INTERNATIONAL MOLYBDENUM ASSOCIATION
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Cost-saving super duplex

The quantifiable benefits of stainless steel are often future-oriented, namely reducing maintenance throughout service life and reducing life cycle costs. But stainless steel, especially the strong duplex grades, sometimes emerges as the most affordable option from the initial investment! The following case study discusses how a 2507 super duplex stainless steel exhaust stack replacement option was less expensive than a weathering steel alternative.

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In 2017, the exhaust stack of a sintering plant suffered a partial collapse during severe weather. The facility agglomerates iron ore fines, which provide feed for an adjacent blast furnace operation. The enormous stack, approximately 60 m high with a 3.7 m diameter, was constructed with a double wall design. The design consists of a 6 mm thick inner wall made of weathering steel, a layer of thermal insulation, and an outer layer of galvanized steel sheet. This design relies on the insulation layer to keep the temperature inside the stack above the dew point to avoid corrosive condensate on the inner surfaces. However, the insulation layer began to deteriorate in the harsh service conditions of the seaside industrial plant. Indeed, inspections before the collapse revealed severe loss of wall thickness on the weathering steel at locations where the insulation layer had deteriorated.

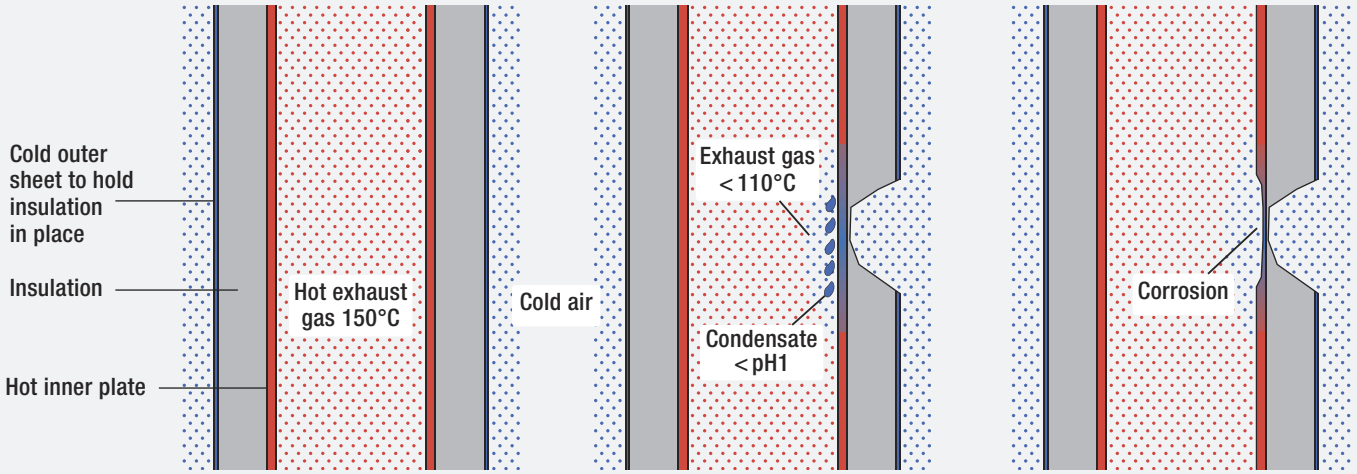
Stacking up the competition

With its exhaust stack snapped in half, the plant needed a quick and effective replacement solution with significantly improved corrosion resistance. Industeel assisted in corrosion testing and provided technical support in exploring potential replacement options, considering several key service and environmental parameters. The plant's location is in an industrial environment near the sea with considerable annual temperature variation and strong winds.

The plant runs around the clock, with an average fume temperature of 150 °C. The fumes have an acid dew point of 110 °C with an extremely acidic pH of 1, meaning that when the temperature falls beneath 110˚C, highly corrosive condensate can form in the stack. This phenomenon is made even worse by sea salt in the air. An analysis of particles in the stack found chloride contents far higher than weathering steel can tolerate.

A nearly 60 m high exhaust stack is difficult to inspect and maintain, to say the least. Its triple layered design is a double edged sword: though the layers protect each other, it's difficult to access and repair the inner layer once damaged. Even measuring the thickness of the inner most material is challenging, compromising the integrity of inspection. Because the stack's service life fell short of its anticipated 20 years, various replacement designs with improved corrosion resistance were evaluated. All options offer increased resistance to corrosive attack over the original design, but they each have pros and cons. For instance, three of the designs require the construction of a new foundation due to increased wall thickness and weight, which is not only costly but also extends construction time. On the other hand, the other two options require more expensive construction materials based on cost per kilo, but they avoid the cost of an insulation layer and can be constructed on the existing foundation. Both single wall designs using either 2507 super duplex or 904L stainless steel can resist the service environment.

Corrosion mechanism in insulated exhaust stacks



Well performing stack

If outer sheet comes off, insulation deteriorates and cold air cools down exhaust gas below dew point

Aggressive condensate leads to thinning of weathering steel stack

	Option 1	Option 2	Option 3	Option 4	Option 5
Material and design	Double wall weathering steel shell with inner protective liner	Single wall self-supporting 2507 super duplex stainless steel	Single wall self-supporting 904L austenitic stainless steel	Double wall Type 316 Ti shell with inner protective liner	Reinforced concrete structural shell/ refractory brick inner liner
Thermal insulation	yes	no	no	yes	no
Corrosion protection	Thicker shell (↑corrosion allowance) plus liner	not needed	not needed	Thicker shell (↑corrosion allowance) plus liner	not needed
Foundation	new	existing	existing	new	new
Lead time	9 months	7 months	7 months	9 months	12 months on site
Expected life	20 years	30 years	30 years	20 years	50 years
Cost of stack and foundations	**Reference = 100**	**88**	**100**	**100**	**128**

The two stainless steel solutions (option 2 and 3) which are able to withstand condensate corrosion provide the best combination of simplicity, speed of replacement and service life. Super duplex emerges as the lowest cost solution due to its higher strength and lower alloy cost.

But both increased corrosion resistance and strength of the 2507 duplex stainless steel allows for a reduced wall thickness. Saving material with thinner, stronger walls often leads to a significant cost reduction, as it did in this case. A summary of the relative costs, construction times, and relevant design factors are listed in the table above.

Less material and longer service life

Based on the cost, timing, and expected performance of the candidate designs, the stack was replaced with option two, a single wall model using 2507 super duplex

› **Work on the 2507 super duplex stainless steel stack sections in the fabrication shop.**

The stack was shipped in segments that were bolted together on site. Ladders and platforms are directly attached to the self-supporting wall. This is much simpler than anchoring them through the outer skin and the thick insulation to the structural inner wall in a double wall system.

stainless steel. This duplex stainless steel is alloyed with approximately 3.5% molybdenum. The grade also has a nitrogen addition of approximately 0.25%, and the combination of chromium, molybdenum, and nitrogen provides outstanding resistance to localized chloride attack.

Because this design option does not involve thermal insulation, the costs associated with maintaining insulation are avoided. There is also the potential to increase the intervals between inspections. Moreover, a single wall design is easier to inspect for loss of wall thickness than double wall designs. Although this investigation found that the 2507 duplex stainless steel replacement option had the lowest capital costs, if total life cycle costs were included in the evaluation, it would have even greater savings over other designs.

The stack was replaced using 6 mm to 10 mm thick plates that were cold formed and seam welded into massive rings. These were joined at the fabricator to create stack lengths that could be shipped to the job site for erection. Like a giant ring tower, each round section of welded plate was placed atop the next using a gargantuan crane. The replacement stack was completed and put into service in the summer of 2019.

Since installation, the stack is issue-free and should continue to provide low maintenance service for the next 30 years and beyond. This case study exemplifies how the advanced strength and corrosion resistance of duplex stainless steels often enable not only weight savings but immediate cost savings. Stainless steel is also one of the most highly recycled materials on earth – therefore, at least a portion of the initial investment can be recouped at the end of service life as scrap value. Given full consideration for its service life and maintenance needs, what seems like a luxury material sometimes proves to be the most affordable option. (Jim Fritz)

Reddish-brown deposits of iron ore dust from the processing plant have accumulated over the years on the stack surfaces, but thanks to the excellent corrosion resistance of super duplex stainless steel, they will not cause any deterioration of the stack.