



GALFAN[®]
IMPROVED GALVANIZING

***20th* GALFAN
TUBE LICENSEE MEETING
PROCEEDINGS**

Holiday Inn, Auburn Hills, Michigan USA

November 28, 1995

Sponsored by

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

TUBE LICENSEES MEETING PROCEEDINGS

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Galfan® Tubing Licensee Meeting

held at

Holiday Inn, Auburn Hills, Michigan

on

November 28, 1995

LICENSEES IN ATTENDANCE:

<i>Name</i>	<i>Company</i>
Adkins, Del	Bundy Corporation
Anderson, G.N.	Cominco-Product Technology Centre
Emmons, Charley	Pilot Industries
Eschenburg, Mark	Bundy Corporation-Marysville
Everett, Jerry	ITT Archbold
Fleeman, Larry	Pilot Industries
Gibbs, Glen	ITT-Automotive
Hostetler, John	GTC
Kejriwal, Ranjan	ITT-Automotive-Newlex
Kreiman, Dan	Handy & Harman Auto.
Kreis, Al	Markin Tubing
Leupold, Conrad	Pilot Industries
Malmgreen, John	Eastern Alloys
McDaniel, Jim	ITT Automotive
Patel, R.D.	Form-Rite
Ruebsam, Keith	Form-Rite
Schwiebert, Tim	ITT Archbold
Skubick, Skip	Eastern Alloys
Vlahakis, Paul	Pilot Industries

MEETING CONVENED:

John Hostetler, Director, Galfan Technology Centre (GTC) declared the meeting in session at 9:00 a.m. Those present introduced themselves with a brief description of their involvement with Galfan.

GALFAN STATUS REPORT

Table One, showing the number of licensed production lines by region and by category, was discussed. The addition of several new sheet licensees should be of interest to tubing licensees because it enables the Research Committee to commit significant funds to Galfan research.

This also makes evident the importance of tube licensees purchasing GTC unitshares so that tube licensees have representation in determining where the research money is allocated.

The addition of three small parts licensees is also important to tube licensees because all three are research licenses to develop and commercialize processes to use Galfan for spin-galvanizing small parts such as those used with automotive tubing.

Mr. Hostetler reported that Southeast Asia and to a lesser degree, Mexico, are regions that show great interest in Galfan for sheet, wire and tube.

GTC estimates that nearly 4,000,000 metric tons of steel will have been Galfan-covered by the end of 1995. This includes about one billion feet of tubing in North America.

Each Galfan category (sheet, wire and tube) is becoming more dissimilar in terms of issues, marketing and production technology. This has led to separate meetings in 1995 and we expect this will be the standard format for the next few years. The sheet licensees met in September 1995 in Chicago, the tube licensees are in session now and the wire licensees will meet in Dusseldorf, Germany in April 1996.

The first year of GTC is nearing its end with good results. ILZRO owners and members, after spending nearly \$2,000,000 for Galfan research from 1980 through 1993, stopped any further direct support to the Galfan program. GTRC was self-supporting in 1994 but did not sponsor any significant research. GTC will finish the year as a self-supporting department with commitment to substantial Galfan research.

All active licensees are encouraged to purchase a GTC unitshare to support the GTC operating budget. Research funds are derived from new license fees that come from GTC's efforts.

Mr. Gibbs raised the question regarding the status of the Galfan patents and their relationship to the Galfan license. Mr. Hostetler responded by saying the patents in most of the industrialized countries will expire in the years 2000 or 2001 and that all licenses granted prior to 1994 will terminate on the patent expiration date. ILZRO will, however, offer to convert any older license to the new agreement during the year 1996 at no charge or fee. The new agreement grants license rights for ten (10) years with an automatic five (5) year renewal if not canceled in writing by either party. Full details will be distributed in early 1996.

Mr. Hostetler then presented the paper, "*Positioning Galfan for Future Requirements for Automotive Tubing Protection.*" A copy of the paper is attached as GTC Document 95-025.

John Malmgreen, Eastern Alloys, presented the paper, "*Metal Yield - Dross Management.*" Dross generation in the tubing line baths is much greater than for wire or sheet and is a problem common to all licensees. A copy of the paper is attached.

The discussion that followed Mr. Malmgreen's presentation reported that attempts to shroud the bath in nitrogen did not significantly reduce the dross generation. There was also discussion concerning the presence of copper. Mr. Malmgreen volunteered to analyze simultaneous samples of bath, dross and coating where copper is present.

Mr. Hostetler announced GTC's plans to produce and publish an 80-100 page book called "*Galfan Anti-Corrosion Systems for Automotive Tubing.*" It is in response to the fast-growing interest from automakers and refrigeration manufacturers throughout the world.

The book shall be divided into five parts:

- (1) *Characteristics of Galfan Systems*
- (2) *Production Processes*
- (3) *Process Control*
- (4) *Specifications and Testing*
- (5) *Engineering Addendum*

GTC welcomes black and white photographs of tube-making, coating lines, testing and final fabrications and assemblies from licensees. One or more color photographs suitable for use on the cover are especially solicited.

A preliminary outline of the manuscript is enclosed. Licensees are urged to comment on it — any input will be very useful and greatly appreciated. The manuscript is scheduled for completion by February 15, 1996 with publication by June 1996.

A paper recently presented at Tube China '95 is included with these proceedings although it was not presented or discussed at the meeting. It is available as GTC document No. 95-021.

GALFAN CONSTANT IMPROVEMENT PROGRAM

GTC will customize the Galfan Constant Improvement Program to apply specifically to automotive tubing. It shall feature a manual available by June 1996 to all licensees as GTC Document 96-002.

The program starts with the recognition that Galfan tube-coating lines are a sequential series of industrial processes. It accepts the premise that if the processes operate within appropriate limits, the final coating specifications and performance will consistently be within limits. Reducing the process variations will improve the coating's consistency and performance by reducing its variability.

The document includes analytical and evaluation techniques and devices based on the Automotive Industry Action Group's (AIAG) publications Potential Failure Mode and Effects Analysis (FMEA) and Advanced Product Quality Planning and Control Plan (APQP) as well as other statistical techniques.

This Galfan Constant Improvement Program (GCIP) will include comprehensive data for both type production lines now in use: Type 1: Cold chemical and Type 2: Hot chemical. It shows how to develop a specific Production Control Plan using an analysis and evaluation of each process. The user must thoroughly know or learn the following about each process:

- *What is the process meant to do?*

-
- *How will the effect of the process be measured?*
 - *What are the process variables?*
 - *How is each process variable controlled?*
 - *How do the processes interact?*
 - *What are the potential defects?*
 - *What are the effects of each defect?*

GTC will also offer a comprehensive training program to teach the principles of each process, how to test and/or measure the processes, how to control the processes and how to collect the data and present it in statistical form. Training can be done at GTC's Training Center or at the licensee's site. More details including registration fees and schedules will be announced later.

Jodie Yannick, Fischer Technologies, presented information and demonstrated how to measure thicknesses of Galfan and various top-coats using the model MMS Fischerscope. A product brochure is included in these proceedings.

The MMS is able to use various type probes to match the type and thickness of coating and, of particular interest, the duplex probe which can measure a top-coat and Galfan simultaneously.

Victor Dorsten, Galvacor, Inc., presented the Delot Process as it will be used for applying Galfan to tubing in either a horizontal or vertical passline. The system features mechanical abrasion to clean and de-oxidize the tube surface, then heats the tube as it passes through an electric induction coil around a nitrogen/hydrogen atmosphere. The tubing then passes through a "bubble" of Galfan after which it is quenched in water mist. The Galfan bubble is contained in a very small vessel that is still protected by the N₂/H₂ atmosphere. Galfan is contained within the vessel by electromagnetic seals and is circulated from a holding pot by a magnetic induction pump.

The original installation is being re-installed in another location in France and a new line with a vertical passline is being installed in Quebec City. The line in France is scheduled for commissioning in February, the Canadian line in June or July 1996.

A more detailed description is included in the proceedings.

Jack Anderson and Mark Benkovich, ERA Systems explained and demonstrated the principles used in measuring the clean-ness of steel tubing surfaces using the new Meseran. Limits of organic contamination on steel to be single-dip Galfan coated have been set at $0.3 \mu\text{g}/\text{cm}^2$ which is well below the normal detection levels for water-break or white cloth smudging. The Meseran is the only reliable, accurate and practical method known for making this measurement.

A description of this instrument is included in the proceedings.

12/5/95

**POSITIONING GALFAN FOR FUTURE REQUIREMENTS OF
AUTOMOTIVE TUBING PROTECTION**

GALFAN LICENSEES MEETING

NOVEMBER 28, 1995

BY

JOHN L. HOSTETLER, DIRECTOR
GALFAN TECHNOLOGY CENTRE

BACKGROUND

When the Galfan®/Al-Rich Epoxy (ARE) duplex system for coating small-diameter automotive tubing was introduced in 1990, its performance compared to super-terne coatings in the corrosion tests then specified was so much better that it quickly became very popular with the automotive industry.

A dozen new continuous hot-dip Galfan coating lines were built incorporating few changes from 1980's technology. These lines, with minor improvements since 1990 have, however, successfully coated more than one billion feet of tubing.

Simple salt spray tests (SST) at that time required 1,000 hours before 5% red rust in ASTM B117 conditions. This requirement was easily surpassed by Galfan/ARE coatings produced on these lines. The only control specification for the Galfan coating was that its average mass be no less than 0.16 oz/ft², an easily-achieved process requirement. Results exceeded performance requirements.

The first complaint brought to our attention came from Ford Motor Company. A small but statistically significant number of the Galfan/ARE systems were failing prematurely in Ford's cyclical Arizona Proving Ground (APG) tests. Even though the system was consistent in its performance in SST, it was inconsistent in CCT.

Galfan Technical Resource Center (GTRC) had production samples from several producers evaluated and found the average coating weights to be well above the 0.16 oz/ft² (50 g/m²) but when measuring thicknesses around the tube's circumference,

both the Galfan and the ARE showed very high standard deviations (SD) with many locations showing zero thickness.

Most producers made minor improvements to various processes in their coating line resulting in some reduction in the SD but performance was still short of the bogeys. A few of the producers changed to another top-coat but this is an expensive effort to treat the symptom rather than the problem.

The challenge facing the Galfan licensees is, "*How can we meet the increasingly more demanding requirements with statistically acceptable performance without increasing costs to non-competitive levels?*"

There are three improvements that can be made to help meet the requirements now under consideration.

1. The coating's corrosion resistance can be optimized by producing a fully eutectic microstructure.
2. The average weight of the Galfan coating can be increased to 0.33 oz/ft² (100 g/m²).
3. Thickness SD should be no more than 30% of the average thickness. Average thickness based on average weight = 15 μm so SD should not exceed 4.5 μm.

OPTIMIZING THE GALFAN MICROSTRUCTURE

Galfan is generally described as Zn-5% Al but is well-known as a eutectic alloy. Galfan coatings are, however, found to be hypo-eutectic, eutectic or hyper-eutectic microstructures.

Hypo-eutectic microstructures are those that contain some primary Zn-rich phases in a eutectic matrix. (See Figure 1)

A *eutectic* microstructure is one that is homogeneous from interface to surface with no primary phases or other multi-phase characteristics. (See Figure 2)

Hyper-eutectic microstructures are those that contain primary Al-rich phases surrounded by a eutectic matrix. (See Figure 3)

The microstructure of the Galfan coating has a significant influence on its corrosion resistance. *The eutectic microstructure provides maximum resistance to atmospheric corrosion.*

Fully eutectic microstructures can be achieved by controlling the Galfan bath composition and the rate of cooling during the coating's solidification. Other production line variables have a lesser influence but cannot be totally ignored. The main ones are bath temperature and incoming tube temperature.

The microstructure's effect on the coating's corrosion resistance has been known for more than ten years. Akira Yasuda et al., Kawasaki Steel Corporation, first reported this in a paper at the Galfan Licensee Meeting November 8, 1984 and a follow-up report at the licensee meeting December 5, 1985.

Why then is not every Galfan coating fully eutectic?

There are at least two answers:

- (1) It is normal for the bath to lose about 10% of its original and make-up aluminum composition because a greater percentage of aluminum is lost to Fe reactions in the bath and to top scum and oxides that are removed from the bath. If the producer uses Zn-5% Al alloy as the initial melt and subsequent make-up, the steady-state bath will probably assay at 4.5% to 4.7% Al.

The aluminum composition of the initial charge and the make-up alloy must therefore be greater than the controlled Galfan bath Al composition.

- (2) Some producers intentionally compromise a fully eutectic microstructure in order to optimize another characteristic. For example, some licensees applying Galfan for pre-painted sheet often choose lower aluminum compositions to reduce the depth of shrinkage dents at cell boundaries. This results in a hypo-eutectic microstructure.

BATH COMPOSITION

A eutectic microstructure is mainly the result of two process controls, the bath composition and the rate of cooling through the coating's solidification process. The kind of eutectic microstructure, whether rod type or lamellar, is largely dependent upon the cooling. Most Galfan eutectic microstructures are lamellar.

The Galfan bath composition should be maintained near the eutectic point. The eutectic point may be shifted slightly by the composition of elements other than zinc and aluminum but will be between 5.2% and 5.4% Al. If the Al composition is higher, the microstructure will be hypereutectic, if lower, the microstructure will be hypoeutectic.

Aluminum composition of the tube-coating Galfan bath should be maintained at 5.2% with LCL = 5.1% and UCL = 5.3%.

If the bath's present Al composition is below this range, make-up alloy with Al-7% composition may be used in some ratio with Al-5% bars to bring the bath's Al composition within the control range as follows:

When Bath Composition Is:	Add 7% Bars	With 5% Bars	Result Make-Up %
4.5 - 4.69	10	0	7.0
4.7 - 4.89	8	2	6.6
4.9 - 5.09	6	4	6.2
5.1 - 5.29	*4	*6	5.8

*After the bath's Al composition is inside the control range, the make-up ratio to keep it there must be carefully determined. This involves frequent bath assays and monitoring both the amount and composition of the skimmings removed from the bath.

Note: The actual composition of the higher Al% bar may vary. The selected Al % ordered must consider that the higher the Al composition, the higher the temperature required

to melt it. For instance, a 10% Al composition will require a melting temperature of approximately 430°C (bath temp of about 440°C) whereas a 7% bar will melt at about 400°C.

Tests have shown that the temperature of the entering tube and the temperature of the bath also influence the microstructure but these elevated temperatures are significantly higher than those recommended for tube-coating. The entering tubing temperature should not exceed 500°C and bath temperatures should not exceed 460°C.

Optimum conditions are 440°C tube temperature entering a 420°C bath but this condition will require very clean tube surfaces. If the entering tube temperature is less than 440°C, the bath temperature and residency time must be increased to obtain a homogeneous eutectic microstructure.

Bath temperatures above 480°C needlessly increase the thickness of the interfacing Al-rich intermetallic. Less than adequate bath time-temperature may cause defective interfacing and bare spots.

COOLING RATE

The rate at which the coating is cooled starting at a particular coating temperature will have an influence on the coating's microstructure.

Slow or moderate cooling rates may allow primary phases even in eutectic ratio coatings. Zn-rich phases may solidify before the eutectic solidification temperature (382°C) is reached. At cooling rates of about 5°C/sec., Zn-rich phases may form at the interface while at cooling rates about 20°C/sec., Zn-rich phases may form at the surface. *The much higher rates achieved by water-quenching assure maximum homogeneity of the microstructure.*

Corrosion tests in SST using similar coating thicknesses but cooled at different rates show greater resistance to red rusting by coatings that are water-quenched.

The water quenching must be initiated above the freezing temperature (382°C - 387°C) to influence the microstructure. Initiating the water quench at too high a temperature

however, may unacceptably roughen the coating's surface. The water quench should therefore, be initiated between 395°C and 387°C.

COOLING CONTROL

The preceding information suggest the use of a pre-cooler to reduce the tubing temperature to $\approx 390^\circ\text{C}$ immediately before it enters a water quench.

If the tube temperature entering the quench water is constant, the microstructure and surface aspects of the coating should also be constant. Temperature of the quench water may however, need to be a process control variable.

The pre-cool process must have adjustable cooling capacity because the heat removal load will vary by the following:

- a) tubing O.D. and wall thickness*
- b) line speed*
- c) bath temperature*
- d) wiping gas temperature*
- e) temperature drop of tubing before entering pre-cooler.*

Typical conditions on a modern high-speed tube-coating line will create a heat load beyond the capability of typical impingement type air coolers within a reasonable distance. Higher efficiency methods for cooling with ambient air are being developed specifically for tubing applications. A suggested control scheme of the cooling process is shown in Figure 4.

INCREASING THE GALFAN COATING THICKNESS AND IMPROVING ITS UNIFORMITY

The final amount of Galfan on the tubing is the result of the amount of coating drag-out

from the Galfan bath less the amount removed by a coating control system as:

$$C_f = C_{do} - C_r$$

where:

- C_f = the final coating (thickness or mass)
- C_{do} = coating drag-out from the bath
- C_r = coating removed

Coating drag-out is the result of several variables including:

- (1) line speed
- (2) coating fluidity
- (3) smoothness of tube surface

Change in the coating mass drag-out is approximately a square root relationship to the line speed.

$$C_2 = C_1 (N_2/N_1)^{1/2}$$

where:

- C_2 = coating mass at line speed N_2
- C_1 = coating mass at line speed N_1
- N_1 = line speed at known coating mass
- N_2 = new line speed.

Example: If a line speed of 150 fpm drags out 60 g/m², a line speed of 250 fpm will drag out about 75 g/m².

Galfan's fluidity is a function of its Al composition and temperature. Generally, the greater the Al composition, the more fluid the alloy becomes, but it appears to be minimized at the eutectic ratio.

Galfan's fluidity also is a function of its temperature, it decreases with decrease in bath temperature. *Thus the coating drag-out can be maximized by maintaining the bath at 5.2% Al and the lowest possible temperature.*

The tube's surface smoothness also affects the drag-out. Typical surface smoothness of the steel strip at the entry to the tube mill is 50 to 70 micro-inches but the tube mill processes typically reduce the smoothness to 8-32 micro-inches. GTC conducted hand-dip proof-of-principle experiments that showed an 80% increase in drag-out when abrading a typical 3/8 OD tube surface to 52 micro-inches. The thickness variance coefficient was also reduced by 50%.

Most of the production lines rely on gas knives to control the coating mass and uniformity but gas knives are most effective when they remove 25% to 50% of the drag-out coating. Thus, if the final coating is to be 100 g/m², the drag-out should be at least 133 g/m² (20 μm). The desired thickness SD may require a drag-out of 150 g/m² (23 μm).

CONCLUSIONS

A totally eutectic microstructure corrodes uniformly whereas hypo-eutectic microstructures may corrode more rapidly at Zn-rich primary phases. Hypo-eutectic coatings also show greater edge creep both in painted and unpainted applications.

Homogeneous eutectic microstructures provide maximum corrosion resistance, both in terms of general rate of corrosion and in uniformity of corrosion.

Thicker Galfan coatings and improved uniformity can only be achieved if the coating drag-out from the bath is increased so that the gas wipe coating control can be more effective by removing a larger percentage of the drag-out.



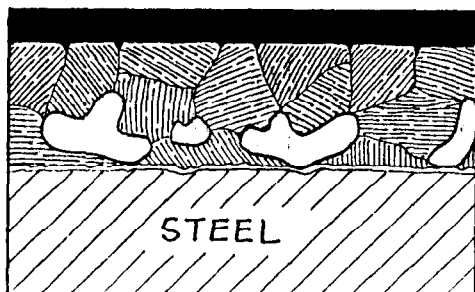


FIGURE 1
 HYPO-EUTECTIC MICROSTRUCTURE
 Showing zinc-rich primary phases

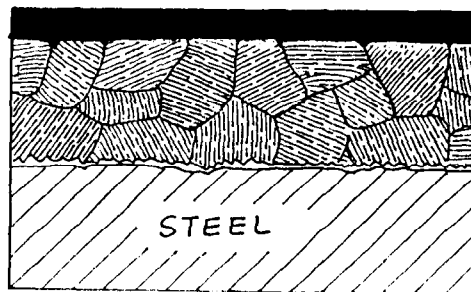


FIGURE 2
 FULLY EUTECTIC MICROSTRUCTURE
 No primary phases

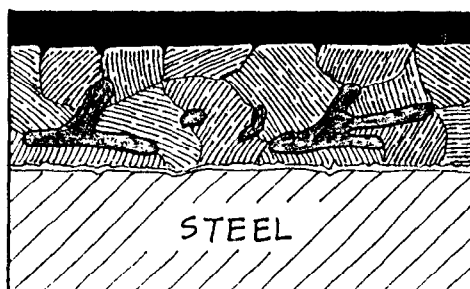


FIGURE 3
 HYPER-EUTECTIC MICROSTRUCTURE
 Showing aluminum-rich primary phases

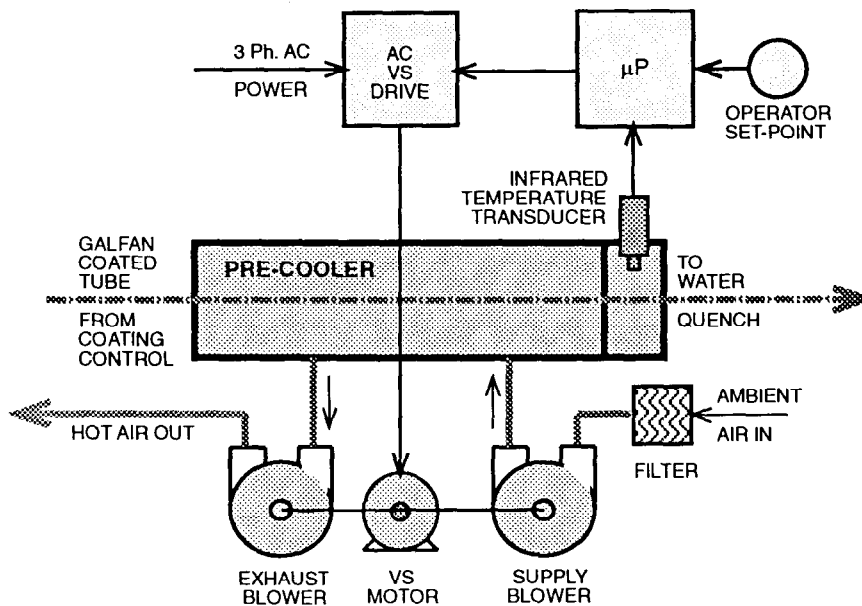


Figure 4
 PRE-COOLER CONTROL DIAGRAM

METAL YIELD - DROSS MANAGEMENT

by

John Malmgreen

Presented to the

Galfan Tube Licensee Meeting
Holiday Inn, Auburn Hills, MI

November 28, 1995

Metal yield is best defined as the amount of metal put into product versus the total amount of metal used in the process. Relating this to the GALFANIZING process: Alloy is melted and held as a reservoir of molten metal. The alloy is removed from the bath as coating and dross. The less dross generated and removed from the bath, the greater the amount used as product, and therefore, the greater the yield.

One might be inclined to dismiss the cost associated with dross formation since it can be sold. However, the loss involves more than just the cost of lost metal. Energy is required to melt the extra metal needed to compensate for the lost metal. Dross production of 20% requires that much extra energy. Labor cost must also be considered since extra time and labor is required to skim the bath. Dross management is the key to reducing these costs. In order to manage a dross problem, one needs to know what dross is, and why excess dross forms.

WHAT IS DROSS?

Dross is the generic name for the scoria that is removed from molten metal. It is comprised of metal salts, intermetallics, oxides, and bath metal.

Salts Excess flux or water carried over to the coating bath can react to form metal salts.

Intermetallics Zinc, aluminum and iron can react to form a high melting compound that will eventually float to the bath surface.

Oxides Zinc alloys will react with air to form oxides.

The metal salts, intermetallics, and oxides are less dense than zinc. They will accumulate at the surface and bind bath metal into a mass that can vary from thick flowing soup to whipped cream in consistency.

SKIMMING PRACTICES

Dross needs to be removed from the bath to prevent it from getting on the product and to allow the addition of fresh alloy. What is skimmed from the bath can contain from 60% to 80% bath metal. Using good metal handling practices can help to minimize dross loss.

Don't Overskim - Skimming the metal clean will expose a fresh surface. As mentioned above, the alloy will react with air and oxidize to form more dross. A thin layer of dross will help protect the surface from further oxidation. So don't overskim; Skim regularly, but not too often.

Skim Carefully - Use a perforated tool and do not dig too deep - try not to disturb the surface. Shake the tool; this allows the denser bath metal to flow back through the perforations into the bath.

Contain the Dross - If certain areas in your bath are more prone to dross formation, baffle and contain it in these areas. Concentrate on these areas when skimming. Extra heat onto the surface in these areas and letting the dross form longer may result in some separation and therefore remove less bath metal.

The best solution is to not create dross. If there are areas of the operation or metal handling techniques that create dross, eliminate or change them.

DROSS FORMATION

One thing that can lead to dross formation is poor upstream process control; "How you prepare the tube and present it to the bath". It is important to remove all scale and organic contaminants. These can lead to dross formation. Avoid drag over of excess flux and water. They can contribute to the dross layer and even react with the bath metal to form salts and oxides.

One major component of dross is metal oxide. Operating conditions can contribute to the formation of oxides and therefore dross. Here are things to avoid:

Overheating - Oxidation will increase as temperature of the bath increases. Top-fired furnaces create more dross. Poorly adjusted burners can lead to hot spots and localized overheating. The preferred furnace is refractory lined with an immersion tube burner or an induction melter.

Exposing fresh metal to air - As mentioned previously, this will allow it to oxidize and form dross. This can be caused by excessive skimming and turbulence.

Turbulence - Turbulence is the most likely cause of excessive dross formation in a coating bath. It can be created by mixing too fast and causing a vortex that sucks metal and air into the bath. This will form a whipped airy dross. Turbulence can also be caused by metal freely cascading into the bath.

SUMMARY

Dross management is an important tool for reducing costs. The best solution is to not make dross. Skim properly. Avoid conditions that will cause oxidation. Minimize turbulent conditions where metal is exposed to air, such as cascading metal.

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Improved Corrosion Resistance for Small Diameter Automotive and Refrigeration Steel Tubing

by

John D. Hostetler, Chief Engineer Decktec, Inc. Canton, OH, USA	John L. Hostetler, P.E., Director, Galfan Technology Centre Research Triangle Park, NC, USA
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for presentation to

Tube China '95
Beijing, China
Nov. 16, 1995

Abstract

Zn-Al alloys, as compared to tin, terne or regular galvanize coatings, provide an improved anti-corrosion coating for steel. This paper reviews the development of Galfan[®], one such alloy that has become popular in North American automotive applications. The paper discusses the development of Galfan, its characterization and the technology currently in use on 15 production lines.

Researchers have published much information relating to Galfan's composition and its use as a galvanizing alloy for steel sheet and wire but very little is available relating to its use on tubing. This is partially true because nearly all tubing production has been used by the North American automotive industry in applications covered by the manufacturer's proprietary specifications.

North American car makers have already used more than 50,000 metric tons of tubing coated with a duplex system consisting of Galfan with an Al-rich epoxy top-coat that typically survives more than 4,000 hours in an ASTM B117 salt spray before the appearance of 5% red rust.

Total production of Galfan-galvanized automotive tubing is estimated at over 300 million meters, most of it produced in the last two years. International Lead Zinc Research Organization (ILZRO), owner of the Galfan patents has now licensed fifteen production lines to galvanize tubing with Galfan in North America. Its Galfan Technology Centre (GTC) provides technology and technical assistance to new licensees.

Considerable interest for Galfan coated tubing in similar sizes and specifications in various refrigeration applications is now developing in other parts of the world as well.

Characteristics of Galfan

GALFAN is a eutectic. A *eutectic* represents a unique temperature-composition point for a system of two or more elements. Lowering the temperature below the *eutectic temperature*, causes a reaction that completely freezes the liquid mixture solid as one phase with no gross segregation of the elements as is the case at non-eutectic points.

Typically, the eutectic composition is that ratio of the elements having the lowest melting temperature and is located at the intersection of the elements' liquidus curves. Figure 1 shows an Aluminum-Zinc Equilibrium Phase Diagram. It shows the melting temperature of the eutectic Zn-5%Al to be 382°C. The eutectic characteristics give Galfan a corrosion mechanism that is different from zinc, aluminum or any other ratio of zinc and aluminum.

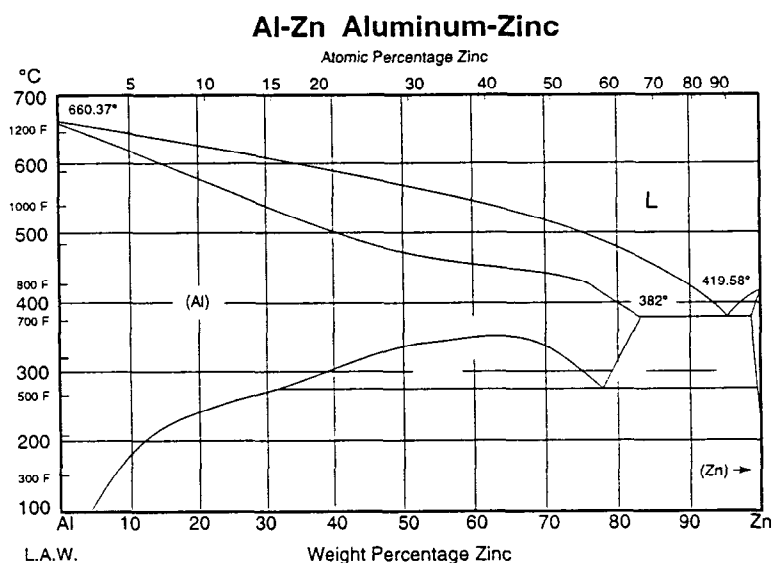


FIGURE 1

Binary Al-Zn Phase Diagram showing Eutectic Point at Zn-5% Al

GALFAN is formable. A hot-dip regular galvanizing coating interfaces with the steel tubing surface by reacting with the iron to form Fe-Zn alloy layers such as seen in Figure 2a. This alloy layer is about 3 μm thick and limits the formability of the tubing because it is very brittle. Galfan's interface shown in Figure 2b is a barely perceptible $\text{Al}_2\text{-Fe}_5\text{-Zn}_x$ intermetallic that is even more ductile than the steel, thus does not limit the tube's formability.

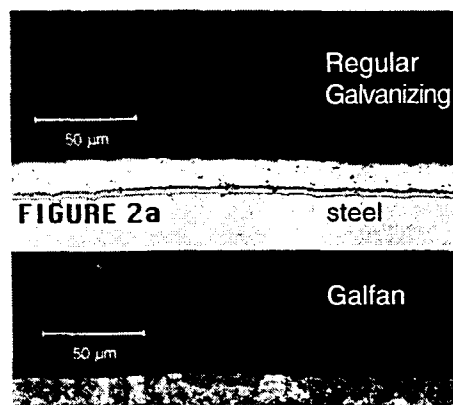


FIGURE 2a

FIGURE 2b

Regular Galvanizing

steel

Galfan

steel

GALFAN is paintable. Its surface is easily passivated and converted with standard pre-treatments to bond to many standard primers and different top coat systems. Adhesion characteristics meet all specifications normally associated with automotive, refrigeration and appliance specifications. The fabricator may choose from a broad range of top-coats to match the particular application requirements with one universal anti-corrosion coating.

GALFAN is synergistic. All zinc coatings are synergistic when used in a duplex system but Galfan provides a higher synergism. Figure 3 shows the synergism of a typical Galfan duplex system using an Al-rich epoxy top-coat.

COATING TYPE	Thickness, microns	Hours, SST
GALFAN (chromated)	8	360
Al-RICH EPOXY	5	1,200
COMBINED TOTAL	13	1,560
GALFAN + Al-RICH EPOXY	13	3,000
SYNERGISM FACTOR		1.90

FIGURE 3

Synergism from Galfan Duplex System on Steel Tubing B117 Salt Spray Test (SST)

GALFAN is solderable. It is soldered or brazed as easily as regular galvanizing with low-melt solders or high-melt braze. Tin-free solders should be used.

Corrosion Mechanisms

Every metallic coating has a *mechanism* by which it corrodes. The mechanism affects the rate at which the coating corrodes and determines whether the corrosion is uniform or non-uniform and other characteristics.

Corrodents in the atmosphere or test environment dissolve metal(s) from the coating that precipitate as oxides of the metal, then dehydrate as hydroxides, after which they combine with elements of the corrodent to form the corrosion products — usually salts or carbonates of the metal.

A single-phase coating such as regular galvanized has one corrosion mechanism but in a non-eutectic alloy coating, each element may behave independently according to its particular reactivity.

The exact corrosion products are dependent upon the coating metal and the corrodent. Industrial atmospheres produce sulfur salts whereas marine environments produce mainly chlorine salts of the metal. The process continues at a near linear rate dependent upon the coating metal's reactivity, the corrodents and cyclical influences such as temperature, humidity, exposure to sunlight, washing, drying, etc.

X-ray Diffraction (XRD) evaluations can be used to determine the composition of the corroded coating's surface. XRD's in Figure 4 compare Galfan and regular galvanized surfaces corroded by the same marine environment for seven years. The corrosion products are seen to be quite different.

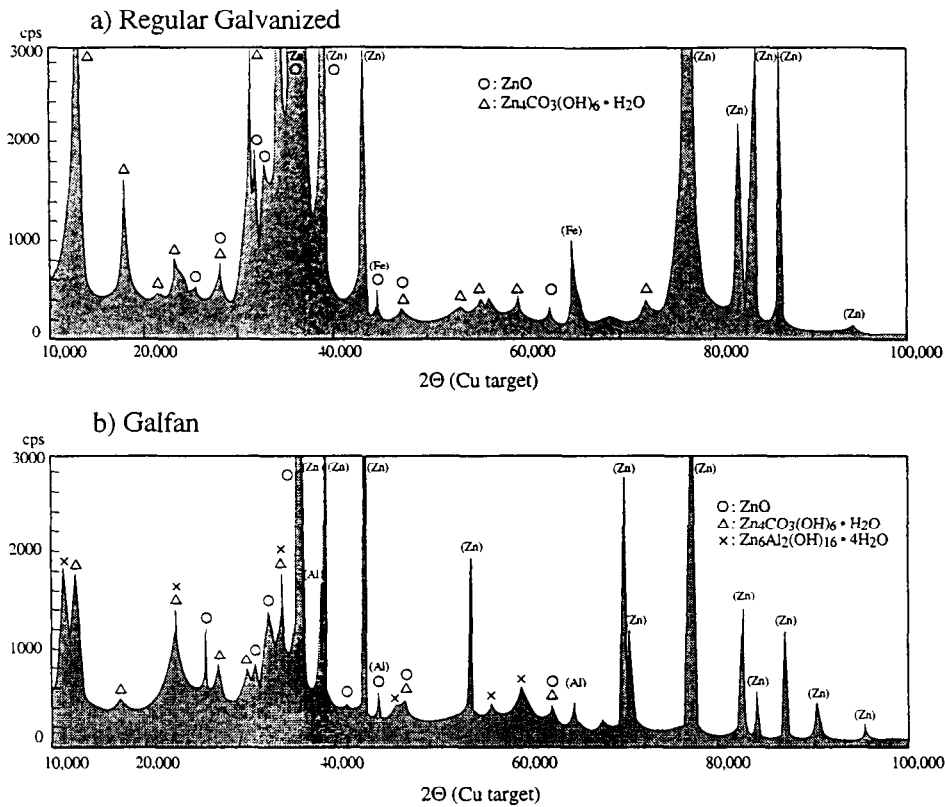


FIGURE 4
X-Ray
Diffraction
Evaluation
of Corroded
Surface.
a) Regular
Galvanized
b) Galfan

Regular galvanized surfaces are mainly zinc hydroxide, zinc oxide and basic salts, chlorides and carbonates. These soft and porous materials allow preferential pathways for local corrosion to occur.

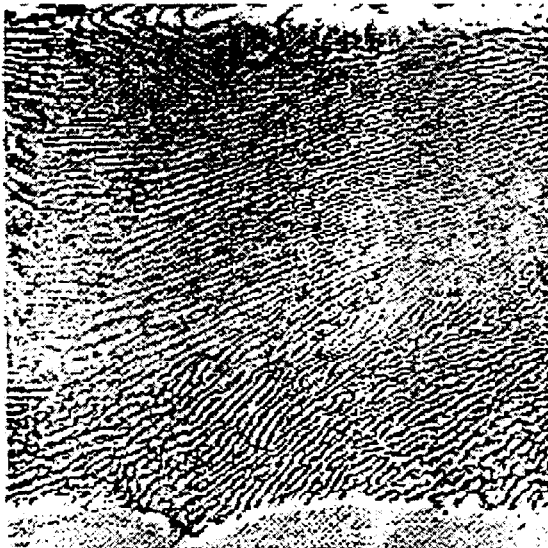


FIGURE 5
Fully Eutectic Galfan Microstructure
Aluminum areas are light, zinc areas are dark

Galfan's corroded surface however, is a complex zinc-aluminum carbonate-hydroxide that is hard and relatively impervious to corrodents and has a low electrical conductivity. The surface forms an even harder patina as it becomes increasingly Al-rich. *Galfan's resistance to corrosion improves with exposure time.*

Galfan's corrosion is non-linear because of its corrosion mechanism. Galfan's eutectic microstructure places the zinc and aluminum so close to each other that they work together as a unique material, not independently as individual elements. See Figure 5.

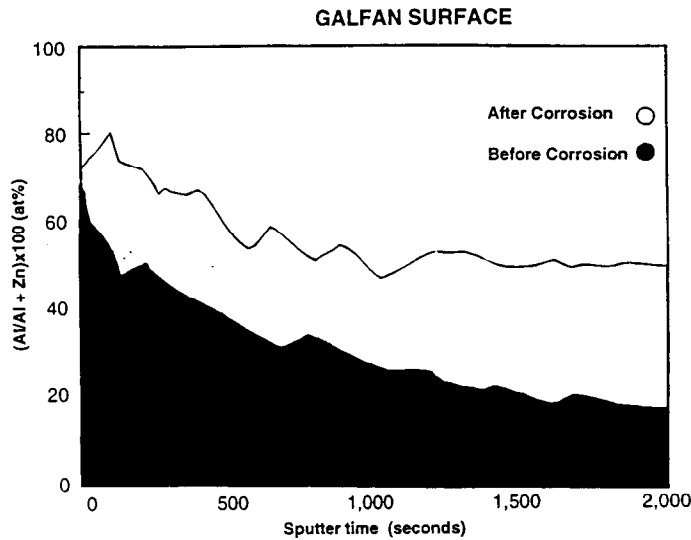


FIGURE 6
AES Evaluation of
Aluminum composition
of the Galfan Surface

The zinc-rich lamellae, being the more reactive, corrode first to form $Zn(OH)_2$ and ZnO . The aluminum-rich lamellae then corrode to form $Al(OH)_3$ and Al_2O_3 . These compounds combine with the corrodents to form a complex $Zn_6Al_2(OH)_{16}CO_3$ and H_2O . The Galfan surface becomes increasingly aluminum-rich with exposure and corrosion, thus more passive with time. Auger electron spectroscopy (AES) in Figure 6 shows this composition change.

This unique characteristic may be observed in short-term accelerated tests as well as long-term outdoor exposure testing.

Tests Prove GALFAN is More Corrosion Resistant

Salt Spray Tests (SST). Although salt spray tests (SST) on zinc-coated products are poorly correlated to actual outdoor performance, they are relatively simple and inexpensive. ASTM Specification B117 establishes specific test conditions and procedures so SST may be universal and repeatable.

Galfan's improved corrosion resistance can, however, be demonstrated using SST. Figure 7 is the result of SST that demonstrates regular galvanizing shows 5% red rust much earlier and with more coating loss than with Galfan. Galfan's rate of corrosion to 5% red rust is only 1/5 that of regular galvanizing.

ASTM B117 SALT SPRAY TEST REGULAR AND GALFAN GALVANIZING ON WIRE			
TYPE COATING	STARTING COATING WEIGHT g/m ²	HOURS TO 5% RED RUST	RATE OF COATING LOSS, g/m ² /hr
REGULAR GALVANIZING	182	192	0.94
GALFAN	144	768	0.19
GALFAN PERFORMANCE RATIO			5:1

FIGURE 7

Kesternich Tests. The SO₂ Kesternich test correlates better to outdoor exposure in industrial environments than SST. Figure 8 shows results of a Kesternich cyclical corrosion test (CCT) in which each cycle consists of two phases:

8 hours in chamber @ 40°C, 100% RH, 1l SO₂
 16 hours in chamber @ 25°C, 75% RH, no SO₂ after water rinsing

The test is ended when the test specimen shows 5% red rust. This test shows Galfan to be 3.2 times more resistant to CCT corrosion than regular galvanizing.

KESTERNICH SO ₂ CYCLICAL TEST			
REGULAR AND GALFAN GALVANIZING ON 4mm WIRE			
TYPE COATING	STARTING COATING WEIGHT g/m ²	CYCLES TO 5% RED RUST	RATE OF COATING LOSS, g/m ² /cyc
REGULAR GALVANIZING	550	15	36.7
GALFAN	275	24	11.4
GALFAN PERFORMANCE RATIO			3.2:1

FIGURE 8

Electro-chemical Tests. Electro-chemical evaluation is an even better correlation to the actual corrosion in an outdoor environment. This test finds the corrosion *potential* and corrosion *current flow* of a specimen in a specified corrosion media by measuring the electrical potential and the current flow between a standard calometric electrode (SCE) and the test specimen.

Figure 9 shows the corrosion potential of regular galvanized and GALFAN are similar in oxygen-flushed seawater as an electrolyte, about -1.035 volts.

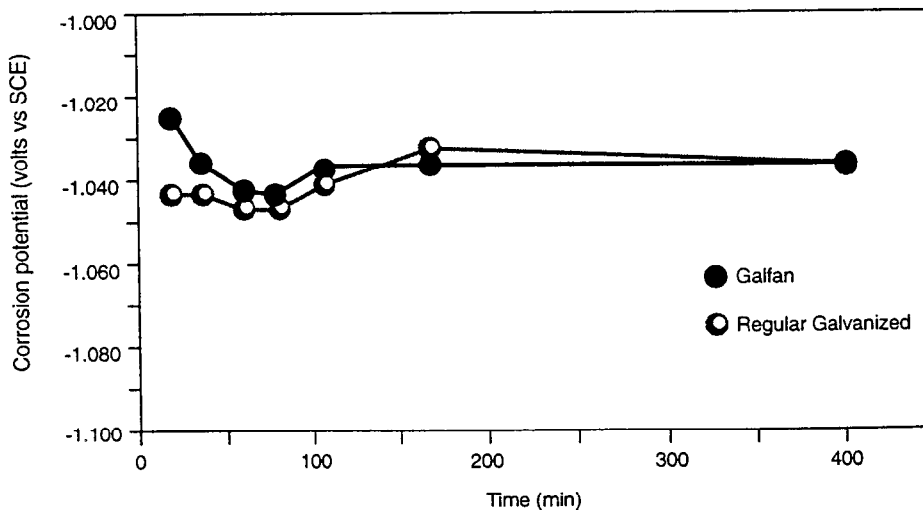


FIGURE 9
 Comparing the Corrosion Potential of Regular Galvanized Wire and Galfan Galvanized Wire in Oxygen-flushed Seawater.

A big difference is seen however, when series-connecting a galvanometer and potentiostat between the SCE and the test specimen to measure corrosion current. Higher current flow indicates a faster rate of corrosion. Figure 10 shows that the corrosion current flow for regular galvanizing is more than six times that of Galfan.

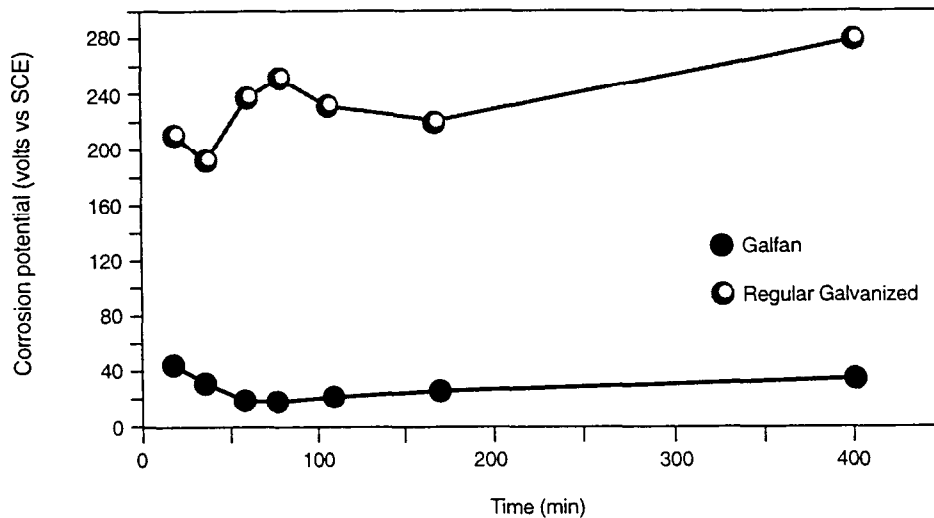


FIGURE 10
Comparing the Corrosion Current of Regular Galvanized Wire and Galfan Galvanized Wire in Oxygen-flushed Seawater.

Outdoor Exposure Tests. The most reliable and accurate tests are long-term exposures of test panels in outdoor environments because these are better simulations of what the product will experience in the real world.

Figure 11 shows actual data from tests exposing panels for ten years in an industrial atmosphere. The actual ten-year results are extrapolated to thirty years. Because of Galfan's parabolic behavior, it can be seen that Galfan's performance ratio as compared to regular galvanized improves with time. It is slightly more than 2:1 at the end of ten years, but will be 3:1 at thirty years.

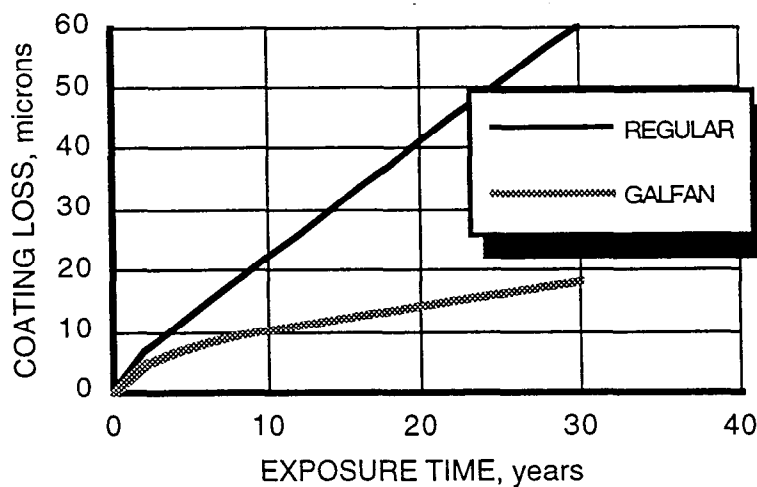


FIGURE 11
Regular Galvanizing and Galfan Coating Loss on Sheets in Industrial Atmosphere.

10th to 30th years extrapolated

Galfan's Formability

Formability is a non-dimensional term used to indicate a material's overall ability to form or be deformed without compromising its properties by combining several measurable characteristics. Figure 12 shows several characteristics for different metal coatings. The lower the coefficient of friction and draw load, the more easily formed. Higher lifting dome heights mean a greater resistance to cracking when the part is stretched.

The absence of the hard brittle Fe-Zn alloys at the interface makes Galfan more ductile than the steel substrate. Thus Galfan does not limit the deformation of the coated tube.

Bending, swaging, stretching, crimping and other forming operations with Galfan can be done to limits beyond those of other metallic coatings. Figure 13 shows that Galfan maintains its corrosion resistance advantage in the deformed conditions.

FIGURE 12

FORMABILITY TEST RESULTS					
FORMING PARAMETER	SPECIMEN: Coating Type				
	ELECTRO GALV EG	REG GALV Z185	GALV- ANNEAL A120	COLD ROLLED AKQD	GALFAN ZA185
THICKNESS: Coating μm	9	15	7	0	10
THICKNESS: STEEL, mm	0.84	0.69	0.79	0.84	0.74
COEFFICIENT OF FRICTION*	0.010	0.020	0.025	0.015	0.015
LIFTING DOME HEIGHT **	39.0	39.0	35.0	38.5	42.0
DRAW LOAD, kN***	80	70	80	84	71

* Steel beads, dry film lubricant

** Hardened steel punch, dry film lubricant

*** Hardened steel die, dry film lubricant

Production Technology

The Process Section of a production line built for coating tubing with Galfan is similar to other continuous hot-dip coating line designs. It includes three sub-sections; namely,

- (1) Steel surface preparation section
- (2) Hot-dip coating section
- (3) Coated surface finishing section

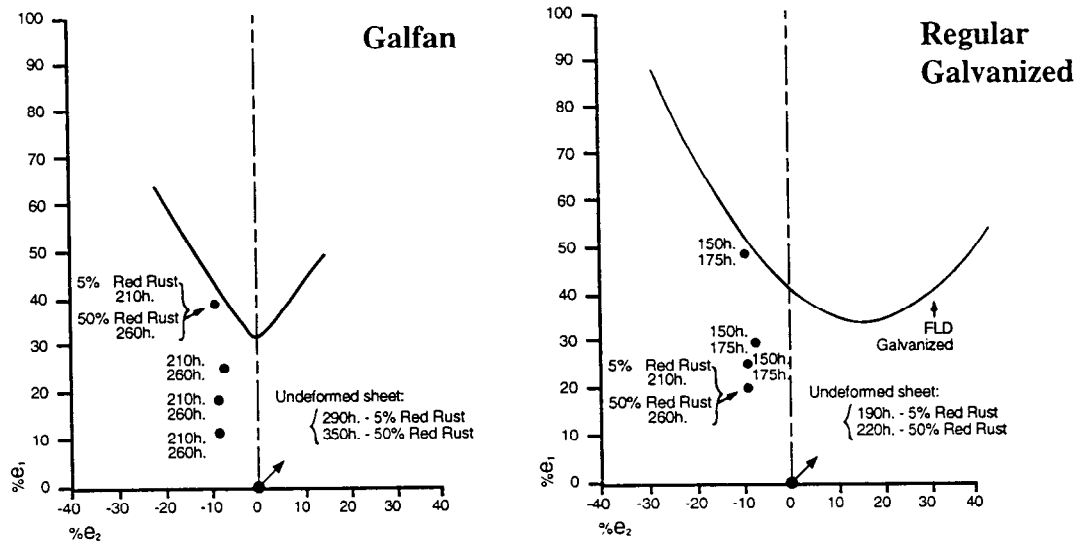


FIGURE 13 Form Limit Diagrams for Regular Galvanizing and Galfan Showing Effect of Major/Minor Strain (e_1/e_2) on Hours to Red Rust in Salt Spray Tests.

There are three basic methods (although many variations of each) for the steel surface preparation section in a hot-dip coating line. These can be identified as:

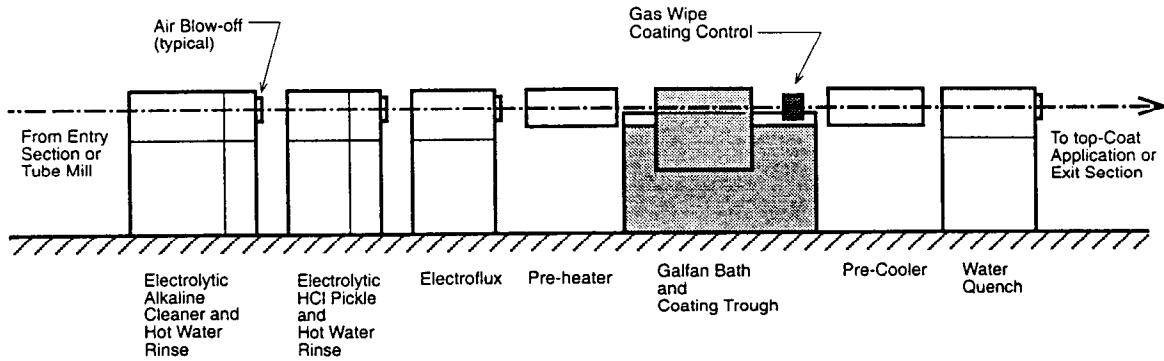
- Type 1 Cold Chemical
- Type 2 Hot Chemical
- Type 3 Hot Mechanical

The final coating characteristics will be similar. The choice of line type is mainly one of cost, convenience, experience or versatility. Figure 14 shows the three basic types in diagram form.

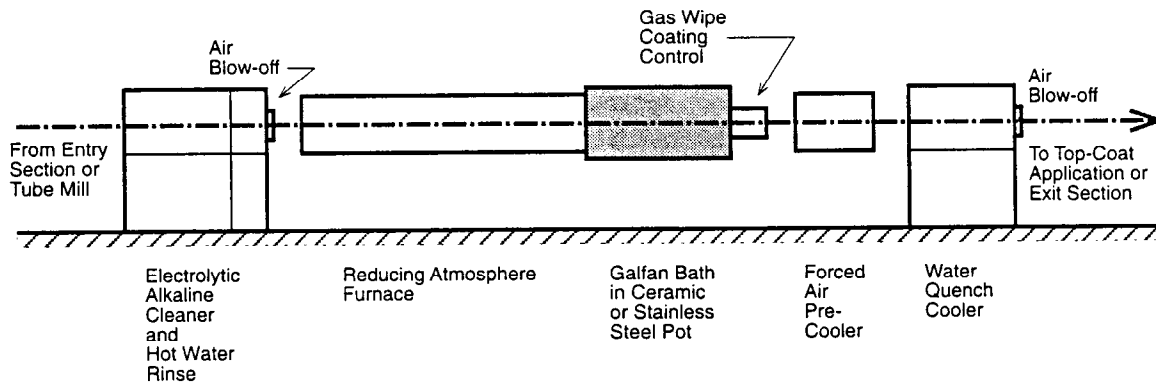
Steel Clean-ness. The steel surface must be cleaner for Galfan coating than for most other hot-dip coatings. If the tubing is contaminated with more than $0.4 \mu\text{g}/\text{cm}^2$ of dirt and soil, a rough and non-uniform Galfan coating may result.

This requires that the tubing be cleaned in an alkaline solution and thoroughly water-rinsed before any other surface preparation can be effective. Lines operating faster than 60 mpm must use an *electrolytic* alkaline cleaner and, depending upon the incoming surface contamination, may require a pre-cleaner ahead of the electrolytic cleaner.

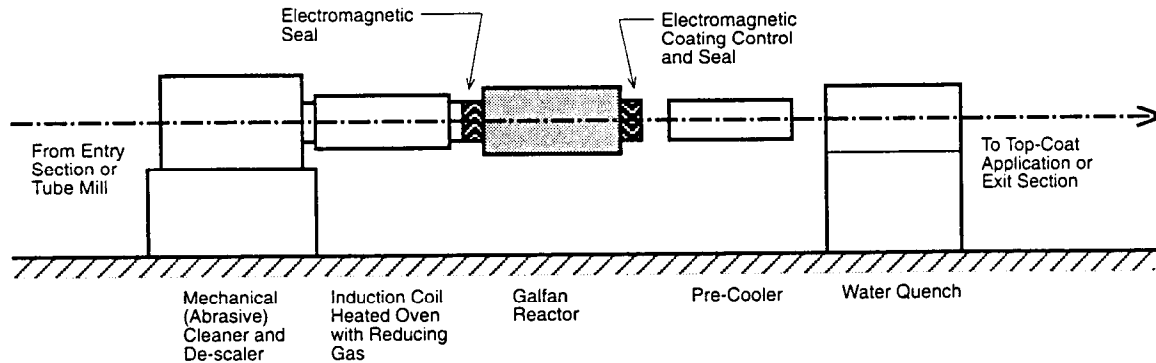
Scale and oxides of iron are removed by chemical dissolution with a solution of hydrochloric acid (type 1 line) or by a reducing gas such as hydrogen at an elevated temperature (type 2 line) in a low dew-point atmosphere. Alternatively, a type 3 line replaces both the soils and oxide removal processes with one that mechanically abrades the tubing surface until clean new metal is exposed.



GALVAN TUBE-COATING PRODUCTION LINE
Type 1: Cold Chemical (Flux)



GALVAN TUBE-COATING PRODUCTION LINE
Type 2: Hot Chemical Line



GALVAN TUBE-COATING PRODUCTION LINE
Type 3: Hot Mechanical

If the tubing must enter the Galfan bath below the bath temperature, it must be fluxed with an aqueous ZnCl solution and additionally, if it enters below 300°C, the Galfan will have difficulty wetting the steel. The Electroflux™ method may be used to electro-deposit a thin layer of zinc on the tubing surface as it passes through the flux solution so the Galfan bath need only wet the zinc.

Most lines use a coating bath arrangement that allows the tubing passline to remain horizontal. Some lines that coat thin-wall small diameter tubing immerse the tubing into the bath by deflecting it downward between entry and exit deflector rolls.

Conclusions

Galfan is an improved galvanizing system including a patented alloy of Zn-5%Al-MM used as a hot-dip coating in a continuous galvanizing line. Although the processes for preparing the steel for hot-dipping are conventional, they must be better controlled than minimal requirements for other coatings.

The major improvements for application on steel tubing include greater corrosion resistance, better formability, better paintability and low cost. Many different top-coat systems are used successfully to form duplex or triplex systems with Galfan as the anti-corrosion sacrificial coating between the top coat and the steel tube.

Galfan has been proven in extensive testing as well as in the use of nearly 4,000,000 metric tons of steel in sheet, wire and tube applications.

References

Much of the material used in this paper is taken from reports by Galfan licensees presented to regular Galfan licensee meetings. Special recognition is given for the use of data and figures as follows:

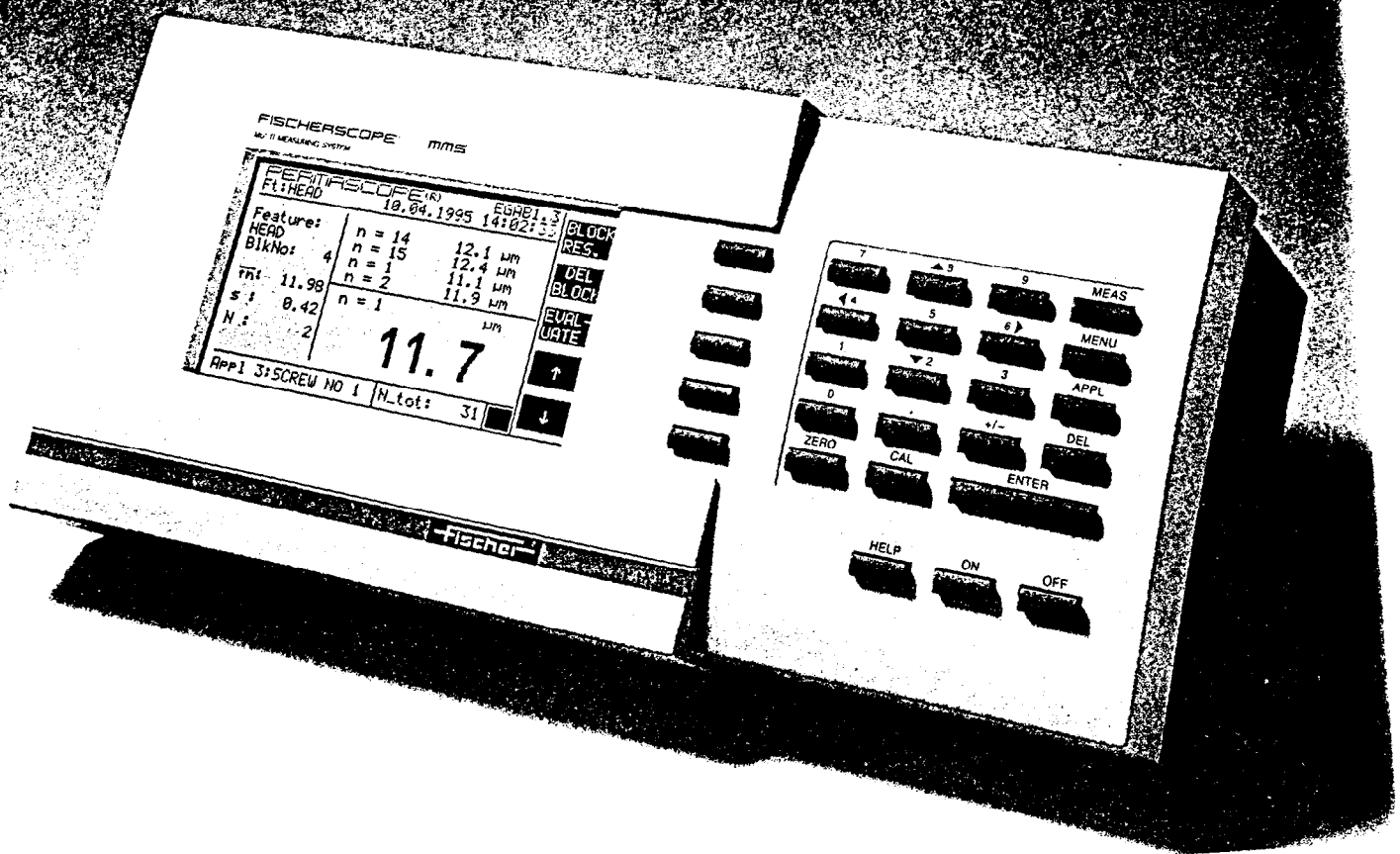
Figs. 2 and 3:	Decktec, Inc.
Figs. 4 and 11:	Nisshin Steel Corp.
Figs. 6 - 10:	N. V. Bekaert Co.
Fig. 12	Hoesch Stahl

FISCHERSCOPE® MMS

Fischer®

FISCHERSCOPE® MMS

Universal Coating and Material Property Measurement System



A compact and extremely versatile desktop multi-function measuring system for non-destructive measurement, data archiving and measurement data processing applications. The operator can

- measure coating thicknesses and other material properties according to different non-destructive test methods;
- document, manage and evaluate data according to customer specifications

and quality system requirements;

- define control charts and evaluate measurement data using modern SPC/SQC methods;
- organize collected measurement data.

The extensive capabilities of this instrument make it one of a kind – worldwide.

Automation of measurement processes and monitoring production are other uses of the MMS. The full statistical

capabilities of the MMS Software provide for the evaluation of a few single measurements or series of thousands of measurements according to user defined criteria.

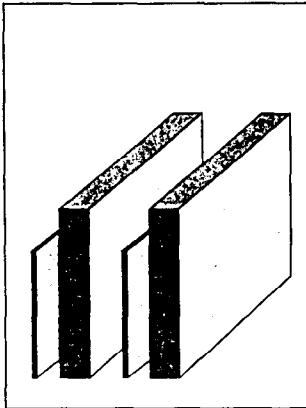
The MMS system is frequently used for full control and monitoring of round the clock production processes. Millions of measurements have already been evaluated by users of the MMS system.

Test methods	magnetic induction, Hall effect, Eddy current, and Beta backscatter test methods for coating thickness measurement and the measurement of electrical conductivity and delta ferrite content in weld metal or duplex steels.
Hardware design	Ergonomic and attractive housing; modular design concept for different test method module installation; the MMS can easily be retrofitted with different modules as requirements change.
Measurement probes	All FISCHER magnetic induction, Hall effect and Eddy current smart probes, Beta backscatter measuring tables and hand probes can be connected to the base unit. A maximum of 5 probes can be connected simultaneously.
Peripheral instruments	RS232 and parallel ports to connect a computer or printer . Connector for external start switch and control signal outputs for specification limit monitoring. Contact closures with external adapter.
Power supply	AC 11 V / 0.8 A from external A/C line adapter.
Dimensions	WxHxD: 350 x 140 x 190 mm (13.8" x 5.5" x 7.5")
Weight	3 kg (6.6 lbs) when fully equipped.
Software design	User friendly menu driven interactive dialogue concept.
Data entry	Clear functional keyboard design for numeric entries and pre-programmed functions; 5 softkeys with menu-sensitive functions, alpha-numeric character entry from character matrix for application and feature descriptions. Security mode available.
Display	Large high-contrast flat screen LCD display (126 x 70 mm – 5.0" x 2.75"). Alphanumeric display to indicate active measurement module, active probe, date and time, measurement data, name of application, and selected feature.
Measurement presentation choices	Large numeric display of the current reading plus window showing the previous 4 measurements with consecutive measurement number, or graphic presentation of measurements within defined specification limits, or SPC control chart display, or difference measurement display (for measurement of specimens with multi-layered coatings). Unit of measurement selectable depending on the application: metric or U.S. units, Ferrite % or WRC-FN; Celsius or Fahrenheit; %IACS or MS/m conductivity units.
Measurement capture	Automatic measurement capture with acoustic signal after probe placement, external start, continuous data display mode or automatic periodic capture after probe placement with selectable time intervals. Deletion of current or preceding measurement / measurement group. Corrective remeasure possible. Automatic data capture after n measurements possible. Ability to enter offset value to be added or subtracted from current reading.
Data evaluation:	Full statistical evaluation of measurement series with mean value, standard deviation, coefficient of variation, maximum and minimum, number of measurements, statistics for single readings and groups; calculation of the process capability indices Cp and Cpk; Skewness; Kurtosis; outlier (freak measurement) rejection; histogram; normal probability chart with test for normal distribution; automatic grouping after n measurements and/or automatic final evaluation after N groups; group evaluation according to group numbers or features.
Measurement data memory	Dynamically allocated data memory for a total of 20,000 measurements that can be distributed into a maximum of 50 application memories; alphanumeric application names, group identification by feature, operator, order number, part number and time/date.
Calibration	Normalization (analogous to a zero correction using the bare substrate material only), corrective calibration using one or two thickness standards (foils), calibration using coated part (when bare substrate is not available). Normalization and corrective calibration saved in current application memory. Master calibration with 4 standards to generate a new master probe characteristic for storage in the memory chip of the active smart probe (does not apply to plug-in testing module BETASCOPE*).
Documentation	Printout of single readings, block results and cumulative final results; specification limits, SPC control charts, histogram, normal probability chart, customer specific print form with selection of the data to be printed can be generated and downloaded to the MMS with separate PC Software. Ability to store up to 5 different print form templates; application-related on-line/off-line output of the measurement data via RS232 to external computer.

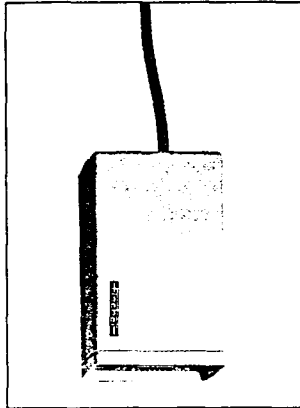
		Order no.
Basic Versions	FISCHERSCOPE® MMS Module PERMASCOPE®	602-110
	FISCHERSCOPE® MMS Module TM85	602-269
	FISCHERSCOPE® MMS Module DUPLEX	602-251
	FISCHERSCOPE® MMS Module NICKELSCOPE®	602-217
	FISCHERSCOPE® MMS Module SIGMASCOPE®	602-156
	FISCHERSCOPE® MMS Module BETASCOPE®	602-155
Plug-in Testing Modules	PERMASCOPE® MMS Plug-in Testing Module (8/8*)	602-264
	TM85 MMS Plug-in Testing Module (8/8*)	602-263
	DUPLEX MMS Plug-in Testing Module (14/19*)	602-268
	NICKELSCOPE® MMS Plug-in Testing Module (14/19*)	602-265
	SIGMASCOPE® MMS Plug-in Testing Module (14/19*)	602-266
	BETASCOPE® MMS Plug-in Testing Module (5/2*)	602-267
	* required probe connector panel Note: Any up-grade of the basic instrument version with additional plug-in testing modules is possible. Exception: plug-in testing modules PERMASCOPE® MMS and TM85 MMS cannot be combined in one instrument. Only one of these modules can be installed. Plug-in testing module DUPLEX MMS also requires a plug-in testing module SIGMASCOPE®.	
Connector Modules	Connector MMS Module 8/8	602-272
	Connector MMS Module 14/19	602-273
	Connector MMS Module 5/2	602-271
Accessories Module BETASCOPE®	Measuring Table Z14NG	602-250
	Universal Measuring Table Z6NG	602-261
	Small Components Fixture grey	602-371
	Hand Probe Z9NG	600-460 (C 05.05)
	Angle Probe Z11NG1	600-471 (C 06.05.01)
	Centering Device for Z9NG	600-461 (C 05.05.01.01)
	Adapter for beta probe	600-550 (C 08.10)
Accessories Module TM85	Test Station TM85	601-954 (B 01.71.10)
Accessories	Support Stand V12	602-260
	Magnetic Fixture	600-019 (A 01.02.09.01)
	Rotary Fixture	600-815 (A 03.01.09.02)
	Jig for Angel Probes	600-077
	Jig for Inside Probes	601-691
	Adapter for Contact Marker	602-270
	Footpedal	600-152 (A 03.88.03)
	Alphanumeric Line Printer F3100	601-962 (P 01.06)
	Interface MMS/PC-AT SET	602-220
	Interface Cable MMS/MP3-4	602-386
	Interface Cable MMS/MP0S	602-387
	Report Software MMS	602-388
	Temperature Probe TF100	602-365
TF100 Plug-in Testing Module	602-366	

FISCHERSCOPE® MMS System Concept

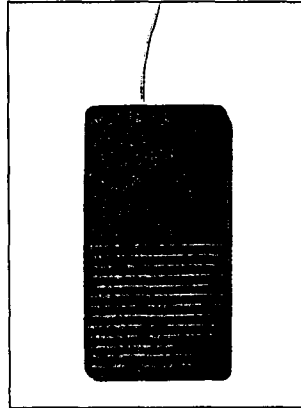
Plug-in testing modules for various test methods



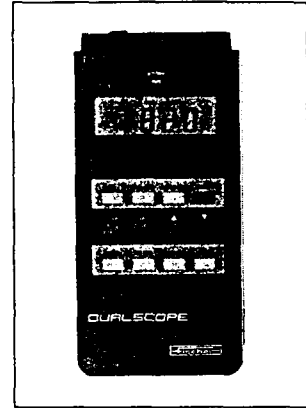
Adapter for contact closure output



Foot switch for external measurement triggering



Measurement data transfer from FISCHER hand-held instrument to MMS



Test method modules

The FISCHERSCOPE® MMS base unit is the heart of the system. Different probes and peripheral instruments can be connected to the base unit. Different plug-in testing modules are installed depending on the instrument version. From a broad assortment of probes, modules and other accessories the user can configure the MMS according to his particular measurement tasks.

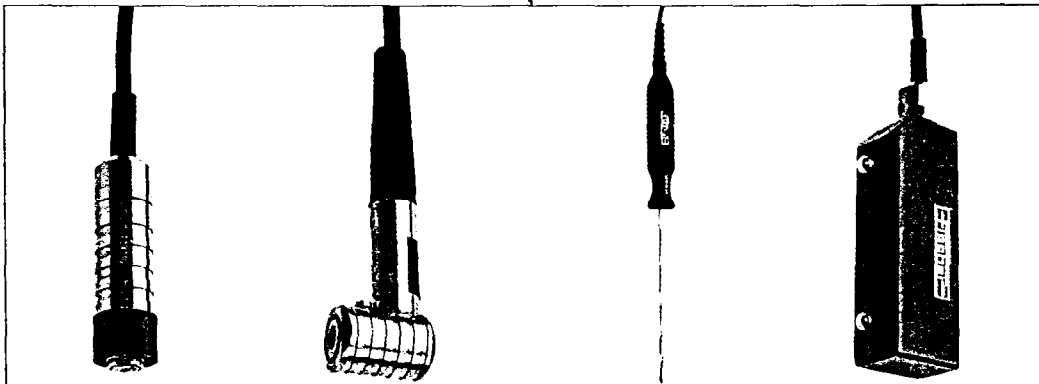
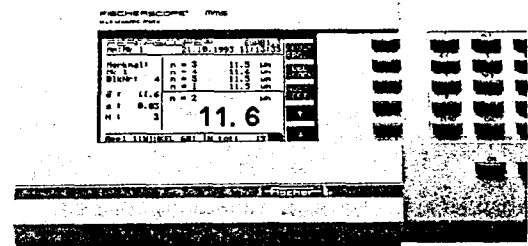
The advantage of the modular system concept becomes immediately apparent: while in the past different instrument models were required for the various test methods, they can now be combined into one universal instrument.



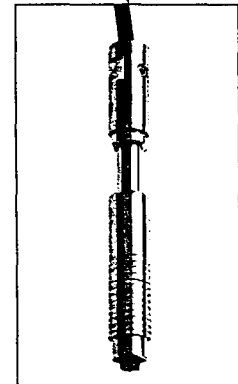
Probes

The FISCHERSCOPE® MMS features a modular design to offer each customer an instrument configuration that is just right for his application. Any desired instrument configuration can be produced using the six available plug-in testing modules. If additional applications are required at a later time, the instrument is retrofittable. Important is the selection of the proper probe. Basically, the

measurement system operates with any FISCHER E-type smart probe and with BETASCOPE® probes/tables. The flexibility of the instrument is in no way limited by the available probe choices considering that FISCHER continues to broaden the wide assortment of standard and special purpose probes.



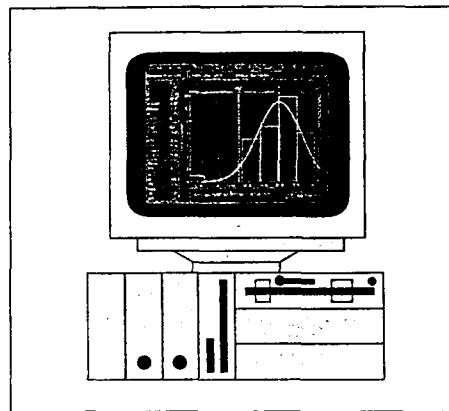
Probes and measuring tables for... coating thickness measurements according to the Hall effect, magnetic induction, and Eddy current methods



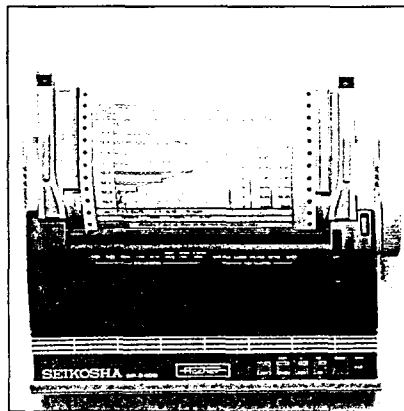
... ferrite content measurement

Use external personal computer for:

- Data evaluation and storage
- Print form template design



Use a printer to document the measurement results



Documentation

Every FISCHERSCOPE® MMS features the interface(s) necessary to transfer data to a printer, PC or other data collecting device. Even data transfer to the MMS from FISCHER hand-held instruments is possible.

Therefore measurements taken on site with the hand-held instrument can be transferred to the FISCHERSCOPE® MMS using the instrument's data management and evaluation capabilities.

The MMS measuring system is universal

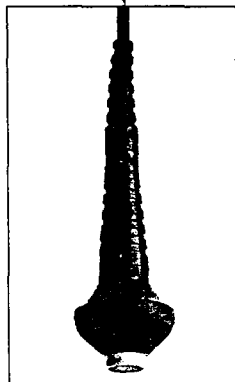
Different probes can be connected to one and the same base unit: all FISCHER E-types smart probes – magnetic, magnetic induction, and Eddy current probes (even future models). In addition: Beta backscatter transducers and probes to measure the electrical conductivity and the ferrite content.

The MMS measuring system is flexible

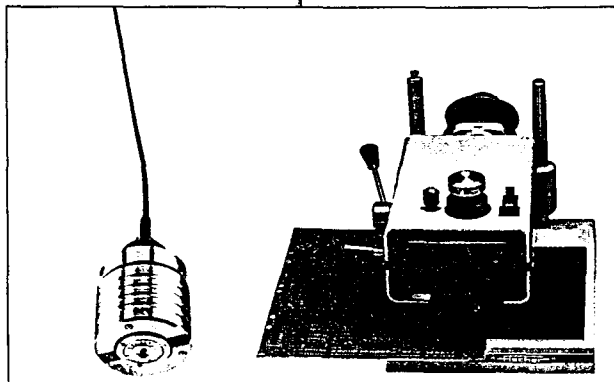
In its most simple version, the MMS is an instrument for magnetic induction and Eddy current coating thickness measurement (PERMASCOPE®). In a fully equipped version the MMS combines five instruments in one. Between these two extremes are numerous other possible instrument configurations which can be expanded at any time to meet the needs of the user.

The MMS measuring system is easy to operate

The instrument features a high contrast large area LCD display and a tactile feedback keyboard. The operator can handle all measurement, storage, evaluation, and documentation tasks through an interactive dialogue with the system. Operation is simple, easy to learn, and uniform for all test methods.



... electrical conductivity measurement



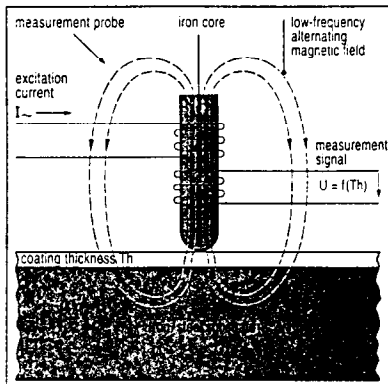
... coating thickness measurement according to the Beta backscatter method

A broad spectrum of test methods

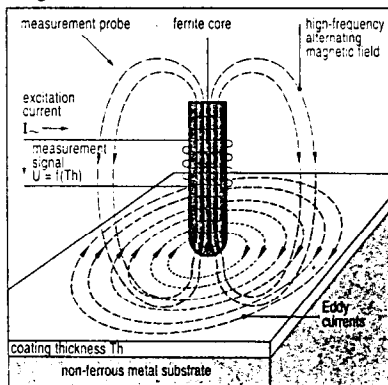
Different applications require different test methods. The FISCHERSCOPE®

MMS can combine the most commonly used non-destructive test methods in one measuring system. The measuring system operates according to the

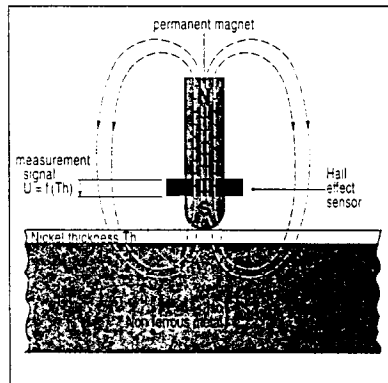
required test method by using specific probes and corresponding testing modules.



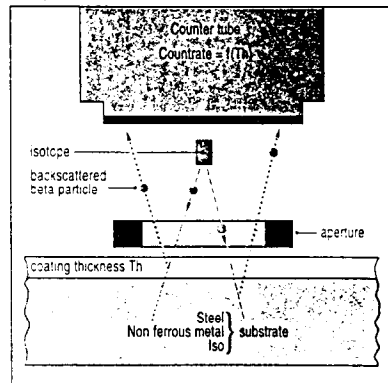
Magnetic induction method



Eddy current method



Magnetic method



Beta backscatter method

Magnetic induction method (DIN 50981, ASTM B499, ISO 2178) used to measure

- non-magnetic coatings on ferromagnetic substrates such as zinc, chromium, copper, tin, or paint, plastic, enamel on steel;
- delta ferrite content in austenitic weld metal or duplex stainless steel.

Eddy current method (DIN 50984, ASTM B244, ISO 2360) used to measure

- electrically non-conductive coatings on non-ferrous metals such as paint, powder coatings, plastics on aluminum, brass, or zinc and anodized coatings on aluminum;
- poorly conductive non-ferrous coatings on electrically good conducting non-ferrous metals, such as chromium, or electroless nickel on copper, aluminum, or brass.

Modified Eddy current method used to measure:

- metallic coatings on electrically non-conductive or ferromagnetic substrates, e.g., copper on epoxy, zinc on steel and nickel on steel;
- the electrical conductivity of non-ferrous metals.

Magnetic method (Hall effect) (DIN 50981) to measure

- electroplated nickel coatings deposited on el. non-conductive or non-ferrous substrates;
- non-ferrous metal coatings, e.g., copper, aluminum, or lead coatings on steel (advantage: no Eddy current errors when measuring thick non-ferrous coatings).

Beta backscatter method (DIN 50983, ISO 3543, ASTM B567, BS5411)

This test method offers a great deal of versatility and can be used to measure:

- paint, plastic, enamel, ceramic and phosphate coatings on metals and some non-metals;
- metal coatings on other metals and non-metals, including some coatings too thick for the X-ray test method.

Test method basics

Contacting test method. A low frequency AC excitation current generates a low frequency magnetic field. The magnetic flux density depends on the distance between the measurement probe and the ferromagnetic substrate. A probe output signal is generated by means of a pick-up coil. In the instrument, the measurement signal is translated to coating thickness based on the probe characteristic and a suitable mathematical conversion model.

Test method basics

Contacting test method. A high-frequency magnetic field induces Eddy currents in the conductive substrate material. The magnitude of these Eddy currents depends on the distance between the probe coil and the substrate material. The measurement signal is derived from the reflected impedance change in the probe coil as a function of the Eddy currents generated in the substrate material.

Test method basics

Contact-free test method. The magnitude and direction (phase angle) of the Eddy current probe signal is evaluated to measure the coating thickness. The method provides for probe „lift – off“ compensation, which allows contact free measurement applications. The test method is particularly useful to measure contact free on rough surfaces. The method also can be used to measure the electrical conductivity of non-ferrous metals because it is inherently sensitive to changes in the electrical conductivity.

Test method basics

Contacting test method. A permanent magnet generates a constant magnetic field. The field strength will depend on the thickness of the nickel coating to be measured. When measuring non-ferrous coatings on steel, the field strength will be proportional to the distance between the probe tip and the steel substrate. The magnetic field strength is measured with a Hall effect sensor, from this signal the coating thickness is calculated.

Test method basics

This test method uses a beta particle (electron) emitting isotope, an aperture and Geiger Müller tube detector. The isotope is located so that a collimated beam of beta particles is directed through the aperture onto the coated test specimen. A portion of these particles is „back-scattered“ through the aperture to penetrate the window of the GM tube. The coating thickness is proportional to the rate of backscattered particles.

Interactive dialog with the operator

The FISCHERSCOPE®MMS includes powerful but easy to operate software. The software enables the MMS to:

- inform and guide the operator by means of a large flat screen LCD display and the keypad;

- process measurement data efficiently, save data in a particular order, evaluate the data according to certain criteria or transfer the data;
- integrate the measurement system in a higher flow of information, e.g., as part of a complex quality management system.

It is important that the operation of the unit is independent of the test method in use. No matter which test method is employed, the user interface remains the same.

Ergonomic aspects are very important for the operator of the instrument, the easy to read data display allows the operator to discern important information immediately, positive avoidance of errors ..., all these aspects have been taken into consideration during the design of the instrument. The large numeric display mode allows reading of the measurements even from a distance.

Data presentation in the form of quality control charts can be used to monitor and control production processes (e.g., coating processes). The FISCHERSCOPE®MMS evaluation software provides full SPC/SQC support capability.

A histogram with automatic selection of class limits and normal probability chart can be displayed and printed with the push of a button. This presentation allows for a quick visual evaluation of the process, particularly useful to see if measurements follow a normal distribution.

The specification limits are freely selectable to allow for control of the process to be monitored using the control chart display. Measurement subgroups are separated by vertical bars.

In today's quality conscious environment, user or customer specific documentation of the measurement result is a service the customer expects from his supplier. Often, documentation of the coating thickness and of other material properties is a stipulation.

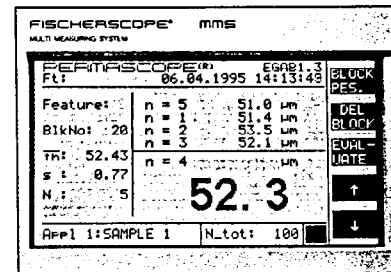
Only the information necessary for the measurement process is displayed. The last or selected measurement is enlarged allowing for clear readability.

The operator is presented with a real time control chart just by making a simple presentation mode selection. The chart appears as a graphics display on the screen while measurement are made. The control chart can be printed if required. Process capability indices Cp and Cpk as well as Kurtosis and Skewness which are important to evaluate the process quantitatively, are calculated continuously.

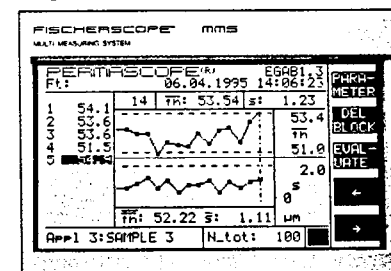
If the distribution is not normal, either the number of samples measured must be increased, or the process is not under statistical control, or the process is not normally distributed by nature. Suitable measures must be taken to eliminate possible assignable causes still present. Only when the measurements show normal distribution can the usual known rules for a capability evaluation be applied.

When a subgroup of measurements is finished, the subgroup evaluation data is displayed at the push of a button. The result includes number and percentage of measurements that violate the upper and lower specification limits.

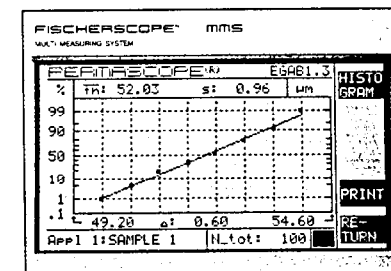
In addition to the standard print form template included, a separate PC based program allows the creation and downloading of up to five customer specific print form templates. They are stored in the FISCHERSCOPE®MMS and are readily accessible for final and batch results evaluation.



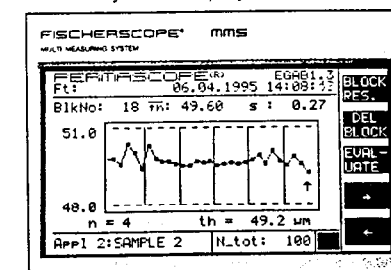
Large numeric display mode



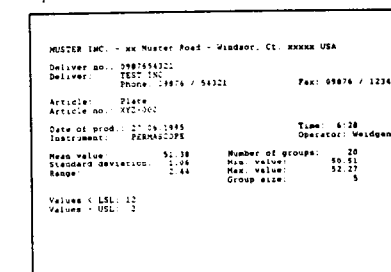
Real time control chart display mode



Probability chart display mode



Specification limit display mode

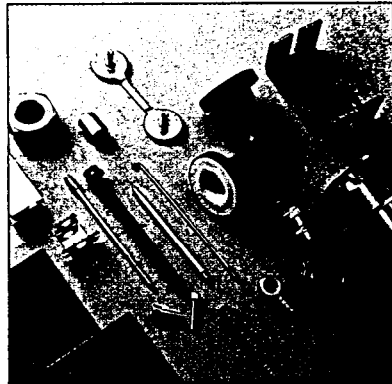


Example for a customer specific print form

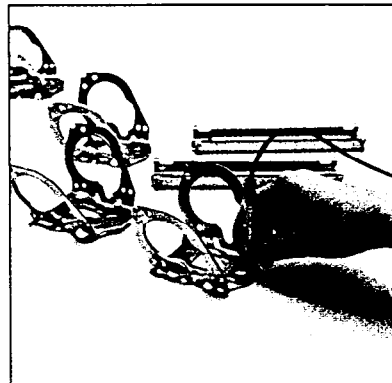
With its broad range of applications, the FISCHERSCOPE® MMS replaces all preceding FISCHER bench top instruments which were based on the test methods

available to the MMS. From a total of 6 different modules, the operator can select the right one(s) for his application. If the application changes,

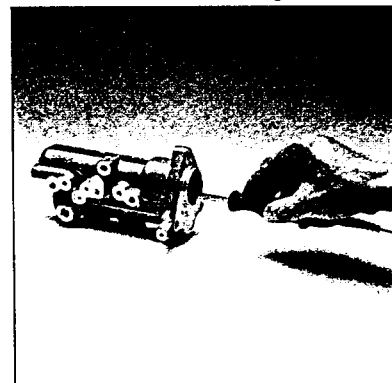
the system can be retrofitted with other modules at any time.



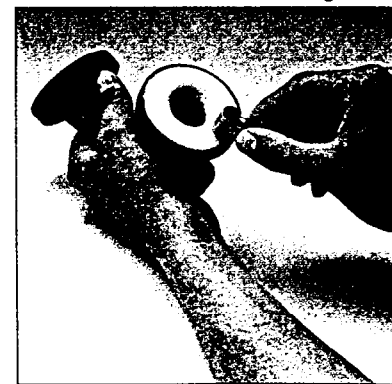
Examples of test specimens



Measurement of zinc coatings



Measurement of anodized coatings



Measurement of an enamel coating

FISCHERSCOPE® MMS Module PERMASCOPE®

Test method

- Magnetic induction method. All type EG...; EK...; V1E...; V6E... probes can be connected
- Eddy current method. All type ET...; EA... probes can be connected.

Application

- High volume electroplating
- Automotive industry
- Paint production and application
- Aerospace industry, metal industry
- Chemical industry
- Etc.

FISCHERSCOPE® MMS Module TM85

Test method

- Magnetic induction method. All type EG...; EK...; V1E...; V6E... probes can be connected
- Eddy current method. Only the F/B container measuring system TM85 can be connected.

Note: cannot be combined with the PERMASCOPE® module.

Application

- Coating thickness measurement on the inside and outside of cylindrical tubes and beverage containers made of aluminum. The system can also be used to measure coatings on flat material.
- Thickness of thin plastic foils

FISCHERSCOPE® MMS Module DUPLEX

Measurement method

- Combination of magnetic induction and Eddy current method. The type ESG2 probe can be connected.

Note: only in combination with the SIGMASCOPE® module.

Application

- One-step measurement of the individual thicknesses of a paint/zinc coating system (duplex coating) on steel, e.g., in galvanizing plants, in the automotive supply industries, in metal industries

FISCHERSCOPE® MMS Module NICKELSCOPE®

Measurement method

- Magnetic method (Hall effect). The type EN3 and ENW3 probes can be connected.

Application

- Electroplating plants
- Automotive supply industries

FISCHERSCOPE® MMS Module SIGMASCOPE®

Measurement method

- Modified Eddy current method. All type ES... probes can be connected.

Application

- Electrical and electronics industries
- Plating shops
- Metal industries
- Aerospace and other industries

FISCHERSCOPE® MMS Module BETASCOPE®

Measurement method

- Beta backscatter method. All BETASCOPE® measuring tables and hand held probes combined with suitable isotopes and platen aperture rings can be connected.

Application

- PC-board and electronics industries
- Automotive industry
- Consumer products industry and others

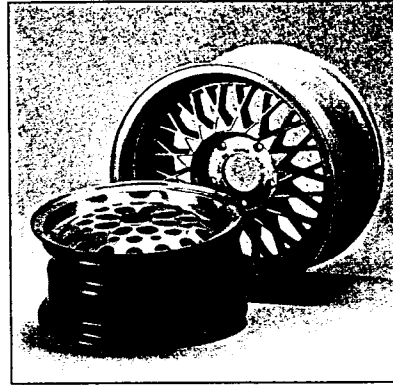
A measurement system that allows a variety of measurement tasks to be performed using a single instrument is the primary feature of the FISCHER-

SCOPE® MMS. The system is ideally suited for high volume measurement applications due to its powerful software and high degree of automation – however,

low volume measurement tasks and single measurements are performed just as easily. A few application examples shall illustrate the operation of the instrument.



The FISCHERSCOPE® MMS is used for high volume measurements of motor safty parts. Every month, hundreds of thousands of parts are measured in round the clock operations.



Aluminum rims are safty parts.



The simple and fast measurement of the copper thickness in through holes of printed circuit boards, using the ESLOBA probe immediately following reinforcement by electroplating, improves the quality and avoids outliers.

Application example Electroplating industry

In a plating shop, coating thickness measurements are performed for various customers on parts with different shapes, sizes and material combinations. The FISCHERSCOPE® MMS Module PERMASCOPE® is the optimal instrument for this application. In this case, the MMS can be equipped with

- probes suitable for the respective applications;
- suitable supports fixtures and a measuring stand to assure precise positioning of small test specimen, such as fasteners, stampings, etc;
- a personal computer for data acquisition to satisfy networking requirements or data analysis using third party software.

In the case of repetitive measurement tasks involving the same products, the proper application is retrieved at the push of a button which loads all application-specific calibration parameters. The measurement is performed in dialog with the measuring system. The operator can evaluate the measurements immediately or store the data in one of 50 application memories for later evaluation. When the measurement task is finished, a customer-specific measurement report can be printed. The print form template for this report is also saved in the specific application memory. The operator can focus on the task of measuring; the instrument performs all other functions.

Application example Performance critical aluminum alloy components

Some aluminum alloy components used in the aerospace or automotive industries have a clearly defined spectrum of physical properties. Non-destructive measurement of the performance related structural condition of the component is required as part of a quality assurance program. Additionally, these components often receive some form of surface treatment: decorative finishes or anodic coatings (alloy wheels), hard anodizing (machine parts, extrusions), or electroplated finishes for certain applications. The FISCHERSCOPE® MMS with the PERMASCOPE® and SIGMASCOPE® modules is ideal to control the quality of these coatings.

- The PERMASCOPE® module is used to measure the thickness of anodized and other nonconductive coatings.
- The SIGMASCOPE® module is used to measure the electrical conductivity, which is closely related to the structural condition and can be used as a correlating parameter. Additionally, this module can be used to measure chromium coatings on aluminum.

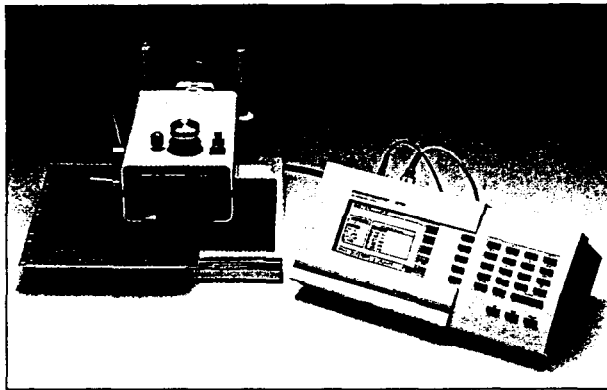
The versatility and measurement accuracy of the instrument make the FISCHERSCOPE® MMS the ideal inspection tool for the quality control of many other performance critical coating applications.

Application example Printed circuit board manufacturing

Aside from the X-ray fluorescence method, electromagnetic methods and the Beta backscatter method can be used to measure the coating thickness in the PC-board manufacturing process. Measurements based on these test methods can be performed with a FISCHERSCOPE® MMS equipped with the modules NICKELSCOPE®, SIGMASCOPE®, and BETASCOPE®.

- The nickel coating, which is deposited under the gold coating as a diffusion barrier, is measured according to the magnetic (Hall effect) method (NICKELSCOPE®).
- Surface copper cladding thickness and copper plating thickness in through holes is measured using the Eddy current method (SIGMASCOPE®).
- The gold coatings on contacts, tin-lead alloy coatings on solder pads and traces, and photo resist coatings are measured using the Beta backscatter method (BETASCOPE®).

A centralized measurement system can perform all of these measurement tasks by simply selecting the proper application. Uniformity of operation regardless of the test method selected keeps operator activities to a minimum. The measurement data can be stored, evaluated, printed or downloaded to an external computer. The FISCHERSCOPE® MMS equipped with the NICKELSCOPE®, SIGMASCOPE® and BETASCOPE® modules offers the PC board manufacturer an economic method to efficiently measure all his applications.



FISCHERSCOPE® MMS Module BETASCOPE®. Measurements on PC-boards with the universal measuring table Z6NG.

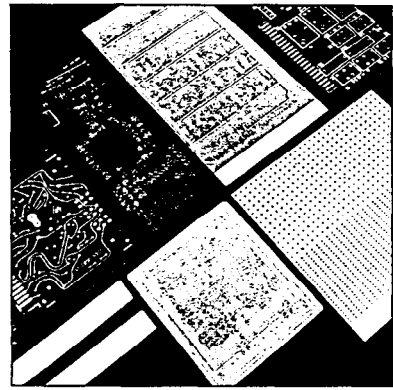


Fig. 1

The Beta backscatter method

This test method continues to have a definite place in production control and quality assurance of coatings. It is a *proven and mature test method* that for a number of applications is better suited than other non-destructive test methods.

Coating thickness measurement according to the Beta backscatter method is non-destructive, fast and accurate. Measurements can be made on areas as small as 0.16 mm (0.006") in width and 1.2 mm (0.05") in length.

Basically, the module BETASCOPE® can be used to measure all coatings where the atomic numbers of coating and substrate differ sufficiently (a minimum of 20%). These prerequisites are fulfilled for paint coatings on metal but also for many metal coatings, such as gold on nickel. Electrical and magnetic properties do not influence the measurement. The measurement ranges are determined by the density and atomic number of the coating material and the energy of the isotope selected. For instance, gold coatings can be measured in a range of approx. 0.5 µm to 35 µm (20 – 1400 µin.), and silver coatings even from 1 µm to 75 µm (40 – 3000 µin.).

The test method offers a multitude of applications for coating thickness measurement. Different measuring probes, tables and isotopes have been designed to cover these varied applications. In addition to the FISCHERSCOPE® MMS one or two measuring tables can be part of the measuring system.

The measuring tables and probes are application specific. Hand-held probes are available to measure coatings on bulky specimens, such as large circuit boards, sheet stock, or armatures and fixtures. Other probes are available to measure the coating thickness on the inside of tubes. Each measuring table operates in conjunction with the appropriate isotope and platen aperture ring. The FISCHER aperture ring is highly wear resistant and features a JEWEL-RING® platens. Slotted and round apertures are available.

The BETASCOPE® application must be calibrated empirically with appropriate coating thickness standards for each measurement applications, that is, a correlation must be established between coating thickness and backscatter rate. For many common applications, a one- or two-point calibration is sufficient. However, calibrations can be performed with up to 4 coating thickness standards for highest accuracy over the entire measurement range. Each application-specific calibration can be stored in one of the non-volatile application memories of the FISCHERSCOPE® MMS. The instrument is then immediately ready when measurements are to be taken.

Differences in the density of the actual coating material to that of the calibration standards used to calibrate can lead to measurement errors. A density correction factor can be computed by the MMS software to correct for this kind of measurement error.

Fig. 1
In the PC-board industry, the Beta backscatter method is used to measure thin coatings of, e.g., gold, tin, tin/lead, solder paste, copper, photo resist, on printed circuits.

Fig. 2
For small electronic components, it is possible to measure, for instance, gold, silver, or rhodium coatings on contacts, solder pads, lead frames, device packages, etc.

Fig. 3
The Beta backscatter method is used to monitor chromium, graphite, or nickel-alloy coatings on cylinders, pistons, bushings, bearing shells, etc.

Fig. 4
The Beta backscatter method is also utilized to measure decorative precious metal or paint coatings on consumer articles, such as cutlery, kitchenware and others.

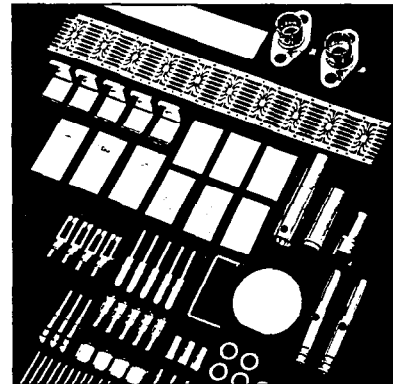


Fig. 2

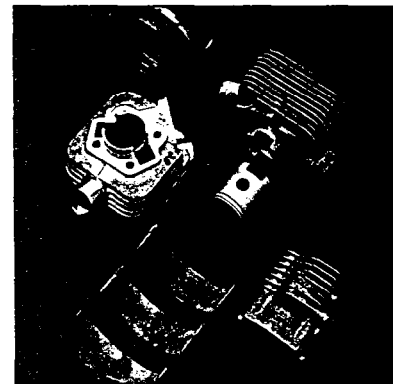


Fig. 3

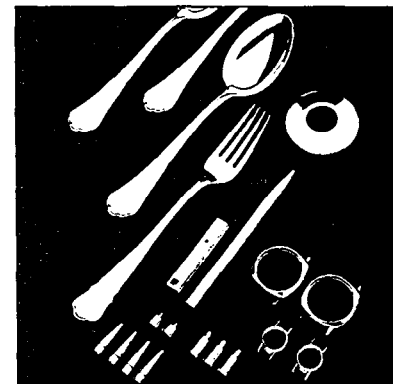
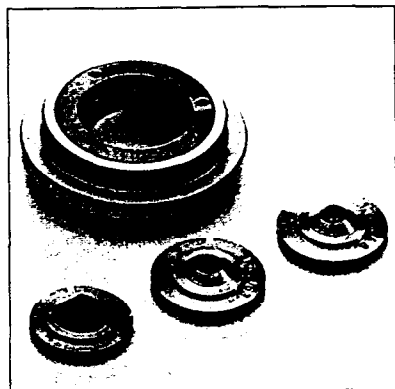


Fig. 4

Beta isotopes

Isotopes of different energies and apertures with different openings (see figure below) are available.



JUWELRING® platens

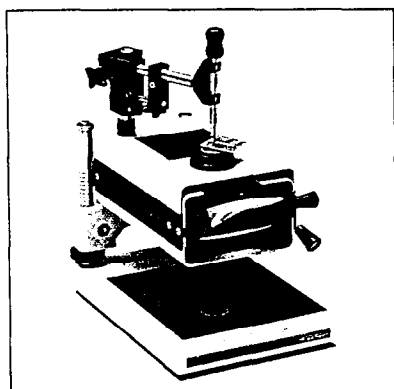
Measurement ranges

The measurement range of the Beta backscatter method is generally determined by the energy of the isotope and the density of the coating material. In the table on the right, suitable isotopes and measurement ranges are listed for typical coating/substrate combinations. The measurement ranges refer to the so-called logarithmic range of the corresponding isotope, which is the range where the best measurement precision is obtained.

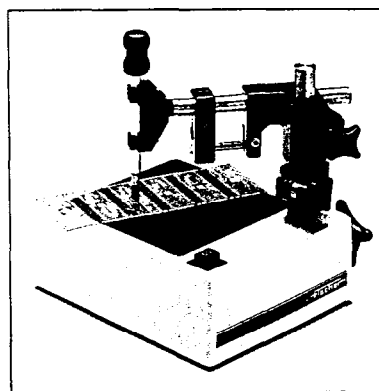
The table below contains all standard isotopes, others are available on request.

Name	Aperture opening	Energy	Half life	Order no.
Pm-147	∅ 0.63 mm 0.02"	0.22 MeV	2.65 years	600-488 (C 07.04.01.05)
	0.63 x 1.2 mm 0.02 x 0.05"			600-489 (C 07.04.01.56)
Tl-204	∅ 0.63 mm 0.02"	0.76 MeV	3.65 years	600-490 (C 07.04.02.05)
	0.63 x 1.2 mm 0.02 x 0.05"			600-491 (C 07.04.02.56)
Sr-90	∅ 1.6 mm 0.06"	2.27 MeV	28 years	600-492 (C 07.04.04.09)
C-14	∅ 20 mm 0.79"	0.156 MeV	5680 years	600-493 (C 07.05.06)

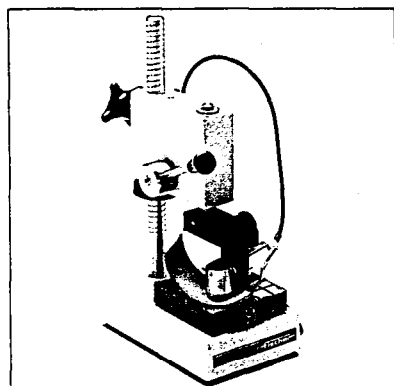
Isotope		Pm-147	Tl-204	Sr-90	C-14
Coating	Substrate	Measurement range in µm (mils)			
Ag, Rh, Pd	Cu, Ni, Fe	1.2 - 4.0 (0.05 - 0.16)	5.5 - 22 (0.22 - 0.88)	15 - 70 (0.6 - 2.8)	-
Al	Cu, Ni, Fe	4.5 - 20 (0.18 - 0.8)	25 - 100 (1 - 4)	90 - 400 (3.6 - 16)	-
Au	Cu, Ni, Fe	0.5 - 2.0 (0.02 - 0.08)	2.5 - 10 (0.1 - 0.4)	5.5 - 35 (0.22 - 1.4)	-
Cd	Cu, Ni, Fe	1.5 - 5.0 (0.06 - 0.2)	7 - 30 (0.28 - 1.2)	15 - 70 (0.6 - 2.8)	-
Cr	Al	2.0 - 8.0 (0.08 - 0.32)	8.0 - 30 (0.32 - 1.2)	-	-
SnPb(60/40)	Cu, Ni, Fe	1.1 - 4.5 (0.04 - 0.18)	5.0 - 28 (0.2 - 1.12)	10 - 80 (0.4 - 3.2)	-
Ni, Cu	Ag, Mo	1.5 - 5.0 (0.06 - 0.2)	9.0 - 30 (0.36 - 1.2)	20 - 100 (0.8 - 4)	-
Sn	Cu, Ni, Fe	1.8 - 5.5 (0.07 - 0.22)	7.5 - 35 (0.3 - 1.4)	15 - 100 (0.6 - 4)	-
Zn	Fe, Al	2.0 - 6.5 (0.08 - 0.26)	4.0 - 30 (0.16 - 1.2)	-	-
Paint	Ni, Cu, Al	11 - 40 (0.44 - 1.6)	50 - 200 (2 - 8)	180 - 800 (7.2 - 32)	3 - 11 (0.12 - 0.44)



Universal measuring table Z6NG
with small parts accessory kit
and weight pin



Measurement table Z14NG
to measure the coating thickness on small
parts with universal weight pin



The angle probe Z11NG1
in combination with support stand V12
in used to measure the coating thickness
in bushings, pipes, bearing shells, etc.
with diameters of 32 mm (1 1/4") and up



Hand probe Z9NG
to measure the coating thickness of, e.g.,
armatures, printed circuit boards,
sheet metal, etc.


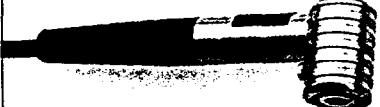

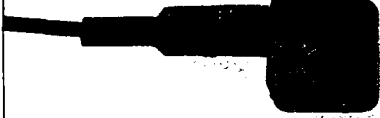
The measurement accuracy of the FISCHERSCOPE® MMS is primarily determined by the proper choice of measuring probe. It is important to keep in mind that any FISCHER E-types magnetic induction and Eddy current smart probe can be connected to the FISCHERSCOPE® MMS that is equipped with PERMASCOPE® module. Each FISCHER smart probe consists of a measuring element, a memory chip and probe connector. The coating thickness dependent measurement signal is supplied by the measuring element. The design and shape of the probe are dependent on the measurement conditions. The master calibration for the probe is stored in its resident memory chip. Therefore the probe is immediately ready to measure when connected to the instrument.

Proper probe selection and the quality of the probe determine the quality of the measurement. Probe selection is determined by various criteria. First, the probe/substrate material combination determines the test method – magnetic (Hall effect), magnetic induction, or Eddy current. FISCHER offers a broad assortment of probes for various applications. The table to the right shows a selection of standard probes.

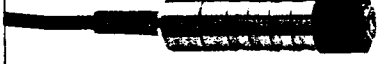

The probe shape is determined by the geometric configuration of the measurement area. Radial, axial, and right angle probes are available. Which probe delivers the best result is finally determined by a number of other aspects. Thickness of coating and substrate are important. The surface roughness of the measurement area should be taken into consideration; for instance, two-pole probes will usually render better results on rough surfaces than single-pole probes. The curvature of the measurement area is another aspect to be considered.

The conditions of the actual measurement are generally different from the near ideal conditions used during the probe master calibration. Such deviations can be corrected through normalization (base correction) or a one point or two point user calibration.





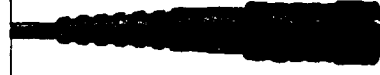

Magnetic induction probes to measure the coating thickness

Design	Type	Meas. range	Order no.
	EGAB1.3	0-2000 μm 0-80 mils	601-793
	EGABW1.3	0-2000 μm 0-80 mils	601-964
	EGABI1.3-150	0-1000 μm 0-40 mils	601-932
	EKB10	0-8 mm 0-320 mils	602-225

Magnetic probes to measure the coating thickness

Design	Type	Meas. range	Order no.
	EN3	0-100 μm 0-4 mils Ni/NF, Iso 0.1-4 mm 4-160 mils NF/Fe	602-305
	ENW3	0-100 μm 0-4 mils Ni/NF, Iso 0.1-4 mm 4-160 mils NF/Fe	602-380



Eddy current probes to measure the coating thickness

Design	Type	Meas. range	Order no.
	ETA3.3H	0-1200 μm 0-45 mils	602-128
	EAW3.3	0-1200 μm 0-45 mils	602-025
	EAI3.3-150	0-800 μm 0-32 mils	602-026
	EA30	0-20 mm 0-800 mils	602-027
	ESD2	0.5-80 μm Cu/Fe 0.02-3.2 mils 1-200 μm Zn/Fe 0.04-8 mils 1-50 μm Ni/Fe 0.04-2 mils	602-308
	ESL08A	2-100 μm Cu/Iso 0.08-4 mils	602-224

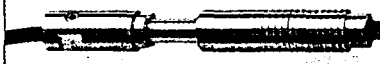

The operator can correct for differences in magnetic properties (permeability) or in the electrical conductivity, and for specimen shape related geometric influences through a simplified user calibration. In most cases, only one calibration standard and the bare substrate need to be measured. In extreme cases, where highly unusual material property or geometric effects are encountered, a two-point or even a master calibration can be performed.

Application-specific user calibration parameters are stored in the application memory of the measurement system, thus avoiding the need for user calibrations when switching applications. Even measurements made at different times will, therefore, correlate well because the same calibration settings are used by the instrument when the application is retrieved. Automatic loading of the application specific parameters avoids mistakes and assures the highest measurement accuracy.

Eddy current probes to measure the electrical conductivity

Design	Type	Meas. range	Order no.
	ES1A	0-65 MS/m 0-112% IACS	602-222
	ES2	0-65 MS/m 0-112% IACS	602-223

Magnetic induction probes to measure the ferrite content

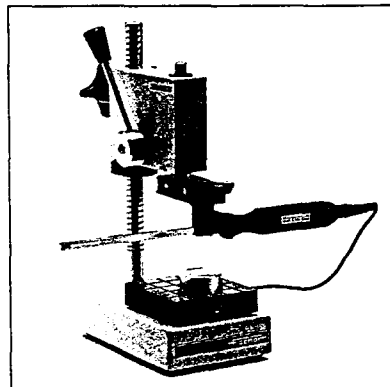
Design	Type	Meas. range	Order no.
	EGAB1.3-Fe	0-80 % Ferrite 0-110 WRC ferrite numbers	602-221
	EGABW1.3-Fe	0-80% Ferrite 0-110 WRC ferrite numbers	602-304

For special applications, measurement aids such as placement fixtures, probe stands and other attachments are available to complement the broad variety of probes that can be used with the FISCHERSCOPE® MMS. These accessories may be used when, for instance,

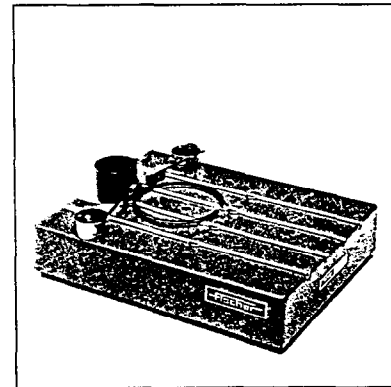
- standard probes can not be used at all,
- the measurement accuracy can be improved with the aid of such an accessory,
- manual probe positioning is not possible.

FISCHER has developed a number of such measurement aids and special attachments. Here are some examples (the number increases continuously):

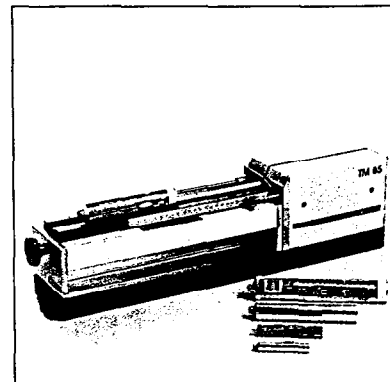
- Support stand V12 with mounting adapter for various probes (shown: inside probe EGAB1.3-150).
- Piston ring measuring table V4EKB4 to measure chromium coatings on piston rings and oil rings.
- Food/beverage container measuring system TM85 to measure the coating thickness on the inside and outside of aluminum containers.
- Probe positioning system to control the probe placement for automatic high volume measurement applications, or automatic measurements on strip, sheet, etc., or to avoid indentation errors on very soft coatings.



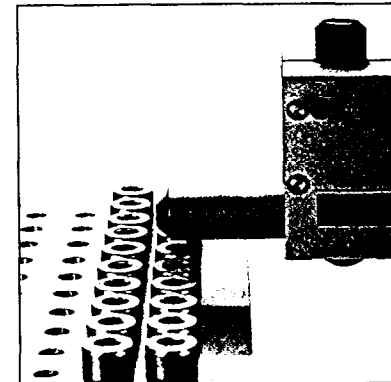
Measurement stand V12 with mounted inside measurement probe EGAB1.3-150



Piston ring measurement table V4EKB4

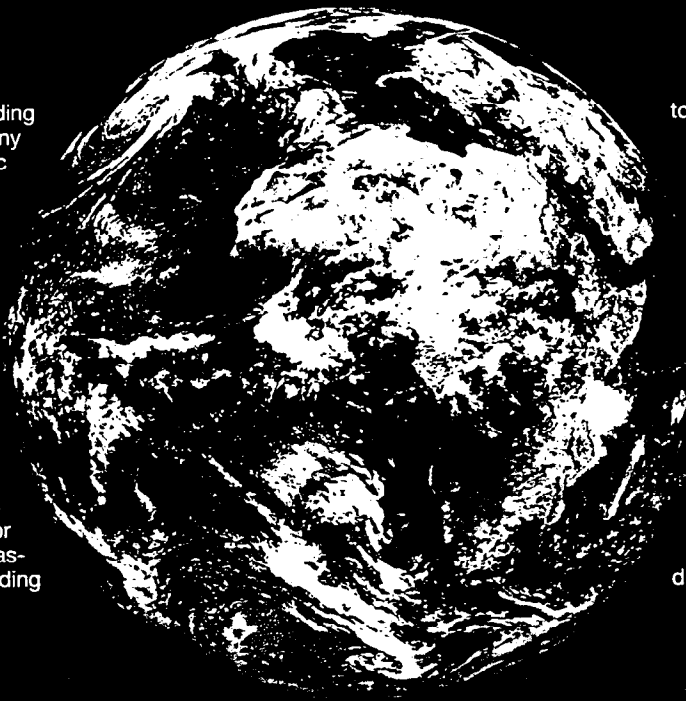


F/B measurement system TM85

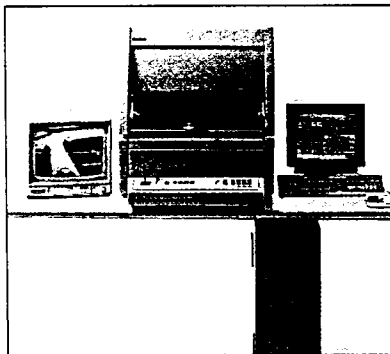


Probe placement system assures indentation free probe positioning for automatic measurement applications

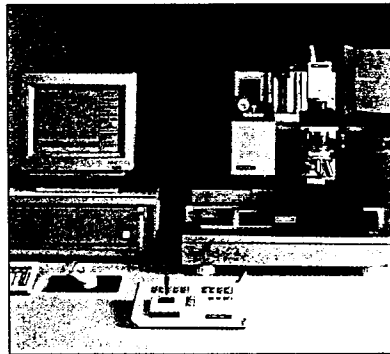
FISCHER is a leading multi-national company in the field of electronic coating thickness measurement and materials testing instruments. The company is able to recommend the best coating thickness measuring instrument for any application, due to the company's extensive experience in this field. The wide range of instruments includes models for coating thickness measurements according



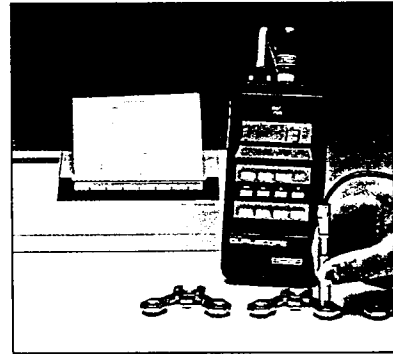
to the X-ray fluorescent, Beta Backscatter, magnetic induction, eddy current and coulometric methods. Additionally, the program includes instruments for measuring micro-hardness, ferrite content, and porosity testing. FISCHER is active around the world. Instruments manufactured by our company are used in many countries. FISCHER has subsidiaries in eight different countries.



FISCHERSCOPE® X-RAY to measure the coating thickness according to the X-ray fluorescence method



Micro-hardness measuring instrument FISCHERSCOPE® H100



DUALSCOPE MP4C with magnetic induction probe for zinc coating on iron

The high quality standard of FISCHER instruments is the result of our efforts to provide the very best instrumentation to our customers.

FISCHER is a reliable and competent partner, offering expert advice, extensive service, and user training seminars.

Today, FISCHER instruments are used successfully in all technological fields of industry and research.

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HELMUT FISCHER GMBH + CO

Institut für Elektronik und Meßtechnik
Industriestraße 21
D-71069 Sindelfingen (Maichingen), Germany
Postfach 600161, D-71050 Sindelfingen
Tel. (07031) 303-0, Fax (07031) 30379
Telex 7265769 fisco

**HELMUT FISCHER
ELEKTRONIK UND MESSTECHNIK AG**
Moosmattstraße 1, Postfach
CH-6331 Hünenberg
Tel. (042) 368626, Fax (042) 362440
Telex 862604 fiagch

HELMUT FISCHER MEETTECHNIEK B. V.
Tarasconweg 10, NL-5627 GB Eindhoven
Postbus 1828, NL-5602 CA Eindhoven
Tel. (040) 482255, Fax (040) 428885

FISCHER INSTRUMENTATION ELECTRONIQUE
Parc d'Activités Nord du Pas du Lac
5, Rue Michael Faraday
F-78180 Montigny le Bretonneux
Tel. (01) 30580058, Fax (01) 34601070

FISCHER TECHNOLOGY, INC.
750 Marshall Phelps Road
Windsor, Ct. 06095 USA
Tel. (203) 683-0781, Fax (203) 688-8496
Watts 800-243-8417, Telex 6906082

FISCHER INSTRUMENTATION (G. B.) LTD.
Hannah Way, Gordaleton Industrial Parks
Pennington, Lynton/Hants, England
Tel. (0590) 683663, Fax (0590) 683640
Telex 477727 fibritg

HELMUT FISCHER S. R. L. TECNICA DI MISURA
Via Columella 40, I-20128 Milano
Tel. (02) 2552626, Fax (02) 2570039

FISCHER INSTRUMENTS S. A.
c/Almogàvers 157, 3a Planta
E-08018 Barcelona
Tel. (03) 3097916, Fax (03) 4850594

FISCHER INSTRUMENTATION (FAR EAST LTD.)
Unit 1708, Metroplaza Tower II
223 Hing Fong Road, Kwai Chung
New Territory/Hongkong
Tel. (02) 4201100, Fax (02) 4870218

FISCHER INSTRUMENTS K. K.
Shinmei 2-3-5, Souka-Shi
Saitama-Ken 340/Japan
Tel. (0489) 323621, Fax (0489) 323618

THE DELOT PROCESS

A NEW TECHNOLOGY FOR AUTOMOTIVE TUBE GALVANIZING

Presented to

GALFAN TUBE LICENSEES

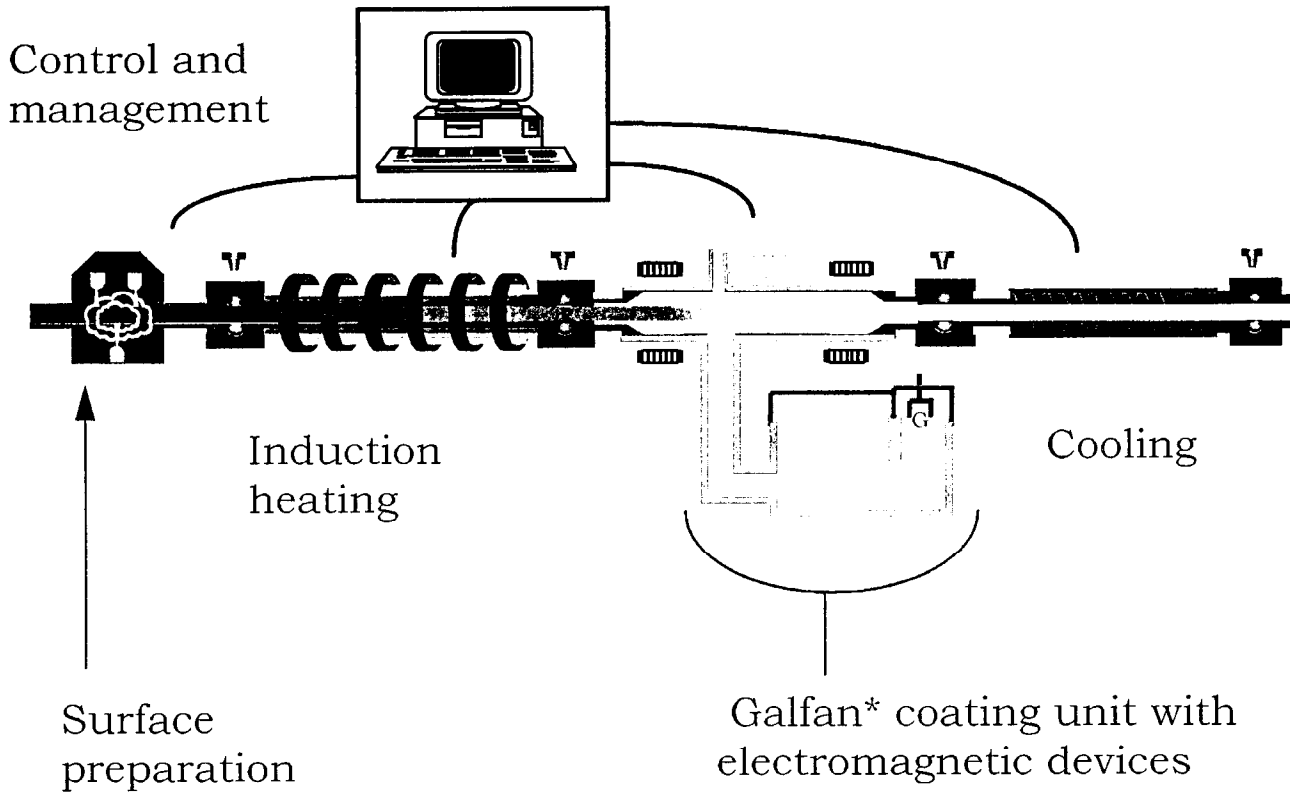
at

AUBURN HILLS, MICHIGAN

November 28, 1995

***By Victor Dorsten
Delot Process N.A.***

Process diagram



THE DELOT PROCESS

A NEW TECHNOLOGY FOR AUTOMOTIVE TUBE GALVANIZING

I. INTRODUCTION

The Delot Process developed by the French firm Delot Process S.A., is a revolutionary high performance galvanizing system. At the heart of the process magnetohydrodynamic (MHD) forces are used to pump, contain and control thickness of molten Galfan or zinc. M.H.D. is the science which combines fluid mechanic and electromagnetic field behaviors to control an electrically conductive metal such as molten Galfan .

This paper will reveal how M.H.D. devices are combined with effective steel cleaning, efficient steel heating, inert gas shielding and rapid quenching to produce superior Galfan coatings on automotive tubing. The four main stages of the process:

- Surface preparation;*
- Steel heating;*
- Galfan application;*
- Steel and coating quench;*

are discussed in detail and illustrated with a diagrams.

The technical advantages of the Delot Process are enumerated including:

- Controlled thickness;*
- Small quantity of molten Galfan ;*
- No acid required for surface preparation;*
- Elimination of dross;*
- Entire process is computer controlled and documented;*

The data presented and claims made for the Delot Process are based on more than five years of development work on long product galvanizing by Delot Process and on specific trial runs of steel tube at the Delot plant in St-Florentin, France, during 1993 and 1994.

II. THE PRODUCTION PROCESS

The Delot tube coating system can be operated in line with the tube mill or as a stand alone system. Tubing coming to a stand-alone system can be in coils or straight lengths. Accumulators may be required for joining lengths by welding or swaging on-the-fly, but the Delot Process can easily be stopped and restarted without waste if that method for coil exchange is preferred.

The process should receive tube which is free of contaminants such as oil, carbonaceous smut, and moisture. Limited mill scale and other oxides are acceptable. The input tube temperature should not exceed 300° F and in higher than room temperature cases an additional radiation thermometer may be added to the heat control circuit.

Processing speeds may be controlled from 15 to 120 m/m, for tube diameter from 3 to 15 mm.

A) STEEL PREPARATION

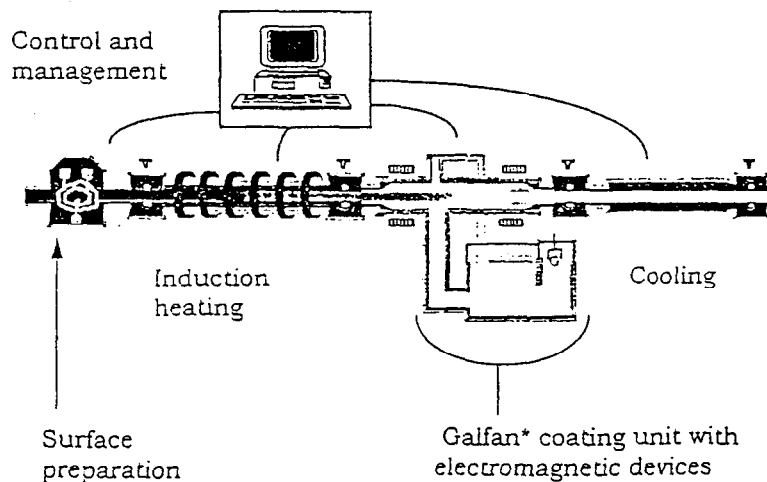
The Delot Process employs the widely used rotoblast wheel method of shot blasting to clean and profile the tube surface. The shot blaster consists of (3) rotoblast wheels arranged at 120° angles around the horizontal tube centerline. Concentrator plates are used to focus the blast pattern on the tube 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 tube exits the 10' blast cabinet through an air ring which blows any residual metal fines back into the vestibule.

The tube now enters a low pressure inert gas shield (95% Nitrogen and 5% Hydrogen) which is maintained through the rest of the process up to quenching. Next the tube passes a two plane laser micrometer (No. 1) which sends diameter data to the process controller.

At this point in the process the large or small tubes may continue on a horizontal path, or the small tubes may be directed to a vertical-up path. The choice will be discussed later in this section. In either case, the tube will enter induction heating coils of 3 to 6 feet in length. Here the power from a 40 to 60 kw power supply will efficiently raise the tube to Galfan application temperature or higher.

Process diagram



B) COATING

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

The reactor is a cylindrical containment about one liter in volume and sealed at both ends by magnetic fields which permit entry and exit of the passing tube, but contain the molten Galfan.

Within the reactor the Al-Fe-Zn intermetallic forms on the tube surface and pure Galfan wets the alloy layer.

Exposure time in the reactor is adjustable from 0.1 to 0.4 seconds depending on line speed and coil separation selected.

Further the exit field force is regulated to control the coating thickness as the tube exits. Thickness of coating can be controlled from (5) to (50) microns.

C) SUPPLY CRUCIBLE

Molten Galfan alloy 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 is controlled to achieve a constant melt level and temperature. Galfan is pumped from the crucible to reactor by a sealed MHD pump with no moving parts. The entire network of crucible, recirculation loop and reactor is temperature controlled to assure uniform temperatures, even if the system is not operating.

D) RAPID QUENCH

The exit of the Delot reactor is nitrogen covered to prevent oxidation as the tube 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*

E) THICKNESS CONTROL

Immediately following quench, the tube passes through laser micrometer No. 2 which sends the two plane coated tube diameter measurement 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 coil power on the Delot reactor.

F) HORIZONTAL OR VERTICAL DELOT REACTOR

When considering the orientation of a Delot reactor, several factors will influence the decision:

- the ratio of coating thickness to product diameter;*
- the range of product diameter to be processed on the given Delot reactor;*
- the allowable tolerance for coating eccentricity;*
- and the combination of product diameter and tensile strength as they influence difficulty in redirecting the tube around transport sheaves.*

In general, large diameters (7.0 to 12 mm) with coatings of 8 to 25 microns are best for the horizontal reactor and small diameters (4.0 to 6.0 mm) with coatings of 25 to 50 microns are best for the vertical reactor. The vertical reactor is not sensitive to the effects of gravity in so far as eccentric coating is concerned.

G) FINAL QUENCH, TUBE TRANSPORT AND TAKE UP

At this stage the vertical tube is redirected to a horizontal plane, receives a final quench, pretreatment for duplex coating and passes on to a take up. The tube transport and take up system provides:

- precise speed regulation from 15 to 120 m / m.*
- is vibration free;*
- has (3) stage tension control, pay-off to shot blast, induction heater to take-up capstan, and capstan coiler;*
- and is capable of scrap free emergency stop.*

III PROCESS CONTROL AND MANAGEMENT BY SCADA

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

*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*

Administration

*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.

The total process sequence for coating tubing is summarized below:

OPERATION	SPECIAL ATTRIBUTES
1. Tube uncoiling and transport	High speed, vibration free, no scrap start and stop
2. Shot blast cleaning steel	High speed, pollution free,
3. Steel heating and precise temperature control	Energy efficient, duplex temperature capability
4. Inert gas protection for steel and Delot Reactor	No polluting flux required, reduced dross and oxides
5. Delot Reactor, Galfan application	M.H.D. technology: - small molten mass - efficient alloy heating - high speed capability
6. Rapid quench horizontal or vertical	High speed, short distance, distortion free, instant start / stop, no leakage
7. Galfan thickness control	Precision, high speed
8. Final quench, horizontal	High speed, vibration free
9. Take up speed regulation to coil or straight	
10. SCADA System management	Computer managed process control and data administration

V COST AND QUALITY ADVANTAGES

The Delot Process for tubes we've described is revolutionary in two significant ways. They are not only cost advantages of the process, but product quality is superior to classical hot dip methods.

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 tube quality produced with this process is enhanced by the very short residence time of the hot steel in the reactor compared to classical methods. The result is a thinner Fe-Galfan intermetallic layer. Even after bending and the resultant cracks in the intermetallic layer, the very ductile coating exhibits no cracks or embrittlement.

And this ductile coating is uniform and precise thanks to M.H.D. wiping technology. The quality approaches electroplated.

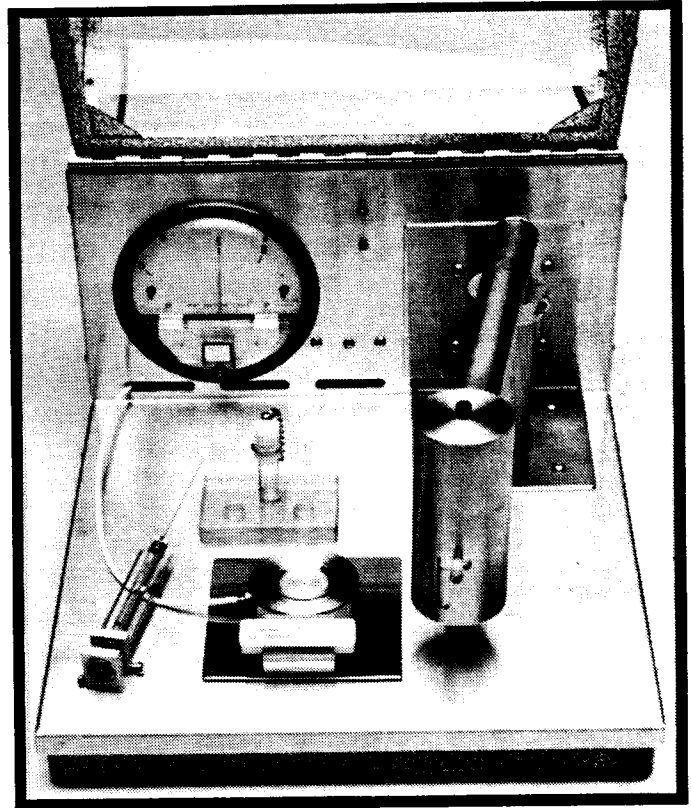
MESERAN Micro-Organic-Residue ANALYZER

Model 400 MOR

A new 486 DOS microcomputer-based analytical instrument for the rapid, quantitative determination of the amount of micro organic residue on a surface. Useful for residues from the nanogram level upwards through four orders of magnitude, the software is preprogrammed to provide values expressed as nanograms per sq cm when calibrated against one or more of several referenced residues.

System Characteristics

- >> Evaporative Rate Analysis (ERA) principle (Overleaf)
- >> Calibration residues deposited volumetrically
- >> 486 DOS interactive microcomputer. Menu driven software supplied without charge with free upgrades
- >> 2 Minute analysis expressed as a function of slope (with suitable calibration as ng / sq cm)
- >> Low cost, reliable, reproducible
- >> Automatic exhaust for vapor-phase chemicals
- >> System may be used for rapid, quantitative measurement of solvent NVR approaching 10 PPB using only 200 ul of liquid.



Instrument shown with hood open, air flow gauge, rotatable detector assembly, sample stage, precision microsyringe with Cheney adapter, and Insertable Closure Device for storing the XLNK-SOLUTION. Not shown is the interactive microcomputer.

**Size: 12" W x 17" D x 7.5" H (closed hood)
(not including the microcomputer)**

Due to the extremely small amount of C - 14 labeled material employed in this test method, use of the system is USNRC EXEMPT.

PRICE AND TERMS

- | | |
|--------------------------------------------------------------------------------|------------|
| 1) Model 400 MOR System
without microcomputer | \$9,600.00 |
| 2) 486 DOS Microcomputer
(may be customer supplied) | \$1,800.00 |
| 3) MOR-SOLUTION
up-to-80 tests per ampule
(quantity discounts available) | \$150.00 |

All items FOB Chattanooga
50% with purchase order; balance Net 30
System warranted for one year
Installation and training optional

The MESERAN Micro-Organic-Residue ANALYZER Model 400 MOR and MOR-SOLUTIONS are provided exclusively by:

The MESERAN Company

TEL: (615) 266 0400

FAX: (615) 698 2633

E R A Systems, Inc.

P. O. Box 3609

Chattanooga, Tennessee 37404-3609

MEASUREMENT OF MICRO ORGANIC RESIDUES ON A SURFACE

The rate of evaporation of a monolayer equivalent of a compound from a surface (at a given temperature and pressure in the absence of any interactions at the interface) is a function only of the inherent vapor pressure of the compound. Any interactions which result from the presence of organic residues in solution with such a compound cause a reduction of the vapor pressure and therefore of the rate at which the compound evaporates. The more the residue, the slower the rate of evaporation.

In a binary solution of non-polymeric compounds, the tendency of one component to occupy any position in the surface (i.e. the solution/atmosphere interface) is a function at least in part of the ratio of the size and number of the molecules of the two components. Since evaporation of a molecule can only occur if that molecule exists in the surface layer, the higher the percentage of non-volatile molecules in the surface, the slower the rate of evaporation. The interactions between molecules in a solution also affects the ability of one molecule to evaporate, i.e. to break those bonds between molecules at or immediately below the interface. This argument also applies to a degree to polymeric materials whose surface-occupying portions deny the spaces to an evaporative molecule.

In current ERA practice, a 17 microliter (ul) quantity of low boiling solvent with a high-boiling-but-volatile C-14 labeled radiochemical dissolved in it (ca. 100,000: 1 ratio) is deposited onto a horizontal or concave surface and onto any preexisting organic residue within the limits of the droplet of solvent. A G.M. detector is then positioned directly over the deposited solvent and, with metered air flowing between the surface and the detector face, the rate at which the solvent and then the radiochemical evaporate is monitored. Each analysis takes only 90 seconds. USNRC license EXEMPT labeled material is routinely employed as the radiochemical.

The observed evaporative process for residue related phenomena follows first order kinetics—the plot of log count per unit time vs time is a straight line. The slope of the observed line serves as the best measure of the evaporative process and thus is used to quantify the amount of preexisting organic residue. Expressed as a positive integer, the slope is inversely proportional to the amount of residue. Calibrations employing typical expected residues are readily carried out using 10 microliter depositions of 10 ml volumetric dilutions of those residues. The resultant relationships of slope versus amount-of-residue permits facile establishment of calibration curves for the measurement of unknowns.

For a wide variety of organic oils and greases, the sensitivity of the method permits quantitative measurement from a few nanograms (a small fraction of one molecular layer per square centimeter) upwards through ca. four orders of magnitude.