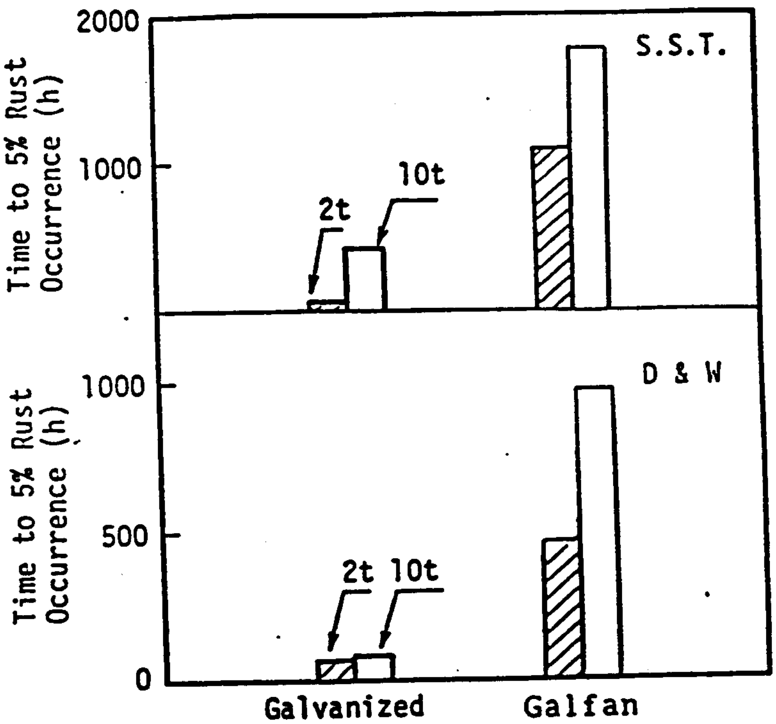


Fig. 3 Time to rust occurrence of prepainted Galfan and Galvanized with bended panels.

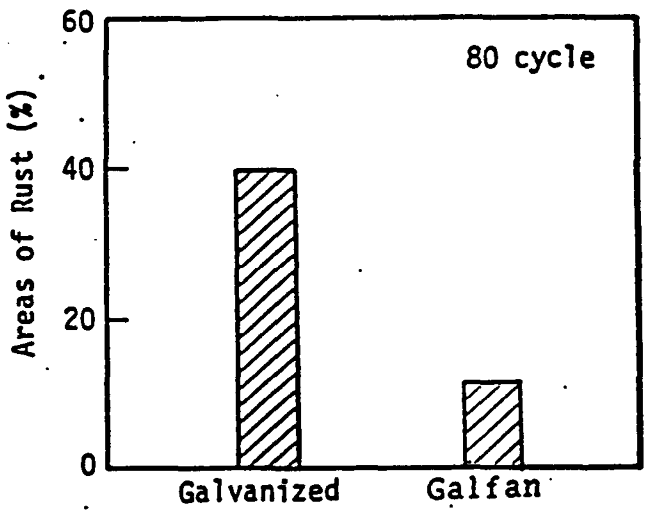


Fig. 4 Areas of Rust of prepainted Galfan and Galvanized by Cyclic Corrosion Test II

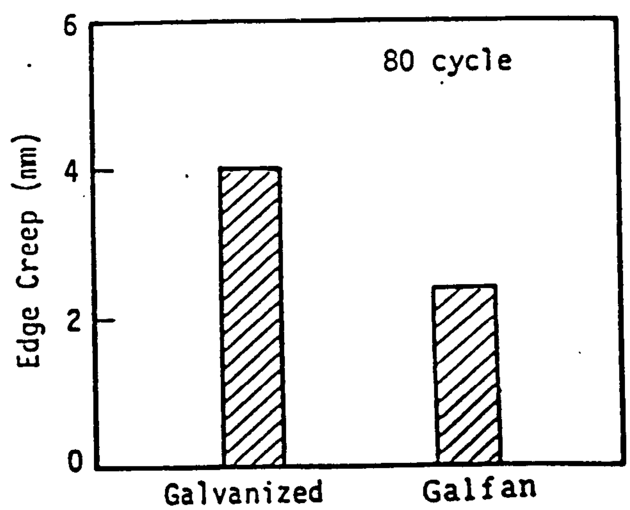


Fig. 5 Edge creep of prepainted Galfan and Galvanized by Cyclic Corrosin Test II.

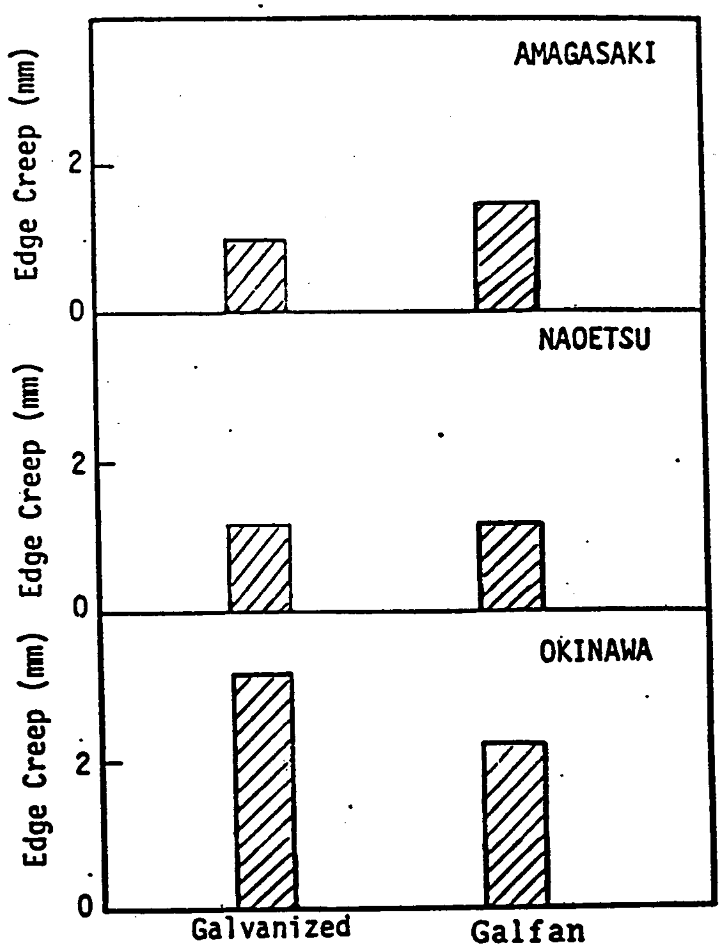


Fig. 6 Atmospheric corrosion resistance of prepainted Galfan and Galvanized (5-years)

PICTURE COURTESY
OF SIDMED (SPAIN)

New protective coatings for continuous metal

PROCOAT is deeply involded in coatings for zinc coated steel concerning protection, paintabilty and drawability.

For GALFAN, our tests have been concerned in the protection against black patina. Bearing in mind the increasing development of GALFAN, and wishing to maintain the cooperation with the siderurgies, we would like to try to give an answer to the different requirements on this material. For this reason we would be grateful indeed to receive an answer concerning following points :

ProCoat

PROCOAT, S.A.

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Cova Solera
08191 RUBI (Barcelona)

Tel. (93) 699 35 00*
Télex 94513 Brug E
Telefax 697 17 51

	Interest degree. 0 - 5	Black Patina HCT	Stack Test	White Rust. S S T	Paint-ability requirements	Friction rate
Coating against black patina.						
Coating against white rust.						
Coating against black patina and white rust.						
Coating designed for car manufacturing industry Improving paintability. Resistance to degreasing and phosphating.						
Anticorrosion coating allowing for further painting in Coil coating lines without pretreatment.						
Pretreatment for Coil Coating.						
Coating to improve the friction coefficient (drawability).						

Name :
Position :
Company :
Address :

CHARACTERISTICS

	Chromium Content	Clear Film	Clear Coloured Film	Opaque Coloured Film	APPLICATION			Thickness Microns
					Roll Squeezer	Roll Coaters	Gun	
Brugal T3MG	—	X	E	—	X	E	E	0.5-1
Brugal 65	—	X	E	—	X	E	E	0.5-1
Brugal GM-4 Colourless	X	X	—	—	X	E	E	0,5-1
Coloured	X	—	X	—	X	X	E	2-4
Brugal TPZ	X	X	—	—	—	X	—	1-2
Brugalcoat 215/217	X	—	—	X	—	X	—	5-10
Brugalcoat HS	X	—	—	X	—	—	X	6-9

E=Eventually

APPLICATION FIELDS

	Black Patina	RUST		Paintability	Coil Coating		As a Single Coating	Paint onto hot Strip Electrostatic	Friction coefficient Reduction
		White	Red		Back Side	Primer			
Brugal T3MG	VG	M	M	NA	—	—	M	—	P
Brugal 65	VG	M	M	NA	—	—	M	—	VG
Brugal GM-4 Colourless	NA	VG	VG	G	—	—	G	—	P
Coloured	G	VG	VG	—	P	—	G	—	P
Brugal TPZ	—	VG	VG	VG	—	—	G	—	P
Brugalcoat 215/217	—	VG	VG	—	VG	G	G	—	P
Brugalcoat HS	—	VG	VG	G	VG	NA	VG	VG	P

VG=Very Good G=Good M=Medium NA=Not Advisable P=Possible

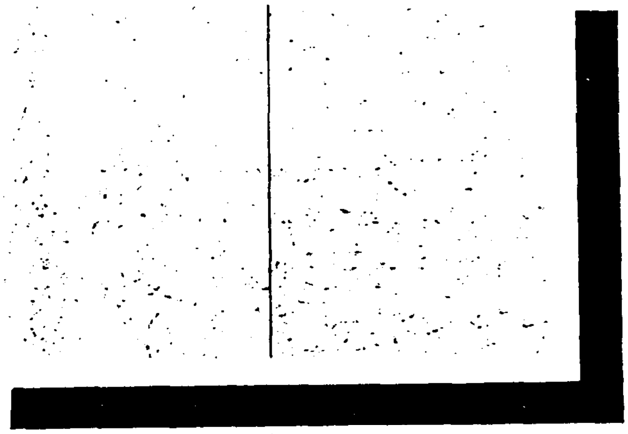
PROCOAT has devoted over 15 years to the development of aqueous film-forming compositions containing, part of them, phospho-chromic solutions.
These compositions are registered under the **BRUGAL** trade-mark, and have been protected by different world-wide patents.

The treatment of continuous metal surfaces, is at present, a new challenge. Being ahead this requirement, **PROCOAT** has created highly performing products for every need.
Anticorrosion, Paintability and Lubricity are the main pillars.
Discover in the **BRUGAL** range of products their surprising qualities, obtained with low coat thicknesses and with an important simplification of the operative process.
BRUGAL incites imagination!

CONTINUOUS PRODUCED METALS		
Protection **Corrosion Protective Coatings**	Colourless	• For unpainted surfaces • *For Coil Coating*
	Coloured	• For unpainted surfaces
Paint **Pigmented thick coatings**	Primer	
	Single coat (back side)	

METAL	BRUGAL						
	GM-4	65	T3MG	215/217	HS	TPZ	4TCC
Galvanized (HDG)	X	X	—	X	X	X	X
Galvannealed	X	X	—	—	X	—	—
Zinc electroplated	X	X	—	X	—	X	X
Galfan	—	X	X	X	X	X	X
Galvalume	X	X	—	—	X	—	X
CRS (Cold Rolled Steel)	—	X	—	X	—	—	X
Aluminium	X	X	X	X	—	—	X

Strip - Wire - Tube.



Coloured BRUGAL GM-4 onto Galvanized (HDG)

New Performances

- Prevent Black Patina onto GALFAN (CRM Tests).
- Maintain gloss onto Galvanized.
- Prevent zinc powder loosening in presses.
- Coloured passivate, highly attractive, finishes.
- Coil Coating painting without Pretreatment.
- Improve anticorrosive performance in Coil Coating.
- Reduce curing temperatures in Coil Coating.
- No emission of solvent vapours (waterborne products).
- No contaminated waste waters.
- Prevent premature white rust formation.
- Reduce zinc thicknesses without affecting the steel protection.
- Improve Friction coefficients, making stamping easier.
- Substitute protection oils by easily removable films.
- Minimal contact time→Eventual speed increase.
- Paint onto strip after zinc coating.
- Multimetallic coating.
- Improve paintability of zinc coated steels.
- Eventual use of the Pretreatment Roll Coaters, for painting.
- High mechanical performances.
- Possibility of producing metallized finishes.

ProCoat

PROTECCION Y RECUBRIMIENTOS

Grupo Brugarolas

Camino de la Riera, s/n. TEL.: (3) 699 35 00
Zona Cova Solera TELEX 94513 BRUG E
08191 RUBI (Barcelona) TELEFAX (3) 697 17 51

SUMITOMO BROCHURE TRANSLATION

Page 2:	(Graph)	Coating weight loss vs. hours
Page 3:	(1)	"Result of Bend Test" "Degree of Bending" GALFAN (left), galvanized (right)
	(2)	"Bulge Test" GALFAN (left), galvanized (right)
Page 7:		"Formability of Prepainted GALFAN and galvanized - top: GALFAN, 2T and 4T - bottom: galvanized, 2T and 4T
Page 8:	Top:	"Roll Forming" GALFAN (left), galvanized (right)
	Bottom:	"Press Forming" GALFAN (left), galvanized (right)
Page 9:	Top:	"Salt Spray Test, 2000 Hours" GALFAN (left), galvanized (right)
	Bottom:	"Cyclic Corrosion Tests, 258 Cycles" GALFAN (left), galvanized (right)

ILZRO PATENT ESTATE: GALFAN

COUNTRY	FILING DATE	SERIAL NO.	PATENT NO.	ISSUE DATE
United States	03-18-81	245,172		
United States	08-02-82	404,405	4,448,748	05-15-84
Argentina	01-04-82	288,029	227,220	09-30-82
Australia	03-18-81	70796/81	544,400	10-21-85
Austria	03-18-81	E48,270		
Belgium	03-25-80	C20-26/8003	882,431	03-25-80
Belgium	01-16-81	C21-07/8101	887,121	01-06-81
Brazil	11-24-81	PI81 07944		
Canada	03-24-81	373,746	1,175,686	10-09-84
Czechoslovakia	01-15-82	PV.323-82		
East Germany	01-15-82	APC 22 C/236 795/5	220,342	03-27-85
European (EPC)		81-901054.7**	0048270	08-14-85
Finland	11-20-81	813,715	70254	09-15-86
France	03-18-81	E0048270		
India	12-21-81	1437/Cal/81		
Italy	12-30-81	68730-A/81		
Japan	03-18-81	501400/1981		
Korea	12-29-81	5,198/1981		
Liechtenstein	(See European - EPC)			
Luxembourg	03-18-81	E48,270		
Mexico	01-15-82	9872		
New Zealand	01-14-82	199,491	199-491	04-09-86
Netherlands	03-18-81	E48,270		

COUNTRY	FILING DATE	SERIAL NO.	PATENT NO.	ISSUE DATE
Poland	02-24-82	P235,209	136,815	11-18-87
Russia	11-24-81	336.1151/02	1,301,320	03-30-87
South Africa	01-07-82	82/0091	82/0091	11-24-82
Spain	01-15-82	508,771	508,771	05-03-83
Sweden	03-18-81	81-901,054.7		
Switzerland	03-18-81	E48,270		
Taiwan	01-16-82	7110131	17,916	11-01-82
United Kingdom	03-18-81	E48,270		
West Germany	03-18-81	P3171 770.5		
Yugoslavia	01-12-82	P-57/82		
Patent Cooperation Treaty	03-18-81	PCT/US 81/00347		

**France, West Germany, Luxembourg, Sweden, Switzerland, Liechtenstein, United Kingdom, Austria, and The Netherlands.

ELECTROFLUX PATENT

COUNTRY	FILING DATE	SERIAL NO.	PATENT NO.	ISSUE DATE
United States	10-15-86	919,225	4,738,758	04-19-88

TRADEMARK "GALFAN"

Recent Grants

Country	REG. No.	Date
Canada	313,867	3 April 1987
Great Britain	1,158,613	31 July 1988
Japan	2,014,730	26 Jan. 1988
New Zealand	150,709	8 Oct. 1986
Czechslovakia	166,876	10 Feb. 1987

ASTM SPECIFICATIONS

B750-87*	Ingot
A855/A855M-86**	Wire Strand
A856/A856M-86**	Wire
A875/A875M-88*	Sheet

Eight (8) additional specifications are in process for fencing, specialty wire, culvert and general sheet products.

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*Already Revised
**Under Revision

GALFAN MARKET DEVELOPMENT

GOAL: Greater Galfan Production

NEED: More Producers of Galfan Coated Steel Products

MEANS: Simultaneously Develop End-User Interest & Producer Awareness of Market Demand

COATING LINES - GALFAN STATUS

ARMCO
Bethlehem
Inland
LTV
National
USS
I/N Tek*

Empire-Detroit
Weirton
Wheeling-Nisshin
Wheeling-Pittsburgh

Dofasco
Stelco

Gulf States Steel
H.H. Robertson
Metal Tech
National Galvanizing
WCI
Sharon

California Steel Industries
Pinole Point
USS POSCO

Gregory
Southwestern Pipe
Triangle PWC
Arrowstrip*
GalvCo *

Arc Tube
Allied Tube & Conduit
Bundy Tube
Century*
Omega *
Western *

Bekaert
Davis Walker
Florida Wire & Cable
Indiana Steel & Wire

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*New Additions to List

NORTH AMERICAN GALFAN STATUS*

9 GALFAN Licensees

3 Lines in Commercial Production

- Arc Tube (1984)
- Weirton Steel (1985)
- Gregory Galvanizing (1986)

*October 1988

U.S. GALFAN SOURCES*

SHEET & STRIP

Domestic - Weirton Steel
Gregory Galvanizing

Overseas - Francosteel
Hoesch America
Nisshin U.S.A.
Kawasaki Steel America
Toyomenka America

TUBING

Domestic - Arc Tube

WIRE

Overseas- TrefilARBED
TrefilUNION

NOTE: Additional major U.S. producers of Sheet, Wire, and Tubing are considering GALFAN production.

*October 1988

U.S. GALFAN APPLICATIONS

AUTOMOTIVE

Motor Housings

Instrument Cases

Fuel Tank Shields

Strapping

Heat Shields

Fuel Filter Shields

Radiator Brackets

Transmission Oil Cooler Lines

Power Steering Tubing

Bus Roof Parts

U.S. GALFAN APPLICATIONS

APPLIANCE

Painted Tops & Lids

Washer Base

Motor Mounts

Washer Legs

Dryer Tumbler Drums

Heater Components

Refrigeration Coolers

Drip Pans

A/C Base Rails

U.S. GALFAN APPLICATIONS

ELECTRICAL EQUIPMENT*

Timing Device Enclosures

Outlet Boxes

Raceways

Motor Housings

Painted Lighting Fixtures

Farm Equipment

*GALFAN is approved by UL

U.S. GALFAN APPLICATIONS

CONSTRUCTION

Decking

Roof Bars

Hurricane Strapping

Air Vents

Stucco Expansion Joints

Ceiling Ties

Pre-Painted SS Roofing

Pre-Painted Box Roofing

Pre-Painted Wall Panels

Pre-Painted Storage Sheds

Pre-Painted Garage Door Panels

GALFAN PRESS RELEASES

- Lynch to Help Market GALFAN in North America - 8/88

- Price of GALFAN License Raised for Larger Lines - 9/88

- GALFAN Finding Widespread Use in U.S. - 10/88

- GALFAN Cuts Appliance Cost and Upgrades Performance - 10/88

- GALFAN Continues Worldwide Growth - 11/88

- GALFAN Five Year Tests Confirm Longer Corrosion Life - 11/88

- Production Welding Techniques Developed for GALFAN

- Etc.

GALFAN (Coarse Structure) VS. GALVANIZED (5-YEAR OUTDOOR EXPOSURE RESULTS*)

Environment	Thickness Loss (Microns) Galvanized	GALFAN	Ratio of Improvement
Industrial	15.0	5.2	2.9
Severe Marine	>20.0**	9.5	2.1+
Marine	12.5	7.5	1.7
Rural	10.4	3.0	3.5

*Slow Cooled Coarse Structure GALFAN
**Completely Red Rusted Before 5 Years

GALFAN (Minimized) VS. GALVANIZED (3-YEAR RESULTS*)

Environment	Thickness Loss (Microns) Galvanized	GALFAN	Ratio of Improvement
Industrial	8.7	2.4	3.6
Severe Marine	12.7	4.0	3.2
Marine	7.8	2.8	2.8
Rural	4.5	1.2	3.8

*Fast Cooled Minimized Structure GALFAN (Optimized)

GALFAN DISADVANTAGES

- **Welding Electrode Life**
- **Surface Smoothness**
- **Gray Patina Formation**

GALFAN DATA SHEETS

Joining

Corrosion Resistance

Sacrificial Protection

White Rust Resistance

Formability

Painted Product Performance

GALFAN DATA SHEET
JOINING

SPOT WELDING

- Introduction
- Weld Strength
- Improvements in GALFAN Weldability
  - Modified Electrode Tip Geometries (Europe)
  - Stronger Electrode Material (Europe)
  - Upsloping (U.S.)
- Effect of Improvements on Weldability
  - Weldability Lobes
  - Electrode Life

SEAM WELDING

- Introduction
- Method
- Production Experience

SOLDERING

ADHESIVE BONDING

HIGH PRIORITY FUTURE ACTION*

- Organize Electroflux Trial
- Complete Key Producer Contact
- Visit Pivotal End-Users
- Prepare Data Sheets
- Publicize GALFAN Advances
- Support Existing Producers

*November 9, 1988

FIRST ANNOUNCEMENT

FOURTEENTH SHEET/FOURTH WIRE-TUBE GALFAN LICENSEES MEETING

5-7 JULY 1989

HOTEL HESPERIA
Mannerheimintie 50
00260 Helsinki, Finland
FAX: 358-0-4310995
Telex: 122117 hespe sf

Wednesday, 5 July 1989: Plant Tour, Rautaruukki Oy - Hameenlinna Works followed by lunch at the "Old Haeme Castle"

Evening meeting - Sheet Licensee, Operations Session, (Active Producers ONLY)

Thursday, 6 July 1989: Morning: Research Session - Sheet, Wire, and Tube
Afternoon: Marketing Session - Sheet, Wire, and Tube

Friday, 7 July 1989: Morning: Wire and Tube Operations Session
Afternoon: GALFAN Research Steering Committee Meeting (Shareholding Members ONLY)

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ROOM RATES

Single Room	Fim	340.-/night
Double Room	Fim	480.-/night