The **ACID REGENERATION PLANTS**
at **CISA, VEGA DO SUL** and **SSI**

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**METALLURGICAL PLANTS and ROLLING MILLS**

**STRIP PROCESSING**

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Technical Report
Hot and Cold Strip Processing
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INTRODUCTION

In February 2002 SMS Demag AG, Germany and Dependeq Industrial Plant Engineering GmbH, Austria entered into a cooperation agreement on the joint supply of Acid Regeneration Plants based on the well known spray roasting technology enhanced by Dependeq. The plants are supplied under the Leadership and Name of SMS Demag AG.

For Dependeq, whose core competences are centred around process design, process specific engineering activities and commissioning, the cooperation with SMS Demag provides well established links to the markets and access to the strong infrastructural backbone of the worlds leading providers of metallurgical equipment.

For SMS Demag, the cooperation with Dependeq provides access to a well proven complementary technology, which seamlessly integrates into the SMS Demag pickling lines as a part of the rich product line of its strip processing lines division, supporting SMS Demag’s „full liner“ business approach. Enhancement in the process specially regarding process control and safety by Dependeq together with the background of SMS Demag regarding order handling, quality management and site organisations gives a competitive edge for the acid regeneration plants supplied by SMS Demag/Dependeq.

Since the start of the cooperation a reasonable number of clients opted for the installation of a now SMS Demag acid regeneration plant; among them CISA and Vega do Sul from Brazil as well as SSI from Thailand.

By March 2003 the plants supplied to said clients have all been successfully commissioned and have subsequently delivered first production results, which perfectly match customer expectations.

THE SPRAY ROASTER ACID REGENERATION PROCESS

Over the last decades hydrochloric acid has replaced sulphuric acid as pickling agent for the chemical descaling of hot rolled carbon steel products in most industrial applications for a number of reasons, which include surface brightness and advanced abilities to dissolve all compounds of the scale layer and as a key advantage the availability of industrial scale processes for the total regeneration of chlorides bound in waste acid and rinse water.

Some processes accomplishing this task have been developed since the late 1960’s, but none matched the broad commercial acceptance of the spray roaster process, which has demonstrated its long term feasibility and viability in more than 200 industrial implementations.

The three basic process steps of spray roaster acid regeneration are preconcentration, roasting and absorption.

During preconcentration, the incoming waste acid undergoes direct heat and mass exchange with the hot exhaust gas from the roaster furnace. The direct heat exchange is accomplished in a venturi evaporator where the waste acid is atomized and turbulently intermixed with the roast gas at high velocity.

The waste acid is thus partially evaporated, leaving behind a preconcentrated waste acid to be used as liquid feed to the spray roasting furnace.
In the spray roasting furnace, the preconcentrated waste acid which is injected from the top by means of high pressure atomizing nozzles undergoes a drop-by-drop evaporation of water and HCl as well as pyrohydrolysis reaction of remaining iron chlorides and excess oxygen provided by the burners, which are tangentially aligned around the furnace circumference in order to form a specific “swirl” flow pattern which increases the droplet retention time by increasing the length of its path through the furnace. Almost any common kind of industrial grade fossil fuel such as e.g. natural gas, LPG, coke oven gas, LNG or oil can be used.

The chemical reaction products of the pyrohydrolysis reaction consist of HCl which is extracted from the top of the furnace together with the steam and combustion products and ferric oxide (Fe₂O₃) powder, which settles at the conical bottom of the furnace and is pneumatically conveyed into a storage bin, from where it can be filled in a variety of commercial transport means such as into big bags or onto trucks.

As a consequence of high iron oxide purity and favourably developed surface structure of the spray roasted iron oxide powder, this by-product of the acid regeneration process represents a valuable input material for a growing number of downstream industries including but not limited to producers of architectural paints, building products, styrene catalysts, toner for laser printers and ferrites.

In the absorption column, the cooled roast gas from the gas exit of the preconcentrator undergoes adiabatic heat exchange with rinse water in a packed column and forms regenerated acid of typically around 18% (aceotropic) HCl concentration, which can be re-used for pickling.

Sophisticated exhaust gas transport and cleaning systems complement the assembly of a spray roaster acid regeneration plant.

Among all known processes for hydrochloric acid regeneration - among them crystallization and fluid bed pyrohydrolysis - the spray roaster process is the most feasible in terms of energy consumption, operating cost, maintenance cost, availability and by-product-marketability.
PROCESS IMPLEMENTATION

Implementations of said general spray roaster process are vendor-specific and vary a lot in terms of design of process subsections and introduction of auxiliary process stages.

The SMS Demag/Dependeq approach to spray roasting emphasizes the reduction of total cost of ownership by the introduction of advanced, smart technologies, which increase the potential net operating time, decrease production cost and limit maintenance cost.

COMMERCIAL FEASIBILITY

From a feasibility point of view, acid regeneration belongs to the “must do” issues in most pickling scenarios, as comparing the cost for fresh acid purchase and waste acid disposal with the moderate capital and operating cost assigned to an acid regeneration facility under most circumstances indicates a favourably short amortization period.

In cases, where the volume of waste acid to available disposal points exceeds the boundaries of logistic reasonability, such as pickling lines operating at high capacities at remote locations distant from available points of disposal, the operation of an acid regeneration plant or even the availability of a backup ARP is crucial for cost effective successful production and ARP downtime becomes a core issue in production risk analysis.

ENVIRONMENTAL IMPACT

In evaluation the environmental impact of acid regeneration plants of spray roaster design, three potential sources for pollutants have to be taken into consideration: exhaust gas from plant stack, waste water from exhaust gas scrubber and iron oxide.

Advanced scrubbing technologies provide efficient means for the removal of hydrochloride acid, chlorine and dust (mainly ferric oxide particles) from the exhaust gas stream.

The wash water from the exhaust gas scrubber can be either neutralised in the acid regeneration process utilizing a caustic scrubber or reused in the process, operating the scrubber non-caustic but thus limiting the ability to consume rinse water in parallel to waste acid.

The content of chlorine and hydro chlorines bound to the iron oxide byproduct can be reduced by well proven technological means such as hot oxide treatment screw conveyor units.

THE CISA ACID REGENERATION PLANT

The acid regeneration plant supplied to CISA, a subsidiary of Volta Redonda based CSN has a rated nominal treatment capacity of 2,800 litres per hour of waste acid. The plant was designed in a “modular” way. All main process components were preassembled in steel containers which match 40” container shipping limitations. Erection of the plant consisted of fixing the containers to the foundation and installing the interconnection piping. By taken that pre manufacturing based project execution route, on site net erection time was dramatically shortened.

Off site training for CISA’s operators had been provided by Dependeq on the acid regeneration plants of its long-term valued customer Delna S.p.A. in Brivio (Lecco), Italy.

THE VEGA DO SUL AND SSI ACID REGENERATION PLANTS

The acid regeneration plants for Vega do Sul and SSI are - despite the fact, that they have been erected on two different continents almost adjacent to the shores of two different oceans for two non-related clients - twins. With a regeneration capacity of 4,300 litres of treated waste acid per hour and a built in turn-up of additional 10%, the plants suit pickling applications for up to one million tons per year - depending on product mix and hot coil conditions.

At Vega do Sul, which is a joint venture between Arcelor and CST, the overall project duration from placement of letter of intent to hot run (preliminary acceptance) was 12 months, which is a remarkably low figure taking into account that no reference design was available and also the whole turn key scope for foundations, buildings and auxiliaries was in SMS Demag’s responsibility.
Off site training of Vega do Sul operating staff had been performed at Arcelor sister company Sollac Mardyck under partial supervision of Dependeq’s engineers.

SSI, which placed the order in February 2003, based its decision for a copy of the Vega do Sul installation on the engineering available so far and the advanced technological concept, represented by the SMS Demag/Dependeq solution.

ADVANCED PROCESS PLANT SOFTWARE ARCHITECTURE

An acid regeneration plant comprises a tightly coupled system which depends on the proper and controlled interaction of a series of backward- and forward linked processing stages, which heavily influence each other.

Unlike a sequential process, which can be switched off or driven into a safe position in case a process fault occurs simply by switching off the relevant sub-processing-units, an acid regeneration process, which requires the execution of complex procedures (heavily depending on the current process conditions) for shutdown and restart, requires a “never give up” control approach, in order to make sure, that the hazard potential imposed by heat, acid gases and corrosive liquids is controlled within tight boundaries and condition evaluation and response triggering is dynamically adjusted to the current operating conditions.

The efficient and safe automation of such systems calls for the use of mathematically validated and verified program blocks, based on formal algorithms representing the whole state-space of process and sub-processes, in order to maintain safe overall plant conditions and ordered shutdown behaviour even in case of severe component failure.

Dependeq’s approach to the automation of the spray roaster process was to implement advanced finite state machines for each process section, process subsection and actuator, as well as a supervisory state machine for the process sequencing.

The result of the employed programming approach is a continuously self-checking program, with a finite number of processing states - each of which has been validated and verified to be safe.

The implementation of the described advanced process plant software architecture not only heavily reduces the risk associated with the section-by-section commissioning of tightly coupled plants, but also increases ARP lifetime and operator safety as operations with potentially harmful consequences for personnel and equipment are consequently avoided.
The key features of the acid regeneration plants delivered to CISA, Vega do Sul and SSI can be classified into safety-features, operability-features and environmental-control-features.

The most crucial issue in terms of spray roaster safety system design is to ensure the cooling of the roast gas before it enters the non heat-resistant sections of the plant even in case of power failure or guillotine-breaks of venturi evaporator liquid supply pipes.

Emphasis has been put on the installation of a set of non-interdependent protection mechanisms, which include an automatically closing hot gas flap in the roast gas duct, self ejecting spray lances with built-on emergency exhaust gas exit functionality and the independent supply of cooling water to the venturi evaporator by means of in-throat-injection.

To improve operability, the plants have been equipped with spare spray booms, which allow the operation of the plant with n of n+1 spray booms in operation and one ejected for maintenance without affecting plant throughput.

To meet growing demand for the use of best available technologies for pollution control the plants at Vega do Sul and SSI have been equipped with a sophisticated exhaust gas cooling device, which reduces exhaust gas temperature to less than 65 °C compared to more than 80 °C at a conventional acid regeneration plant. Consequently decreased exhaust gas temperatures lead to significantly reduced HCl emissions.

By the use of advanced wet venturi scrubbers, which represent the results of a 4 years step-by-step improvement and development process, dust removal has been accomplished to an extent of less than 20 mg
dust per Nm$^3$ dry, which is already in perfect compliance with coming European regulations on pollution control.

The average energy consumption of the plants built so far has been verified to be well below 600 kcal per litre of waste acid treated, which is a remarkably low figure, resulting in reasonably low fuel cost.

**FUTURE DEVELOPMENTS AND CHALLENGES**

As long as hydrochloric acid remains the pickling agent of choice for the vast majority of new carbon steel descaling projects, there will be a demand for cost efficient, environmentally harmless acid recovery.

SMS Demag and Dependeq focus their product specific research and development activities on measures to reduce energy consumption, to improve environmental figures and towards increased sustainability in terms of total cost of ownership over the whole plant life cycle.

In parallel, auxiliary processes, e.g. an advanced silica removal process for waste acid purification, required to support the aim for the production of high pure, ferrite grade iron oxide, are under development and have undergone large scale laboratory studies in cooperation with renowned universities.

**CONCLUSION**

Within only 2 years SMS Demag and Dependeq have achieved a remarkable level of reputation as supplier for leading edge acid regeneration technology.

The plants at CISA and Vega do Sul due to their outstanding performance, technological maturity and not to forget due to their spatial proximity being both located just within 150 km proximity from Curitiba International Airport create an attractive reference hot spot.

The short project implementation times, advanced technology and reduced operating cost of SMS Demag/Dependeq acid regeneration plants should be of interest for many other steel producers.