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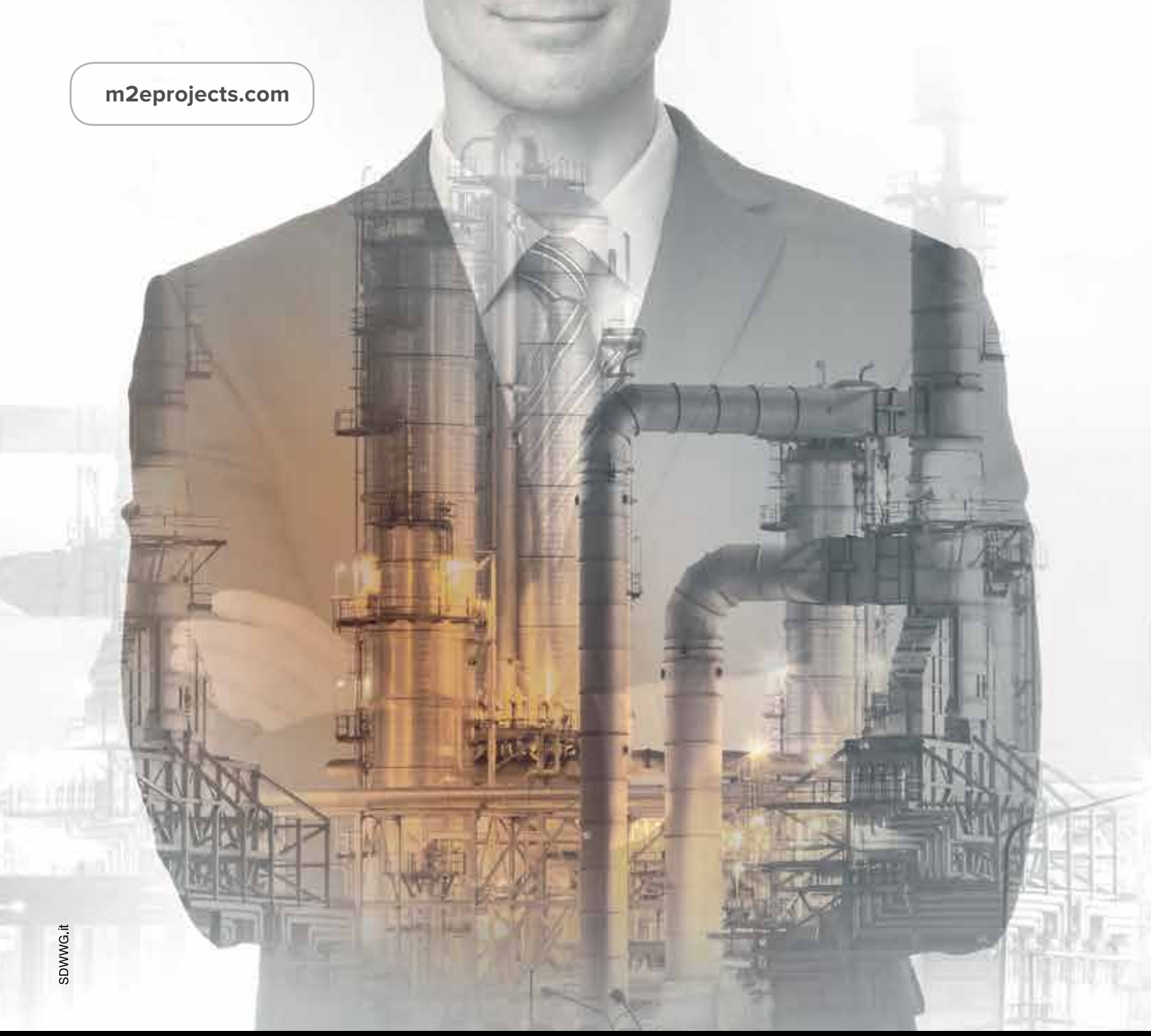

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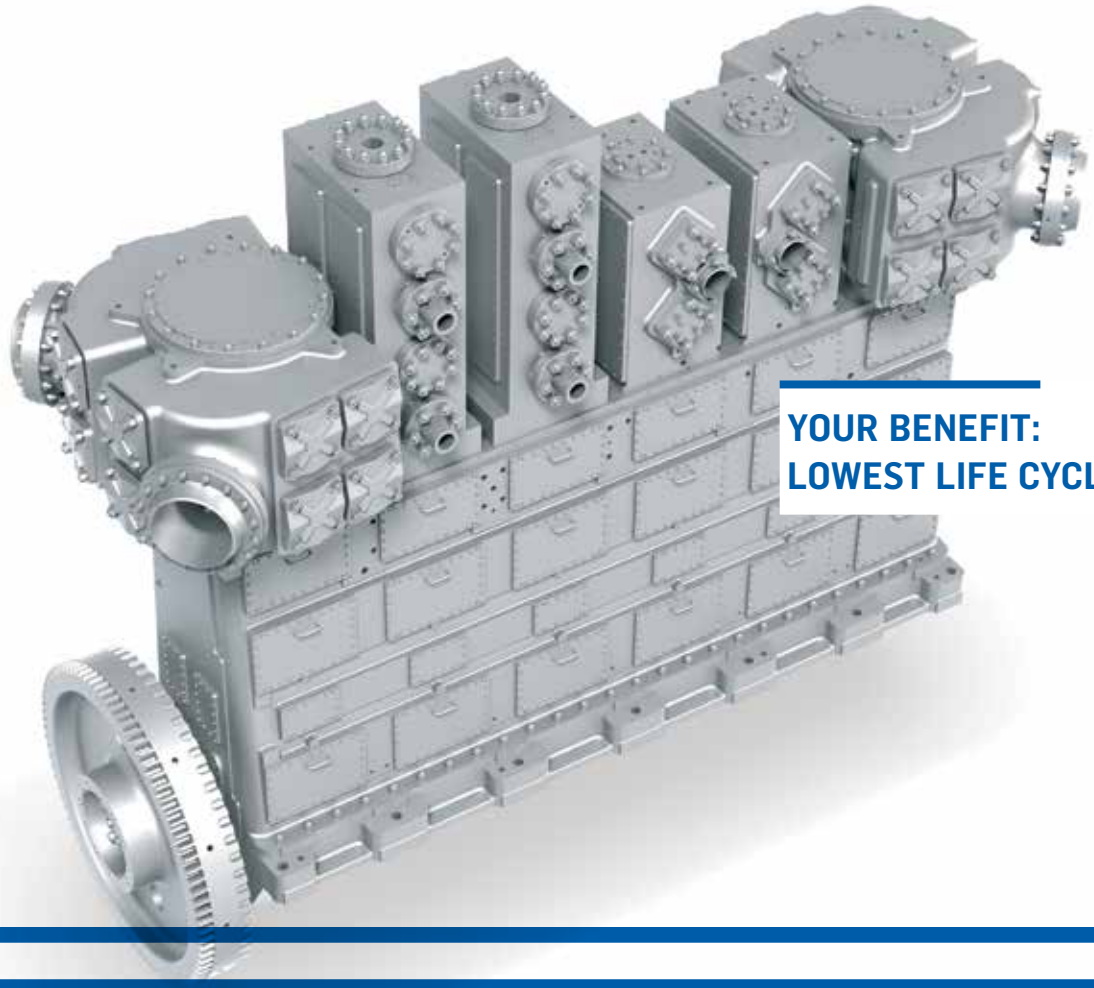

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Editorial

An outlook for the Italian Engineering and Contracting Industry:

restructuring for a more competitive come-back

Claudio Andrea Gemme
ANIMP President

ndustrial Plants, ANIMP's yearly publication for our international audiences, highlights selected recent achievements by the Italian Engineering and Contracting Industry and its numerous suppliers, by illustrating projects currently under execution or recently completed in international or domestic markets.

Today there is no shortage of significant market challenges, with the collapse of the oil price and consequently a big reduction in the investments in new production capacity. However, our Italian industry has proven its competitiveness, innovation and flexibility in almost every remote corner of the world, from Eastern Russia and Eastern Australia all the way to Western Canada and Latin America. Indeed, Italian contractors and equipment suppliers are often among today's global leaders, with high market shares, universal recognitions and growing sales. Therefore, it is conforting to see how our companies are rapidly reorganizing, cutting costs, re-engineering their business processes to gain efficiency and flexibility. In one word, remaining very competitive in global markets.

Indeed, our industry has historically excelled in projects which are ever more and more complex in terms of size, technology, execution requirements, extreme logistics and generally very challenging environments, projects which require high technical and management skills. Our companies' know-how and flexibility retain the competitive advantage vs. newer entrants from emerging markets, often less experienced and not as well organized.

> The Italian industry has recently shown a remarkable resilience and has reorganized and re-engineered its processes to cut costs and gain in efficiency

It could be premature and indeed unreasonable at this point to try to forecast the future. However, we still maintain a moderate optimism, in the belief that the level of new capital investments will bottom out in 2016, and then restart a slow, gra-

dual growth after 2017. In any case, the volume of new investments expected in 2015 and 2016, both in upstream and in downstream markets, still remains substantial, in spite of numerous uncertainties, particularly in some regions.

The Italian industry in general and specifically in oil & gas markets has recently shown a remarkable resilience in "weathering the storm". While some players have reported losses in 2015, this was due mostly to asset write-offs and impairments in a market where prices and rates have been reduced and expectations lowered.

Indeed, our companies have been forced to be ever more flexible and ever more innovative, by applying successful execution models, mitigating the increasing project risks as well as generally by applying a number of very innovative solutions to new challenges, in our complex and rapidly changing global markets.

The overall revenues and sales volume have mostly held up during this period, thanks also to a considerable backlog acquired prior to the downturn. The most recent results have swung back into profitability.

Our industry is ready for the next challenges and it looks at the future with moderate optimism

Generally, therefore, our industry is ready for the next challenges and it looks at the future with optimism, in spite of the many current difficulties.

We thank the Italian industry active in the oil & gas sector for their strong and continuing support to ANIMP. We confirm our commitment to provide an ever improving range of services to all our affiliates and to represent the Italian supply-chain of the Engineering and Contracting Industry in all global contexts.

Claudio Andrea Gemme

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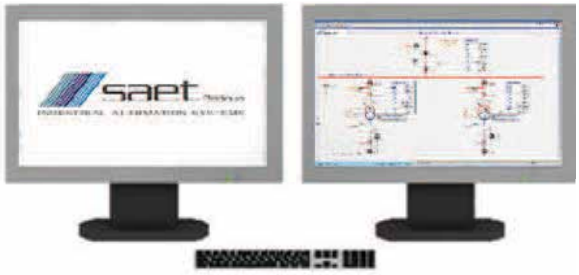

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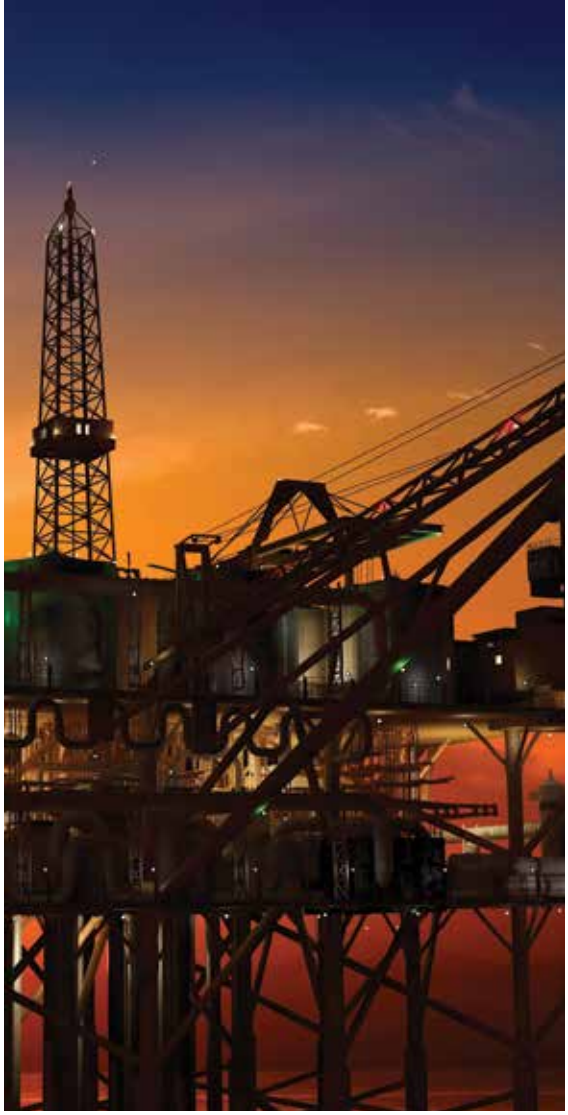
Procurement in a Low Oil Price Environment

According to Bain & Company, the Italian value chain is recognized for its technical leadership and for its ability to support clients in a flexible and dynamic way. Now that clients are struggling in a low oil price environment, Italian suppliers have a great opportunity to reinforce their position as the partner of choice

Roberto Nava, Francesco Cigala
Bain & Company



few months, the industry shelved more than $ 200 billion worth of projects to protect dividends (**figure 1**). All of these represent valuable ways to reduce short-term spending but probably are still not enough to make lasting changes. What's more, in some cases short-term thinking can do long-term damage. For example, maintenance is an easy target for cost reductions, but these cuts may have unintended impacts in the medium term. Production losses resulting from equipment failures can hurt cash flow far beyond any short term savings that may result from maintenance cost cuts.

Now, as the industry faces the likelihood of a long-term low-price environment, procurement teams need to look beyond short-term tactics and take a more proactive and strategic stance within their organizations - for example, working further upstream in project design and collaborating with the engineering and design teams to reduce complexity before it is locked into long-term procurement costs (**figure 2**). Long-term shareholder returns depend on growth and capital efficiency more than paring discretionary costs.

Three areas where procurement teams must strike the right balance

Almost two years after the steep drop in crude prices in middle of 2014, oil & gas companies have made all the easy cuts - the low-hanging fruit is off the tree. Procurement teams across the industry have pushed for price reductions from suppliers, clamped down on discretionary spending and deferred capital expenditures. As oil prices slumped again over the last

In our experience working with clients we have identified three areas where leading procurement teams strike the right balance between short-term cost reduction and long-term optimization. These are:

- *reset supplier relationships*: gaining a better understanding of suppliers' industries and cost structures in order to ensure cost transparency and anticipate supply shocks;
- *improve capex efficiency*: getting involved early in

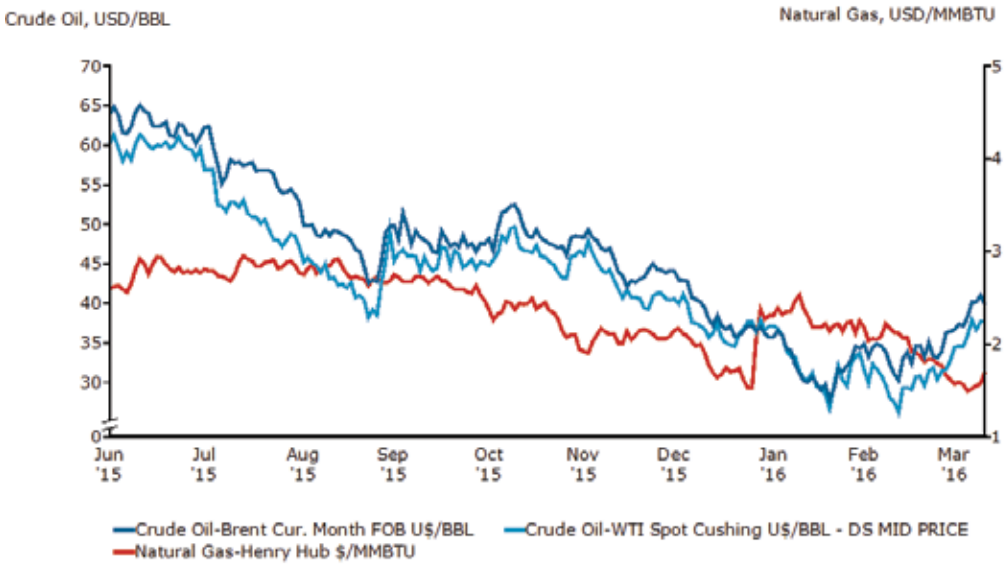
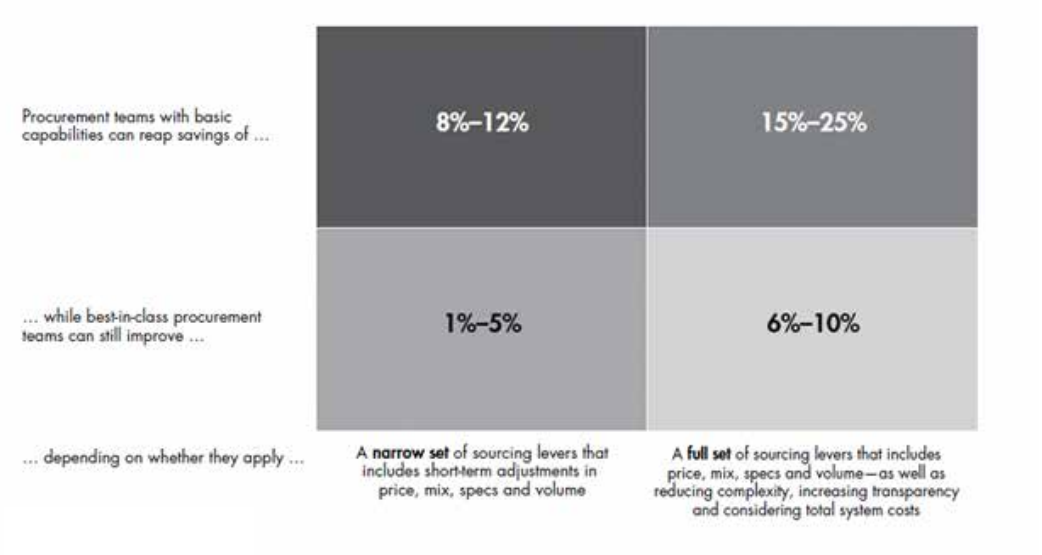


Fig. 1 – Low oil price environment (source: Datastream, 11 March 2016)

Fig. 2 – Procurement savings can be substantial, especially from teams that are just beginning to improve their capabilities (source: Bain & Company analysis)



design processes to reduce complexity and subsequent procurement costs; take advantage of slow cycles to invest in the future;

- *develop a culture of cost consciousness*: developing better transparency so that more people can see how money is being spent; make purchasing decisions based on total cost of ownership.

Reset supplier relationships

As prices dropped, oil and gas suppliers' inboxes filled with letters from customers asking for price reductions of as much as a third. These initiatives helped to reclaim some of the margins that had shifted to service providers in the boom times. But the best buyers also understand their suppliers' cost structures and strategic importance to their business. They avoid squeezing so hard they put suppliers out of business, which benefits no one, especially where strategic relationships have been carefully cultivated over many years.

Buyers should also try to get a better understanding of suppliers' costs and the value of the products and services procured. Among the strategies to reduce costs:

- *aggregate demand*: combine purchases across the entire portfolio, rather than individual projects, to get bigger volume discounts;
- *embrace standardization and modularization*: remind engineers and the front line of the cost advantages of working with existing equipment, especially in lean times; reuse designs and avoid introducing new complexity;
- *avoid onerous terms*: when buyers squeeze suppliers on price or other purchasing terms, suppliers have to find ways to mitigate these risks by purchasing insurance or raising prices down the line;
- *adopt low-cost solutions for shared activities*: identify areas where buyers and sellers can cooperate to realize joint savings; for example, a helicopter contractor and its oil company client could cooperate to jointly plan their schedules to ensure better utilization of their transport service, reducing costs for both.

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Armed with these insights, procurement teams can develop a prioritized action plan that includes negotiations with their largest suppliers, running a sourcing program for the largest and most expensive categories and renegotiating important contracts. Buyers should also be open to bids from competing vendors, as suppliers jockey to gain or maintain share.

Improve capex efficiency

Most if not all oil and gas companies have already reviewed their capital spending, deferring or canceling new projects. Long-term capital efficiency will require more extensive changes, including reducing complexity throughout the organization. Strategically minded procurement teams get involved in the early stages of design, when decisions determine long-term costs.

With sector inflation waning, some companies with strong balance sheets may find this the ideal time to accelerate projects, given reduced competition around opportunities and better rates for services and equipment.

Develop a culture of cost-consciousness

As cost pressures increase, procurement teams attack discretionary spending with a fine-tooth comb, cutting small luxuries such as coffee machines or canceling training. But these moves usually have little effect on spending, and they can damage morale and weaken capabilities.

A more important role for procurement involves fostering a culture of cost-consciousness so that staff across the organization can make the right decisions for themselves. This begins with systematic cost transparency. The employees who specify a product or service, those who purchase it and those who use it may be different people. This makes purchasing difficult. Better to make sure that all three categories—those who specify, buy and use - stay involved in purchasing decisions and can see and understand the cost and value.

Most procurement teams say that they consider total cost of ownership but often overlook it for short-term savings, especially in lean times. Applying total cost of ownership correctly can be difficult because it requires a holistic view on spending across functions and time. For big projects, getting involved early in front-end engineering design allows procurement to participate in decisions that lock in 80% to 90% of costs.

Toward a more strategic approach

Procurement teams can make a more sustainable contribution to their companies' success by taking a more proactive and strategic approach, which requires building up three critical capabilities.

Plan for uncertainty

Given the broad range of outlooks for the sector, a scenario-based approach is the best strategy for dealing with evolving market conditions. Leading procurement teams develop a set of scenarios based on various market conditions. Under each scenario, they determine changes in demand and their appropriate response. They then continuously monitor signposts that indicate the likelihood of the various scenarios materializing and adjust their actions accordingly. For example, in boom times when demand for pipeline materials runs high, it's important to lock in capacity at mills to ensure a steady supply. When demand slackens, it's less important to lock in capacity and probably more important to collect bids from prequalified suppliers to increase the speed to market. The procurement team should advise the business on these kinds of challenges.

"Buy better" but also "spend better"

Most of the traditional focus of procurement teams has been to improve the way they buy using a strategic

sourcing approach. Whilst this is a fundamental prerequisite to drive savings, a better way to drive procurement benefits is to really learn how to spend better. Spending better can be done by extracting maximum benefits from demand management coupled with strong focus on specifications management and supply chain interface management. This can be achieved by having the procurement organization taking a more strategic role and being involved early in the decisions that impact the spend.

Strengthen category management

Procurement teams become more effective as they gain expertise about the industries from which they source. As experts, they should be able to offer deep insights about their suppliers' businesses, including market size, growth patterns and the market share of competitors. By developing a good understanding of the value drivers in a category, teams learn what products and services should cost and how events will affect their suppliers and costs. Best-in-class category managers should be able to answer questions such as:
which suppliers generate superior returns and why?
where will consolidation occur, and what role will their suppliers play?
How will disruptive technologies and changing customer preferences shape the market?

Procurement category managers can improve their capabilities by building bridges with the commercial and engineering groups such as setting up cross-functional teams, sharing information on an online platform or holding focused idea-generating sessions. Investing this way in development benefits the whole company, and the low-cost environment provides a strong motivation for bolstering the procurement team with analytics, commercial and strategic performers.

Improve ability to detect risk

Procurement teams can take steps to get better at assessing the risks faced by their suppliers.

- ***Audit supplier performance***

An audit can help identify potential performance, financial or capability risks. Frank discussions with suppliers can help procurement understand their position and assess their ability to continue to deliver.

- ***Assess midterm market risks***

Looking ahead can help identify potential supply risks from consolidation, regulatory constraints, geopolitical risks or other wild cards.

- ***Look after emerging suppliers***

In many countries, contractors select suppliers in line with local content goals. Sometimes contract requirements with national oil companies or other resource owners may entail supporting these suppliers through difficult economic periods.

Near-term projections for the global oil and gas industry continue to forecast increases in supply against weak demand growth. With no sign of a quick return to higher crude prices, it will become increasingly important for procurement teams to step up their game. By becoming more proactive in their counsel on better purchasing behavior, by becoming experts in the industries that supply them and the contracts that manage the value chain, and by advocating reductions in complexity, procurement teams can become one of the most important agents in the industry's transformation for leaner times.

What risks and opportunities for the Italian value-chain?

The Italian value chain is recognized for its technical leadership and for its ability to support clients in a flexible and dynamic way; now that clients are struggling in a low oil price environment, Italian suppliers have a great opportunity to reinforce their position as the partner of choice. A trade-off between "quality" and "cost" is not viable, as competing only on costs brings to a certain erosion of the current competitive advantage towards emerging competitors.
Indeed, Italian suppliers should work to maintain their technical leadership and provide cost efficient solutions for clients (i.e. responding to the need of reducing costs in the long term), while reducing their cost structure in order to provide such solutions at a competitive price (i.e. supporting the client search for short term capex reduction).

Suppliers can therefore on the one hand sustain and participate in pre-bid joint works in order to develop the best-fit solutions that benefit all (e.g. to support standardization of specs, optimize planning of shared activities, cost efficiency etc.) and on the other hand ensure their competitiveness in bid-phase. With that objective in mind, suppliers should start to redefine their own supply chain and operating model, in order to reduce costs while guaranteeing high quality standards of solutions, and therefore explore and implement new models of fabrication on site, modularization, early involvement in client's processes.

Integration along the value chain is another strategic option as the offer of post-sale services is becoming more and more important for the end client and a significant source of added-value for the supplier. Once again, the access to stable revenue flows based on a service strategy implies a reconfiguration of the internal processes, an integration of the skill set and a shift in the company culture.

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He holds an MBA from Insead in France and an M.Sc. in Industrial Engineering from Politecnico of Milan.

The New Era of Gas Transportation

Fincantieri Offshore is working on an alternative concept for a ship-shaped compressed natural gas carrier (called the CNG32000), that could economically transport gas from stranded fields, compressed onboard to a pressure of 166 bar, to a standard onshore unloading station or an existing regasification plant

by **Fincantieri Offshore**

Floating LNG (Liquified Natural Gas) vessels are emerging as a solution for harnessing gas from mid-size fields remote from offshore infrastructure. But there are many smaller offshore fields that do not justify the huge vessels as some oil companies have commissioned for their current projects.

Fincantieri Offshore is working on an alternative concept for a ship-shaped compressed natural gas carrier, called the CNG32000, that could economically transport gas from stranded fields, compressed onboard to a pressure of 166 bar, to a standard onshore unloading station or an existing regasification plant up to 1,500 miles away.

Aside from providing a market for gas that might otherwise sit in the ground, the concept opens other potential benefits to offshore operators. One is avoiding the expense of installing a gas pipeline in the case of an oilfield with associated gas, or having to re-injecting the gas into the reservoir. Another is an economic means of disposing of gas from extended offshore well tests, ensuring compliance with restrictions on flaring.

Nowadays there are numerous competing Compressed Natural Gas (CNG) concepts, many of them are just concept not sufficiently matured to be considered for industrial production and vessel applications. Fincantieri started work in earnest on the CNG32000 design in 2013, initially studying various containment systems, methodologies and ship configurations. It developed the concept in its present form in 2014, and has performed all work to date in-house with the collaboration of Rina (the Italian Class Authority) for the Approval in Principle and FMEA (Failure Mode and Effect Analysis) of the design.

Main design features

The main dimensions of the ship include:

- an overall length of 220 m (722 ft);
- a molded breadth of 40 m (131 ft);
- a design draft of 7.2 m (23.6 ft);
- a deadweight of around 6,700 metric tons.

Its total compressed natural gas (CNG) transport capacity during a single voyage under standard conditions would be around 6.34 MMcm (223.9 MMcf) at 166 bar (2,407.6 psi) and a temperature of 25 °C (77 °F). This would be stored in pressure vessels grouped together in around 500 racks, stationed in 10 cargo holds (50 racks each).

Next to the cargo holds, the mid-body portion of the ship features a double hull and a double bottom, the inner part of which is used for ballast water tanks. Toward the aft section is the accommodation block, housing 21 crew members, in a superstructure above the main deck containing the engine room.

Two 4.5 MW Azipod propulsion units combined with a bow thruster maintain the ship's position during offshore tandem loading operations. Power is provided by three diesel generators with dual-fuel engines, each outputting around 4.3 MW. A back-up generator is stationed beside the accommodation block above the main deck. The fore part of the vessel has a bulbous bow. Here the CNG handling system and compressor are located, above the main deck and forward of the cargo holds.

Initially the main focus of the designers was on the compressed gas containment and cargo handling systems. Several different building materials have been compared assessing physical properties and chemical compositions as well as market availability aspects and economic applications.

The compression system has been designed to allow the ship to receive gas at various pressures and store it in metallic pressure vessels. Main components are:

- the compressors, similar to those used in re-liquefaction systems in LNG carriers; thermal expansion valves;
- coolers end heaters;
- remote control valves.

Some competing CNG concepts are based on storage pressure of 250-350 bar (3,626-5,076 psi), much higher than the current target for the CNG32000. According to Fincantieri, there are both economic and energy benefits in compression between 140 and 160 bar (2,030-2,320 psi), compared with design pressures of 250 bar and above.

Fincantieri

Fincantieri is one of the world's largest shipbuilding groups and number one by diversification and innovation. It is leader in cruise ship design and construction and a reference player in all high-tech shipbuilding industry's sectors, from naval to offshore vessels, from high-complexity special vessels and ferries to mega-yachts, ship repairs and conversions, systems and components production and after-sales services.
Headquartered in Trieste (Italy), the Group has built more than 7,000 vessels in over 230 years of maritime history. With almost 21,000 employees, of whom approximately 7,700 in Italy, 21 shipyards in 4 continents, today Fincantieri is the leading Western shipbuilder. It has among its clients the major cruise operators, the Italian and the US Navy, in addition to several foreign navies, and it is partner of some of the main European defense companies within supranational programs.

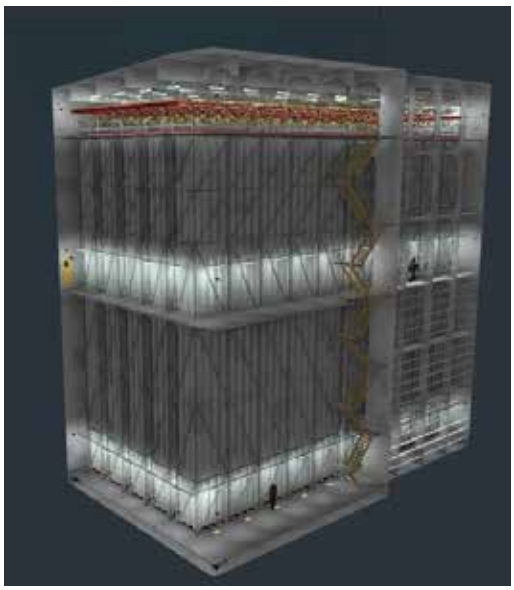
Fincantieri Offshore

Fincantieri Offshore, thanks to a long, strong experience gained in the field of ship design and construction, offers cutting-edge, customized solutions for offshore drilling.
The offshore unit specializes in state-of-the-art offshore units from drillships and semi-submersible drilling rigs to pipe-laying and construction vessels, as well as production platforms and innovative gas carriers.
In 2013 Fincantieri, through its wholly owned subsidiary Fincantieri Oil & Gas SpA, has successfully completed the acquisition of Vard, one of the world leaders in the construction of offshore support vessels for oil and gas extraction and production.

Recent market studies for high-pressure vessels mostly foresee the application of materials not yet tested for CNG being transported at 250 bar, and also envisage very high material costs. The solution proposed by Fincantieri is aimed to possibly achieve the best compromise between the size of the vessel and the quantity of gas transported, at the same time eliminating upstream any possible issue relevant to time-to-market and proven technology.
The dimensions of CNG32000 has been selected in accordance with a specific application which have similarities with many other scenarios all around the world. Of course different geographical areas as well as different input data (e.g. shipping distance, quantity of gas per year, etc.) could suggest to adapt the vessel capacity accordingly. Fincantieri can support the clients to optimize the CAPEX of the project, studying different CNG fleet configurations, in term of number of vessels and their optimal sizes.
Fincantieri stressed that this is not a "one size fits all" concept because each project would need to be approached on a case-by-case basis. That means it is more practical to think in terms of a fleet of CNG vessels, rather than a single carrier, in order to maximize efficiency.

Arrangements for loading/unloading

The compression system could be installed on board in order to make the vessel independent form the platform/shore infrastructure. This system includes scrubber equipment dedicated to cleaning the gas of heavier hydrocarbons and liquid phases. Depending on the amount and characteristics of these quantities, the design of the pre-processing system will require different sizing, equipment and configuration complexity.
Arrangements for loading/unloading are provided in the forward part of the ship, comprising two manifolds with longitudinal bow connections suitable for offshore tandem loading. A hawser would be deployed to secure the ship and flexible hoses during cargo transfers. Transversal connections – two portside and two starboard – are also arranged forward for cargo transfer at the port quayside reception terminal.
Cargo loading/unloading would typically be completed in less than a day (assuming the gas would be received from the source at 60 bar, and delivered to the onshore



Pressurized vessel detai

Compressor room

terminal at 60 bar as well). Offshore tandem loading operations could be performed even in rough seas, he added, although this remains to be validated in tank tests.

Aside from the gas containment system and associated equipment, the shape, layout and facilities of the ship are similar to those of a standard LNG carrier. In terms of safety, while LNG is a cryogenic liquid at -162 °C (-259.6 °F) carried at the "boiling point", and therefore continuously Generating Boil-off Gas (BOG), the CNG is a stable fluid contained inside the pressure vessels at the ambient temperature condition. As for the CNG storage, the 166 bar pressure utilized in Fincantieri design is in line with, or even below, that of the typical maximum used for transportation by road.

On arrival at the reception terminal, the ship could directly transfer its cargo into the onshore network if the latter is configured to receive the gas within a reasonable timeframe. One of the plus of this idea is that in this case very limited facilities would be needed at the reception end, such as gas metering, odorization and a Wobbe index correction system. Alternatively, the ship could be used as a storage facility, remaining at the terminal as long as necessary. If this is not possible or not economically viable, onshore storage would have to be considered.

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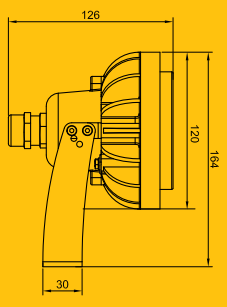

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Installation Challenges for Offshore Frontier Projects

Technology drivers behind the increasing complexity of the field developments. Flex-lay is a further solution employed by the industry: the Normand Maximus, Saipem's new flexible laying and construction vessel currently under-construction, is presented.

Lorenzo Penati, Matteo Ducceschi, Andrea Intieri
Saipem SpA

Fig. 1 - World oil & gas offshore frontiers: current and future

Even with the current weakness in the global oil and gas market and all the clear signs of an ongoing industry re-adjustment, according to one of the most recent sector outlooks [1] global energy demand is expected to grow, fueled by a GDP (Gross Domestic Product) projected to more than double by 2035 due to higher levels of activity and an expected increase in the living standards. The fuel mix will continue changing following gains in energy efficiency and the shift towards lower-carbon resources. However, fossil fuels will remain the dominant source of energy (60% of the energy increase and almost 80% of total energy supplies by 2035). Gas is expected to be the fastest growing fossil fuel thanks also to the supportive environmental policies that are currently being implemented worldwide. Meanwhile, coal consumption is likely to slow as the Chinese economic model changes. The oil demand is still projected to increase, although gradually rebalancing.

With the energy companies trying to weather the current storm, the offshore industry is suffering from a reduction in operators' willingness to engage in projects with significant capital investment and high risks, leading to limited field trials of relatively unproven technologies. Nonetheless, the SURF (Subsea, Umbilicals, Riser and Flowlines) market is still progressing, with the specific short term goal of reducing costs and, in the long run, to be ready to meet the future challenges once the overall outlook becomes favorable again.

As per **figure 1**, future frontiers of the offshore industry may include the Arctic and completely new areas in Latin America, East-Africa, the East Mediterranean and the Asia Pacific (especially Australia and West-India). Fields to be developed are often in ultra-deep water (i.e. > 1,500 m) and/or in harsh and remote environment. Solutions to tackle conditions of unprecedented complexity are mostly based on established technologies and rarely involve unproven concepts. The development of offshore fields in deep waters has been a well-established industrial practice for at least a decade. Currently, drilling and installation equipment enable field developments to achieve water depth of up to 3,000 m and even beyond [2].

Dealing with deep or even ultra-deep water fields requires the engineering and the installation capability to perform demanding offshore operations. For example, the weight of thick pipelines and massive structures requires holding and lowering equipment at the upper bound of the available technology [3]. Technological jewels such as Saipem's FDS2 (**figure 2**) embody the state of the art needed to face such challenges. In addition, logistics, especially when

Fig. 2 - Saipem's J-lay and offshore construction vessel FDS2

projects are executed in remote and isolated geographic locations such as the Arctic, may play a key role in making a pipe-lay spread competitive.

The development of offshore fields in deep waters has been a well-established industrial practice for at least a decade. Currently, drilling and installation equipment enable field developments to achieve water depth of up to 3,000 m and even beyond. Dealing with deep or even ultra-deep water fields requires the engineering and the installation capability to perform demanding offshore operations.

Frontier field developments are in progress, coherently with the increasing energy demand. New challenging projects are only technically and economically viable with top class pipe-lay vessels, supported by fine-tuned logistics. Reductions in the time required for such operations is always a must, even in the deepest and harshest scenarios. Transported product, flow rate needs, pipe diameter and pipeline length may be factors in the choice of the preferred laying technology. The selection of the pipe concept, as a function of flow parameters and strength requirements, is always a key factor. The choice of laying method is not straightforward without a detailed analysis of the requirements related to operations and design time span.. Eventually, the driver of any decision shall take into account the results of expert analyses of project lifetime cycle.

Fig. 3 - the P55 project executed by Saipem in Brazil (source: Petrobras)

Subsea fields and pipelines architectures

The technical solutions for developing the architecture of ultra-deep water fields vary in relation to a number of parameters, such as reservoir dimensions and the quality of the extracted hydrocarbon. Generally, the field layout includes a series of wells, intra-field flowlines that carry the product to manifolds or riser base structures, a production riser system connecting the seabed infra-structure to a surface floating facility (e.g. FPSO, spar, semi-submersible etc.), and a floating unit to the export lines starting base [4]. Saipem has over the years acquired considerable experience in such developments. By way of example, **figure 3**, depicts a challenging subsea field in Brazil.

At present, with the offshore market suffering from persistently low oil prices, there is expectation that technology can render economically viable the production and export from ultra-deep fields, even in remote and harsh environments. Over the last decade and as well as at the current time, new full subsea processing concepts, particularly regarding the 'subsea factory' (i.e. subsea production plants permanently resting on the seabed), have been and indeed are under development (i.e. compression, boosting and separation technologies).

Pipelines for field development

Several products, with different characteristics and specific issues have to be adopted to complete a field development.

Production and export risers are designed to withstand high pressure and high temperature, and often transport aggressive products that may cause corrosion and threaten carrying capacity even in the short term. Products with internal linings made of special steel or plastic, or full wall noble materials, constitute the family of Corrosion Resistant Alloy (CRA) pipes. These are a fairly expensive but proven option offered by materials technology to protect offshore production pipelines against corrosion.

Furthermore, in deep waters external pressure requires thick walls and, consequently, heavy strings need to be

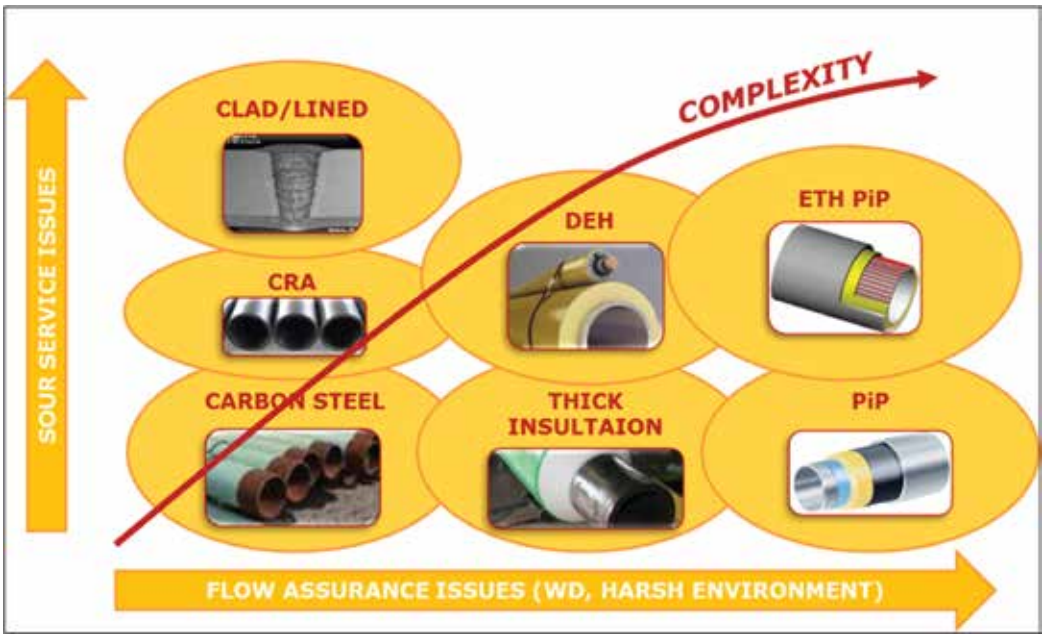

Fig. 4 - Typical pipe solutions for field development

held by pipe laying vessels during installation. In most deep-water applications, the mechanical fatigue of girth welds under the cyclic loads from seawater environment is the topical issue driving any development program and the relevant choices. Excellent weld ability properties is a key factor for such materials. Corrosion, fatigue and severe transport conditions, often multi-phase, are challenges driving the development of riser and layout concepts; solutions are not unique and are often solved at a design stage requiring in service assistance through extensive monitoring in order to minimize risks (**figure 4**).

New challenging projects are only technically and economically viable with top class pipe-lay vessels, supported by fine-tuned logistics

Similar issues can be extended to intra-field flowlines, nevertheless excluding the criticality of dynamics and fatigue derived from external hydrodynamic loads.

The lines on the seabed that transport treated and untreated products are generally less complex than risers. They do have, however, some criticalities in relation to length and sometimes to flow-assurance issues that require thermal insulation. In-service global buckling caused by thermal expansion recovery and pipe walking may be other challenges, particularly when layout is congested and in all those cases where flow fluctuations can cause fatigue. A high level of complexity must be faced in congested subsea layouts with a high density of structures and pipelines, where ending or starting a line often poses quite stringent requirements [5]. **Figure 5** shows some of the structures usually deployed in a subsea development.

Export pipelines can be considered independently from the foregoing as long distance and large diameters dictate different line pipe requirements. Such lines are generally rigid: the minimum wall thickness requirement of the pipe is determined according to the grade and both to the internal–bursting limit state and to the external–collapse limit state containment pressure. In ultra-deep waters this leads to thick-walled heavy pipes, whose transport over long distances and installation require lay vessels to have significant welding and holding capacities. In general, long export pipelines with large diameter are made of carbon steel and are longitudinal seam arc welded.

Notably, pipeline operators do not want to risk leaks due to corrosion. Plenty of care is therefore taken in production plants by treating pipes in order to obtain a reliable final product even for sweet service. In some circumstances, the product cannot be treated; in these cases, the line pipe in carbon steel will include a corrosion allowance or have a clean chemistry, suitable for mild sour service. Examples of long-distance export

Fig. 5 - Subsea structures under construction that have been installed by Saipem in offshore Egypt (Burullus field)

Fig. 6 - Saipem's New Offshore Construction Vessel: Normand Maximus

pipelines made of CRA are few and far between in the recent past, but future projects should look into the CRA option with increasing interest.

In the interest of cost reduction, even fewer ventures with pilot solutions are proposed, with field development concepts tending to rely more on mature technologies such as steel (rigid) pipes. Nevertheless, flexible pipes are considered a robust and effective alternative to rigid pipes and in fact have been successfully installed and operated for more than 40 years.

> Normand Maximus [...] is the result of an innovative design philosophy which aims to combine SURF installation requirements with field development activities in ultra-deep water with unique operational benefits

The technology is continuously evolving to higher temperature and pressure operative conditions and deeper waters. Recently, the use of flexible pipes in ultra-deep water applications exceeding 2,500 m and 3,000 m has emerged as the next-to-come frontier: they are in fact of particular interest for floating platforms scenarios, where they are commonly used as dynamic risers connecting seabed flowlines to production facilities and as intra-field fluid transfer lines. With their ease of installation and very good corrosion resistance they are also of interest for use as static seabed jumpers and sometimes flowlines, especially in the Brazilian developments. This versatility is mainly achieved thanks to the structural modularity of flexible pipes composed of several layers of helically wound metallic wires, extruded thermoplastics and recently even composites, that carry out different functionalities (e.g. collapse strength, fluid barrier, fatigue and corrosion resistance) and that can be combined based on the specific application requirements.

For the above mentioned reasons, flexible pipes are currently used in many field development architectures, especially in shallow waters and up to deep and ultra-deep waters. This is why offshore contractors, including Saipem, have been equipping their construction vessels with flexible pipe installation capabilities.

The Normand Maximus, Saipem's new flexible laying and construction vessel currently under construction, is a good example of this trend. The vessel is the result of an innovative design philosophy which aims to combine SURF installation requirements with field development activities in ultra-deep water with unique operational benefits: equipped with versatile lay systems, reconfigurable for multiple and simultaneous project tasks, provided with a large main deck and below deck payload abilities and designed to perform in the harshest environmental conditions subsea lowering and URF installations.

High capacity laying equipment

A market scenario moving towards deeper waters inherently implies an increase in laying equipment minimum requirements. In fact, pipe diameter strictly depends on field architecture and development strategy (i.e. one well, one flow-line, one riser vs manifold based). It can be stated that in deep water a great number of production risers are 6" to 12" OD, whereas for flow-lines and export-lines, 16"- 28" OD are commonly adopted. The adoption of complex pipe concepts is growing: plenty of PiP (Pipe in Pipe), DEH (Direct Electric Heating) and insulated pipe systems are in service with satisfactory performance.

Figure 7 a shows the Wall Thickness (WT) of a rigid pipe string, one water depth long, for a 12" OD seamless pipeline. The black dashed line shows the minimum WT requirements for pipe reeling onto a 16 m diameter hub. **Figure 7 b** shows the weight of a rigid

pipe string as long as one water depth. For an application at 3,000 m WD (Water Depth), the collapse strength capacity leads to weights ranging between 18.5 and 22.5 mm, as a function of steel grade and the initial out-of-roundness of the line pipe.

The weight of an empty rigid pipe ranges between 1,500 and 2,500 kN; in case of incidental water flooding, the weight to be held increases in the 3,500÷4,500 kN range. These figures provide useful indications about the availability of line pipe and the minimum holding capacity required by the lay vessel at the reference water depth. As for the latter, a factor ranging between 1.35 and 1.5 needs to be multiplied by the pipe string weight to get the minimum holding capacity that has to be ensured on the lay vessel while operating respectively in J-lay or reel-lay mode.

Pipe-lay methods

The S-lay technology mostly targets long and large diameter export and trunk lines, to be laid in shallow and deep waters. Currently, large vessels and long smart stingers allow for steep S-lay, i.e. exit angle at the tip of the stinger close to 90°, which means nearly vertical as per J-lay. S-lay technology may be constrained, particularly in terms of lay rate, when in-line items (e.g. valves, Plet, Plem etc.), that should pass through the stinger, need to be laid along the pipeline in open sea. S-lay in ultra-deep water remains the most competitive option for large pipes when the intrinsic high productivity of this method compensates the above reported issues and for installation of long lines, i.e. > 100 km [6].

Pipe laying by means of vertical towers, either J-lay or reel-lay, is more appropriate than S-lay for ultra-deep water field development projects, because it implies an easier management in congested brown fields, including heavy subsea equipment lowering. Often the J-lay target is the required quality of the welding process rather than the productivity, but in harsh environments, when the time window for laying is limited, lay rate remains the key factor. In certain circumstances, this applies also to reel-lay, which generally is less affected by metocean restrictions.

On the other hand, since the reeling process applies huge plasticization onto the prefabricated pipe, (pipe is bent on a large diameter spool, e.g. 16-20 m), the wall thickness has to be large enough to avoid a detrimental influence of large cumulated strains on collapse resistance and sometimes on fatigue resistance.

Looking at the problem from a logistical perspective for frontier field developments, Reel and J-lay appear as two complementary methods; the greater productivity of reel-lay allows for a significant reduction in installation duration but the method is also affected by a number of significant factors arising from more complex logistics:

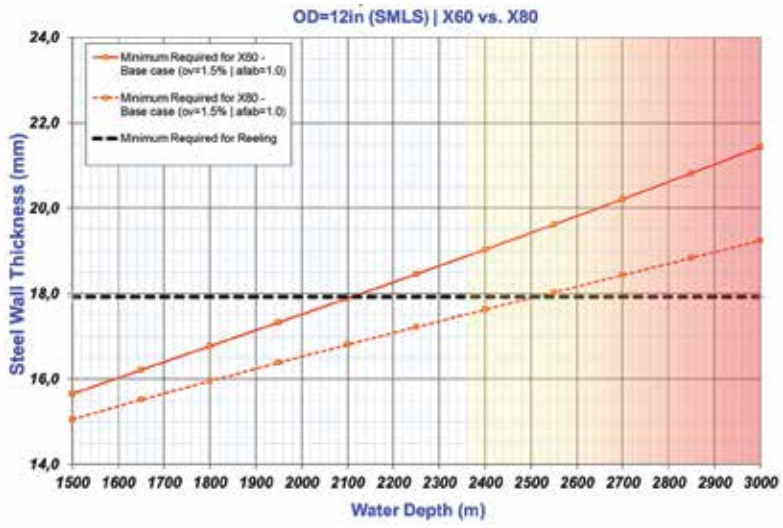

Fig. 7 – Minimum required weight: a) and pipe string wall thickness; b) for a 12" OD pipeline

the storage reel needs to be continuously fed, with consequent vessel stand-by or idle times.

Therefore, as shown in **figure 8**, J-lay technology is still the most competitive for medium-high diameter pipes (above 18" reel-lay is not feasible) and for long distance lines (i.e. > 50 km). Reel-lay is especially effective whenever the field is composed by a great number of small diameter risers (i.e. 6"-12") or intra-field lines of moderate length (i.e. < 15 km), even if those are heavy PiP.

In recent years, the offshore industry, aiming at reducing

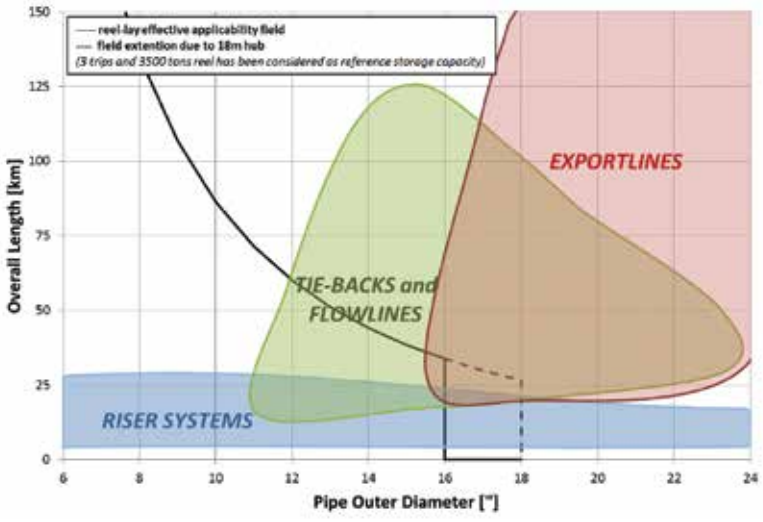

Fig. 8 - Field applicability of typical SURF steel pipes

costs associated with integrally anticorrosive stainless steel or Inconel pipes, has introduced pipes composed of a thick wall of C-Mn steel and a thin liner of anticorrosive alloy, bonded by means of a metallurgical link (i.e. clad pipes) or mechanical interference (i.e. lined pipes). However, special welding procedures, which have a negative influence on the cycle time, have to be adopted. For this reason cladded or lined pipelines installation is mostly performed by reeling vessels, moving almost the entire jointing phase out of the critical path of offshore activities; a spoolbase has therefore to be included in the spread.

Laying such pipes through reeling technology has a great impact on design and installation criteria since these are sensitive to fatigue phenomena and large plastic deformation that, especially for lined pipes, can produce CRA liner wrinkling or even disbonding. To control the damaging of pipe integrity some special precautions (e.g. steel wall over-thickness, internal pressurization) have to be taken during the application of the large strains typical of reeling process.

Harsh and remote environment

In harsh environment, the main criticalities faced are due to the shortness of the operative season and weather window, as well as to the severe and unpredictable metocean conditions. Therefore, the availability of an adequate pipe-lay spread is just one of the key factors to deal with in such a challenging scenario. Moreover, the correct and complete knowledge of the environment impact on subsea pipeline installation is essential.

Working in difficult scenarios means being able to evaluate the dynamic loads induced by metocean conditions; this affects both the mission equipment engineering and selection phase, and the design of pipeline subjected to fatigue phenomena. The shortness of the operative season causes the concentration of offshore works in a few months. Optimization of logistics is therefore a driving factor requiring a dedicated development of innovative solutions based on scenario peculiarities.

A problem to be faced in Arctic environment is the presence of ice for several months, as well as iceberg gouging; the installation of hydrocarbons treatment facilities above the sea surface (e.g. jacket or concrete platforms) can become unfeasible, and their placement on the seabed in shallow waters (i.e. < 100 m) can be a source of risk as well.

The scenario described above must be associated with the characteristics of typical projects: in most cases, the fields are located in relatively shallow water (e.g. up to 500 m) and in remote areas, distant from any existing infrastructure. In these cases, the construction of offshore platforms may be sometimes impossible, and the connections to distant existing fields (i.e. intra-field lines) or long tie-back to shore is preferable. This scenario involves the laying of long pipelines (i.e. 50-150 km), which are often affected by flow assurance criticalities that can be tackled through special and complex pipes, such as PiP, electrically heated or wet insulated pipes.

In harsh environment, the main criticalities faced are due to the shortness of the operative season and weather window, as well as to the severe and unpredictable metocean conditions. The availability of an adequate pipe-lay spread and the correct and complete knowledge of the environment impact on subsea pipeline installation are essential.

Less common but equally critical scenarios are those combining difficult geographical and environmental conditions with deep water seabeds such as in Statoil's Aasta Hansten in the northern sector of the Norwegian Sea. In these cases, the transportation of the product from the seabed to surface is achieved by means of riser systems. Since they are affected by fatigue issues during their operative life, they have to be carefully installed, avoiding dynamic loads and large plastic deformations. The described scenario shows that the whole process of installation of pipelines needs to be carried out relatively quickly, optimizing the logistics of materials in order to maximize the exploitation of the operative season, using lay vessels that allow work to be carried out extensively and safely, without damaging the products because of dynamic motions.

Conclusions

Offshore oil and gas frontiers are introduced and discussed. In particular, attention is paid to the near future context that installation technologies are going to face in the SURF market (subsea, umbilical, risers, flowlines). Early experiences have provided evidence that both ultra-deep waters and harsh environment require adequate installation spreads.

Field development projects in such environments can be efficiently performed using dedicated equipment. J-lay and reel-lay are complementary technologies; their relative effectiveness is strictly dependent on products, field architecture and geographical location. J-lay shows satisfactory performance for the installation of complex pipe concepts and long/large diameter export pipelines.

Flex-lay is a further solution employed by the industry: the Normand Maximus, Saipem's new flexible laying and construction vessel currently under-construction, has been presented.

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Lorenzo Penati

Lorenzo graduated in Mechanical Engineering at the Politecnico di Milano in 2011 and soon after joined Saipem SpA in the Technology Innovation Department, located in San Donato Milanese (Milan), where he worked for four years. During this time, he was involved in several significant projects related to the development of special offshore equipment, pipe-lay process innovation and performances upgrading.
Currently, Lorenzo is Project Manager on a number of technology innovation activities concerning the development of methods and equipment for ultra-deep water operations.

Matteo Ducceschi

Graduating with honors in Mechanical Engineering at the Politecnico di Milano in 2007, Matteo started his career as a Process Innovator for Saipem SpA's Research and Development Department in the same year. He worked as Project Engineer for the New Pipelay Vessel Castorone Project while, since 2008, as R&D Process Innovator and Project Manager, he has been responsible for the development of several deep-water laying and heavy duty subsea deployment systems and methods.

Andrea Intieri

Andrea has ten years of experience in the oil & gas industry. Currently working in Saipem's Strategy and Innovation department, he was involved first in offshore EPC/EPCI projects for ExxonMobil, Eni, CNR and Maersk and subsequently in the Business Development department.

Andrea holds a Master's Degree with honours in Industrial Engineering from the Technical University of Milan, Italy. He is currently attending an MBA at the MIP School of Management, Italy.

Transport and Logistic Activities for the Suriname Expansion Refinery Project

Fagioli were contracted by Saipem / Staatsolie for the heavy transport, lifting and logistics activities of modules, heavy items and general cargo for the Paramaribo expansion refinery

Rudy Corbetta
Fagioli Publicity Officer

The Suriname Country

Suriname, officially known as the Republic of Suriname, is a country on the North Eastern Atlantic coast of South America. It is bordered by French Guiana to the East, Guyana to the West and Brazil to the South and it is the smallest sovereign state in South America.

The country can be divided into two main geographic regions. The Northern, lowland coastal area has been cultivated, and most of the population lives here. The southern part consists of tropical rainforest and sparsely inhabited savannah along the border with Brazil, covering about 80% of Suriname's land surface.

Lying 2 to 5 degrees North of the equator, Suriname has a very hot tropical climate, and temperatures do not vary much throughout the year. Average relative humidity is between 80% and 90%. Its average temperature ranges from 29 to 34 °C. Due to the high humidity, actual temperatures are distorted and may therefore feel up to 6 °C hotter than the recorded temperature. The Paramaribo Suriname expansion refinery project performed by Fagioli project run from June to August, during one of the two wet seasons of the year.

The state of infrastructure in Suriname is weak. The road network consists of 4570 km of roads, of which 1125 km are paved, that it is about the 26%. Most roads are in poor condition and transportation into the heavily forested and sparsely populated interior is still extremely difficult.

Fagioli main activity

The key success to the contract award was Fagioli' capacity to offer to the client a turnkey project solution involving all of our capabilities including in-house project forwarding, heavy transport and lifting, engineering know-how, allowing us to perform the overall timely handling of all of the different aspects of such a challenging project.

The project comprises of three main activities:

- shipment of general cargo materials;
- shipment of heavy items (weighing up to 830 tons) and modules (24 PARs' and PAUs' modules from Italy) together with the local transport;
- lifting and installation of 11 main heavy item;
- some numbers of the project;
- 152 axle lines SPMTs (Self Propelled Modular Transporters) (some with connecting beams);
- strand jack and 60 m high tower lift system;
- climbing jacks;
- crawler cranes;
- dedicated barge for inland river transport;
- ballast pumps;
- 2 years project duration;
- 7500 engineering hours;
- 175,000 manhours on site;

Staatsolie, Suriname's state-owned oil company, signed an agreement with Saipem SpA for the engineering, procurement and construction of an expansion refinery project, few kilometers South of the capital Paramaribo. Fully commissioned during December 2015, the expansion has more than doubled the refinery's crude capacity to 15,000 b/d (barrel/day) from its previous 7000 b/d to produce high-quality diesel and gasoline. The expansion took more than 10 years to be completed from prefeasibility studies, which began in 2004, to its December 2015 startup.

Fagioli were contracted by Saipem / Staatsolie for the heavy transport, lifting and logistics activities of modules, heavy items and general cargo for the Paramaribo expansion refinery.

Fig. 1 - Countries from which goods originated

Fig. 2 - HL vessel with heavy items

originating from all over the world with the delivery to site managed by Fagioli Suriname branch. The red zones on the map (**figure 1**) are the main countries/ continents where general cargo, heavy items, modules originated. The total quantity of material to be shipped and delivered to site was around 60,000 m^3 of general cargo and a total of 167,000 m^3 of modular and oversize heavy items. The activities involved the sourcing of suitable liner and chartered vessels as well as dedicated H/L (Heavy Lift) vessels for the transportation of the biggest modules (**figure 2**).

The liner services to Suriname are not so regular and one of the main issues was to establish the best strategy to guarantee that the materials arrived at site in the correct sequence and on time. In compliance with the client construction schedule requirements and urgencies, Fagioli's operational project division ensured that vessels were chartered to maximize the amount of materials that could be shipped, performing the collection and delivery to the export ports of the materials on a timely basis to guarantee their loading on the specially chartered cargo vessels. In order to guarantee a regular flow of the delivery of the materials, the general cargo was also shipped in box or special container. For what concerns the biggest items (mainly originated from Indonesia, Vietnam and India), Fagioli booked dedicated self-geared H/L ship vessels.

- 40 average Fagioli personnel involved in the project;
- zero accidents.

Fagioli project logistics activity

Fagioli project forwarding department managed the shipment and site delivery for all the materials manufactured for the Suriname project with material

Fagioli heavy transport and lifting, installation and engineering activity

For this project Fagioli were contracted for the sea transport of 24 modules (**figures 3, 4, 5, 6**) from manufacturing area in Arbatax (Sardinia, Italy) to

Fig. 3 - Load out of modules at Arbatax

Fig. 4 - Module

Fig. 5 - Module

Paramaribo refinery. The sea transport of the modules were performed by chartering two heavy lift vessels with ro-ro capability (**figure 7**).
The other heavy items were sea transported and unloaded by lo-lo vessels at the port of Paramaribo directly onto Fagioli trailers.

PAR and PAU modules

The 24 modules PAR (Heavy Lift) and PAU (Pre Assembled Unit) fabricated in Arbatax ranged from 125.5 to 348 tons with different dimension characteristics which compelled Fagioli engineering department to provide the most efficient transport configuration in order to optimize time and costs. The engineering department examined and reviewed the input information and client's technical documents, taking into account the specific Fagioli activities to the applicable extent. During this phase for the load out operation in Italy and the load in activity Paramaribo of the modules, the engineering department considered the following main aspects:

- environmental design conditions;
- physical and functional interfaces;
- Health, Safety and Environmental (HSE);
- site arrangement and layout;
- operational requirements including the number of trailers to be used;
- eventual failure effects of structures and components;
- tests and examinations;
- stability during transport, handling and storage;
- contingency solutions.

For the calculation reports of this project Fagioli considered:

- the load out bridge structural calculation report;
- barge mooring calculation report;
- barge ballast plane calculation report;

Fig. 6 - Module

Fig. 7 - Sea transport of modules

- barge stability calculation report;
- barge grillage structural calculation report; barge sea-fastening structural calculation report;
- tower system strength and stability calculation report for the installation of the biggest module by means of strand jack and tower lift system;
- calculation report of structural hardware for operation (spreader beams, transport beams etc.).

Once all the necessary documentation and specific drawing were issued, Fagioli operators were ready to execute the load out operations at Arbatax.

Load out operations at Arbatax, Italy

The modules PARs, and PAUs had different dimensions and weight which required the use of several SPMTs trailers for the ro-ro activity. The main challenge was the handling of a module which was extremely high for

Fig. 8 - PAU 2604 at Arbatax

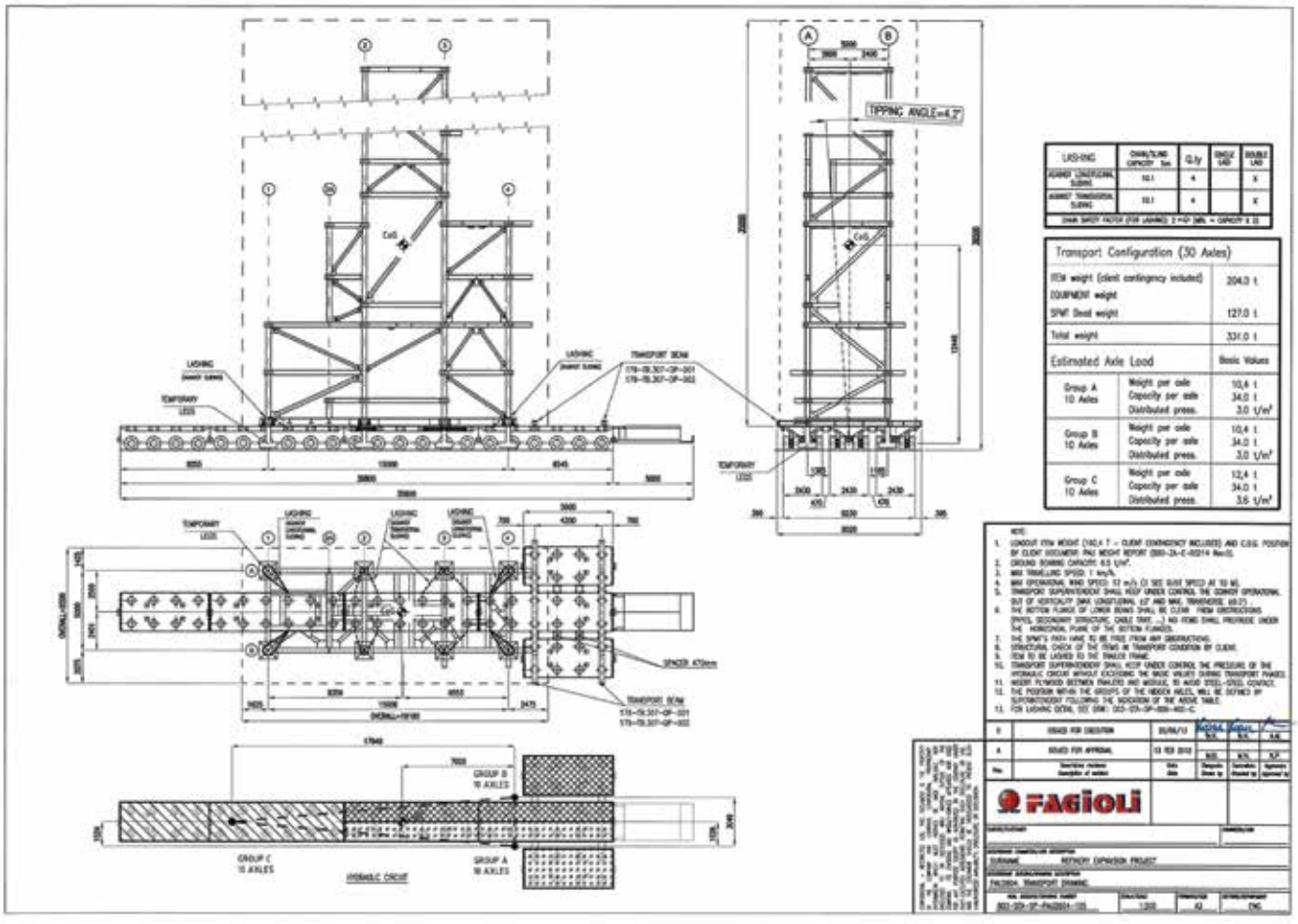


Fig. 9 - Tipping angle detail

Fig. 10 – Ning Sea Fastening

which Fagioli prepared a dedicated SPMT configuration The unique dimensions of PAU module 2604 (**figure 8**) compelled Fagioli to study the best feasible solution. Fagioli prepared a dedicated SPMTs configuration in order to move the PAU module 2604 from the manufacturing area, to the quay and for the load out operation onto the dedicated H/L vessel chartered for the sea transport of the modules.

The module height was about 35 m and its centre of gravity at about 12.4 m. Considering that the tipping angle was 4.2 degrees maximum, a minimum lateral bend would have caused the fall of the item (**figure 9**). Fagioli proposed a configuration with 22 axle lines in the centre and 2 sets of 4 axle lines positioned at the bottom of the convoy and assembled with two connecting beams. The module was transported ro-ro onto the H/L vessel with great care and laid onto the bottom of the ship through the lowering operation obtained by the hydraulic suspension of the SPMTs.

The modules were lashed and sea fastened (**figures 10, 11**) while the trailers were taking away. After 21 days of navigation the ship vessel arrived at Paramaribo.

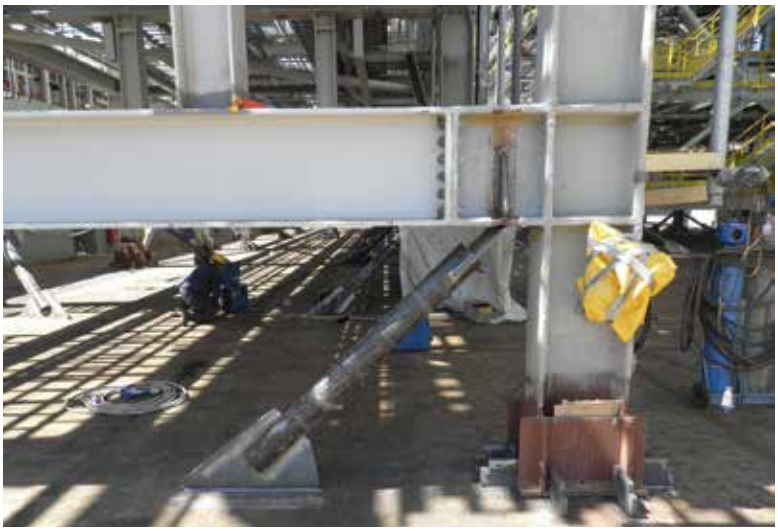


Fig. 11 - Sea fastening

Challenging aspects

The refinery was about 15 km from the port but, as already written above, the poor conditions of the road did not allow the heavy rod transport of the items (**figure 12**). The best solution to get to the site was the use of dedicated barges (**figure 13**). The site was located on a river's bank and due to shallow waters the ship could not reach the site. Fagioli conceived a direct transhipment from the vessel to a river barge, which

Fig. 12 - Road conditions

Fig. 13 - Dedicated barge

Fig. 14 - Direct unloading operations of heavy items onto the barge

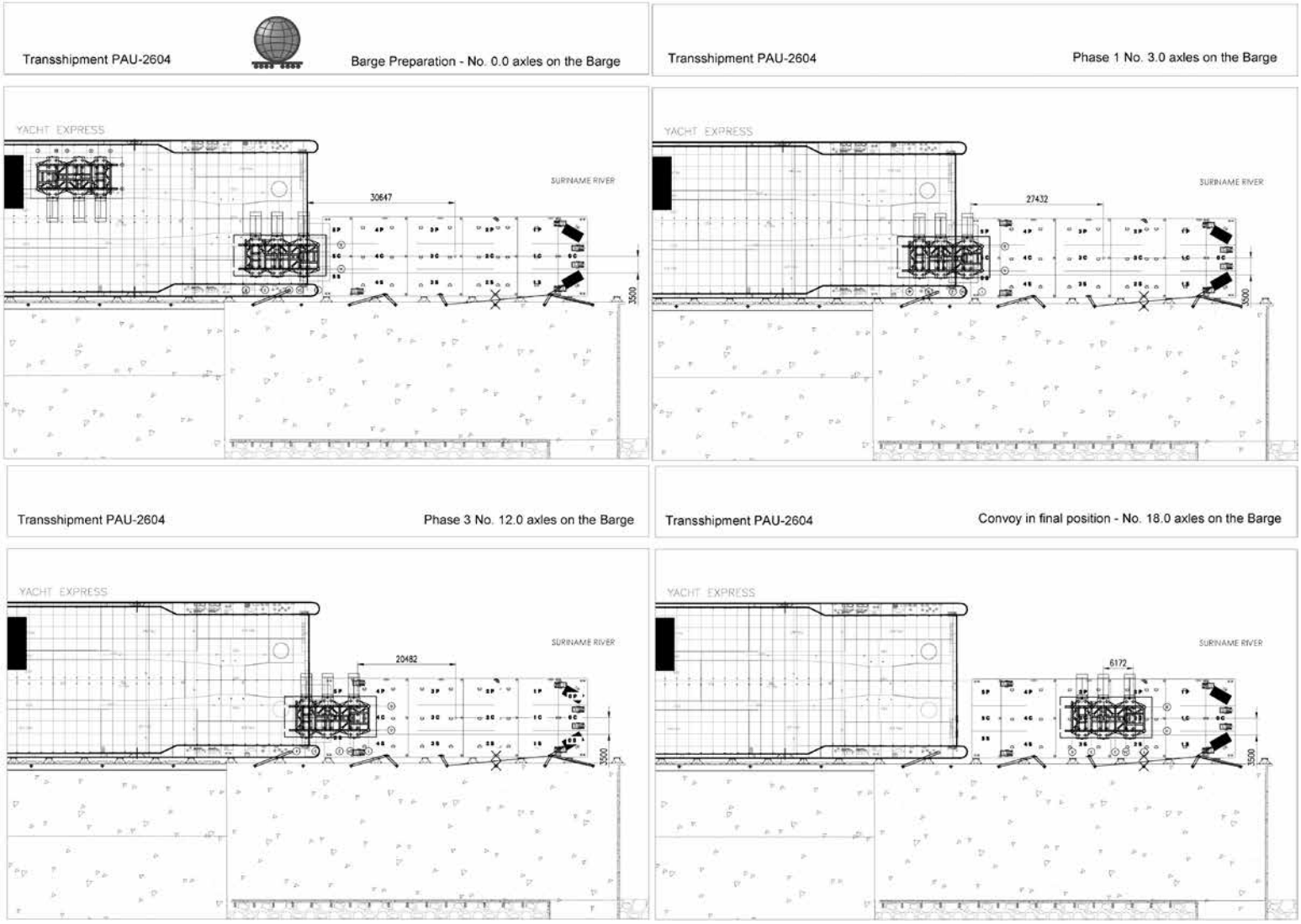
Fig. 15 - Direct load in ro-ro of modules onto the barge

Fig. 16 - Direct load in ro-ro of modules onto the barge

could float on the river and heading directly to the site. The heavy items were discharged with vessel gears directly onto Fagioli SPMTs positioned onto the barge (**figure 14**). The main challenge was the unloading of the modules (PARs / PAUs) loaded ro-ro in Italy. The first ten modules arrived with the first H/L vessel, they could only be off loaded by ro-ro means from the vessel to the quay via a dummy barge prior to be able to reach the designated storage area. Then the modules were reloaded from the quay ro-ro by means of SPMTs onto the barge to arrive at site, after a load in operation. For the second vessel the fourteen modules were unloaded ro-ro onto the barge which was then directly moved to the site, skipping the storage activities (**figures 15, 16**).

Due to the strong current and tides it was impossible to position the H/L vessel perpendicular to the quay for a direct roll off operation of the modules. So it was decided to berth it parallel to the jetty being careful to execute safe moves, considering all of the possible contingencies related to the ballasting of the two floating vessels. The direct transhipment of the module from H/L vessel onto the barge was a risky operation which required a deep study of the tides, issuing of ballast procedures, stability and mooring calculations.

The transhipment onto the barge required a different



configuration for the PAU 2604, hence 3 × 6 axle lines SPMTs were used to perform the offload from the H/L vessel onto the barge. No. 6 steel plates 50 mm were utilized as ro-ro bridge whilst No. 4 ballast pumps (340 m^3/h) were used to compensate the weight of the module during the transhipment. Once the PAU was safely transferred onto the barge, it was lashed and fastened again, ready for the river transportation activity (**figures 17a** and **17b** show the transhipment phases of PAU module 2604, **figures 18, 19, 20** show the module onto the barge). The whole operation took one day to be executed, and the river navigation up to the refinery site took about 3 hours.

Arrival at site

The barge, after the transhipment of the modules, went back and forth from site quay to Paramaribo port. During the load in operations onto the river barge, our staff faced precipitations and the wind was very blustery. Nonetheless, thanks to the ballasting calculations of our skilled Engineering Department we were able to accomplish the work.

Fig. 17 – a) Transshipment phases of PAU 2604; b) transshipment from ship to barge of PAU 2064

Fig. 18 - PAU module 2064

Fig. 19 - PAU module 2064

Fig. 20 - PAU module 2064

Fig. 21 - Arrival at quay site

After 3 hours of navigation the barge, going upstream, reached the site. Load in operation from the barge to the refinery dedicated quay were quickly performed (**figure 21**). The modules, and heavy items reached their final destination on site (**figure 22**) and were installed with different methods.

Once at site, after the load in, the PAR modules were directly positioned onto foundations (**figures 23, 24, 25, 26, 27**) whilst the PAUs' needed Fagioli climbing jacks to be settled. Within the contract for the installation of 11 main items (excluded the modules), Fagioli used the tower lift and strand jacking system to lift and install the biggest item being a reactor 50 m long and weighing 790 tons (excluding saddles) (**figure**

Fig. 22 - Road transport at site

Fig. 23 - Final positioning

Fig. 24 - Final positioning

28). A crawler crane was used for the tailing operation. A 60 m tall tower lift was employed, provided with 2 × 750 tons capacity strand jacks. For the smaller heavy items, some dedicated crawler cranes under Fagioli responsibility were used to execute the final installation. For the items lighter than 50 tons, they were transported by road form Paramaribo port to site.

General conclusions

This project was accomplished accidents free and on time. Fagioli were in a unique position to handle both

Fig. 25 – Final positioning

Fig. 26 - Final positioning

Fig. 27 - Final positioning

Fig. 28 - Installation with strand jacks and tower lift system

core businesses involved in the project:

- heavy transport and lifting;
- project forwarding activity.

Huge organization to perform at the same time all the activities involved considering the peculiar location of the refinery, the weather conditions and the weak state of the infrastructures. A project which put Fagioli's abilities to the test, with a positive ending.

I'd like to thank Mr. Davide Santi, Fagioli Sales Director Project Forwarding Department, Saipem and Staatsolie companies

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The distinguishing feature of Kinetic Technology "Sour Gas SOAP™" (Selective & Oxidative Auto-thermal Process) is the production of valuable products: hydrogen and liquid sulphur through sour gas catalytic cracking partial oxidation, instead of production of waste gases (SO_2) as per benchmark process technology. In this way, it is capable to generate revenues from the treatment of sour gases (H_2S and NH_3).

Michele Colozzi, Simona Cortese, Lucia Barbato
Kinetics Technology SpA (Maire Tecnimont Group)
"Excellence in Process Engineering"

1. Current best available techniques for sulphur recovery facilities

Environmental regulations all around the world are imposing nowadays very stringent SO_2 emissions requirements. H_2S flaring is no more tolerated in all industrial complexes. Best Available Techniques (BAT) have to be utilized to satisfy such new requirements. The achievement of high value of reliability and availability is also mandatory for Sulphur Recovery Unit (SRU) installed in full integrated industrial complex where production must be maximized.

The main targets of the SRU to be installed in a new industrial complex can be summarized as follow:

- SO_2 emissions not higher than 150 mg/Nm^3 (50 ppm Vol.);
- ensure complete destruction of impurities contained in Sour Gases feedstock (NH_3, HC, COS, CS_2, RSH, HCN etc.);
- maximize energy recovery;
- maximize availability and reliability of the plant;
- minimize Opex and Capex.

In the years 90', KT has introduced in the market the proprietary RAR™ (Reduction, Absorption, Recycle) technology which is recognized as BAT and has been specifically developed to minimize SO_2 emissions with the purpose to be full in compliance with the most stringent environmental regulation in force all around the world.

The RAR™ Process is a Reductive Amine based Tail Gas Treatment capable of achieving the maximum of the overall Sulphur Recovery Efficiency (SRE > 99.9+%) nowadays requested by the market.

The block diagram of Sulphur Recovery Unit with KT Proprietary "RAR™ Process" is presented in **figure 1**.

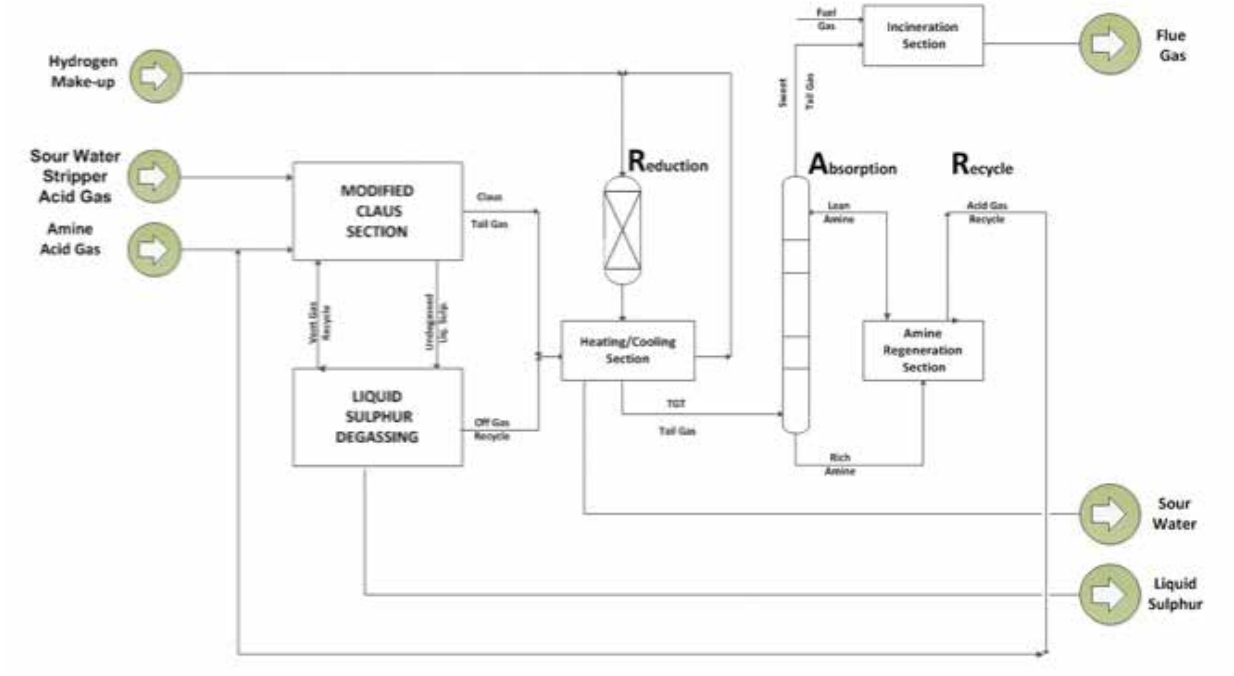
The Modified Claus section of SRU can achieve a SRE of 92-96% when provided with two reactors and 94-98% when provided with three reactors, therefore, the addition of a Tail Gas Treatment section is always required to achieve a SRE higher than 99.9% as requested by the market.

In the proprietary KT Tail Gas Treatment section, the Claus Tail Gas is mixed with Hydrogen Rich Gas from battery limits, when available, or it can be produced in a dedicated Reducing Gas Generator (in-line burner). Tail Gas is then sent to the Hydrogenation Reactor, where all components containing sulphur are reduced and/or are hydrolyzed to H_2S.

Tail Gas is then sent to Quench Tower where, through direct contact with circulating water, steam is condensed and gas is cooled down. The H_2S contained in Tail Gas is removed by the use of amine solution. Sweet Tail Gas with few ppm of H_2S is sent to the Thermal Incinerator to be converted to SO_2 before flue gases are released to the atmosphere. The amine solution is normally regenerated in a dedicated Amine Regeneration Section, included in the Sulphur Recovery Unit. The produced liquid sulphur is treated in the liquid sulphur degassing section where hydrogen poly-sulfides and H_2S are completely removed. In order to minimize the SO_2 all the gas released during the liquid sulphur degassing are recycled back to Claus and TGT section.

The typical process flow scheme of KT SRU with Modified Claus and KT RAR™ Process is presented in the **figure 2.**

Fig. 1 - Block Diagram of SRU with "RAR Process"



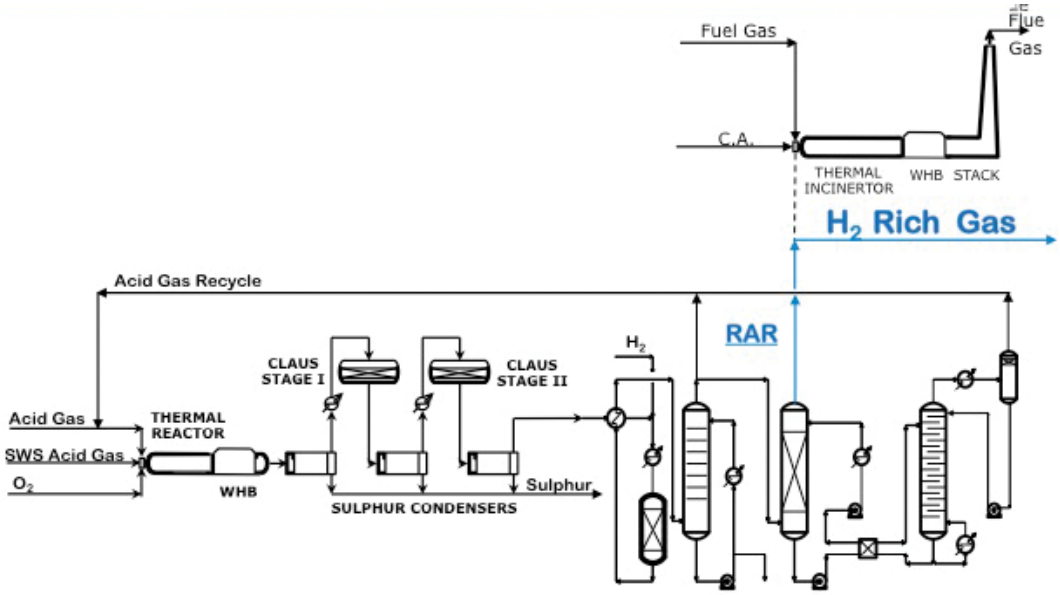


Fig. 2 - Typical Process Flow Scheme of KT SRU with "Modified Claus and RAR™ Process"

2. Why sour gas SOAP™ integrated in KT RAR™ technology?

Environmental regulations will become more and more stringent, in the near future, requiring for SO_2 emissions to the atmosphere much lower than 150 mg/Nm^3 (lower than 50 ppm Vol.). Therefore, new process schemes will be required in order to be in compliance with such strictest future regulations. For this reason, KT is now developing an Innovative Process and a New Concept of Sulphur Recovery Unit.

The New Concept of Sulphur Recovery Unit (SRU) developed by KT is mainly divided in two main sections:

- Sour Gas SOAP™ section;
- Tail Gas Treatment Section amine based.

The core part of the new SRU configuration is the Sour Gas Selective & Oxidative Auto-thermal Process (Sour Gas SOAP™) section, where the H_2S cracking reaction is enhanced by the Innovative KT Proprietary Catalyst. This Sour Gas SOAP™ section is fully integrated in the KT RAR™ Tail gas Treatment defining the KT proprietary plant configuration and Novel Process.

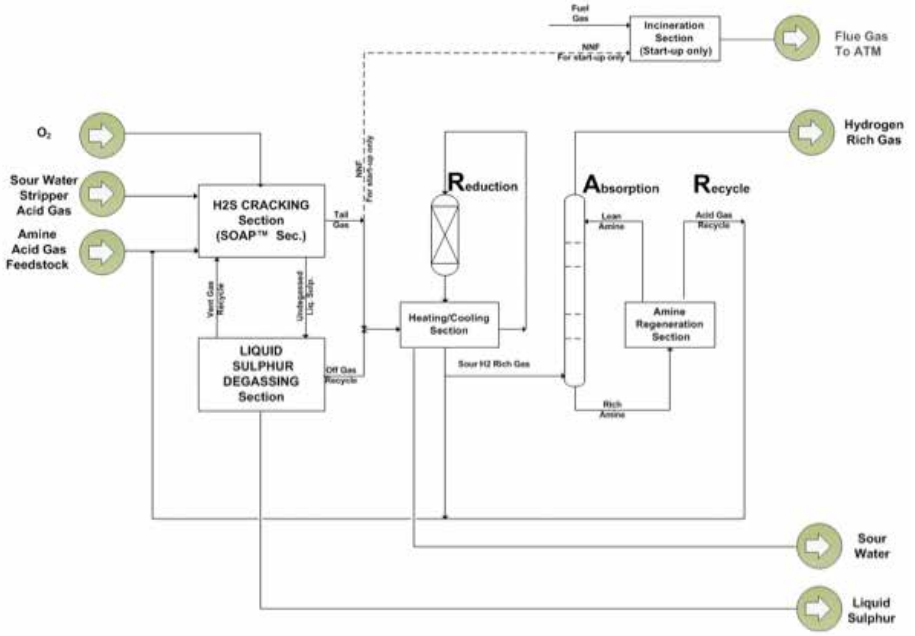
The block diagram of the Novel Process is shown in **figure 3**.

Fig. 3 - Block Diagram "New Concept of SRU – KT Novel Process"

3. Why the new SRU configuration?

The New Concept of SRU designed by KT is a simplification of current SRU plant configuration thanks to the innovative Reaction Furnace filled with KT proprietary catalyst (Catalytic Reaction Furnace, CRF) followed by only one Sulphur Condenser, a Liquid Sulphur Degassing section and TGT section. The reason of such "minimal" configuration is strictly related to the new idea to operate the Claus Section in a different way:

- use of a totally new and KT Proprietary Catalyst in the Reaction Furnace to minimize SO_2 production;



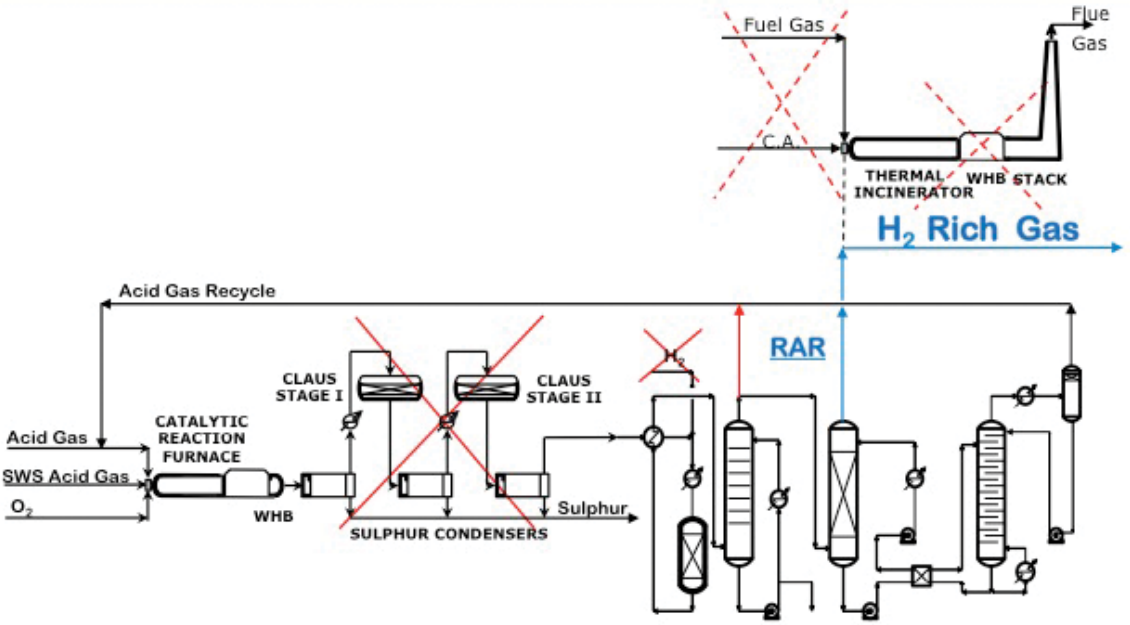


Fig. 4 – Process Flow Scheme "New Concept of SRU"

- use of specific ratio H_2S/O_2 in order to maximize the production of hydrogen minimizing the production of SO_2;
- use of oxygen (enriched air) instead of ambient air.

The technical ingenuity is to install a catalyst block directly in the Reaction Furnace, in order to enhance the selective conversion of H_2S directly to H_2, S_x and H_2O instead of S_x, SO_2 and H_2O.

An interesting advantage of the new SRU concept developed by KT is the possibility to achieve important Capex reduction minimizing the number of equipment to be installed in the plant as shown in **figure 4**.

Also Opex can be drastically reduced with the New Concept of SRU, virtually Thermal Incinerator is no more required in normal operation, and the Hydrogen Rich Gas produced can be utilized by some hydrogen users in a petroleum refinery or in other industrial complexes, while SO_2 and CO_2 emissions are drastically reduced.

In Gas Field, where hydrogen users are not available, the operating parameters may be adjusted to minimize the production of Hydrogen Rich Gas.

4. Reaction mechanism

The H_2S cracking through partial oxidation in the CRF by the means of the new and KT proprietary catalyst is based on the following reactions:

(1) $H_2S + 3/2\ O_2 \rightarrow H_2O + SO_2$
(Oxidation Reaction)

(2) $H_2S + 1/2\ O_2 \rightarrow 1/2\ S_2 + H_2O$
(Partial Oxidation Reaction)

(3) $2\ H_2S + SO_2 <\rightarrow 2\ H_2O + 3/n\ S_n$
(Claus Reaction)

(4) $H_2S <\rightarrow H_2 + 1/2\ S_2$
(Cracking Reaction)

KT has developed the proprietary catalyst in collaboration with University of Salerno (Unisa), Italy. A dedicated laboratory plant to test the proprietary catalyst and the Novel Process has been designed, built and is running at University of Salerno. KT has selected Unisa since in Europe they have the best facilities on academic level as well as the highest competences in the field of Sour Gases heterogeneous catalysis.

Up to now, more than 8000 hours of tests in laboratory plant at Unisa have been performed treating sour gases feedstock. As feedback of laboratory tests, KT has developed a thermodynamic and kinetic model which is fitting with good accuracy the results of the laboratory plant. The model utilizes more than 100 reactions simulating the system behavior.

A demonstration pilot plant is currently under construction to validate the new technology. Start-up of the demonstration on plant is expected in this year.

The **figures 5, 6** and **7** show the main mechanisms of reaction involved in the SOAP™ Process at the presence of the catalyst.

4.1 Catalytic H_2S reaction mechanism

The heat for cracking reaction (4) is made available by oxidation reaction (1 & 2) of H_2S.

The oxygen provided to the system is only sufficient to achieve the proper reaction temperature to activate all the relevant reactions over the catalyst.

A part of H_2S is oxidized to SO_2 and H_2O (1) and another part of H_2S is partially oxidized to S_x and H_2O (2) producing the heat required for the other reactions.

At the same time part of H_2S adsorbed over the catalyst reacts with SO_2 according to the Claus Reaction (3) and then other part of H_2S produces H_2 by cracking reaction (4).

The campaign of laboratory tests performed by KT and Unisa for several operating conditions has validated the first-class performances of the KT proprietary catalyst.

The capability of the totally new catalyst to promote the

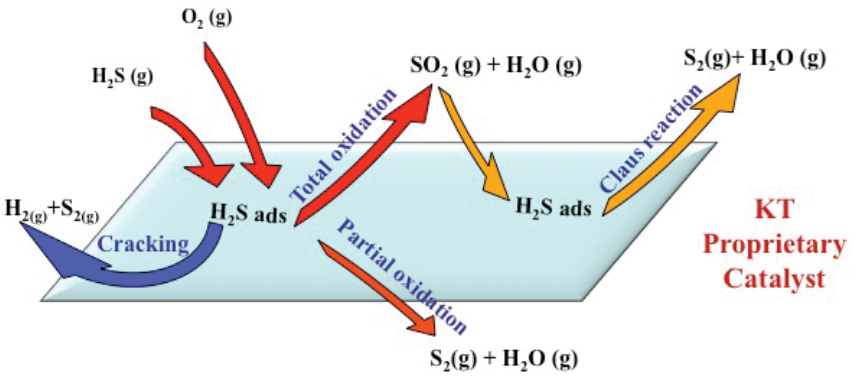


Fig. 5 - H_2S reaction mechanism over KT Proprietary Catalyst

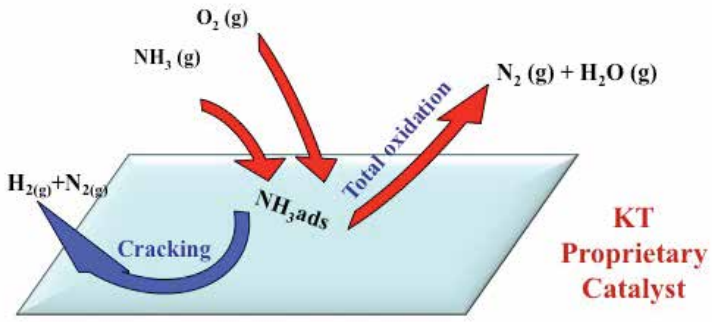


Fig. 6 - NH_3 reaction mechanism over KT Proprietary Catalyst

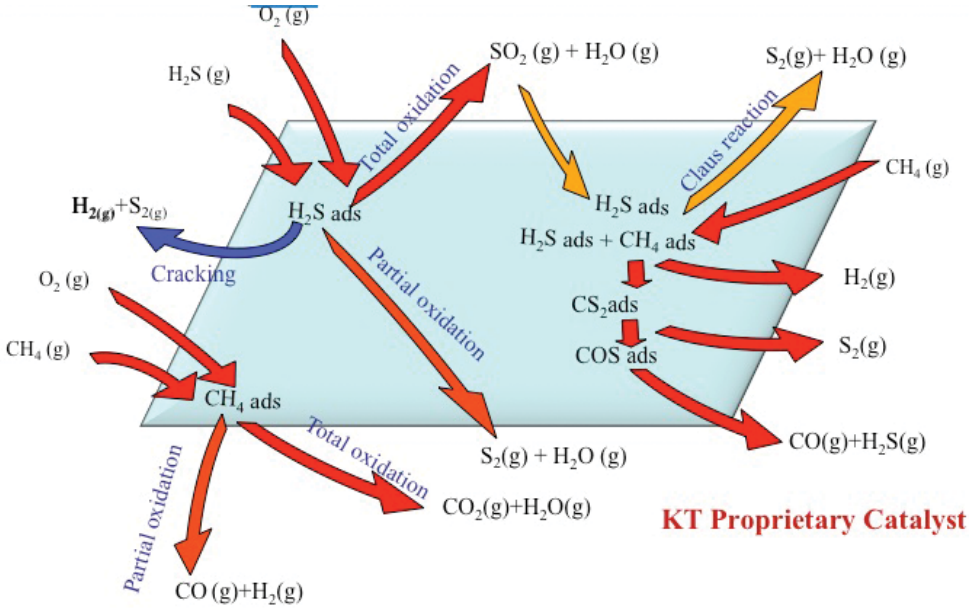


Fig. 7 - Hydrocarbons, COS and CS_2 reaction mechanism over KT Proprietary Catalyst

H_2S cracking reaction, with a negligible SO_2 formation, has been indeed validated.

4.2 NH_3 reaction mechanism

The new catalyst has also immediately highlighted the possibility to treat very high content of ammonia even without the presence of H_2S.

As verified during KT and Unisa laboratory tests, the NH_3 destruction follows the same mechanism of H_2S conversion therefore also this reaction is conducted auto-thermally. A part of ammonia is oxidized with the oxygen provided to the system to produce N_2 and H_2O supplying the heat required for the NH_3 cracking reaction producing N_2 and H_2.

The observed catalyst behavior was promising for future treatment of the new Extra Heavy Crudes that will be utilized in next years.

4.3 Hydrocarbons (HC), COS and CS_2 reaction mechanism

Other peculiarity of the new catalyst analyzed during the tests campaign is that Hydrocarbons adsorbed over the catalyst react preferably and exclusively with H_2S because no coke formation was observed. In this way it is possible to avoid completely COS and CS_2

presence in gas phase at the outlet of the Catalytic Reaction Furnace.
COS and CS_2 destruction mechanism is based on the adsorption of HC and H_2S over the catalyst surface. HC and H_2S react over the catalyst producing CS_2.
CS_2 produced reacts with SO_2 producing COS which reacts with H_2; CO and H_2S are the final products of reaction.

5. "New Concept of SRU" for different industrial applications

All the knowledge and data acquired the from laboratory tests have allowed KT to set-up an optimized process simulations of the Novel Process choosing the best process scheme and the best operating conditions. In this regard it was possible to perform several case studies for different industrial applications like:

- petroleum refinery;
- oil & gas fields;
- coal gasification;
- Integrated Gasification Combined Cycle (IGCC) Complex;
- chemical and petrochemical complex.

In order to investigate the feasibility of the new SRU process configuration, an Opex and Capex analysis for a petroleum refinery case and Gas Field case have been studied.

5.1 "New Concept of SRU in a Petroleum Refinery "

Table 1 shows the results of Opex analysis comparing conventional plant configuration versus Novel Plant configuration for SRU installed in a Petroleum Refinery:

The conventional plant configuration consists of a Modified Claus Section equipped with two Claus reactors followed by a Reductive TGT amine based with a dedicated Amine Regeneration system and the relevant Thermal Incineration section. Liquid Sulphur Degassing section is also foreseen.
The Novel Process is equipped only with a Catalytic Reaction Furnace System and a Sulphur Condenser followed by a Reductive TGT amine based with a dedicated Amine Regeneration System and Liquid Sulphur Degassing Section with full recycle of H_2S to Claus and TGT section. Thermal Incinerator is foreseen but designed to be operated only during start-up and shut-down scenarios.
For the novel process two possible plant operating configurations "A" and "B" have been investigated:
in "Plant Configuration A" of the Novel Process, part of the HP steam produced is utilized as heating medium in the Novel Process and in the TGT section while the excess steam is let-down to Low Pressure Steam which is utilized as heating medium for the Amine Regeneration of the complex; with this proposed configuration Steam export will not be provided;

"Plant Configuration B" of the Novel Process utilizes the produced HP steam as heating medium in the Novel Process and in the TGT section; Low Pressure Steam for amine regeneration of TGT is imported from battery limit while the excess of steam is sent to High Pressure and/or Medium Pressure Steam header at relevant network conditions.

5.2 "New Concept of SRU in a Gas Field "

Table 2 shows the results of Opex analysis in case of SRU installed in a Gas Field.

Table 1 - Opex analysis for a SRU installed in a Petroleum Refinery

(*) Profit = (Total Cost of utilities)/(ton of sulphur produced)

(*) Profit index = (100 x Profit) / (Profit of Plant Configuration with max. Profit)

Opex Comparison	Conventional Plant Configuration	Novel KT SRU "Plant Configuration A"	Novel KT SRU "Plant Configuration B"
LPS Import (Low Pressure Steam Import)	Yes	Yes	Yes
	37%	2%	100%
MPS Export (Medium Pressure Steam Export)	Yes	No	Yes
	100%	_	63%
Hydrogen rich gas	No	Yes	Yes
	-14%	100%	100%
CO_2 emissions	Yes	No	No
	100%	10%	10%
Fuel Gas	Yes	Yes	Yes
	100 %	11%	11%
Electrical Power	Yes	Yes	Yes
	100 %	45%	45%
Profit Index (*)	26%	34%	100%
Profit Ratio	1	1.3	3.8

Opex Comparison	Conventional Plant Configuration	Novel KT SRU New Plant Configuration
LPS Import (Low Pressure Steam Import)	Yes	Yes
	100%	93%
MPS Export (Medium Pressure Steam Export)	Yes	No
	100%	67%
Hydrogen rich gas	No	No
	0	0
CO_2 emissions	Yes	Yes
	100%	83%
Fuel Gas	Yes	Yes
	100 %	42%
Electrical Power	Yes	Yes
	100 %	28%
Profit Index	-100%	-74%
Profit Ratio	-1	-0.74

Table 2 - Opex analysis for a SRU installed in a Gas Field

6. Main Results of the "New Concept of SRU" in different industrial applications

According to the selected Plant Configuration, Capex reduction up to 30% may be achieved due to the reduced number of equipment foreseen in the Novel SOAP™ Process.

The major merit of the Novel Process is the possibility to minimize SO_2 emissions, since the total Sulphur (H_2S, COS and CS_2) contained in the gas from TGT Absorber is much lower than in the conventional one as summarized here below:

$$\left[(S_{Tot})_{TGT}\right]_{New\ Proc.} < \left\{\frac{\left[(S_{Tot})_{TGT}\right]_{Conv.\ Proc}}{n}\right\}$$

The "n" factor s in the range of 5 < n < 10.

In terms of SO_2 content in the flue gas when the hydrogen rich gas from TGT absorber of the novel process is oxidized in the incinerator, it is measured that with the New SRU Concept (SOAP™ + RAR™ TGT) it will be possible to achieve SO_2 emissions to that the atmosphere lower than 50 mg/Nm^3 (18 ppm Vol.). This figure cannot be achieved with the current best available technology.

50 mg/Nm^3 (18 ppm Vol.) is expected to be the new SO_2 emission value imposed by the environmental regulation all around the world, and KT will be ready for this new challenge.

7. Conclusions

The Sour Gas SOAP™ prove to be an environmental friendly solution capable to valorize Sour Gases, which is considered a waste in all industrial complexes, in Hydrogen Rich Gas, a valuable product achieving , in this way, the goal of "zero emissions".

Especially, the major value of KT Technology Innovation is to have created an alternative to traditional SRU process, able to produce Hydrogen rich gas instead of SO2 emission, with a profitable reduction of Capex and Opex.

Overall, the main advantages of the New SRU configuration and Novel Process are summarized here below:

- possibility to achieve SO_2 emissions lower than 50 mg/Nm^3 (18 ppm Vol.), this is not possible with the current Reductive Amine Based BAT;
- complete destruction of COS, CS_2, hydrocarbons, RSH, ammonia, HCN and other impurities in the Catalytic Reaction Furnace;
- possibility to treat Sour Water Stripper Acid Gases, without any limitation on the Ammonia content in Sour Gases; this is not possible with the Conventional Process;
- installation of only one Catalytic Converter System (Catalytic Reaction Furnace);
- claus Catalytic Converters system is no more necessary due to low content of SO_2 in the process gas from the CRF system. The Conventional Plant requires two or three Claus Catalytic Converter System (pre-heater, reactor, sulphur condenser) to minimize the SO_2, COS and CS_2 content in the Tail Gas to the TGT section;
- the Novel Process will produce a lower quantity of exhaust catalyst compared to the conventional one;
- the reduced number of equipment makes the Investment Cost of the Novel Process cheaper than the conventional one. In addition also the associated maintenance costs will be reduced;

KT – Kinetics Technology

(Maire Tecnimont Group)
With more than 40 years of experience in designing constructing and operating sulphur recovery facilities, KT - Kinetics Technology SpA ("KT") is a leader in delivering end-to-end tailor-made turn-key solutions with the highest quality standard with unrivalled competitiveness. These targets are achieved leveraging on KT core values: "commitment and passion to serve our clients, pursue of continuous innovation and flexibility, unconditioned respect of our human capital and environment".
KT is a Process Engineering Company heavily involved in creating new industrial standard capable to minimize the environmental impact. KT considers this challenge as integral part of its daily work to be addressed with passionate spirit, conscious pride and sense of belonging.
We can indeed offer to our customers advanced skills in Licensing, Engineering Services, EP (Engineering Procurement), EPC (Engineering Procurement and Construction) through our flexible business model. We have an impressive track record in complex projects in different context worldwide.

Our challenge

KT is developing now a new concept of Sulphur Recovery Unit (SRU), utilizing a novel process SOAP™, an Innovative Proprietary Catalyst and a New Process Scheme for the treatment of all Sour Gases feedstock.

- the major advantage of the novel process is the higher overall SRE. Indeed SRE of H_2S Cracking + TGT is 99.9++% much higher than 99.9+% of current BAT. The reason of this difference is due to the fact that in the Novel Process the quantity of Total Sulphur (H_2S + COS + CS_2) in the top of TGT Absorber is much lower than in the conventional one;
- use of the same Flow Scheme for the SRU in all industrial complex.

Lucia Barbato

Lucia is a Business Development Engineer of KT - KT-Kinetic Technology SpA,, Rome - Italy. She graduated in Chemical Engineer *cum laude* at the University of Salerno in 2010 with a thesis named "Hydrogen Production from H_2S through Catalytic Cracking and membrane separation". She is involved in several Research and Development Projects in particular in projects for partial oxidation of hydrocarbons and H_2S. She is co-author of 4 patents for H_2S cracking, and she published several papers and contributed to the preparation of a book entitled "CO_2 a valuable source of carbon" (Springer-Verlag London).

Simona Cortese

Simona is a chemical engineer graduated at the University of Rome "La Sapienza". She joined KT - Kinetics Technology SpA in 2003 where she acquired his professional experience in Sulphur Recovery & Tail Gas Treatment. She is currently a Business Development Project Coordinator working on the development of technical and commercial proposal for PDP & FEED activities and feasibility studies. She is also responsible as Project Manager of the execution of the assigned project relevant to the core business of the KT and Research & Development of innovative technologies.
Prior to joining KT, she was process engineer stager for Eni Technology (Italy) and in the 2006 - 2007 she joined Suncor Energy Inc. (Canada-AB) as Upgrading Process Engineer leader for the pre-commissioning, commissioning and start-up of new SRU and as Deputy Process Engineer Leader during the Plant Turnaround 2007.

Michele Colozzi

Michele holds a Chemical Engineering Degree, University of Rome "La Sapienza".
Since 1991 he has been working in KT-Kinetics Technology SpA (KT) in Rome. He is currently the Technology & Licensing Manager responsible also for commercialization of all KT technologies.
In KT, he has been involved in the design, construction, commissioning & start-up of sulphur and gas treatment plants, gas processing plants, oil & gas treatment plants, hydrogen & synthesis gas generation plants, waste disposal plants mainly in Europe, Middle East and Far East.

Advanced Oxidation Processes for Recalcitrant Pollutants from Refinery Waste Water

Recalcitrant organic constituents, such as phenols and aromatics, can often be found in refinery effluents. Phenols in particular can seriously affect living organisms by bioaccumulation. For this reason very strict limits are set on water discharge. Starting from a laboratory scale, Artes Ingegneria (Cannon Group) has developed an innovative cost effective industrial scale solution for a refinery plant facing the Caspian Sea

Serena De Maria. Ivan Saracino
Artes Ingegneria SpA (Cannon Group)

Recalcitrant compounds are organic molecules very difficult to be degraded through a biological process. Such compounds include aromatics, phenols and phenol-derivatives such as o-, m- and p-cresol. Phenols in particular are the organic constituents in effluents of coal conversion processes, coke ovens, petroleum refineries, phenolic resin manufacturing, plastics, adhesives, steel, aluminium, leather, pulp & paper and petrochemicals. In particular many refinery processes produce phenol-rich water as an effluent: catalytic cracking, crude desalting, thermal cracking and catalytic hydrotreating.

When phenols are incorporated in the food chain, they cause relevant environmental troubles since they are toxic, recalcitrant and bioaccumulating in organisms. Phenols accumulation in water proved to be toxic for both the flora and fauna, mortal for fishes for concentrations higher than 5 mg/l.

Due to the high toxicity, phenols are subjected to specific regulations:

- the European Union considers phenol a priority substance (EC 1179/94, OJ L131, 26.5.94) under Regulation 793/93 on the evaluation and control of the risks of existing substances;
- according to the Italian law (D.L. 152/99) phenols shall be limited to less than 0.5 mg/l in treated effluent disposed into surface water;
- according to the "German Framework Administrative Guideline for Minimum Requirements on the Discharge of Waste Water into Water Bodies" (Rahmen-AbwasserVwV of 1.6.2000) a phenol index value of ≤ 0.15 mg/l is set for waste water before mixture with other waste water for the production of hydrocarbons and oil processing;
- phenol ranked 11th place under 129 specific priority chemicals that are considered toxic under the 1977 Amendments to the Clean Water Act and for which the US Environmental Protection Agency (EPA) has issued water quality criteria; in USA the discharge limit is fixed to less than 1 mg/l in the treated effluent.

It is clear that the wastewaters containing phenols require careful treatment before release into the receiving water sources.

In 2014 Artes Ingegneria has been awarded the engineering, procurement, shop construction and supervision contract for the effluent treatment & water re-use plant of a refinery on the Caspian Sea. For this specific job it was mandatory to meet, among other parameters, the extremely strict limit of less than 1 ppb of phenols in the treated water in order to fulfil at the same time the requirements for water re-use and discharge into the Caspian Sea.

The overall Refinery Effluent Treatment Plant, whose capacity is more than of 300 m^3/h, includes:

- a *primary treatment* focusing on the removal of free and emulsionated oil; the treatment is realized through a Corrugated Plates Interceptors (CPIs) and Dissolved Air Flotation (DAF);
- a *secondary treatment*, targeted to re-using the largest share of treated water, implements a biological oxidation unit through Membrane BioReactor (MBR);
- a *tertiary treatment*, needed to remove organic residues, that resulted efficient in the phenol compounds removal.

The request of very long times for phenols degradation by conventional treatments affects the adoption of huge reactor volumes, having a negative impact on capital (Capex) and operative (Opex) processing related costs. For this reason the application of an Advanced Oxidation Process (AOP) has been developed according to the following steps: an accurate theoretical

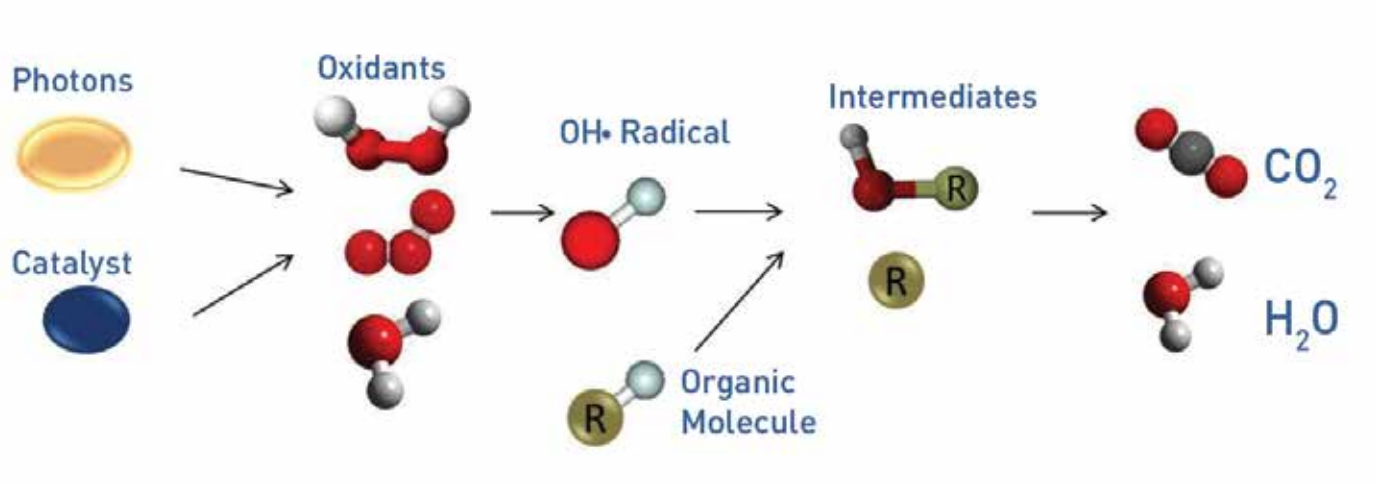


Fig. 1 – The Advanced Oxidation Process (AOP) reaction

investigation on the available AOPs, followed by a laboratory test of two of the preferred AOP technologies and the industrial implementation of the selected technology as a tertiary treatment.

Advanced Oxidation Process, a promising technology for the degradation of refractory chemical pollutants

Innovative treatments could represent a valid alternative method for the degradation of recalcitrant chemical pollutants. Among these, Advanced Oxidation Processes (AOPs) could be adopted for that chemicals like phenols and aromatic compounds which are resistant to biological and conventional physical-chemical treatments.

AOPs treatments are based on a pollutants degradation mechanism which consists in the production of intermediate hydroxyl radicals. These are very reactive species that are continuously generated and able to react in a quick and non-selective manner with the most part of water chemical pollutants.

The organic compounds are transformed by the hydroxyl radical in the same moment in which it is produced and, consequently, the effluent is degraded to other intermediate products (**figure 1**). Major AOP processes are the following:

- UV irradiation;
- ozone;
- ozone in combination with UV;
- ozone in combination with hydrogen peroxide (H_2O_2);
- hydrogen peroxide in combination with UV;
- Fenton and Fenton-like reactions.

The Advanced Oxidation Process reaction

The advantages of the AOP process are:

- efficient destruction of pollutants, in particular those recalcitrant to conventional treatments (pesticides, chlorinated solvents);
- alternative process to mass-transfer treatments where pollutant is transferred from liquid phase to solid (like adsorption on activated carbons) or liquid one (stripping).

Among the AOPs, Artes decided to investigate two treatments:

- the use of hydrogen peroxide with UV light (H_2O_2 + hv);
- the use of hydrogen peroxide with a liquid catalyst (H_2O_2 + catalyst).

The other AOP treatments were not eligible: with UV irradiation alone is not possible to reach the 1ppb limit requested by the customer, the ozone based technology is very energy consuming and critical for safety issues, Fenton reaction produces sewage sludge to be disposed.

In the first case, the ultraviolet radiation is used to cleave the O-O bond in hydrogen peroxide and generate the hydroxyl radical (**figure 2**).

$$H_2O_2 + hv \rightarrow 2HO\bullet$$
$$H_2O_2 + HO\bullet \rightarrow HO_2\bullet + H_2O$$
$$H_2O_2 + HO_2\bullet \rightarrow HO\bullet + H_2O + O_2$$
$$2\ HO\bullet \rightarrow H_2O_2$$
$$2\ HO_2\bullet \rightarrow H_2O_2 + O_2$$
$$HO\bullet + HO_2\bullet \rightarrow H_2O + O_2$$

Fig. 2 – AOP reaction using hydrogen peroxide and UV light (hv) competitive reaction

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO^- + HO\bullet$$
$$Fe^{2+} + HO\bullet \rightarrow Fe^{3+} + HO^-$$
$$HO\bullet + RH \rightarrow H_2O + R\bullet$$
$$R\bullet + Fe^{3+} \rightarrow R^+ + Fe^{2+}$$

Fig. 3 – AOP reaction using hydrogen peroxide and ferrous catalyst

In the second case, a mixture of ferrous catalyst and hydrogen peroxide (oxidizing agent) can be considered as a powerful oxidant for organic contaminants (**figure 3**).
The two different AOPs treatments were investigated, with the collaboration of Naples "Federico II" University:

- the adoption of hydrogen peroxide in combination with UV light;
- the combination of hydrogen peroxide with a liquid catalyst.

In particular, the degradation kinetics of both the two treatments was evaluated at different concentrations of both liquid catalyst and hydrogen peroxide.

Experimental plan

A synthetic solution was prepared as surrogate of the real wastewater produced by the refinery. It contains phenols but also sulphides and chlorides for a better simulation of the wastewater characteristics and in order to include all the possible interferences among various compounds.
The chemical composition of the synthetic water is reported in the **table 1**.

Compounds	Concentration
Phenols	100 ppb
Sodium chloride	8000 ppm
Sulphates	5500 ppm
COD	100 ppm
Dodecylbenzenesulfonate	500 ppm

Table 1 - Chemical composition of the synthetic water

The synthetic solution was submitted to the two different AOPs treatments. After being processed at different reagents composition, the content of phenols concentration was evaluated by HPLC (High Performance Liquid Chromatography) analysis.
The experimental plan can be summarized as following:

- preparation of the synthetic solution;
- sample processing by AOP 1 (hydrogen peroxide and UV light);
- sample processing by AOP 2 (hydrogen peroxide and liquid catalyst);
- post processing analysis: determination of residual phenols concentration by HPLC;
- design of the AOP basin of the best treatment and at selected operative conditions.

AOP treatment 1: hydrogen peroxide and UV light

A UV quartz laboratory scale lamp with mercury vapours was used with the operative conditions reported in **table 2**.

Reactor H_2O_2 + UV	Operative conditions
Reactor volume	500 ml
Lamps type	mercury vapours
Chamber	quartz
Light wavelenght	254 nm
Energy power	2.87 10^{-6} Es^{-1}
Average optical path	2,2 cm

Table 2 – Operative conditions of a UV quartz laboratory scale lamp with mercury vapours

AOP tests were conducted at two different hydrogen peroxide concentrations (10 and 100 ppm). The samples were analysed at different reaction times thus having the phenols degradation kinetics.
The graph in **figure 4** reports the degradation of the phenols: it can be observed that at higher treatments times, higher degradation can be reached at both H_2O_2 concentrations. Furthermore, the effect of the concentration on phenols degradation in not very strong: if hydrogen peroxide concentration is reduced

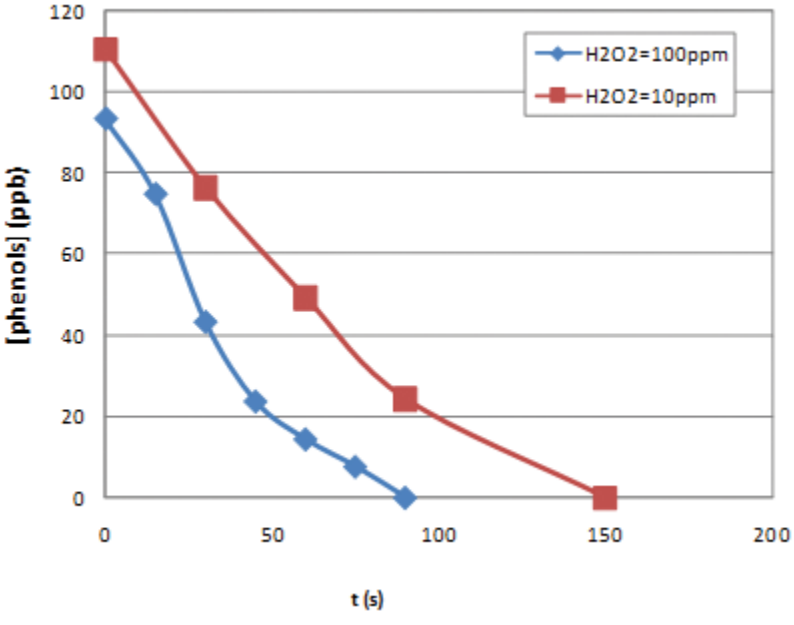


Fig. 4 – Phenols degradation AOP treatment 1

TEST	H_2O_2 ppm	CATALYST mL_{SM}/L	pH
A	1	0.017	8.0-8.5
B	30	0.510	8.0-8.5
C	50	0.850	8.0-8.5
D	100	1.700	8.0-8.5

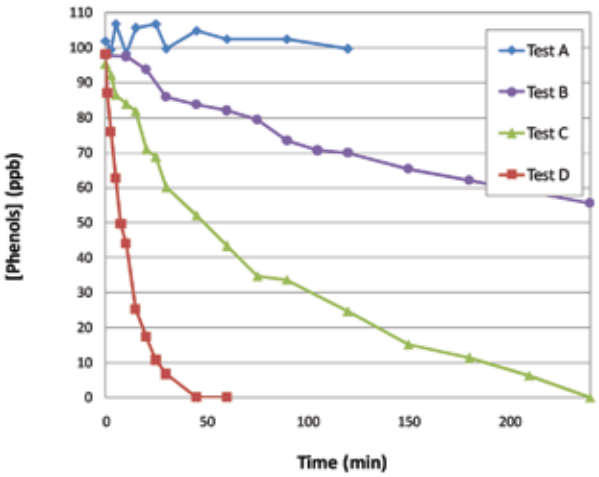


Fig. 5 - Phenols degradation-AOP treatment 2 at highest hydrogen peroxide and lower catalyst concentrations

TEST	H_2O_2 ppm	CATALYST mL_{SM}/L	pH
1	100	0.85	8.0-8.5
2	100	0.57	8.0-8.5
3	50	1.70	8.0-8.5
4	50	0.57	8.0-8.5

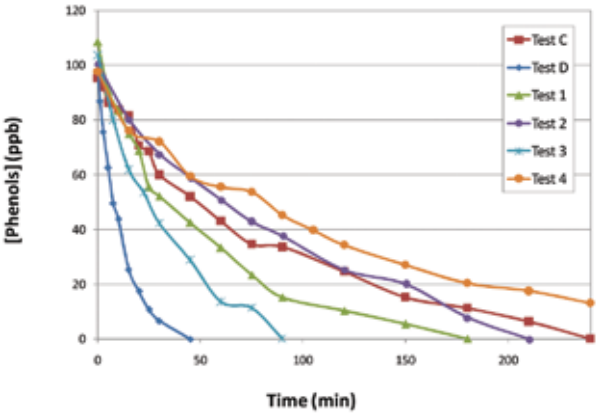


Fig. 6 – Phenols degradation AOP treatment 2

from 100 ppm to 10 ppm, the reaction time request for the complete degradation of the phenols compounds is increased only of the 66%. This can be explained by the competitive reaction occurring between OH radicals and hydrogen peroxide molecules (figure 2).

AOP treatment 2: hydrogen peroxide and liquid catalyst

Similarly to the previous treatment, this AOP treatment is based on the use of hydrogen peroxide, in this case hydrogen peroxide is used in combination with a liquid ferrous catalyst. The experimental tests were conducted with a laboratory scale plant at the processing conditions reported in **table 3**.

Reactor H_2O_2 + catalyst	Operative conditions
Rector volume	500 ml
Starting reactor time	addition of catalyst
Ending time	addition of catalyst (enzyme stopping the reaction)

Table 3 – Operative conditions of an experimental test using hydrogen peroxide in combination with a liquid ferrous catalyst

The tests were conducted at different hydrogen peroxide (1, 30, 50 and 100 ml_{SM}/l) and liquid catalyst concentrations (0.017, 0.510, 0.850 and 1.700 ml_{SM}/l) at pH = 8.0 – 8.5 in the following combinations: reported in **figure 5**.

The results report that higher reaction times were request for the complete phenols oxidation when using hydrogen peroxide in combination with a liquid catalyst (order of minutes). In addition, best results were performed at higher concentrations of hydrogen peroxide at 50 ppm (test C) and at 100 ppm (test D). In order to reduce reagents consumption, additional tests were performed at highest hydrogen peroxide concentrations (50 and 100 ppm) but with lower catalyst concentrations (**figure 6**).

Best results in terms of phenols degradation were reached in the following conditions:

- H_2O_2 = 100 ppm + catalyst = 1.7 ml_{SM}/l (test D)

Artes Ingegneria

Artes Ingegneria, is an Engineering and Construction Company in the water and waste water treatment business with extensive experience in the oil&gas industry, either upstream or downstream.
Artes' solutions addressing specifically the oil&gas are: produced & injection water, desalination, raw water pre-treatment, demineralization systems, condensate polishing, thermophysical deaerators, vacuum degassing package, effluent water treatment, sanitary water treatment and drinking water makers, cooling water filtration.
Artes Ingegneria is part of Cannon Group.

- H_2O_2 = 50 ppm + catalyst = 1.7 ml_{SM}/l (test 3)

Since differences in performance between the two treatments were not so high, the second condition was chosen as AOP treatment for the industrial scale up since it involves less consumption of hydrogen peroxide.

Industrial scale up of AOP treatment

The two AOPs tested and optimized in the lab-scale are now compared taking into cosideration the Capital & Operating Costs related to the industrial installation.
Even though shorter reaction times are requested by appling H_2O_2 + UV light (order of seconds) than by appling H_2O_2 + catalyst (order of minutes), the latter allows both lower Capex and Opex. Results are displayed in the **table 4**.

Treatment	Conditions	Capex (euro)	Opex (euro/m^3)
H_2O_2 + UV	H_2O_2 = 10 ppm Q J_{254} = 400 J/l	450,000	0,068
H_2O_2 + catalyst	H_2O_2 = 50 ppm catalyst = 1.7 ml_{SM}/l	100.000	0,019

Table 4 – Results of the two AOP tested and optimized in the lab-scale compared taking into cosideration Capex and Opex related to the industrial installation.

The kinetics of the H_2O_2 + UV treatment is more performing but the costs associated with the energy consumption and UV lamps (installation and periodical replacement) makes this process less competitive when compared with the H_2O_2 + catalyst treatment.
The most cost effective solution, jointly defined by the laboratory test and the Capex / Opex analysis, is therefore the hydrogen peroxide +catalyst treatment that was preferred for scale up from laboratory scale to the industrial one.
This solution has been adopted for the supply of the tertiary equipment included in the effluent water treatment plant for the Caspian Refinery.
Once optimized the reaction conditions at a laboratory scale, the design of an advanced oxidation basin was conducted, on the basis of the client's specifications (inlet/outlet water quality and flows).
The AOP basin represents a tertiary treatment in an integrated system including Coalescent Plate Interceptors (CPI), flotation as deoling and MBR (Membrane BioReactor). The basin has been realized in order to reproduce the reaction at the optimized conditions:

- hydrogen peroxide: 50 ppm;
- catalyst concentration: 1.7 ml_{SM}/l;
- reaction time: 120 min.

The AOP basin design was conducted to guarantee the optimized reaction conditions and it was supported by a mixing system in order to ensure the reaction uniformity and by a sodium hydroxide (NaOH) dosing system to keep the continuous pH regulation.
The volume of the AOP basin was calculated by considering a volume flow rate equal to 300 m^3/h and a reaction time of 120 min, which is the time requested for the phenols oxidation below the discharge limits (< 1 ppb).
The reaction was performed in a concrete basin having an internal diameter of 16.5 m and an height of 2.8 m: the high D/H ratio (greater than 3) was due to the aquifer constrains associated to the plant (limited soil elevation and low feeding pressure to the basin).
In order to guarantee the complete mixing between the two reagents in the AOP tank, a vertical mixer was installed assuring continuous mixing during treatment thus leading such system in a CSTR (Continuous Stirred Tank Reactor) configuration.

The selected mixer moved about 24,500 m^3/h of water, in this way each fluid element had a turn-over of around 120 s and was mixed about 60 times before going out assuring a complete and homogeneous mixing.
The system was also accomplished by sodium hydroxide injection for the maintanance of the desired pH = 8.0 – 8.5 (optimum pH for the reaction) through the installation of dosing pump skid; also hydrogen peroxide was added to the tank by means of dosing pumps.

Conclusions

To comply with the strict request of phenols removal till less than 1 ppb for a Caspian Refinery Effluent Water treatment for which Artes Ingegneria has been awarded, the company investigated two Advanced Oxidation Processes:

- H_2O_2 + UV light;
- H_2O_2 + liquid catalyst.

They were first analysed in terms of degradation kinetics at different H_2O_2/catalyst. In addition, the treatments were compared in terms of both Capex and Opex costs.
The results showed that the reaction time necessary for the degradation of phenols below 1 ppb in the case of hydrogen peroxide + UV light is lower than in the case of treatment using liquid catalyst at parity of hydrogen peroxide concentration.
On the other side the process implying UV light is much more expensive because of the high energy costs associated with the UV light and the need of frequent replacement of UV lamps. For this reason, the treatment with hydrogen peroxide and liquid catalyst was implemented in the industrial scale up to the Caspian project conditions: once selected the best AOP treatment and optimized in terms of operative conditions, the AOP basin was adopted as tertiary treatment in the integrated wastewater treatment.
Results showed that lower treatment times were requested at the highest concentration of both the reagents (H_2O_2 = 100 ppm, liquid catalyst = 1.7 ml_{SM}/l) but in order to reduce hydrogen peroxide consumption, the condition of 50 ppm of hydrogen peroxide and 1.7 ml_{SM}/l of catalyst were used as optimum.
The scale up to the real waste water flow of the Caspian Refinery drove to the design and construction of a 600 m^3 AOP basin capable to guarantee the respect of the 1 ppb phenols limitation with a 300 m^3/h flow rate and a residence time of 120 minutes. An atmospheric cylindrical continuous stirred reactor hosts the reaction.
Artes Ingegneria's solution was really appreciated by the customer that, thanks to the optimized kinetics, had benefited from a significant reduction of the investment and operating costs in comparison to a conventional treatment complying the same limitations.

Serena De Maria

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Since 2015 has been working in Artes Ingegneria as R&D Engineer being currently involved in several projects in the field of wastewater treatments.

Ivan Saracino

Graduated *cum laude* in Chemical Engineering in 2002 at University of Salerno, in the same year started working as a project engineer at Artes Ingegneria SpA. Project manager from 2007 up to now, in 2008 he was nominated directional consultant in HSE. From 2012 he received the assignment as R&D Manager focusing on energy efficiency, water reuse and innovative processes.

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Aerial view of the Litoral CFPS (Coal Fired Power Station) plant; the Unit #1 is on the left, aside to the coal yard

Environmental Upgrading of the Litoral Coal Fired Power Station

Endesa Generation (an Enel Group Company) awarded to Enel E&C a contract to align to IED the emission performances of this plant, but during the construction the target has been improved up to BEP

Giampiero Valenti
Engineering & Research, Enel

The Litoral thermal power station is located in the municipality of Carboneras (Almeria, Spain), in the Mediterranean coastal area, owned by Endesa Generation SA, an Enel Group Company. Two units, of about 580 MW each, are present there with an overall power output of 1159 MW.

According the traditional Endesa approach, the localization of any coal fired power station has been chosen by the presence of the coal mine and/or by the local request of an high energy consumption. In the Litoral scenario, no one of the previous reason was at the base of the plant localization. The circumstances that drove it can be related to the growth of the Spain economy (and specifically in Andalusia) occurred in the late seventies, joined with the consequence of the 2nd oil crisis (1979).

The power request and necessity to diversify the primary energy source for power generation, to get rid of the dependence from oil, pushed Spain to launch the "Plan Acelerado de Centrales de Carbón", in line with the "1979 National Energy Plan" to add not only power, but "modern power", minimizing, as far as possible the impact to the overall environment.

Carboneras was selected as one among those new plants location, exploiting the harbor infrastructures devoted to an already existing Cement industrial complex. The new power station is fed with imported coal.

The project for two units was launched in 1980, but the construction initially for one unit only. The commercial operation of first unit started in February 1985. The power output of about 550 MW, then increased in 2001 up to 577 MW.

Fig. 1 – Litoral Unit #1&2 with data

The second unit construction was released in 1993, with the commercial operation start in August 1997. The power output was initially 550 MW, then, in year 2000, increased up to 582 MW. This unit was equipped since its construction with a Desuphurization unit, sized to handle ab. 50% of the overall exhaust flue gas flow rate (**figure 1**).

The harbor infrastructure was adapted to fit with the coal transportation in 1984, and later on, in 1999, updated to match the overall coal consumption.

In 2009, the Unit #1, was equipped with a 100% desulphurization unit and sized for performances to comply with European norms 2016.

1. Litoral upgrade according European rules 2016 in a competitive energy market

In 2012 Endesa Generation (Enel Group) decided to pursue in the environmental upgrade of the two units of Litoral according the emissions target dictated by the new European Regulation to be applied since

NOx (as NO_2)	200 mg/Nm^3 @6% O_2 dry-monthly average
SO_2	200 mg/Nm^3 @6% O_2 dry-monthly average
Dust (solid particulate)	20 mg/Nm^3 @6% O_2 dry-monthly average

Table 1 – European emission limits IED (Industrial Emissions Directive) 2016

January 2016, the IED (Industrial Emissions Directive) 2016 rules (**table 1**).

Due to the facts that the performances of existing dust removal systems for both units and the SO_2 removal system of Unit #1 are already in compliance with the target, the scope of the upgrading, described in the following, is mainly focused to the installation of the DeNOx system (for both units) and the improvement of SO_2 removal systems (for Unit #2 only), including obviously any modification required to the rest of the plant to withstand and to operate correctly in the new operating condition.

Moreover, the competition in the energy market forced Endesa to operate the plant with a broad range in the load variation. The units are day by day moved to extend the span between full load, requested in the peak hours, and the minimum technical load (environmentally compliance) to be applied during the night, or the week end. Consequently the new systems (but existing one as well) have been sized to comply with the rules with the largest possible load range. And the existing equipment have been tuned accordingly.

Enel Engineering and Research, in 2014, received the order for the design, construction and commissioning for the Litoral #1&2 environmental upgrading.

The 2012 Unit #1&2 plant configuration before the upgrading is shown in **figure 2**.

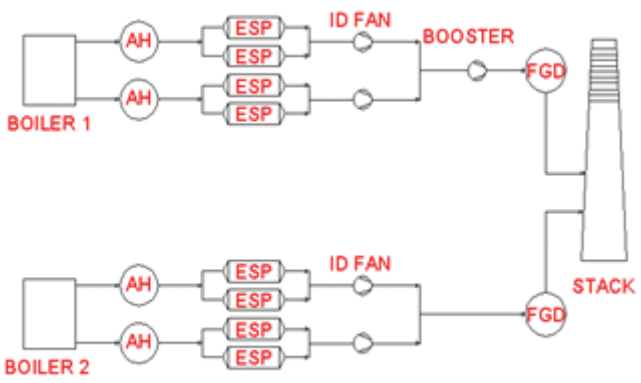


Fig. 2 - Litoral Unit #1&2: existing plant configuration

1.1 Main issues coming from the plant status and operating data

The mandatory requirements of the upgrading project are:

- to comply with the environmental rules;
- to increase the plant load flexibility;
- to squeeze as much as possible the outage of the units.

There were project specific issues that requested a dedicated focus since the initial phase of the feasibility to be sure that project execution would remain stick to the schedule and the operation could not be jeopardized. The following list highlights the most important ones.

DeNOx technology choice;

- exhaust flue gas temperature at boiler outlet (both units);
- exhaust flue gas temperature at stack inlet;
- units outages duration.

1.2 Project key points and relevant applied solutions

1.2.1 NO_x technology choice

Techniques to reduce NO_x (nitrogen oxides) emissions from coal/oil power plants are divided into primary and secondary measures. Primary measures control NO_x formation and reduction in the boiler proper, whereas secondary measures are end-of-pipe techniques to reduce NO_x emissions.

The primary measures are normally used for NO_x reduction in a range of 10-50%. Efficiency up to 70% may be reached with air staging in the furnace, but in any case the real NO_x reduction achieved with primary measures depends largely from the existing assets and their characteristics.

Due to the more strict emission limits, these technologies are generally combined with secondary measures, that consist on the injection of ammonia, urea or other compounds, which react with the NO_x in the flue-gas reducing it to molecular nitrogen. Secondary measures can be divided into:

- selective catalytic reduction (SCR);
- selective non catalytic reduction (SNCR).

The SCR process is a widely applied process for the reduction of NO_x in exhaust gases from large combustion installations in Europe and in other countries throughout the world. This technology is widely used because it guarantees very high NO_x reduction (higher than 90%), controlled NH_3 consumption and reduced NH_3 slip (lower than 2 ppm). This technology is applicable for many of the fuels used in combustion processes and the conversion of NO_x does not create any secondary pollution components. The drawbacks of this process are mainly the non-negligible capital cost and the impact on the boiler layout. The volume of the catalyst reactor is large and needs sufficient space to locate it in the proper position

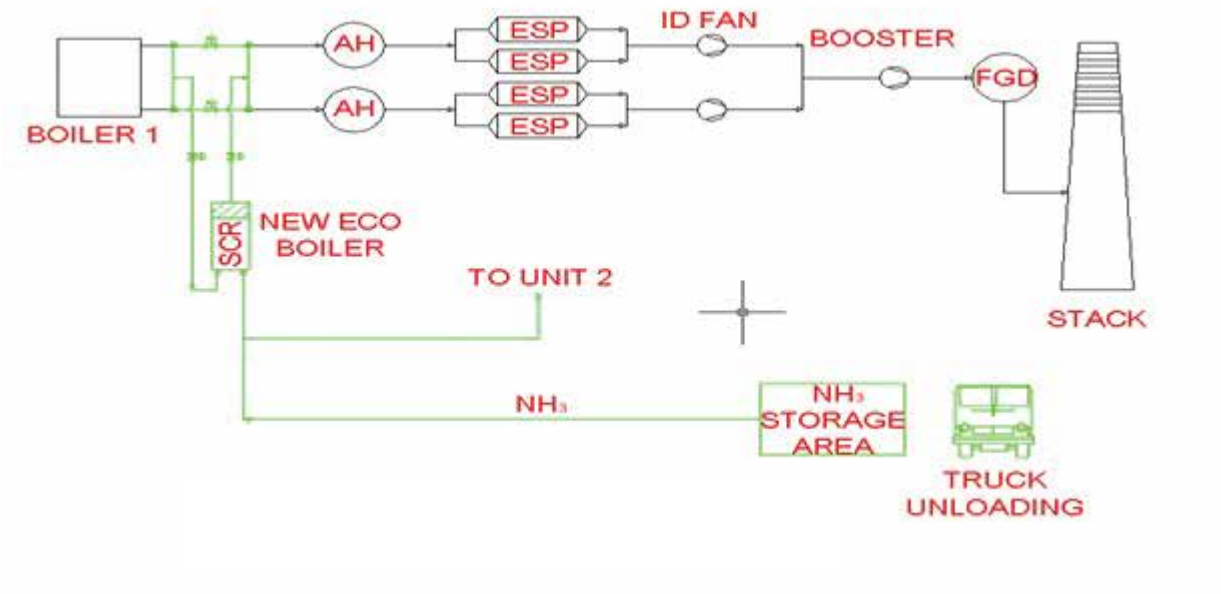


Fig. 3 – Litoral Unit #1&2: SCR installation

and to support it. Sometimes may happen that the space required and the position required lead to the inapplicability of such system.

The SNCR process is another secondary measure to reduce nitrogen oxides already formed in the flue-gas of a combustion unit. It is generally operated without a catalyst and at very high temperatures. This technology is generally combined with primary measures, being capable to achieve only 30-50% NO_x reduction. An higher NO_x removal efficiency may be generally achieved increasing ammonia or urea dosage, but that drives to unacceptable high ammonia slip in the flue gas line (higher than 5-10 ppm).

In Litoral #1-2 power station, being the value of NO_x at boiler outlet ranging around 500-550 mg/Nm^3 @6%O_2, dry base, a 60-70% NO_x reduction is required to fulfill safely future NOx emission limits.

In this revamping, SCR technology has been considered the solution for high NO_x reduction, because it guarantees the achievement of NO_x target emission in any operating condition, with minor modification on boiler proper and with minor upgrading on flue gas line and allows a better fly ash marketability. Further, sizing properly the casing, an additional catalyst layer may be installed, improving the maintenance operation and, in future, having the possibility to increase the performances.

The **figure 3** shows the conceptual flow diagram of the SCR insertion in the flue gas path of Litoral #1.

1.2.2 Flue gas temperature at boiler outlet (both unit)

Just after a first check, the boiler outlet operation data show that the range of the boiler Eco outlet temperature between full load and the boiler technical minimum load was not suitable for an installation of an high dust SCR system.

In the SCR process, at relatively low temperatures, ammonia reacts with SO_3 to produce ammonium sulphate $[(NH_4)_2SO_4]$ and ammonium bisulphate $[NH_4HSO_4]$.

The ammonium sulphate is a free flowing powder that does not create any problem for the catalyst, but ammonium bisulphate, even at relatively high temperatures, is present in liquid phase and has the capability to plug catalyst pores that become blinded and as a consequence not available for the reaction.

In order to avoid this phenomenon, it is necessary to operate the SCR system above a certain temperature called Minimum Continuous Operating Temperature, (**figure 4** reports diagram of catalyst minimum continuous operating temperature). The value is a function of SO_3 content into flue gas.

If the SCR system is operated for a small amount of time (up to 12 hours) below the Minimum Continuous Operative Temperature, then it is possible to remove the bisulphate condensed into the pores operating the reactor above the Minimum Continuous Operative Temperature for a certain amount of hours. As high is the operating temperature, as low is the recovery time.

If the SCR system is operated below the Minimum temperature for a longer period, it could be necessary to wash the catalyst to completely remove the bisulphate deposit.

Fig. 4 – Diagram of catalyst Minimum Continuous Operanting Temperature

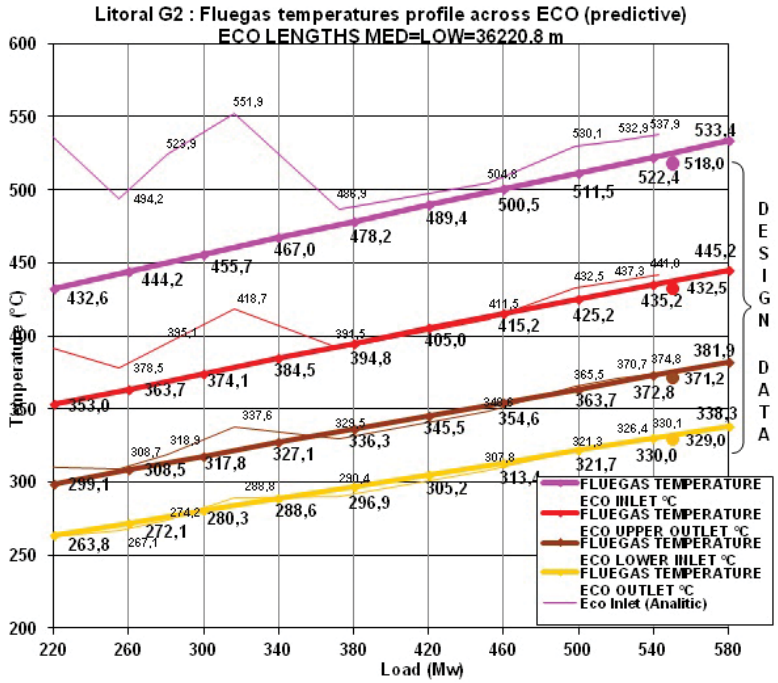


Fig. 5 – Graph with the predicted profiles of flue gas temperature across the economizer for Litoral Unit #2

A boiler performance model has been built to simulate the process.

For the Litoral Power Plant, the Minimum Temperature for ammonia injection is ab. 305 °C with SO_3 calculated on the basis of the performance model. The critical operating condition occurs at boiler low load, when the Eco outlet temperature is lower. In consideration of the above, the minimum acceptable value for the flue gas temperature at Eco outlet has been conservatively set at 320 °C.

The main goal of the model is to simulate the boiler behaviour and estimate the flue gas temperature in each section of the economizer (in particular upstream and downstream the Litoral Eco, i.e. the last section before boiler outlet). As example, in **figure 5** the graph with the predicted profiles of flue gas temperature across the economizer for Litoral #2.

According to the above data, the flue gas temperature at Boiler outlet is not suitable for the correct operation of the SCR over the whole load range; at low part load, the temperature falls down to values not suitable to allow the proper operation of the DeNOx. Furthermore, the boiler back-pass of both units is completely covered by membrane wall down to the lower Eco outlet so that an ECO by-pass flue gas side is not easily feasible.

Starting from the above concerns, during the preliminary study various alternatives have been considered, ranging from a boiler Eco modification to feed water recirculation through the Eco, but at the end of the day, the better compromise eventually resulted the Eco exhaust flue gas by pass. The damper located in the by-pass duct was not sufficient to achieve the desired flow rate distribution necessary to have the right temperature at SCR inlet along all the operating range . This is due to the not negligible part of the exhaust flue gas to be diverted through the Eco by pass at boiler lower load and due to the geometric constraints. Consequently another damper has been positioned at Eco outlet.

1.2.3 DeSOx of Unit #2 and flue gas temperature at stack inlet

The flue gas temperature at stack inlet shall not be less than 80 °C for stack internal materials preservation. The existing wet FGD (Flue Gas Desulphurization) of the Unit #2, originally, has been sized to achieve a SO_2 limit of 800 mg/Nm^3. That SO_2 reduction was achieved cleaning only a part of the exhaust flue gas, mixing the

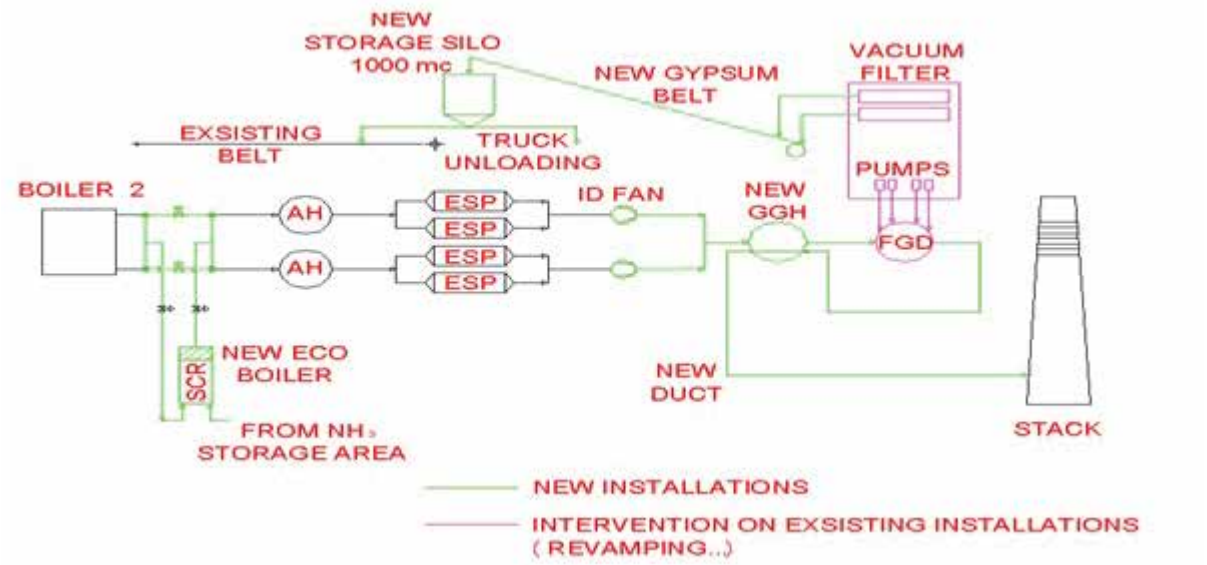


Fig. 6 - Litoral Unit #2: final configuration

two stream, the treated one and the untreated one.
Fortunately the volume of the reactor was sized for the full flow, so upgrading the number of the spray racks and the slurry distribution and flow rate, the emission target can be achieved. But with the future operation of the wet FGD, a GGH (Gas Gas Heater) installation has to be considered to get the right flue gas temperature at stack inlet. Unit #1 was already equipped with a suitable GGH system.
ID (Induced Draft) fans have been replaced and all FGD auxiliaries have been updated according the new design condition.

1.2.4 Plant outages

The plant layout in the boiler back pass is very crowded and the installation of a Denitrification system with its interface with the existing boiler casing and boiler supporting structures is really tough.
The entire construction sequence, starting from the safeguards, has been studied in details. Existing services relocation (underground trenches, cable routing and support, minor piping etc) has been done in advance exploiting any planned maintenance outage.
The DeNOx plant construction must be almost completed before stopping the relevant boiler and the last exhaust flue gas connecting ducts must be erected and the boiler modification with final connection accomplished in a very limited period of time, in order to allow gas in and unit restarts just in 75 days only since the boiler stop.
Equipment design and system layout have been sized suitable to allow the quickest erection sequence.
The DeNOx reactor has been split in two sections of about 50% capacity located between the boiler back pass and the ESP. The two blocks are connected and supported by an huge bridge steel structure. Separation among the two blocks is necessary to locate the connecting flue duct and to achieve a better load distribution upon the foundation.

2. Constructability and erection sequence

2.1 Erection sequence: Unit #1, DeNOx

The erection sequence for DeNOx installation was defined in details and divided in:

- activities to be performed in advance, exploiting boiler maintenance shut down (such as: provisional works to remove interference and to assure safe operation of the units during the DeNOx erection works);
- activities to be performed with the unit in normal operation (such as: foundations for structures supporting reactor casing, erection of SCR reactor, DeNOx auxiliary systems and rack to connect the reagent storage and preparation area and eventually interconnection piping);
- activities have to be performed during the Unit #1 shut-down period (such as: boiler back pass modification to allow economizer flue gas partial by pass, SCR to boiler ducts final connection, replacement of the existing ID fans and APH, Air PreHeaters, heating elements).

The view of the initial layout of the plant

2.2 Erection sequence: Unit #2 DeNOx and DeSOx

The erection sequences for Unit #2 had been defined as following:

- activities to be performed in advance, exploiting boiler maintenance shut down (such as: provisional works to remove interferences and to assure safe operation of the units during the DeNOx/DeSOx demolition/erection works, isolation of the existing absorber using the DeSOx by-pass duct that will be operated up to the main shut-down period);
- activities to be performed with the unit in normal operation (such as: foundations for structures supporting reactor casing, erection of SCR reactor, DeNOx auxiliary systems and rack to connect the reagent storage and preparation area and eventually interconnection piping);
- activities to be performed with the unit in normal

In yellow the part to be removed

Final view

operation with the DeSOx system put in by-pass operation (such as: erection of new GGH including foundations, steel structure, mechanical, electrical, I&C etc., erection of the new connection ducts up to the area where the existing ducts are still in operation, implementation of all the activities to modify and to upgrade the existing DeSOx system);

- activities have to be performed during the Unit #2 shut-down period (such as: boiler back pass modification to allow economizer flue gas partial by pass, SCR to boiler ducts final connection, replacement of the existing ID fans and APH heating elements and modification of the existing ducts downstream ID fans).

The unit shut-down period of the two units were scheduled in such way not being concurrent.

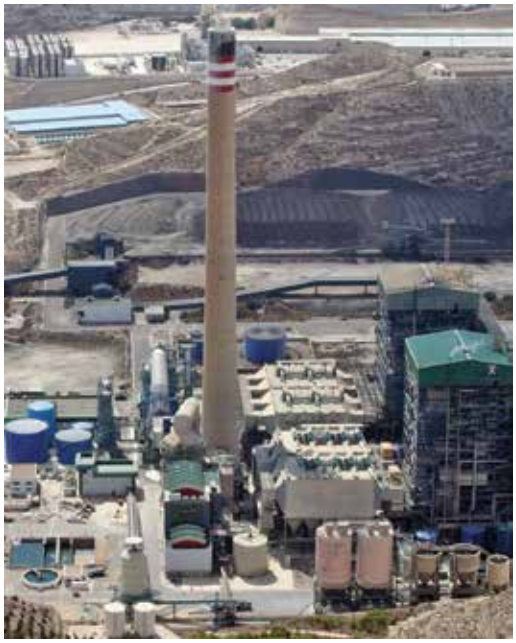
3. Scope of the upgrading and performances

Finally the scope of the job may be resumed as following.

3.1 Unit #1 plant configuration and target performances at the stack

The interventions on Unit #1 mainly consist of:

- new DeNOx system based on SCR technology and relevant structures and auxiliary systems (with reagent storage and preparation system common to both units);
- replacement of the existing APH heating elements with new ones suitable for SCR operation (if needed);
- boiler economizer exhaust flue gas partial by pass



Parallel view to compare before and after

Erection of blocks connecting duct of Unit #2

system to allow SCR to operate with a suitable flue gas inlet temperature range, from min stable load up to 100%;
- ducts for SCR to boiler connection;
- existing flue gas duct and ESP casing reinforcement to withstand to the new pressure condition during transient;
- existing ID fans modification;
- all the civil, mechanical and electrical works and existing control system modifications coming from the above installation.

In order to achieve the regulatory requirements, the limits for emission performances considered for plant sizing are reported in **table 2**.

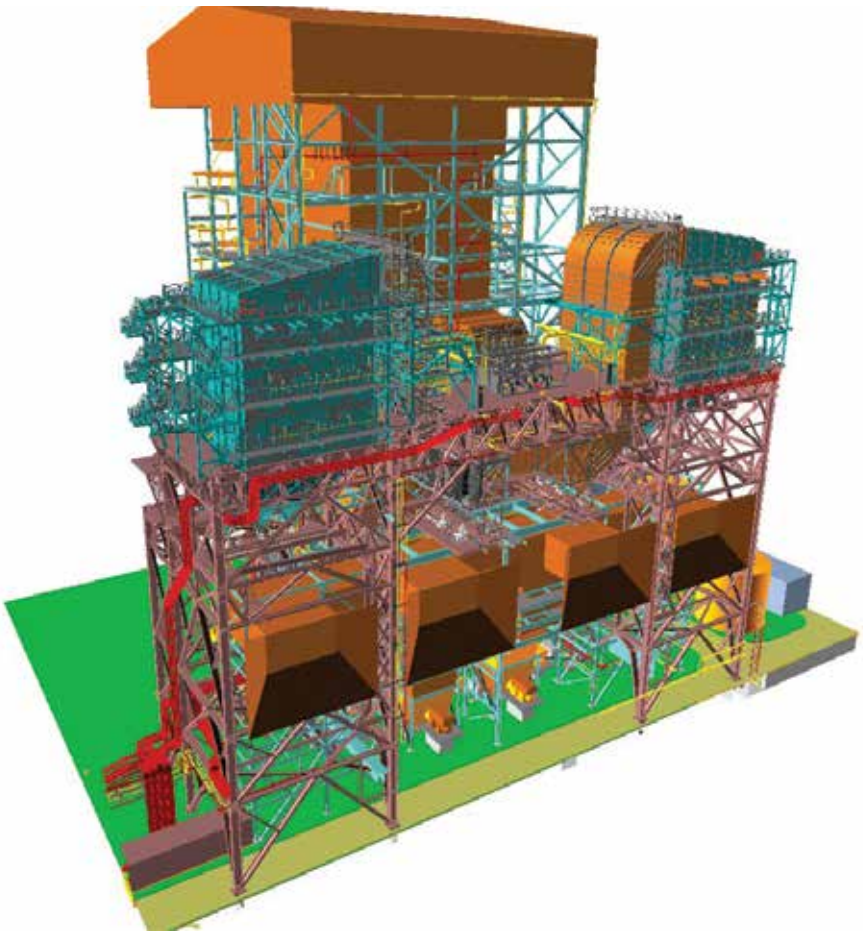
NOx outlet emission	180 mg/Nm3 dry 6% O_2 for coal
Ammonia slip	2 ppm at 16,000 operating hours
Redundant criteria	space for a spare catalyst layer

Table 2 – Unit #1 initial performances

3.2 Unit #2 plant configuration and target performances at the stack

The interventions on Unit #2 mainly consist of:
- new DeNOx system based on SCR technology and relevant structures and auxiliary systems (with reagent storage and preparation system common to both units);
- replacement of the existing APH heating elements with new ones suitable for SCR operation;
- boiler exhaust flue gas partial by pass system to allow SCR to operate with a suitable flue gas inlet temperature range, from min stable load up to 100%;
- ducts for SCR to boiler connection;
- existing ID fans replacement with new ones (according to the new piezometric line);
- new GGH;
- ducts relevant to:

3D view of the SCR blocks and connecting ducts for boiler of Unit #2



SO_2 outlet emission	180 mg/Nm^3 dry 6% O_2 as daily average
NO_x outlet emission	180 mg/Nm^3 dry 6% O_2 for coal
Ammonia slip	2 ppm at 16,000 operating hours
Redundant criteria	space for a spare catalyst layer

Table 3 - Unit #2 initial performances

- connection between ID fan discharge and GGH inlet;
- connection between GGH and existing DeSOx absorber;
- connection between GGH and stack;
- existing FGD system modification to improve the relevant performances;
- DeSOx auxiliary systems (dewatering, Gypsum handling etc.) modification/replacement for the new sizing required;
- new Gypsum storage silo;
- all the civil, mechanical and electrical works and existing control system modifications coming from the above installation.

In order to achieve the regulatory requirements, the limits for emission performances considered for plant sizing are reported in **table 3**.

4. The plant construction

4.1 Project time schedule

The Project Time Schedule of the interventions considered:

- the two units cannot be shut-down in the same period (priority is given to the Unit #2);
- the units shut-down period have been planned avoiding the summer time.

Following the above criteria the start of the EPC project was estimated on January 2012.
The main milestones and relevant impact on the Power Station Operation is shown in **table 4**.
The unit outages impacting on the power generation of Units 1&2 consist of:

- few days Unit #1&2 shut-down for DeNOx/DeSOx predisposition/safeguards works;
- 75 days of Unit #2 shut-down for main erection works;

One SCR semi-block of DeNOx of Unit #2

Notice to Proceed to EPC Contractor (NTP)	15 April, 2014
Start of works at site and safeguards	5 August 2014
Start of civil works (GGH foundation) of Unit #2	20 January 2015
Start of mechanical works (GGH Unit #2)	22 June 2015
Start of erection of steel structure of SCR Unit #2	10 July 2015
Start of civil works (foundation of SCR) Unit #1	3 Aug 2015
Start of DeSOx Unit #2 refurbishment	
(DeSOx Unit #2 unavailability)	6 October 2015
Start of erection of steel structure of SCR Unit #1	14 October 2015
Unit #2 shut-down	1 September 2016
Unit #2 restart (gas-in to DeNOx/DeSOx)	15 November 2016
Unit #1 shut-down	1° December 2016
Unit #2 PAC (Preliminarry Acceptance Certificate)	13 February 2017
Unit #1 restart (gas-in to DeNOx)	14 February 2017
Unit #1 PAC	15 May 2017

Table 4 – Litoral Unit #1&2: time schedule updated February 2016

- 75 days of Unit #1 shut-down for main erection works.

4.2 Criteria applied for unit shut-down time

In order to reduce as much as possible the time estimation of the unit shut-down period, the following criteria has been applied:

- the erection works during the unit shut-down period have been considered to be executed by double shift corresponding at about 140 hours/ week;
- provisional works and any critical activities have been considered to be anticipated as far as possible during an already scheduled unit shut-down for maintenance;
- the possibility to reuse/adapt the existing foundation (in detail for ID fans and critical ducts), minimizing civil works, has been considered.

Civil works	65%
SCR Unit #2 supporting structures	85%
SCR Unit #2 casings and ducts	40%
DeSOx Unit #2	35%
Area around DeSOx Unit #2	30%
GGH (Gas Gas Heater)	50%
Unit #1 ESP and duct reinforcement	80%
SCR Unit #1 supporting structures	35%
SCR Unit #1 casings and ducts	0%

Table 5 - Litoral Unit #1&2: accrued works erection main areas, updated February 2016

4.3 Progress accrued

The present accrued works is reported in **table 5**.

5. Conclusion, further performance upgrade

As final step, it is presently in progress also the activity to further improve the overall environmental performances of both units.

Exploiting the margin of the systems, installing the spare layer catalyst and improving the reactivity of the DeSOx slurry operating all the main recirculation pumps, the environmental performances of the units will be in line with the Best Practices in Europe (BEP) , such as NOx/SO2/dust 100/100/10 mg/Nm3 @6%O2 dry condition (**table 6**).

SO_2 outlet emission	100 mg/Nm^3 dry 6%O_2 as monthly average
NOx outlet emission	100 mg/Nm^3 dry 6%O_2 as monthly average
Dust (solid particulate)	10 mg/Nm^3 dry 6% O_2 as monthly average

Table 6 – BEP (Best Practices in Europe) performances

The improvement is on the way and it is foreseen to achieve those performances since the new re-starting of the plant.

Giampiero Valenti

Giampiero is employed as Feasibility study Department Manager, based in Enel Ingegneria e Ricerca (Engineering and Research), Italy. His job includes the early study of the fossil and hydro power plant approached by the Company.

He started his career as HRSG designer, then as process engineer, as Process and I&C manager and as Engineering Manager through various leading company in power sector (GIE, Ansaldo, ABB, Enelpower, Enel Produzione).

He has a degree in Mechanical Engineering Science from Politecnico di Milano (1980).

Italian Fire Extinguishing Technologies Meet the Challenge of International Oil & Gas Companies

A strong, customer–focused approach and the constant quest for top-class quality have enabled Sanco SpA to attain and sustain leadership in its major lines of business over the last 30 years

Nico Zorzetto
Export & Marketing Director, Sanco SpA

At the heart of new drilling methods there is an easy equation: bigger capacity corresponds greater hazard. As high volumes of crude oil and/or gas reaching a single point becomes the norm, there is a noteworthy growth in the demand for infrastructures to safely handle the load. Each environment needs a different solution and approach to the project in order to provide high standards for human health, safety of properties and environment.

Sanco SpA has paid great attention to its capability to manage projects by providing detailed engineering and supplying fire fighting products in order to fulfill end users' requirements while respecting environment. The Company has been strengthening its global competitiveness through strategic cooperative efforts with the world's renowned construction companies and developers. In fact, Sanco has turned its vision towards the world by demonstrating its special capabilities and talent engineering while earning valuable experience with vital international projects.

In addition to the above services, Sanco has been providing also pre-commissioning, commissioning assistance including performance testing according to local characteristics in several locations all around the world (98 Countries).

Here under to cases of project: hot and cold.

Kuwait project: the "hot"challenge

Among the several Countries with really hot climates there is Kuwait, a Middle Eastern State with harsh environmental conditions: temperatures reach 55 °C with a relative humidity touching 100%.

One of the latest jobs performed by Sanco in this Country has been the protection for one of the most important and largest part of an oil refinery for the strategic growth plan in the international hydrocarbon sector. A wide range of fire fighting systems and equipment have been supplied there: from the fire & gas detection systems to the hydrant networks with water/foam monitors, water deluge systems and foam packages with pumping units, clean agent gaseous systems (IG541), as well as all fixed and mobile equipment (**figures 1, 2, 3, 4**).

A special case study has been carried out by Sanco for three different EPCs in order to identify the risks to be protected: basic design has been reviewed together with hydraulic calculations of all water/foam pipes as well as for gas systems and all connected downstream activities.

A complete range of knowledge has been needed to develop this type of projects: dealing not only with the contractual intricacies coming from the large variety of Institutions involved in the projects. Sanco expertise cover the management of project with contractors but even with end users, local communities and institutions. For this special purpose the whole project has been submitted to the local Fire Service Department (KFD), that has the duty to superintend and check that what has been designed is in accordance with the local fire authority standards.

Fig. 1 – Kuwait project: deluge valves on skid

Fig. 2 – Kuwait project: gaseous systems

Fig. 3 – Kuwait project: fire monitor on hydrant

Fig. 4 – Kuwait project: fire & gas detection panels (UL listed)

Fig. 5 - Uzbekistan project: foam bladder tanks with thermal insulation for very low temperature

Uzbekistan project: the "cold" challenge

Sanco has been performing several projects also in East Eurasia Countries, like Russia, Turkmenistan, Kazakhstan and Azerbaijan.

One of the many latest projects carried out in a really cold climate is Uzbekistan, with its extreme temperature fluctuations that reach -35 °C: deserts and semi deserts occupy 80% of the territory of this Republic and it causes a really wide-ranging temperature excursion that has to be faced with special measures.

This challenge, resulting from a contract with a Korean EPC, has involved the engineering and manufacturing of fire suppression systems meant to be suitable for very low temperatures: for this purpose, also we paid a special attention to the selection of material suitable for very low temperatures and relevant mechanical tests have been carried out in order to meet end users special requirements.

During the project a dedicated team of Uzbeki Fire Department has been visiting Sanco factory in order to evaluate our capability and the skills of our technical department (35 qualified engineers and qualified technicians). The inspection involved also two manufacturing lines: the electronic line for fire & gas detection systems and mechanical line for fire suppression systems, equipment and vehicles (**figures 5, 6**).

At the end of the audit special hydraulic tests have been carried out in order to check performances of systems part of the scope of supply, consisting of water deluge systems, foam packages, fire hydrants and monitors as well as safety showers and other fixed and mobile units. In this occasion, thermal insulation for water and foam systems has been essential, by means of a special isolation procedure and electrically trace heated systems and devices, thus keeping overall power consumption very low.

After the completion of installation in Uzbekistan, Sanco performed a dedicated training for local operators.

An additional challenge: training

For both the above mentioned projects, the EPCs have been asking for the training of personnel in charge for the operation and maintenance of the systems and equipment that have been supplied. For this reason, Sanco has provided assistance with two qualified technicians with decennial experience in the fire fighting field.

To prepare firefighters for actual fires, training officers

use purpose-made facilities to conduct live fire training, offering trainees the opportunity to develop their skills by learning appropriate behavior through repeated experiences.

In order to train firefighters, a fire training facility that is tailored to their risks is the best solution, complete with both theoretical training and practical course. For this purpose Sanco has designed and built fire training modules for a State oil Company in Algeria (**figures 7, 8, 9**).

The fire training ground was based not only on NFPA 1403 (Standard on Live Fire Training Evolutions) and other international norms, but also on the specifications of international oil & gas enterprises such as Shell and BP, not to mention the additional specific demands of the client.

Sanco adapted the training equipment for the use of LPG (Liquified Petroleum Gas) as the fuel for gaseous fires and with an option for flammable liquid fires. As LPG is more difficult to extinguish than gasoline the training outcome can be better.

To provide the fuel for all fire scenarios a dedicated LPG vessel from which some piping lines feed each fire training module. Each one can be independently controlled by the trainer at the fire control room by a command console inside it, that is able to ignite and stop the fire, as well as increase and decrease the fire's intensity in response to the fire suppression actions of the trainees.

A number of gas detectors installed throughout the fire training ground provide additional fire and gas detection information to a panel in the control room, enabling an automatic emergency shutdown and the flushing of trenches in case of any LPG leakage.

Several additional emergency push buttons have been installed throughout all the various scenarios, in order to immediately stop fires in the case of an emergency occurring during the fire extinguishing training. Low, medium or high-risk scenarios can be created thanks to nine burning modules managed from the control room like:

- torch fire (simulating a fire erupting from the end of a broken pipe cap);
- pool fire, 4 m^2 (simulating the rupture of a blind flange on a pipe, the leakage and ignition of fuel spilled from the flange and the fire from the flange);
- T-shaped cross pool (simulating a wide-area liquid fire);
- inclined plate (simulating fire from fuel that is dripping on an inclined plate);
- ruptured vessel surface fire;
- relief valve fire;
- loose flange fire;
- exploded pipe fire with pipe interception valve closure simulation;

Fig. 6 - Uzbekistan project: deluge valves for very low temperatures

Fig. 7 - Fire training ground LPG vessel

Fig. 8 - Control room for fire training ground

Fig. 9 - Training ground: night fire

- "Christmas tree" fire (simulating a large-volume fire in a complex system of cross pipes).

In addition to the aforementioned gas detection unit that is interfaced with the training ground system, Sanco also installed a flushing system for the LPG pipe trenches to prevent explosions caused by LPG leakages.

In addressing the major challenges we face, our goal requires to promote human safety and environmental protection. In fact when it comes to safety, progress can never be taken for granted, especially given the increasing complexity of operating environments. That is why we must make sure that safety is at the heart of our strategy, our activities and our values.

Honoring these important commitments is the foundation of our license to operate and one of our uppermost strategic priorities.

For further information: marketing@sanco-spa.it

Nico Zorzetto

Nico Zorzetto, Export & Marketing Director as well as shareholder of Sanco SpA, has been working in the fire fighting field for over 40 years. Even if he graduated in Economics, he has always been dedicating its interest to technological innovation for "reliable products".

He has been participating to the realization of several new products and systems; in particular he is co-creator of airbome fire fighting systems (fixed and rotating wing) for the fire fighting of forest fires. He has been publishing several articles – national and international - relevant to fire fighting subjects.

He operates also with national and International organizations for the Civil Protection Organizations, as well as with security matters, with jobs also with NATO.

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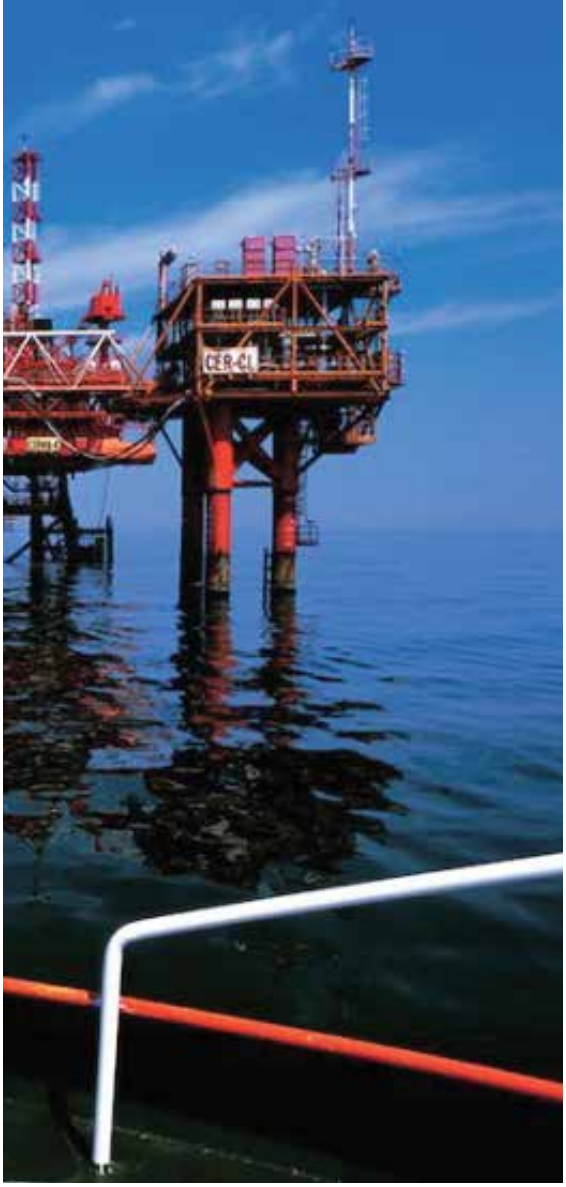
The HAZOP Formal Safety Assessment Process as a Risk Analysis Tool for Offshore EPIC Projects

For the IKA KZ Adriatic offshore platform, Basis Engineering carried out a series of HAZOP (HAZard & OPerability analysis) workshops in order to confirm the adequacy of the design of the facility in terms of safety and operational issues for the platform as a whole

Francesco Saviozzi, Nicola Mondelli
Basis Engineering Srl



During the EPIC (Engineering Procurement Installation Construction) phase of the IKA KZ Adriatic offshore platform, which may be considered a good example of the last generation of offshore Croatia gas platforms, a series of HAZOP (HAZard & OPerability analysis) workshops have been carried out in order to confirm the adequacy of the design of the facility in terms of safety and operational issues for the platform as a whole. So, particular attention was given to hydrocarbons processing, hence with focus on the process P&IDs (Piping & Instrumentation Diagrams). The operability problems considered were generally operational upsets, such as ESD (Emergency ShutDown), isolation valves failure, draining and venting operations. The whole Hazop process including recommendations tracking and action endorsement into the design has led to a remarkable improve of the platform safety as well as a vast simplification and an increase of reliability of the whole installation operation.

Scope of this paper, besides illustrating the methodology adopted, is to focus on the outcomes of the entire Hazop process (including follow-up and close activities) in terms of risk reduction results.

1. The Hazop Strength

The objective of the Hazop reviews is to identify, recognize and record causes and consequences of deviations from the normal process expected behavior, from the point of view of both safety and plant operability and, when deemed necessary, to provide recommendations to be implemented for further optimization.

The Hazop reviews findings represent the team consensus on actions suggested for eliminating or reducing process-related risks, for improving and optimizing the process operability as well as enhancing safety during plant operation. This is done by reviewing the P&IDs in a systematic manner to:

- identify any potential deviations from normal operating conditions;
- identify the hazards and consequences associated with the deviations identified;
- examine the effectiveness of the safeguarding measures, already incorporated in the design, aimed at mitigating the frequency and/or severity of the identified hazards and consequences;
- classify actions and recommendations for addressing the identified issues (when not already satisfactorily addressed) and thus improve the overall safety and operability of the system.

The main strength of the Hazop procedure is the possibility to analyze the entire system, systematically node by node, and exploiting a team effort, integrating individual design and operating resources normally limited to their own areas of expertise.

Gathering expertise from different disciplines and field of competence guarantees a multidisciplinary approach in analyzing single issues of the plant, not limiting the analysis of an aspect to a single point of view.

Despite the idea of Hazop workshop being tedious and merely time consuming, this problem analysis – and the consequent problem solving – can be very powerful in enhancing the platform safety, the operation simplification and sometimes the costs reductions.

The main drivers of achieving a successful Hazop review are implicit on the people that together form the Hazop team, attending the session, with focus on:

- competency;
- proactive attitude;
- open minded;
- prepared for changes.

Finally yet importantly, the Hazop chairman figure, which has as main objective to guide the team through the analysis, not to be intended as the judge who has the final word, but the person who has to intercede and mediate when different/incompatible ideas are under discussion.

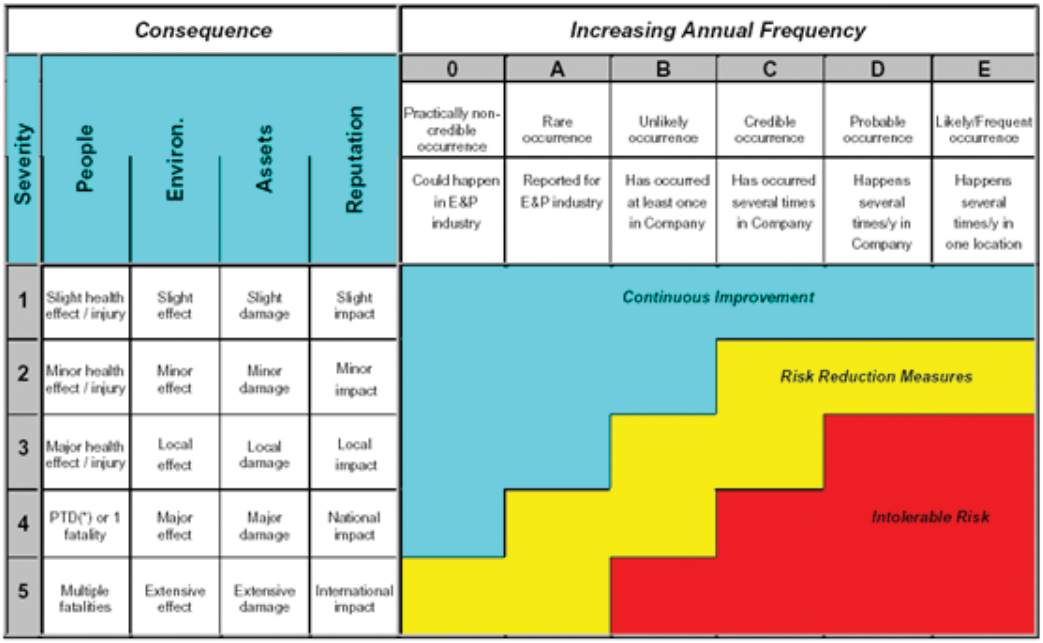


Fig. 1 - Event risk screening matrix

2. The Hazop: Worksheet, Recommendation Action Lists …

During the Hazop workshop, the entire team fills and therefore agrees in real time the Hazop worksheet. These worksheets include:

- session ID and date;
- node number and node design intent;
- operating and design conditions (temperature/ pressure/flow) for each node;
- parameter/guideword / deviations, results of the discussion and any requested recommendations.

The study produces a number action items or recommendations, which are summarized in the "action list". For each action, the following information has to be recorded on the report:

- identification of the node where the action has been issued, relevant P&IDs;
- deviation and possible consequences which requires the action;
- action identification number;
- recommendation (action);
- responsible party ("BY" column).

3. The Hazop Tools 2: the Risk Ranking …

For each hazard, leading to a recommendation the related risk has been evaluated before recommendation implementation to assure the risk reduction does not fall in the "intolerable risk" region. The risk is calculated as a combination of the likelihood (or frequency) and consequence(s) (or severity) of a specified hazardous event occurring. The risk evaluation has been assessed using the matrix of **figure 1**.

Table 1 - All assets and operation upsets analyzed for the whole plant, divided into "nodes" sharing the same design intent

Node #	Description	Parameters
01	Short String	Flow Pressure Temperature Composition
02	Long String	Flow Pressure Temperature Composition
03	Long String + Heater	Flow Pressure Temperature Composition
04	Heater (Shell side)	Additional Hazop Required
05	Production separator short string	Flow Pressure Temperature Level Maintenance
06	Production separator long string	Flow Pressure Temperature Level Maintenance Service
07	Test separator	Flow Pressure Temperature Level Maintenance
08	Process water filtration	Flow Pressure Temperature
09	Sea line (from LPT to RPT)	Flow Pressure Temperature Maintenance
10	Instrument Air (vessel + line from IKA A)	Flow Pressure Temperature Level Maintenance
11	Methanol injection	Flow Pressure Temperature Level Composition
12	Open/Closed drain	Flow Pressure Temperature Level Composition

Table 2 - The supplementary Hazop study has been carried out in order to consider the Vendor's Packages not analyzed in the main Hazop study divided into the air dryer and the heater (shell side)

Node #	Description	Parameters
13	Air Dryer	Flow Pressure Temperature Composition
14	Gas Heater (Shell Side)	Flow Pressure Temperature Level Maintenance Starp-up/Shut-down

4. The EPIC Project IKA JZ: main Hazop

All assets as well as operation upsets have been analyzed for the whole plant, divided into "nodes" sharing the same design intent (**table 1**).

4.1 The "Additional Hazop"

The supplementary Hazop study has been carried out in order to consider the Vendor's Packages, not analyzed in the main one, since the level of engineering was not enough detailed to make a profitable study. These packages are the air dryer and the heater (shell side) (**table 2**).

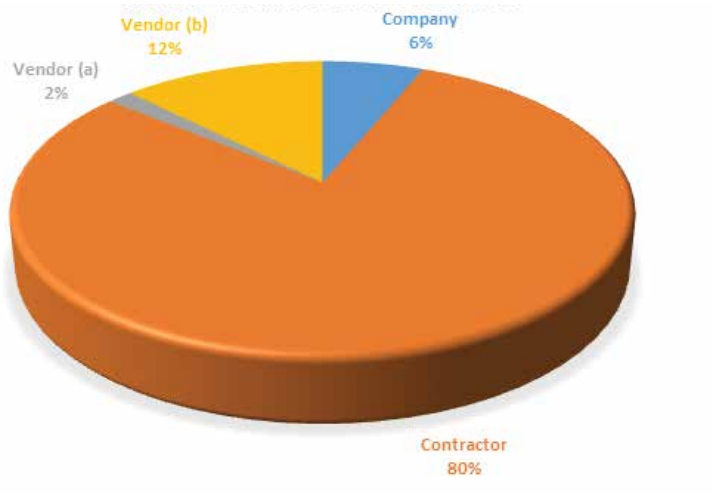


Fig. 2 - Hazop actions responsibility distribution

5. Hazop Workshop Findings

The conclusions of both the Hazop studies were mainly represented by recommendations sorted during Hazop meetings from Hazop team for total of actions (64). Among them, there was a significant number of recommendations concerned with operational issues that involved both normal operation as well as maintenance issues.

The total number of Recommendations arisen from the three Hazop Workshops was 64, divided as follows (**figure 2**):

- Company Recommendation: 4
- Contractor Recommendation: 51
- Vendor (a) "Air Dryer" Recommendation: 1
- Vendor (b) "Gas Heater" Recommendation: 8

The risk ranking exercise allowed categorizing each recommendation according to the risk matrix of **figure 3**. Which resulted in the following risk categories action distribution (**figure 4**):

- 23 actions in the "continuous improvement" region;
- 34 actions in the "risk reduction measures" region;
- 6 actions in the "intolerable risk" region.

5.1 Operating Procedures

Some recommendations relevant to the general operating philosophy were raised up during the Hazop study and are summarized in **table 3**.

As shown in that list, recommendation include

		Frequency					
		0	A	B	C	D	E
Severity	1	1	0	4	0	0	0
	2	0	3	12	3	1	1
	3	0	3	13	7	0	3
	4	0	7	2	3	0	0
	5	0	0	0	0	0	0

Fig. 3 - Hazop actions risk ranking distribution after the workshop

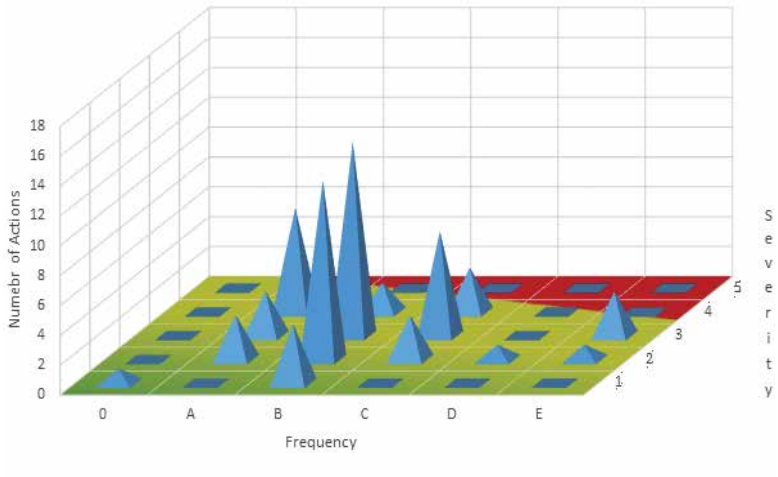


Fig. 4 - Hazop actions distribution after the workshop

Table 3 - Operations recommendations

Action #	Recommendation
03	O&MM Provide detailed procedure for flow line depressurization (e.g. through purge burner or high pressure vent via test separator)
10	O&MM Provide detailed procedure for recovering measure due to fire scenario during BDV maintenance test
11	O&MM Prohibit valve dismounting without depressurization
30	O&MM provide detailed procedure to prescribe draining of process water filtration system when not in use. Describe also to leave open manual valve on filter outlet in order not to isolate PSV
31	O&MM Provide detailed procedure for PI checks during monthly filter inspection
36	O&MM Provide procedure to remove SDV-102 from logic during plant maintenance
43	O&MM Provide detailed procedure to use accumulator by pass when PSV-001 maintenance is required and ensure accumulator is depressurized
52	O&MM Provide detailed procedure to check LG-002 before any drainage operation takes place to verify enough room is available
64	O&MM Provide detailed procedure for first filling of water bath now intended by gravity through top hand hole

Table 4 - Safety recommendations

Action #	Recommendation
1	Provide means to avoid uncontrolled gas to purge burner (e.g. interlock the 2" manual valve on the short string or provide 3" manual valve on purge burner locked close etc.)
15	Verify adequate protection on heater package to avoid temperature higher than design
9	Verify provision of audible alarm for fire on platform when manned
28	Verify PSV-001 on solids removal filters is sized also for gas back flow from sea line or provide adequate protections

procedure involving draining, purging operation as well as maintenance and inspection requirements during the production phase of the installation. In particular, scheduled maintenance, including depressurization of flow lines (action n. 03) and other equipment, requires a local/process shut down status of the section to be maintained. The depressurization, described in the operating and maintenance manual, lists the step by step procedure of the operation which includes:

- start the purge burner unit;
- close the manual valve on the production line (downstream choke valve) toward the production and test manifold;
- verify that the purge burner system choke valve is closed;
- select the purge burner position considering the wind condition;
- ignite the pilot of the purge burner by means of the ignition panel and using propane as fuel gas;
- open completely the manual wing valve;
- open the manual valves to purge burner;
- slowly open the choke valve that feeds the purge burner;
- purge production line with nitrogen;
- open manual valve in order to drain production lines;
- verify that the system has been properly purged with nitrogen and the oxygen concentration is below the minimum allowable limit, in order to avoid the possibility of gas/air explosive mixture formation during maintenance operations.

The above operation list provides a good example of how a detailed follow-up analysis may drastically drive the operating of the whole installation, aimed to avoid any potential operator error in case of significant, even though standard, actions.

5.2 Safety Main Findings

Besides operation issues, considering the consequences affecting people the following scenarios are considered quite significant and the recommendation implementation definitely improves the safety level (**table 4**). Safety actions listed have led to some design changes, with respect to the previous project phases, of the platform.

While Action n.1 resulted *only* in an addition of a manual valve, action n. 15 led to a change in the design temperature of the gas heater package (coils and shell) set at 120 °C higher than bath boiling temperature in order to avoid mechanical damage of the equipment potentially leading to loss of containment. Other actions (n. 9 and n. 29) led to addition verification of the design, which in the particular case has been confirmed – i.e. the provision of audible and visual alarms or the confirmation of the correct supply of an item such as the flow orifice.

6. Hazop Process Final Results

The final step of a complete Hazop shall always be the Hazop follow-up activity, which has to include all the

participant of an EPIC project, including designers, installations, and commissioners. Each actor to whom the action has been assigned is then obliged to endorse the recommendations, giving evidence that what declared in the action sheet was endorsed in the design.

The data and graphs of **figure 5** and **figure 6** clearly and unsurprisingly show the increase of safety of the whole installation, in terms of numbers of action which now fall *all* in the "Continuous improvement" region.

The risk reduction was obtained acting both in the reduction:

- Frequency of deviations, which is obtainable with a change in approach of the original design acting on the cause of the deviation;
- Severity, which is achievable introducing mitigation measures in the plant in order to lower the consequences of an hazardous event.

Among the 64 action after the Hazop workshop for:

- 27 actions there has been a reduction in Severity;
- 44 action there has been a reduction in Frequency;
- 11 actions a combined reduction of Frequency and Severity has been achieved.

All action, even though, not changing drastically the design of the plant, show the importance of the Hazop review process, which until the very final stage of a project (i.e. the engineering to construction step) can give issues and a number of important points to be considered in documents which eventually have been already analyzed and assessed several times during the past project phases.

		Frequency					
		0	A	B	C	D	E
Severity	1	6	7	6	1	0	0
	2	4	18	3	0	0	0
	3	8	4	0	0	0	0
	4	6	0	0	0	0	0
	5	0	0	0	0	0	0

Fig. 5 - Hazop actions risk ranking distribution after the complete Hazop process

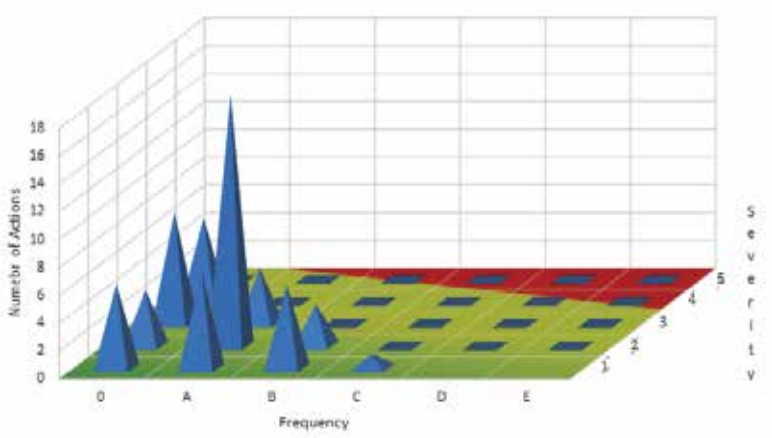


Fig. 6 - Hazop actions distribution after the follow up

Nicola Mondelli

With Basis Enginering since 2013 Nicola is a Senior Director with over 30 years experience in process design, engineering, marketing, business development and company management with the most reputed international E&C Companies for the oil & gas and petrochemical industry, such as Technip Italy, ABB Process Solution, KTI, Tecnimont, Rosetti Marino and Basis Engineering.

He also gained a significant experience in Saudi Arabia as Managing Director of a start-up Contracting Company operating in the Oil & Gas sector.

Francesco Saviozzi

Francesco is an HSE Design expert, with over 10 years of experience inherent to safety, consequence analysis, formal safety assessment and risk analysis for offshore Oil & Gas installations. Auditor of the Kashagan detail design integrity team he has attended more than 30 formal safety assessment workshop (i.e. Hazid, Hazop, SIL) as Chairman and HSE Design focal point.

Experiencies include advanced knowledge of major atmospheric and underwater dispersion modeling codes, including transient analysis and 3D wind field reconstruction as well as atmosphere dispersion models developer.

Currently discipline manager of the HSE Design team in Basis Engineering, which includes Technical Safety and Environmental Studies departments.

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Improve the Filtration Efficiency in FCC and RFCC Units

The alliance between Asco Filtri and Mott Corporation allows refineries to install a reliable and proven filtration system to FCC (Fluid Catalytic Cracking) and RFCC (Residue Fluid Catalytic Cracking) units, with limited maintenance requirements, very low Opex and short payback time

Massimo Mascheroni
General Manager, Asco Filtri SpA

Petroleum refiners use a process called Fluid Catalytic Cracking (FCC) to convert heavy petroleum fractions into products such as gasoline, kerosene and feedstock for petrochemical processes. The conversion of crude oil fractions into higher value products requires the use of catalysts. The product stream from the FCC unit contains silica and alumina fines generated from catalysts used in the process. After distillation, these fines are concentrated in the heaviest fraction or slurry oil.

Filtration systems designed for the removal of catalyst fines from slurry oil utilizing sintered porous metal media were introduced in the mid 1980's. Filtration of slurry oil using an advanced filtration system design and sintered metal media continue to demonstrate long-term filter operating performance in the separation of FCC catalyst fines from slurry oil to reduce the ash content.

Unlike centrifuges or electrostatic techniques, the filtration media acts as a positive barrier to remove downstream catalyst contamination. Sintered metal filtration technology using inside-out filtration configuration provides a reliable method of achieving high quality slurry oil product by reducing catalyst content. The backwash capability of the media provides an economic alternative to the use of settling tanks. Removal of the fines increases FCC product yield improves the market value of the filtered product and reduces wear and tear of downstream equipment in addition to improving the catalyst recover and handling process.

There are numerous grades and manufacturers of catalyst since FCC was introduced in the early 1940's. Filtration feasibility testing continues to be an effective means in media selection and verification of filter operating parameters to confirm process scale-up design for commercial installations. Feasibility testing is recommended as catalyst fines vary in size, with a range from submicron to 30-40 µm, and occasionally larger.

Filter media selection for removal of FCC catalyst fines

Due to variations in slurry oil viscosity, catalyst particle size and slurry concentration of each refinery process the preferred method of selecting filter media is via laboratory or pilot trials. Feasibility tests verify filter-operating parameters such as particle removal efficiency, pressure drop vs. solids loading, recovery pressure after backwash and cycle length. Experience in similar service may be the basis for filter selection,

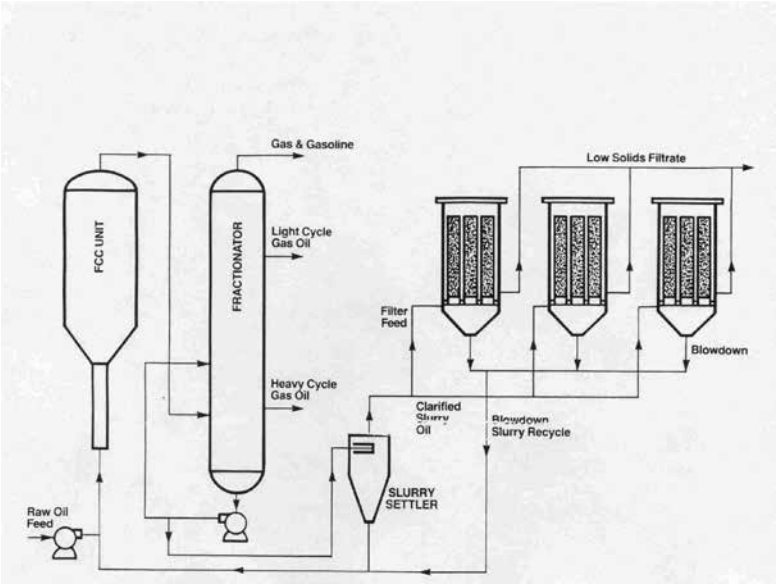


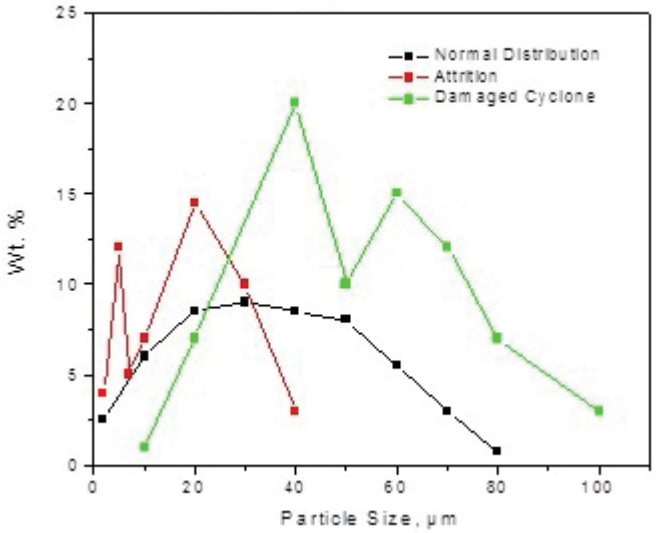
Fig. 1 - FCC filter system schematic

taking into account the specific solids and liquid of the process and if actual test data cannot be obtained.

The particle size range of catalyst material varies with the operating performance of the FCC unit (**figure 1**). FCC catalysts are broadly classified on the basis of the method of manufacture: silica or clay based and active alumina. The mechanical integrity of the catalyst combined with cyclone efficiency influence solids concentration and catalyst particle size distribution of the slurry oil. Optimum filtration results are obtained with a broad particle size distribution.

Cyclones are the first stage of catalyst fines removal in the FCC unit. Efficiently operating cyclones can remove sufficient fines from the reaction product to produce slurry oil with solids content of about 0.2% by weight (2000 ppm) or lower even that concentration between 2000-5000 ppm of Total Suspended Solids (TSS) in slurry oil is quite common.

Fig. 2 - FCC fines catalyst distribution



The variations of the FCC catalyst fines distribution are shown in. Normal catalyst fines particle size distribution observed in FCC cyclones is typically a normal bell curve ranging from < 5 to 80 µm, with a peak in the 30-40 µm range (**figure 2**). Bimodal distributions are the result of either attrition of the catalyst or damage to the cyclone or plenum.

Attrition of the catalyst causes the curve to shift to the left, with a peak in the 2-3 µm range. Fracturing catalyst at a high velocity stream generates submicron particles. A shift to the right of the normal bell shaped curve with a peak in the range of 40 µm or greater is the result of full-range catalyst being drawn into the cyclone or plenum.

Filtration principle

Sintered metal filters are high efficiency, two-dimensional, straining type with particulate being collected on the media surface. The proper selection of media grade must balance the needs of the filtration application regarding particle retention, pressure drop and backwash ability. There are basically three process factors to consider: fluid velocity through the filter media, fluid viscosity and particle characteristics. The important particle characteristics are particle shape, size and density. Particles that are hard, regular shaped and form incompressible cakes such as FCC catalyst are well suited for surface filtration.

Filtration operation is based on constant flow, increasing pressure drop until the terminal pressure drop is reached. Terminal conditions will be reached when the catalyst cake thickness increases to a point where the fluid flow pressure drop is at a maximum for a given flow and viscosity condition. The filter is then backwashed by pressurizing the filter with gas, then quickly opening the backwash discharge valve. This backwash procedure generates a momentary high reverse differential pressure, which effectively removes solids from the media surface. Reverse flows of clean liquid (filtrate) through the media assists in the removal of solids and flushes them out of the filter.

Filter operating experience and commercial installations

In 1985, the first continuous use of a sintered metal filter using inside-out (LSI) HyPulse® filtration technology developed by Mott Corporation demonstrated the suitability of sintered metal media for high temperature filtration of slurry oil.

Since then, refineries around the world have become aware of the benefits of filtration using sintered metal media for catalyst fines removal in slurry oil service.

Throughout the 1990's numerous LSI filtration systems

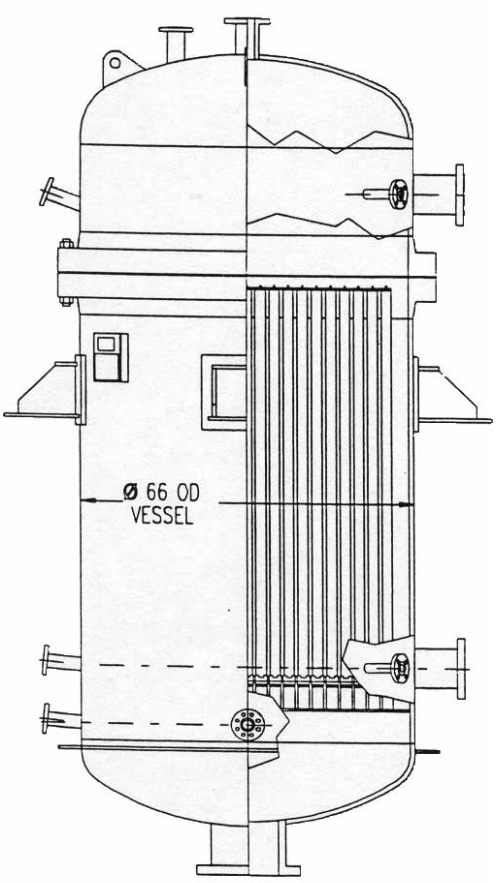


Fig. 3 - LSI 66" filtration system

have been installed for FCC slurry oil filtration at numerous refineries worldwide the largest employing (3) 66" LSI filters (**figure 3**). Filtration cycle time ranges from 2 to 16 hours operating at 2-4 bar, respectively in the filtration of 1000 ppm slurry oil. Extended cycle times were obtained by running two filters simultaneously, but staggered in cycle time, with the third being on stand-by for utilization when one of the other filter units is backwashed. The filter design uses a full shell backwash. Efficiency of the recovered product using two filters on line exceeds 99.8%.

Since 1997, several refineries in China have installed LSI filtration systems for catalyst removal in Residue Fluid Catalytic Cracking (RFCC) units. A filtration system with (2) 24" LSI filters was installed in a RFCC unit with 1.4 million tons per year capacity and an output of slurry oil of 180 t/d. The slurry oil has an average 3000-5000 ppm solids concentration. Cycle time varies from 2-8 hours. The filtrate solids content is under 50 ppm. The system is running continuously since then supplying a local company with clean filtrate to produce carbon black.

Another unit has 1.2-million t/y capacity but only has about 75 t/d slurry oil output. The system utilizes (3) 20" LSI filters controlled by local PLC. Each filtration unit is capable of handling entire flow, or two filters can run simultaneously to optimize product yield. The unit operates mostly during the winter months to supply the clean slurry oil to replace fresh crude as fuel oil for heating in the oilfield and local residential area. Average slurry oil concentration is 4000-6000 ppm, and is occasionally over 10.000 ppm under unstable conditions. Cycle time varies from 30 minutes to 4 hours depends on the operating conditions and solids concentration.

Until today, Mott has delivered, worldwide, more than 30 FCC / RFCC slurry oil filtration systems, with incomparable reliability in operation and performance.

Starting from 2010, Asco Filtri, thanks to the technological alliance with Mott was able to deliver two large scale project while one more is under execution now and others under negotiation.

Case 1

Complete skid mounted slurry oil system was delivered on 2011 to a refinery located in Saudi Arabia (**figure 4**). The system is designed to comply with the following process requirements:

- flow-rate 6.05 t/h
- pressure 5.5 barg
- temperature 260-280 °C
- catalyst inlet quantity 1100-3300 ppm
- catalyst inlet design quantity 10.000 ppm
- catalyst size 0-50 µm
- FCC unit licensor Axens

We have delivered a filtration package equipped with 2 × 100% filters 32" LSI equipped with genuine Mott sintered metal powder elements and relative accessories: gas accumulator, control and manual valves, instrumentations, structure etc.

With the above arrangement we can guarantee the following performance:

Fig. 4 - Case 1: slurry oil unit

Asco Filtri SpA

Asco Filtri is an Italian filtration company specialized in the design and manufacture of process filtration solutions for a broad range of industrial markets: from oil & gas to petrochemical, from water treatment to fine chemical, food & beverage, cosmetics and pharmaceutical, our innovative and proprietary process filters, can be used in a multitude of filtration applications.
The Engineering Division provides complete filtration packages to EPC and end users alike, designed and manufactured according to all the main construction codes and standards (ASME VIII Div 1&2, PED etc.) building on the combined resources of an Engineering team with more than 40 years' experience in the field. To satisfy the requirements of the oil & gas and petrochemical sectors, Asco Filtri can also provide pressure vessels and systems with U-Stamp 1&2 and/or CE Stamp fabricated in its own work-shop.
The engineering expertise can provide solutions for the most difficult liquid or gas filtration problems; Asco Filtri application expertise includes:

- catalyst removal & recovery;
- precious metal removal & recovery;
- guard filtration for fixed bed reactor;
- FCC slurry oil filtration;
- FCC 3rd and 4th stage separators;
- FCC and CCR vent hopper filters;
- biomass gasification blow-back filters;
- carbon removal filters;
- amine filtration system;
- gas/liquid coalescer;
- liquid/liquid coalescer.

The Technical Alliance with Mott Corporation extend the capability to supply advanced filtration technologies. The combination of leading-edge technologies and highly experienced personnel allows for comprehensive in-depth application analysis resulting in optimal filter operating recommendations.
Since 1959, Mott has focused exclusively on porous metal manufacturing and applications. Mott researchers were among the first to examine metal filtration as an intriguing alternative to membranes. This is the most experienced, most capable name in the field.
Mott Corporation developed the HyPulse® filter systems in response to the market needs for an automated self-cleaning filter that would increase run times and improve operational efficiencies through more precise control of operating conditions. Mott pioneered the unique use of high strength, long lasting porous metal media available in over 20 different alloys to handle high temperatures, high pressures, corrosive environments, and exacting process requirements. Over the past 32 years, Mott has designed and installed more than 600 HyPulse® Filtration Systems providing outstanding service in the applications were performance is critical.
Mott Corporation products have been approved for use by the most prominent innovators and developers of chemical and petrochemical processes, analytical equipment, and flow control devices.

- catalyst outlet quantity < 50 ppm
- filtration cycle: 5.75 hours with 3300 ppm inlet
- separation efficiency 99% for solids > 1.5 µm

Case 2

Complete skid mounted slurry oil system was delivered on 2015 to a refinery located in India (**figure 5**). The system is designed to comply with the following process requirements:

- flow-rate 13.75 t/h
- pressure 11.2/15.5 barg
- temperature 330 °C
- catalyst inlet quantity 3000-6000 ppm
- catalyst size 0.5-20 µm (35% < 3 µm)
- FCC unit licensor Technip Stone & Webster

We have delivered a filtration package equipped with 2 × 100% filters 48" LSI equipped with genuine Mott Corp. sintered metal powder elements rated and

Fig. 5 – Case 2: slurry oil unit

relative accessories: back-was receiver, gas accumulator, control and manual valves, instrumentations, SIL3 local PLC, structure etc.

With the above arrangement we can guarantee the following performance:

- catalyst outlet quantity < 100 ppm
- filtration cycle 3 hours with 6000 ppm inlet
- separation efficiency 99% for solids > 1.5 µm

and short payback time.

The slurry oil catalyst recovery systems supplied by Asco Filtri / Mott can easily improve the quality of the FCC slurry oil into a more valuable product (clean fuel blend, feedstock for carbon black producers, feedstock for needle-coke unit etc.) and allow the customer to minimize the wasted products considering that separated catalyst is usually routed in the FCC rector riser instead of settled and disposed as special waste.

Conclusion

Sintered metal media has demonstrated its suitability in a highly efficient catalyst removal filter system for slurry oil service. The Asco Filtri / Mott alliance allows refineries to install a reliable and proven filtration system with limited maintenance requirements, very low Opex

Reference

Rubow K.L., Stange L. (from Mott Corp.): *Sintered Porous Metal Filtration Systems for Petroleum Refining Applications* - Paper presented at AFS 2002 Annual Technical Conference and Exposition, April 2002 Galveston, Texas, USA

Massimo Mascheroni

Massimo has acquired nearly 30 years of experience in the filtration market thanks to the multitude of collaborations with some of the top class filtration companies with different responsibility. His skill it is mainly oriented to oil & gas / petrochemical markets. He is one of the founders of Asco Filtri SpA where currently covers the role of General Manager.

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- Fire safe to API 607

OPTIONALS

- IP 65 weatherproof box in St.St. 316 with/without windows; with/without insulation
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- With breathing plugs
- Terminal boxes for cables wiring
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Oxygen Generation Plant for Gold Leaching

PSA (Pressure Swing Adsorption) oxygen generation plant from Noxerior put into operation at the Ad Duwayhi Gold Mine of the Saudi Arabian Mining Company (Ma'aden Gold and Base Metals Company)

Oscar de Groen
Managing Director, Noxerior Srl

Fig. 1 - Installed PSA oxygen generation plant at the Ad Duwayhi Gold Mine, KSA

The company Noxerior, formerly known as IGS Italia, is a 100% privately owned Italian company and focuses on all aspects of the non-cryogenic on-site generation of nitrogen and oxygen by means of either PSA (Pressure Swing Adsorption) or hollow-fibre membrane technology.
In 2014 Noxerior supplied a custom-designed PSA oxygen generation plant to the Ad Duwayhi Gold Mine of the Saudi Arabian Mining Company (Ma'aden Gold and Base Metals Company) through an EPC company from South Korea, which was commissioned and started-up successfully during the third quarter of 2015.

Principles of gold leaching

Up till now gold leaching with a cyanide solution has remained the most widely used hydrometallurgical process for the extraction of gold from ores and concentrates. During this electrochemical process oxygen will pick-up electrons from the gold at a cathodic area, whilst gold ions will be rapidly complexed by the cyanide around the anodic area to form the soluble aurocyanide complex according to the Elsner Equation:

$$4\ Au + 8\ NaCN + O_2 + 2H_2O - 4\ NaAu(CN)_2 + 4\ NaOH$$

A slurry of the ground ore is mixed with cyanide in the presence of activated carbon. The carbon has a very high affinity for the aurocyanide complex and adsorbs the gold out of solution resulting in very high loadings on the carbon (typically 1000 – 4000 g/t). At the end of the leach the loaded carbon is removed from the slurry and the adsorbed gold is stripped out at high temperature and pressure with sodium hydroxide and cyanide solutions to form a high value electrolyte solution.
Gold bullion is then recovered from the electrolyte by electrowinning.
As a deficiency in dissolved oxygen in the solutions would slow the leaching speed, gaseous oxygen is bubbled through the slurry to increase the dissolved oxygen concentration. Intimate oxygen-slurry contactors are used to increase the partial pressure of the oxygen in contact with the solution in order to raise the dissolved oxygen concentration significantly above the saturation level at atmospheric pressure.

Need for on-site oxygen generation

The open-pit Ad Duwayhi Gold Mine is situated in a very remote desert area of the Mecca Province, Saudi Arabia, approximately 440 km southwest of Riyadh.

Fig. 2 - PSA oxygen generation plant in 2 × 50% configuration

Located at latitude 22° 17' N and longitude 43° 17' E, at an elevation of 980 m a.s.l. the site is some 380 km west-northwest of the provincial capital Mecca.

Due to this location the conventional supply of oxygen by means of truck transported liquid oxygen and local cryogenic storage tanks would not be possible so that the required oxygen has to be produced on-site through an air separation process.

The oxygen production process

Considering the required rated oxygen production capacity of 2,5 t/d, Noxerior has applied its proprietary Pressure Swing Adsorption (PSA) process to separate oxygen from the other air gases by flowing compressed ambient air through a bed of Zeolite Molecular Sieve (ZMS). The applied zeolites are crystalline, highly porous materials with a strong electrostatic field on their internal surface. Due to the characteristic that nitrogen is more polarisable than oxygen, a charge induced dipole is formed when nitrogen will get in close proximity to the exposed cations of the zeolite crystal so that the nitrogen molecules present in the compressed air will be attracted into the zeolite crystal while the oxygen molecules are able to pass unrestricted.

The PSA process will take place in two adsorption vessels filled with ZMS, which will be alternatively loaded with clean compressed air in order to obtain a continuous oxygen flow. The flow direction through the ZMS bed in each adsorption vessel is from bottom to top, but the air supply will be interrupted just before the equilibrium load is reached at the top of the ZMS bed in order to prevent a nitrogen-break-through. After a subsequent pressure equalization between the two adsorption vessels, the ZMS bed of the closed adsorption vessel will be regenerated (desorbed) by means of a pressure decrease (depressurization), which is obtained by venting through the bottom of the adsorption vessel to the atmosphere. The process is then cyclically repeated.

The gas produced by means of the PSA process has an oxygen content of 95% vol. and the balance is mainly made up by argon. The capacity of the PSA oxygen plant, however, has been corrected by the purity in order to guarantee the requested flow rate of contained oxygen (= pure oxygen) to supply a sufficient oxygen mass flow to the downstream leaching process.

Fig. 3 - Close-up of PSA oxygen generation plant

Specific solutions for the PSA oxygen plant

Considering the criticality of the oxygen for the leaching process and the remote location of the mine, it was decided to design the PSA oxygen generation plant in a 2 × 50% configuration. Because of the high ambient temperatures with maximum values up to 55 °C, a special cooling system was designed for the air compressor station in order to keep the temperature of the feed air to the PSA oxygen generation plant below 45 °C under all operating circumstances.

The combination of both gas expansion and a reduced adsorption efficiency of the ZMS at increasing temperatures causes a significant drop of performance compared to the standard operating condition of 20 °C. The aforementioned maximum feed air temperature of 45 °C allowed a limited size increase of the PSA oxygen generation plant, necessary to compensate this temperature effect in order to guarantee the required rated oxygen mass flow even at the highest ambient temperature on-site. As a consequence, the PSA adsorption vessels had to be insulated to avoid external heating by the ambient air.

Due to the extreme ambient conditions and the outdoor

installation, the PSA oxygen generation plant is controlled remotely by an Unit Control Panel (UCP) located at the mine's central control room for fully automatic and unattended operation. The UCP was designed and manufactured by Noxerior as well.

First experience and current situation

The PSA oxygen generation plant was commissioned and started-up successfully by Noxerior's technical staff during the third quarter of 2015 and shortly afterwards the Saudi Arabian Mining Company (Ma'aden Gold and Base Metals Company) announced the start of trial production at Ad Duwayhi gold mine. This new mine is Ma'aden's largest and is a key part of the company's strategy to develop several new gold mine facilities in the central western region of Saudi Arabia, which contains much of the Kingdom's gold ore deposits.

At full capacity, Ad Duwayhi is expected to produce 180,000 ounces of gold annually (≈ 5.6 t/y). Commercial production is scheduled to begin in the first quarter of 2016. The PSA oxygen generation plant from Noxerior has been operating flawlessly so far.

Oscar de Groen

Oscar graduated in Mechanical Engineering at the Delft University of Technology, the Netherlands, with Heavy Diesel Engines and Gas Turbines as specialization.

He started his career as Project Engineer Advanced Engineering Engines for DAF Trucks N.V. in the Netherlands in 1991, but switched to the industrial gases industry in 1995, where he worked initially as Market Developer Floxal Membrane Systems and successively as Product Manager Membrane Systems Germany for Air Liquide GmbH, Germany.

In 1998 he became Managing Director of Noxerior in Grosseto, Italy, and has developed the company from a local workshop to an international player for the supply of non-cryogenic nitrogen and oxygen generation plants. He is (co)inventor of eleven international patents and three international patent applications owned by Noxerior.

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80 Years of Global Challenging Projects

Founded in 1936 by Agar Sorbatti and his husband Fernando Bonati, Spig was a pioneer company in cooling towers market. Over the years it has evolved from a family business to international corporate, which nowadays ranks among the leading global players in the industrial cooling sector, with a strong presence in over 100 countries of the world

Claude Souvenir
Vice-President Market Development, Spig SpA
Marianna Caputo
Marketing Manager, Spig SpA

In the early years of the 19th century, many process industries in Italy were established next to coastal areas or lakes and rivers to draw water from for their cooling needs. Those industries did not use cooling towers as it was more economic cooling by using the natural water resources. Later on, restrictions on the water usage and discharge came about with new legislation. Spig, as a pioneer company, responded to these market shifts and was already providing expertise and technology in cooling tower applications. In fact, it was sometimes back in 1936, when one of the first ten female engineers in the Kingdom of Italy, Agar Sorbatti founded Spig (which stands for "Società Per Impianti Generali") in Italy, together with her husband Fernando Bonati, an engineer as well (**figure 1**).

Originally, Spig was set up to design, build and commission cooling systems and cooling towers (**figure 2**).

In 1970s the Company business name is changed to Spig International SpA with reference to the internationalization strategy and expansion in foreign markets.

Between 2004 and 2008 the enhancement of the international presence take place and Spig becomes one of the most reputed world leaders in providing cooling towers, air cooled condensers, air fin coolers and service. In those years Spig set up subsidiaries in Turkey, Germany, Russia, Romania, UAE, India, Brazil and USA.

In 2010 Ambienta, a private equity fund invests in Spig acquiring a minority stake, while the third and the fourth generation of dynasty founder continue running the company.

In 2012 Spig establishes its presence in China and Korea, with plans for further growth abroad.

Over the years Spig has evolved considerably from a family business to international corporate which nowadays ranks among the leading global players in the industrial cooling business sector, with a strong presence in over 100 countries across the globe. Today, some 90% of Spig business is outside Italy, with a focus on the emerging markets.

Fig. 1 - The Spig founders: Agar Sorbatti and his husband Fernando Bonati

Fig. 2 – Spig cooling towers installed in the fifties of 20th century

The Group steady growth moves in three complementary directions: on one side the international expansion, on the increased share of the air cooled condensers and air fin coolers market, other then consolidating the service business offering even an online monitoring system for predictive maintenance.

Innovation

Spig cooling systems are complex projects designed thanks to the core competence of interdisciplinary engineers, technicians and experienced draftsmen coupled with the most up to date proprietary programs suitable for thermal and mechanical calculation. Spig uses the most advanced design softwares to provide customers with the most efficient and cost-effective solutions to their heat transfer requirements.

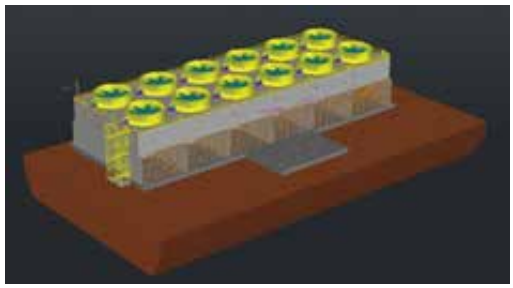

Fig. 3 – a) General arrangement ACC (Air Cooled Condenser) view; b) CT (Cooling Tower) design

Fig. 4 - Ecojet® nozzles installed inside a cooling tower

Fig. 5 - Futura® fill

Fig. 6 - H-Moon® drift eliminator

A dedicated team of experts is committed to studying, engineering, designing, manufacturing, installing and commissioning a wide range of specialized solutions, on a wide variety of project specific, such as noise emission and vibration control, plume abatement, seismic vibration, harsh environment, severe average temperatures and many more. The engineered solutions provided by Spig include complex 3D plant design, piping, controls, instrumentation, erection, commissioning & testing, because design makes the difference in each and any project (**figure 3a** and **3b**). Our approach is characterised by engineering excellence, flexibility and high regard for total customer satisfaction.

Even state-of-the-art internal components design is carefully studied and selected. At Spig R&D facilities cooling tower fills, drift eliminators and spray nozzles are conceived and tested, in order to meet thermal performance and environmental requirements. The facilities offer the capability of simulating a wide range of conditions to match all the possible actual applications among the most advanced in the industry.

Extreme attention is payed to the water distribution, enhanced by Spig EcoJet® patented nozzles, for an optimum uniform and efficient distribution, very important to achieve the best thermodynamic performance (**figure 4**).

Spig committment in products improvements, resulted in the following patents: the Futura® splash filling; the H-Mon® drift eliminator to prevent excessive drift; a major cause of equipment corrosion, environmental contamination and health & safety problems.

The Futura® filling increases sensibly the thermodynamic performances, even keeping unchanged the no-clogging characteristics and air pressure drop (**figure 5**).

Our R&D engineers motivated by a need for excellent performance, technical superiority, quality of final assembly and material are currently committed in the ongoing development of two new fills, to be introduced soon .

The cellular and H-Moon drift eliminators are developed to guarantee low drift rate from 0.001% to 0.0005% and low pressure drop. This innovative product has been successfully tested by third party laboratory and got the Eurovent Certification (**figure 6**).

A proprietary extremely sophisticated computerized Data Acquisition Systems, based on Unico®, a customized Unique Online Continuous Monitoring System, collect more than 75 instruments to ensure precise measurements of thermal performance data and any other useful characteristics (**figure 7**).

The future

Spig has been actively promoting energy optimization, carbon footprint reduction and power saving by using its advanced design technology and patented components that have been proven and tested in worldwide projects.

The Group future will be shaped by the consolidation of its

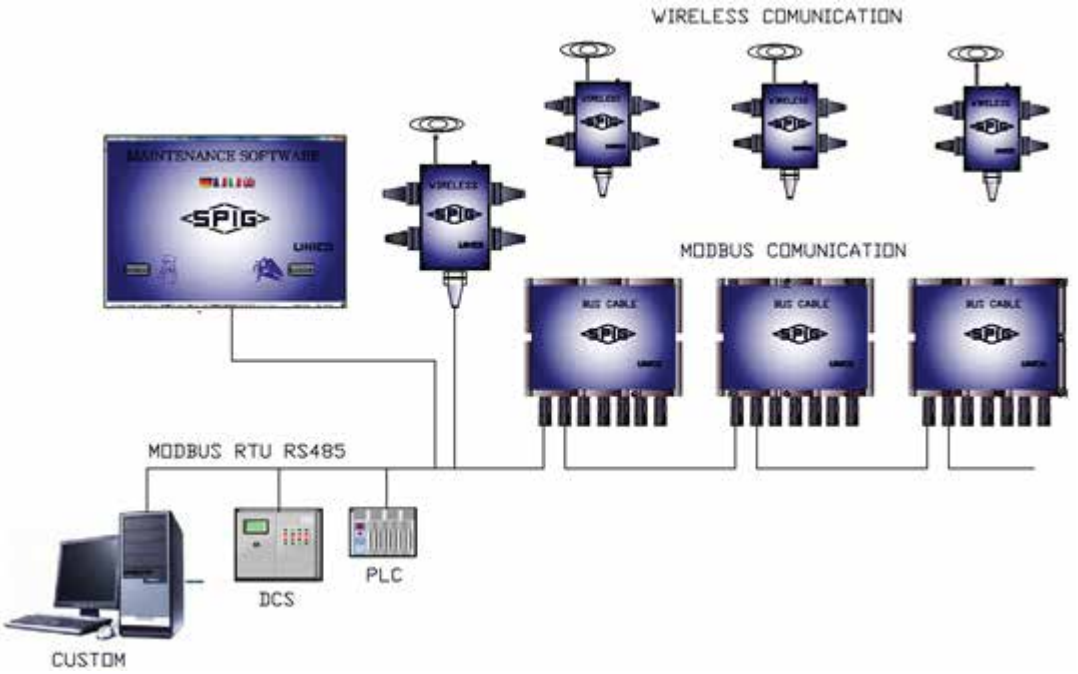

Fig. 7 - Unico hardware connection scheme

global market position as a leader committed in products and process innovations aimed at developing energy efficient, resources saving, corrosion free and environmentally friendly cooling technology.
Clients will benefit all together from less energy absorption from the ventilation group, noise abatement, optimization with a subsequent cost reduction in the steel structure, an improved water distribution in wet cooling systems. All these results may be achieved in a short payback period.

Water saving

The expected increasing worldwide energy demand will for sure boost dry cooling systems technology deployment, mainly in those regions suffering from water shortage. Given this future scenario, Spig is strongly committed to further enhance its market share in air cooled condensers, single row tube technology worldwide (**figure 8**).
Combined wet and dry cooling together with hybrid cooling towers are part of the development aiming at an optimized used of water.

Renewable energy

The renewable energy sector has gained an important market share in the recent years with wind, biomass and geothermal leading the segment (**figure 9**). In light of that Spig will further push its involvement in the sustainable segment.
In the medium-long term Spig will keep on growing in the upgrade of the worldwide installed cooling fleet, by introducing the most up to date technologies. In particular, Spig will further enhance its specific competences and references in the dry cooling business, according to environmental preservation requirements. Spig will over and over pursue new markets niches with high technological value, aimed at reducing the overall impact on the environment.

Fig. 8 - Air cooled condenser

Fig. 9 - Spig air cooled condenser for geothermal binary plant

Fig. 10 - Spig Unico online monitoring system

Fig. 11 - Unico installed on an ACC and a CT for predictive maintenance

Integrated monitoring

In parallel, Spig engineers will readily offer customized maintenance Long Term Service Agreements (LTSA) to improve the overall performance of the cooling systems. This service activity is supported by Spig Unico, a continuous online monitoring system, as a part of a package solution (**figure 10**).

Unico is aimed at assuring the global performance of cooling towers, air cooled condensers and air fin coolers, improving plant management, by processing parameters and equipment conditions.

Over the years the continuous monitoring allows future design review to guarantee reliable efficiency of the cooling plant and enhancing customer revenue, minimizing lost time production (**figure 11**). The Spig proprietary software is able to provide a predictive long term analysis of obsolete plants and avoids the detrimental impact on the performance.

Claude Souvenir

Claude recently joined Spig SpA as Vice-President Market Development as a new challenge in further developing the fast growing cooling activity of Spig. He is based in Arona, Italy.

Graduated Mechanical Engineer from the University of Mons in Belgium in 1979, Claude took his first major assignment for the Schlumberger Drilling Operations in the Middle East and Africa. In 1990 he joined Hamon, a world leader in cooling systems to promote the now reputed single row air cooled condenser totalling more than 25 years of experience in cooling technology worldwide.

Marianna Caputo

Marianna graduated in Political Sciences at the University of Pavia and then obtained a Marketing and Sales Management B2B master diploma at SDA Bocconi, in Milano. She has been working with Spig since 2001 as Marketing Assistant, supporting executives on projects directed at maximizing the company profits and developing sales strategies and marketing campaigns.

As Marketing Manager she is actually responsible for performing many duties such as Brand Development, Competitive & Market Intelligence and Public Relation, aimed at developing and implementing the long- and short-term marketing strategies and enhancing the Spig Group awareness and positioning on the global market.

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Costruzioni Elettrotecniche Cear's workshop

Responding to the Electrical and Automation Requirements of Industrial Plants

Costruzioni Elettrotecniche Cear's effort to anticipate trends in demand of industrial plants doing the electrical revamping of existing plants, the execution of specialized supplies and investing in R&D for acquiring new products certifications

Alessandra Ranno
Sales and Marketing Manager, Costruzioni Elettrotecniche Cear

In recent years, manufacturers of industrial plants have seen an escalation in the challenges posed by the continually changing global market, which requires entrepreneurs and corporate groups to adapt quickly to change; failure to do so may result in loss of market share and even disappearance from the industrial scene.

Ever since it was first established in the 80s, Costruzioni Elettrotecniche Cear has always followed a philosophy of anticipating trends in demand, staying on the cutting edge of the electrical technology and automation industry to offer its clients the highest levels of technology and quality in the sector. And so Cear was among the first pioneers in the field of logic relay to introduce PLC logic in industrial automation and suggest to our customers to go from synoptic panels to the use of Scada on industrial PCs, offering customized engineered solutions.

An additional challenge for Cear was multidisciplinarity: offering clients all-round consulting services integrating know-how in electrical technology, instrumentation and automation; a know-how which the company has accumulated and consolidated over the years, which is still difficult to find in companies in the field, that tend to be highly specialized in specific disciplines or types of production.

Our international, multi-sectorial heritage is another distinguishing element which has allowed us to grow and expand our knowledge hand in hand with our customers, who work in big international industries in a variety of different sectors and therefore have different requirements, allowing us to add to our technical and cultural know-how and qualifying us to participate in prestigious projects all over the world.

In these highly complex and competitive times, Cear's approach of going against the trend in the sector and opening up the company to new opportunities, on the market has been rewarded, allowing Cear to expand its sales network, move its head offices and expand its prospects for sale and production into new market niches.

Versatility in revamping projects

On the basis of these prospects, Cear fully expresses its capacity in revamping projects on existing plants. Cear modifies and adapts existing engineering documents, changing electrical parts which must be replaced or adapted for new uses and updating them with the latest new technologies. Our specialized technicians often find themselves attempting to revamp obsolescent equipment decades old, or having to make changes on-site, often facing unforeseen circumstances and unpleasant working conditions (**figure 1**).

Over the past seven years Cear has worked on a state-owned gas treatment plant in Egypt (shared with International Oil&Gas Company), modernising and

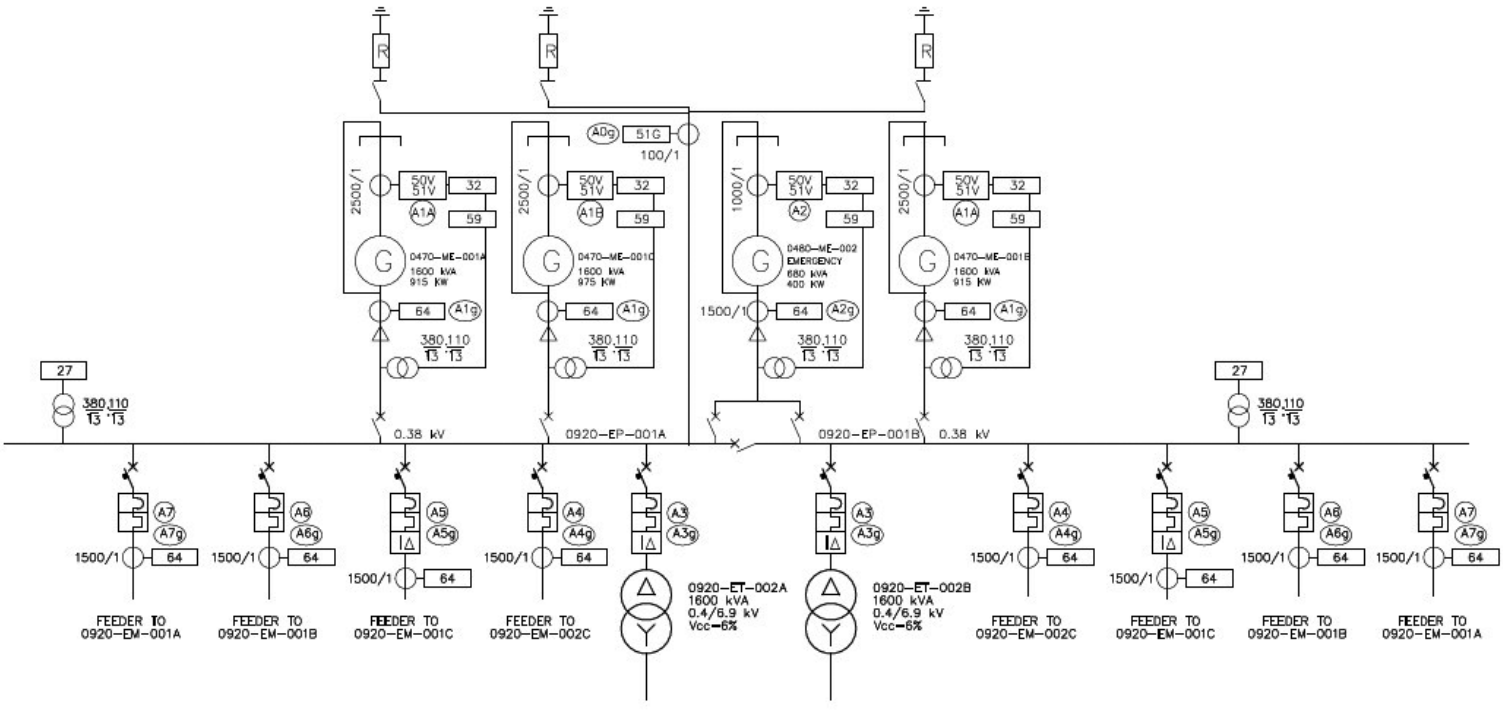

Fig 1 – A detail of the power study

expanding the complex. In 2008 Cear worked on the enlargement of some existing switchboards located in the main switchgear building.
The customer asked us to revamp equipment made by manufacturers who are no longer in business on the market, and specifically to:

- supply a new 500 kVA 0.38/0.4 kV transformer;
- modify the power rate (rating from 2.2 kV to 30 kV) and some existing motor starter drawers in two motor control centers;
- modify a power center to increase the current rating from 800 A to 1200 A, changing a number of cubicles and circuit breakers on incoming lines to adapt the structure of the cabinet, also modifying the main busbar.

These changes were not limited to replacement of electrical components, but were part of a much more complex supply in which Cear sent fully trained & competent personnel to perform a site survey and collect all the required data & drawings from the site in order to prepare a technical offer and develop the required engineering package modification and documents for review and approval (**figure 2**).
Subsequently, in response to the requested changes, part of the work was performed in Cear's workshops, but most of the more complex changes had to be implemented in the workshop of our Sales Representative, based in Cairo, and directly on site.
To complete the revamping and testing, Cear's personnel performed commissioning and start-up, and, as per the customer's procedure, field acceptance testing and a dedicated training program, complete with certificate of attendance for local specialized technicians in the plant.
In 2011 a second revamping project was performed on the same plant, in which Cear made further changes and expanded the plant's electrical structure, working on site once again to revamp electrical and mechanical equipment:

- a competitor's PMCC (Power Motor Control Center), with addition of two columns of cubicles to be utilized as a 1 MVA transformer feeder;
- two MCC (Motor Control Center), replacing a number of drawers required as motor starts and power feeders.

Following these changes, the client made an even more complex request: an overall protection relay coordination study and relay setting tables for the whole distribution system, including short circuit calculation, load flow calculation and motor starting analysis for medium and low voltage apparatuses. The aim of this work was calculation of the protective relays' set value, in order to ensure protection for users and obtain selectivity in the event of faults in the electrical network. The study pertained to the low and medium voltage switchgear and did not take generator protection into account; basically, the protection philosophy was based on the knowledge that faults or abnormal operating conditions can lead to:

- overloads;
- ground faults;
- phase to phase and three phase faults.

Fig. 2 – The PLC control panel for the job in Mexico

Know-how and multidisciplinarity in specialized supplies

Know-how is not only a matter of technical knowledge, but also includes a company's ability to adapt to the specific needs of a plant, dictated by specific construction standards, such as UL/CSA regulations, RINA maritime standards, or international rules such as Atex standards for construction of electrical panels in the presence of an hazardous area.
Cear has obtained certification to manufacture control panels listed by UL, which meets the applicable safety standards valid for the US and Canadian market. In 2013 Cear's familiarity with these standards allowed our technicians to supply power and control panels built to UL standards and an entire automation system for an air dryer package in one of Mexico's biggest petrochemical plants, recently constructed.
The air dryer package was composed of twin drying systems, one in operation and one on standby, with two dryer towers for absorption and regeneration of the operating cycle, controlled by two PLC panels (**figure 3**).
These power and control panels, complete of an touch

panel PC as HMI, manage the entire system through a redundant Siemens S7-400 PLC (Hot backup) and interfaces with the client's DCS by serial link. Furthermore, the PLC controls a package that is fully automatic and also implements all interlocks necessary to protect the plant and the personnel against operating faults or plant failures.

Cear's part of the project was not limited to construction of the panel, but included development of the engineering behind the automation system, development of the operating software for the process and on-site support during installation and commissioning of the system.

Fig. 3 - The prototype of Ex p substation

Research and development as investment in the future

Research and Development is definitely the best investment for an enterprise: useful for qualifying and expanding its range of production, and for meeting very high quality and safety standards. For Cear, Research and Development means keeping up with the new demands of the market. By the first half of 2016 the company will conclude a plan for acquiring the following product certifications:

- *QDP Power Center* ("Quadro elettirco di Distribuzione Primaria") certified with internal arc proof up to 100 kA / 1 s, obtained in 2015, as per 61439-1 and 61439-2 standards;
- *Containerized Transformer Substation* (model CTE-IAC) certified to withstand an internal arc of 20 kA / 1 s, according to IEC 62271-202 and IEC 62271- 200, obtained in 2015. The advantage of this application is its focus on "operational safety", even more important in yards and workplaces. Cear's substations are therefore designed and tested for Class AB (IAC-AB-20 kA / 1 s), Protection for Industrial Operators and for public service utilities in general;
- *Compact Transformer Substation* (CTS) as per Atex/94/9/CE regulations, with "internal over-pressure" Ex safety construction with protection mode "p", suitable for installation in mines in areas classified as Group I Category M2 and for Petrochemical and oil & gas plants in Group 2G with protection level Gb. The apparatuses making up the pressurization system are designed to guarantee maximum safety and continuity of operation, with automatic management of washing and maintenance cycles through a SIL 2 PLC;
- *12 and 24 kV MV junction box* as per Atex/94/9/CE rules, with Ex e safety construction and, to further improve safety, suitable for installation in mines in areas classified as Group I Category M2 and for petrochemical and oil & gas plants in Group 2G with protection level Gb.

Conclusion

This multidisciplinary, multi-faceted vision completes the picture of a company that has managed to build a very clear vision of its identity over the years: versatile, quick and dependable, offering clients products and solutions featuring exceptional levels of technology, safety and quality.

Alessandra Ranno

Alessandra has studied Languages and Communication, then graduated in Marketing& Communication at the University of Milan. She's in Cear since 2010 and she's in charge as Sales and Marketing Manager for coordinating marketing activities, sales team and implement international markets.

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Pumping Units for the ESPO Oil Pipeline

Termomeccanica Pompe asserts itself further on the Russian oil & gas market thanks to the award of a significant order for the state company Transneft regarding the East Siberia Pacific Ocean oil pipeline

Edoardo Garibotti
TM.P. SpA - Termomeccanica Pompe

Fig. 1 - ESPO (East Siberia Pacific Ocean) oil pipeline with its 41 pumping stations

In the first trimester of 2015, Termomeccanica Pompe was assigned an order for the ESPO (East Siberia Pacific Ocean) oil pipeline. The end user is Transneft, the Russian state company with head office in Moscow that manages the oil pipelines network of the country. The company was established in 1993 and handles today the largest pipeline system in the world with a total length of almost 50,000 km.

The 5000 km long ESPO oil pipeline is a pipeline system for exporting Russian crude oil to the Asia-Pacific markets (China, Japan and Korea) which connects Taishet to Kozmino through Skovorodino. It consists of 41 pumping stations, which include both the main stations (crude oil stocking and transport) and the delivery stations (**figure 1**).

Termomeccanica Pompe's scope of supply includes the design, manufacturing, testing and on-site supervision of the erection and commissioning of 21 pumping units divided as below:

- n. 8 + 5 main oil pumps with a flow rate ranging from 6000 to 9600 m³/h and a head ranging from 184 to 380 m. The pumps, BB1-type according to API 610 latest edition, are equipped with a double mechanical seal and a 53B system plan. The electric motors have a power ranging from 6000 to 12,000 kW and some of them are equipped with a variable frequency drive (VFD);
- n. 4 + 4 booster pump units with a flow rate ranging from 600 to 1250 m³/h and a head ranging from 90 to 110 m (**figure 2**). The pumps, VS7-type according to API 610 latest edition, are equipped with a single mechanical seal and a 13/66A system plan and are complete of suction tank. The electric motors have a power ranging from 250 to 500 kW.

Each pumping station is equipped with 4 main oil pumps working in series (3 in operation and 1 in stand-by), therefore the last pump is subject to a suction

Fig. 2 – Booster pump assembly at Termomeccanica Pompe La Spezia workshop

static pressure ranging from 7.5 to 10 MPa. One of the specificities of these machines stems from the fact that the pump casing and cover must be designed so as to house 3 different rotors that will allow a future variation of performance of the machines.

The booster pumps, on the other hand, are installed outdoors with temperatures varying from -60 to +40 °C. The specificity of these pumps originate from a tracking/tracing and insulating system in the bearings and seals area, system which allows to guarantee a correct operation both in winter with very low temperatures and in summer when temperatures can reach +40 °C.

The string tests of the various units will be performed at TMP's test center, tests which include the use of the job's motors, VFDs, seal system, lubrication units, hydraulic couplings and instrumentation.

Training sessions are also planned for Transneft's personnel. Such trainings are related to the main components of the various units and will take place at Termomeccanica Pompe's La Spezia headquarters during the phases of assembly and testing of the units.

The delivery of the first units is planned for May 2016 and the supply should be completed by end-October 2016.

Edoardo Garibotti

Edoardo, who graduated in Mechanical Engineering from the University of Genoa in 1984, has been Managing Director of TM.P. SpA – Termomeccanica Pompe (La Spezia, Italy) since its inception in 1999.

In such capacity, he has been a key figure in the design and implementation of the re-organization and re-launching of the pump business of this historical company which was state-owned till 1995.

Under his leadership, Termomeccanica Pompe has become an international leading manufacturer of engineered pumps for applications in the fields of power generation, desalination, water transmission and oil & gas, with a turnover that has grown more than five-fold with continuous profitability, reaching more than 110 million euros in 2015.

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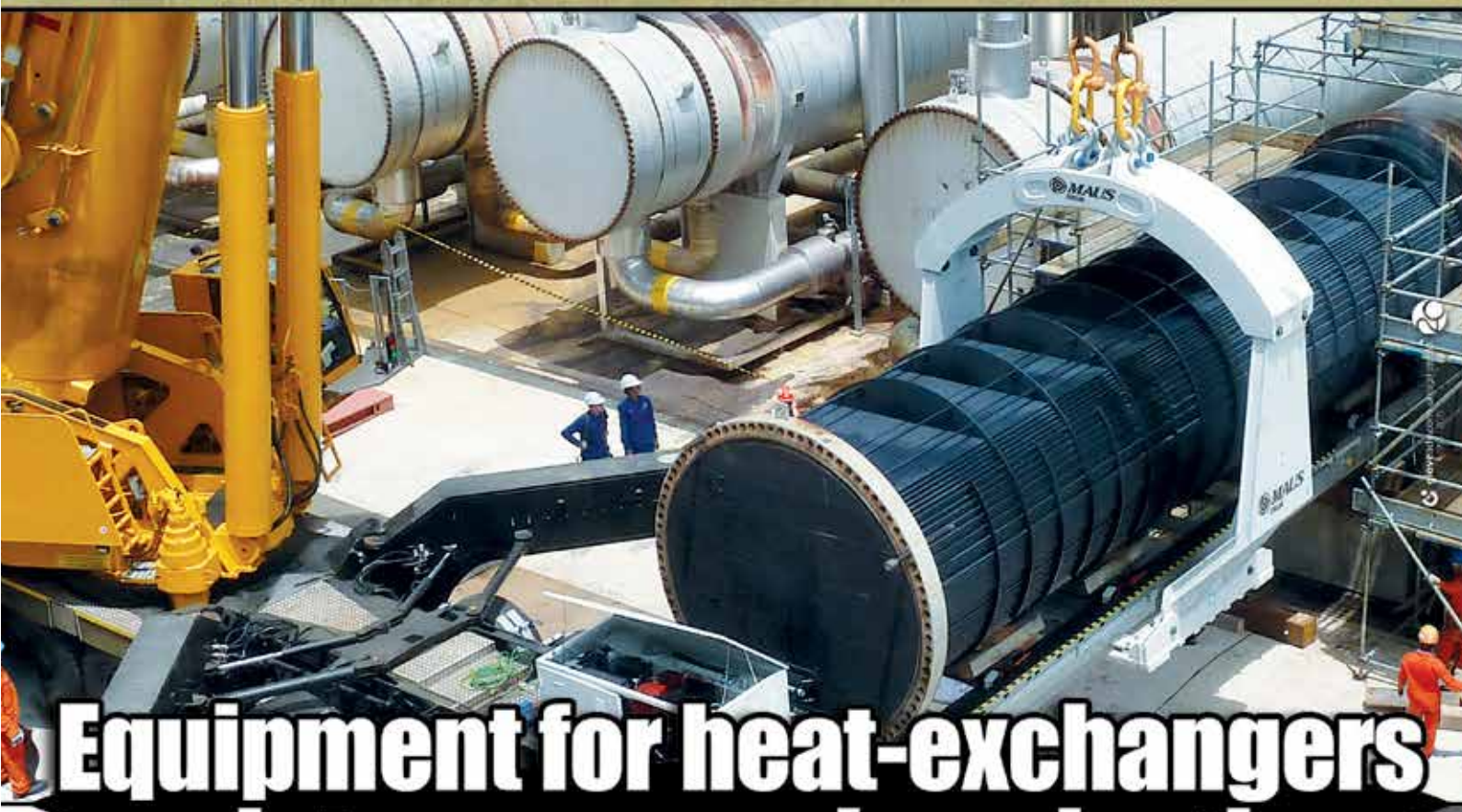

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Complete Blast Furnace Revamping

The joint venture of Ferretti International and Metprom is a key-player in the modernization plan of El Hadjar Steel complex in Algeria

Elena Ferretti, Ayman El Gindy, Andrea Scudeletti
Ferretti International

On July 2014, Ferretti International has been awarded an important contract for the complete revamping of the blast furnace No. 2 at Arcelor Mittal Algerie, within the Steel Complex of El Hadjar, Annaba.

Ferretti International was invited to bid directly by the mother Company Arcelor Mittal Luxembourg and awarded the contract on a lump-sum turnkey basis. The scope of work includes: demolition, disassembling, assembling, civil, refractory and erection work activities.

Ferretti International was assigned this important project thanks to its competitive price, a detailed short time schedule and a professional know-how. In fact, the project will be executed during the plant shut-down period and this is made possible thanks to the joint know-how of Ferretti International and Metprom, two international companies that rely on a long-standing relationship. Ferretti International is an engineering & construction company based in Dalmine (Bergamo, Italy) and specialized in providing engineering, construction and erection services for projects in the steel industry since 1903; while Metprom is one of the major engineering companies of metallurgical sector in Russia, founded in 1992 and with a deep experience in blast furnaces.

The blast furnace project is part of a larger investment plan that the Algerian State has decided to allocate. A budget of $ 400 million has been made available to revamp the blast furnace No. 2 and the relevant structures destined to the preparation of raw materials and agglomerated (PMA) with the aim to achieve 1.2 million tons of steel. The modernization plan of El Hadjar steel complex also provides $ 300 million for the construction of a new steel plant with a capacity of 1 million tons.

The non-profitability of today's steel complex of El Hadjar penalizes the Country, that already imports 10 billion dollars of steel products per year, representing the 80% of its steel requirements. Therefore, this investment plan will contribute to bring a deep improvement both to the Country and to the national economy.

The blast furnace revamping project is an important piece of the puzzle in this investment plan, as shown by the project's details.

The blast furnace No. 2 has a useful volume of 2200 m^3 with a hearth diameter of 9.75 m. The original blast furnace was done by Russian design and was commissioned in the 70s. In October 2015 it was stopped for the capital repair and the following actions must be carried out.

As regards the furnace:

- partial replacement of the belly casing and stack (cooled section);
- replacement of the cooling staves in boshes, belly and stack area;
- installation of thermal probes and new control instrumentation;
- installation of bellows-type tuyere stock;
- installation of double-chamber tuyere;
- replacement of working layer of the bustle pipe lining;

Fig. 1 – Location of the project

Building tomorrow: Ferretti International next steps

The winning formula of Ferretti International? Realizing industrial plants on a lump-sum turnkey basis following all the process: from basic design to the very last refractory lining installations, if any.
"Our strength lies in providing a turnkey package to the clients by proposing a single contact person who then becomes the single point of responsibility during the whole process", explains the founder Alberto Ferretti. This is also made possible by another cornerstone of Ferretti Group: strategic partnership with local and international companies, in order to reduce the learning curve and become more competitive in the chosen markets. In fact, Ferretti International can count on numerous partnerships worldwide, and on its presence in Mexico, Brazil, Africa, Middle East and Russia.
Moreover, thanks to this important project, Ferretti International has decided to invest in the Algerian market, and in 2014 established its fully owned branch office, that can now count on a staff of 350 people.

Fig. 2 – Blast furnace general view

Fig. 3 – Cast house: casting activity

- enlargement of the tuyere platform area;
- installation of compensators on straight run of the hot-blast line;
- replacement of the hearth lining;
- thin-walled lining of the blast furnace stack.

As regards the cast house:

- replacement of all runners and increase of section runner covers;
- installation of the flat floor and ramp to approach tuyere area;
- new hydraulic machines for two tap holes.

As regards the gas cleaning:

- Installation of a new water separator after the septum valve;
- Reconstruction of the water level control system

As regards the hot-blast stove:

- replacement of the combustion chamber lining and partial replacement of the hot-blast stove;
- checkerwork's top part;
- lining of the burner connections and hot blast with formed parts;
- installation of ignition burner and flame checkout instruments;
- reconstruction of the combustion air supply system with installation of new updated fans, arrangement of the air flow control.

Table 1 – Performances after the blast furnace No. 2 reconstruction

Output (t/day)	3500
Output (th/year)	1200
Coke consumption (kg/t)	480-490
Natural gas consumption (m^3/h)	up to 100
Blast oxygen content (%)	up to 26
Blast consumption (th Nm^3/h)	200
Blast gas output (th Nm^3/h)	260-280
Gas pressure under top (MPa)	up to 0.17

As regards the bin trestle:

- revamping of existing weighing hoppers;
- installation of coke breeze offloading equipment with installation of horizontal conveyers system.

As regards the slag granulation:

- reconstruction of the slag granulation units.

As regards the electric power supply, automated process control system:

- full replacement of electric equipment and automated process control system of the blast furnace, bin trestle, blast furnace gas cleaning, cast house and pump station.

Fig. 4 – Gas coke pipe

After the blast furnace No. 2 reconstruction, the performances indexes are anticipated in **table 1**.

Elena Ferretti

Elena has a Master's Degree in Psychology with a major in Communication strategies at the University of Bergamo. She joined Ferretti International in 2014 as Business Development assistant, developing sales strategies and marketing campaigns.

Ayman El Gindy

Ayman has a Degree in Civil Engineering and a Diploma in Project Management and International Cooperation. With 25 years of large experience in various projects worldwide and different roles, he has been appointed By Ferretti as Project Director for the revamping of blast furnace No. 2 in Annaba.

Andrea Scudeletti

Andrea has a Degree in Management Engineering with a major in Economic-Productive field. He began his career 11 years ago as Project Engineer for civil works and then became Project Manager of International projects. Last year he was involved in the revamping of blast furnace No. 2 in Annaba, as Project Manager.

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Boldrocchi recent supplies to outstanding international customers in Middle East

The oil & gas sector has been for many years one of the most significant markets for Boldrocchi Srl. The Company has acquired experience all over the world and has been supplying for decades all major EPC and end-users a wide product portfolio, amongst which, heavy-duty dampers and diverters, special purpose fans, blowers and air coolers.

Tailor-made products compliant with international standards and client requirements, product performance, reliability and high quality standards aimed at the customer satisfaction are the key factors, which enable Boldrocchi to be a major supplier in oil & gas. Continuous innovation, strong synergy among all product lines and highest attention to competitiveness are implemented both acting on the product value chain and on the supply chain.

Boldrocchi is in fact equipped with a 2 MW test stand for fans (one of the largest in the world), a one-to-one scale test bench for high efficiency pulse cleaning filter systems according to Saudi Aramco standards, test areas for large size heavy duty dampers, acoustic test rooms as well as technicians duly skilled to follow up outsourced fabrication and offer site service worldwide.

Confirmation of the value of our approach may be found in recent supplies of diverter & guillotine dampers successfully delivered to outstanding international HRSG (Heat Recovery Steam Generator) manufacturers: Qewc Ras Abu Fontas A2 project (Qatar), PDO Amal 1C project (Oman) and PDO Rabab Arweel project (Oman).

Fig. 1 - Ras Abu Fontas A2 (Qatar): diverter and guillotine dampers fully preassembled and tested in Dubai

Dampers have been designed in our headquarters in Italy with state-of-the-art computer-based tools (CAD, FEM, CFD etc.), taking into account from the very beginning the main key drivers for our customers such as optimization of the shipment and of the erection activities at site.

Core parts have been developed and manufactured in our factory while heavy carpentry works, as well as assembling and testing, have been localised abroad under continuous supervision from our technicians. Diverter dampers and guillotines, together with relevant hydraulic oil and air sealing systems, have been fully assembled and tested at workshops before delivery: critical parameter verification like operation time, geometric sealing and air sealing pressure have been duly performed at the presence of the client.

After successful testing and positive release the equipment has been dispatched to site as a single piece fully assembled or divided in a reduced number of sub parts minimizing the logistic and the installation related costs thanks to a high level of preassembling: the best compromise between transportation and erection cost is always sought.

The Company is organized in skilled project teams with consolidated project management experience and capable to follow the project development in the related aspects both in its workshop and at foreign fabrication yards, according to the most demanding quality standards required by these kind of projects.

For over 20 years production quality has been assured by ISO 9001 certification and since 2012 integrated with OHSAS 18001.

Fig. 2 - Amal 1C (Oman): diverter and guillotine dampers fully preassembled and tested in Oman

Fig. 3 - Rabab Arweel (Oman): diverter and guillotine dampers fully preassembled and tested in Oman

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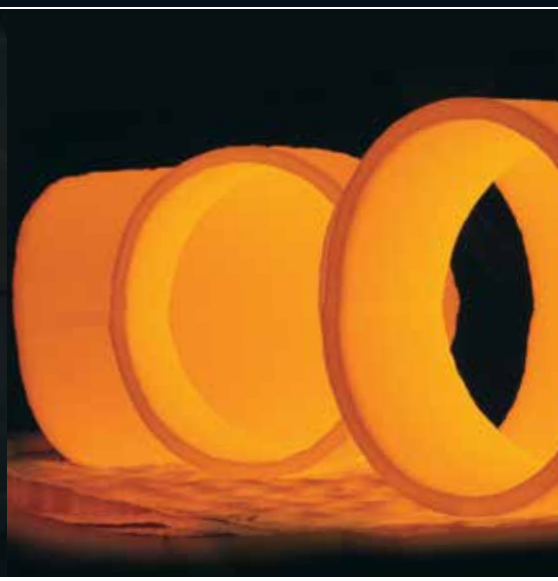

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CEG Elettronica Industriale designed, assembled and installed all the strategic AC and DC UPS for the control and feeding of Jeddah South Thermal Power Plant, in Saudi Arabia

CEG Elettronica Industriale SpA is a Tuscan excellence that designs, produces and commissions advanced electrical systems for industrial sectors for domestic and international markets. It was founded in 1965 as a manufacturer of electrical panels for medium and low voltage applications, first on crafts scale, then industrially, and then developing current AC and DC UPS production.

From the beginning has grown constantly, establishing itself both in Italy and abroad at the highest levels of the energy oil & gas, chemical, petrochemical and power sectors defying the repeated crisis that arose in the last 50 years of industrial history of our country. This growing trend is the result of the winning strategies adopted by the CEO Uberto Canaccini, who has been able to lead the Company to current levels, increasing the income over 10 times in the last 12 years.

CEG, by increasing its business and by awarding continuously larger shares of foreign markets, has been qualified as a preferred supplier of the main Italian and international General Contractors and end user, in the energy sector.

Despite the 80% of the product is exported to the customers of the main oil areas (Gulf Area, North Africa, Far East), the Company continues to be rooted to the territory where it was first established: Bibbiena (the Casentino capital, near Arezzo, Tuscany), where the Canaccini family is always involved in the social and territorial promotion.

CEG's success is due to the products diversification and customization that makes them flexible for use in various industrial applications. Moreover, we shall not forget the very efficient after-sales service that allows a first intervention anywhere in the world with highly specialized engineers.

CEG, not only wants to consolidate the current position, but also wants to keep its trend of continuous growth especially abroad in the areas of major industrial and economical development.

* * *

At the end of 2013, one of the most big thermal power station of the world for the supply of AC and DC UPS systems was awarded to CEG: the Stage-1 of the Jeddah South Thermal Power Plant, in Saudi Arabia. This power station is located near Mecca city and at the end of all stage will add 4.4 GW of power generating capacity. Whole phases will be five in total, the first three involve the installation of 650 MW each, the final two will add 1.2 GW each, with global amount of 4.5 USD billion. The EPC contractor involved was Hyundai Heavy Industries, one of the most famous and stronger not only in South Korea, but worldwide. Hyundai Heavy Industries was selected from the end user SEC (Saudi Electricity Company), that actually has in charge all the electrical power expansion of Saudi Arabia electricity. The construction of the plant means Saudi Arabia, the world's largest crude exporter, will continue to burn millions of barrels a week of oil for power generation for years to come.

CEG, qualified from long time for this project and strong of good relationships with both companies, due to a lot of past suppliers for which obtained a complete satisfaction and appreciation from Hyundai Heavy Industries but more from SEC , designed, assembled and installed all the strategic AC and DC UPS, for the correct control and feeding of the plant.

All design and construction of the AC and DC UPS systems required around one year of work at Italian facility in Bibbiena, working in strict contact and in team group with Hyundai Heavy Industries technicians, while all the activities for installation, supervision and commissioning till the final acceptance from SEC, shared in different phases, required around one year and a half. All the site activities have been followed with the best skilled technicians of CEG, that worked there with a proper team, exchange all the experience with the technicians of Hyundai Heavy Industries and SEC, but in particular with the last one, giving the maximum professional and technical support and getting a lot of appreciation.

General view of the Jeddah South Thermal Power Plant, in Saudi Arabia

The headquarter of CEG Elettronica Industriale at Bibbiena (Tuscany, Italy)

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Delta Engineering Srl was founded at the beginning of the 80's. The industrial market is its natural home with particular attention to the oil & gas and power generation sectors.

In 1992 it takes the first important step: Delta Engineering acquires Cosmec Srl, an Italian company certified ISO 9001, U-stamp, U2-stamp and S-Stamp. Thanks to this acquisition in terms of human resources and workshop equipment it becomes, in a short time, a leading actor in *pressure vessel* market in Italy.

In the middle of the 90's Delta Engineering passes on to a second phase creating the "Filtration Department". Water and gas treatments become like a pole of attraction, the Managing Board pursues the goal of being able to offer something more than a single equipment. That's why in 2000, after Siteco's company acquisition, Delta Engineering brings in-house engineering capabilities and know-how for process *filtration packages* destined to the oil & gas market.

In 2005 all the efforts bring to Delta Engineering the first important market expansion outside the Italian borders. EPC contractors, mainly in Europe and North Africa, become the main target customer for the Company. Both design and manufacturing capabilities, perfectly match the EPC requirements, and in a few years Delta Engineering obtains many registration in the most attractive areas, like the Arab Gulf countries, Russian Federation, Australia and South America.

Fig. 2 - Shell & Tube heat exchanger (80 tons)

Fig. 1 – Skid PSA unit

In 2012 Delta Engineering acquires Elfor Controls, an Italian company specialized in the production of pneumatic, hydraulic and electric valves actuators.

Service is the key word, *Excellent Quality + Customized Solution + Short Delivery = Total Customer Satisfaction* is the formula.

Later, in 2013, Delta Engineering continues the process of know-how enhancement breaking into heating transfer market. In less than three years the production of Shell & Tube Heat Exchangers and Indirect Water Bath Heaters sales revenues match the filtration equipment ones.

In more than 30 years Delta Engineering has proved its flexibility and capacity to anticipate and meet the market requests. With this same spirit we look to the future focusing on our background and know-how.

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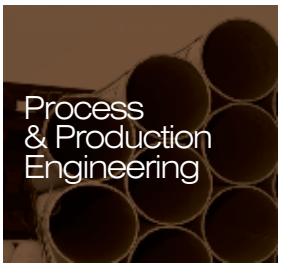

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The innovative application of the thermal seawater desalination plants within the industrial complex, at the purpose of production of desalinated water (distillate water) at ZERO primary energy cost through waste heat recovery, is also a method for improvement of the energy efficiency.

The application mainly consists in operating the desalination plants with low grade heat, normally or often wasted in the major process plants, pursuing the energy efficiency of the whole industrial complex. In this connection in the EU Counties, the method allows to benefit of the incentives granted by the national legislations regarding the energy efficiency following the directive 2012/27/EU. The method grants to certain extent, environmental benefit deriving by the reduction of the emissions connected with the energy saving, contributing to achieve the target the Kyoto Protocol; this additionally to the benefits for the environment inherent the creation of alternative sources of water supply.

The waste heat can be recovered in the main plants from various sources; for instance cooling circuits, process vapours, vents, exhaust flue gases, condensates, various hot waters and fluids with heat content normally not recovered due to temperature level and/or quantity inadequate for use in the process system or however not convenient. Thanks to the application, the desalination plants can be also used as dual purpose system, operating as cooling system of some sections of the main plant or partially surrogate a dedicated cooling circuit. Typical cases of heat normally wasted and recoverable at the purpose of the application are the cooling systems by air coolers, extensively used in the industrial plants.

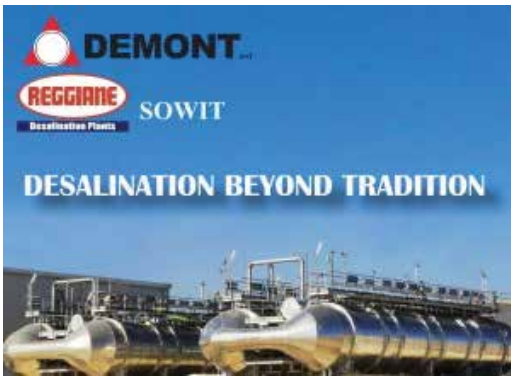
At the purpose of the application, the desalination plant configuration and design is studied and developed for each case in team with the users, according to the specific conditions and requirements, and to perfectly integrate the desalination plant within the main plant.

The application results in the production of distilled water for industrial use or eventually for potabilization, at lower cost than any other water supply source; this particularly for the production of demineralized water for process or boiler make up purpose.

The innovative application is in addition to the consolidated applications of conventional cogeneration, inherently energy-efficient, and therefore entitled to the benefits provided for by legislation on cogeneration.

The method offers an optimal solutions for the water supply management of the industrial complex, both in cost effectiveness and strategic terms. Actually, further to the very low cost of the water produced, it allows to prevent criticisms of the water supplies (limitation by local authorities, supply cost and treatments etc.), moreover the enfranchisement from external circumstances beyond control along the time.

This method for energy efficiency improvement can be applied for new plants with dedicated design, as well as to existing plants based on both applicable technologies MSF (Multi-Stage Flash distillation) and MED (Multiple Effect Distillation). This is the case of the existing MSF plant installed in a refinery in Italy, which has been modified to operate with waste heat recovered from a cooling system and upgraded by Demont. The same refinery is planning to implement a new energy efficiency project consisting in the installation a new dedicated desalination plant of significant capacity based on the study and predesign carried out in cooperation with Demont.



Generally, the distinguishing characteristics of the thermal desalination systems, at high technology content and specially designed to be integrated in the main complex, is the low maintenance requirements limited to the very normal of any plants, without need of periodic replacement of process components; moreover easy operation, top availability and reliability in critical feed water conditions, environmental impact almost nil. The well proofed construction materials used and the consolidated technical solutions adopted resulting from 40 years of experience, assure a plant life longer than 30 years.

In certain circumstances, the thermal desalination plants may be convenient also for treatment of brackish/saline waters other than seawater, and even to solve problems of effluent discharge.

Demont is in position to propose tailor made desalination plants of last generation based on consolidated thermal desalination technologies, in a wide range of capacities and performances, moreover special and non- conventional applications.

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Manufacturer, stockholder and supplier Raccortubi Group is providing customers with pipes, tubes, fittings and flanges in stainless steel, duplex, superduplex, 6Mo and nickel alloys from strategic locations around the world. It fulfils piping packages for *critical applications*, such as chemical and petrochemical plants, oil installations, power plants, shipyards, fertiliser plants and offshore platforms.

Over the course of the last three years, Raccortubi Group has undergone significant expansion, with the establishment of three stockholding subsidiaries in Brazil, Dubai (UAE) and Singapore, the acquisition of a second butt weld fittings manufacturer in Italy, the opening of a branch office just outside London, and the acquisition of a renowned stockholder for offshore platforms in Aberdeen (Scotland). These investments have all been made to offer customers added value; a single Group which can fulfil requirements both from stock and from production in the provision of complete packages, as well as single item necessities, to short timescales.

Manufacturing capabilities

With the acquisition of Petrol Raccord (**figure 1**) at the end of 2014, Raccortubi Group extended its butt weld fittings' *manufacturing range from ½" to 56",* almost without wall thickness limitations. In addition, an increasing part of production is dedicated to *special/customised fittings*, which are produced in accordance with customer drawings.

Thanks to its integrated production facilities, Raccortubi Group is able to guarantee not only the quality of the final product, but also short lead times resulting from adaptive planning and flexibility.

Synergy between stock and production

Within Raccortubi Group, pipes from stock are used as raw material in the manufacturing of butt weld fittings. Raccortubi stocks are then constantly replenished by the Group's integrated mills, giving them a consistent supply of fittings from which to fulfil customer orders immediately. The combination of *stockholding* and *manufacturing* activities allows for quick, cost-effective, comprehensive solutions for the most demanding fields of application (**figure 2**).

The *quality control throughout production* means that the highest standards are achieved and *fully-certified products* in accordance with the most stringent market requirements are available off-the-shelf.

Global distribution network

With stocks in Italy, Brazil, Dubai, Singapore and the UK, Raccortubi is able to supply pipes, fittings and flanges, for both projects and maintenance operations, quickly and efficiently.

The Group's latest developments, including last year's establishment of the *Raccortubi UK* branch office and the even more recent acquisition of Norsk Alloys (now *Raccortubi Norsk*), have allowed Raccortubi to extend its distribution network and therefore its value-added service provision. The Raccortubi Norsk warehouse offers direct distribution of piping components, cutting time and costs for customers in the region, whilst Raccortubi UK provides EPC contractors, fabricators and blue chip companies with a dedicated service for complex order management and project handling.

Fig. 1 - Manufacturing at Petrol Raccord in Italy

Fig. 2 - Raccortubi stock of pipes and butt weld fittings

IT Solutions and Infrastructures for Oil & Gas Production Optimization

Kuwait Oil Company increased the onshore 49 well's productivity from Emerson's integrated technologies and instrumentation

Kuwait Oil Company (KOC) has a challenging strategy to boost and sustain production at 4 MMBOPD by 2030. This has led to a greater focus on new technologies in order to enhance wells' productivity, reduce well down time and enhance reservoir recovery. Meeting this aggressive target would not be possible without the introduction of new, pioneering technology.

In order to increase recovery and enhance production, KOC needed to create a collaborative decision environment so the automation could provide real-time data availability, and right time decision support information for production optimization and reservoir management. The project of 49 wells included the upgrade of the oil field's power and IT infrastructure was executed by Emerson.

Emerson's solution included Rosemount pressure and temperature instruments along with Roxar multi-phase flow meters that capture real-time wellhead data to give the entire picture of what is happening in the field. ROC800-Series RTUs transmit the data to a nearby gathering center and the Open Enterprise Scada system receives, controls, and analyzes the data. This data is then integrated to the KOC collaboration center. Emerson's ROC800 and Rosemount instruments were installed along all the ESP (Electrical Submersible Pumps) wells in order to improve monitoring, diagnostics and generate automated recommendations for optimum operating condition of the pump.

The wide range of real time information from the wells is used to develop comprehensive workflows by KOC to help speed up their decision making. Users can view real-time alerts, consolidate advisories and assign tasks to relevant departments. This integrated operations approach enables them to effectively monitor and evaluate well performance, analyze reservoirs, avoid losses, and allocate production.

The benefits of the strategy can already be noticed thanks to Emerson's process automation and communication solutions. Enabling the workers to access real-time information and collaborate with other personnel, resulting in timely and effective production decisions.

Emerson's integrated solution brings the problems to the experts and the data to make decisions. oil & gas producers gain the ability to collaborate and share information in real time, address issues before they become major problems and maximize their field's productivity.

Results

- Enhanced oil production by enabling workers to access real-time data throughout the field for better decision making;
- minimized production shortfalls and reduced downtime;
- reduced delay time in response to alerts and alarms.

Daniela Bastico

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Pumps for Marine Offshore, Navy and Industrial Marketing

Pompe Garbarino has recently acquired new orders from Kuwait, UAE and China

Founded in 1932 Pompe Garbarino SpA has two factories in Acqui Terme (Alessandria, Piedmont, Italy) and, from 1994 a sales branch in Milan. The company maintains its core business in the marine, offshore and naval fields and has diversified its production facing also the industrial market.

Instead of adopting mass production methods, Garbarino has chosen the technological search in sophisticated and demanding fields. The attention is focused on the constant improvement of the products designed according to the customer's requirements and selecting the most suitable materials for the different applications. Garbarino always puts the customer's needs first thanks to the highly flexible approach and the capability to produce more than 450 different models of pumps and offers an excellent service to customers in terms of technical consultancy and after sales service ensuring the availability of engineers on site.

Garbarino has closed 2015 with the following figures: regarding the orders got over the year +7,1% compare to 2014 whilst the annual turnover has increased by 14% compare to the previous year.

Fig. 1 – "CN Series", chemical pumps according to ISO 2858 and ISO 5199

Fig 2 – "MU Series", centrifugal pumps according to EN 733 standards

Orders from Kwait

In Kuwait Pompe Garbarino is increasing the cooperation (started in 2012) with the contractor Alghanim International General Trading Company: for the project Sabiya OCGT2 Power managed by MEW (Ministry for Electricity and Water).

Garbarino will supply several vertically suspended line-shaft pumps and several chemical pumps according to ISO 2858-5199.

Orders from UAE

Two important orders arrived from the Middle-East: in the marine & offshore market Garbarino will supply two jack-ups for Eversendai Offshore (UAE), whilst in the industrial market Garbarino will supply several horizontal pumps to Fisia Italimpianti for the EPC company Hyundai Engineering Construction&Co.

The end user is Mirfa IWPP (Independent Water and Power Project) located in Abu-Dhabi (UAE).

Orders from China

Garbarino starts positively 2015 with two important orders from China:

- 2 self-elevating drilling rigs for Blue Ocean Drilling Ltd in Shanghai Waigaoqiao Shipbuilding;
- 2 jack-up barges for National Petroleum Construction Co. in Shanghai Zhenhua Heavy Industry Co.

Fig. 3 – "MU-L Series", vertical in line centrifugal pumps

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Project Management Consultancy Activities for Industrial Plants

Starting from the beginning of 2016, M2E Projects has been involved in the Al-Zour Refinery Project in Kuwait, designed to increase crude oil refining capacity to 5 million tonnes a year and achieve an output that conforms to Euro-5 standards

M2E Projects has been selected by Amec Foster Wheeler in order to provide staffing solutions for a Project Management Consultancy (PMC) activity for the new contract with Kuwait National Petroleum Company (KNPC) for a new oil refinery at Al Zour.

Completion date is expected in 2019, the new refinery will be designed to process 615,000 barrels/day of Kuwait Export Crude (KEC) or 535,000 barrels/day of mixed heavy crudes. Overall investment for the project is estimated to reach KWD 6.7 bn ($ 23 bn). The Al-Zour Refinery project (ZOR) will primarily supply 225,000 barrels/day of Low Sulphur Fuel Oil (LSFO) to local power plants.

It will be a key part of Kuwait's long term strategy, producing cleaner fuels to meet its electrical power generation growth and demand while adhering to the latest environmental standards. The project will enable the refinery to increase crude oil refining capacity to 5 million tonnes a year and achieve an output that conforms to Euro-5 standards.

M2E is actually involved in the packages 4 and 5 as follows:

- Package 4 consists of engineering, procurement, construction, pre-commissioning and assistance during commissioning/start-up/performance testing for the tankages, related road works, buildings, pipe racks, pipelines, water systems and control systems for the Al-Zour refinery. Package 4 will be completed by the beginning of 2019;
- Package 5 consists of the offshore maritime export facilities for the Al-Zour NRP. The scope of work includes engineering, procurement, construction, pre-commissioning and assistance during commissioning/start-up/performance testing for a solids pier, sulfur pelletizing/conveying, subsea outfall lines, a construction dock, an offshore sea island and a small boat harbor. Package 5 will be completed by the 2018.

Fig. 1 – Al-Zour Project location

Fig. 2 - Al-Zour refinery

Massimo Farina, M2E President and CEO, said: "This cooperation with Amec Foster Wheeler supports our vision strategy and it is also an example of our ability to implement our global engineering and construction services in order to execute complex projects for our client".

Marco Ungari, M2E Managing Partner, added: "This project is very significant for M2E, we can consolidate our experience in the PMC activities and at the same time we have the possibility to increase our employees skills; on the other hand, we will have the opportunity to continue our internationalization path having the opportunity to approach at an important market such as the Middle East market".

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