A MEANS TO CONTROL SOLUTION STAIN
THE SMS DEMAG DRY STRIP SYSTEM

Dipl. Ing. Wolfgang Denker [1]
Michael J. Peretic ASQ-CQE [2]
Joseph J. Saxinger [3]

Strip surface appearance has become an increasingly important quality attribute in recent years. One particular area of focus has been prevention of the "Solution Stain" that results from rolling fluids coming in contact with the finished sheet after the last pass or stand in cold rolling mills.

A number of approaches to blow, wipe and/or squeegee away these fluids have been tried with varying degrees of success.

The patented SMS Demag Dry Strip System represents a departure from these more conventional technologies in that its focus is to manage the movement of airborne coolant in a manner that prevents it from falling onto the sheet surface after the sheet exits the roll bite.

Dry Strip Systems have been applied in both single stand and tandem mills, rolling ferrous as well as non-ferrous sheet. Systems are readily integrated into new mill designs, and can also be retrofitted into existing mills.

This paper will describe several causes of Solution Stain. It will also discuss how the Coanda and Venturi effects are utilized to direct airborne coolant away from the strip. It will conclude by showing the reduction in rejection rates for coils before and after installation of a Dry Strip System.

Keywords: dry strip, solution stain, blow-off

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[1] Manager of Plant Technology for Hot and Cold Rolling Mills and CSP – Hot and Cold Rolling Mills Division – SMS Demag AG – Hilchenbach, Germany

[2] Principal Engineer – Flat Rolling Mills Process Technology - SMS Demag Inc. – Pittsburgh, PA, USA

[3] Engineer 3 – Flat Rolling Mills Engineering - SMS Demag Inc. – Pittsburgh, PA, USA

1. Introduction

Producers of both ferrous and non-ferrous sheet have found that strip surface appearance has become an increasingly important quality attribute in recent years. One particular area of focus has been prevention of the “Solution Stain” that results when residual rolling fluids either splash or condense and drop onto the finished sheet after the final mill stand pass.

A number of approaches have been tried to remove residual fluids from the sheet surface with varying degrees of success. These approaches typically involve attempting to blow, wipe, or squeegee it away *after* it has been deposited on the finished strip.

The SMS Demag patented Dry Strip System represents a unique solution to this problem. It is designed to employ fluid dynamic principles to manage the movement of the airborne coolant at the exit end of the mill stand, so as to prevent it from ever reaching the finished strip surface.

These Dry Strip Systems have been applied in both single stand and tandem mills. They are designed to operate at maximum rolling speeds, over a wide range of strip widths, and they can be directly integrated into new mill installations, or retrofitted to existing mills. Applications include mills for both ferrous and non-ferrous sheet with emulsion or rolling oil (i.e. kerosene) based fluids.

This paper begins with a description of the causes of “Solution Stain” and provides some comments regarding the meaning of the term “Dry Strip”. It also discusses the configuration, operating principles, and capabilities of the SMS Demag Dry Strip System. Finally, it concludes showing the reduction in strip surface defects that occur after installation of an SMS Demag Dry Strip System in operation.

2. Solution Stain and the Meaning of Dry Strip

There is no universally accepted industry standard that quantifies the appearance of a finished strip surface. In fact, sheet surface appearance is usually assessed subjectively -- by an Inspector who decides whether the sheet is “OK or not” by looking at it and making a judgment based on past personal experiences.

In reality, there are many factors that impact sheet surface appearance -- and Solution Stain is only one of them. Sheet surface roughness, surface defects that result from roll marks, and surface conditions that form due to lubricant breakdown in the roll bite, are some of the other factors that can also influence appearance. A discussion of these other factors is beyond the scope of this paper, which will focus exclusively on Solution Stain.

Solution Stain will be defined in this paper as the sheet surface defect that results when coolant droplets are deposited on the strip surface after it exits the roll gap on the last cold rolling pass.

Different materials have different responses to the presence of Solution Stain.

For sheet steel products rolled with water-based emulsions, Solution Stains typically lead to localized patches of oxidation. This oxidation takes place as the water and oxygen react with the surface of the steel sheet in the rewound coil. Results found upon later inspection are typical of that shown in Figure 1.

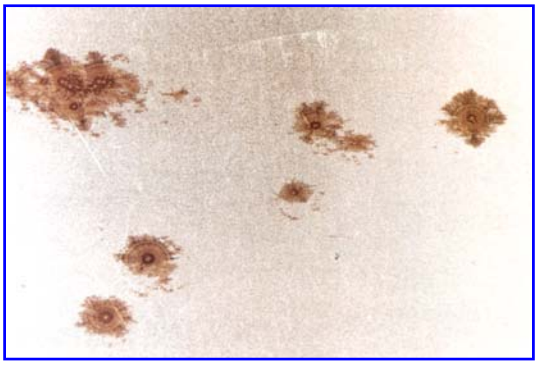

Figure 1: Solution Stain on Steel Strip

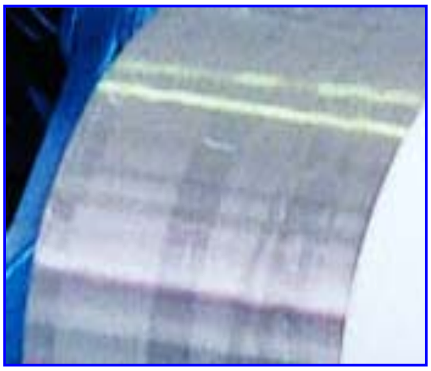

Figure 2: Solution Stain on Aluminum Coil

Non-ferrous sheet (such as aluminum) exhibits a different type staining from water that often appears as a white spot on the sheet. Also, Solution Stain resulting from uncontrolled kerosene based coolants usually appear as patches or spots that continue to look much like fluid stains.

These stains are unacceptable for subsequent processing and must be removed via special treatment processes when they occur. Figure 2 shows one such example of Solution Stain from rolling oil on the outer wraps of an aluminum coil.

It should be noted that Solution Stain does not result from coolant droplets passing through the roll bite (i.e. between the work rolls and the strip). In fact, under normal rolling conditions, it is generally accepted that the rolling loads on the work rolls form an effective "squeegee" which prevents this from happening.

Nonetheless, coolant can reach the exit side of the mill by other means, such as:

- Coolant can pass through the opening between the work rolls that is outboard of the width of the strip, and then adhere to the finished strip – predominantly at its edges.

- Coolant can pass from the entry side work roll surface to the entry side back-up roll surface. This coolant can then be flung as droplets from the back-up roll directly onto the finished sheet, or onto other exit side equipment where they collect, form larger droplets, and then drip onto the finished sheet.

- Droplets of coolant can bounce off of the roll and/or incoming sheet, and then rebound onto equipment on the exit side of the stand. These deflected droplets can collect on the exit side equipment and later drip onto the finished sheet.

- Vapors can condense and/or droplets collect in ventilation duct work or on relatively cold piping and then drip onto the finished sheet after a period of time.

The application of entry side coolant is, of course, critical to the cold rolling process. Solution Stain must therefore be controlled by redirecting the path of any airborne coolant droplets that reach the exit side of the stand in a manner that prevents them from reaching the strip surface. This is the design philosophy of the SMS Demag Dry Strip System which utilizes the Venturi and Coanda principles of fluid dynamics to achieve this goal.

It should also be noted that a successful cold rolling operation relies upon a thin lubricating film that is formed in the roll bite from a small portion of the entry side coolant. Depending upon the chemical composition of the coolant, and the roughness of the sheet and roll surfaces, a small amount of oil from the coolant *will* pass through the roll bite, and hence will be found on the finished sheet surface.

Clearly, this residual oil film is different from the droplet related Solution Stain that was previously discussed, and hence it is not a focus of this paper. Oil films of this type can be measured using weight loss tests, and by certain optical instruments[1]. Electrolytic cleaning and strip dryers are applied in process lines where removal of this oil film is required[2].

In recognition of this fact, the term "Dry Strip" will be used in this paper to indicate a finished strip that is free from the impingement of stray coolant droplets, but may have a defined oil coating that remains from the rolling process.

3. Overview of Dry Strip System Configuration

The SMS Demag Dry Strip System hardware is designed to manage the movement of the airborne coolant droplets on the exit side of the mill. The equipment design incorporates applications of the Venturi and Coanda principles to redirect the airborne coolant away from the strip, so that it is either collected in a vacuum system, or falls away into the collection pit. The system is comprised of the Roll Barrel Blow-off System, the Roll Barrel Sealing System, the Strip Surface Blow-off System, and the Strip Edge Exhaust System as shown in Figure 3.

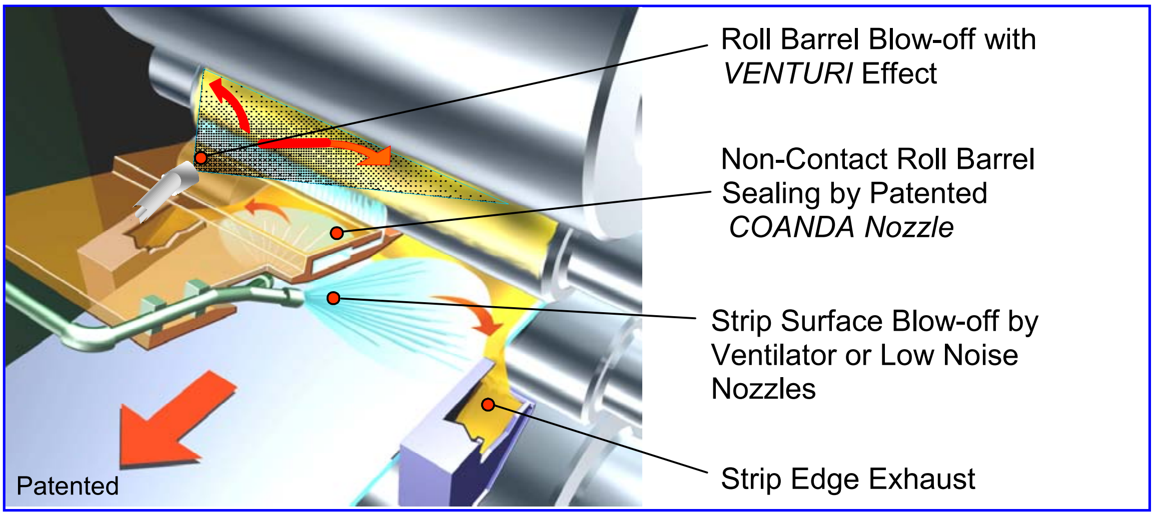

Figure 3: Overview – SMS Demag Patented Dry Strip System

A discussion of each of these major system components is provided in the following sections of the report.

(Note that this figure shows a Six-High Roll Stack configuration, but these same principles can also be applied in a Four-High Roll Stack where the back-up roll/work roll interface would replace the intermediate roll/work roll interface shown in this figure.)

4. Roll Barrel Blow-off System

The Roll Barrel Blow-off System is designed to remove coolant from the interface between the work roll and back-up roll (or work roll and intermediate roll in the case of the Six-High stack). Coolant droplets that are flung from the back-up roll, as well as those that fall from the exhaust ventilation system, and/or other equipment components in this area, may also fall into this air stream and be thus directed away from the sheet area.

These functions are accomplished by using a low noise nozzle to direct a stream of air at the nip point of the roll interface as shown in Figure 4. The geometry of the roll contact zone sets up a cross flow of air that moves coolant on the roll barrels toward the edges of the rolls as shown in the bottom portion of Figure 4.

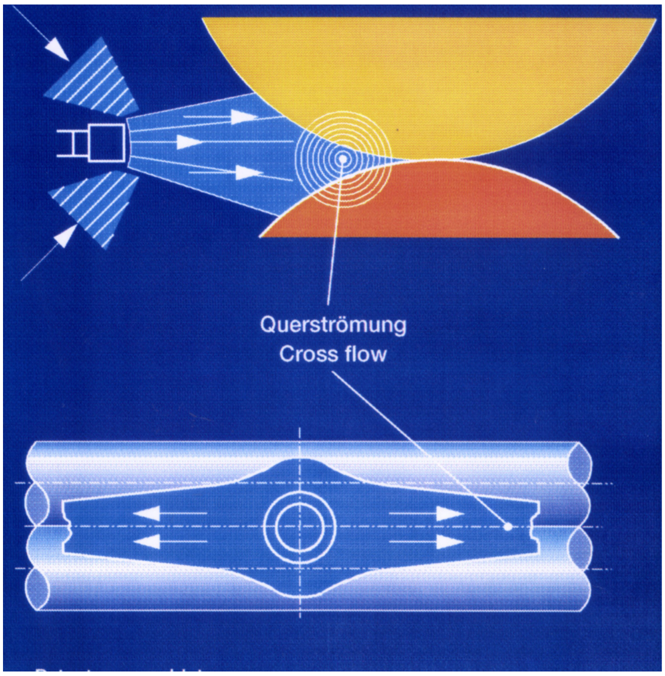

Figure 4: Roll Barrel Blow-off System

Additional make-up air is also drawn into the area of the nozzle via the Venturi effect as shown in the top section of Figure 2.

Droplets of coolant that are flung from the back-up roll, as well as those that fall from the exhaust ventilation system and other equipment components in this area are either blown beyond the strip edges or they may also be entrained in this make-up air stream.

This make-up air joins the cross flow of air from the previously mentioned nozzles to move all of the airborne droplets to the ends of the roll.

Once these air streams reach the edge of the rolls, the droplets will either be blown onto the housing posts where they fall into the mill collection pan, or they may be drawn to the low pressure area of the Edge Exhaust System.

5. Roll Barrel Sealing System

The main function of the Roll Barrel Sealing System is to prevent any airborne droplets from falling past the roll body and onto the strip.

The Roll Barrel Sealing System consists of a Bulkhead, which supports much of the system hardware, and a special nozzle with an entry edge that is positioned very close to the work roll surface as shown in Figure 5.

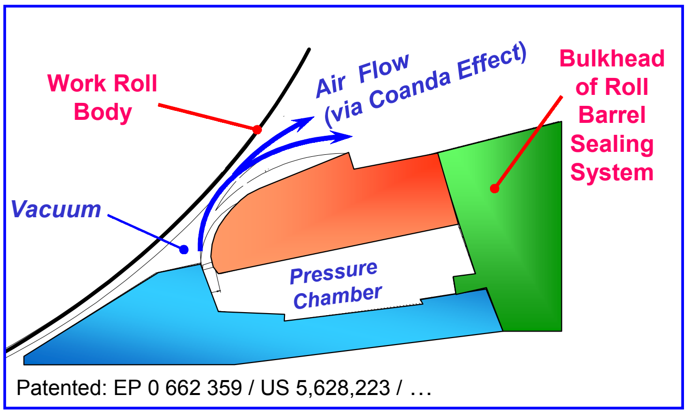

Figure 5: Roll Barrel Sealing System

This special nozzle provides an effective non-contact seal against the work roll body. It creates a low pressure area (vacuum) near the roll surface by using the Coanda principle to direct the nozzle's air flow with any captured coolant droplets away from the roll body.

These captured droplets are then either directed to the ends of the rolls by the cross flow air motion of the Roll Barrel Blow-off System, or into special fluid collection troughs that are incorporated into the Bulkhead.

6. Strip Blow-off System

In a conventional mill stand without the Dry Strip System, the linear speed of the strip, and the geometry of the mill stand equipment tend to form an area of relatively low pressure above the center of the strip at the exit side of the stand. This behavior is a result of the Bernoulli Effect and is schematically shown in Figure 6.

This area of low pressure tends to draw the local air with entrained coolant droplets toward the strip surface where they contact it and produce solution stain.

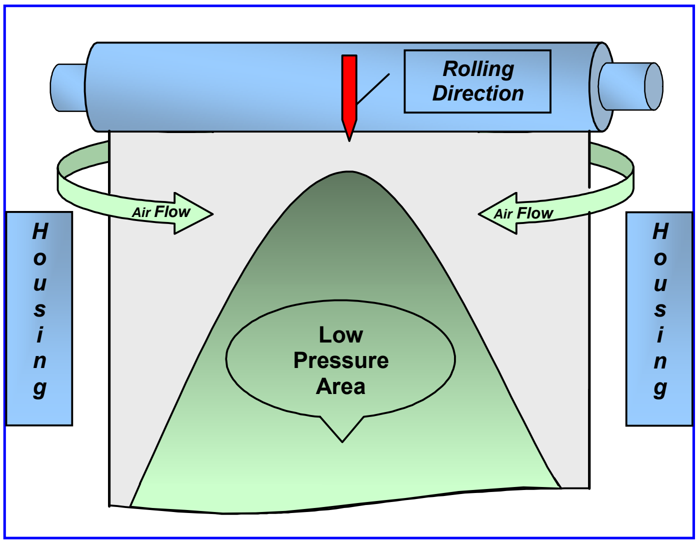

Figure 6: Conventional Mill Stand

The Strip Blow-off System was developed to counteract this situation. It is located below the Bulkhead of the Gap Sealing System, but above the strip. Its function is to create fluid dynamic conditions that will prevent any airborne droplets that are below the Bulkhead from falling onto the strip.

Specifically, the Strip Blow-off System employs a specially designed high volume, low noise nozzle to create a relatively high pressure area in this zone. This high pressure zone tends to direct any droplet-laden air away from the strip surface as shown in Figure 7.

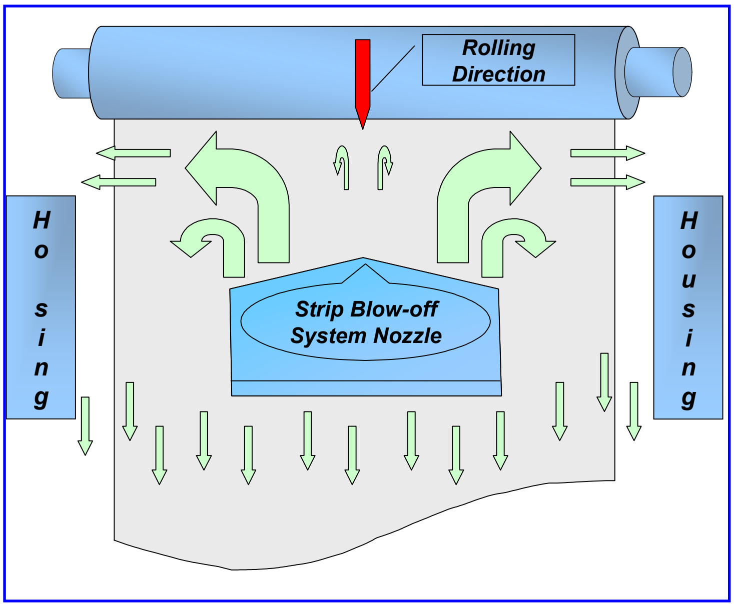

Figure 7: Strip Blow-off System

Note also that as the air from the Strip Blow-off Nozzle impinges on the work rolls, the stream lines tend to direct any coolant that would pass through the open roll gap away from the strip edge.

Furthermore, these streamlines are redirected toward the openings to the Edge Exhaust System that is located under the edges of the strip. Thus this coolant in the air stream is collected and drawn away by the Edge Exhaust System.

Finally note that the high pressure conditions that are created by this nozzle also tend to reverse the air flow out of the area between the housing posts, thus preventing the infiltration of any air containing coolant from the exit end of the stand.

7. Edge Exhaust System

The function of the Edge Exhaust System is to provide a means to draw the air streams with entrained coolant droplets away from the exit side of the mill. The system is comprised of a blower, interconnecting piping, safety/environmental equipment, and special collection openings near the strip edge. It is conceptually shown in Figure 8.

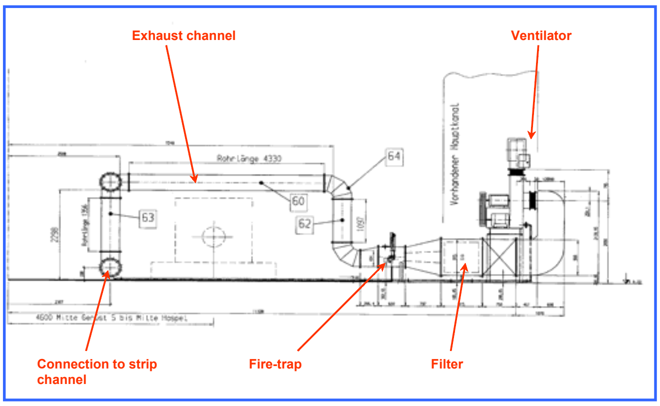

Figure 8: Edge Exhaust System

The collection openings are located in the apron under the strip as was previously shown in Figure 3. Note that the openings begin just inboard of the minimum width sheet and continue to a position just beyond the maximum sheet width.

The captured air stream with entrained coolant is then drawn down into the exhaust channel where the fluid components are separated from the air.

8. Operating Cost Analysis vs. Conventional Blow-off Systems

The SMS Demag Dry Strip System can be operated using compressed air, or alternatively by air from ventilators. When compressed air is used, is very important that the air be clean and dried so that moisture is not directly introduced onto the strip in the air streams that are contacting it.

Sound pressure levels and operating costs can be reduced by operating the Dry Strip System with low pressure ventilators. Figure 9 shows a cost and sound pressure level comparison for four different configurations with different combinations of compressed air and ventilators. They include:

- Case 1 - Conventional Blow-Off System
- Case 2 - Dry Strip System driven entirely by compressed air
- Case 3 - Dry Strip System with all Blow-offs and Coanda Nozzle driven by compressed air and Exhaust System driven by ventilator.
- Case 4 - Dry Strip System with Coanda Nozzle driven by compressed air and Blow-off and Exhaust Systems driven by ventilators

Item	Case 1:	Case 2:	Case 3:	Case 4:
Compressed Air Consumption (Approx.)	2,500 Nm³/h	1,800Nm³/h	1,400Nm³/h	800 Nm³/h
Costs per Year at €0.01 per Nm³ for 6,000h/Year	€ 150, 000	€ 108,000	€ 96,000	€ 48,000
Electrical Power	--	--	€ 12,000	€ 24,000
Sound Level (Approx.)	100 DbA	85 DbA	80 DbA	78 DbA
Air Compressor and Ventilator Cost	€ 300,000	€ 400,000	€ 440,000	€ 480,000

Figure 9: Representative Cost and Sound Level Comparison

The additional initial cost of the ventilators is offset by their reduced operating cost through time. This can be seen in Figure 10 which shows the total of purchasing and operating costs at the end of each year for a 10 year period.

The ventilator based system of Case 4 provides a lower total cost after approximately 4 years when compared against the conventional system of Case 1. This comparison assumes the noted €0.01 per Nm^3 of compressed air. Results would, of course, vary with local electrical costs.

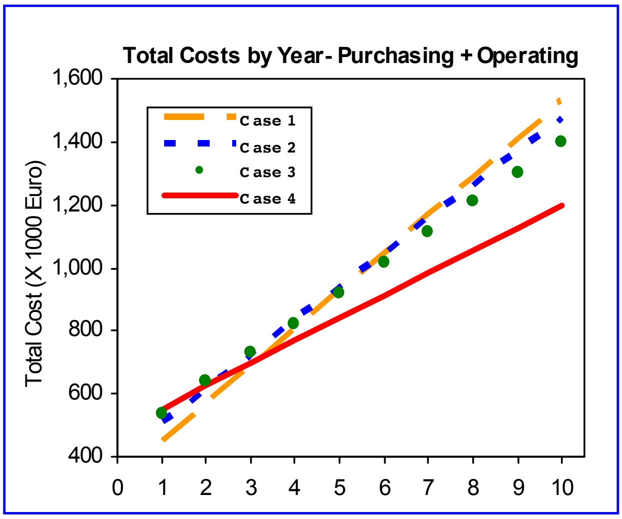

Figure 10: Total Cost Comparison

9. System Performance

The effectiveness of the system can best be evaluated by comparing the percentage of coils held for solution stain before installation of the Dry Strip System against the corresponding measurement after installation of the system.

One such test was conducted by a European cold mill rolling steel sheet with a water based emulsion with results shown in Figure 11.

Prior to installation of the Dry Strip System, coil retention rates for this producer were typically approximately 4% of total production. After installation of the Dry Strip System, retention rates fell below 1% representing a 75% drop in retained coils.

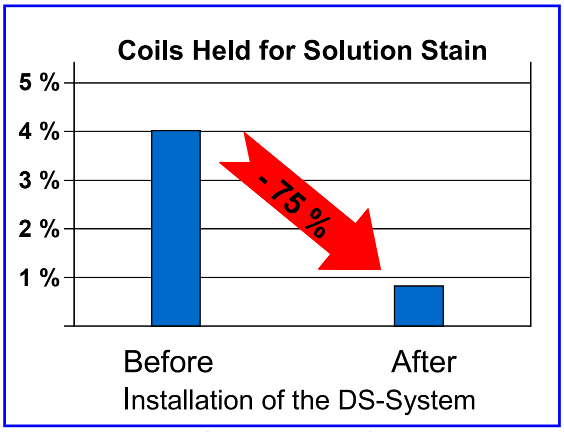

Figure 11: System Performance

10. Summary

Conventional strip surface cleaning technologies attempt to blow, wipe, or squeegee coolant from the finished sheet surface after it has exited the mill stand. These systems have met with varying degrees of success.

The SMS Demag Dry Strip System provides a technological solution to the problem of solution stain based on fluid dynamic principles. It employs the Coanda and Venturi effects to produce conditions that manage the movement of air in the mill stand. This enables the system to redirect any coolant droplets away from the finished strip surface where they can either be returned directly to the coolant collection pan, or to a vacuum system that can effectively remove the fluid to an area where it will not contact the strip.

Because of this unique approach to managing Solution Stain, the SMS Demag Dry Strip System has received patents in various countries as noted in Figure 12.

Europe:	EP 0 765 696	United States:	US 5,775,152
Japan:	Hei-8-246537	China:	96122491.6
South Korea:	96-41037	India:	1668/Mas/96
Thailand:	033 371	Malaysia:	Pi 9303872

Figure 12: Patents for the SMS Demag Dry Strip System

11. References

[1] ThermoRadiometrie, “SC 4000 Oil Detector User’s Manual”, Doc. AS00001b, 2001.
[2] Roberts, William L., “Cold Rolling of Steel”, p. 717, 1978.