KAWASAKI STEEL TECHNICAL REPORT
No.27 (November 1992)
Hot-Rolled, Cold-Rolled and
Surface Coated Steel Sheets
and Electronics and Instrumentation

In-line Thin Organic Film Coating Facility in the Electrogalvanizing Line

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1 Introduction

The electrogalvanizing line at Chiba Works had in the past a simple coating facility and was producing fingerprint resistant steel sheets River Zinc-F[1] coated with an organic resin. In August 1988, the in-line coating facility was extensively modified to manufacture PLASCOAT K V[2] coated steel sheets for automobiles by replacing the old simple coating facility with a full-scale composite line capable of both electrogalvanizing and coating treatments.

PLASCOAT K V provides a Zn-Ni alloy plating over the steel sheet base, which is chromate-processed before being given a filmy resin coating. In order to manufacture PLASCOAT K V in a single line, it was necessary to substantially revamp the old coating facility. Within 6 months after commencing the in-line production of PLASCOAT K V, the monthly production was 8 000 t, which at present reaches 15 000 t.

This report describes the in-line coating facility and its operating conditions.

2 Examination of the Objectives

2.1 Quality Requirements for PLASCOAT K V

PLASCOAT K V, which has been developed as a coated steel sheet for automobile use, is a filmy organic-composite-coated steel sheet that is given Zn-Ni alloy plating, a chromate coating, and finally an organic-resin coating containing colloidal silica. the cross-sectional structure is shown in **Fig. 1**. Plascoat K V has outstanding corrosion resistance, although its coating thickness is only 1 μm. It also provides high spot weld-ability.[2] Further, in order to facilitate its application to the bake hardenability (BH) steel sheet, it is designed so that resin baking can be achieved by short-term heating at 150°C or less.

2.2 Technical Problems with Filmy Coating

In the past, the electrogalvanizing line had a roll coater for finger print resistant steel sheet use, but in order to meet the high-level quality required for PLASCOAT K V, the following new techniques needed to be devel-

* Originally published in *Kawasaki Steel Giho*, **23**(1991)4, 315-320

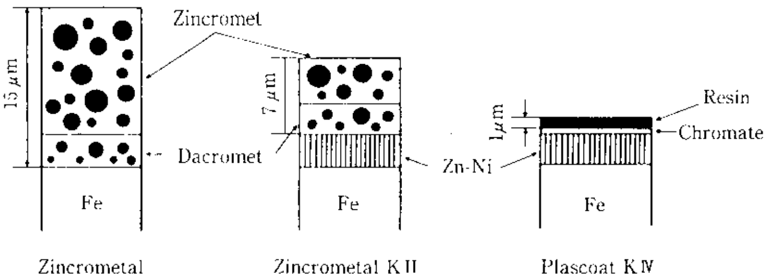


Fig. 1 Schematic views of Zincrometal, Zincrometal K II and Plascoat K V

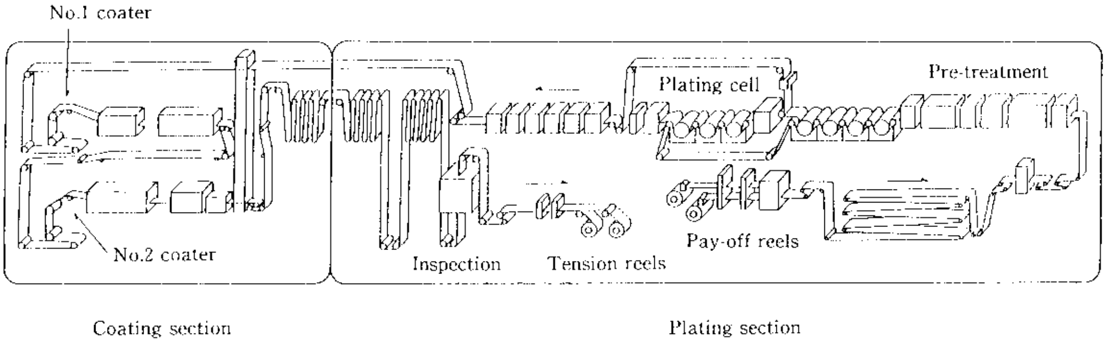


Fig. 2 Schematic diagram of electrogalvanizing line

oped:

(1) High-accuracy coating thickness control
(2) High-accuracy strip temperature control
(3) On-line coating thickness measurement

In particular, in the continuous line for plating and coating, simultaneous control of coating thickness and strip temperature with line speed fluctuations are important, and the facility must provide stable operation without lowering the productivity of the electrogalvanizing line.

3 Outline of the Facility

An outline of the new electrogalvanizing line is shown in **Fig. 2**, the right side showing the existing electrogalvarizing line and the left side, the newly added coating line. The electrogalvanizing line is based on the CAROSEL system of U.S. Steel (currently USX) to which our own special improvements were applied.[3] This electrogalvanizing line was completed in 1982 and commenced operation with four plating cells. Later, the number of cells was increased to seven, before the coating line revamping was made in August 1988 to complete the present in-line electrogalvanizing and coating line. **Table 1** shows the basic specifications of the line, and **Fig. 3** shows an out-line of the in-line coating

Table 1 Line specifications

Item	Specification
Production capacity	25 000 t/month
Line speed	
Entry	150 m/min (max)
Center	120 m/min (max)
Delivery	150 m/min (max)
Sheet thickness	0.4~1.6 mm
Sheet width	760~1 830 mm
Coil weight	
Entry	42 t (max)
Delivery	25 t (max)
Plating cell	CAROSEL type 7 cell (25 kA × 20 V × 14 units)
Coating equipment	
Coater	2 roll reverse coater × 8 units
Oven	Circulated hot air jet
Cooler	Air cooler (No. 1), water cooler (No. 2)

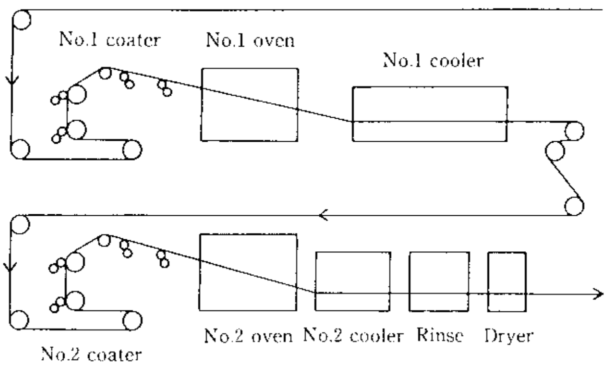


Fig. 3 Outline of in-line coating facility

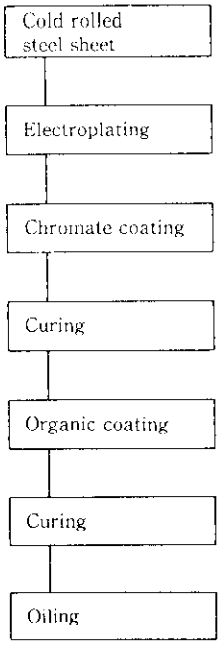


Fig. 4 Manufacturing process

facility. **Figure 4** shows the manufacturing process for PLASCOAT K V, which is the principal product from this line.

3.1 Paint Supply Facility

The paint supply facility consists of the paint warehouse, paint mixing tank and paint circulation tank. To save labor automatic management of the paint warehouse and automatic control of paint viscosity are carried out, and an outline of the automatic paint bath control system is shown in **Fig. 5**. In order to achieve high-accuracy control of the coating weight, controlling the paint viscosity is indispensable, while paint temperature control, which greatly affects viscosity, is also important. The present system provides a heating system which uses warm water, for both the paint mixing tank and paint circulating tank, and automatically controls the temperature of the paint bath to a constant level. The paint circulating tank is also provided with an on-line viscometer and, while continuously measuring the paint viscosity, a diluting solution is automatically supplied to control the viscosity at a constant level.

3.2 Reverse Roll Coaters

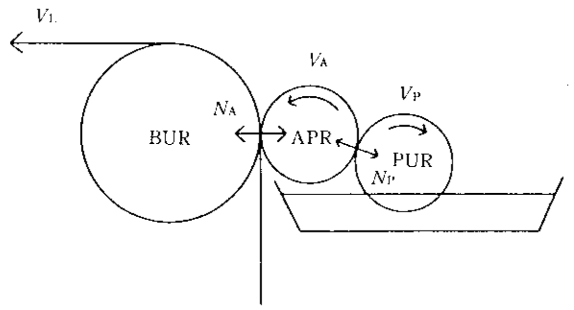
The roll coaters consist of No. 1 coater for chromate processing and No. 2 coater for resin coating, each coater having two heads on the top surface side and two heads on the bottom surface side, thereby providing eight coaters in total. **Figure 6** shows a schematic diagram of the roll coaters. The two-roll reverse coating method consisting of the applicator roll (APR) and pick-up roll (PUR) is employed, but the system is also designed to perform natural coating.

3.2.1 Roll speed control

The speed of APR and PUR is controlled to a high accuracy by an AC motor fitted with variable voltage/variable frequency (VVVF) control.

3.2.2 Inter-roll pressure control

The inter-roll pressure of the coater greatly affects



BUR : Back up roll
APR : Applicater roll
PUR : Pick up roll
V_L : Line speed
V_A : Roll speed of APR
V_P : Roll speed of PUR
N_A : Roll pressure between BUR and APR
N_P : Roll pressure between APR and PUR

Fig. 6 Reverse roll coater

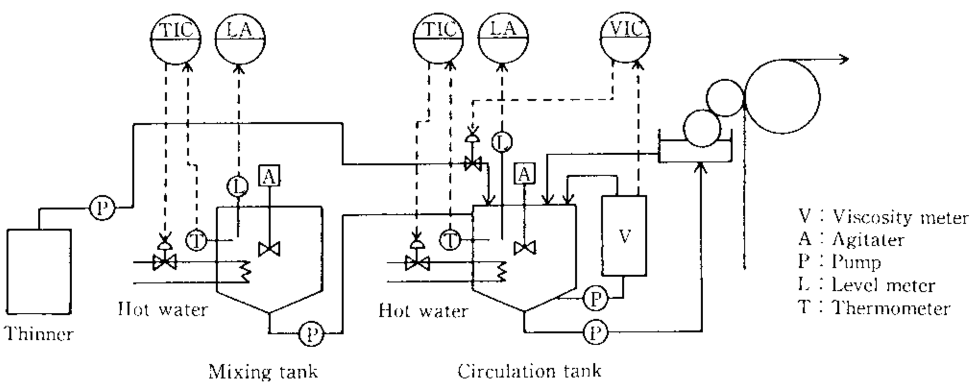


Fig. 5 Paint bath control system

Table 2 Coating weight control formula

Model formula No. 1 (Linear model)	$L=AV_A+BV_P+CV_L+D$
Model formula No. 2 (Non-linear model)	$L=KV_A{}^x V_P{}^y V_L{}^z$

L: Coating weight
V_A: Roll speed of APR
V_P: Roll speed of PUR
V_L: Line speed
A, B, C, D, K, x, y, z: Coefficients

Table 3 Oven and cooler specifications

	No. 1 oven	No. 1 cooler	No. 2 oven	No. 2 cooler
Heating method (cooling)	Circulated hot air jet	Air jet	Circulated hot air jet	Water spray
Strip conveying	Catenary	Floater	Catenary	Catenary
Furnace length	7.5 m × 2 zone	10 m × 3 zone	7.5 m × 3 zone	5 m
Temperature	Max 500°C	15~30°C	Max 500°C	20°C

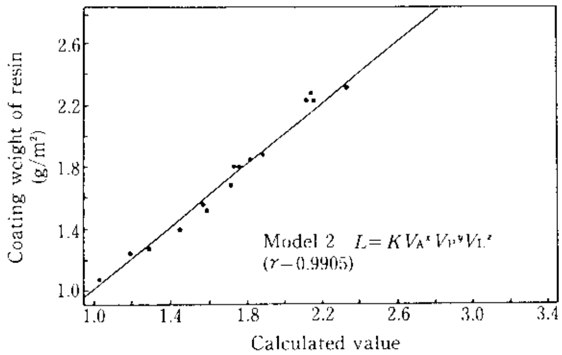


Fig. 7 Calculated and measured values of resin coating weight

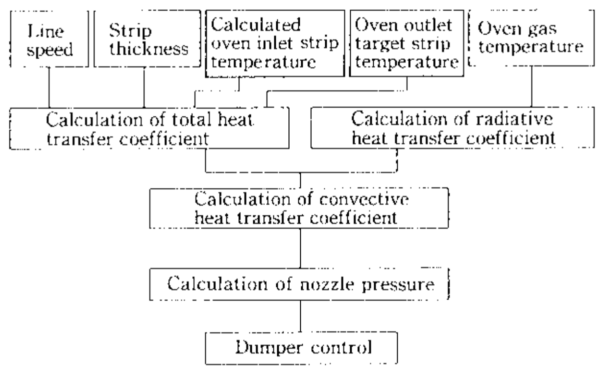


Fig. 8 Strip temperature control system

the coating weight, and is particularly important for adjusting the paint coating-weight profile in the strip width direction. In the present facility, a load cell is provided between each respective set of two rolls (between PUR and APR, and between APR and BUR) to detect the inter-roll pressure, and a servo-motor is installed to maintain the inter-roll pressure at an appropriate level.

3.2.3 Coating weight control

The line uses the two coating weight control formulas shown in **Table 2**. Formula No. 1 is a linear model, while formula No. 2 is non-linear, and the use of these formulas enables the coating weight to be controlled to a constant value against fluctuations in line speed by changing the speed of either APR or PUR. In **Fig. 7**, a comparison is shown between the calculated and measured values of the resin coating weight when formula No. 2 was used, and illustrates the high control accuracy of the coating weight.

3.3 Oven and Cooler Facilities

The oven and cooler facilities comprise No. 1 oven and No. 1 cooler for chromate use, and No. 2 oven and No. 2 cooler for resin coating. **Table 3** shows the specifications of these facilities.

3.3.1 Ovens

Circulated hot-air gas jet heating is used, and line speed fluctuations are compensated by varying the hot air jet speed with the opening of the circulated hot-air damper. **Figure 8** shows the logic for controlling the temperature of the sheet. The strip temperature is controlled by setting up the necessary hot air flow rate from such data as the oven gas temperature, line speed, and strip thickness, and adjusting the opening of the circulated hot air damper.

3.3.2 Coolers

No. 1 cooler for the chromate treatment is air-cooled, while No. 2 cooler for resin coating uses water-cooling. The strip temperature in No. 1 cooler is controlled in the same way as that in the ovens by the damper opening, after setting up the required cooling air flow rate from such data as the cooling air temperature, line speed and sheet thickness. No. 2 cooler provides rapid cooling by a high-pressure water spray.

3.4 On-line Quality Assurance Equipment

To ensure quality along the entire length of the product coil, on-line analysis apparatus is provided. The line employs on-line flourescent X-ray analysis to measure the alloy-plated coating weight and Cr coating weight, and on-line infrared (IR) analysis to measure the resin coating weight.

3.4.1 On-line fluorescent X-ray analyzing system

The line uses the same on-line flourescent X-ray analyzing system to measure the alloy-plated coating weight as that has been used since earlier days.[4] An outline of this system is shown in **Fig. 9**. This system provides continuous measurement of the alloy-plated coating weight and Cr coating weight, thereby giving quality monitoring along the entire length of the product coil.

3.4.2 On-line IR analyzing system

On-line measurement of the resin coating weight is done by an IR analyzing system an outline of this system being shown in **Fig. 10**. Its operating principle lies in measuring the absorbance peak of infrared rays caused by the C–H stretching vibration in the resin coating film, and in converting the degree of absorbance into the resin coating weight. This system uses a special filter for enhancing the measuring accuracy.

3.5 Computer Control System

An outline of the computer control system used in this line is shown in **Fig. 11**. When the new coating facility was installed, electrical DDC (direct digital control, CP-3500) and instrumentation DDC (TDCS) were added. Electrical DDC is applied for line operation control, catenary control, coater roll speed control, inter-roll pressure control and paint coating weight control in the

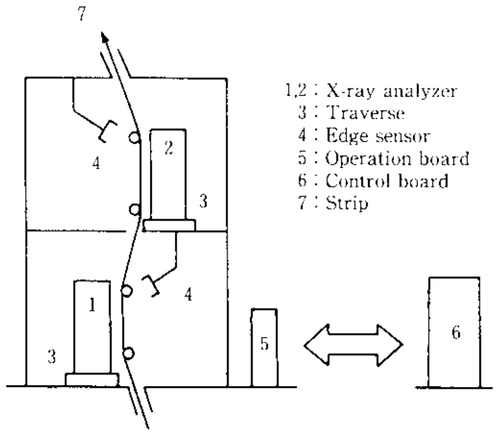


Fig. 9 Outlook of on-line X-ray analyzing system

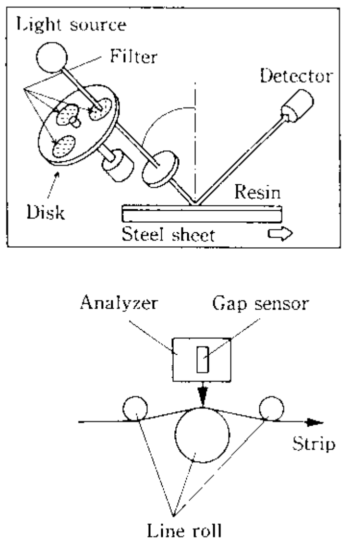


Fig. 10 Outlook of on-line IR analyzing system

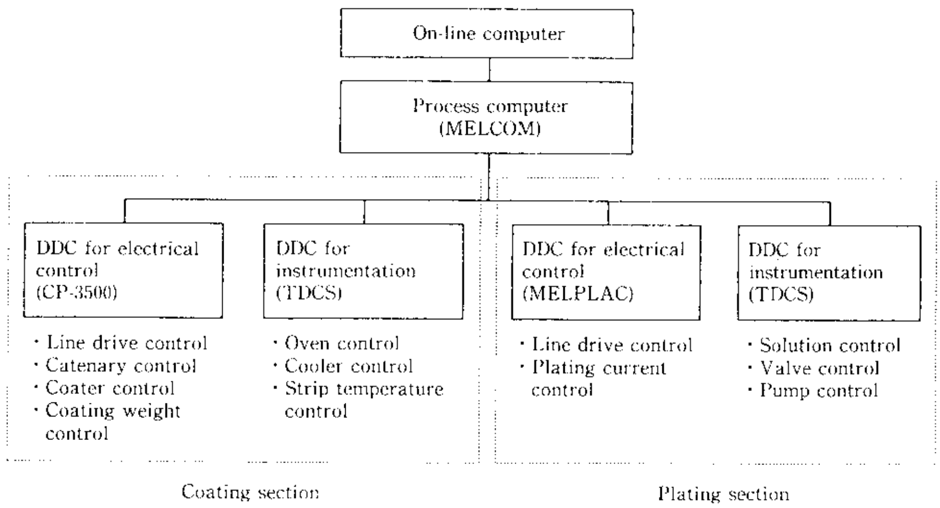


Fig. 11 Computer control system

coating section, and instrumentation DDC is applied for oven control, cooler control and strip temperature control.

Each control system operates through a CRT display to save labor and rationalize the operation of the line.

4 Operating Conditions

4.1 Production

PLASCOAT K V from this line reached a monthly production of 8 000 t as early as April 1989, 6 month after starting operation. The present monthly production is 15 000 t or more, showing that it has been possible to apply mass-production techniques within a short time.

4.2 Quality

4.2.1 Coating weight

Figure 12 shows the frequency distribution of the Cr and resin coating weights. The Cr coating weight is within $\pm 20\ mg/m^2$ of the target value, and the resin coating weight is within $\pm 0.1\ g/m^2$, illustrating the high level of coating weight control. **Figure 13** shows the fluctuation in Cr and resin coating weights when the line speed is changed. When the line speed is changed from 120 m/min to 80 m/min, and then from 80 m/min to 45 m/min, the Cr coating weight fluctuation is within $\pm 10\ mg/m^2$ and resin coating weight fluctuation is within $\pm 0.05\ g/m^2$. This illustrates that coating weight control, which has been a technical problem, is now satisfactory.

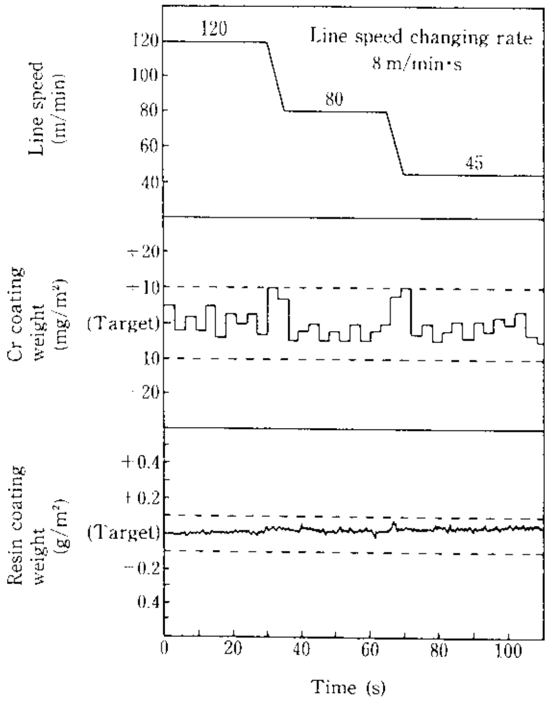


Fig. 13 Fluctuation of Cr and resin coating weights when line speed changes

4.2.2 Baking temperature

The frequency distribution of baking temperatures of products is shown in **Fig. 14**. Both No. 1 and No. 2 ovens show satisfactory strip temperature control to

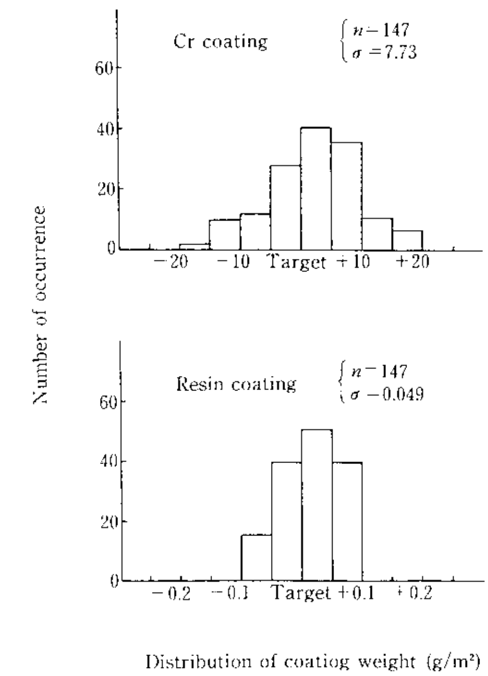


Fig. 12 Distribution of Cr and resin coating weights

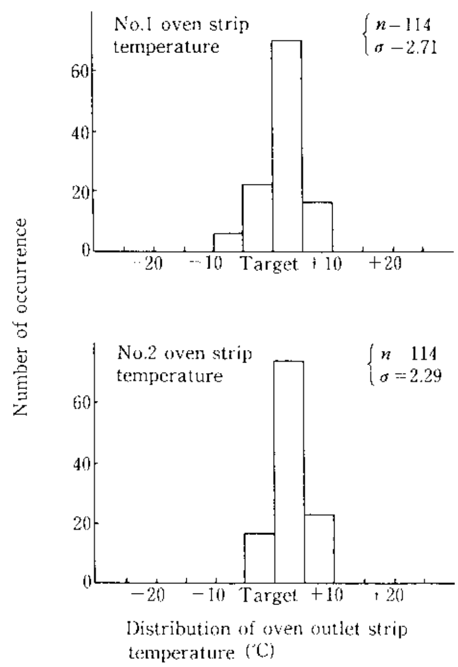


Fig. 14 Distribution of baking temperature

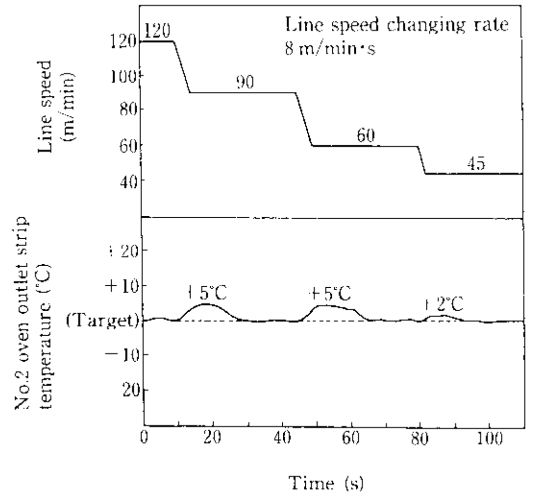


Fig. 15 Fluctuation of No. 2 oven outlet strip temperature when line speed changes

within ±10°C of the target value. **Figure 15** shows the fluctuation of No. 2 oven outlet temperature after line speed changes. The response speed for sheet temperature control is satisfactory, resulting in a temperature within ±5°C of the target value.

5 Conclusions

This report provides an outline and operating conditions of the in-line thin coating system which has been added to the electrogalvanizing line at Chiba Works.

(1) PLASCOAT K V, which has been in production on this line since October 1988, recorded a monthly production of 8 000 t in 6 months, and at present is achieving a monthly production of 15 000 t, illustrating the establishment of mass-production techniques within a short period.

(2) The quality of PLASCOAT K V is also satisfactory, and it is possible to control the Cr coating weight to within $\pm 20\ mg/m^2$ of the target value, the resin coating weight to within $\pm 0.1\ g/m^2$, and the baking temperature to within ±10°C.

(3) The coating weight control and strip temperature control, which have given technical problems in the past, are now satisfactory, and it has become possible to control the Cr coating weight to within $\pm 10\ mg/m^2$ of the target value, the resin coating weight to within $\pm 0.05\ g/m^2$, and the paint baking temperature to within ±5°C of the target value.

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