

DAINOX BRIGHT™
INNOVATION
IN COLD ROLLED
STAINLESS STEEL
STRIP



DANIELI

Dalnox Bright™

New Annealing & Pickling Line process technology for cold rolled stainless steel strip

Annealing & pickling process

At the present time, cold rolled stainless steel strip is generally supplied in two surface finishes (according to EN10088/2):

> 2D/2B cold rolled, annealed, pickled and skin passed (2B)

> 2R cold rolled, bright annealed (BA) and skin passed.

2D/B surface finish is generally produced on horizontal high capacity continuous Annealing and Pickling Lines (A&PL), with a productivity of up to 150 tph, in which the strip is annealed in oxidising atmosphere (combustion gas mixture). The oxide layer produced during annealing has to be removed and then passivity has to be restored. This is generally achieved through by an electrolytic descaling process followed by a chemical pickling treatment, usually using mixed acid (HNO₃-HF) or alternatively ecological baths. A large amount of polluting substances such as NO_x emissions, nitrates in the disposal water and sludge requiring special treatment processes are so produced.

2R surface finish is obtained on Bright Annealing vertical plants in which the strip is annealed in a H₂/N₂ gas mixture with a controlled dew-point, able to prevent surface oxidation and consequently pickling processes are not required.

The vertical furnace orientation reduces the possibility of increasing productivity, presently limited to a maximum of 20-25 tph approx.

Due to their mirror properties and good appearance, 2R surface finish products are generally preferred to 2D/B for the so-called "on sight applications".

By joining the main positive features of both existing methods, a very innovative process technology has been developed for annealing and pickling of cold rolled stainless steel strip.

Dalnox Bright™ process and technology

The worldwide steel market globalization is driving steelmakers to research new processes and technologies able to reduce production costs and increase competitiveness, also through steel quality enhancement, while reducing at the same time the environmental impact of production processes. In pursuing such targets, Danieli and Centro Sviluppo Materiali (CSM) have developed a very innovative process technology, trade named Dalnox Bright™, able to obtain stainless steel strips

with an enhanced surface quality, close to 2R, with plants having the same production capacity and cost of conventional A&PLs. Further benefit expected is a decrease in the environmental impact of chemical pickling processes.

The key-point of Dalnox Bright™ is a dramatic reduction in oxidation during annealing, compared with conventional A&PLs.

As a consequence, chemical pickling treatment is eliminated or reduced, which in turn results in an enhanced surface quality, saving in pickling treatment and reduction in volume of waste solution to be neutralized.

The control of the oxide film formation is achieved by using specific strip thermal cycles and through a close control of the oxidising capability of annealing atmospheres at each processing step (heating and cooling), with particular attention to higher temperature ones.

Fundamental steps of the Dalnox Bright™ process technology:

> a first rapid heating stage in controlled oxidising atmosphere in which oxide nucleation and thin oxide film formation occur;

> a second annealing stage, to complete metallurgical transformation (for reaching required mechanical properties, grain size, carbide solubilisation, etc.), in non-oxidising atmosphere (N₂) in order to limit oxide layer growth;

> a cooling stage, at cooling rates able to avoid carbides precipitation, in non-oxidising atmosphere;

> electrolytic descaling stage properly set-up;

> light chemical pickling stage with reduced environmental impact and surface passivation.

Dalnox Bright™ Research and Development

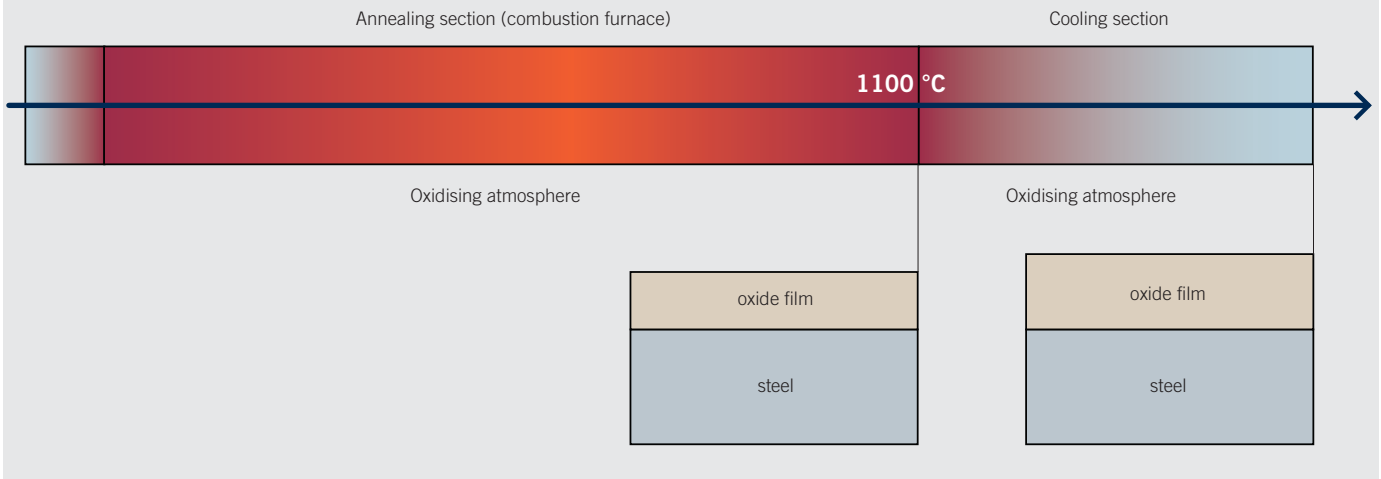
Starting from the existing know-how in the field of continuous annealing and pickling continuous processes and plants for stainless steel strip, Dalnox Bright™ was preliminary developed at CSM lab-scale facilities. Later on, the experimental validation of the new process was performed on the continuous annealing pilot plant purposely designed and installed at Danieli R&D Dept.

Surface characterization and pickling tests of annealed samples were performed at CSM laboratories. Dalnox Bright™ is a patented process technology and a Danieli trade-mark.

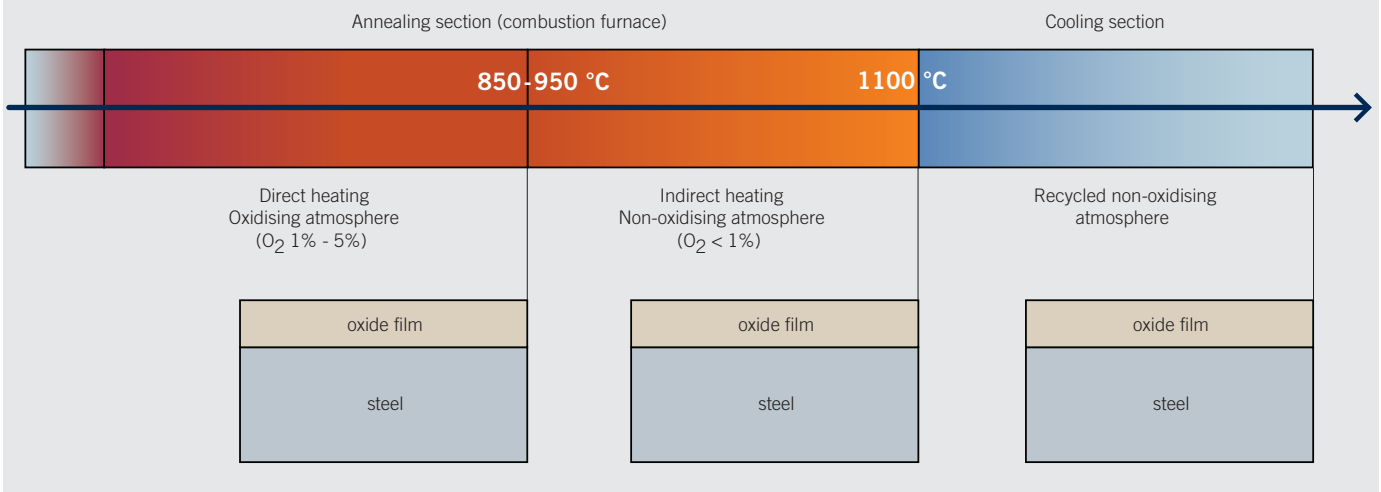


Typical appearance (light blue) of annealed Dalnox Bright™ strip.

Conventional annealing process

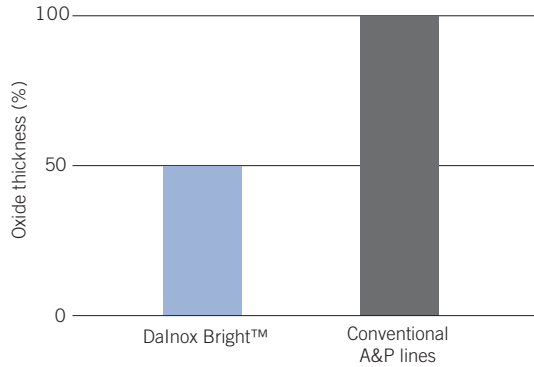


Dalnox Bright™ annealing process

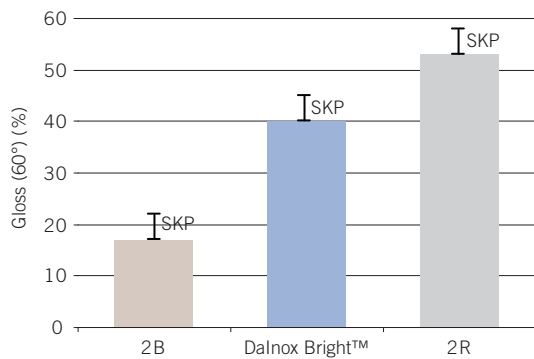


1 Oxidation phenomena occurring in conventional and in Dalnox Bright™ annealing processes, AISI 304 stainless steel strip.

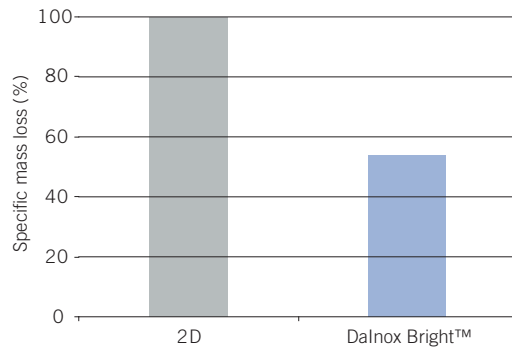
2 Dalnox Bright™ vs. conventional A&PL: proportion in oxide generation.



3 Gloss (60°) measurement observed on 2D, Dalnox Bright™, 2R. The short strokes added on top indicate the increase in gloss normally measured after skinpass. (AISI 304)



4 Dalnox Bright™ specific percentage mass loss in mixed acids chemical pickling (HNO₃ - HF) compared to that observed on standard annealed products (2D). (AISI 304)



Dalnox Bright™ annealing process

The oxidation phenomena occurring in conventional and in Dalnox Bright™ annealing processes, in the case of AISI 304 stainless steel strip, are described in Fig. 1. In the initial heating stage (up to 850-950°C) of Dalnox Bright™ annealing, oxidation is reduced by the formation of a protective thin oxide layer in controlled atmosphere due to higher heating rates than conventional ones. In the annealing at the higher temperature range, where major oxidation occurs, the presence of non-oxidising atmosphere guarantees limited oxide build up. During cooling the presence of non-oxidising conditions prevents further oxide growth. Fig. 2 shows the mean oxide film thickness present on AISI 304 annealed strip produced with conventional and Dalnox Bright™ processes.

Dalnox Bright™ pickling process

On conventional cold rolled A&PL the pickling section is generally subdivided into two different parts. An electrolytic section (generally neutral Na₂SO₄ bath) which dissolves the oxide layer, and a chemical section (mixed acid baths made of HNO₃/HF or ecological baths) which removes residual scale by dissolving the reactive layer underneath and restores passivity. Due to the reduced oxidation, the thin oxide layer can be easily removed by a simple electrolytic descaling treatment in a conventional electrolytic section properly set-up. After electrolytic treatment, the strip surface appears free from oxide with an aspect (in terms of mirror properties) close to 2R. Bar diagram in Fig. 3 shows the gloss measurements (60°) of samples obtained with Dalnox Bright™ after electrolytic descaling compared with those of standard 2B and 2R surfaces. The short strokes added on top of the gloss bars indicate the increase in gloss normally obtained after skin-pass. The final light chemical treatment (low temperature, low HF content, shorter treatment time) ensures complete pickling even in A&PL non standard working conditions (e.g. furnace transitory due to both productivity and material changes, line slow-down). Due to the dramatic reduction in oxidation, which in turn strongly decreases the steel surface reactivity, the final light chemical pickling is characterized by reduced specific mass loss and pickling times, compared to conventional processes. Fig. 4 shows the specific percentage mass loss in mixed acids chemical pickling (HNO₃ - HF) compared to that observed on standard annealed products (2D).

Dalnox Bright™ pilot plant

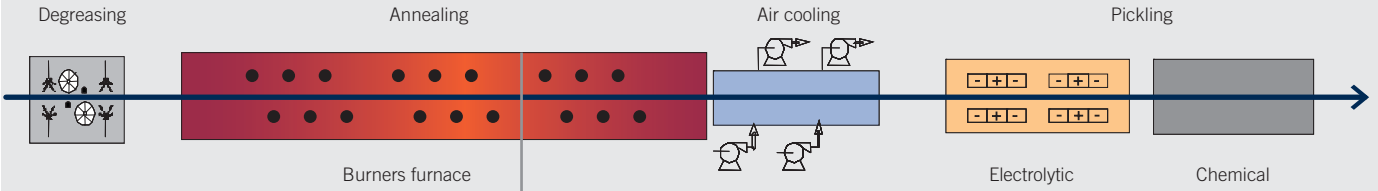
The annealing pilot line, installed at Danieli R&D is able to treat in continuous 0.4-2 mm thick and 300 mm wide steel strips at a speed of up to 10 mpm. It is designed with a modular structure in order to reproduce different annealing cycles as heating curves and furnace atmospheres.



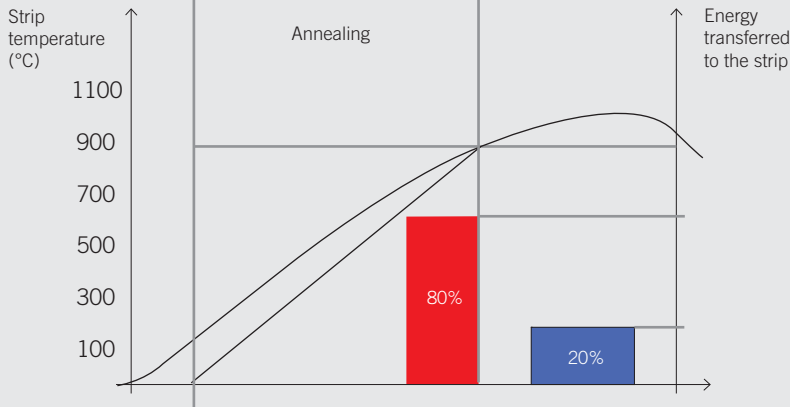
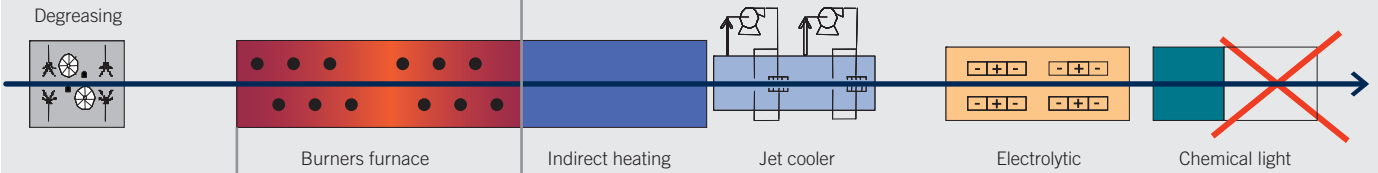
It is made with refractory materials that allow to reach, in the heated zones, temperature up to 1400 °C and is equipped with process control instrumentations. The second zone of the furnace, where the strip reaches the maximum temperature,

is heated in an indirect way by means of electrical resistances or by flame burners. Many experimental campaigns were devoted to the definition of the best process conditions. Scaling-up criteria and related industrial technologies were also defined.

Conventional A&PL



Dalnox Bright™ A&PL



5 Comparison of the schematic process layout of conventional A&PLs with Dalnox Bright™.

Cost evaluation

A cost analysis based on average Italian energy and material market prices was performed, by taking into account only the following operating charges:

- > energy (fuel gas) and process gas consumption in the annealing section;
- > electrical energy and chemicals consumption in both electrolytic and chemical pickling sections;
- > neutralisation and disposal of waste solutions and fumes;
- > human resources directly involved on plant operations;
- > metal loss (yield) due to annealing and pickling treatment.

The specific management cost of Dalnox Bright™ A&PL, for the above mentioned operating costs, is roughly 35% - 40% lower than for conventional A&PL ones (AISI 304).

Field of application

All stainless steel grades (austenitic, ferritic, duplex, ...) can be produced using the Dalnox Bright™ process technology.

In a plant based on the Dalnox Bright™ process it is possible to obtain both surface qualities "close to BA" and to standard 2B-2D.

Fig. 5 compares the schematic process layout of conventional A&PLs with Dalnox Bright™ one. As shown in the diagram, only about 20% of total energy transferred to strip in annealing process is supplied by indirect heating systems such as electrical resistances or radiant tubes.

Main advantages

In brief, the main advantages of Dalnox Bright™ process technology are:

- > same productivity as conventional A&PL;
- > high flexibility in terms of surface appearance of the product 2D or close 2R finish;
- > reduced or eliminated chemical pickling with consequent saving on equipment and management costs;
- > reduced environmental impact and saving on emissions and waste neutralization treatment costs;
- > enhanced surface quality.

Dalnox Bright™ is proposed for both new and existing plants.

In existing plants, by replacing the furnace, the potential benefits are:

- > increased productivity;
- > enhanced surface quality, close to 2R;
- > drastic lowering of pickling management costs;
- > drastic lowering of waste treatment volume.

New plants will benefit from all the advantages described in this brochure.



DANIELI THE RELIABLE
AND INNOVATIVE PARTNER
IN THE STEEL INDUSTRY



innovaction

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