PERFORMANCE RESULTS AND FUTURE DEVELOPMENTS FOR POT EQUIPMENT[1]

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Abstract

Pot Equipment purchasing decisions are one of the most important business decisions a company makes. These are typically based on a cost and benefit analysis using known costs and assumed benefits. This is particularly true for experienced line operators when upgrading older equipment. This paper looks at the typical performance results obtained over an extended period and quantifies the benefits that the pot equipment and associated controls have provided to the business. Historically there has been a focus on transition control as the main method of gaining value from the pot equipment and coating mass control system. Downgraded product costs typically exceed the value of the coating metal shortfall on each occurrence where the coating class transition failed. However, with the increase in coating metal prices over the last 10 years, steady state coating performance again holds great potential for reducing operating costs. This trimming of the excess coating has to be done while providing a consistently high quality product that meets the target grade. The increasing use of automatic coating systems has made production cost savings harder to realise. With ample automatic and manual operating data for existing lines, we quantify the benefits of pot equipment design with an integrated control system. Based on the results, this paper examines the future developments that are required to make further gains in operational effectiveness and savings.

Key words: Achieva pot equipment; Coating mass control; Dynamic targeting; Strip stabilisation.

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1 INTRODUCTION

The Achieva pot equipment design project started in response to a list of requirements drawn up by an experienced coated products producer. The aim was to produce a fully integrated electro-mechanical package, combining an integrated control system. The control incorporated a process model for faster transition control, and a mechanical design that addressed the safety concerns with operating heavy pot equipment in the pot area. The resulting system has proven itself on many sites and can demonstrate good steady state, transition control and is capable of operating fully automatically.
Ongoing development is important to any technology based product. Determining the path to be taken is guided by many factors, in this instance the emergence of new coating compositions that require unique coating strategies. To allow the systems development path to be better defined, the Hatch IAS AchievaCE pot equipment was benchmarked against an older system. The analysis of the operational performance logs from two sites shows the capacity of the coating equipment in the production environment. Looking to the future and with the aid of a defined development path, opportunities have been taken to advance the system further.
Firstly, the ability demonstrated by the pot equipment to respond to small changes, which allows a potential development for lines that ‘sell from the gauge’. This is one of the few remaining avenues for optimising the coating metal usage while maintaining the prime percentages.
The other route is the equipment development path. The metallic coated steel product range has been relatively stable for many years; however the last five years has seen an increase in the range of alternative compositions for the coating material. These new coatings offer superior performance and do so with thinner coatings than previously used, enabling lower production costs. These new coatings require a change to traditional stripping strategies and some changes in the pot area aimed at reducing the conversion costs and enabling the stripping of many of the new coatings.

2 POT EQUIPMENT LIFE CYCLE

The timing for the renewal and upgrade phases varies depending on the business sector and business development plans. For instance, a coating mass control computer can be added to existing pot equipment. A processor can be added to the existing pot equipment control scheme by physically adding a computer running the software and communicating to the existing equipment using a serial data connection.

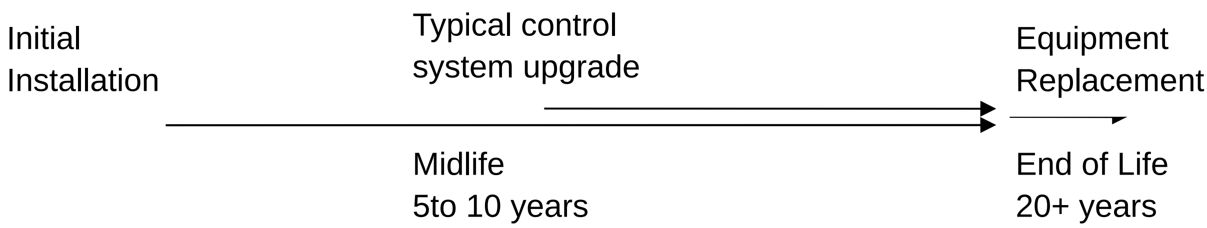

Figure 1 Typical Equipment Lifecycle.

To justify replacing the pot equipment, the new system has to offer improvements in production costs and safety. While safety is a driver, the decision to replace the equipment will involve a cost benefit analysis and a financial justification. Replacing the pot equipment is expensive and the returns have to be measurably higher to justify the outlay. Any business that has run for this length of time will be well versed in this process.

2.1 Control System Design

Design of the control system has to consider the life expectancy of the equipment. The aim is to produce a software package for the operation of the equipment rather than be specific to a narrow part of the process. The control has to avoid creating obsolescence issues as the technology of the product evolves. This can also occur through configurations and settings becoming obsolete as the process evolves. Line improvements which increase production speed, widths, thickness and chemical or composition changes mean that the settings embedded in the control system at the time of commissioning are no longer satisfactory. Aggressive process improvement can render control systems obsolete in less than 6 months. A strategy has to be developed to allow for easy retuning or self tuning overcoming this problem. The skill sets available on site have to be taken into account then developing a strategy to avoid ‘locking’ the control to a single product or process configuration. Process changes often represent the greatest threat to the service life of an automatic control system operating on a production plant. Failure to allow for this will severely limit the finical return assumptions that justified the purchase.

2.2 Benefits of Integrated Design

By designing the electrical and mechanical systems together, elements of the control can be specified. Servomotors with integrated gearboxes, encoders and using soft limits allow single units to be mounted, saving time and complexity in the mechanical design. Integration allows a system with fewer functional components and far fewer physical components. The system uses the simple languages found in typical industrial PLC equipment and serial data links have been eliminated because all the processing is now on a single platform with the separate function now merged into a single program. The accuracy of the servo equipment and the integration with the mechanical equipment allows excellent coating control with operation that covers all typical plant operating conditions.

The equipment can start on automatic and remain in this mode for the operation of the line. With the reduced need to reselect the automatic control, the equipment spends more time in automatic mode giving greater financial returns.

3 POT EQUIPMENT DESIGN

Positioning the air knives reliably and with a high degree of certainty allows the efficient use of feed forward control systems. This contributes to the product quality and increases the coating accuracy during production transitions. In addition to the feed forward control benefits, the positioning accuracy increases the effectiveness of the closed loop control. The potential metal savings are a function of the ability to continually position the air knives accurately. Minute changes to the strip roughness, coating composition, temperature and barometric pressure all contribute to inaccuracies or drift in the applied coating. The changes are small and occur slowly; however they can be limited by the closed loop control. Typical control sensitivities are between 3 and 5 grams/mm giving a gain of 0.2 to 0.33mm/gram. To control these levels, we need the ability to adjust the air knives at a resolution 4 times better. This sets the design resolution and accuracy requirement to less than 0.05mm. Using this value will give the best practical control of the coating mass under steady state conditions. It is not necessary to refine the positioning accuracy further because the gauge's ability to measure the coating will become a significant issue.

3.1 Motor and Feedback Devices

Selecting brushless servo drives was the best option when considering the accuracy required for an effective closed loop system. The ability to control the coating to fine tolerances and the speed of positioning would give the required financial return. Modern servo motors have built in encoders that provide high resolution feedback. By combining these with the ultra-low backlash reduction gearboxes and preloaded ball screws, a practical positioning ability of +-of 0.05mm is guaranteed.

4 FUNCTIONAL BENEFITS

4.1 Coordinated Referencing

We now have control over the air knife position, both in air knife to strip distance and skew. The elevator height and pressure are also controlled and can be independently set for each coating class and line speed. The majority of coating mass errors in the product stem from air knife to strip distance problems. Whether these are caused by roll setup, bearing wear, strip conforming to the roll circumference, thermal expansion and strip camber or crossbow. It is better to adjust the air knife to strip distance accurately than use the air knife pressure to control the coating. Position control now becomes the principle method for controlling the coating. This allows the pressure to be set for the product, an advantage on Zn/Al coatings where the pressure range is limited to avoid surface defects.

4.2 Balanced Air knife Pressures

Independent control of the position allows the pressure to remain equal in the two air knives avoiding the divergence in pressures typically seen when only the air knife pressure is used to control the coating.

4.3 Air knife Skewing and Tapering

With independent position control on each end of each air knife, the automatic control is free to balance the coating on the left and right hand sides of the strip. This balancing across the width of the strip can not be achieved by pressure control. This can happen symmetrically where the strip has a twist or independently in the case of surface roughness differences or the various effects caused by the incorrect operation of the furnace.

4.4 Coating Mass Control and Crossbow Decoupling

When using a single stabiliser roll configuration, the stabiliser roll can be repositioned to reduce the crossbow that develops in thicker products. The air knife position is automatically adjusted to compensate for this, effectively decoupling the coating mass control from the crossbow adjustment. This allows greater freedom for the operator to adjust the intermesh and eliminates the risk of the strip striking the air knives.

5 DETERMINING CONTROL CAPABILITY

5.1 Reviewing Coil Coating Data

Comparing the results from two lines producing products with similar dimensions and coatings composition, a system capability can be determined. This was done by reviewing the average coating applied to production coils which are normalised to their respective coating mass set points.
Looking at the coil average coating mass results of a large sample of coils from each line, we can compare the performance of Line-A when operating in manual and after an upgrade when operating in automatic. This is compared to Line-B which uses the Achieva ACE pot equipment operating in automatic. The coil average coating distribution is analysed for both the general operation and when running close to a steady state.
Data Sample Size

Line A – Manual coating operation	684 coils
Line A – Post Upgrade in Automatic Operation	2647 coils
Line B – Automatic Operation (All Coils) [1]	10977 coils
Line B – Automatic Operation (Steady State)[2]	8763 coils[3]

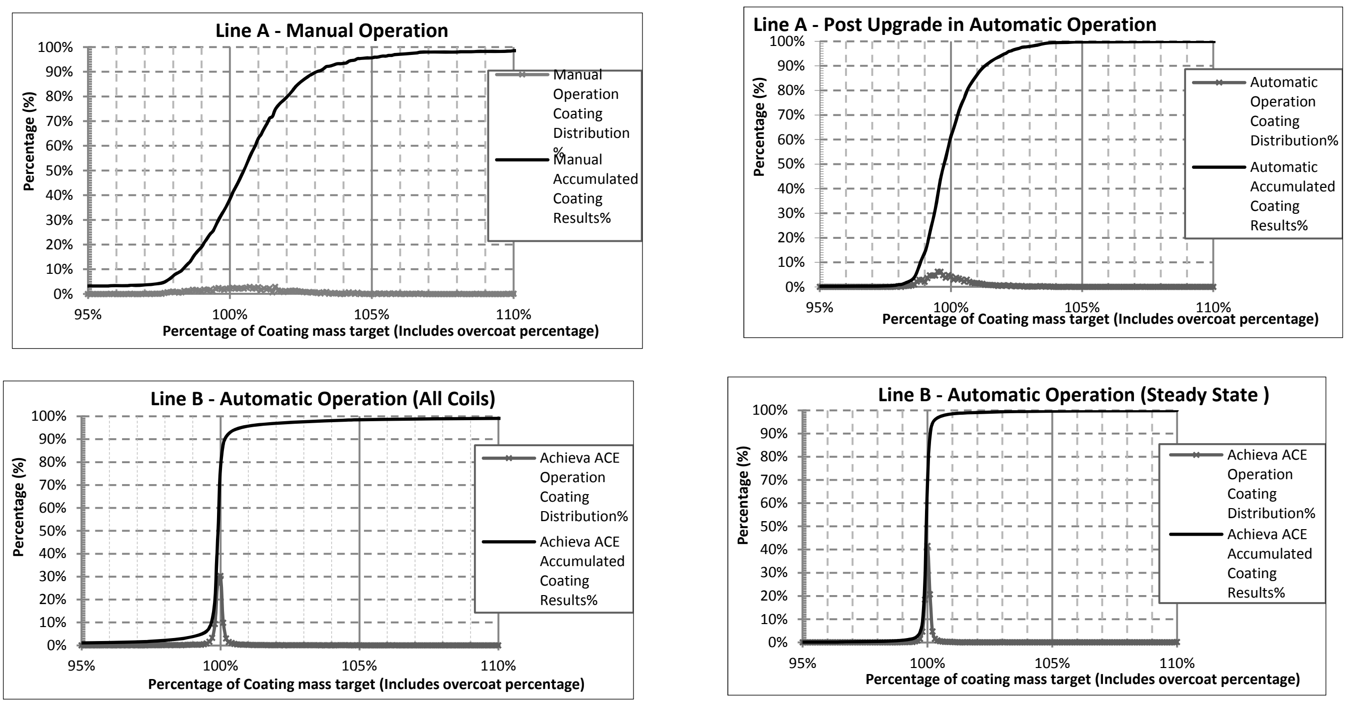

Figure 2 – Comparision of coating accuracy produced on Line A and Line B.

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1 All coils includes coils that are processed using automatic control, at greater than 30 m/min and have at least valid 5 gauge measurement scans logged.

2 Steady state includes the above coils where the process speed changes less than 10m/min and there is no coating class change.

To make the comparison and quantify the performance, the data for each case has been analysed and the standard deviation calculated. A setpoint or target that would give an equal proportion of coils above and below the target grade is calculated. For simplicity, taking a 2.5 Sigma offset will give 0.62% of the coils as undercoated and 99.38% meeting the target grade. Adding 2.5 times the standard deviation to the nominal target, we should achieve only 0.62% of the coils being undercoated. The following graphs present the coil coating distribution for two different production plants. The results show the distribution of coils around the nominal coating mass setpoint.

With enough coils to provide a good snapshot of the lines performance, we're able to analyse the data to provide an accurate prediction for the required coating mass setpoint to achieve a specific undercoated percentage. The general control focus in recent years has been on handling transitions and reducing the losses due to undercoated material. The equipment's control system offers a feedforward correction for each major operating parameter allowing transitions to be executed; however there are significant material costs to be saved in accurately executing the position commands in the body of the coil. This fine level of control demands precision servo system and zero backlash mechanical equipment. These results highlight the very good positional accuracy of the equipment as essential to the efficiency of the control system and resultant cost effectiveness of the coating control.The following table is based on a line processing one metre wide product at 150 metres per minute and assumes the line is operating 86% of the time. This example uses a nominal coating class of 150g/m2 (45% Zn/ 55%Al).

Table 1 – Cost of excess metal to achieve 0.5% undercoated coils

	Line-A		Line-B	
	Manual Operation	After control system upgrade	All coils in automatic	Steady state operation
Over Coat Bias percentage (+2.5 Sigma)	15.62%	5.86%	1.48%	0.95%
Target including Over Coat Bias Grams (+2.5 Sigma)	173.4 g/m2	158.8 g/m2	152.2 g/m2	151.4 g/m2
Coating Target to achieve 150g/m^2 (g/m2)	1584 Tonnes	594 Tonnes	150 Tonnes	96 Tonnes
Excess Coating Metal used in 1 year (Tonnes)	$3,168,511	$1,187,855	$299,165	$192,683

The simple analysis presented in Table 1 has centred on the coating performance, focusing on total metal consumption per coil. When all other costs are analysed, a more complete cost map can be created.[2] The flatness of the strip at the point of stripping is important in allowing the pot equipment to work effectively and the costs of strip defects at this point can be calculated. In this case, the strip is relatively flat allowing a good comparison of the equipment performance.

Transition control is implemented with the positioning ability complementing the coating process model. Independent skew control allows both front and rear air knives to be independently positioned for total coating mass and balancing the coating on both edges of the strip.

6 NEW DEVELOPMENTS

With an ability to tightly control the steady state operational condition, modulation of the setpoint can be employed to achieve the required average coating thickness in the body of the coil. Moving away from etching samples of the product and using a modern coating mass gauge opens up an opportunity to control the setpoint rather than control to a setpoint.

6.1 Dynamic Setpoint Targeting

The level of control demonstrated allows techniques such as Dynamic Setpoint Targeting (DST) to be implemented, further reducing the overcoat allowance while minimising the risk of undercoating. The result would represent the next logical step in coating control development.

Coating metal savings based on reducing consumption are harder to make as we get closer to the ideal. The next development will be dynamic coating mass setpoints or 'Dynamic Setpoint Targeting' control based on the ASTM A924/A924M standard for selling from the gauge. With the resolution of control demonstrated by the data analysis, we are able to develop a dynamic setpoint that will produce a coil with the required coating metal applied. The coating specification ASTM A924/A924M states that a coils coating can be calculated by taking the average of at least 5 random scans. As the body of the coil is processed, the target will be dynamically altered to keep the coating just above the target grade while conforming to the standard. Knowledge of the length of the coil will have to be provided to the control system to allow new targets to be calculated with a view to completing the coil with the desired mass.

This requires high resolution in positioning the air knife and steady strip to allow a consistent coating applied. Loose or unstable strip will produce a higher scan by scan standard deviation, making the ASTM calculation method results more erratic. It would be possible to pick several lighter scans have the coil fail. The stability of the strip at the stripping line is important to the control target of the coating mass control system. There are many reasons for the adoption of stabilising systems for the strip and this is beneficial in enabling an improved setpoint strategy.

6.2 Air Flotation based Stabiliser Systems

The application of strip stabilisation systems has been increasing over the last 5 years. These systems address common problems found in the operation of coating lines. In response to client demand, Hatch IAS has co-developed a strip stabilising system that can be integrated into the air knife beam or retrofitted to existing pot equipment systems, known as the **'Achieva Flotation Stabiliser' or AFS**.

The system consists of a pair of carefully designed pressure pads placed on either side of the strip. Air is introduced to create a higher pressure region between the pad and the strip. This high pressure region between each pad and the strip creates a centring force on the strip, correcting the position and dampening vibrations in the strip.

The air flotation stabilising unit creates an area of higher pressure between the unit and the strip (Figure 3). The total force applied to the strip surface is dependant on the strip width, unit depth, operating distance and supply pressure. These are adjusted in the design phase to give the desired balance between stabilisation, cooling and energy consumption. The supply pressure is controlled to the same setpoint on each side of the strip so the resultant force on the strip is dependant on the distance between each strip surface and the associated AFS unit.

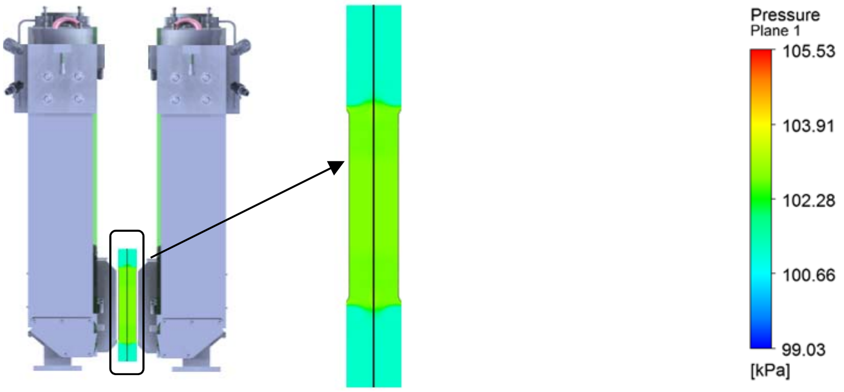

Figure 3 - Strip with high pressure region either side.

As the strip deviates from the centre position, the distance to one unit increases, decreasing the pressure between the unit and the strip and therefore the force applied to the strip (Figure 4). As the distance on the reverse side of the strip decreases, a corresponding increased pressure between the unit and the strip gives a greater force between the unit and the strip. The resultant force (Figure 5) on the strip is one that works to restore the strip to the centre or balanced position.

6.3 Static Correction Forces

Using an AFS unit mounted in the beam with an effective depth of 215mm and an air source controlled to give a constant pressure, the following forces are to be expected on a one metre wide strip.

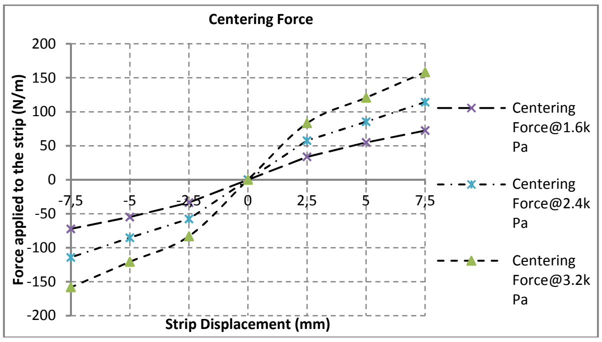

Figure 4 - Static Reaction Force.

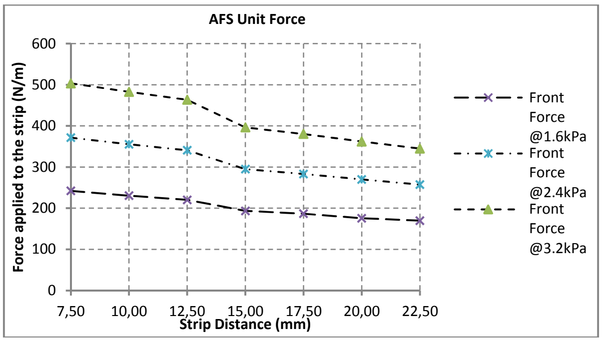

Figure 5 - Strip Deviation Correction Force.

Each installation has been designed to fit onto existing lines and this example is indicative of a typical installation. The final performance is determined by the surface area of the unit, the internal arrangement and capacity of the air supply circuit. The design parameters are altered to optimise the stabilising, cooling and air supply constraints.

6.4 Crossbow Reduction

The resultant force on the strip has a correcting action on the longitudinal waves present in the strip from the pot to the top deflector roll. The forces also have a correcting effect on the crossbow in the strip. The forces increase as the strip deviates from a flat state greatly reducing crossbow particularly on lighter gauges. The use of the AFS's stabilising and flattening features has allowed the removal of the stabiliser roll on thin gauge lines, lengthening the campaign time and saving both equipment and rebuild costs.

On heavy gauge lines, correcting excessive crossbow by adjustment of the pot roll intermesh is still the preferred solution.

6.5 Air Knife Strikes

With the trend to sophisticated new coatings that have associated production difficulties, the typical stripping strategies are trending towards smaller air knife to strip distances and lower pressures. This places a greater focus on the relationship between the passline and air knives, particularly the movement of the strip and the increased chance of air knife strike. While strip stabilisers have been seen as ways to improve consistency of the coating applied, they will increasingly find applications to stabilise the strip and prevent air knife strike.

6.6 Simplicity

The system uses a natural air cushion phenomenon. The cushioning effect is controlled by regulating the supply of air to the plenums and the geometry of the internal air flow passages. The air is typically supplied by a centrifugal blower, similar to the unit used for a typical air knife supply. The speed of the blower governs the pressure supply and the manual control valves maintain the pressure balance between the two plenum pressures at all times. The blower speed is controlled to a predetermined setpoint using a VVVF drive, based on information recorded during the commissioning phase.

On lines where the air knives operate over a small range of distances, such as products with light coatings, the unit is built into the air knife beam. On lines where there is a larger air knife to strip distance range, the AFS unit will be mounted in a way that allows the option of varying the relationship between the AFS face and the air knife lips.

7 CONCLUSIONS

The fresh start to the design of the pot equipment allowed a new look at the automatic and manual control interface as well as the electrical and mechanical interfaces. The simplification that comes from the integrated design has been one of the primary design goals.

- One requirement to achieve a long service life is not to lock the control to a specific condition. Control schemes specifically tuned to a process condition can lock the control to a specific plant condition. This limits the life of the control scheme as the process varies.
- Add simplicity and remove electricity. There will be a point where the additional complexity will fail to provide significant short term rewards and will increase the probability of early retirement of a system through complexity.
- Training comes and goes but simplicity lasts. Choose the platform to suit the maintainer's skill set. Keep the available plant skill set in mind when making these decisions. Modern PLC processors are very fast, reliable and their operating system is intended for industrial process control.

The Achieva Coating Equipment has demonstrated a high degree of coating control accuracy in service. The use of CNC style electrical and mechanical position equipment has allowed fast transition control and maintains close tolerances during the body of the coil. Being able to achieve specific coating targets allows the coating target to become controlled, with the aim of ensuring that every coil passes the required coating standard. Tighter or active coating targets can be used when 'selling from the gauge' is in use.

New equipment developments are underway to extend this operating envelope and to provide technologies to assist in the production of for new coating types. The Achieva Flotation Stabiliser aims to introduce a simple and rugged strip stabiliser to coating lines that offers many of the advantages of the alternative systems currently on the market. The inherent self stabilising nature of the technology allows a passive system without onboard electronics and associated controls. These benefits are achieved with relatively little impact to the handling needs of the units during pot equipment changes. When combined with the existing equipment and Dynamic Setpoint Targeting, the stripping process is both more reliable and cost effective.

The first Achieva Flotation System (Figure 6) entered service with our development partners in January 2011 and the commissioning of the AFS on the third line will take place in June 2013.

Figure 6 - Achieva Flotation Stabiliser built into the Achieva CE Air Knife Beams

REFERENCES

1 Ellen, C. H., and Tu, C. V., "An Analysis of Air knife Stripping of Liquid Coatings," Journal of Fluids Engineering, Vol. 106, 1984, pp 399-404.

2 Glen Wallace and George Voss, et al. Metal Coating Control Economics // Galvanizers Association 97th Annual Meeting 2005.