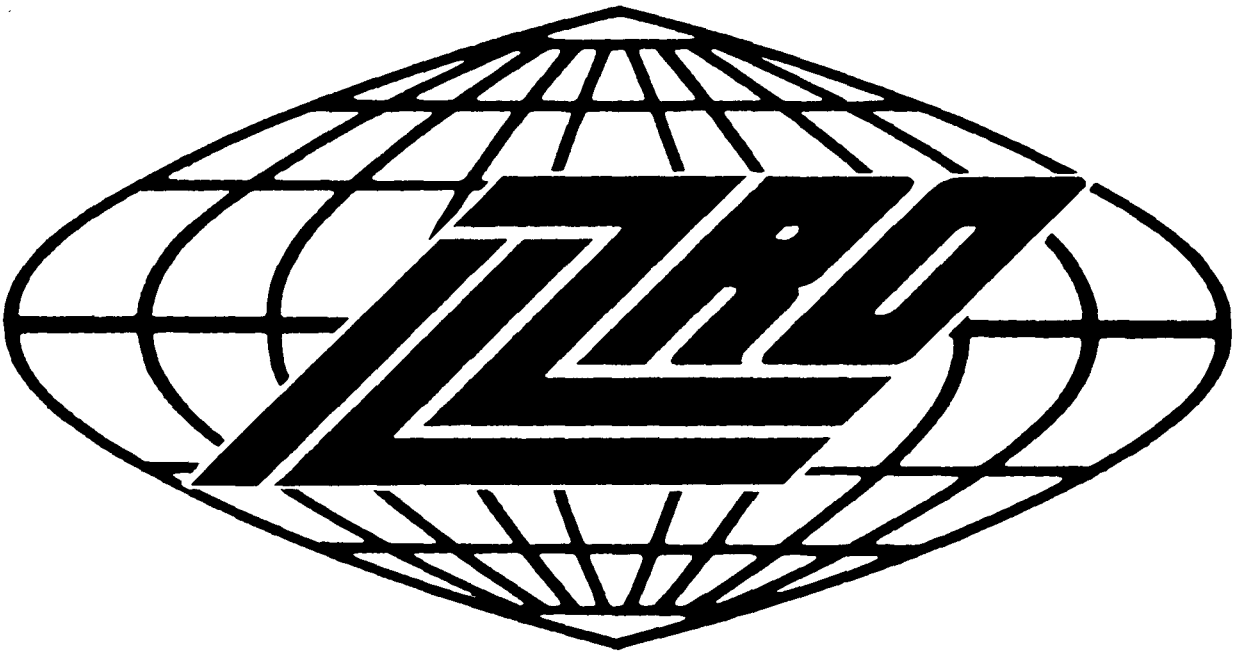

INDUSTRIAL CONFIDENTIAL

MINUTES OF THE THIRD GALFAN
WIRE LICENSEES MEETING

January 18, 1988

Reims, France

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.

INDUSTRIAL CONFIDENTIAL

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Monday, January 18, 1988

Altea Champagne Hotel
31 Boulevard Paul Doumer
51100 Reims, France

ATTENDANCE

NAME	COMPANY
Anderson, D.	Laporte R&D
Ayoub, C.	C.R.M.
Coutsouradis, D.	C.R.M.
deWitte, M.	Bekaert
Elser, P.	Indiana Steel & Wire
Gerome, P.	Trefilunion
Gillet, A.	Trefilunion
Goodwin, F.	ILZRO
Harrison, F.	Stelco, Inc.
Hatano, Y.	Nippon Denro Mfg.
Hendrickx, R.	Bekaert
Hogan, J.	Brailsford Wire
Hostetler, J.	Hostetler & Decker
Kubiak, B.	Penarroya
Pierre, M.	Centre du Zinc
Pouyfaucon, J.	Procoat
Renaux, B.	C.R.M.
Roman, M.	ILZRO
Sempels, R.	Vieille-Montagne-Belgium
Skenazi, A.	Metallurgie Hoboken-Overpelt
Sokolowski, R.	Vieille-Montagne-France
Southern, J.	AM&S Europe
Stoneman, A.	Zinc Development Association
Suzuki, T.	Nippon Denro Mfg.
Toomer, I.	Palmer Tube (Zinctek)
vandenBussche, J.	Bekaert

MEETING CONVENED

The meeting was convened at 9:30 by Mr. M.P. Roman, Chairman, who also recorded the minutes of the meeting. Mr. Roman welcomed everyone to the Third GALFAN Wire Licensee Meeting and then introduced Dr. F.E. Goodwin. Dr. Goodwin also welcomed all to the meeting and made special note of the ILZRO members in attendance. They were Mr. Raymond Sempels of Vieille-Montagne, Belgium, Mr. Richard Sokolowski of Vieille-Montagne, France, Mr. John Southern

of AM&S Europe, Mr. Andre Skenazi of Metallurgie Hoboken-Overpelt. Dr. Goodwin also welcomed Mr. Michel Pierre of the Centre du Zinc, Paris, France and Mr. Alan Stoneman of the Zinc Development Association in London, England. The attendees then introduced themselves and the attendance roster was passed around.

RESEARCH SESSION

The Drawing Behavior of Wire

Mr. Roman introduced Mr. B. Renaux of C.R.M. who presented his report on the drawing behavior of wire. A copy of some of the parameters tested is attached in the Appendix of these minutes. Main highlights of the report were as follows:

The three main points of study that Mr. Renaux described were the adherence of zinc during redrawing, a comparison between galvanized and GALFAN (single and double dip) coated wires, and the study of the pickup of zinc. The main conclusions/observations were: 1)GALFAN double dip (low lead) showed the best behavior and could be drawn without galling and without rupture. Otherwise a total reduction of 60% seems to be the limit before galling and rupture for the other products, especially so for galvanized wire. The metallographic study showed that there was an increase of coating concentricity after each step. There was no cracking observed and a finer eutectic structure and uniform intermetallic layer was seen for the double dip GALFAN wire, therefore this double dip product had better drawability in spite of a higher weight loss compared to the single dip GALFAN product.

Dr. Goodwin noted that the target for redrawing was 95% reduction. He asked what samples did not make that 95% figure. Mr. Renaux replied that neither the galvanized sample nor the double dip GALFAN with high lead made it. At that point, Dr. deWitte noted that 95% reduction is normal for commercial production and higher percentages are possible. He wondered what type of die was used in the research program. Mr. Renaux replied that it was a normal tungsten carbide die. Dr. Coutsouradis noted that these studies were comparative and the figures should not be generalized from this study. He noted that a general conclusion could be that the zinc loss declines as the intermetallic layer is reduced.

Dr. Coutsouradis also noted that the GALFAN single dip wire approaches behavior characteristics of electrolytically galvanized wire. Dr. Goodwin asked Mr. Renaux what the thickness of the intermetallic layer was. Mr. Renaux replied that the double dip GALFAN had an intermetallic layer of 1 to 2 microns thickness and the galvanized product has an intermetallic layer 5 to 7 microns thick. There was no intermetallic layer in the single dip GALFAN

product. (i.e. less than .2 microns). Dr. deWitte noted laboratory trials at 10 meters per minute drawing speed did not duplicate real life commercial production which was much faster - up to at least 50 meters per minute. In commercial practices, the zinc loss is much higher, especially from galvanized product. Dr. Coutsouradis noted that all the findings could not be explained, especially the weight loss figures and the study should be continued. Mr. Joe Hogan noted that the thickness of the intermetallic layer of GALFAN product was very important and wondered how producers can control the diameter of the intermetallic layer on double dip product. Mr. Renaux noted that variables to be controlled are the immersion times, cooling rates, and wiping characteristics. Dr. Goodwin noted that GALFAN accommodates drawing more than does galvanized, but wondered if the slow speeds in the lab trials were representative. Dr. deWitte noted that the research illustrated fundamental properties for wire and should be followed up to simulate industrial practice. Dr. Coutsouradis reminded the attendees that these lab results were preliminary and were conducted to give an indication of properties. Dr. deWitte felt that the direction of the C.R.M. studies is correct at this point in time. Dr. Coutsouradis noted that Mr. Ayoub's report to follow could show that the low zinc loss for GALFAN product can be very advantageous. Mr. Elser asked Mr. Renaux what the pure zinc thickness was on the single dip materials resulting from the electrolytic fluxing process. Mr. Renaux replied that thickness was less than half a micron.

Corrosion Study

Mr. Roman introduced Camille Ayoub also of C.R.M. who presented the results of his study on the corrosion behavior of GALFAN single dip product, GALFAN double dip product, and galvanized wire. Results of these studies on wire are in progress report 17 and are reproduced in the Appendix. The product tested was galvanized wire, GALFAN wire, wire coated with a 5% aluminum alloy (no mischmetal), Zamak product with magnesium, and a 50/50 mixture of GALFAN and Zamak. Wires were exposed in a highly twisted form with eleven (11) months outdoor exposure. So far, after eleven (11) months, the conclusion is that GALFAN coated wire performs well. It was noted that at high lead levels the Zamak coated product loses the beneficial effect of magnesium. Mr. Ayoub then reviewed the results of the industrially produced wires in accelerated testing program. Some of the highlights of the accelerated tests are in the salt spray, single dip GALFAN product was noted to have exhibited intercrystalline corrosion after three days in a cabinet. For Kesternich testing it was noted that the high lead levels in GALFAN affected its corrosion resistance. Galvanized wire exhibited severe intercrystalline corrosion and it was noted that for GALFAN, magnesium levels were ineffective for high lead concentrations (greater than 250 ppm). In the humidity tests there was no major differences noted between single and double dip GALFAN, however there was seen to be preferential attack on the galvanized material. In summary, Mr. Ayoub noted that there are differences in the dipping process for GALFAN (single or double dip), that the lead content is deleterious to the corrosion resistance of GALFAN, and the inhibitive effect of magnesium is minimal at high lead levels.

Dr. Goodwin noted that severe intercrystalline corrosion on the single dip product is very disturbing and wondered if single dip should be produced at all. Mr. Ayoub noted that the study was inconclusive and required further study along with long-term exposures instead of only laboratory accelerated tests. It was too soon to make conclusions. Dr. Goodwin asked if fully eutectic single dip GALFAN was looked at, noting that the double dip fully eutectic GALFAN exhibited the best behavior. Mr. Ayoub noted that he had not yet done so because of the lack of sample availability. He reminded the attendees that the samples for these test surveys were industrially produced. Dr. Coutsouradis noted that concluding that single dip results are yet significant is premature and that further concluding that single dip product is bad is also premature. The product needs more study. Mr. Southern noted that he would understand uniform corrosion on single dip GALFAN but did not understand the intercrystalline attack. He noted that further research should include fault analysis on such samples and that all variables should be examined. Dr. Goodwin also noted that it is known that the microstructural fineness effects corrosion behavior. Fundamentally, it is not expected to see intercrystalline corrosion on single dip product and it would be expected to be seen on double dip product because the intermetallic layer acts as a cathode. Mr. Ayoub noted that with the coarse eutectic structure noted the anodes are more isolated and the intercrystalline corrosion is seen. Dr. deWitte agreed with Mr. Ayoub but noted that there is still a need for an explanation for the single dip intercrystalline corrosion. Dr. Coutsouradis repeated that the results were preliminary and further study is warranted. Dr. Harrison asked if any weight losses had been performed and would there be any correlation between weight loss and results already seen. Mr. Ayoub noted that weight losses had not yet been done for the accelerated test material. Mr. Skenazi asked for an ILZRO recommendation for an ideal GALFAN composition. Dr. Goodwin noted in response to Mr. Skenazi that the lead level in GALFAN is clear - should be less than 70 to 80 parts per million and a maximum of 50 parts per million would be most desirable. As far as magnesium is concerned, up to .1% (1,000 ppm) is allowable (for the inhibition of intercrystalline corrosion), however, it is to be noted that magnesium loses it effectiveness at higher lead levels. The optimal aluminum level is still yet to be determined. It is known that 5% in the coating only is desirable but including the intermetallic layer, an overall aluminum content of up to 8% has been seen. Mr. Southern noted that the group is stating that GALFAN (product with alloy with aluminum) is better than galvanized but we can not establish an optimum aluminum level. Dr. Coutsouradis noted for the record however that the fine eutectic structure for GALFAN is optimal.

OPERATING SESSION

Trefilunion Report

Mr. Roman introduced Mr. Gillet of Trefilunion who presented his report on Trefilunion. A copy of the graphs are included in the Appendix. Dr. Coutsouradis provided the translation from French to English for the group.

Mr. Gillet began with a history of Trefilunion. Trefilunion, formerly FICAL, began to produce GALFAN in their facility at Lens. The first trials were produced in 1983 for industrial GALFAN. The first production was steel fishing cables which would be exposed to very aggressive environments. It was found that GALFAN is very effective in resisting corrosion in this application and two types of GALFAN wire were produced by Trefilunion: Cordon-Rouge, and Super Cordon-Rouge. The first industrial trials were coordinated with C.R.M. wherein the industrial trials confirmed previous laboratory test results. Mr. Gillet noted that Cordon-Rouge and Super Cordon-Rouge make up 50% of shipments to the fishing industry.

The second application of GALFAN is their product CorZal which is their redrawn GALFAN product. It is a high strength wire applied for such products as springs. CorZal is first GALFAN coated and then cold redrawn. Trefilunion has noted double the life in salt spray tests for CorZal and they feel it has better alloy adherence to the steel substrate.

The Lens plant also produces wire for special cables such as for the transport of electricity and for support (guy) wire. Mr. Gillet then showed his slides. The first two slides showed the relationship between low strength wire and coating weight for varying diameters. The first slide is for their Galvalens product, the second slide is for their redrawn CorZal product. The second slide shows behavior in salt spray with GALFAN averaging two to three times better corrosion resistance than galvanized. The fourth slide is just a transformation of salt spray data to weight loss where GALFAN shows weight losses one-third to one-half that of galvanized, i.e. two to three times better performance. At that point Mr. Hendrickx of Bekaert noted it was not his experience to see galvanized product last 500 hours in salt spray. The last two slides showed the number of 24 hour cycles in salt spray versus coating weight noting that the galvanized samples are 700 grams per square meter and the GALFAN samples are 350 grams per square meter, and that the performances of each coating were equal at those coating weights. Mr. Gillet finished by noting that some activities of Trefilunion in research and development Trefilunion is interested in mild steel wire trials, however the Lens plant where GALFAN is licensed only produces high carbon product and implied that such product would have to be produced at another Trefilunion plant and perhaps shipped to Lens for coating. Mr. Gillet also noted that 400 to 450 grams per square meter is the heaviest coating that they can apply in GALFAN.

Mr. Hendrickx asked for an explanation of the results of the first two slides. Mr. Gillet noted that they were just observations and could not explain the results. Dr. Goodwin asked if those results had any correlation with speed in the patenting bath. Mr. Gillet noted that those wires were not patented and he stated again that was just an observation and could be described as low strength wires require low coating weight and high strength wire require higher coating weight.

Procoat Report

Mr. Pouyfaucon of Procoat France presented a short report on Procoat activities in corrosion protection. Procoat produces a film-forming resin dispersion which originally was tested on GALFAN for the prevention of gray patina. Mr. Pouyfaucon related some results on GALFAN testing for the maintenance of brightness reflectance after extended exposure. A copy of those results are included in the minutes appendix. Dr. deWitte asked what possible line speeds could be achieved while dipping in the Procoat product. Mr. Pouyfaucon replied that he felt that up to 500 meters per minute could be accommodated. Mr. Elser asked about what temperature would be used in the curing oven and Mr. Pouyfaucon noted that it would be 100°-150°C. Mr. vandenBussche asked about the price and consumption rate of the Procoat product. Mr. Pouyfaucon noted that the product is applied at coating weight of 1 to 1 1/2 microns at a 50% concentration, however the concentration may be diluted which would effect the final price. Mr. Pouyfaucon is a research associate and noted he should not be quoting prices.

Other Reports

Dr. Goodwin took the opportunity to mention the ongoing work of the GALFAN Flux Consortium. He noted that trials were about to commence at C.R.M. and would be followed up by industrial trials. Dr. Coutsouradis noted that Mr. Ayoub should mention the results of the five year exposure panels for sheet product. Mr. Ayoub commented that those five year results have confirmed lab tests that GALFAN has two to three times better performance than galvanized. Mr. Hogan asked Mr. Ayoub to repeat that confirmation of two to three times better performance and correlation with lab results. Mr. Ayoub complied and reconfirmed his results. Mr. Hostetler asked if there were any correlations between flat and deformed GALFAN product. He noted that there should be a comparison of deformed GALFAN to illustrate the corrosion resistance in the deformed state.

Dr. deWitte asked if the passivation characteristics are linear with time. Mr. Ayoub noted that he was not sure and needed more time and study. Dr. Goodwin noted that it should be expected that those passivation characteristics be asymptotic. He noted that passivation occurs mostly in the first year of exposure.

MARKETING SESSION

Mr. Roman opened the meeting by noting to all attendees that the success of the meeting depended upon the participation of the individual attendees. He then introduced Mr. Joe Hogan of Brailsford Wire who gave his marketing report on the United Kingdom.

United Kingdom

Mr. Hogan opened his report by noting that the growth of GALFAN has been spurred by the demand of customers for increased corrosion resistance. He noted that the fishing industry was one of the first to demand better results (high carbon wire 0.4 to 0.6% carbon). One of the possibilities was to increase the coating weight of galvanized wire to get to realize better corrosion resistance, however such a solution was not realistic. GALFAN can offer increased corrosion resistance at low coating weights. Mr. Hogan noted that there are no wire licensees in the United Kingdom and now is concerned with the competition such as the Spanish company TYCSA whose aluminum coated wire product "Dragon Plata" is now being promoted in the U.K. At that point Dr. Goodwin asked if Mr. Hogan could obtain samples to send to C.R.M. for analysis. Mr. Hogan indicated he would attempt to do so.

Mr. Hogan continued his presentation by highlighting the agricultural market in the U.K. He began with an example of Estate Wire. This company was one of the 10% of the market that indicated they would pay a premium for a better product. Estate Wire uses some FICAL (Trefilunion) product for their agricultural fencing. (The agricultural market utilizes low carbon wire, i.e. carbon of less than 0.1%). Mr. Hogan continued noting that the agricultural market for GALFAN had been hurt previously by Tinsley Wire with some highly publicized inaccurate statements about GALFAN.

Mr. Hogan continued his report with the automotive market in the U.K. Automotive wire normally uses high carbon wire substrate in the range of 0.9% carbon with applications for springs and cables. With the increasing use of road deicing salt in the U.K., there is a growing demand for more corrosion resistant parts utilizing springs (such as headlamp retaining springs, wind screen wiper parts). For the same reason, more corrosion resistant cable assemblies are desired such as clutch cables and brake cables. Ford in the U.K. is satisfied with GALFAN performance but will not commit to GALFAN with only one supplier in the U.K. region. At that time the only supplier was FICAL. Ford and General Motors in the U.K. are interested in GALFAN but indicate that they need more suppliers to stimulate the auto companies to write specifications with GALFAN in them.

Mr. Hogan continued his presentation with his report on the construction market in the U.K. He noted that the use of GALFAN sheet in Europe is very successful and that GALFAN wire is a natural follow up for that market. In the U.K. there is a need for more study on the pH values of mortars and cements to determine their effect on GALFAN product. There is also a need to determine the electrical current carrying capacity of GALFAN wire for use in electrical transmission applications such as ACSR center core wire (ACSR aluminum conductor steel reinforced). He noted that a big application and opening for GALFAN has been the Denmark TV2 order which consumed 380 tons of

GALFAN wire for use for TV tower mast stays and there are now two more TV orders in the U.K. Mr. Hogan believed that this would be a huge market for GALFAN in that most European TV towers are about 25 years old and they are all very close to replacement need for all their stay cables, however Mr. Hogan indicated that there is a tremendous need to come up with a standard GALFAN quality specification to encourage the use of GALFAN wire.

Bekaert Marketing Report

Mr. Robert Hendrickx of Bekaert presented the marketing report. He indicated that Bekaert most often produces GALFAN in a medium size range of 1.8 to 4.0 mm diameter. Most of their production is in the low carbon range. They do produce some redrawn high carbon wire with limited success for GALFAN. Mr. Hendrickx agreed with Mr. Hogan that there is a tremendous need for standards to help the marketing effort in GALFAN. It was indicated that most of their low carbon wire was for agricultural and construction but Bekaert is achieving some limited success applying low carbon GALFAN to the automotive market. Mr. Hendrickx noted that he has received some negative reports on GALFAN from the United States, specifically referring to the General Motors testing program. Apparently the GALFAN tested was not good enough to issue a ten year warranty and wondered if ILZRO could assist in this area. Mr. Hendrickx concluded by noting that Bekaert expects to be able to produce GALFAN wire up to 6 mm in diameter soon. Mr. Hendrickx noted that in 1987 Bekaert produced almost 3,000 tons of GALFAN coated wire and indicated that in 1988 the forecast would be at least for as much and they would hope to produce more depending on the market demand. At that time, Dr. Goodwin noted that the GM tests which Mr. Hendrickx referred is a corrode coat test where a corrosive paste is wrapped around the GALFAN tube or wire and is an extremely corrosive test. GALFAN can not yet pass that test, so normally only aluminized product is approved via that test.

Mr. Alan Stoneman of the Zinc Development Association in London echoed both Mr. Hendrickx' and Mr. Hogan's reports. He noted that he had presented data on GALFAN to the automotive industry along with a paper and samples at an automotive conference, trying to promote GALFAN. Mr. Hogan asked Mr. Stoneman what type of reaction was seen to Mr. Stoneman's paper. Mr. Stoneman replied that there was really no reaction. He felt that more energy was spent at the conference trying to discourage the use of plastics than to encourage the use of new substrates such as GALFAN. Dr. Goodwin asked Mr. Stoneman if the paper had been published. Mr. Stoneman replied it had been and would supply a copy to Dr. Goodwin.

European Zinc Institute Presentation

Mr. Sempels of Vieille-Montagne representing EZI gave a short presentation on the EZI position for GALFAN. Mr. Sempels opened by noting that the development of zinc and zinc alloy markets should be up to the regional market

development associations and that the EZI was promoting GALFAN as one of several zinc coated products. He noted that EZI is active in the promotion of GALFAN in an educational manner and referred to the recent GALFAN Seminar in Dusseldorf, sponsored by EZI. It is the aim of EZI to educate the zinc suppliers. Further development of that educational system would involve GALFAN slides, photographs, and perhaps a video for promotional purposes. Mr. Sempels concluded by noting that in order to promote GALFAN more efficiently, there is a need for more actual case studies in which GALFAN is performing well.

Indiana Steel and Wire

Mr. Phil Elser presented the report for Indiana Steel and Wire. There has been no production of GALFAN wire for 1987, however Indiana does plan to run a GALFAN wire trial in the near future and would hope to produce 500 tons in 1988. Their main product is for chain link fencing, high carbon line wire, and guy strand.

Trefilunion Report

Mr. Gillet noted that there was no more information to add to the report which he had presented earlier. A question was raised as to their tonnage for 1987. Mr. Gillet responded approximately 2500 tons and indicated he would hope to produce at least the same in 1988.

Standards

Dr. Goodwin presented a report on GALFAN wire standards. He noted that the carbon steel wire standard for GALFAN ASTM A856 was not correct and would be modified to agree with the metric version of that standard ASTM A856M which was the correct version. Dr. Goodwin also noted that there is the GALFAN strand specification ASTM A855, A855M also.

Mr. Hogan asked if there was going to be any alteration to ASTM B750 (ingot specification). He referred to any change in lead composition. Dr. Goodwin noted that there would be no modification to the lead level. Mr. Hogan asked if there could be more room in this specification to work with lead. Mr. Elser intervened saying that the specification should be tighter for the alloy ingot in order to prevent higher levels of lead coming in to a bath. Mr. Hogan noted that it would be useful to have a specification for the coated product alloy composition. Dr. Goodwin noted that when ASTM B750 was made there was not enough commercial experience to produce such a coated product alloy specification. Mr. Elser noted that he was working closely with ASTM and noted that it was not possible to specify a coated product alloy composition and that such an idea was not well supported. Mr. Hendrickx also felt that it was better not to specify the alloy composition of the coated

product and should only specify the ingot composition. Mr. John Southern asked that regardless of the ingot specification, was there any specific ILZRO recommendation on the GALFAN alloy specification? Specifically, he wanted to know if there were any minimum or maximum levels which should be followed. Mr. Roman noted that there are guidelines in the manual relating to current operating practices and experience. Dr. Coutsouradis noted that the corrosion and other research data in the manual should be used for guidance. Mr. Southern repeated that there should definitely be recommendation on alloy composition for wire. He indicated that one bad report would really be harmful for the product. Mr. Hogan noted that there should really be a specification on the GALFAN alloy in that the effect of lead should be somehow shown and the effect of magnesium on lead should also somehow be shown. Mr. Skenazi noted that obviously producers must control the lead level in GALFAN. He was interested in knowing what is the "real" practical difference between 50-75 ppm versus 75-100 ppm and what work is involved in keeping the lead levels down. Dr. Goodwin noted that perhaps there is a need for defining an index of lead aggressiveness with varying levels in the alloy. Mr. Hostetler noted that if there is a specification, as a producer he would known what he is getting through specifications and felt that specifications aid in reducing questions by customers. Dr. Coutsouradis noted that there is perhaps only 10,000 tons per year of GALFAN wire production, only a very small fraction of the worldwide total galvanized wire production; so, GALFAN is now very small but is growing and as it grows experience with the product will grow and such questions as being raised now should be answered. Mr. Southern questioned whether the effect of lead on corrosion would be included in the new wire manual. Dr. Goodwin and Mr. Roman noted that it would be, as per the research previously presented. Mr. Southern directed a question to Mr. Suzuki, asking if Nippon Denro Manufacturing had any comments on what they see in the wire industry. Mr. Suzuki noted that there seems to be a large interest in Japan for GALFAN, especially at the Communications Bureau and some other government bureaus. He indicated he knows that several wire producers are looking seriously at GALFAN.

Dr. Goodwin continued on the standards issue, noting that ASTM is developing a chain link specification as requested by Cyclone Fence. Cyclone Fence currently uses GALFAN strip posts and would like to have GALFAN wire for the fence itself. There is also the development of the specification for ACSR (aluminum conductor steel reinforced) power lines. He also noted the Underwriters Laboratory specifications where GF60 coating equal to a G90 coating and the GF45 coating is equal to G60 coating. These equivalences are based on accelerated laboratory testing results and UL now has approved GALFAN for those equivalences. Dr. Goodwin concluded by noting that he has heard many comments on the need for specifications and standards develop the GALFAN market. He questioned the entire group as to how can those standards be best developed. He asked if there were any British standards for GALFAN. Alan Stoneman replied that there are no standards currently existing and said that

there are not likely to be any until there is a wire producer in the U.K. for GALFAN. Joe Hogan noted that British Ropes is very influential in producing British standards and he felt that until British Ropes is a GALFAN licensee, there would probably be no standard. Mr. Hogan noted to the group as a whole if it would be possible to establish a cooperative producers group. The group concurrence was that such a question would be considered.

Discussion

Mr. Roman opened this session by briefly showing the slides for the Ziegler sheet material after five years of exposure in the industrial, rural, and marine sites, so that the group could see the results and relate them to GALFAN in the general sense. Mr. Ayoub noted for the group that the galvanized coating as shown on the slides should be 20 microns thickness (not 30 as noted) and also that the heavy gauge 1 mm GALFAN sample was not chromated, whereas the rest of the samples were chromated.

Dr. Coutsouradis gave a brief indication of what activities for 1988 research was to be at C.R.M. Mr. Ayoub reviewed some 1988 plans, noting that corrosion studies would include a continuation of the exposure series and would look for the effect of process details on corrosion resistance. Mr. Ayoub asked for any recommendations for further study. Mr. vandenBussche noted that there should be more study on the single dip product. Mr. Ayoub agreed. Mr. Ayoub then asked Mr. vandenBussche what was the quality of the single dip product that C.R.M. has received from Bekaert. Mr. vandenBussche noted that it was a single dip pilot trial, it was not a well established product at the time. Mr. Hogan noted that there should be definitely more testing on deformed wire in that deformation characteristics of GALFAN is its strongest advantage. Dr. Harrison asked if C.R.M. could test the corrosion resistance of only a thick alloy layer on wire. Dr. Coutsouradis felt that something could be arranged to do so.

Summary and Review

Mr. Roman quickly reviewed the days activities noting the interest of ILZRO members in the wire meeting. He reviewed the C.R.M. research on drawing behavior and the corrosion study update. He thanked Mr. Hogan and Mr. Gillet for their formal contributions, as well as the other wire licensees for their reports. Mr. Roman noted that there was obviously a tremendous interest in developing standards for GALFAN wire and indicated as the growth of GALFAN continued, such standards would be developed.

Mr. Toomer asked what the oldest GALFAN wire still in service was. Mr. Hogan noted that there is 1983 production of FICAL fishing ropes and some fencing still in service. Mr. Elser asked if there were any potential wire licensees known to ILZRO. Mr. Roman replied that there is some interest in the U.K.,

however no one would commit. There are several potential interests on the European continent and that there were no further interests noted in North or South America. Mr. Roman indicated that he would pursue the Japanese market as indicated by Mr. Suzuki. Dr. Goodwin asked Mr. Toomer if he knew when Palmer Tube would expect to run GALFAN. Mr. Toomer replied that he felt that there still was a need for another year's research and was especially waiting for results on the flux trials.

MEETING ADJOURNED

As there were no further questions, and discussion had ended, Mr. Roman adjourned the meeting at 4:30 p.m.

DRAWING BEHAVIOUR OF COATED WIRES

- ADHERENCE OF ZINC DURING REDRAWING

- COMPARISON BETWEEN GALVANIZED AND GALFAN (SINGLE AND DOUBLE DIP) COATED WIRES

- STUDY OF THE PICK-UP OF ZINC

CHARACTERIZATION OF COATED WIRES (INDUSTRIAL LINE)

REF.	COATING	DIAMETER (MM)	COATING THICKNESS (μ)	PI (PI
B1	GALFAN SINGLE DIP	2,2	35	2(
B2	GALFAN DOUBLE DIP	2,2	45	2(
B3	GALFAN DOUBLE DIP	2,2	46	12(
B4	GALVANIZED	2,2	49	5(

SUBSTRATE = LOW CARBON STEEL

DRAWING TRIALS

LENGTH OF TESTED WIRES = 10M

INITIAL DIAMETER = 2.2 MM

DIE ANGLE = 12°

SUCCESSION OF DIES WITH DECREASING DIAMETER (MM) :

1.90 - 1.70 - 1.53 - 1.37 - 1.23 - 1.14 - 1.05
0.97 - 0.90 - 0.83 - 0.77 - 0.71 - 0.66 - 0.61

TOTAL REDUCTION IN AREA = 92.3%

REDUCTION IN AREA PER STEP = 15 - 25%

TOTAL LENGTHENING = 13

LENGTHENING PER STEP = 1.18 - 1.32

WET DRAWING :
MIXTURE OF TRAXIT TYPE EDH 200 (10%) IN WATER

DRAWING SPEED = 10M/MIN

WEIGHT LOSSES AFTER DRAWING

REF	COATING	WEIGHT LOSS (GR)	(VS GALVANIZED)
B1	GALFAN SINGLE DIP	0,08	5
B2	GALFAN DOUBLE DIP	0,29	18
B3	GALFAN DOUBLE DIP (HIGH PB)	1,19	73
B4	GALVANIZED	1,64	100

WS

QUALITATIVE OBSERVATIONS

- GALFAN DOUBLE DIP (LOW LEAD) SHOWED THE BEST BEHAVIOUR AND COULD BE DRAWN WITHOUT GALLING AND WITHOUT RUPTURE

- A TOTAL REDUCTION IN AREA OF ABOUT 60% (DIE DIAMETER $\leq$ 1.23MM) SEEMS TO BE A LIMIT FOR THE OTHER PRODUCTS ESPECIALLY FOR THE GALVANIZED WIRE (GALLING-RUPTURE-PICK-UP)

- METALLOGRAPHIC STUDY

  INCREASE OF COATING CONCENTRICITY AFTER EACH STEP

  NO CRACKING

  FINER EUTECTIC STRUCTURE AND UNIFORM INTERMETALLIC LAYER FOR THE DOUBLE DIP GALFAN WIRE (B2)

  —> BETTER DRAWABILITY IN SPITE OF A HIGHER WEIGHT LOSS COMPARED TO SINGLE DIP (B1)

2.2. Galfan Coated Wires.

2.2.1. Introduction.

The present chapter considers three programmes dealing with Galfan and galvanized coated wires.

The first and third programmes aim at testing the harmful influence of Lead (Pb), in small amounts (150-300ppm) on Zinc-Aluminum alloys and more particularly to check

- The nature of the corrosion (through cross-sectionnal microstructures) generated by the presence of Lead and ;
- The difference in thickness loss.

Besides, the influence of Magnesium was also checked and more especially its ability to inhibit the deleterious influence of Lead.

The second and third programmes deal with the comparison of the corrosion resistance of single and double dip Galfan coatings.

2.2.2. First Programme ; Pilot Line Wires.

2.2.2.1. Coatings Characteristics.

This programme deals with low carbon wires which were coated in the C.R.M. mini-line. It aims at testing the Lead influence over several Zinc-Aluminum alloys and also the inhibitive effect of Magnesium.

Table 6 lists the characteristics of the coatings involved in this programme. Four Zinc-Aluminum alloys (thus four different baths) have been run[1], as well as three Lead levels per alloy : low Lead (50 to 80ppm Pb), medium Lead (100 to 180ppm Pb) and high Lead (200 to 350ppm Pb).

For each Zinc-Aluminum alloy, Lead level and exposure site[2] table 6 gives the Lead content of the coating and its thickness (measured by a chromate pickling).

Note 3 : Concerning the coating thickness, we notice (table 6) that they range between 10 µm and 15µm which is quite low compared to the thicknesses of industrial coatings (which are around 35 µm to 40 µm). These low values are certainly due to the low speed of the mini-line leading to a low drag out of molten material.

These wires were exposed in the twisted form, the twisting being achieved around a mandrel the diameter of which is three times that of the wire.

Figures 24 to 27 give the cross-sectionnal microstructures, before exposure, of the coatings corresponding to each of the four baths and for two Lead levels[3] per bath.

Figures 24 and 25 show a low concentration of the zinc rich globules, which are localized at the top of the coatings because of the high cooling rates of the wire coating process. These high cooling rates are certainly due to the high specific surface offered by the wires.

Figure 26.a shows the much higher concentration of Zinc rich globules for the Zamak coating whereas the Zamak + Galfan coating (figure 27.a) shows an intermediate concentration of Zinc-rich globules.

(1) The four alloys are : Galfan, Zinc-5% Aluminum (without mischmetal), Zinc-4% Aluminum - 0.03% Magnesium (called Zamak) and 50% Galfan + 50% Zamak.

(2) Two exposure sites have been used : the severe marine and the industrial sites.

(3) These two levels being : the low level (microstructure (a)) and the high level (microstructure (b)).

No particularity can be noticed in the microstructures of the coatings corresponding to the high Lead content (figures 24.b to 27.b).

2.2.2.2. Results and discussion.

A. Thickness Loss Data.

They are listed in table 7 which gives the thickness loss for each bath, Lead level and exposure site, after eleven months of outdoor exposure.

From table 7, we can see that the thickness loss evolution is more significant in the industrial site where the data show a remarkable increase in thickness loss as the Lead level increases. It also appears that[1] :

- At low Lead level, the Galfan coating showed the lowest thickness loss.
- At high Lead level, the Zinc-5% Aluminum coating showed the highest thickness loss.
- The thickness loss difference, between the coatings at high Lead and those at low Lead is the highest for Galfan (1.5µm = 4.5-3.0) whereas it is low for the Zamak coating (0.5µm = 4.2-3.7). This could be due to the presence of Magnesium, in the Zamak coating, which is known to inhibit the harmful influence of Lead.

Note 4 : Although the Magnesium has an inhibitive effect over the corrosion generated by Lead, the data show an increase in the thickness loss. This increase is much more significant when comparing the medium and high Lead contents (Zamak 0.4µm = 4.2-3.8) than the increase between the low and medium Lead contents (0.1µm - 3.8-3.7).
This tends to prove that the effectiveness of the inhibitive effect of Magnesium decreases when the Lead level exceeds a critical concentration, the level of which must be around 150ppm of Lead.

---

(1) The following conclusion are based on the data coming from the industrial site.

This is confirmed by the data from the severe marine site[1] where a high difference in thickness loss is noticed between the medium and high Lead contents (refer to the second and third baths), and also by the microstructures, as will be discussed in the following section.

B. Cross-Sectionnal Microstructures.

The corrosion condition of the coatings, corresponding to each bath and each Lead content per bath, after eleven months of outdoor exposure are given respectively in figures 28 to 31 for the severe marine site, and in figures 32 to 35 for the industrial site.

The results from both sites show the same trends and can be summarized as follows :

- The Galfan and Zinc-5% Aluminum coatings are deeply pitted at high Lead levels (figures 28.c, 29.b, 32.b and 33.b), these pits reaching the steel substrate.
  However, in the industrial site, the Zinc-5% Aluminum coating with a Lead level of 200ppm is still sound (figure 33.a) whereas in the severe marine site this coating with 150ppm Pb (figure 29.a) as well as Galfan with 90 ppm Pb (figure 28.b) are highly corroded.
  This means that the critical concentration of Lead[2] would be lower in the severe marine site than in the industrial site and thus is related to the exposure site.
- At high Lead levels, the Zamak and Zamak + Galfan coatings show a higher corrosion rate although no intercristalline corrosion occured (figures 34.c and 35.c for the industrial site).
  However in the severe marine site, some pits can be seen for both coatings (figures 30.c and 31.b).

---

(1) The reader must not consider the data of the Galfan in the severe marine site because the thickness loss decreases which contradicts all the other results.

(2) By critical concentration, we mean the minimum concentration which generates higher corrosion rates and/or intercristalline corrosion.

This means that the inhibitive effect of Magnesium decreases with the increase in the Lead content and the severity of the exposure conditions (site).
This result confirms what has been stated in note 4 about the analysis of the thickness loss data.

C. Conclusions Concerning the Coated Pilot Line Wires Programme.

After eleven months of outdoor exposure in the industrial and severe marine sites, the influence of Lead and Magnesium on the corrosion resistance of different Zinc-Aluminum alloys was clearly evidenced by the thickness loss data as well as by the cross-sectionnal microstructures.

In the absence of Magnesium, a high Lead content generates a severe intercristalline corrosion (see microstructures) and a higher corrosion rate (see table 7). The deleterious influence of Lead increases with its concentration and with the severity of the exposure site.

The results (mainly the microstructures) also established the effectiveness of Magnesium to inhibit the intercristalline corrosion at high Lead levels. But this effectiveness seemed to be altered in severe exposure sites. Moreover, the thickness loss data (table 7) proved that the Magnesium has not decreased the higher corrosion rates generated at high Lead contents.

D. An Attempt of a Comprehensive Understanding of the Magnesium Effect in the Presence of Lead.

No experimental data are available yet and we intend to undertake a specific programme (see the section concerning the proposals) aiming at a more thorough understanding of the Magnesium effect.

However a first literature review has been achieved and some theories have been stated over the subject.

From the experiences carried out by Roberts over Zinc-Aluminum cast alloys, contaminated by small amounts of Lead (200ppm to 300ppm), with and without Magnesium, it appears that (Réf. 3) :

- The maximum resistance to intercristalline corrosion is obtained for a Magnesium concentration of 0.02% to 0.03%. Further additions do not bring significantly greater benefit.
- Even in the presence of Magnesium, the severity of the attack increases with increasing amounts of Lead[1].

To explain the inhibitive action of Magnesium, Roberts stated that the solubility of Magnesium in Zinc being very low (0.002%), the excess is precipitated at the grain boundaries (at room temperature), probably as the intermetallic compound Mg Zn_5, and forms a continuous envelope which hinders the Zinc rich phases. This compound is not attacked by moisture at the ambiant temperature.

Other experiences, carried out by the same author, tends to prove (Ref. 4) that when the Lead concentration exceeds a critical value, another compound precipitates (Mg_2Pb) which is rapidly attacked by moisture at room temperature.

Besides the "screen" effect of the compound $MgZn_5$, Roberts tried to give an electrochemical explanation for the Magnesium effect (Ref. 4).

According to this electrochemical point of view, the Magnesium is anodic to both Zinc and Aluminum and may be expected to protect these elements from attack.

The electrode potential measurements indicate that the grain boundary zones of the Magnesium containing alloy are less anodic than those of the Magnesium-free alloys. This may be due, to some extent, to the fact that Magnesium reduces the grain size of such alloys leading to the distribution of any cathodic impurities over a greater area with a corresponding reduction in their effective concentration. The lattice distorsions, generated by Lead at the grain boundaries, will thus be attenuated leading to a sharp decrease of the Aluminum diffusion rate in these zones.

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(1) The maximum amount of Lead tested by the author is of 0.025%.

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M E M O R A N D U M

TO: GALFAN Wire License Meeting Attendees
GALFAN Technical Resource Center Sponsors
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GALFAN Confidentiality Signers
Mr. Jean Lamesch, ARBED Research
Mr. D. G. Esson, ARC TUBE, Inc.
Mr. Del Adkins, Bundy Tubing
Mr. G. Sasson, Florida Wire & Cable Co.
Mr. J. Wegria, Vieille-Montagne - Belgium

FROM: Marshall P. Roman, Director,
GALFAN TechnicalResource Center, ILZRO, Inc.

DATE: February 18, 1988

SUBJECT: Minutes of the Third GALFAN Wire Licensees Meeting
January 18, 1988, Reims, France

Enclosed are the subject minutes. Please note that in 1987, 8,800 tons of GALFAN Wire were produced (including 3,300 tons reported by ARBED - not in minutes) and the forecast for 1988 in 10,000. This includes approximately 500 tons for Indiana Steel & Wire, who will start GALFAN Wire production in 1988.

MPR/ja

Encl.

Moreover, Devillers and Niessen have proved that (Ref. 5), although Magnesium is not a noble element[1], it has an appreciable solid solubility in Aluminum (approximately 1.5% in weight) at room temperature. It is likely therefore that Magnesium, added to a Zinc-Aluminum alloy, will be present in the Aluminum particles.

The effect of Magnesium in solid solution in Aluminum is to reduce markedly the open-circuit potential (or corrosion potential) of Aluminum and its critical current density for passivation. This is shown in figure 58 for different values of pH and temperature.

It can thus be concluded that the presence of Magnesium in Aluminum facilitates the passivation of Aluminum and will therefore reduce the grain boundary corrosion rates.

2.2.3. Second Programme; Outdoor Exposure of Industrial Galfan Coated Wires.

2.2.3.1. Introduction.

This programme aims at comparing the corrosion resistance of :

- Single and double dip Galfan coatings.
- Galfan and Galvanized coatings..

All these products were coated on an industrial line.

2.2.3.2. Coatings' characteristics.

The characteristics of the coatings are listed in table 8. We notice that the Aluminum content of the Galfan single dip coatings are low (3.6%) whereas it is slightly higher for the Galfan double dip coating (4.2%)[2]. The Lead content is the same for the three Galfan coatings (100ppm) and is below the critical level[3].

---

(1) Thus it cannot influence the corrosion rates in the way that copper does.

(2) The low Al content of the Galfan coatings is due to the heating apparatus, of the Galfan pot, which generates surface drosses the Al content of which is very high thus leading to a decrease of the Al content of the bath.

(3) According to the previous section (Pilot Line Wires), this critical level is around 150ppm of Pb.

The coatings' thicknesses are comparable and range between 35 and 40µm.

It must also be specified that the electroflux process has been used for the single dip Galfan whereas normal fluxing was performed for the double dip Galfan.

Cross-sectionnal microstructures of the Galfan coatings (before exposure) are given in figure 36 which shows the very high concentration of Zinc rich globules, for both single and double dip Galfan coatings, due to their low Aluminum content. The fact that the size of these globules is small is due to the rapid cooling of the wires at the outlet of the bath.

2.2.3.3. Results and Discussion.

The evaluation has been performed after eleven months of outdoor exposure in the severe marine and industrial sites.

No thickness loss data are available for this programme and only cross-sectionnal microstructures of the severe marine site will be presented (the same behavior having been noticed in the industrial site). Out of these microstructures, the following conclusions can be drawn :

- The thickness loss of the Galvanized coating can be estimated (in figure 38.a) at 14µm.
- This is quite high when compared to the thickness loss of the Galfan double dip coating (figure 37.a and b) estimated to range between 3 and 4µm, thus leading to a thickness loss yield (Galfan/Galvanized) which ranges between 3.5 and 4.7.
- Disappointing was the behavior of the Galfan single dip, shown in figure 38.b which reveals a deep intercristalline attack although its Lead content is below the critical value.

This result is further confirmed by the third programme, but we cannot conclude at once that generally the Galfan double dip is better than the single dip and this result needs to be checked more thoroughly.

FIGURE 24

PILOT LINE WIRES

MICROSTRUCTURE (500 x) BEFORE EXPOSURE

COATING : GALFAN

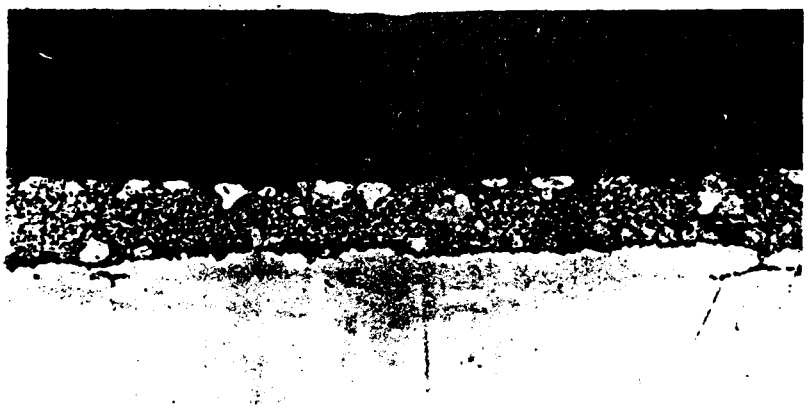
Pb Level (ppm)

a

50

(086/45/2)

b



180

(250 x)
(086/45/4)

FIGURE 25

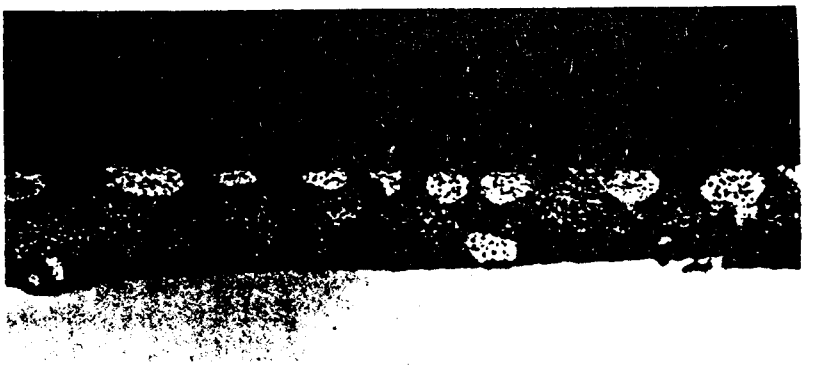
PILOT LINE WIRES

MICROSTRUCTURE (500 x) BEFORE EXPOSURE

COATING : Zn-5 Al

Pb LEVEL (PPM)

a



50

(086/45/7)

b

350

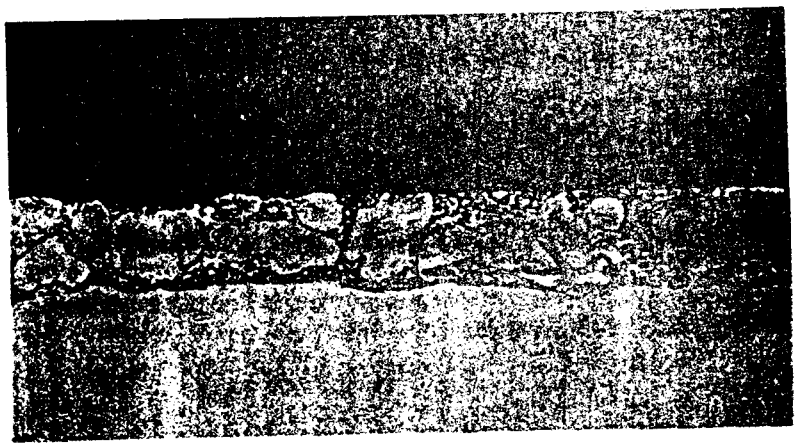
(086/45/10)

FIGURE 26

PILOT LINE WIRES

MICROSTRUCTURE (500 x) BEFORE EXPOSURE

COATING : ZAMAK 3



Pb Level (ppm)

60

(86/440)

270

(86/443)

FIGURE 27

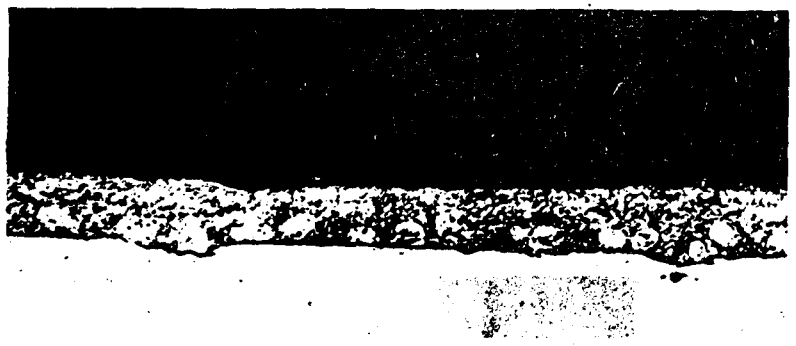
PILOT LINE WIRES

MICROSTRUCTURE (500 x) BEFORE EXPOSURE

COATING : ZAMAK 3 + GALFAN

PB LEVEL (PPM)

a



60

(86/444)

b

270

(86/446)

FIGURE 28

PILOT LINE WIRES - COATING : GALFAN

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN SEVERE MARINE SITE.

		Pb Level (ppm)
a		50 (087/84/4)
b		90 (087/84/6)
c		160 (087/84/7)

FIGURE 29

PILOT LINE WIRES - COATING : ZN,5 AL

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN SEVERE MARINE SITE.

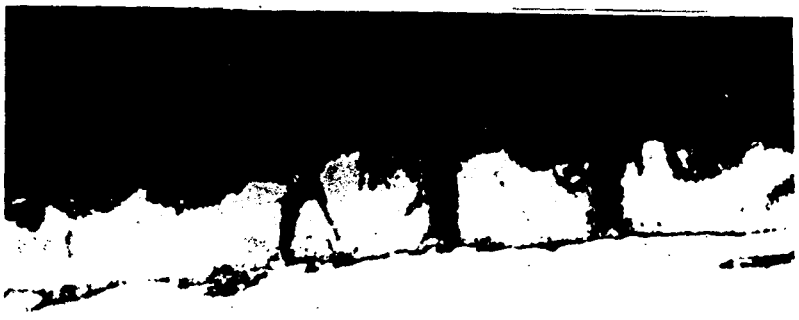
PB LEVEL (PPM)

a

150

(087/86/15)

b



300

(087/86/16)

FIGURE 30

PILOT LINE WIRES - COATING : ZAMAK 3

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN SEVERE MARINE SITE.

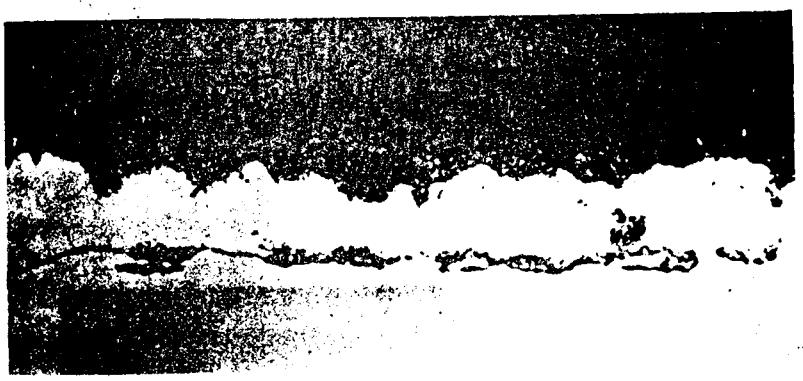
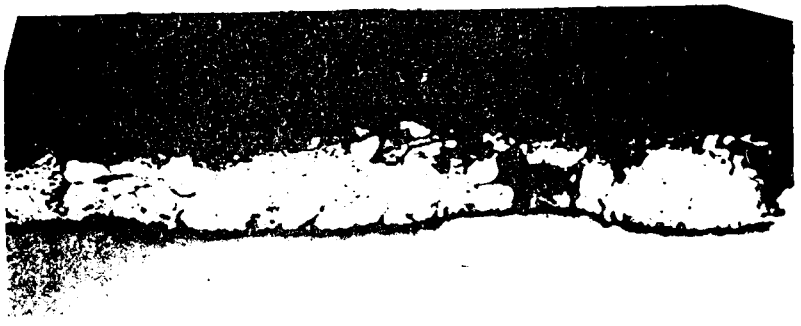
		Pb Level (ppm)
a		80 (087/86/18)
b		150 (087/86/22)
c		240 (087/84/8)

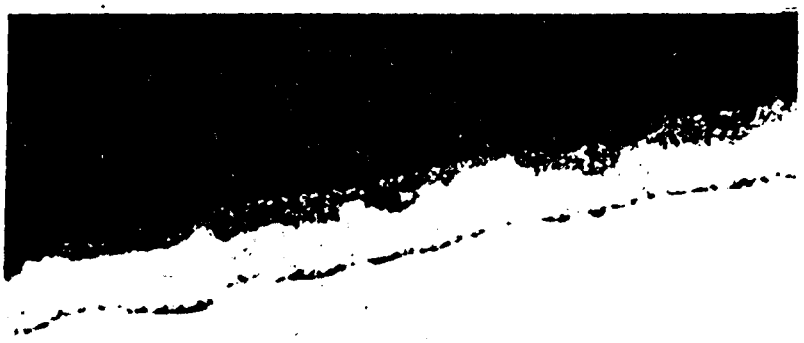
FIGURE 31

PILOT LINE WIRES - COATING : ZAMAK 3 + GALFAN

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN SEVERE MARINE SITE.

Pb Level (ppm)

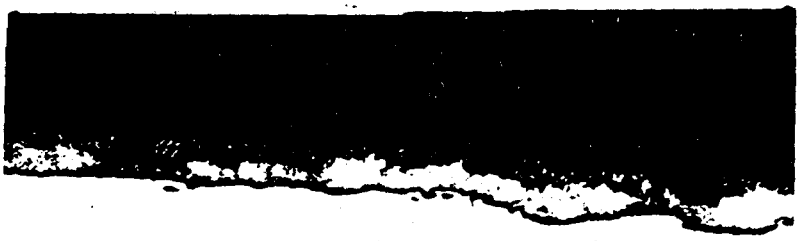
a



60

(087/84/9)

b



160

(087/84/11)

FIGURE 32

PILOT LINE WIRES - COATING : GALFAN

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN INDUSTRIAL SITE.

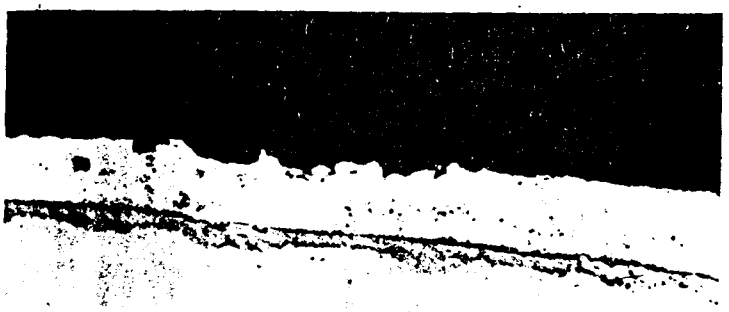
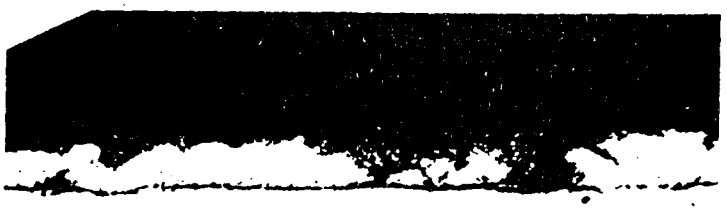
	Pb Level (ppm)	
a		50 (087/84/14)
b		180 (087/84/17)

FIGURE 33

PILOT LINE WIRES - COATING : ZN.5 AL

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN INDUSTRIAL SITE.

PB LEVEL (PPM)

a

200

(087/86/2)

b

350

(087/86/3)

FIGURE 34

PILOT LINE WIRES - COATING : ZAMAK 3.

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN INDUSTRIAL SITE.

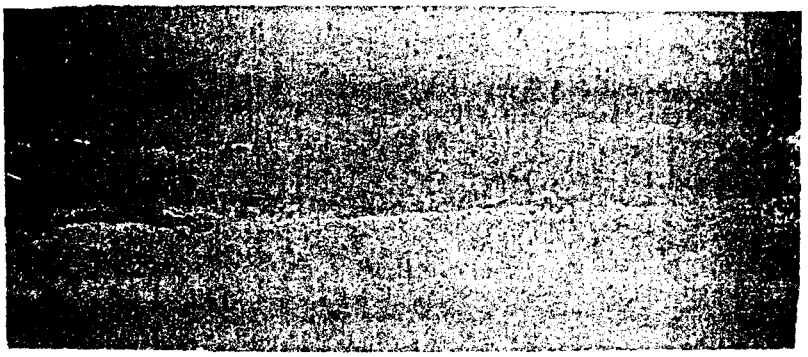
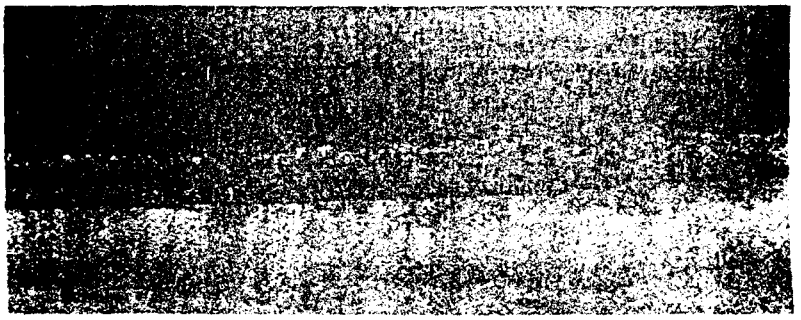
		Pb Level (ppm)
a		60 (087/86/5)
b		180 (087/86/6)
c		270 (087/86/9)

FIGURE 35

PILOT LINE WIRES - COATING : ZAMAK 3 + GALFAN.

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN INDUSTRIAL SITE.

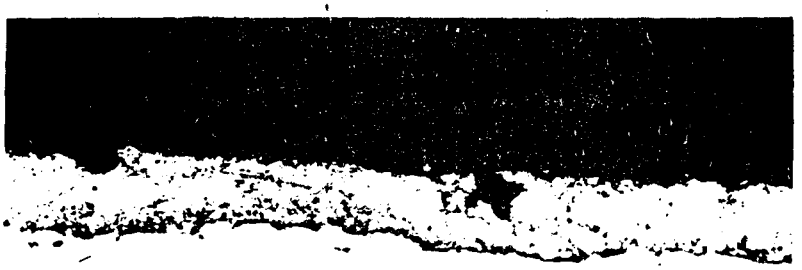
		Pb Level (ppm)
a		60
	(087/86/10)	
b		120
	(087/86/12)	
c		270
	(087/86/14)	

FIGURE 36

INDUSTRIAL WIRES

MICROSTRUCTURES (500x) BEFORE EXPOSURE

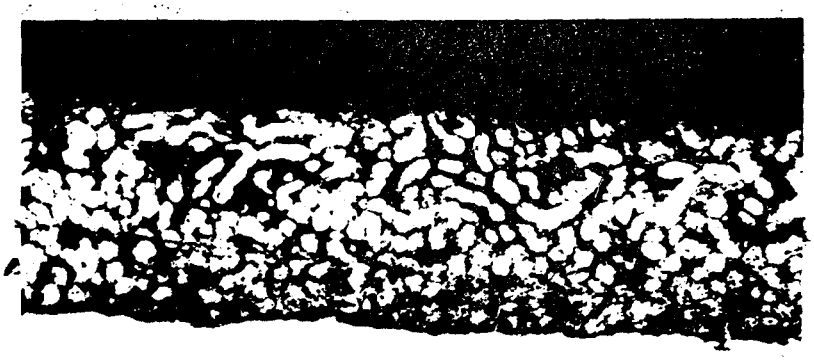
COATING : GALFAN

a

SINGLE DIP

(86/88)

b



DOUBLE DIP

(86/83)

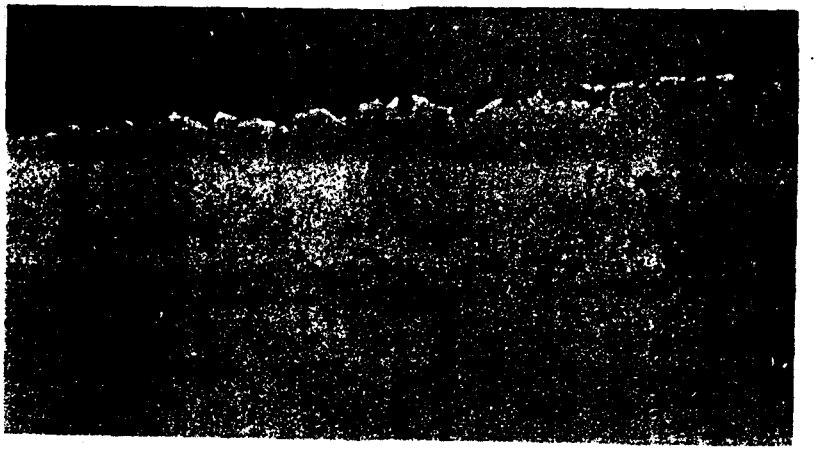
FIGURE 37

INDUSTRIAL WIRES

MICROSTRUCTURES (500 x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN SEVERE MARINE SITE

COATING

a



GALFAN
DOUBLE DIP

(087/97/6)

b

ID

(087/84/2)

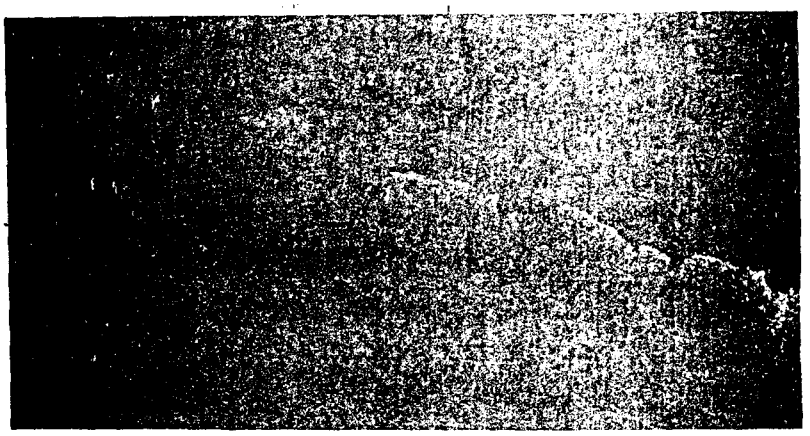
FIGURE 38

INDUSTRIAL WIRES

MICROSTRUCTURES (500x) AFTER 11 MONTHS OF OUTDOOR EXPOSURE IN SEVERE MARINE SITE

COATING

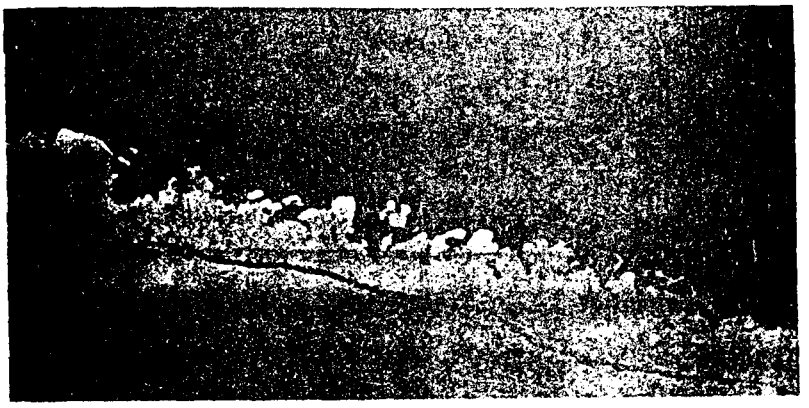
a



GALVA

(087/97/3)

b



GALFAN

SINGLE DIP

(087/84/19)

FIGURE 39

INDUSTRIAL WIRES - ACCELERATED TESTS PROGRAM

COATINGS STRUCTURE (500x) OF GALFAN

DIP

a

SINGLE (B1)

(087/100/7)

b

DOUBLE (B2)

(087/100/9)

c

DOUBLE (FG)

(87/162)

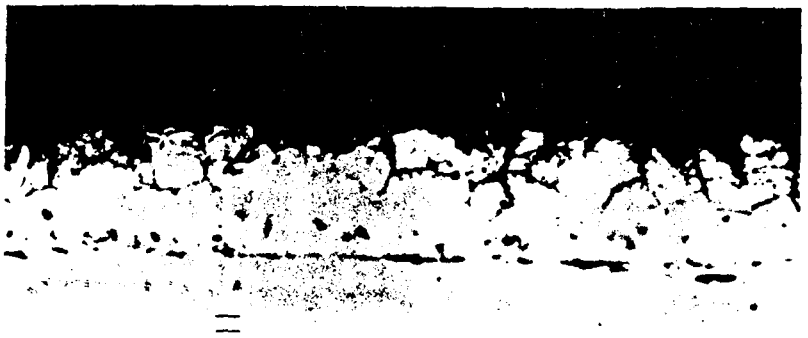
FIGURE 40

INDUSTRIAL WIRES - SALT SPRAY TEST

COATING : GALFAN SINGLE DIP (B1)

EXPOSURE
(DAYS)

a

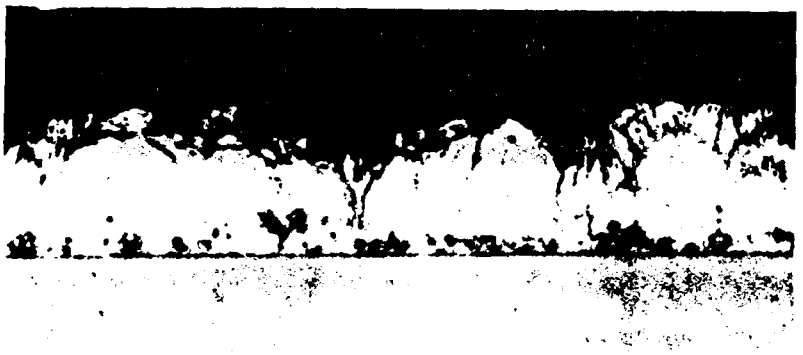


3

(087/94/27)

(250x)

b



8

(087/94/30)

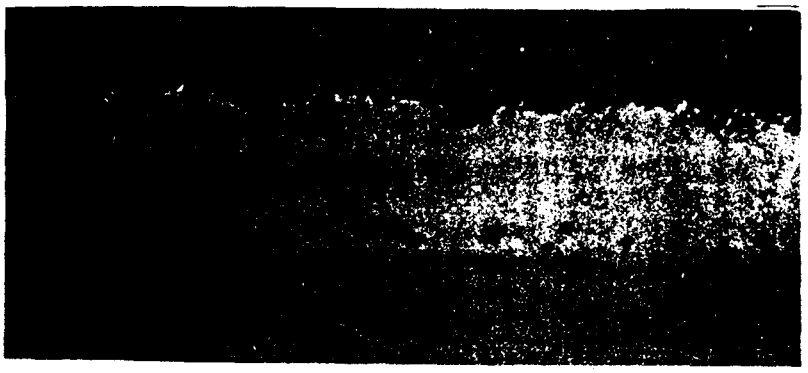
FIGURE 41

INDUSTRIAL WIRES - SALT SPRAY TEST

COATING : GALFAN DOUBLE DIP LOW Pb (B2)

EXPOSURE (DAYS)

a

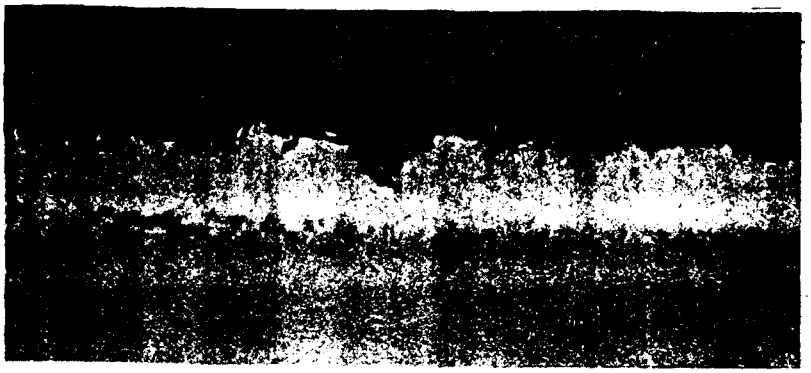


3

(087/94/31)

(250x)

b



8

(087/94/32)

FIGURE 42

INDUSTRIAL WIRES - SALT SPRAY TEST

COATING : GALFAN DOUBLE DIP HIGH Pb (B3)

EXPOSURE (DAYS)

a

3

(087/95/1)

(250x)

b

8

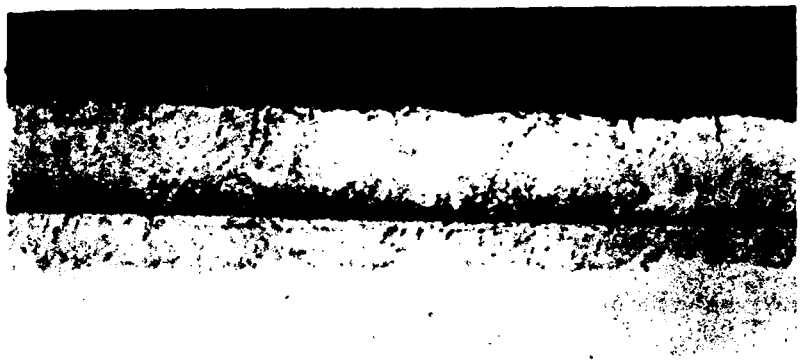
(087/95/3)

FIGURE 43

INDUSTRIAL WIRES - SALT SPRAY TEST

COATING : GALFAN DOUBLE DIP HIGH Pb (FG)

EXPOSURE (DAYS)

a  3

(087/95/10)

(250x)

b  8

(087/95/12)

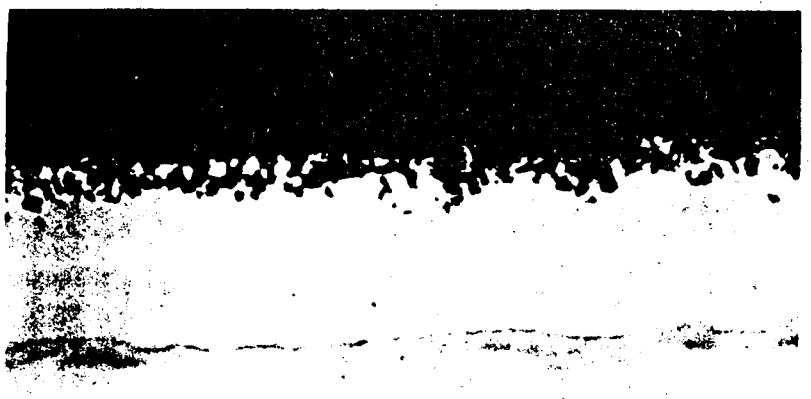
FIGURE 44

INDUSTRIAL WIRES - SALT SPRAY TEST

COATING : GALVA (B4)

EXPOSURE (DAYS)

a

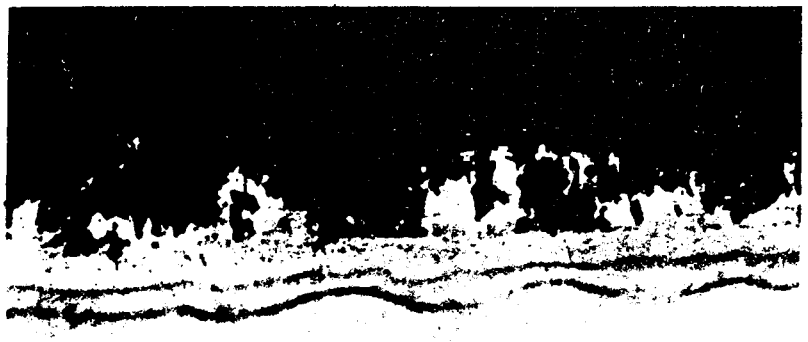


3

(087/95/4)

(250x)

b



8

(087/95/6)

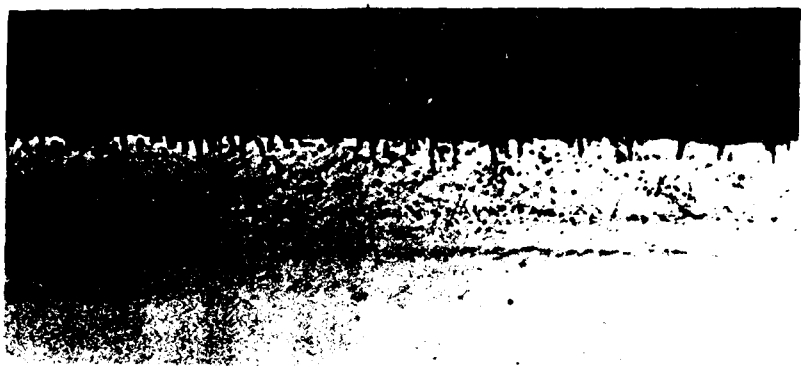
FIGURE 45

INDUSTRIAL WIRES - SALT SPRAY TEST

COATING : GALVA (FZ)

EXPOSURE (DAYS)

a



3

(087/95/7)

(250x)

b

8

(087/95/9)

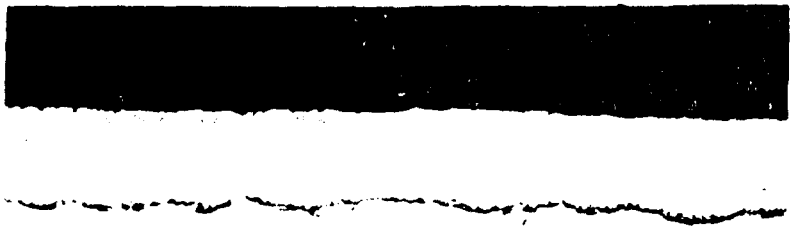
FIGURE 46

INDUSTRIAL WIRES - HUMIDITY CABINET

COATING : GALFAN SINGLE DIP (B1)

EXPOSURE (DAYS)

a

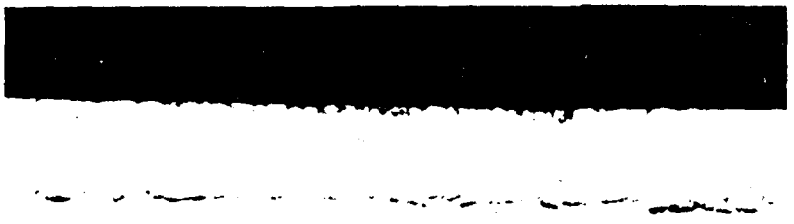


5

(087/94/2)

(250 x)

b



17

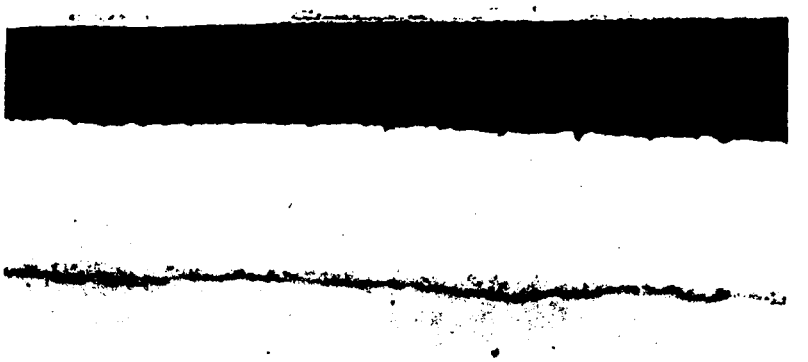
(087/94/12)

FIGURE 47

INDUSTRIAL WIRES - HUMIDITY CABINET

COATING : GALFAN DOUBLE DIP LOW Pb (B2)

EXPOSURE (DAYS)

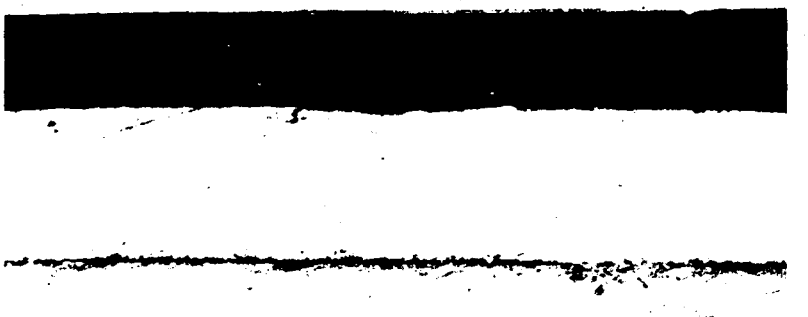


a

5

(087/94/3)

(250x)



b

17

(087/94/13)

FIGURE 48

INDUSTRIAL WIRES - HUMIDITY CABINET

COATING : GALFAN DOUBLE DIP HIGH P_B (B3)

EXPOSURE (DAYS)

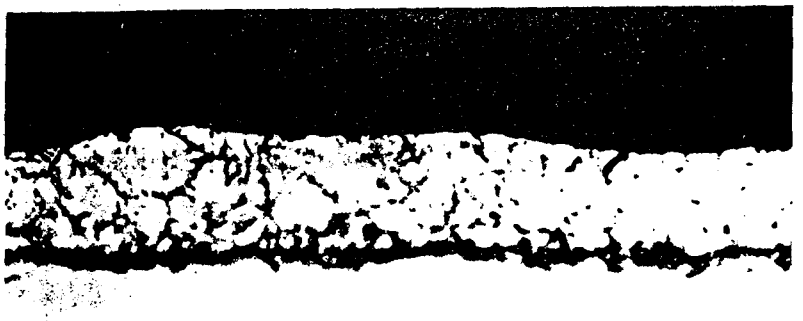
a

5

(087/94/5)

(250x)

b



17

(087/94/15)

FIGURE 49

INDUSTRIAL WIRES - HUMIDITY CABINET

COATING : GALFAN DOUBLE DIP HIGH Pb (FG)

EXPOSURE
(DAYS)

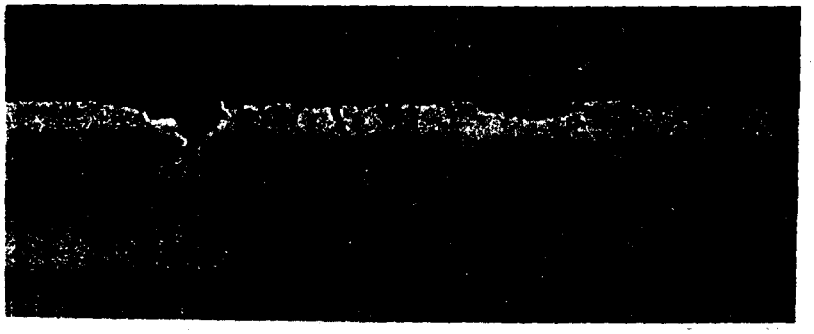
a

5

(087/94/19)

(250x)

b



17

(087/94/25)

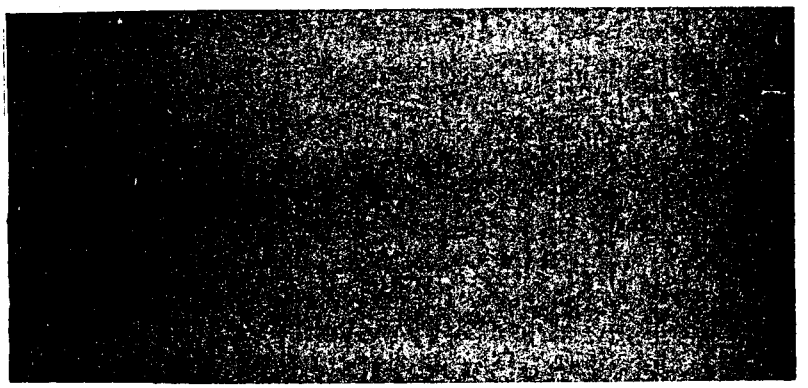
FIGURE 50

INDUSTRIAL WIRES - HUMIDITY CABINET

COATING : GALVA (B4)

EXPOSURE (DAYS)

a

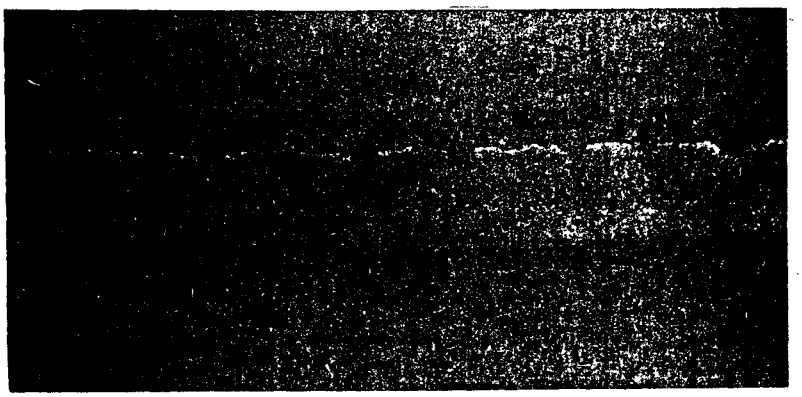


5

(087/94/6)

(250x)

b



17

(087/94/11)

FIGURE 51

INDUSTRIAL WIRES - HUMIDITY CABINET

COATING : GALVA (FZ)

EXPOSURE (DAYS)

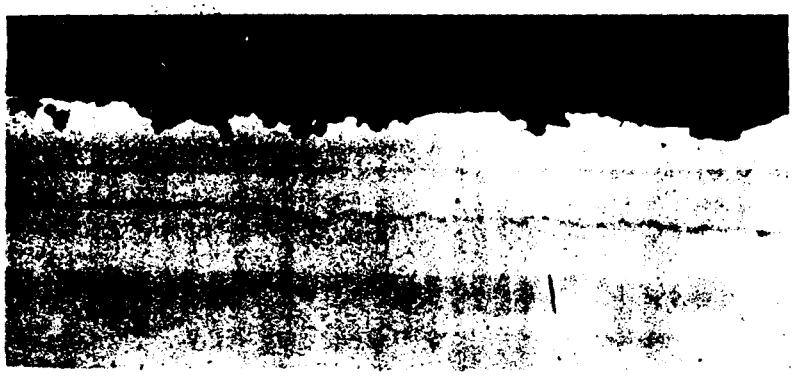
a

5

(087/94/17)

(250x)

b



17

(087/94/20)

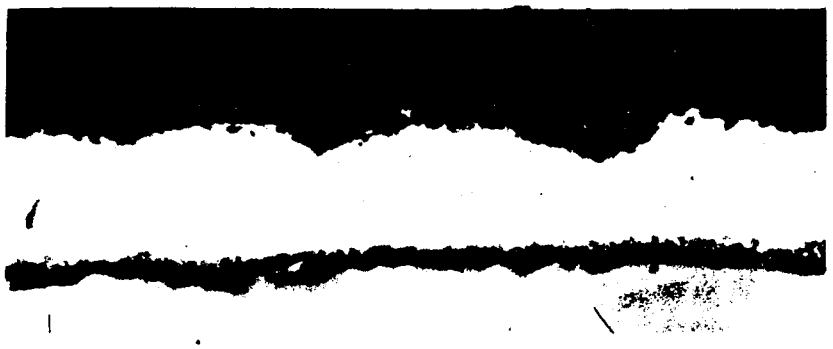
FIGURE 52

INDUSTRIAL WIRES - KESTERNICH TEST.

COATING : GALFAN SINGLE DIP (B1), (MAGN. 500 x)

EXPOSURE (CYCLES)

a



4

(087/130/1)

b

7

(087/130/7)

c

10

(087/130/13)

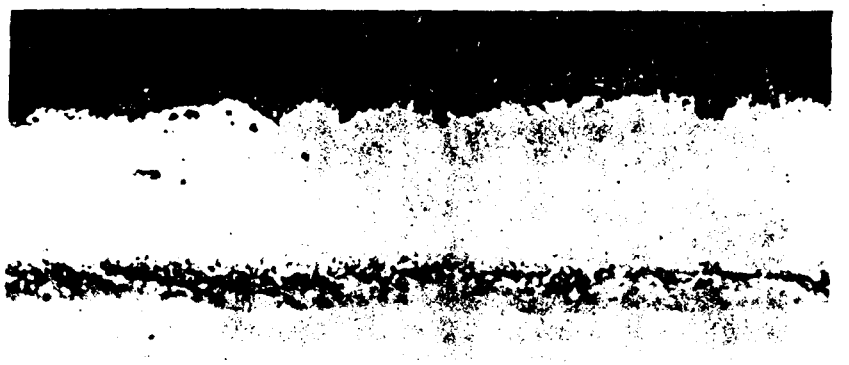
FIGURE 53

INDUSTRIAL WIRES - KESTERNICH TEST.

COATING : GALFAN DOUBLE DIP LOW PB (B2), (MAGN. 500 x).

EXPOSURE
(CYCLES)

a



4

(087/130/2)

b

7

(087/130/8)

c

10

(087/130/14

FIGURE 54

INDUSTRIAL WIRES - KESTERNICH TEST.

COATING : GALFAN DOUBLE DIP HIGH PB (B3), (MAGN. 500 x)

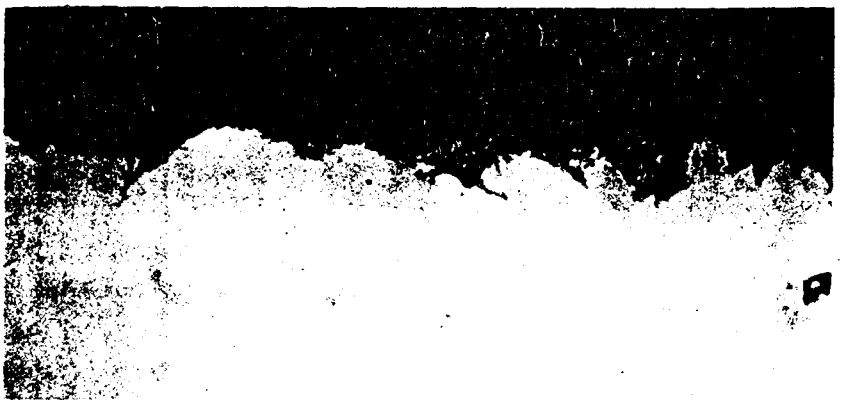
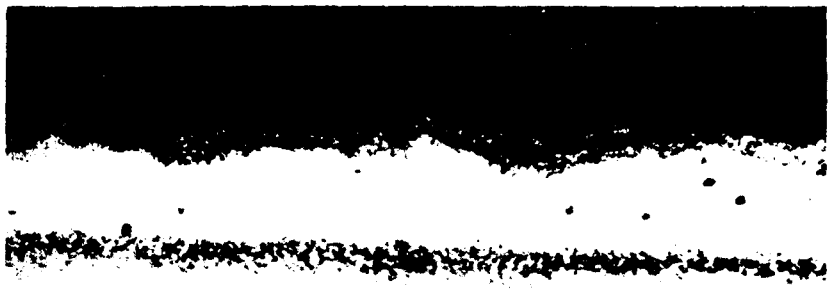
		EXPOSURE (CYCLES)
a		4 (087/130/3)
b		7 (087/130/9)
c		10 (087/130/15)

FIGURE 55

INDUSTRIAL WIRES - KESTERNICH TEST.

COATING : GALFAN DOUBLE DIP HIGH PB (FG), (MAGN. 500 x)

EXPOSURE (CYCLES)

a  4 (087/130/6)

b  7 (087/130/12)

c  10 (087/130/18)

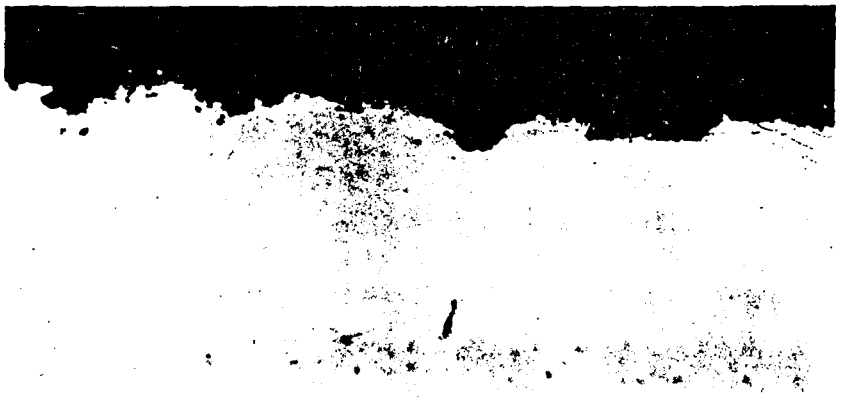
FIGURE 56

INDUSTRIAL WIRES - KESTERNICH TEST.

COATING : GALVA (B4)

EXPOSURE
(CYCLES)

a



4

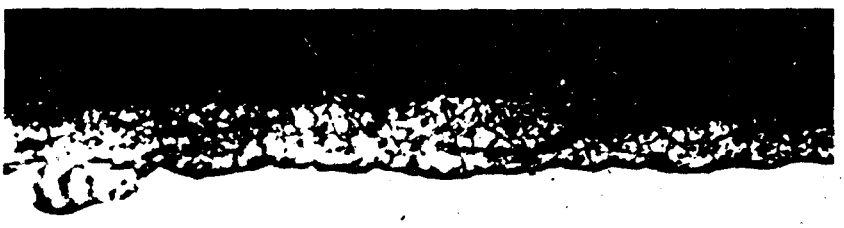
(087/130/4)

b

7

(087/130/10)

c



10

(087/130/16)

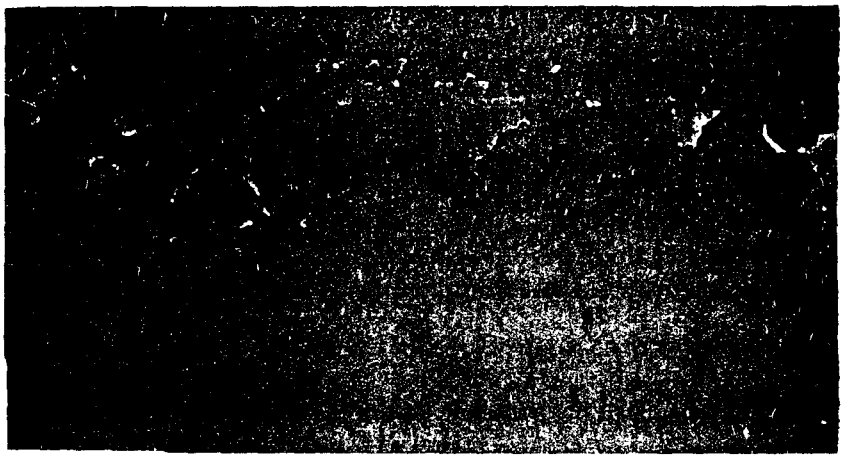
FIGURE 57

INDUSTRIAL WIRES - KESTERNICH TEST.

COATING : GALVA (FZ)

EXPOSURE
(CYCLES)

a



4

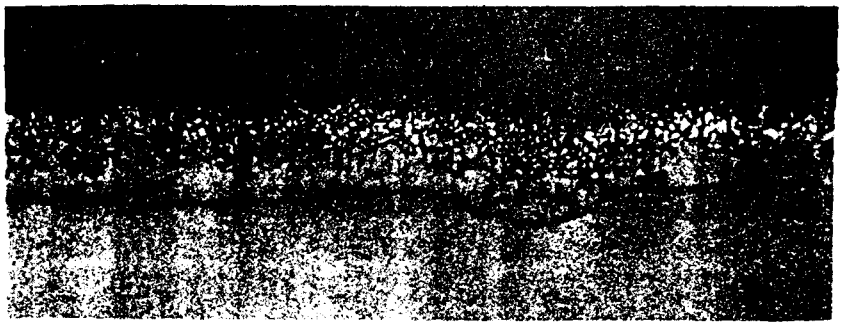
(087/130/5)

b

7

(087/130/11)

c



10

(087/130/17)

COMMUNICATION PRESENTED ON JANUARY 18TH 1988
THIRD GALFAN WIRE LICENSEES MEETING
REIMS

The company FICAL has been integrated with the new COMPANY TREFILUNION, on august 1, 1987. FICAL constitutes the LENS establishment of TREFILUNION.

TREFILUNION's LENS plant was one of the first companies producing high carbon steel wire, that has been interested in GALFAN. Because of the main orientation of its production, our company is very concerned with corrosion problems in steel. As early as 1983 the first trials on galfanized wire were initiated on a production line.

The first production runs were intended for the fabrication of cables for fishing. The marine environment is indeed particularly agressive and the corrosion resistance of redrawn galfan wires proved quite evident.

Since then our company develops two types of cables for fishing boats:

-The "CORDON ROUGE" brand, is composed of 6 strands of 26 wires cabled on a polypropylène core,

- The "SUPER CORDON ROUGE" brand, is of the same constitution but its wires have been profiled in order to provide a better restance to abrasion.

At that time, laboratory tests as well as exposure in industrial and marine sites carried out in collaboration with the CRM of Liège showed the high performance level of GALFAN. Since then, use in service of fishing cables has confirmed the results of prior tests. The cables " CORDON ROUGE AND SUPER CORDON ROUGE" represent, at present, more than 50% of our deliveries to the fishing market

A second application of Galfan has been developed in parallel : the high strength steel wire intended for the fabrication of springs particularly exposed to corrosion, e.g., springs used in the automotive industry. In this case also cold worked coated wires are considered.

We have produced and we have obtained agreements from french manufacturers for galfan coated wire. The excellent corrosion resistance (doubling of life in salt spray for the same thickness) as well as the very good adherence of the coating are the main reasons for the success of these products.

We are commercializing this product under the trade mark CORZAL.

An important part of the activity of the TREFILUNION-LENS plant is devoted to the production of wires and strands used for the fabrication of bridge cables, of cables for the transport of electricity or guard cables. We have also produced and commercialized under the trade-mark GALVALENS, medium and high strength wires coated with GALFAN at the final stage of fabrication. We have progressively extended our production program, beginning with the smallest diameters (1.8 to 2mm), to a diameter of 6 mm. We produce at present on an industrial scale GALFAN wires of 5.5 and 6 mm in diameter with steels containing 0.83-0.88 C.

CHARACTERISTICS OF THE PRODUCTS

The tables and graphs that we shall present show the results of tests carried out in our laboratories or in those of the group USINOR-SACILOR or in laboratories outside our company.

They give the present "state of the art" of the quality of the products of the TREFILUNION-LENS plant.

1° COMPARISON BETWEEN THE WEIGHTS OF ZINC AND GALFAN COATED on wire in our industrial equipement. This comparison is made as a function of the wire's diameter and the range of strength.

Our GALAVANIZING process is the conventional one : pickling, rinsing, fluxing and galvanizing.

GALFANIZING is performed by double immersion : zinc bath - galfan bath.

2° COMPARISON BETWEEN THE WEIGHTS OF ZINC AND GALFAN on redrawn wires.

Upper part : Galvanized redrawn wire.

Lower part : CORZAL wire.
The parameters are as above : wire diameter and mechanical strength. The values are of course averages.

3° COMPARISON BETWEEN TESTS IN SALT SPRAY carried out in different laboratories on wires originating from our production of zinc or of galfan wires. The scale on the absiscea is in microns and indicates the initial thickness of the coating.
It is confirmed that the first apparition of red rust is twice as rapid for the zinc coatings;

4° SALT SPRAY TESTS

First of all we show the results obtained at a british laboratory concerning corrosion resistance in salt spray expressed as weight loss of the coating. The curves are very evident.

Finally we show two tables comparing zinc coated wires to galfan coated ones. The tests were carried out at the research center of USINOR at Unieux (UNIREC). The times indicate the number of days (cycles of 24 hours) corresponding to the presence of 5% red rust or to the formation of 75% od red rust. In fact they correspond to the beginning and the end of the test.
One can note that the galfan coated wires exhibit a corrosion resistance in salt spray which is equivalent to that of zinc coated wires with the double thickness.

RESEARCH PROGRAM AND TRIALS

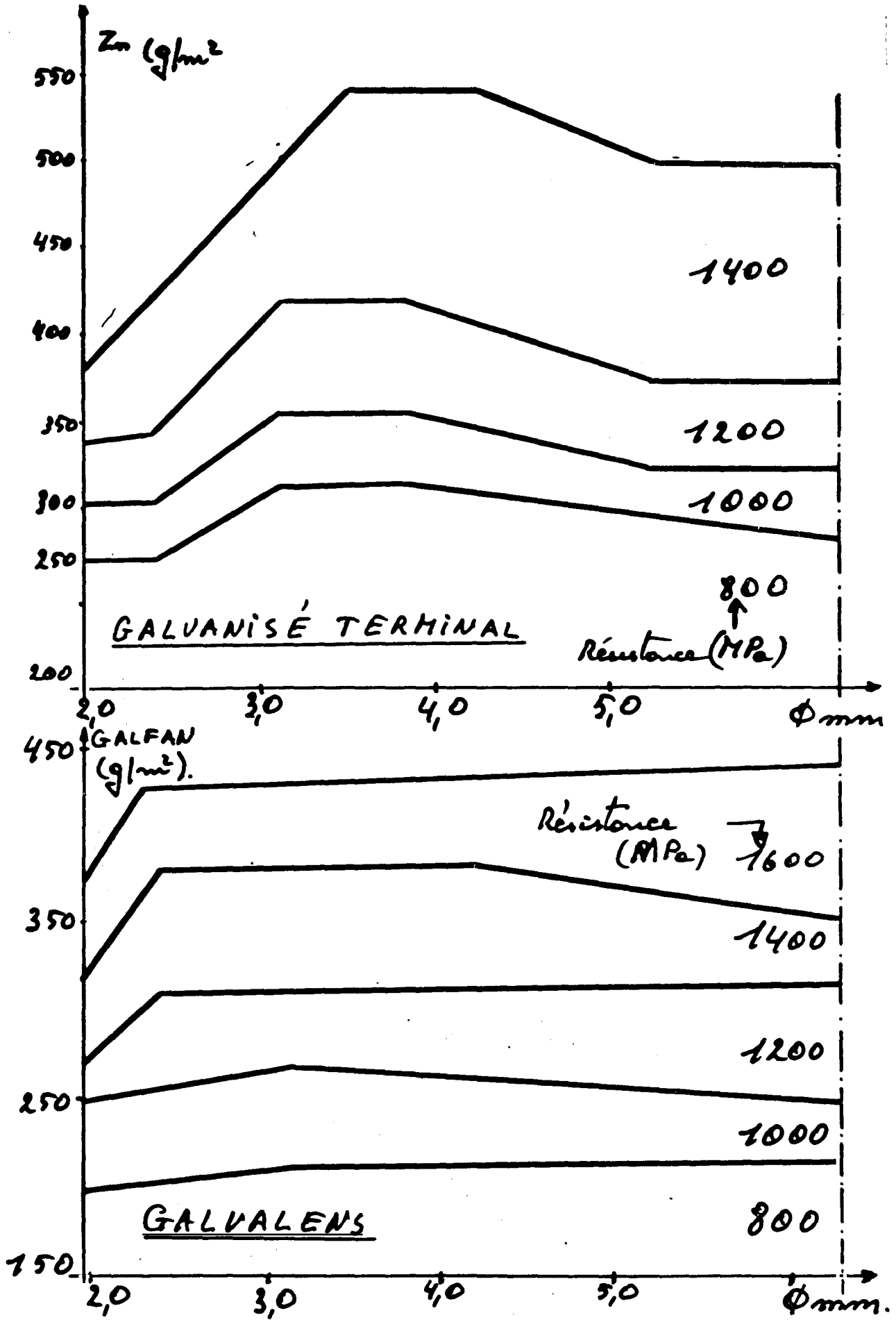
We have last year carried out trials on mild steel wires (carbon content lower than 0.2%).
In parallel, an other plant of the TREFILUNION Group had started trials in the same area.
Since the restructuring of the wire activities of the USINOR-SACILOR Group and the integration of FICAL in the new structure, the LENS plant has been confirmed in its pilot role within the company to pursue the studies aiming at the development of Galfan uses for all grades of steel wire.

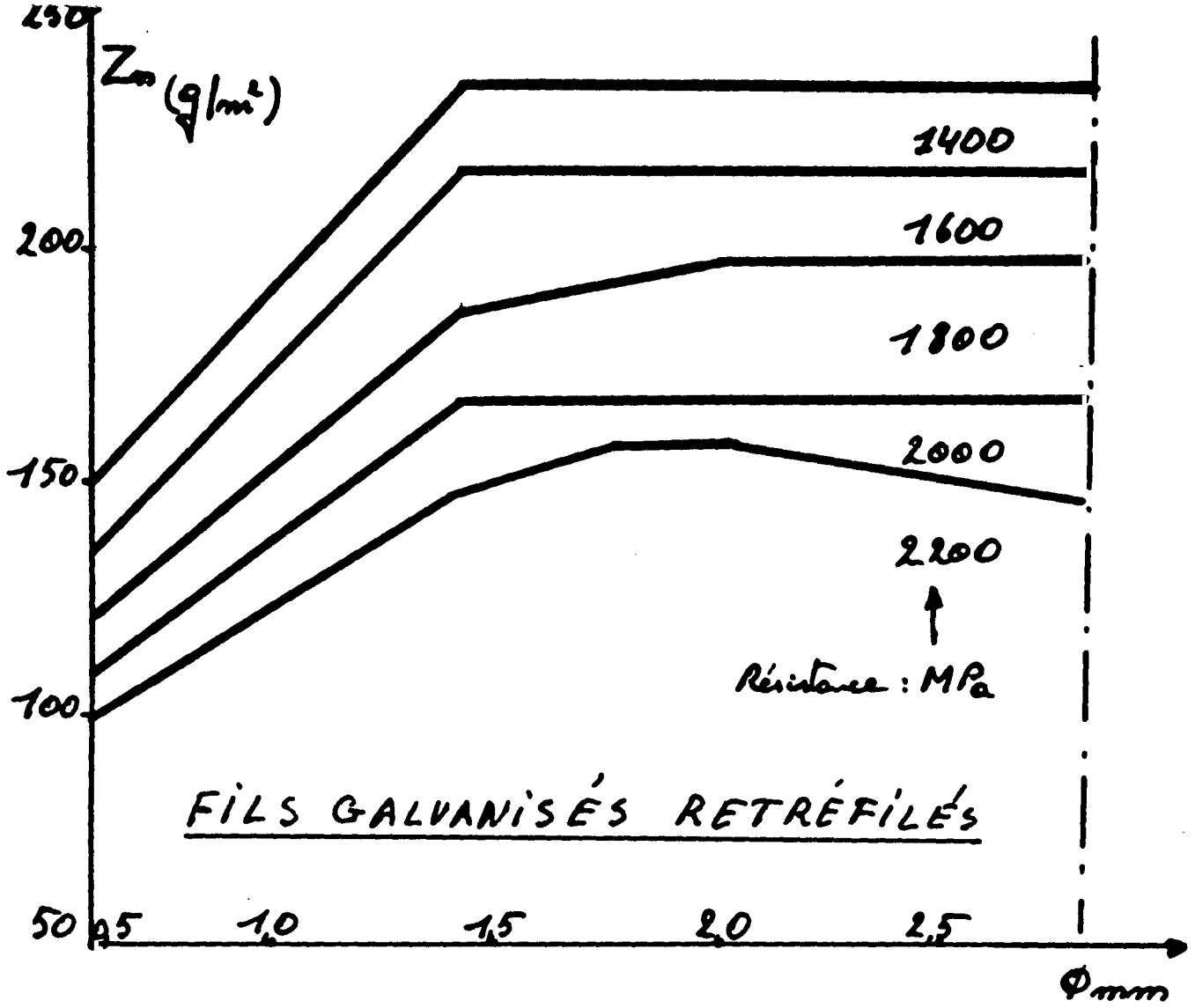
2° Our trial planning will particularly deal with :

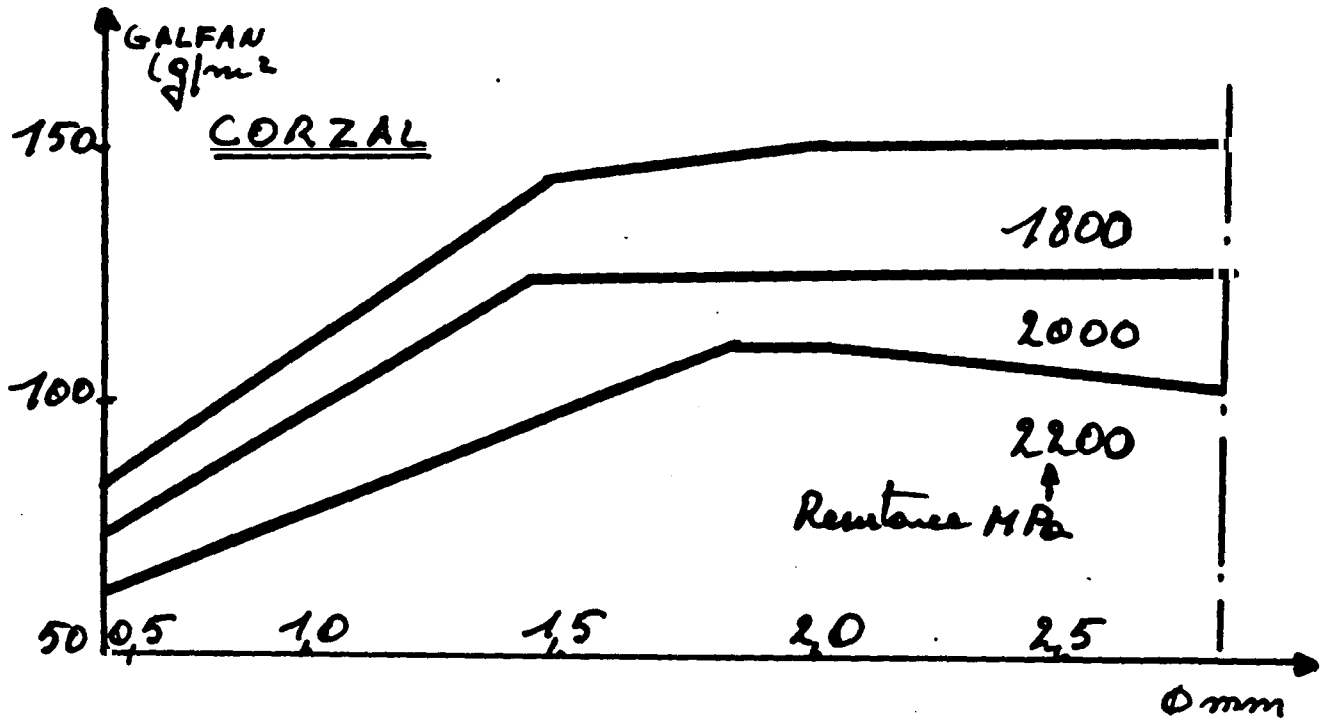
- Heavy weight coating of GALFAN on wires and particylarly on GALVALENS.
- The industrial developement of the single dip GALFANIZING process
- The improvement of the coating quality as regards its constitution, the homogeneity of the coatings and their aspect. We consider in fact commercial products and this last point cannot be neglected.

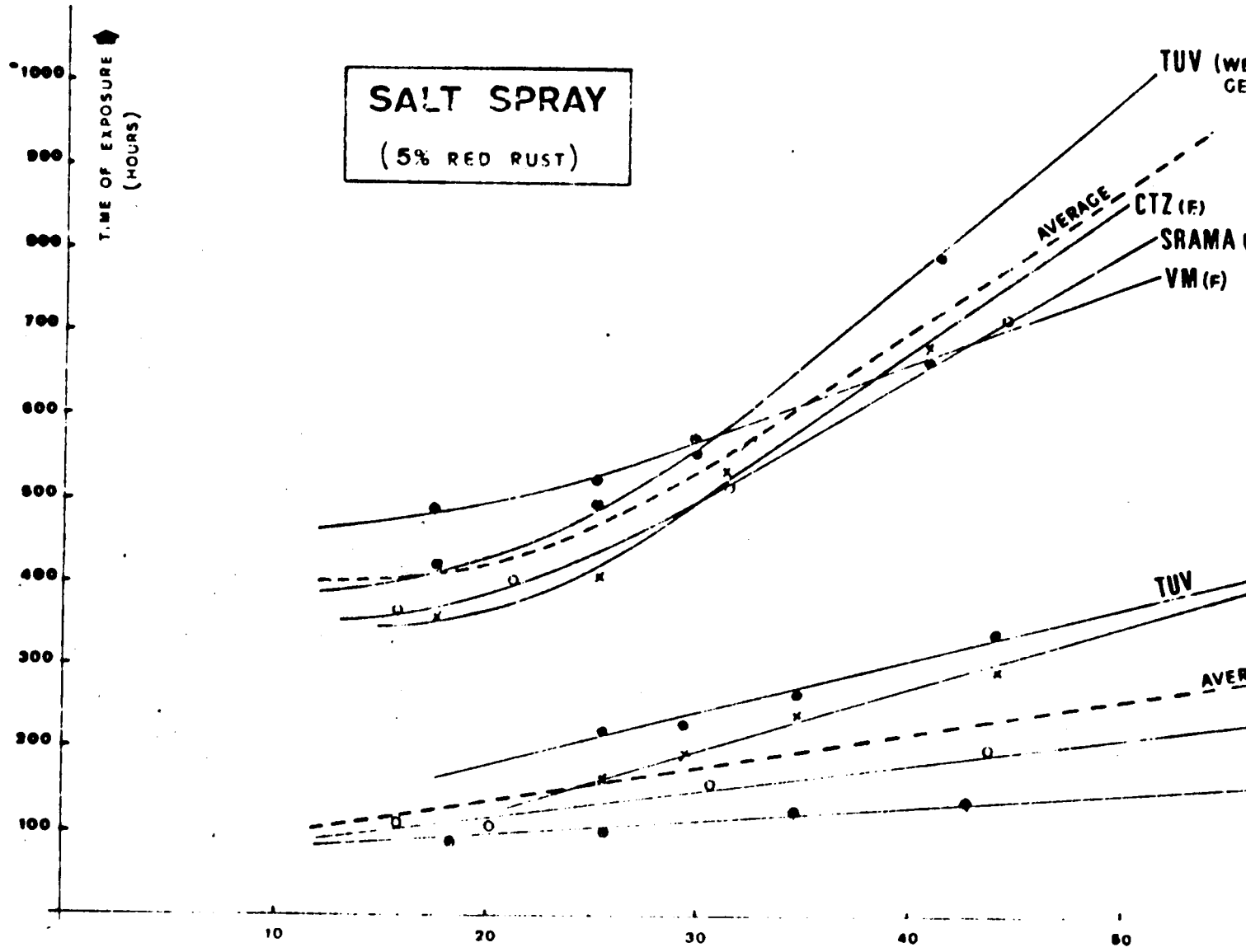
I thank you for your attention .....

****


Zn (g/m²)
550
500
450
400
350
300
250
200
1400
1200
1000
800
GALVANISÉ TERMINAL
Résistance (MPa)
2,0
3,0
4,0
5,0
Φ mm
450
350
250
150
GALFAN (g/m²).
Résistance (MPa)
1600
1400
1200
1000
800
GALVALENS
2,0
3,0
4,0
5,0
Φ mm.


250
Zm (g/m²)
200
150
100
50
1400
1600
1800
2000
2200
Résistance : MPa
FILS GALVANISÉS RETRÉFILÉS
0,5
1,0
1,5
2,0
2,5
Φ mm


GALFAN (g/m²)
CORZAL
150
100
50
1800
2000
2200
Resistance MPa
0,5
1,0
1,5
2,0
2,5
Φ mm


SALT SPRAY
(5% RED RUST)
TIME OF EXPOSURE (HOURS)
1000
900
800
700
600
500
400
300
200
100
10
20
30
40
50
TUV (WI
CE
AVERAGE
CTZ (F)
SRAMA
VM (F)
TUV
AVER

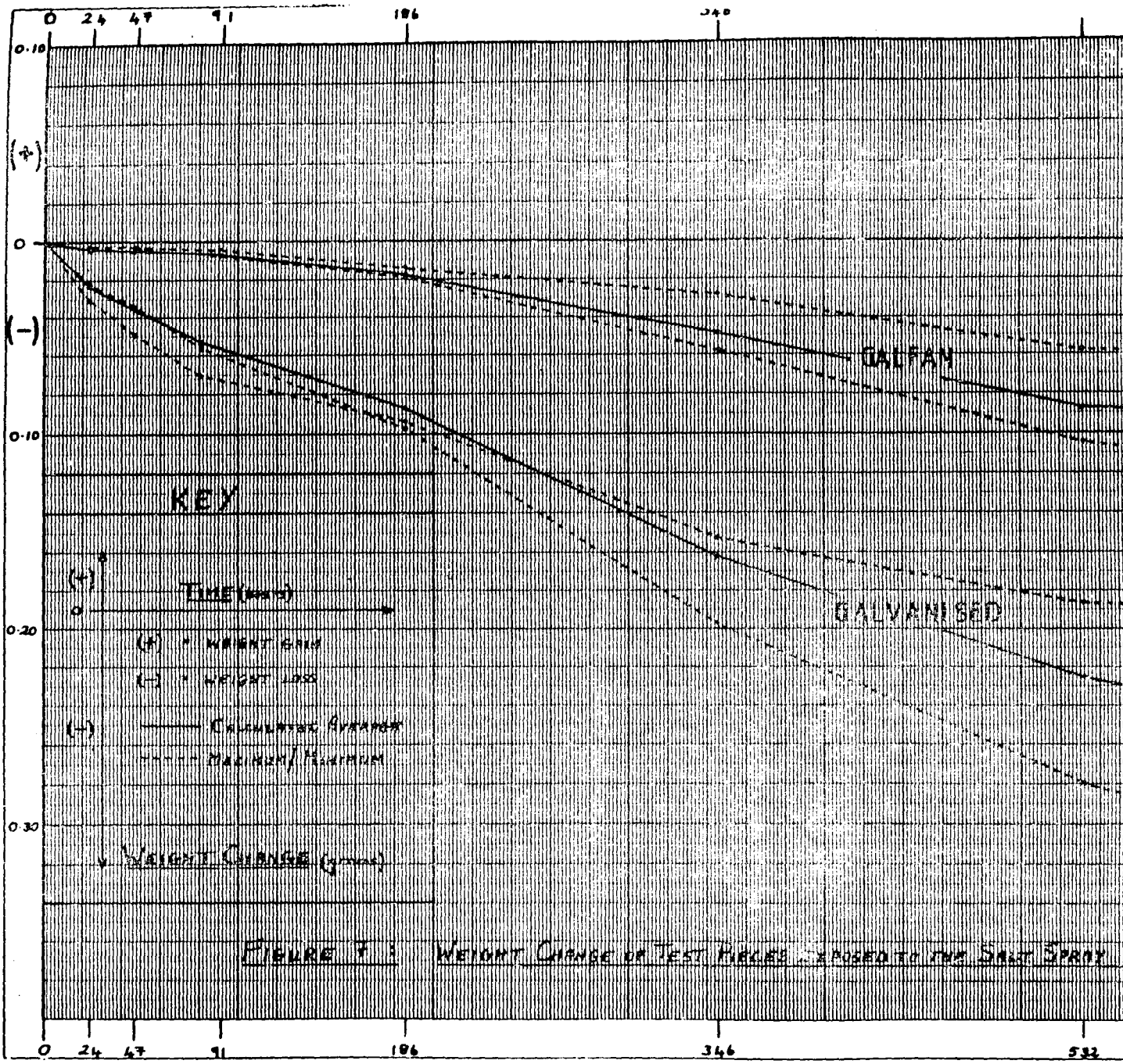


FIGURE 7 : WEIGHT CHANGE OF TEST PANELS EXPOSED TO THE SALT SPRAY

Lab Ref No: MET/86-114

Date: 15.12.86

TABLE 3 Weight Loss of Galvanised Test Pieces in Salt Spray Test

Test Period Hours	Days	Test Pieces 1	2	3	4	5	6	Average
Original weight		14.0120	14.0336	14.0949	13.5175	13.8344	13.4501	13.8238
0	-	0	0	0	0	0	0	0
24	1	0.0219	0.0240	0.0248	0.0120	0.0231	0.0297	0.0226
47	2	0.0338	0.0367	0.0343	0.0167	0.0365	0.0487	0.0345
91	4	0.0563	0.0518	0.0543	0.0250	0.0602	0.0701	0.0530
186	7	0.0966	0.0929	0.0862	0.0560	0.0965	0.0932	0.0869
346	14	0.1971	0.1646	0.1626	0.1120	0.1822	0.1524	0.1618
532	21	0.2804	0.2406	0.2256	0.1649	0.2518	0.1857	0.2248
696	28	0.3177	0.2854	0.2624	0.2008	0.3039	0.1903	0.2600

(all values given in grams)

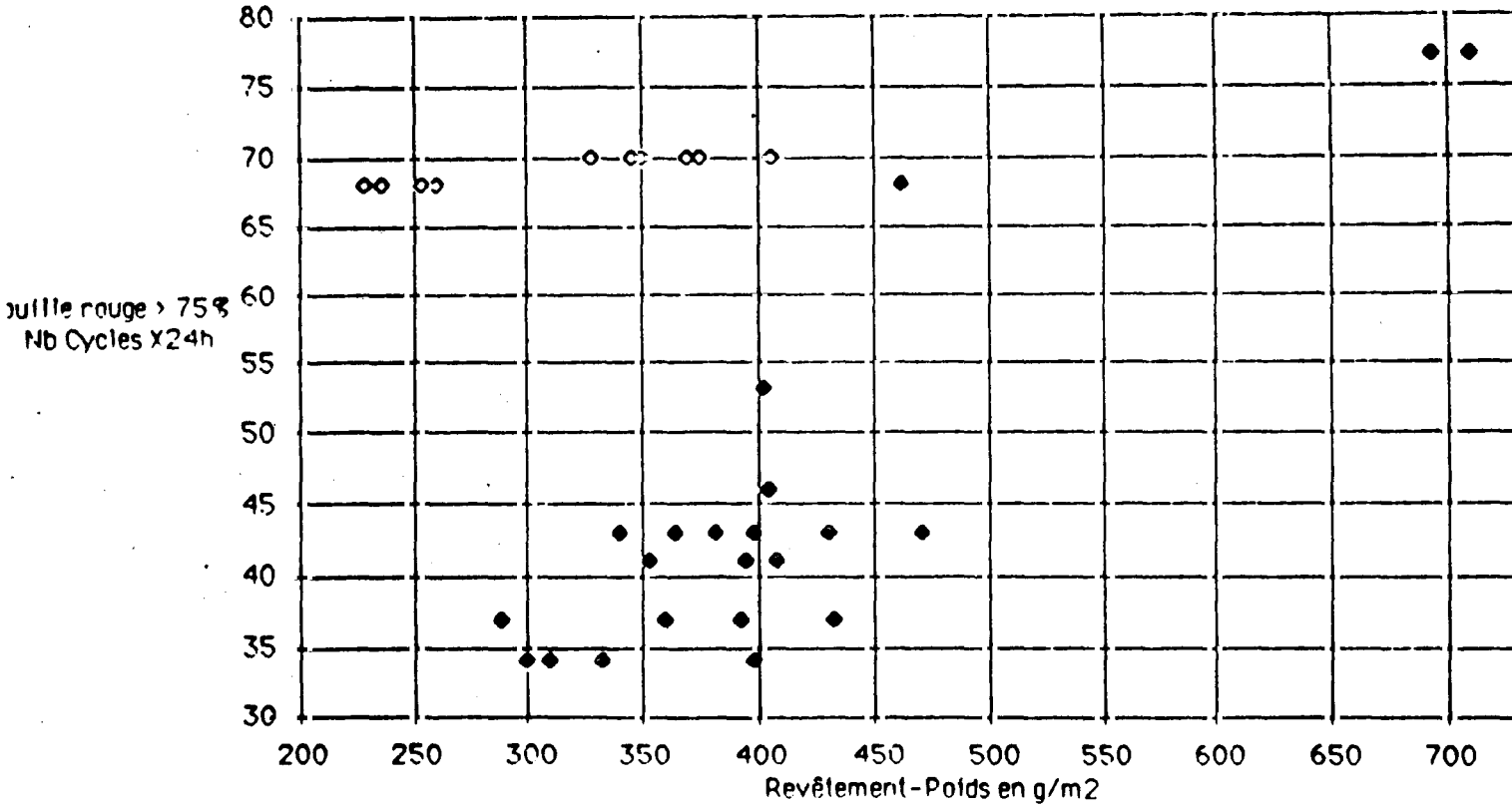
TABLE 4 Weight Loss of Galfan Test Pieces in Salt Spray Test

Test Period Hours	Days	Test Pieces 1	2	3	4	5	6	Average
Original weight		13.5141	13.1249	13.3569	13.1320	13.3022	13.5553	13.3311
0	-	0	0	0	0	0	0	0
24	1	0.0023	0.0049	0.0045	0.0029	0.0041	0.0032	0.0036
47	2	0.0028	0.0059	0.0062	0.0039	0.0048	0.0026	0.0044
91	4	0.0048	0.0078	0.0092	0.0053	0.0066	0.0053	0.0065
186	7	0.0142	0.0224	0.0246	0.0152	0.0175	0.0158	0.0183
346	14	0.0277	0.0579	0.0609	0.0480	0.0582	0.0458	0.0488
532	21	0.0580	0.1128	0.0926	0.0755	0.1042	0.0793	0.0871
696	28	0.0592	0.1186	0.0921	0.0838	0.1261	0.0850	0.0941

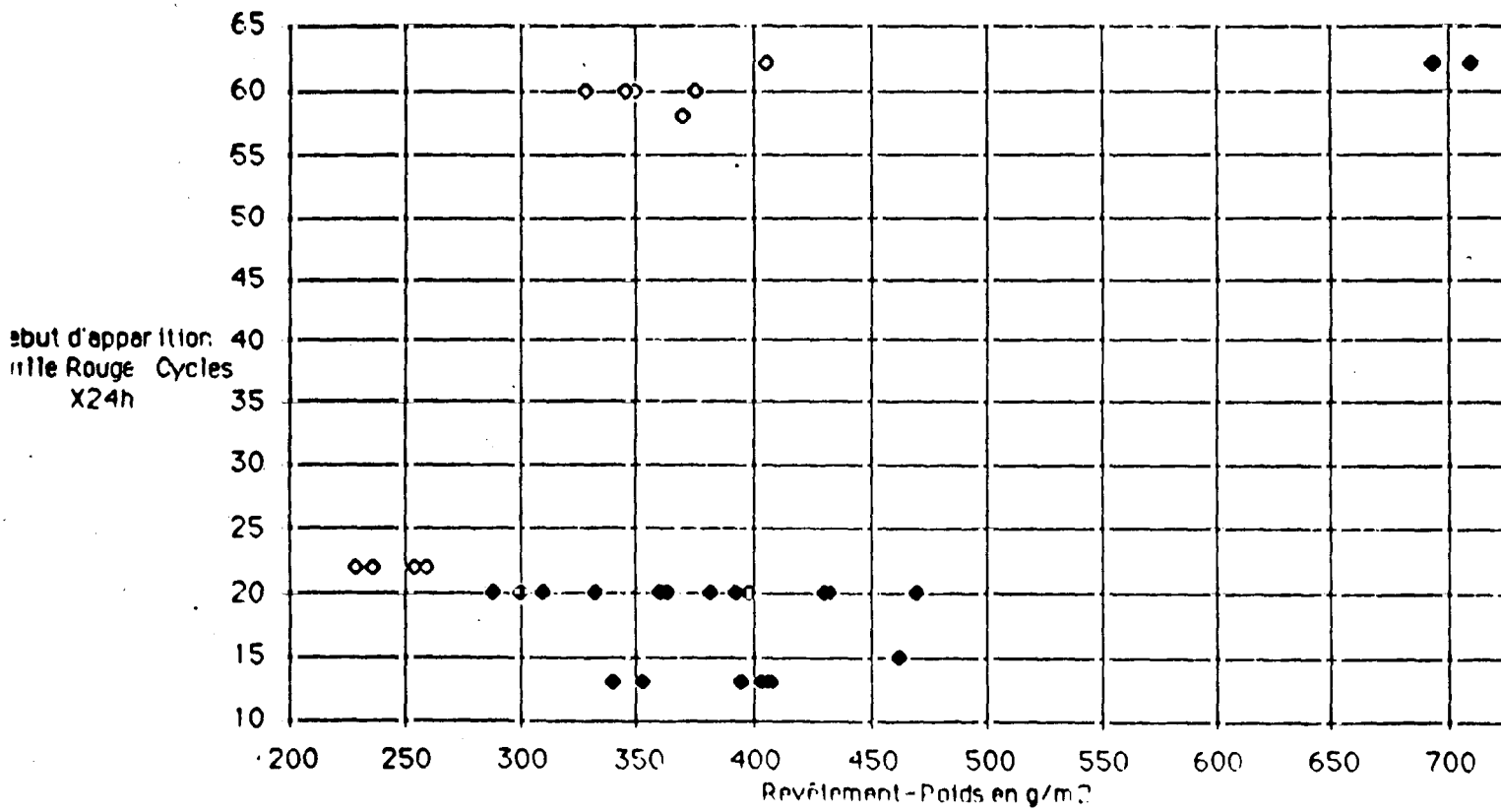
(all values given in grams)

Wimpey Laboratories Limited,
Beaconsfield Road, Hayes,
Middlesex UB4 0LS
Telephone: 01-573 7744
Telex: 935797

ESSAI DE CORROSION Brouillard Salin NFX 41002



ESSAI DE CORROSION Brouillard Salin NFX 41002



PROCOAT - Reims, 18 January 1988

TELEX

Liege, September 21, 1987

TO THE ATTENTION OF MR. J. BRUGAROLAS

I SEND TO YOU THE RESULTS OF THE REFLECTANCE MEASUREMENTS AFTER ATMOSPHERIC EXPOSURE (URBAN SITE - LIEGE INDUSTRIAL).

SUBSTRATE: HOESCH GALFAN - MINIMUM SPANGLE, SKIN-PASSED, NO CHROMATE, NO OIL

MEASURES OF RESIDUAL REFLECTANCE COMPARED TO INITIAL STATE:

EXPOSURE DURATION MONTHS	BRUGAL T 3 MG	WITHOUT POST-TREATMENT
2	90	61
4	87	55
6	87	53
8	86	
10	86	
12	85	
14	84	

SALUTATIONS,

BRUNO RENAUX
CRM

THE GALFAN WIRE MARKETS 18.1.88.

Gentleman,

Before we discuss the market place for Galfan wire let us firstly review the reasons why we should be producing a wire offering greater corrosion resistance and thus longer life. Exactly who is wanting such a product, or are we producing a Galfan wire purely for our own interests.

The best way to answer this question is to take as an example one market place - fishing ropes. Historically hemp ropes were used by the fisherman however with the introduction of steel wire ropes greater strength was available and longer life due to the increased resistance to abrasion but as it is well know steel rusts, so zinc was introduced as a corrosion resistance. The fisherman then demanded greater corrosion resistance, the easiest and most convenient method to offer the demanded corrosion resistance was to increase the coat weights of zinc. This however presented the rope manufacturers with problems of excessive zinc flaking. It also presents problems to the wire manufacturers to acheive the higher coat weights. GALFAN wire meets and fully satisfys all parties, the fisherman and the rope manufacturers and the wire manufacturers.

If we accept therefore the demands for a corrosion resistant wire comes from the end users i.e., our customers and not purely as a manufacturing convenience then we can start to find our market. It is the easiest route to take to replace the existing "traditional galvanised wire" market and not seek new markets. However as a demand already exists for a corrosion resistant product we must study that market first. Naturally we must also take into consideration the type or nature of the corrosion. One example of this has already been mentioned i.e., the

marine environment, an atmosphere heavily ladened with salts. Other corrosion elements such as humidity, the corrosive gases found in mines like wise the corrosive chemicals found.

So where are the markets, how do we best approach the markets and how do we offer Galfan as the answer to our customers prayers. Even when approaching the markets we must first establish exactly what we are going to offer.

MARKETS

1. ROPES We have already mentioned fishing. This is a market with great potential for a number of reasons. It has now been well established the advantages of using Galfan wire in fishing ropes and the increased corrosion resistance achieved. W.R.I. in Canada have carried out long term trials obtaining excellent results. In the U.K. long term trials have also been carried out with the same excellent results by John Shaws in S. Wales.

   The rope market place is a very competitive market so offering a Galfan rope, you have an advantage over your competitors thus it is possible to obtain the extra premium in price needed. However the market must be made fully aware of the advantages of GALFAN. Selective advertising will I am sure make this close built market well aware of the advantages.

   Another market for ropes must be for mining ropes or any down hole application. British Coal (formually N.C.B) like so many other coal

and mineral mining companies has always objected and refused to accept aluminium down a mine, however following recent testing by the German coal industry it is now generally agreed and accepted that alloys with up to a maximum of 12% aluminium is acceptable, GALFAN therefore is acceptable. For down hole applications Vector Cables USA are currently studying the total advantages of GALFAN.

The rope manufacturers in the U.K. in general now fully accept the advantages of Galfan wire however due to the very conservictive attitude of th British manufacturers they would rather take a "wait and see" attitude. This situation is slowly changing however as specifiers are now stating Galfan.

2. AGRICULTURE

In 1984 our company sold the first Galfan wire to be used in the Agricultural fencing market. Fical although a high carbon wire manufacture were pursuaded to produce low carbon/mild steel Galfan wire. This was purchased by Estate Wire in Sheffield U.K.

Estate manufacture stock fencing and barbed wire and succeeded in the latter part of 1984 and through 1985 is introducing Galfan fencing onto the U.K. market. Tinsley Wire, a company partly owned by Bekaert, and the largest manufacture of galvanised m/s wire in the U.K. issued a letter to 92 stocklist condeming GALFAN. Although after a legal battle Tinsley issued a corrective statement the damage had been done. Estate have managed to retain that part of the market converted on to Galfan there is a no growth situation. This no growth situation is not as result of the lack of potential growth but purely due to the actions of Tinsley who during the legal battle were supported by Bekaert.

In the agriculture field other companies have had success similar to the early development of Estate. Arbed's success in the vine yard market in the southern European companies is well know. In the States, Galfan is enjoying a similar success with H. Robinson and Cyclone fencing at present all Galfan wires used in the USA are off European manufacture.

3. STRAND and STAYS

Although the agricultural market purely by volume is the market with the largest potential a new "replacement" market is currently emerging in Europe. Twenty to twenty five years ago a major development in television took place in so much that where as most countries had only one or two television stations a whole new situation came about with new stations being launched, with regional television stations. All these television stations needed new transmittors and therefore mast stays. British Ropes gained the order for the Denmark T.V. 2 stays a total of 420 tonnes of Galfan wire. B.R. since T.V. 2 have obtained two other masts stay orders although much smaller than T.V. 2. This wire was supplied by FICAL.

Current enquiries are for the Middle East and of great potential in Canada.

On strand an area of great potential is ACSR however some inroads have been made by Aluminium wire due to its current carring features. In the U.K. the Central Electricity Generating Board are currently studying Galfan wire as the centre strand strength member. Much interest is also been shown in Brazil to cope with the humidity factors.

4. AUTOMOTIVE

The automotive market offers several areas of potential for Galfan. It is well recorded the development for Galfan sheet but for wire due to the volume less has been reported. Areas of interest can fall into two categories 1. springs and 2. cables.

The springs such as "head lamp" retention springs or wind screen wiper springs are a natural application of Galfan wire and there is certainly a potential demand for wind screen wiper arms to be made up from Galfan. Our company currently has an enquiry for Galfan wire for his specific application. It is our opinion the area within the auto market with the greatest potential must be the "cable" application. Hand brakes both cable and casing, clutch cable and casing, accelorator cable and casing. Bonnet release cable, and inner door cables and rods, door release and window cables.

Some two years ago FORD had a problem with the hand brake on the Sierra model 4 WD. Whereas due to the exhaust system been placed nearer the hand brake mechanism the heat from the exhaust created a humidity situation between the cable and the casing thus causing sweating of the cable, white rust and the eventual failure of the breaking system. Galfan wire was proposed tested and approved. Ford were most pleased until the price was proposed. At that time a premium of 40% was added to galvanised prices thus killing the potential of the application of Galfan wire. Ford eventually resolved their problem by welding a heat shield between the exhaust and the brake cable.

This must therefore prove the point that a realistic premium must be applied and not a policy of greed. From our studies 18-20% is an acceptable addition for Galfan for which all markets would be more prepared to pay.

5. CONSTRUCTION INDUSTRY

The Galfan sheet producer Hoesch have had some success in th construction industry and therefore the way is opened slightly in acceptability of the product for wire manufacturing. Applications suited to Galfan wire would be U-bolts or retention bolts for the Galfan sheet however further studies need to take place concerning Galfan in a wet mortor situation.

6. OTHERS

There are many other potential markets for Galfan wire both in high carbon and mild steel conditions. Other examples, such as a requirement for long shelf life of product is in pop rivets. By tradition the wire stem in pop rivet has been a phosphate coated wire however due to the cost of process and the limited shelf life the industry is now looking at galvanised wire but again dictated by the manufacturing process a very low coat weight is required but a high corrosion resistance is needed of the product, Galfan wire is currently been tested and fully investigated.

Another area of great potential for Galfan mild steel wire must be for cable armouring wire. In the U.K. the electricity cable manufacturers have always insisted in a high coat weight of zinc on the wire BS 443 for e.g., 1.60 mm dia 230 g/mm2 or 0.90 mm at 150 g/mm2

Theee fairly heavy coat weights do present manufacturing problems to the wire producers however as corrosion resistance is of paramount importance to the cable armouring industry Galfan wire could very well be substituded and at lower coat weights offer the same if not better corrosion resistance.

As I hope I have demonstrated a very good market potential exists for Galfan wire considerable research has been carried out in the market place.

It is now up to you as manufacturer to establish the ground rules on selling policy of the Galfan wire product. All customers ask for is three factors to be met, quality, delivery and price.

Again if possible we as Galfan producers must agree on all there three points so as not to kill or disrupt the development of Galfan wire.

QUALITY We must agree amongst ourselves and our associate companies on the advantages of Galfan. We must agree on the quality aspect in so much a coat weights are uniform amongst all manufacturers ILZRO have already set the programme in so much we now have an ASTM standard DIN, NF, BS spec's must be agreed or ISO approval.

DELIVERIES The market is poised to take on Galfan wire, amongst the Galfan wire producers an CRM we have full knowlege of the process, its problems and more important the answers to these problems. It is our opinion that at present all the producers are running at different speeds in the manufacturing development. If we take one example of this situation Ford Motor Co., will not give specification of Galfan wire to its supplies when there is only one manufacture able to produce the particular wire requirement. This situation in now holding back the development and usage of Galfan wire.

JOE HOGAN 18.1.88.
BRAILSFORD WIRE SUPPLY LTD.