"NEW TECHNOLOGIES FOR THE PRODUCTION OF GALVANIZING STEEL SHEETS AT NIPPON STEEL" (1)

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S U M M A R Y

In recent years, the demand for coated sheets with high corrosion resistance has increased significantly.
Nippon Steel, with its accumulated experiences and technologies in the field of hot-dip galvanizing and electrogalvanizing, has developed various technologies to meet this demand with high efficiency.

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1. Introduction

Cold rolled sheets are widely used for its good formability, good finishing and cheeper cost. However, cold rolled sheets are poor in corrosion resistance and, usually, have to be painted for commercial use.

In recent years, from the standpoint of efficient usage of materials and guarantee of products to customers, demand for corrosion resistance of sheets have become more severe, and just a painting of cold rolled sheets with paint is not enough to meet the market needs.

The most popular corrosion resistance steel sheet is the hot-dip galvanizing sheet and, after invention of sendzimir process in 1931, many continuous hot-dip galvanizing lines have been installed throughout the world and the amount of its production has increased significantly. (Fig. 1)

Hot-dip galvanized sheets have good characteristic of corrosion resistance but inferior to formability, weldability and good-finishing. Thus, so far, they have been used mainly for building materials, such as roofing, siding, etc, for pipes and for rather simple containers, such as buckets and the like.

In recent years, however, due to the many innovations introduced in the hot-dip galvanizing technology, Nippon Steel is now able to produce a hot-galvanized steel sheets of high quality with the same properties as that of cold rolled sheets.

Electrogalvanized steel sheets, coated by electrolitic action on the cold or hot rolled sheet, have many excellent properties and have found a wide range of applications among home electrical appliances, automobile, furniture, building material, etc. The number of lines and volume of its production have been phenomenal in recent years (Fig. 2) This paper introduces some of the latest hot-dip galvanizing and electrogalvanizing techniques, as developed exclusively by Nippon Steel.

2. Hot-dip galvanizing technology

This chapter introduces the progress made by Nippon Steel Corporation in hot-dip galvanized sheet production techniques to cope with the demand of high quality products and variety of final usage. Nippon Steel's latest hot-dip galvanizing line is the No. 4 CGL at Nagoya Work which was put into operation in January 1979 (Fig. 3)

This line operates at very high speed and was constructed by Nippon Steel under an aggressive plan to meet the increasing demand for higher quality products, such as good formability, flatness and paintability, including one-side galvanized sheets.

This new CGL was also installed especially to reduce the production costs significantly and so as not to disrupt the surrounding environment. Following points are principle characteristics of this new line.

(1) Employment of vertical furnace (including Non-oxide furnace)

(2) High speed coating

(3) New equipment for high quality products

(4) Automatic operation and presetting by computer

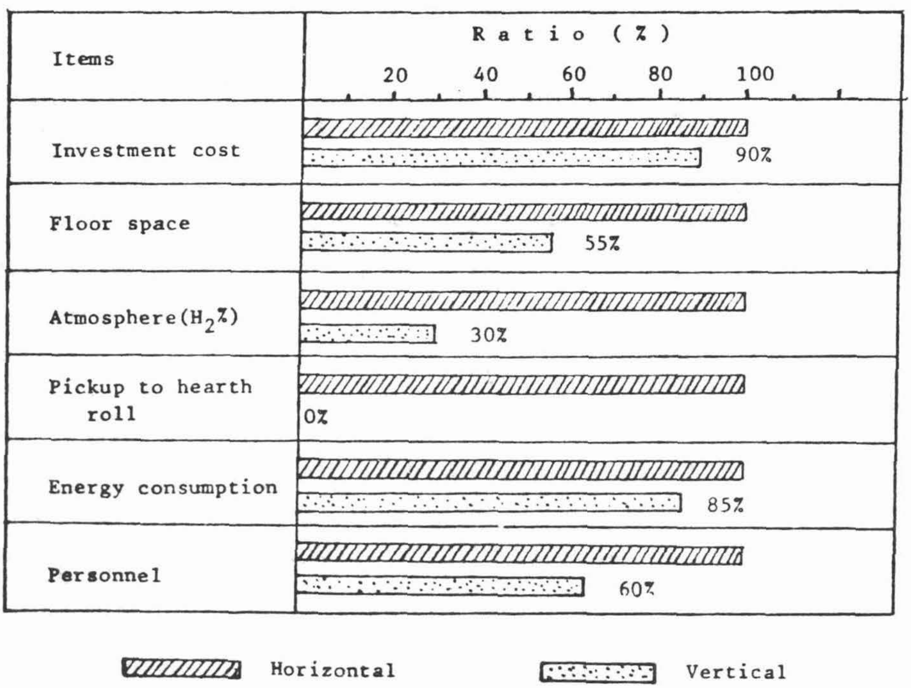
(5) Energy conservation and control of environmental pollution.

Some especific characteristics are explained in detail hereunder.

2.1 Employment of vertical furnace

With increases in the speed and capacity of equipment, the heating capacity of the in-line annealing furnace has had to increase, too. However, in order to accompany these increases the line with conventional horizontal furnace would make the furnace line very long, increasing the area of the building and lowering the efficiency of operations. In order to overcome this problem, Nippon Steel employed Japan's first vertical furnace at Kimitsu No. 3 CGL in 1974. Many advantages of vertical furnace are shown in Table I.

Table I. Comparison between vertical furnace and horizontal furnace



2.2 Non-oxidizing furnace (NOF)

The oxidizing furnace based on the Sendizimir method removes the rölling oil deposited on the sheet by burning it off in air. The drawback of this method is the thickness of the oxide film, and it needs to be reduced at a relatively high temperature, more than recrystalization temperature. Thus the Sendzimir method does not permit the production of full hard galvanized sheets.

In the NOF, gas fuel such as LPG, COG or the like is combusted at an air ration of 0.9 - 0.95 while the furnace is maintained at 1000 to 1300ºC, and the strip is rapidly heated up to 450 to 800ºC in a non-oxidizing condition. Most of the rolling oil on the strip surface evaporates, and deposited carbon on the strip surface is removed by reaction with H_2O and CO_2 in combustion exhaust gas.

The strip passes through the furnace in such a short time that the oxide film is much thinner than in the ordinary oxidizing furnace, so that it is possible to remove it at relatively low temperature.

In addition to the advantage of allowing production of full hard galvanized sheets, the NOF offers a number of other advantages in that the strip heating rate can be increased for higher productivity and the H_2 concentration in the process that follows the reducing furnace can be lowered for better safety, etc. Since its developement, the NOF has been used in all newly installed equipments and existing Sendzimir-type equipment is also being modified to the NOF type not only at Nippon Steel but in Japan.

2.3 Fluid wiping process

During the 1960's, fluid wiping process was developed to overcome various disadvantage of the coating roll method. The fluid wiping process permits to uniform the coating weight and to stabilize wiping at high speed up to 150 m/min. But it was necessary to resolve the following problems to perform wiping operation at more than 180 m/min.

(1) Excessive increase of zinc left up with strip from Pot.

(2) Increase of zinc splash by hard wiping

(3) Increase of noise by hard wiping

To overcome these problem, NSC made improvement in galvanizing equipment, such as nozzle profile, etc., and the development of technique to prevent vibration of strip rizing from zinc bath. (Fig. 4)

2.4 New equipment for high quality products

a) High precision sheet pyrometer

It is not easy to measure accurately the sheet temperature in a high-temperature furnace. Nippon Steel has used a sheet pyrometer provided with an antidisturbance device for several years. (Fig. 5)

This permits measurement of the sheet temperature with high accuracy and high stability if the emissivity (ε) of the sheet surface is stable and if there exists no gaseous body having radiating and absorbing power, such as CO_2, H_2O, etc., between the sheet pyrometer and the object to be measured.

At the delivery of the NOF in the CGL, where emissivity is unstable, the disturbance-proof sheet pyrometer does not permit temperature measurement with sufficient accuracy.

Thus Nippon Steel developed the TERM sheet pyrometer (Temperature and Emissivity by Reflection Measurement) that feature the capability of measuring ε of the surface of a moving sheet and the true temperature simultaneously. After installation of TERM, strip temperature is well controlled at the delivery of the NOF. (Fig. 6)

b) In line over-aging furnace (OAF)

As generally known, since the strip goes through the process of rapid heating, short-time annealing and rapid cooling in the continuous annealing furnace, the mechanical properties of continuous hot-dip galvanized sheets become harder and the workability becomes poorer than that of cold rolled sheet.

Table II An example of mechanical properties of hot-dip galvanized sheets for deep drawing

Grade	Production process	Yield point (kg/mm^2)	Tensile strength (kg/mm^2)	Fracture elongation (%)	Lankford value ($\bar{r}$)	Erichsen value (mm)
For light drawing	Coating speed down 20%	27.5	34.8	38.6	1.22	9.07
For deep drawing	Post-anneal (270 C x 18 h) →2% skin pass	20.6	32.1	42.2	1.20	10.75
For extra-deep drawing	Ultra-low carbon Ti-added steel C:0.005% (Ti:0.1%)	14.2	33.0	43.9	1.78	11.10
For deep drawing	Coated after decarburizing at annealing	20.4	29.3	41.6	1.57	10.68
For deep drawing	In-line over aging	20.4	33.2	41.3	1.52	10.15

Note: Coating is done by the Sendzimir method.

It is inevitable to process at low speed and high temperature for obtaining drawing quality and to process box annealing after coated or to use decarburized material for obtaining deep drawing quality. But this presents problem in terms of production cost and time. To solve these problems, Nippon Steel succeeded in developing the world's first in-line OAF, where material equivalent to the post-annealed material could be obtained by holding strip temperature at 375ºC for three minutes after coating as shown in Table II. Fig. 7 shows the schematic arrangement of the No. 4 CGL in-line over-aging furnace.

c) In-line one-side galvanizing

For several years, two-side hot-dip galvanized sheet have been used in USA for underbody of automobile not easily visible from outside, in order to prevent corrosion. When anticorrosion code for motor vehicles was put into force such as, "Canada Code", it became necessary to apply new coated sheet for outer panels.

For this reason, the demand of one-side galvanized sheets has increased rapidly because they have a galvanized surface with a cathodic corrosion preventive capability, surfaces that are excellent in external appearance and finish after painting and spot weldability which is indispensable in the assembly of automobiles.

Several methods of one-side galvanizing by hot-dip process have been studied, but quite a few were adopted because of its difficulty in comparison with electro-galvanizing process. One-side galvanizing technique by hot-dip process can be classified into the following types.

(1) Coating on two-side first and then remove zinc

from one side.

.1. Mechanical removal

.2. Removal by electrode reaction

(2) Coating on one-side

.1. Make contact one side with zinc bath

.2. Special treatment on non-coating side

Nippon Steel established the one-side galvanizing technology by using the grinding method in May, 1976 and started production of one-side galvanized sheet in February, 1977 (Fig. 8).

The grinding method, however, is not totally satisfactory in terms of production cost and efficiency. After extensive studies of a number of methods, it has been confirmed that the following two methods have a number of advantages as substitutes for the grinding method.

I. U.C.P.* (Universal Coating Process) Method (Fig. 9)

II. E.M.P. (Electro Magnetic Pump) Method (Fig. 10)

* Roll Coating Method

They have been succesfully put into practical operation at Nagoya Works and Yawata Works respectively in June, 1981.

3. Electrogalvanizing technology

For electrogalvanizing process, cold and hot rolled strip are used as raw-material sheet, thus electrogalvanizing line (EGL) is comprised of five sections without annealing section. (Fig. 11). The most important section is the plating section. Zinc plating is an electrode reaction to electrolyze a zinc ion-containing solution and, thereby, deposit a film of zinc on the strip which acts as a cathode. In order to obtain good plating and productivity, it is vital to choose a suitable plating solution, appropriate electrodes and good conductor rolls, etc. No less crucial are the structural quality of the electrolytic cell and its control system. Post-treatment is an essential step to strenghten the corrosion resistance of the zinc coat itself and to improve the paint adhesive property of the galvanized surface.

In the post-treatment section, the strip is subject to a chromic acid treatment, phosphating and oiling according to customer's requirement. Nippon Steel installed Japan's first electrogalvanizing line and it went on-stream at Yawata Works in 1953. Since then, Nippon Steel has accumulated large amounts of electrolytic plating technology and expertise and succeeded in developing the unique and efficient EGL equipment. Fig. 12 shows the general arrangement and specification of Kimitsu No. 1 EGL which was put into operation on February, 1972. Following points are principle characteristics of this new line.

(1) High speed plating

(2) Unconsummable and horizontal plating cell

(3) Combination of two and one-side coating

(4) Long life conductor roll

Some specific characteristics are explained in detail hereunder.

3.1 Plating cell

Until recently, conventional plating cell for EGL was consummable and vertical type, the same as that of electrotinning line. This plating cell has the following disadvantages.

(1) It is impossible to have high-current density because of low flow speed of plating solution.

(2) It is difficult to get uniform coating because of the

variation of interelectrode (electrode to strip) distance

(3) Anode replacement is necessary

(4) It is difficult to have one-side coating because of overcoating.

To overcome these problems, Nippon Steel had developed the JET CELL. Later on, this was improved into ACIC (Anode Center Injection Cell) which was established in 1982. (Fig. 13)
It has a unit construction composed of an inner cell, an outer cell, conductor rolls and backup rolls. The inner cell contains a nonconsumable anode and a plating solution injection header. The outer cell serves to collect the plating solution and return it to the recirculation tank. Upon being injected between the anode and the strip from the injection header, the plating solution is diverted into two flows, one in the direction of the entry side and the other in the direction of the delivery side, both being subject to electrolysis during the flow. Thus, ACIC has the following advantages over other system.

(a) The gas that evolves from electrolysis can easily find its way out of the cell.

(b) This reduces the unit amount of gas that might otherwise "stick" to the electrode surfaces. This in turn decreases the electric resistance of the electrode and the plating voltage.

(c) Where the plating solution is injected from the electrode center, the fluid acts to support the strip. Hence, the distance between the strip and the anode can be decreased.

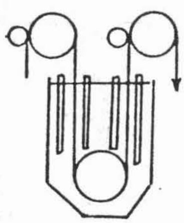
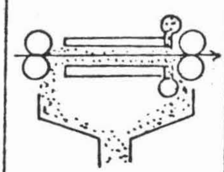
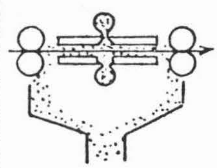
(d) This in turn raises the plating solution flow velocity in the cell; improves the state of zinc ion diffusion, and drastically expands tolerances for electric current density.

Operating experience with the Kimitsu No. 1 EGL has confirmed that the limiting current density of electrolytic plating can be extended to 240 A/dm^2 (at 150 m/min). (Fig. 14)

In case of same current density, the plating voltage also falls resulting in an energy saving of 30 percent (at 100 A/dm^2) relative to the capacity of the Jet Cell.

Table III compares the merits of the ACIC type, Jet Cell type, and the conventional vertical cell type. The superiority of the ACIC is evident from the table.

Table III Comparison between types of plating cells

		Vertical plating cell	Jet Cell	ACIC
Types of cell	Structure			
Types of cell	Anode	Consumable type	Nonconsumable type	Nonconsumable type
Types of cell	Plating Solution	Dipping	Jet flow (counter current)	Jet flow(counter current plus parallel flows)
Types of cell	Strip anode distance	35 mm	22 mm	12 mm
Limiting current density		50 A/dm^2	150 A/dm^2	240 A/dm^2
Plating voltage ratio		1.6	1.3	1.0
Ratio of the required number of cells		2.4	1.6	1.0
Construction cost ratio(including civil eng'g costs)		1.0	0.85	0.75

3.2 Long life conductor roll

Conductor rolls are subject to corrosion by the plating solution, mechanical breakage, arc flawing on account of current flows, zinc deposition on roll surfaces, etc. These defects affect the productivity of the EGL and the quality of the products. Periodical replacement and regrinding of conductor rolls, therefore are indispensable.

Conventionally, copper or stainless steel was used as the material for conductor rolls and it was necessary to replace the rolls on a seven to ten-day cycle. At Nippon Steel, this problem was solved with Ni-Ci-Mo alloy roll by decreasing the surface reactivity and by increasing the surface hardness of the roll.

The product cost has dropped and operating efficiency has improved markedly. (Table IV)

Table IV Comparison between roll materials and roll life

	New roll dia.	Final roll dia. to be used	Amount of grinding per one time	Life (exchanging period)	Number of times of grinding to final roll dia.	Total life to final roll dia.
Cu conductor Roll	300 mmϕ	285 mmϕ	1.6 mm	10.2 days	9	92 days
New conductor Roll	313 mmϕ	285 mmϕ	0.8 mm	55.4 days	35	1,939 days

3.3 One-side coating technology

The one-side coated steel sheets for automobile is attracting increased industrial attention as a measure to prevent car body rusting. At Nippon Steel, by using the Jet Cell and ACIC System, one-side coating operation can be carried out easily and effectively by only changing the

rectifier on the non-plating side to the plating side and by setting the edge masks in proper position.
The edge mask function to prevent overcoating, which results from current concentration on the strip edges. It also serves to prevent zinc from extending to the other side (non-coating side) of the strip. The edge mask now used at Nippon Steel is a thin, unique type developed by the company.

4. Future prospects

Galvanizing steel sheets have improved remarkably in order to meet the various demands of the market in recent years.
Hot-dip galvanizing sheets have expanded its application not only to building material but also to home electrical appliances and automobile, by the development of new products, such as one-side coating sheet, galvannealed sheet and type A/B.
With electrogalvanizing line, it is easy to produce alloy coated sheets and double coated sheets which ensure high corrosion resistance with minimum coating weight. These new products are, now, under development and some of them have already been commercialized.
In future, a various types of these new product will be developed to meet the everchanging market demand.

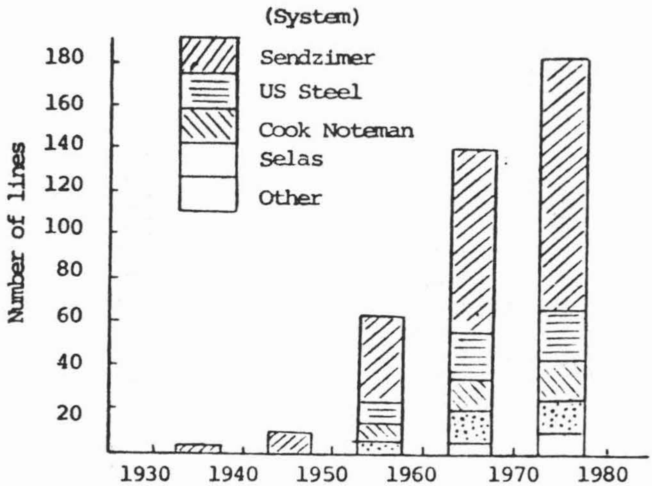


Fig. 1 Number of continuous hot-dip galvanizing lines

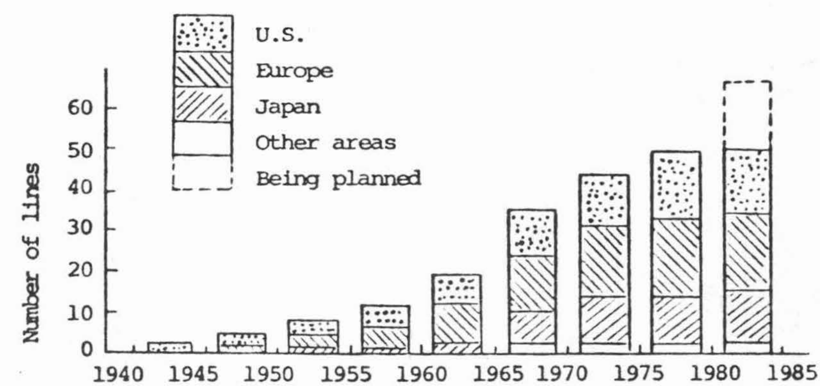


Fig. 2 Distribution of continuous electrogalvanizing lines among major world steelmakers

Capacity		24,000 T/H
Production Spec.	Thickness	0.4 - 1,6 mm
	Width	610 - 1,530 mm
	Coil Weight	Max. 20 ton
	Productions	One side Galvanneal Spangle-free Regular spangle
Line speed		200 m/min.
Furnace capacity		65 ton/hr (at 0.45 x 1,530 mm)
Line lenght		198.6 m

1. Pay-off reel (2 Reels)
2. -Ray thickness gauge
3. Entry loop car
4. NOF-RTF-SCF-JCF
5. Ceramic pot
6. Coating unit Machine
7. Galvanneal Furnace
8. Air Jet cooler
9. Over-aging Furnace
10. Water quench Unit
11. S.P.M.
12. Tension leveller
13. Chromic acid treatment unit
14. Coating weight gauge
15. Delivery loop car
16. Mark printer
17. Strip width gauge
18. Oiler
19. Tension reel (2 Reels)

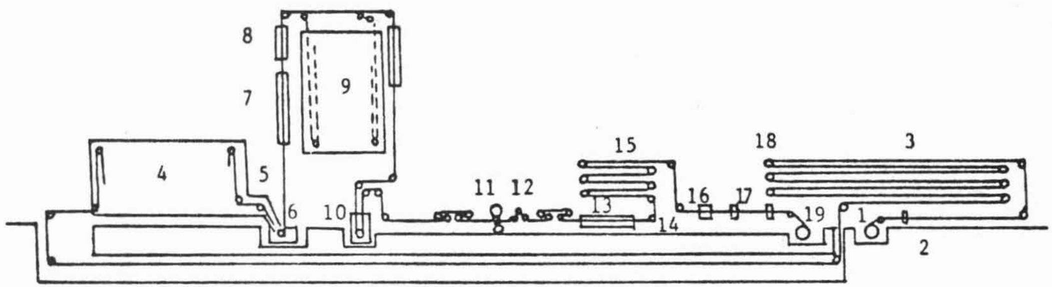


Fig. 3 - No. 4 CGL at Nagoya Works

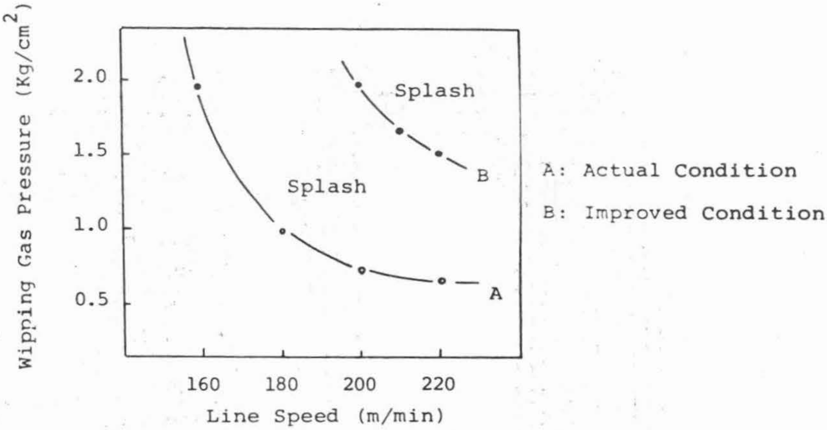


Fig. 4 Relation between Operation Condition and Splash

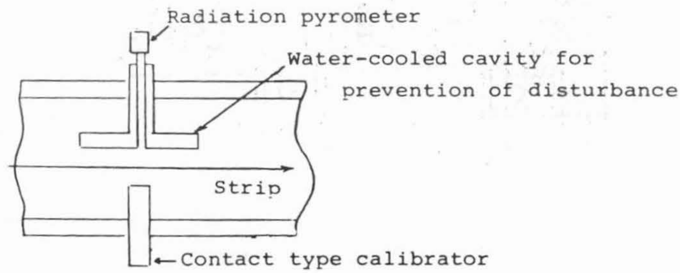


Fig. 5 Disturbance-proof sheet pyrometer

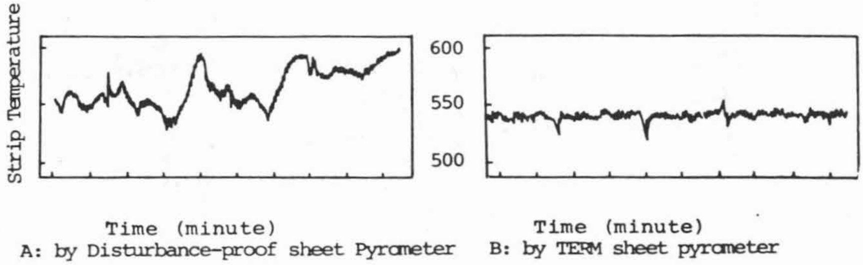
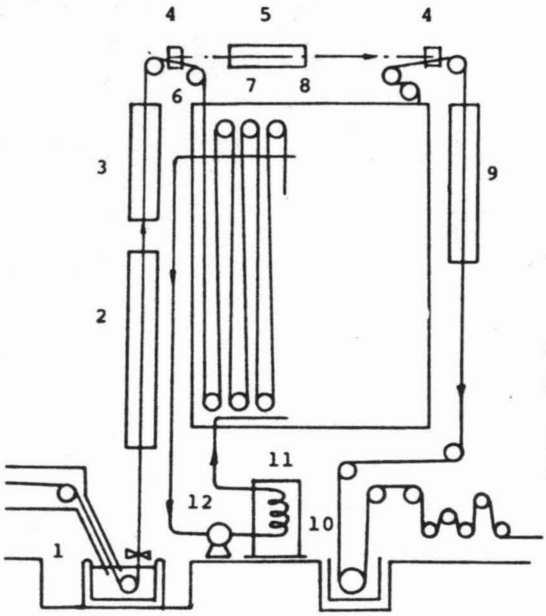


Fig. 6 Strip Temperature Control



1. Zinc Pot
2. Alloy furnace
3. 1 J.C.
4. Stitcher and Shear
5. 2 J.C.
6. Seal roll
7. Furnace body
8. Hearth roll
9. 3 J.C.
10. Quench tank
11. Circulating gas heat exchanger
12. Circulating gas blower
13. Annealing furnace

Fig. 7 Schematic arrangement of the over-aging furnace.

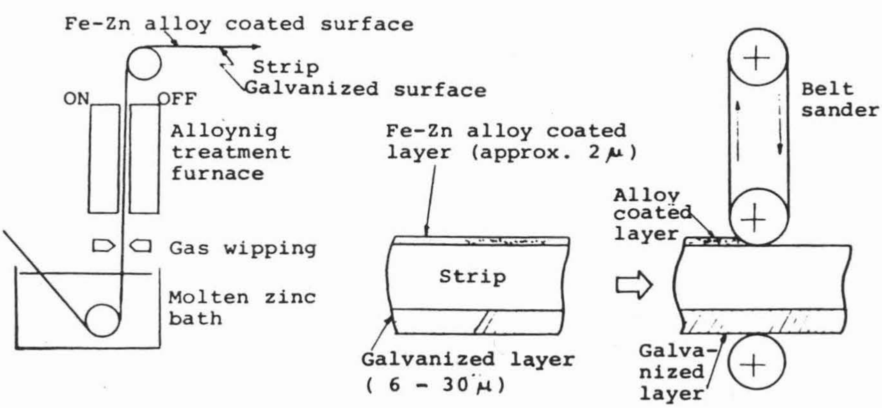


Fig. 8 Diagram of one-side galvanized sheet production by the grinding method

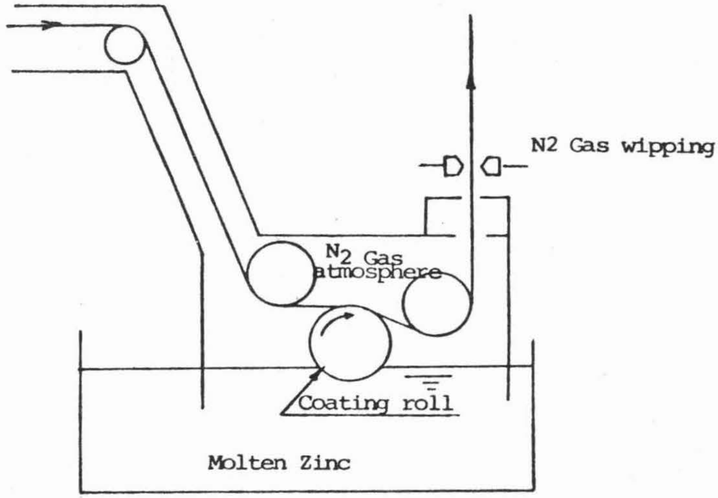


Fig. 9 Roll coating process one-side galvanizing equipment

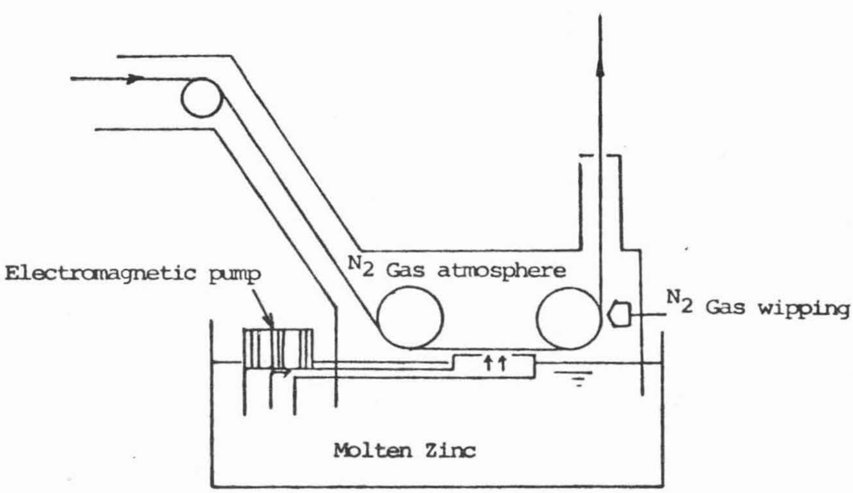


Fig. 10 Equipment outline of electromagnetic pump type one-side hot dip galvanizing process

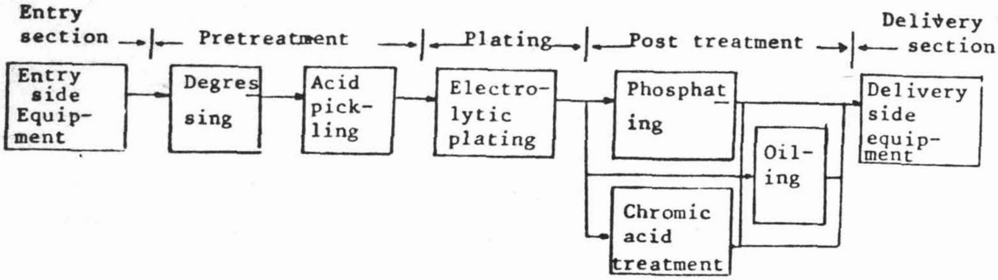
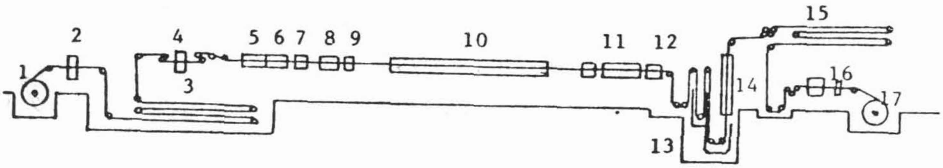


Fig. 11 Outline of EGL



1. Pay-Off Reels (2 Reels)
2. Narrow Lap-Seam Welder
3. Entry Loop
4. Tension Leveller
5. Brush Scrubber
6. Electrolytic Cleaning Cell
7. Water spray
8. Pickling Cell
9. Water Spray
10. Plating Cells (19 Cells)
11. Phosphating Cells
12. Water Spray
13. Chemical Treating Cell
14. Dryer
15. Delivery Loop
16. Oiler
17. Tension Reels (2 Reels)

Line Speed		150 m/min. max.	
Material Thickness		0.4 - 1.6 mm	
Material Width		1,240 mm max.	
Coils	ID(entry)	508,610 and 711 mm	
	ID(exit)	508,610 and 711 mm	
	OD(entry)	2,820 mm max.	
	OD(exit)	2,000 mm max.	
	Weight(entry)	48,600 kg max.	
	Weight(exit)	20,000 kg max.	
Coating Weight, g/m^2		40	
Capacity, KA		240	330
Type of Plating Tank		Horizontal(Jet Cell)	ACIC
Type of Anodes		Nonconsumable	Nonconsumable
Chemical Treatment		Phosphatizing/Chromatizing	
Date installed		February 1972	March 1982

Fig. 12 Kimitsu No. 1 EGL equipment

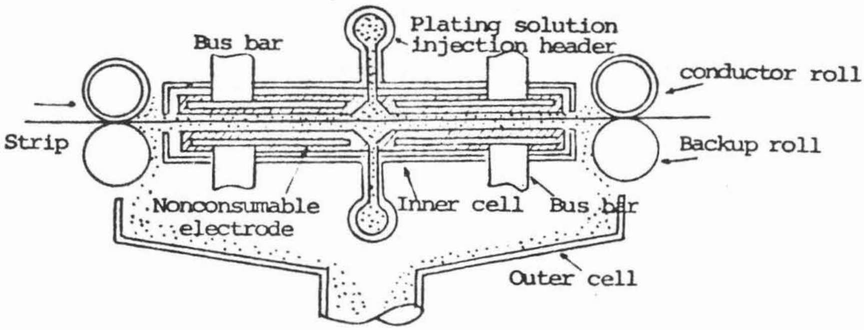


Fig. 13 Sectional structure of ACIC

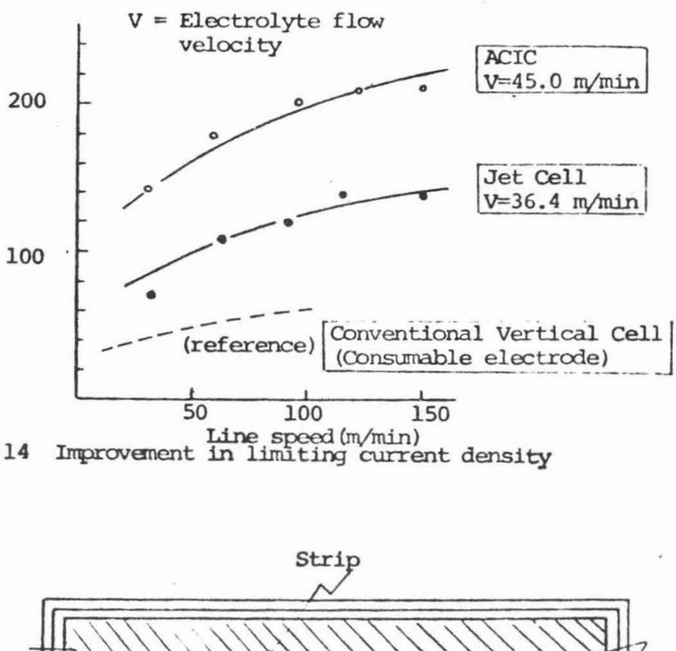


Fig. 14 Improvement in limiting current density

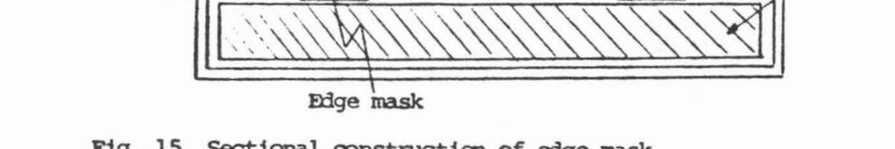


Fig. 15 Sectional construction of edge mask