

INTERNATIONAL LEAD ZINC RESEARCH ORGANIZATION, INC.



GALFAN TECHNICAL RESOURCE CENTRE

POST OFFICE BOX 12036
RESEARCH TRIANGLE PARK, N.C. 27709-2036
TELEPHONE 361-4647 (AREA CODE 919)
TELEX: 261533
FACSIMILE: (919) 361-1957

MEMORANDUM

TO: Galfan® Wire Licensees
Galfan Alloy Licensees
All Licensee Meeting Attendees

FROM: Alan M. Stoneman, Director *AMS*

DATE: 17 July 1996

SUBJ: Proceedings of the Galfan Wire Licensee Meeting

Enclosed are the Proceedings of the Galfan Wire Licensee Meeting held at the Novotel Hotel in Dusseldorf on April 17, 1996.

If you have any questions regarding the proceedings, I would be glad to speak with you.

AMS/ja

Encl.



GALFAN[®]
IMPROVED GALVANIZING

***20th* GALFAN
WIRE LICENSEE MEETING
PROCEEDINGS**

**Novotel Hotel, Dusseldorf, Germany
April 17, 1996**

Sponsored by
**International Lead Zinc Research Organization, Inc.
Galfan Technology Centre
Research Triangle Park, NC USA**



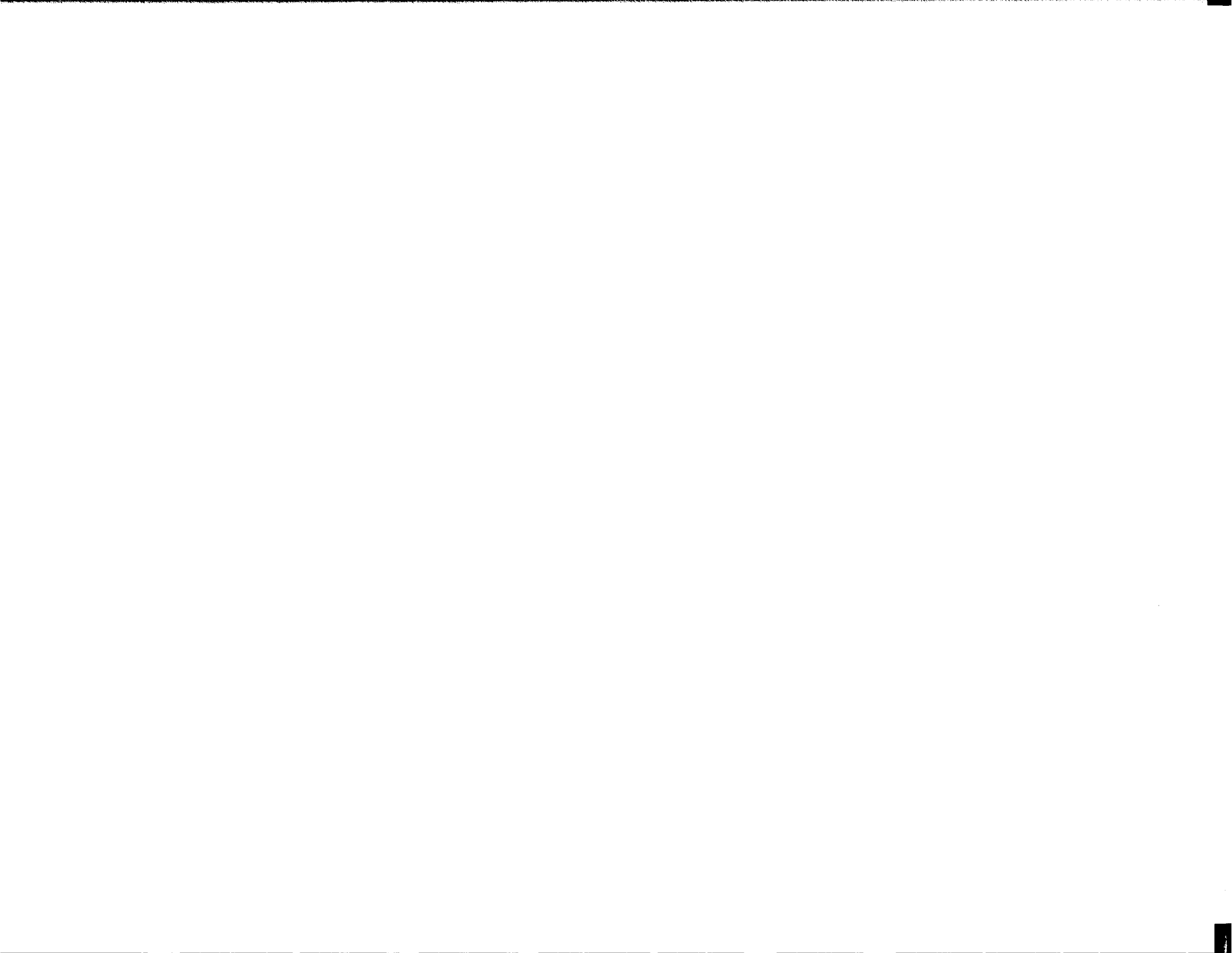
**20th GALFAN
WIRE LICENSEE MEETING PROCEEDINGS**

Novotel Hotel, Dusseldorf, Germany

April 17, 1996

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WIRE LICENSEE MEETING

Novotel Hotel, Dusseldorf, Germany

April 17, 1996

LISTING OF ATTENDEES

Name	Company
Aamot, H.	Aamot GalvaChem
Beguín, Philippe	Union Miniere
Cellone, Fausto	Officine Maccaferri SpA
Davis, William A.	Florida Wire & Cable, Inc.
Dewilde, Hubert	N.V. Bekaert, S.A.
Dewitte, Marc	N.V. Bekaert
Drake, Stephen	Tinsley Wire (Sheffield) Ltd.
Havrda, Mirek	HoMa Prague
Hogan, Joe	GTC Europe
Hostetler, John	GTC ILZRO
Kmatkowski, Lech	GTC/Institute of Precision Mechanics, Poland
Kwiecien, Jerzy	GTC/Institute of Precision Mechanics, Poland
Lapostolle, Bertrand	Trefil EUROPE
Matsumoto, Shizuo	Kawasaki Steel Techno-Wire
Metzler, Stefano	Officine Maccaferri SpA
Nunninghoff, Rolf	Univ. Wuppertal/Trefil ARBED
Pankert, Roger	Union Miniere
Payne, Derek	Bridon
Proctor, Dale	Florida Wire & Cable, Inc.
Proskurkin, Engeue	State Tube Institute (Ukraine)
Warwick, Heath	Smorgon Wire

The status of Galfan wire and GTC

*A report to the Galfan wire licensees
at the 20th wire licensee meeting*

Hotel Novotel Dusseldorf-Ratingen, Dusseldorf, Germany

Apr. 17, 1996

by John L. Hostetler

Of the dozen or more zinc-aluminum coatings introduced in the last 25 years, only two have significantly influenced the industry.

Galvalume[®], introduced in the early 1970s, and Galfan[®], introduced in 1982, are very different from each other but because they are the only survivors, they are often *perceived* as similar.

The original search for Galfan was motivated by the threat of losing zinc sales to Galvalume[®]. Increased zinc sales is still the objective but to be effective today, our strategies and tactics have to be different from those of the early years. The threat from Galvalume was real then and, in most areas, it is even more so today.

Whereas Galvalume was developed to provide a *cheaper* coating than regular galvanizing, Galfan was developed as an *improved galvanizing*. Galfan, with its 95% zinc, is a *galvanizing alloy*; Galvalume, with its 55% aluminum, is more like *aluminizing*.

We know of no Galvalume-coated wire production, but because Galfan's overall success is to some degree dependent upon its ability to compete with Galvalume in sheet products, those applying Galfan on wire need to know and appreciate the reputation of each.

We find, however, that the new phase will require even more research to prevent loss of zinc sales to Galvalume because Galvalume's aggressive promotional activities try to create the perception that galvanizing is grossly inadequate.

Galvan is important to the zinc industry

ILZRO's functions to target and manage research that leads to increased use and sales of zinc makes it an important part of the zinc industry. The list of current ILZRO-managed projects and its worldwide recognition are signs of its success.

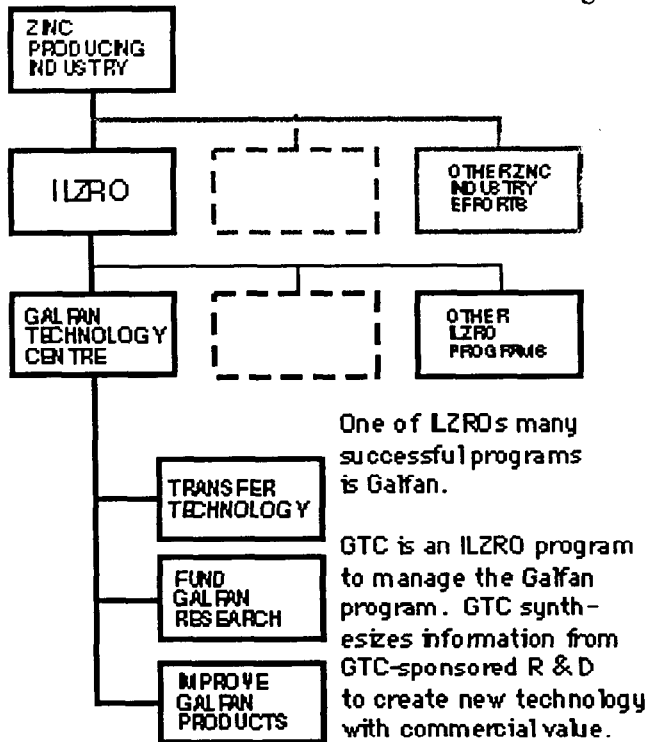


Fig. 3 Diagram showing GTC's role in the zinc industry.

One of ILZRO's major contributions to the zinc industry has been the basic scientific research of the early 1980s that led to the invention and patenting of Galfan alloy.

Galfan-coated wires have performed exceptionally well. By performing better than other coating choices, Galfan will affect the industry and be a positive influence for zinc-based coatings.

Wire licensees use much less alloy than sheet licensees do but their contribution to the common recognition that Galfan is a superior coating should earn them as much support of the zinc industry.

We have optimized the Galfan alloy but end users are raising quality and performance standards. Therefore our focus must shift from a search for basic knowledge to *continuous improvement* of processes and products. We need to exploit to the fullest every possible application that enhances the image or use of Galfan wire.

of the technology. Licensees who buy a GTC unitshare are GTC unitholders. See the current edition of the GTC Business Plan for more details.

The Galfan Sales Representatives and Galfan Technology Transfer Contractors are an important part of the plan because they give GTC the advantage of a field support presence without the burden of a large staff.

1994 Galfan production

Three regions are actively producing significant tonnages of Galfan; Europe, Japan and North America. Japan has been the dominant region but as Figure 5 and Table One show, Europe became the largest Galfan producing region in 1994.

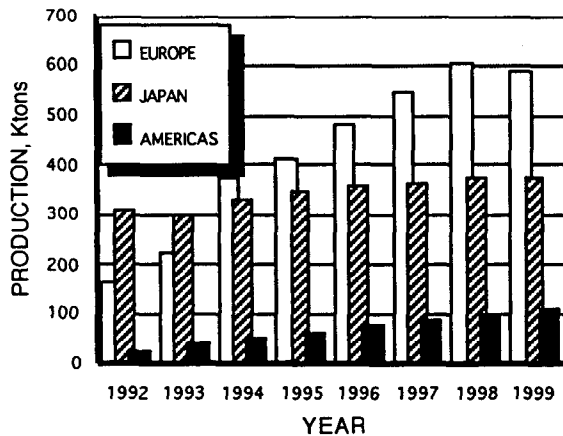


Fig. 5 1992-1999 Galfan production by region. 1992-1994 is historic, 1995-1999 is forecast.

The forecasts predict Europe will continue a rapid rate of growth while Japan remains approximately flat. This may be more the result of differing forecast policies because we know of no reason why the Japanese region will not continue to grow as before.

Forecasts and production data are based on information reported by licensees. We need more complete reporting to build an accurate database.

Although some licensees report production accurately and on time, reports from many are generally only fair with poor forecasting. Complete reporting is a requirement of the license and must be honored in the future. Accurate production and forecast data will be essential to the success of future planning and promotion.

used on all their models world-wide. This requirement alone will use the output of six to nine new high-speed production coating lines.

GTC also expects to introduce automatic batch-dipped Galfan auto parts into Europe. A research effort involving two spin-part Galfan galvanizing licensees is scheduled for completion in 1996.

Four new Galfan sheet licensees and three alloy licensees in Southeast Asia have formed the Southeast Asia Galfan Development Association. GTC expects another sheet licensee in that area plus two in North America this year.

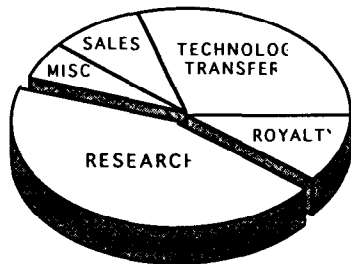


Fig. 6 Proforma distribution of income from new licenses

Income from new licenses is projected to be about \$450,000 by the end of 1996 from which GTC expects to provide funding for about \$200,000 in Galfan research.

Proforma disbursement of the income from new licenses is shown in Figure 6.

Sales are costs directly attributable to the sale of a new license and commissions paid on sales to Galfan License and Technology Sales representatives.

Technology transfer includes (a) initiation fees paid to GTC, (b) payment for the licensee's first year's GTC unitshare, and (c) fees paid to sub-contractors including the Galfan Technology Transfer Contractor.

A *royalty* is paid to ILZRO.

Research is the money that should be available to the Research Committee to spend for GTC-sponsored research and development. Research includes process development and improvement as well as basic scientific research.

Improved communications with GTC

ILZRO is upgrading their communications strategy with special attention to more timely distribution of reports and correspondence. The new strategy will rely strongly on the Internet and e-mail.

E-mail capabilities will go on-line as soon as ILZRO gets sanction for their Web site from Interimic. E-mail will allow us to send correspondence and technical information such as research reports to anyone with an e-mail address. Distribution will be much faster and more cost effective.

Phase 1 of ASTM project completed

GTC sponsored ILZRO project ZCO-5-4 which was to identify all ASTM specifications that affect Galfan-coated products. The work identifies 47 specifications. It also describes the procedures and methods for creating, or changing ASTM specifications.

Phase 2 is proposed as an effort to influence ASTM specifications to recognize the superior corrosion resistance of Galfan as compared to regular galvanizing when specifying thicknesses on wire products.

Need for cooperation amongst licensees

The more mature position dictates and allows for more cooperation amongst the licensees -- between alloy licensees and user licensees and especially between licensees of the same category.

Where there are three or more licensees in a region, such cooperation is best motivated by the formation of regional a Galfan development association. GTC strongly recommends establishment of such organizations and pledges to wholeheartedly support them.

John L. Hostetler 17 Apr., 1996

MAGNETIC PUMPS FOR GALVANIZING BATHS

by E.V. Proskurkin
(Ukraine, Dnepropetrovsk)

for Presentation at
20th Tube Licensees Meeting
April 17, 1996

In the second half of the XX Century, one of the principally new directions of development in metallurgy as a science became the application of magnetic hydrodynamics methods (i.e., methods of science which is studying conformity of interaction of media electrical conductivity with electromagnetic fields).

Using a contactless, practically inertialess, easily-controllable electromagnetic field influence upon fluid metal which is realized with the help of specially designed magnetodynamic (electromagnetic) units (MDU) allows us to introduce cardinal perfections in different technological processes in metallurgy and in other industrial fields where fluid metals are used.

It is of knowledge that different magnetodynamic units (pumps) have been developed for transport and dosage of fluid metals, based on interaction of current, flowing in metal melt with magnetic field of outside. Under attack of generating in fluid metal volumetrical electromagnetic forces, its flow follows the "left hand thumb" rule.

As a result of interaction between the current flowing in metal and the magnet's magnetic field, electromagnetic forces are generated in an active zone and their direction depends upon the sequence of switching on of both magnetic systems of the unit.

Proskurkin Paper (cont'd.)

Thus, in that way, in a magnetodynamic unit (pump), the most perfect heating method is used and also the most modern transport method for fluid metal with assistance of an electromagnetic field is realized.

The electromagnetic method of metal transport allows provision of complete automation of the process.

Metal temperature in the pump depends mainly from voltage consumed by the inductor winding.

Because we have to observe the patent protection rules, we cannot report on the full parameters of the magnetohydrodynamic pump, the technological data nor design details of new module automated installation.

During passing through the magnetohydrodynamic plant's working zone, metal is being intensively attacked by magnetohydrodynamic forces: volumetric forces with changing signs (they can be equal to 10-20 values of gravity) with the frequency of 100Hz (current frequency 50 Hz); after that, metal passes across an area of lower pressure, where gases begin to evolve out and through zones with closed vertical streams. Here centrifugal separation of inclusions and gasses takes place. Because the distribution of electromagnetic forces in a heterogeneous medium depends on retention between specific electrical resistance of its components, all non-electroconducting particles or particles conducting current worse than liquid metal will be forced out of the working zone in a direction opposite to the direction of the electromagnetic forces. This is termed "effect of magnetohydrodynamic" or the "electromagnetic screen." As a result of all these effects, metal which has passed through MDU will become thoroughly refined.

Proskurkin Paper (cont'd.)

We are now using the pilot module installation which has the following technical data:

- Productivity: 20 kg/sec of metal melt
- Power Consumption: 40kW
- Height (lifting metal melt): 1.0m
- Efficiency: 85-95%

With the help of a pump, one can preheat, melt, transport, refine the melt and raise the head of fluid metal. It can be used only for pumping fluid metals, but also for arranging casting plants and plants for applying metal coatings.

Magnetohydrodynamic pumps acting onto working medium without contact electromagnetic forces have many advantages in comparison with any other mechanical means (devices) such as:

- They have no parts which are rotated mechanically and work in contact with fluid metal;*
- They do not need external cooling;*
- The pipeline for melted metal is reliably hermetic;*
- One can continuously gradually (sliding) regulate the pump capacity in wide limits of metal pumping;*
- The characteristics of melted metal flows can be controlled directly by changing volumes of electricity (current, voltage);*

Proskurkin Paper (cont'd.)

- *Pump remote control is possible;*
- *Pump maintenance is simple during its work;*
- *Pump performance is reliable and safe; and*
- *Working sanitary conditions are optimized as well as ecological situations in the working rooms;*

Magnetohydrodynamic pumps allow construction of simple and reliable systems for automated control of technological processes. High economic effects with the use of magnetohydrodynamic pumps of the new type are attained because:

- *Pumping over melted metal — cost reduction;*
- *Lowering of capital investments due to longer kettle life; and*
- *Zinc losses are eliminated during zinc pumping over operation.*

The system of a magnetohydrodynamic pump (as a system “man-machine”) consists of:

- *Controlled item — galvanizing kettle containing melted zinc;*
- *Set of instruments and programming unit, including magnetohydrodynamic system;*
- *Interaction/interface with interchange protocols; and*

• *Dispatcher/operator.*

Such module automated installation opens a new stage in production of wire, tubing or small diameter, reinforcement and other products with coatings.

During experimenting, low carbon rimming steel 2.0 and 2.5 mm dia. wire and electric welded tubes with straight weld seam, 20.0 mm dia., 1.0 and 2.0 mm wall thicknesses were investigated.

Methods of product surface pretreatment included:

OXIDATION — in air at a temperature of $550 \pm 10^{\circ}\text{C}$

REDUCTION — in dried hydrogen (at a temperature of dew point - 50°C) at a temperature of $780 \pm 20^{\circ}\text{C}$.

At this point the products were cooled to the temperature of the zinc or aluzinc melt.

When using this method of surface pretreatment, a part of wire or tube just from the moment of its entering in the zone of reduction and coating application is being fed in a protective gas medium and its surface is free from any oxides.

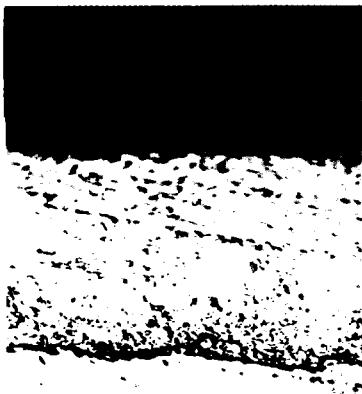
The coatings quality has been evaluated by its continuity, adhesion strength with the substrate and by coating thickness. The coating microstructure and thickness were examined and evaluated with help of metallography.

Experimental checking of the new coating application method (using magnetohydrodynamic pump) for wire and tubes showed that the coatings

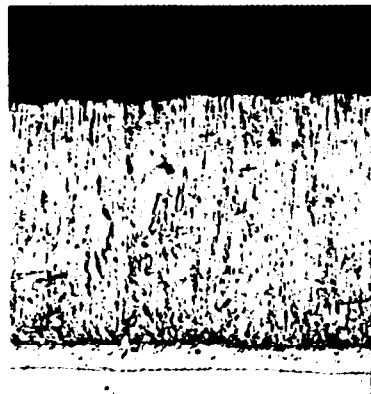
Proskurkin Paper (cont'd.)

produced have 100% continuity, high adhesion strength with the steel base as well as good appearance.

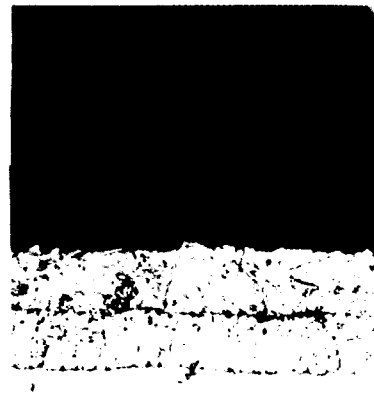
Microphotos of coating structures produced by the new method of application on wire and tubes are shown below.



500X



400X

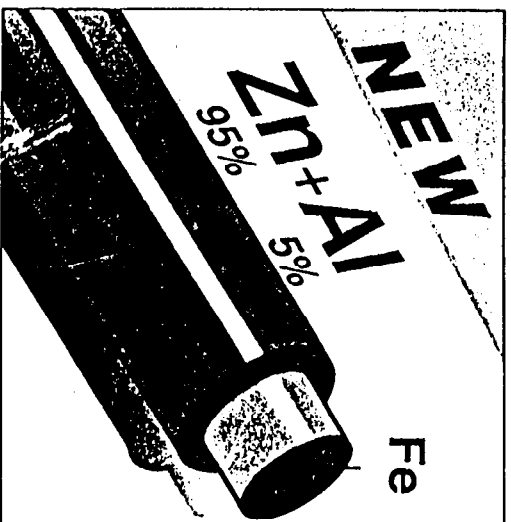


400X

Microstructure of regular galvanized coating on the steel el.welded tube. We can obtain very good deformable coatings, because we are able to eliminate brittle phases forming (e.g. δ -phase)

End

Bezinal®



Better co:rosion protection

Good deformation

Cathodic protection

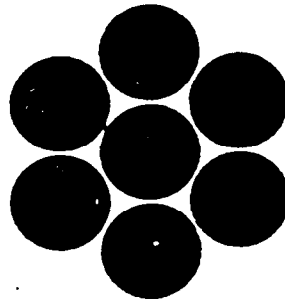
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EVALUATION OF THE CORROSION PROTECTION ON STRAND WIRES

ZINC CLASS A
 CLASS C

BEZINAL CLASS A

7 X 1 STRANDS



1/4 " STRAND DIAMETER \cong 7 X (1 X 2,10 MM)

5/16 " STRAND DIAMETER \cong 7 X (1 X 2,65 MM)

3/8 " STRAND DIAMETER \cong 7 X (1 X 3,15 MM)





CORROSION TEST RESULTS ON STRAND WIRES

- FROM - 1/4" STRANDS
- 5/16" STRANDS
- 3/8" STRANDS


CORROSION TEST PROCEDURES


- SALT SPRAY TEST
 - DIN SS 50021
 - ASTM B 117
- SO₂ TEST (KESTERNICH)
 - DIN 50018 SFW 1,0S

Salt spray test conditions

-  **ASTM B 117 - DIN SS 50021**
-  **Conditions :**
 - 100% Relative Humidity
 - 35° C
 - 5% NaCl (SodiumChloride)
-  **Control every 24 hours**
-  **End of the test at 5% red rust**

Kesternich - SO₂ Sulphurdioxide Test Conditions

 **DIN 50018 SFW 1,0 S (Kesternich)**

 **Conditions : 1 cycle :**

- 8 hours	- 40°C
	- 100% relative humidity
	- 1l SO ₂ addition
- 16 hours	- Room temperature (18-28° C)
	- No SO ₂ addition
	- Max. 75% relative humidity
	- Complete water rinsing of the test room

 **End of the test at 5% Red Rust**

TEST RESULTS

- ASTM COATING WEIGHT SPECIFICATION FOR CLASS A AND CLASS C.
- INITIAL COATING WEIGHT ON THE STRAND WIRE.
- OVERALL TEST RESULTS :
 - I) HOURS TO FIRST RUST IN SALT SPRAY TEST
RESIDUAL COATING AT FIRST RUST IN SALT SPRAY TEST
 - II HOURS TO 5% RED RUST IN SALT SPRAY TEST
CYCLES TO 5% RED RUST IN SO₂ TEST.
- INDIVIDUAL FOLLOW-UP OF THE CORROSION TESTS + CURVES

ZINC COATED (GALVANIZED) AND GALFAN COATED WIRE

Minimum Weight of Coating Per Unit Area of Wire Surface

Wire Diameter in (mm)	Class 1 Coating oz/ft ² (g/m ²)	Class 3 or (A) Coating oz/ft ² (g/m ²)	Class B Coating oz/ft ² (g/m ²)	Class (C) Coating oz/ft ² (g/m ²)
0.035 (0.89)	0.15 (45.7)	0.45 (137)	0.90 (274)	1.35 (412)
0.041 (1.04)	0.15 (45.7)	0.50 (153)	1.00 (305)	1.50 (458)
0.048 (1.22)	0.15 (45.7)	0.55 (168)	1.10 (336)	1.65 (503)
0.054 (1.37)	0.20 (61.0)	0.60 (183)	1.20 (366)	1.80 (549)
0.062 (1.57)	0.20 (61.0)	0.65 (198)	1.30 (396)	1.95 (595)
0.072 (1.83)	0.20 (61.0)	0.65 (198)	1.30 (396)	1.95 (595)
0.076 (1.93)	0.25 (76.3)	0.70 (214)	1.40 (437)	2.10 (610)
0.080 (2.03)	0.25 (76.3)	0.70 (214)	1.40 (437)	2.10 (610)
0.092 (2.34)	0.28 (85.4)	0.75 (229)	1.50 (458)	2.25 (686)
0.099 (2.51)	0.28 (85.4)	0.80 (244)	1.60 (488)	2.40 (732)
0.106 (2.64)	0.30 (91.5)	0.80 (244)	1.60 (488)	2.40 (732)
0.120 (3.05)	0.30 (91.5)	0.85 (259)	1.70 (518)	2.55 (778)
0.135 (3.43)	0.30 (91.5)	0.85 (259)	1.70 (518)	2.55 (778)
0.148 (3.76)	0.35 (106)	0.90 (274)	1.80 (549)	2.70 (824)
0.162 (4.11)	0.35 (106)	0.90 (274)	1.80 (549)	2.70 (824)
0.177 (4.50)	0.44 (134)	0.90 (274)	1.80 (549)	2.70 (824)
0.192 (4.88)	0.50 (153)	1.00 (305)	2.00 (610)	3.00 (915)
0.207 and larger (5.26)	0.53 (162)	1.00 (305)	2.00 (610)	3.00 (915)

*Diameters, other than those shown above, are produced with a coating equivalent to those of the next smaller size.

INITIAL COATING WEIGHT g/m²

	ZINC		BEZINAL
	* CLASS A	* CLASS C	* CLASS A
Wires of 1/4" strand	405	665	240
Wires of 5/16" strand	261	905	310
Wires of 3/8" strand	302	907	356

SALT SPRAY TEST ON WIRES

HOURS TO FIRST RED RUST

	ZINC		BEZINAL
	* CLASS A	* CLASS C	* CLASS A
Wires of 1/4" strand	192	864	1008
Wires of 5/16" strand	96	96	1320
Wires of 3/8" strand	96	504	2208

RESIDUAL COATING g/m²

AT FIRST RED RUST

	ZINC		BEZINAL
	* CLASS A	* CLASS C	* CLASS A
Wires of 1/4" strand	206	95	35
Wires of 5/16" strand	209	682	24
Wires of 3/8" strand	125	465	21

* According to ASTM A 641 M

SALT SPRAY TEST ON WIRES**HOURS TO 5% RED RUST**

	ZINC		BEZINAL
	* CLASS A	* CLASS C	* CLASS A
Wires of 1/4" strand	864	1272	1824
Wires of 5/16" strand	768	1704	2352
Wires of 3/8" strand	960	2040	2472

SO₂ TEST ON STRAND WIRES**CYCLES TO 5 % RED RUST**

	ZINC		BEZINAL
	* CLASS A	* CLASS C	* CLASS A
Wires of 1/4" strand	34	56	53
Wires of 5/16" strand	18	74	68
Wires of 3/8" strand	29	77	78

* According to ASTM A 641 M

WIRE FROM CORD 1 x 7
CLASS C ZINC diam: 1/4"

SALT SPRAY

SO2

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION	CYCLE	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	597	452	145	NO RUST	4	603	454	149	NO RUST
192	671	423	248	NO RUST	8	678	448	230	NO RUST
360	680	317	363	NO RUST	15	630	358	272	NO RUST
504	665	267	398	NO RUST	25	667	291	376	NO RUST
864	727	95	632	points DBR	40	668	146	522	NO RUST
1152	626	27	599	places DBR	50	641	12	629	places LBR
1272	690	2	688	DBR (5%)	56	723	5	718	DBR (5%)

WIRE FROM CORD 1 x 7
CLASS A ZINC diam: 1/4"

SALT SPRAY

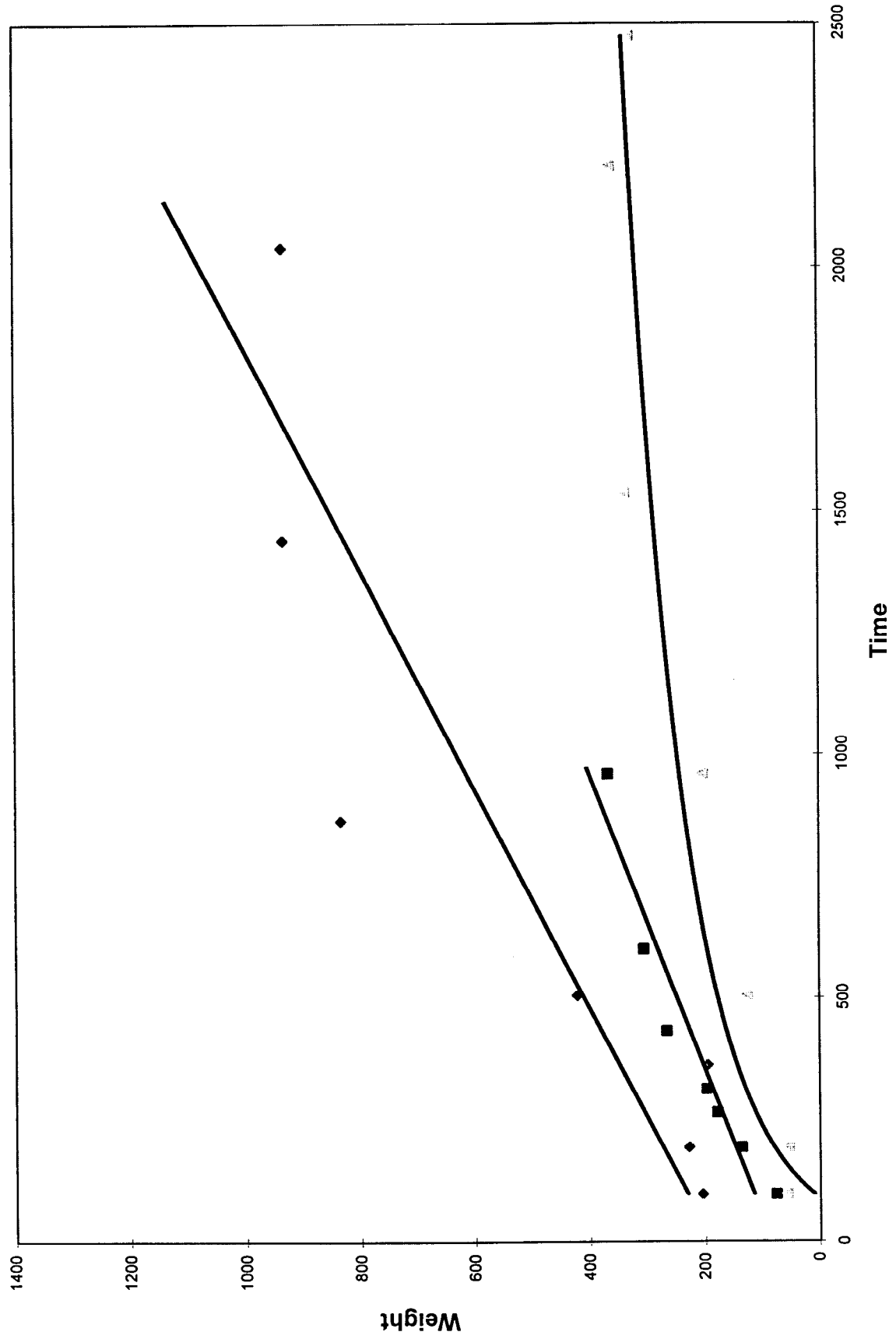
SO2

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION	CYCLE	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	325	237	88	NO RUST	4	416	353	63	NO RUST
192	395	206	189	points LBR	8	483	370	113	NO RUST
264	453	185	268	places LBR	12	322	130	192	points LBR
336	286	33	253	points DBR	15	279	55	224	points LBR
432	353	11	342	place DBR	21	331	24	307	place DBR
768	511	6	505	places DBR	32	514	44	470	places DBR
864	513	10	503	DBR (5%)	34	497	11	486	DBR (5%)

WIRE FROM CORD 1 x 7
BEZINAL diam: 1/4"

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	VALUATION	CYCLE	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	VALUATION
96	254	221	33	NO RUST	4	253	183	70	NO RUST
192	241	188	53	NO RUST	8	204	119	85	NO RUST
432	209	122	87	NO RUST	15	255	142	113	NO RUST
648	257	102	155	NO RUST	21	213	62	151	points LBR
1008	212	35	177	points DBR	36	256	63	193	points LBR
1272	242	18	224	places DBR	45	254	21	233	places DBR
1824	242	15	227	DBR (5%)	53	272	17	255	DBR (5%)

Wire from 1 X 7 Diameter 1/4"



Czinc
 Azinc
 Bezinal
 Linear (Czinc)
 Linear (Azinc)
 Log. (Bezinal)

WIRE FROM CORD 1 x 7
CLASS C ZINC diam: 5/16"

SALT SPRAY

SO2

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION	CYCLE	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	855	682	173	point. LBR	4	926	729	197	NO RUST
192	841	650	191	points LBR	8	955	730	225	NO RUST
360	956	674	282	points LBR	15	879	609	270	NO RUST
504	941	453	488	places LBR	32	906	438	468	NO RUST
864	882	209	673	places LBR	56	828	126	702	NO RUST
1368	912	31	881	points DBR	68	850	7	843	places LBR
1704	951	2	949	DBR (5%)	74	944	6	938	DBR (5%)

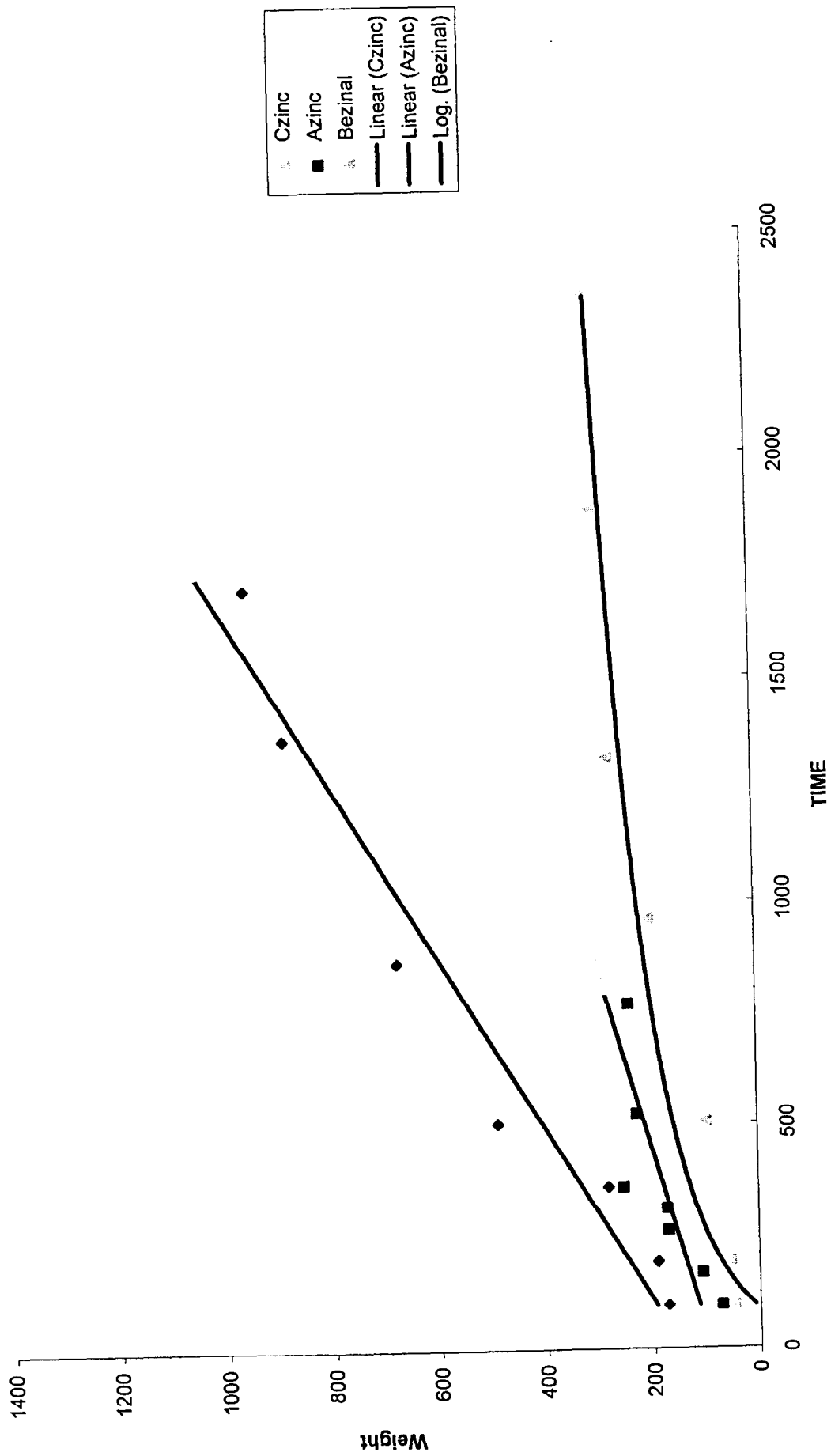
WIRE FROM CORD 1 x 7
CLASS A ZINC diam: 5/16"

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION	CYCLE	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	281	209	72	points LBR	4	235	173	62	NO RUST
168	294	186	108	places LBR	8	266	143	123	NO RUST
264	247	77	170	places LBR	12	267	88	179	points LBR
312	214	42	172	places LBR	14	251	51	200	places LBR
360	304	50	254	points DBR	17	273	22	251	places DBR
552	244	18	226	place DBR	18	259	22	237	places DBR
768	246	7	239	DBR (5%)	21	241	6	235	DBR (5%)

WIRE FROM CORD 1 x 7
BEZINAL diam: 5/16"

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION	CYCLE	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	312	262	50	NO RUST	4	292	224	68	NO RUST
192	306	250	56	NO RUST	8	317	224	93	NO RUST
504	289	192	97	NO RUST	21	294	156	138	NO RUST
960	329	129	200	NO RUST	36	334	127	207	NO RUST
1320	296	24	272	points LBR	56	292	44	248	NO RUST
1872	316	20	296	points DBR	64	326	33	293	points DBR
2352	323	17	306	DBR (5%)	84	326	28	298	DBR (5%)

Wire from cord 1x7 Diameter 5/16"



WIRE FROM CORD 1 x 7
CLASS C ZINC diam: 3/8"

SALT SPRAY

SO2

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUTIO	CYCLI	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	861	656	205	NO RUST	4	891	671	220	NO RUST
192	934	706	228	NO RUST	8	950	752	198	NO RUST
360	907	712	195	NO RUST	15	936	627	309	NO RUST
504	886	465	421	points LBR	32	874	313	561	NO RUST
864	947	347	600	places LBR	56	910	179	731	NO RUST
1440	875	41	834	points DBR	69	873	62	811	places LBR
2040	937	3	934	DBR (5%)	77	940	6	934	DBR (5%)

WIRE FROM CORD 1 x 7
CLASS A ZINC diam: 3/8"

SALT SPRAY

SO2

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUTIO	CYCLI	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	201	125	76	points LBR	4	222	157	65	NO RUST
192	368	232	136	places LBR	8	310	190	120	places LBR
264	278	100	178	places LBR	12	283	94	189	places LBR
312	226	30	196	points DBR	14	215	30	185	points DBR
432	317	51	266	places DBR	18	265	20	245	places DBR
600	329	24	305	places DBR	23	321	12	309	places DBR
960	393	26	367	DBR (5%)	29	411	23	388	DBR (5%)

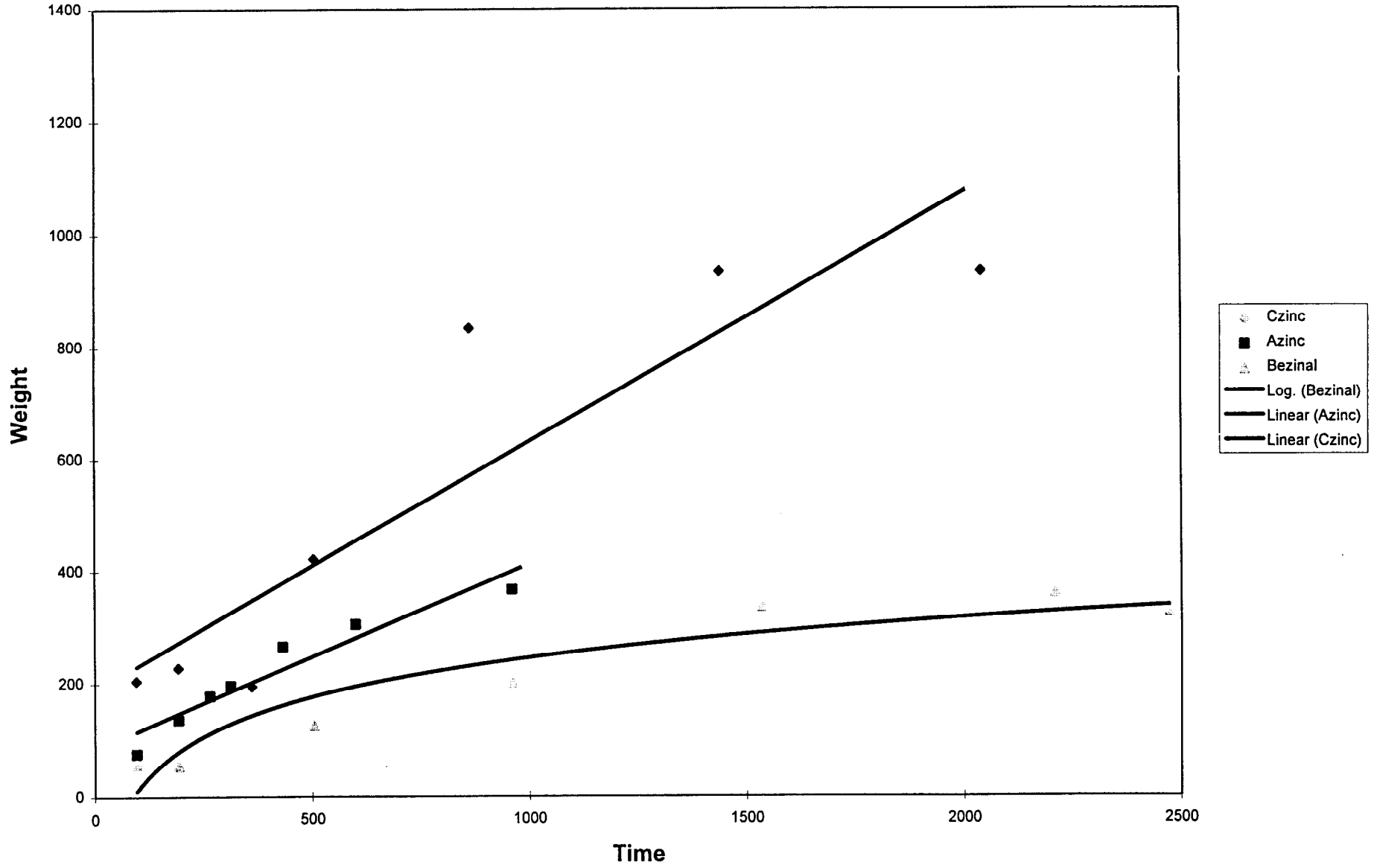
WIRE FROM CORD 1 x 7
BEZINAL diam: 3/8"

SALT SPRAY

SO2

HOURS	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUTIO	CYCLI	COATING WEIGHT BEFORE	COATING WEIGHT AFTER	COATING WEIGHT DIFFERENCE	EVALUATION
96	358	300	58	NO RUST	4	371	288	83	NO RUST
192	347	292	55	NO RUST	8	349	243	106	NO RUST
504	338	212	126	NO RUST	21	335	193	142	NO RUST
960	361	159	202	NO RUST	36	358	171	187	NO RUST
1536	368	32	336	NO RUST	56	301	41	260	points LBR
2208	381	21	360	points DBR	71	373	95	278	places LBR

Wire from 1 X 7 Diameter 3/8"



CONCLUSIONS

**1. BEZINAL (CLASS A) CAN COMPETE
WITH ZINC CLASS C**

**2. ESPECIALLY ON WIRES, THE ZINC-ALUMINIUM
COATING AT THE EUTECTIC COMPOSITION**

95 % ZINC - 5 % ALUMINIUM

IS THE BEST OF TWO WORLDS.

- THE ACTIVATION OF ZINC.

- THE PASSIVATION OF ALUMINIUM.

**3. THE RUST FORMATION OF THE STEEL
SUBSTRATE IS POSTPONED DUE TO THE
EFFICIENT CORROSION BARRIER OF THE IRON-
ALUMINIUM INTERFACE.**

**COMPARISON OF THE CORROSION
PROTECTION BETWEEN GALVANIZED
AND BEZINAL[®] COATED FISHING ROPES**

2 1/2 YEARS IMMERSION AND EMERSION
IN SEA WATER.

FROM 26/01/93 TO 20/07/95

SALT SPRAY TEST RESULTS ON THAT FISHING ROPE STRANDS

CONSTRUCTION OF THE FISHING ROPES :

Zinc : 6 x (1 + 6 x 1,5 mm) galvanized.
Bezinal : 6 x (1 + 6 x 1,4 mm) Bezinal coated.

I REDRAWN GALVANIZED WIRES	REDRAWN BEZINAL COATED WIRES.
132-147 g/m ²	130 g/m ²

Hours : 216
to 5 % red rust

1272

II REDRAWN GALVANIZED WIRES	REDRAWN BEZINAL COATED WIRES
157 g/m ²	150 g/m ²

Hours : 456
to 5 % red rust

1248
stopped : not yet 5%
red rust

Periodic Sea Water Immersion test

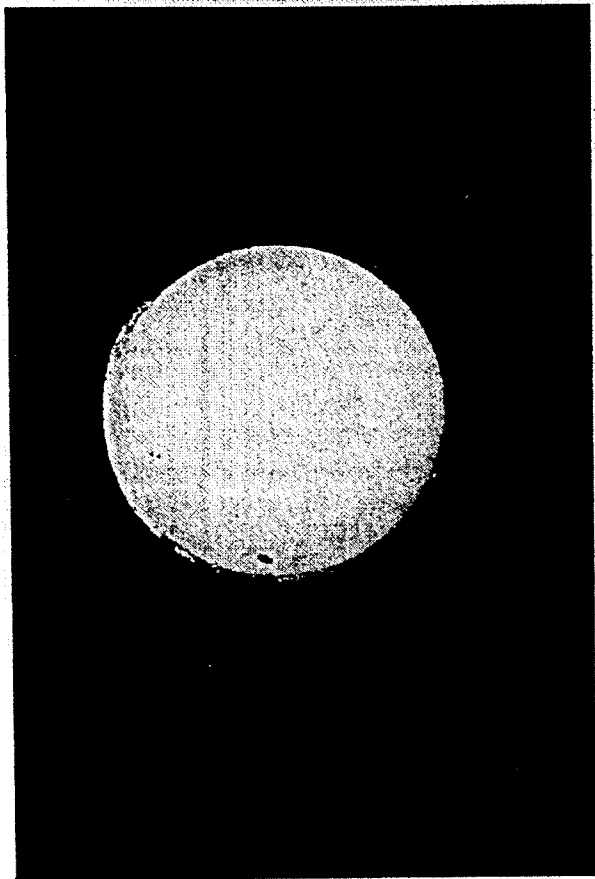
Composition of the sea water (DIN 50917)

NaCl	28 g/l
MgSO ₄ · 7 H ₂ O	7 g/l
MgCl ₂ · 6 H ₂ O	5 g/l
CaCl ₂	1,22 g/l
Na HCO ₃	0,2 g/l

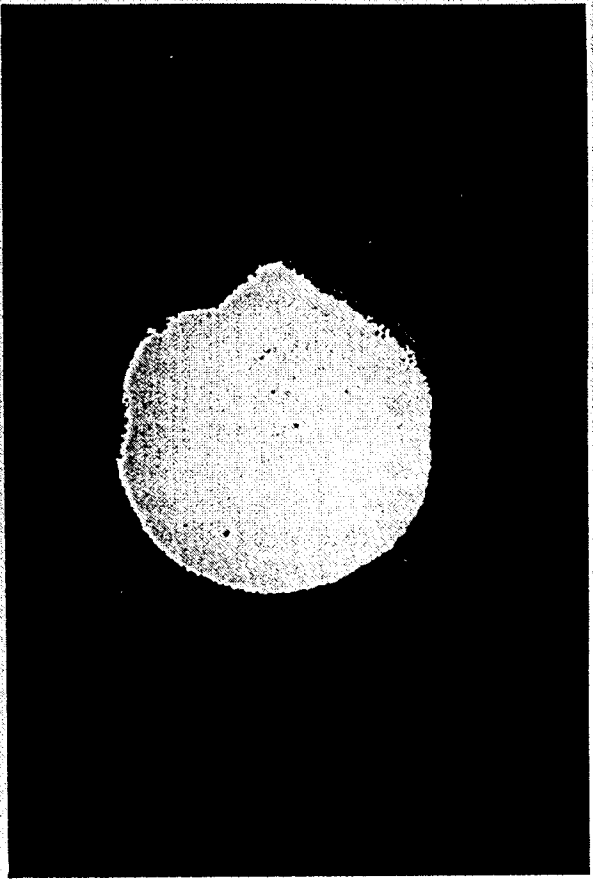
Daily Cycle of immersion and emersion of the samples

17 hours	immersed
2 hours	emersed
3 hours	immersed
2 hours	emersed

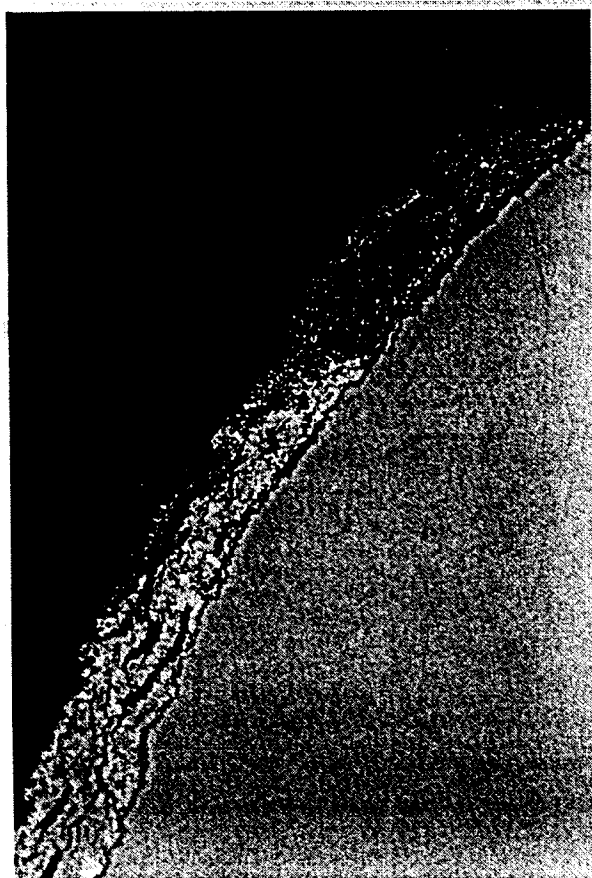
End of the test at 5% Red Rust



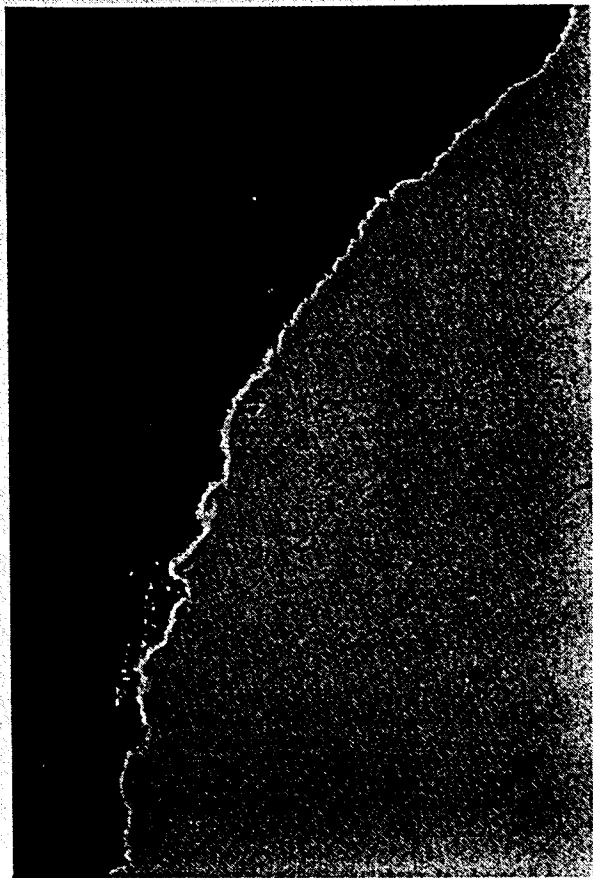
Bezinal (m = 50 x)



Zinc (m = 50 x)



Bezinal (m = 500 x)



Zinc (m = 500 x)

THESE TEST RESULTS CONFIRM EARLIER STATEMENTS.

1. BEZINAL IS PROTECTING BETTER THE STEEL SUBSTRATE.

THE BETTER PROTECTION IS VERY MUCH RELATED TO THE EFFICIENT CORROSION BARRIER AT THE VERY THIN BUT ALSO VERY ACTIVE IRON-ALUMINIUM ALLOY LAYER.

2. THE GALVANIC PROTECTION IS SUFFERING FROM THE PRESENCE OF GREASE ALONG THE FILAMENT SURFACE.

THAT GREASE IS DESIRABLE TO MINIMIZE FRETTING BETWEEN FILAMENTS IN A ROPE.

THE UNEQUALLY DISTRIBUTED AND NON-CONDUCTIVE ORGANIC FILM IS HINDERING THE GALVANIC CORROSION PROTECTING ACTION OF THE METALLIC COATING.

OPEN QUESTION :

HOW TO KEEP THE CORROSION PROTECTION SAFE FOR GALVANIZED OR GALFAN[®] COATED ROPES ?

DISCUSSION:

Effect of Greases on Galfan® and Regular Galvanized Fishing Ropes

Discussion followed Dr. DeWitte's presentation. He further commented on their observation that the non-uniform and aggressive corrosion on fishing ropes appears to be more the result of the manner of grease application than the type of grease used.

Irregular application of grease establishes anodic and cathodic areas, promoting aggressive corrosion, particularly after withdrawal from the seawater.

The group agreed this matter should be investigated further by nominating it as a project for GTC-sponsored research.

Galfan® Wire Licensee Meeting
Dusseldorf 17th April '96

Discussion: Lead Levels of Galfan Coatings on Wires

Bridon Ropes have an inquiry for ropes and have proposed Galfan coated ropes. They have agreed that the ropes would be made by Thyssen with wires supplied by Bekaert. The question of how high the Pb levels may be as acceptable Galfan.

Response:

Two of the major Galfan wire producers in Europe responded. Firstly Prof. Nunninghoff representing Arbed stated, "Pb may well be a problem on sheet coated with Galfan but his experience had not been the same with wires. Arbed have worked with Pb levels as high as 500ppm over the past twelve years and had experienced no failure due to high Pb levels."

Dr. Marc DeWitte representing Bekaert stated that, "Bekaert had worked with the Pb levels around 150/300ppm and had not experienced problems." Further Dr. DeWitte commented that in their salt spray tests in accordance with the ASTM 117 they had not seen any failure due to high Pb levels.

Mr. Roger Pankert from Union Miniere gave the attendants a full explanation as to how the higher Pb levels affected steel sheet and made cross references to previous test results.

It was noted however that all parties concerned i.e. TrefilEurope, TrefilArbed and Bekaert as manufacturers and Bridon as a user did not wish to see any restrictions. It was noted that a proposal has been put forward for further research to be conducted on the effects of Pb and to establish the upper limits of Pb in Galfan coatings.

Conclusions:

From the discussions Mr. Hostetler proposed that 300ppm be accepted by the meeting based on the submissions and comments made. This level was acceptable to Bridon.

SLIDE No.
-1- DELOT PROCESS
-2- THE REVOLUTION
-3- M.H.D.
-4- PILOT LINE
-5- M.F. SCHEMATIC
-6- MAG LEV TRAIN

THE DELOT PROCESS

A NEW TECHNOLOGY FOR STEEL WIRE GALFAN®-IZING

The Delot Process, developed by the French firm Delot Process S.A., is a revolutionary high performance wire, rod and bar galvanizing system. At the heart of the process, magnetohydrodynamic forces are used to apply GALFAN coatings.

MAGNETOHYDRODYNAMICS, or M.H.D. for short, is the science which combines the principles of fluid mechanics and electromagnetism to explain the behavior of an electrically conducting fluid in a magnetic field. The science is widely applied from ionized gases or liquid metals in the laboratory to the phenomena of conductive matter in planets or stars.

In recent years, engineers and scientists at Delot Process S.A., France, have developed M.H.D. technology to dramatically improve three important molten metal process functions. The practical results have been higher product quality, reduced manufacturing costs and a cleaner environment.

Specifically, the three functions improved by M.H.D. technology

- molten Galfan pumping
- containment and
- thickness control,

enable the entire hot galvanizing process for long products to be improved in a revolutionary way.

The data presented and claims made for the M.H.D. technology are based on five years of development work on long product galvanizing by Delot Process S.A. and on specific production and trial runs at the Delot plant in St-Florentin, France during 1993, '94 and '95.

THE M.H.D. CONCEPT

In the world of electrical machines, the behavior of a linear motor is well known. The motor's field circuit provides excitation (flux) while the nearby armature circuit experiences a generated voltage and resultant mechanical force. The intensity of voltage and current impressed on the field determines the resultant force on, and velocity of, the armature. The common solenoid and the exciting MAG-LEV trains are worldly examples of linear motors.

<p align="center">-7-</p> <p align="center">M.H.D. PUMP</p>	<p>Now consider the case of a linear motor where the field coil surrounds a suitable, magnetically permeable tube. Inside the tube is molten Galfan. When the field coil is excited, a magnetomotive force is imposed on the liquid metal (the armature). The liquid metal either moves or, if restricted, develops hydrostatic pressure in the pipe.</p> <p>By adjusting the intensity of the field coil, it is possible to regulate the flow rate of the molten Galfan or to stop the flow entirely. The principles of M.H.D. predict behavior of the above described electromagnetic pump. We will consider how this is applied to the heart of the Delot Process, the Galfan coating unit, in the next section.</p>
<p align="center">-8-</p> <p align="center">THE PROCESS</p>	<p><u>THE PROCESS</u></p> <p>The Delot Process for wire, rod and bar is a continuous process and consists of five primary steps included in the following descriptions:</p>
<p align="center">-9-</p> <p align="center">PROCESS DIAGRAM HORIZONTAL</p>	<ul style="list-style-type: none"> - Surface preparation - Steel heating - Galfan application - Steel and coating cooling - Steel transport
<p align="center">-10-</p> <p align="center">SPOOLS</p>	<p>A) Raw Material</p> <p>The Delot wire, rod and bar coating system can receive the long products on spools, in coils, or in the case of bars, in straight lengths. Accumulation may be desired for joining lengths by welding, but the Delot system can be easily stopped and restarted without waste if that method of coil exchange is preferred.</p>
<p align="center">-11-</p> <p align="center">ROD MILL</p>	<p>The process should receive wire or rod which is free of contaminants such as oil, carbonaceous smut, residual drawing lubricant and moisture. Mill scale and other oxides are acceptable. Residual drawing lubricants may be removed with popular hot water cleaning systems, provided the steel is dry when it enters the steel preparation stage.</p> <p>The input product temperature should not exceed 150°C and, in higher than room temperature cases, an additional radiation thermometer may be added to the heat control circuit.</p>
<p align="center">-12-</p> <p align="center">UNCOIL & STRAIGHTEN</p>	<p>Processing speeds may be controlled from 15 to 150 M/min for product diameters from 2 to 12 mm, and coating thickness from 8 to 100 microns.</p>

-13-

**STEEL
PREPARATION**

B) Steel Preparation and Heating

The Delot Process employs the widely used rotoblast wheel method of shot blasting to clean and profile the wire surface. The shot blaster consists of three (3) rotoblast wheels arranged at 120° angles around the horizontal wire centerline. Concentrator plates are used to focus the blast pattern on the wire surface for greater efficiency. An abrasive cleaning, recycling and replenishing network maintain uniform shot characteristics and provide machine ventilation and dust control.

The blast cleaned wire exits the 3 M long cabinet through an air ring which blows any residual metal fines back into the vestibule.

-14-

**LASER
MICROMETER**

The wire now enters a low pressure inert gas shield (nitrogen) which is maintained through the rest of the process up to quenching. Also, the wire passes through laser micrometer No. 1 and the diameter is transmitted to the process controller.

At this point in the process, the large or small wires may continue on a horizontal path, or the small wires and rod may be directed to a vertical - up path.

-15-

**PROCESS
DIAGRAM
VERTICAL**

C) Horizontal or Vertical Reactor

When considering the orientation of the wire path, several factors will influence the decision:

- the ratio of coating thickness to product diameter;
- the allowable tolerance for coating eccentricity;
- and the combination of product diameter and tensile strength as they influence difficulty in redirecting the wire around transport sheaves.

In general, large diameters (7.0 to 12 mm) with coatings of 8 to 25 microns are best for the horizontal path and small diameters (2.0 to 6.0 mm) with coatings of 25 to 50 microns are best for the vertical path. The vertical path is not sensitive to the effects of gravity in so far as eccentric coating is concerned.

-16-

**INDUCTION
HEATER**

In either case, the wire will enter an induction heating coil of 1 M in length. Here the power from a 60 KW power supply will efficiently raise the wire to Galfan application temperature or higher.

-17-

**LIQUID
GALFAN
FEED
SYSTEM**

D) The Galfan Coating Unit

Upon leaving the induction heating coils the hot wire, still shielded in nitrogen, passes a radiation thermometer for non-contact verification of correct temperature. The hot wire now enters the Galfan Coating Unit.

This coating unit consists of a crucible and a reactor.

Molten Galfan is supplied to the reactor via a recirculating loop from and back to the crucible. The crucible is housed in a nitrogen blanketed electric furnace and contains only one metric ton of Galfan. Melting of ingots occurs in the crucible and is controlled to achieve a constant melt level and temperature. The entire network of crucible, recirculation loop and reactor is externally temperature controlled to assure uniform temperature, even if the system is not operating.

In addition, all molten Galfan wetted surfaces are constructed of specially engineered ceramic materials, to prevent corrosion.

Galfan is pumped from the crucible to the reactor by a sealed M.H.D. pump whose internal geometry minimizes fluid disturbances yet consumes less power than previous electromagnetic pumps. Precise adjustment of the pump field current controls the Galfan flow rate to match wire size, desired coating weight, line speed and return flow requirements. The pump cannot leak and has no moving parts to wear out.

-18-

**THE
REACTOR**

The reactor is a cylindrical containment of about one liter in volume and sealed at both ends by M.H.D. pumps which permit entry and exit of the passing wire, but contain the molten Galfan.

The entry pump exerts force in the direction of wire travel to prevent any Galfan leakage.

Within the reactor, the iron-zinc-aluminum alloy forms on the wire surface and pure Galfan wets the alloy layer.

Wire exposure time in the reactor is adjustable from 0.1 to 0.4 seconds, depending on line speed and M.H.D. pump separation selected.

Further the exit pump force, opposite the direction of wire travel, is regulated to control the coating thickness on the exiting wire. Thickness of coating can be controlled from 8 to 100 microns by precise regulation of the exit pump field current.

-19-

CONTROLLED
SOFT
COOLING

E) Rapid Quench

The exit of the Delot reactor is nitrogen covered to prevent oxidation as the wire passes into the rapid quench stage. In the case of the horizontal reactor, a classic water flooded trough of controlled temperature is used to freeze the coating.

In the case of the vertical reactor, a specially engineered water quench system:

- quickly freezes the coating in only 1.3 seconds;
- does not distort the molten Galfan or;
- allow coolant leakage into the reactor below and;
- reacts to emergency stops without damaging the product or equipment.

F) Thickness Control

Immediately following quench, the wire passes through laser micrometer No. 2 which sends the two plane coated wire diameter measurements to the process controller. With diameter measurements before and after coating, Galfan thickness is computed and compared to the desired value. A P.I.D. function control then makes adjustments, if required, to the exit pump on the Delot reactor.

-20-

ACCUMULATING
TAKE-UP

G) Final Quench, Wire Transport and Take-Up

At this stage, the vertical wire is redirected to a horizontal plane, receives a final quench and passes on to a take-up. The wire transport and take-up system:

- is vibration free;
- has three (3) tension controls, pay-off to shot blast, induction heater to take-up capstan and capstan coiler;
- is capable of scrap free emergency stop;
- and provides precise speed regulation from 15 to 150 M/min.

-21-

TYPICAL OP'N

H) Process Control

-22-

PROCESS
CONTROL

The entire Delot Process is managed by a Supervisory Control and Data Acquisition (SCADA) system adapted to a hot Galfan process.

The SCADA process management system performs in two areas:

Function

Administration

Product & Process Menu
 Set Points
 Regulation (P.I.D. Function)
 Display Real Time
 Alarm (L.C.L. & U.C.L.)
 Shutdown
 Emergency Stop
 Start Prevent
 Reset
 Annunciation - Troubleshoot

Record
 Long Term Store-Disc
 Lot No., Quantity & Identity
 Trend Analysis - Display
 Statistical Analysis - Display
 Print, Hard Copy Chart & Tables
 Customer Documentation

The SCADA system facilitates I.S.O. certification, insures optimum product quality and best utilization of process energy and materials.

We will now take a pictorial tour of the plant in France where the trials on wire, rod and bar were conducted.

-23-
ST-FLORENTIN OVERVIEW
-24-
PAY-OFF
-25-
STRAIGHTENER
-26-
SHOT BLAST
-27-
BLAST EXIT
-28-
INDUCTION
-29-
RAD. CAMERA
-30-
DELOT REACTOR
-31-
QUENCH
-32-
COILER
-33-
COILS
-34-
S.C.A.D.A

Beginning with the pay off from coils

thru a two plane straightener,

into the three (3) wheel shot blast surface preparation,

and thru a nitrogen filled tube to the

induction heating coils.

The hot product passes a radiation camera to verify temperature, and

enters the Delot Reactor where the Galfan coating is applied with precision and uniformity using M.H.D. technology.

The coated product is quickly cooled in a high flow water loop

and wound up on a coiler to produce

these 500# coils

and the entire system is computer managed for optimum process control and data administration.

-35- OPER. FRIENDLY
-36- OLD GALLI
-37- ENV. FRIENDLY
-38- ENV. AWARD
-39- THE PRODUCTS
-40- COIL IN T/U
-41- MELANGE
-42- ROPES
-43- INDENTED COILS
-44- IND. CLOSE-UP
-45- DELOT ADVANTAGES PRODUCT
-46- TRADITIONAL

The Delot Process is operator friendly, it offers easy, scrap free start and stop, no dressing required, maintenance free Galfan pumping, and no wipe maintenance. The process is environment friendly, it requires no chemical cleaning or rinse treatments, no flux, no acids, and the small molten mass consumes less fuel. In fact, Delot Process was honored with the "Clean Technology" Award by the French Ministry of the Environment.

The Delot Process is the modern cost effective method for applying superior Galfan coating to the full range of wire products,

as wire at finished diameter with heavy coating

for a variety of fabricated items or

as process wire, galvanized and redrawn for strands and ropes

or for indented wire reinforcement used in concrete.

The Delot Process applies uniform Galfan coverage to the hills and valleys for better bonding strength and superior corrosion resistance

The process offers:

- Uniform Galfan thickness
- Smooth coating
- Galfan coating without double dip

and the Delot Process permits a change in the very way some products are manufactured (now to G-rod)

GALVANIZED ROD METHOD

Throughout the world, most steel wire galvanizing has traditionally been produced by this process sequence:

- 1.- Clean and coat rod,
- 2.- draw wire,
- 3.- hot dip galvanize wire.

<p align="center">-47-</p> <p align="center">NEW APPROACH</p>	<p>In recent years, some producers have reordered this sequence for certain products:</p> <ol style="list-style-type: none"> 1.- Clean and electrogalvanize rod, 2.- draw wire.
<p align="center">-48-</p> <p align="center">G.R. PAY-OFF</p>	<p>We'll call this the "galvanized rod" method. Usually, rod chemistry must be adjusted to maintain the desired physical properties, but that change eliminates a costly process step and allows coated wire production at speeds in excess of 600 M/min instead of the traditional 60 to 100 M/min hot dip galvanizing speed. The manufacturing cost savings are substantial even when the electrogalvanized rod is purchased from sources outside the company.</p>
<p align="center">-49-</p> <p align="center">NEWEST APPROACH</p>	<p>Now, the Delot Process makes it possible for wire manufacturers to economically clean and Galfan®-ize their wire rods, with a ductile, drawable coating.</p>
<p align="center">-50-</p> <p align="center">G.R. INTO D.M.</p>	<p>Wire producers may enjoy "just in time" scheduling of rod size, chemistry and coating weight,</p>
<p align="center">-51-</p> <p align="center">GALLI T/U'S</p>	<p>by operating a Delot system in their plant. Galfan®-ized wire at more than 6 times the speed of traditional methods.</p>
<p align="center">-52-</p> <p align="center">THE STRONG FEATURES</p>	<p>Galfan applied with the Delot Process benefits in several ways:</p> <ul style="list-style-type: none"> • The M.H.D.pump at the reactor exit exercises discrete control of coating thickness. The field excitation is regulated by the SCADA computer which is informed of wire diameter, speed and desired coating thickness. Feedback from the laser micrometers to the computer provides fine tuning instantaneously and automatically. • The surface cleaning and preparation by acid is eliminated, as are chemical vapors, dissolved metal flux and the need to treat waste acid and rinse water. • Less energy required. • Efficient induction heating of the steel under controlled atmosphere permits independent steel temperature control and higher line speeds with no increase in line length. • The small melting/supply crucible (ONE METRIC TON) significantly reduces the expense of keeping and heating 30 to 60 tons of molten Galfan. Because the crucible is ceramic and nitrogen blanketed, dross and oxide waste is virtually eliminated.
<p align="center">-53-</p> <p align="center">DELOT LOGO</p>	<p>For these advantages, the application of M.H.D. technology to wire galvanizing is possibly the greatest process improvement since M. Sorel of Paris first dipped wire in 1836.</p>

V. Dorsten