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ADVANTAGES OF MODULAR CONSTRUCTION FOR SMALL SCALE SRU IN HARSH CLIMATES

SULPHUR CONFERENCE 2014
3rd - 6th November, 2014

T. HEIM, B. MARES & V. SIMONNEAU
PROSERNAT
Paris, France



PROSERNAT

HEURTEY PETROCHEM • IFP Group Technologies

PROSERNAT

Mr Vincent Simonneau - Sulphur Business Development Manager

Tel. + 33.1.47.67.19.85 Fax. + 33.1.47.67.20.07

E-mail : vsimonneau@prosernat.com

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T. HEIM, B. MARES, V. SIMONNEAU
PROSERNAT
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Considering production decline of large quantities of Canada gas fields on one hand and the Russian government recent decision to actively work on reducing gas flaring and venting, there is an increased demand for modular small capacity Sulphur Recovery unit able to operate in extremely cold conditions and remote areas.

The present paper shows the advantages of modularization in place of on-site construction, and how it is particularly beneficial for these types of projects.

PROSERNAT advanced know how in modular fabrication has been applied on recent projects achievements for which PROSERNAT has supplied to its customer complete H₂S removal and recovery facilities composed of Gas Sweetening Unit, Sulphur Recovery Unit, Tail Gas Incineration and Liquid Sulphur Degassing. These projects involve several major design challenges regarding:

- Construction constraints: remoteness, extreme climate and lack of manpower in the implantation area impose the ability to manage prefabrication remote from the project site.*
- Logistic considerations: the design of prefabricated units with stringent transportation constraints is a challenging issue that shall be solved since the early stages of the proposal phase.*
- Extreme climate: extreme climate conditions (cold, blizzard) impose the development of an advanced winterization philosophy to guarantee plant performance and avoid major operation and maintenance issues.*

This paper will show into details how PROSERNAT handles all these challenges thanks to its extensive experience as an acid gas treatment chain licensor and a modular construction solutions supplier.

INTRODUCTION

An estimation show that in 2013 Russia has flared more than 17 billion cubic meters associated petroleum gas, i.e. about 25% of total associated gas production¹. Flaring reduction requires investments for associated gas treating and recovery as sales gas. Achievements are greenhouse gases emission reduction as well as financial benefits from associated gas marketing. A gas recovery rate of 95% (gas flaring rate 5%) is commonly set by Russian political authorities as a policy target for flaring. An associated petroleum gas generally requires sweetening and sulphur recovery facilities among other treatments (dehydration, dew point control, compression, liquefaction) before it is marketed.



Fig. 1: Russian Oil and gas industry²

As illustrated in Fig. 1, more than half of the Russian oil and gas production is concentrated in the West Siberia region, characterized by its remoteness and particularly harsh climate. Achieving a new gas treating project in these areas involves design, logistic and construction challenges that can be solved by selecting a modularization strategy.

THE CONCEPT OF MODULARIZATION

The purpose of modularization is to provide a completely prefabricated skid-mounted unit, thus minimizing site works. Each individual skid is generally designed as the largest transportable component of the facility. The assembly of several skids results in the building of one module. One unit may be composed of several interconnected modules.

Module construction is performed in a workshop or yard remote from the final project site and equipped with adapted manufacturing and personnel capacities.

The extent of skid pre-fabrication is typically:

- Structural steel works: base frames and secondary structure are assembled.
- All equipment are installed and connected.
- All piping and valves (manual and automatic) and piping accessories (supports) are installed.
- Skid interconnecting piping spools are adjusted during a workshop trial assembly - as extended as possible - and delivered loose.

- Depending on the transport limitations, tertiary structure - such as stairs, ladders, support gratings - are delivered installed in the skids or loose but ready for site erection. All instruments are fully installed and connected with instrument air and cables up to skids junction boxes. Cables are supplied laid down on their cable trays with extra length to allow final connection to the junction boxes when necessary.
- Power and lighting cable trays are installed; remaining site works consists in connection to end user electrical network.
- Final painting and insulation are installed.

Each individual skid is fully assembled and tested (equipment hydro test, piping hydro test and cables continuity tests). Interconnected piping spools and structural steel are adjusted during trial assembly.

Why choose a modularization strategy?

A new plant erection requires skilled manpower and adapted construction means. Depending on the project context, a modularization strategy offers numerous advantages versus on-site manufacturing.

The delivery of a complete skid-mounted module is a key choice in the following contexts:

- Remote areas, with complex access for construction means and lack of manpower.
- Extreme climates, where working possibilities are restricted by seasonal constrains.
- Lack of labor quality and availability.
- Offshore sites, where on-site manufacturing is hardly possible and plot area optimization is compulsory.
- Existing plants, where on-going operations are an obstacle to safe on-site manufacturing.

A modularization strategy is an asset with following project drivers:

- Shortened schedules, with requirements to market the products rapidly.
- Cost savings.
- Improved safety requirements.
- Tense project location or unstable political context.
- Limited work at site.

A successful modular experience involves the Contractor's ability to manage simultaneously various interfaces with the Client, the Detail Engineering Subcontractor and the skid Manufacturer. Each project is unique and has to be specifically tailored according to specifications and transportation availability. A modular construction offers potential schedule and investment reduction during project execution, as well as a high quality product with HSE advantages. Contractor's experience and know how are crucial to take full advantage of a modularization strategy.

According to transportation constraints and the unit capacity, a Sulphur Recovery Unit can potentially be delivered fully modularized. The equipment dimensions will reasonably allow a modularization strategy up to about 100 TPD of sulphur per train, and even above if transportation is feasible. Modularization feasibility should be studied case by case according to project context and drivers.

Substantial schedule reduction

The modularization strategy offers schedule reduction possibilities during the Front End Design Phase as well as during Project Execution. During Front End Design Phase, the schedule normally allowed to execution of detailed studies, preparation of technical requisitions, requests for quotation of equipment suppliers and EPC Contractor, as well as evaluation of offers and placement of orders is cancelled. When the technology is supplied by Contractor, layout and modularization studies are already anticipated during Basic Engineering studies. Combined Licensor and Contractor know-how allows an earlier Detail Engineering studies start-up, limits the rework and results in several weeks schedule reduction.

A 25% schedule reduction is usually achievable during project execution when modular construction is considered, as illustrated in Fig. 2. Most of the labor intensive tasks are achieved in a workshop or on a yard chosen for its favorable and efficient working conditions. The labor skills and density can be adapted

according to the execution phase requirements. Construction permits are not necessary and there is no interaction with on-going site operations, it greatly reduces owner's safety concerns. The major schedule reduction is obtained because the module construction can be performed at the same time as the construction phase on site (civil works for accessibility, foundations, piling). By the time the modular unit reaches the owner's site, the field is ready for module installation and connection with existing facilities.

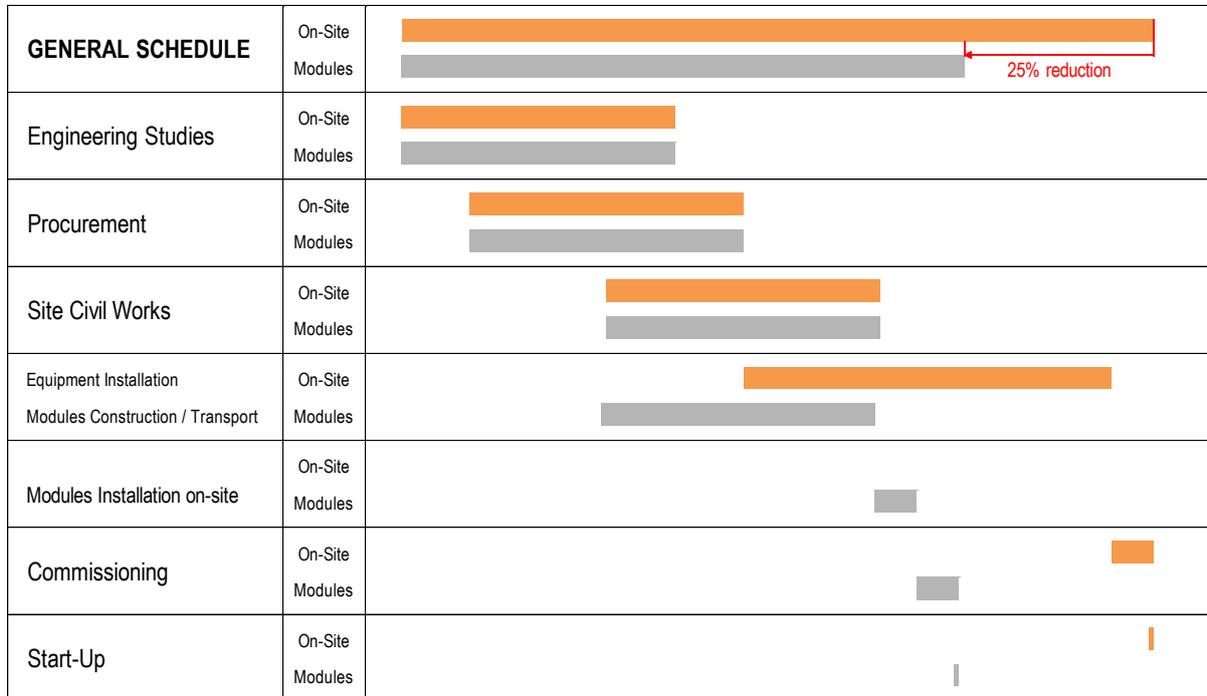


Fig. 2: On-Site Manufacturing versus Modularization schedule

Investment cost reduction

By maximizing workshop construction and assembly, full advantage is taken from an efficient and organized work progression. Higher labor productivity is achieved and supervision time with a trained and skilled workforce is reduced. With less site activities during construction, savings are also observed regarding campsite installation and manpower logistic.

Cost savings are also achieved on field, where a modular unit generally requires less plot area and simpler foundation than a similar stick built unit. Site preparation costs are therefore reduced. Owner's supervision efforts on site are reduced and can be dedicated to other critical aspects of the project.

Quality and HSE

Know-how and past experience are key points during workshop selection. Skilled and acquainted manpower supervised by Contractor's construction specialist's result in a high quality work without unexpected delays and cost exceeding. High quality testing and inspection are performed on workshop by skilled technicians with adapted facilities. Any piping or layout correction can be completed in ideal conditions during module workshop trial assembly.

Contractor takes care of HSE issues during workshop construction, and the potential impact on ongoing operation is reduced by less activity on Owner's site.

PROSERNAT advanced know how in modular fabrication has been applied on recent performed projects for which complete H₂S removal and recovery facilities have been supplied.

CASE STUDY: ARCTIC EP PROJECT

PROSERNAT was recently involved in the development of a new project for an existing oil field located in Russia, north of the Arctic Circle. The new stage of development of the field involved an increase in oil production capacity by bringing new wells online. The upgrade also involved using the associated gas as

sales gas, and therefore the addition of treatment facilities for H₂S removal to allow export gas specifications to be met.

For this purpose, PROSERNAT was selected for the engineering, procurement, fabrication and supply of one brand new Gas Treatment Plant composed of one Gas Sweetening Unit (GSU) and one Sulphur Recovery Unit (SRU).

Remote area, extreme climate

The remote location of the oil field was one of the key factors that led a modular unit selection. In addition to the lack of manpower, the extreme climate makes the working conditions rough and would have delayed on site manufacturing.

A huge logistic challenge had to be solved since the early stage of the bidding phase in order to transport the modules from the construction yard to the oil field site. The following route was chosen:

1. All the equipment, piping, instruments, valves, structure... etc was shipped to a yard located in Malaysia where the modules were constructed.
2. Once constructed, each individual skid was packed in a wooden box adapted to the rail and road transport limits (Fig. 3).

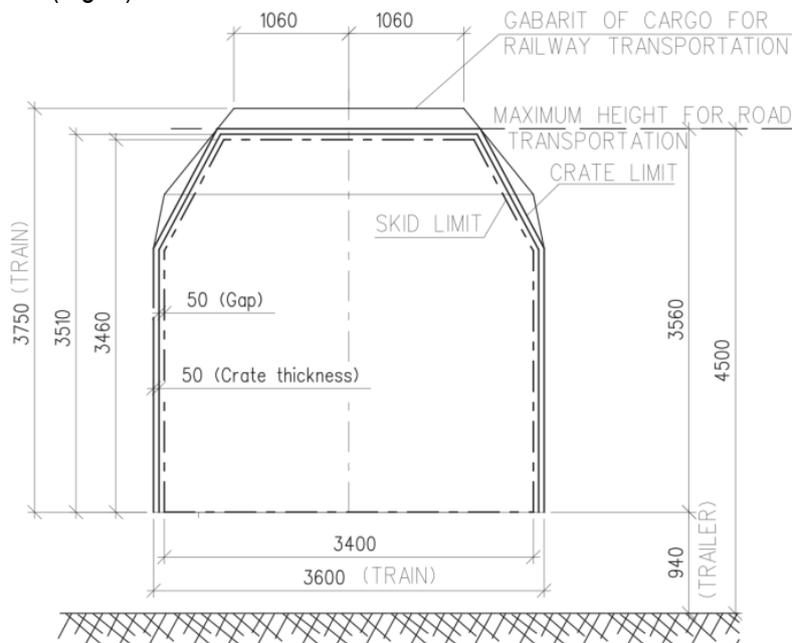


Fig. 3: transport gauge

3. The wooden boxes were then transported by road from the yard to the nearest harbor (Fig. 4).

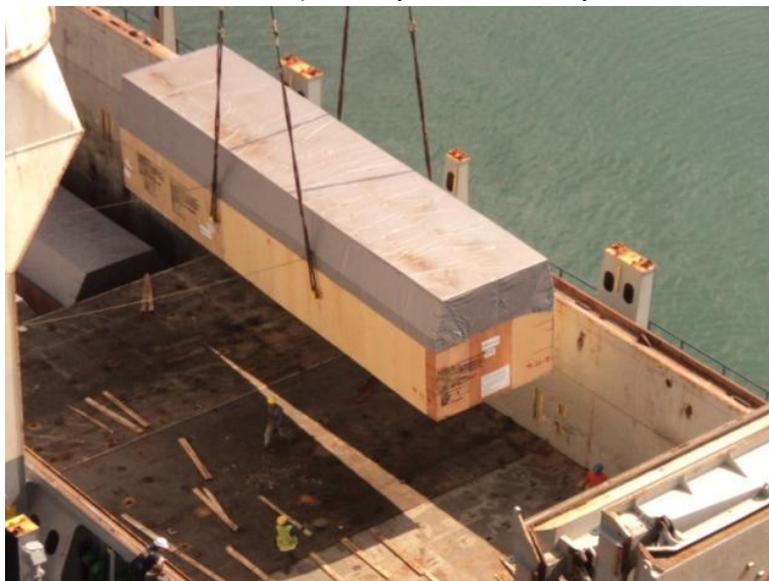


Fig. 4: boat loading

4. The transport from Malaysia to St Petersburg was achieved by boat.
5. The transport from St Petersburg harbor to the oil field nearest city was achieved by train (Fig. 5).



Fig. 5: railway loading

6. Each individual skid was finally routed from the nearest city to the oil field by road (truck).

Transport by road and by train imposed strict transport gauges that have been fixed during project bidding stage and never revised. The skid limit was set to 3 400 mm with x 3 460 mm height x 18 000 mm length. The maximum weight limitation by road was 37 tons per transported element. Some equipment have been dismantled from overloaded skids and transported separately in order to remain below the maximum weight limit.

The final transport by road to the site location was only feasible during the winter season (from October to March) when the roads are frozen and passable by trucks. Any delay in the modules construction schedule at the Malaysian yard could lead to missing the truck transport season and finally to a six month delivery delay to the oil field.

Construction

The SRU capacity is less than 20 TPD of sulphur considering 95% recovery performance. The resulting equipment, piping and valves dimension is adapted to a modular construction, nevertheless the skid dimension limitations are considered as challenging. The Gas Sweetening Unit includes 2 x 50% Absorbers able to handle turndown ratio down to 14% and one Regeneration section, with a solvent flowrate of 34 m³/h.

The Sulphur Recovery Unit is composed of 38 main equipment installed in 11 skids. The SRU modules weight 300 tons.

The Gas Sweetening Unit is composed of 43 main equipment installed in 12 skids. The GSU modules weight 330 tons. Amine absorption and regeneration columns are supplied in loose.

The whole Gas Treating Plant is composed of 23 skids and weights 630 tons.

All the equipment supply, piping, instruments, valves, structure... etc was shipped to the Malaysian yard where the skids were constructed (Fig. 6) and the modules erected for a trial assembly before shipping.

The refractories for Reaction Furnace and Incinerator were installed by specialists at the supplier's workshop and pre-dried in Europe before shipping to Malaysia. Materials are insulating and refractory concrete, no bricks have been installed. Prosernat believes that in such a project context, refractory workshop installation is the most adapted solution. Indeed, on-site refractory installation in arctic conditions faces qualified labor issues and cold weather constraints according to the season. It is generally accepted that the ambient temperature should be comprised from 10°C to 28°C during refractory casting.

Prosernat recommends the installation of refractory lining support during transportation as a protection from breaking. For that purpose, timber choring beams are installed inside the refractory lining as a support as illustrated in Fig. 7.



Fig. 6: yard construction

After delivery to the oil field location, the plant has been completely assembled under the supervision of PROSERNAT's construction engineers (Fig. 8).

The plant is erected on a permafrost ground: concrete pillars on which modules are laid down were dug deep in the ground. Pillars height above ground is 2000 mm.

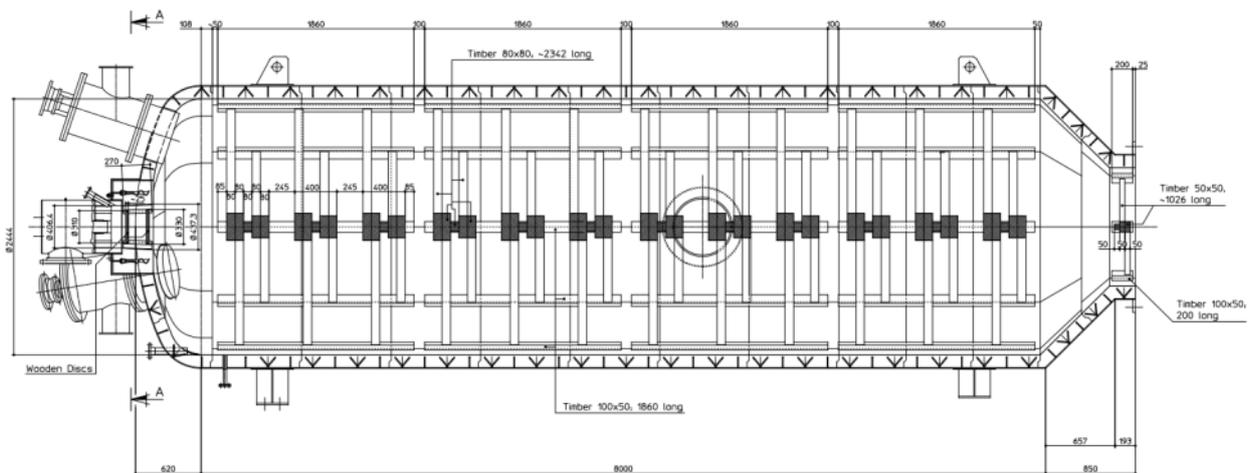


Fig. 7: typical refractory transportation support drawing



Fig. 8: on-site assembly

Design challenges

Transport limitations imposed severe constraints during basic process equipment sizing and 3D engineering studies. It was essential to freeze the transport gauge at the early stage of the proposal to avoid exposure to rework, cost impacts and delays.

Due to the permafrost ground no civil construction was allowed below ground, therefore the construction of a concrete sulphur pit was not allowed.

The pit was replaced by one skid mounted stainless steel degassing sulphur drum, installed at the lower floor of the module. The degassing drum dimensions are 2 000 mm OD x 4500 mm TL-TL, for a working volume of 12 m³.

The skids have been stacked on four floors in respect to the equipment differential elevations usually encountered in Sulphur Recovery Units, as illustrated in Fig. 10.

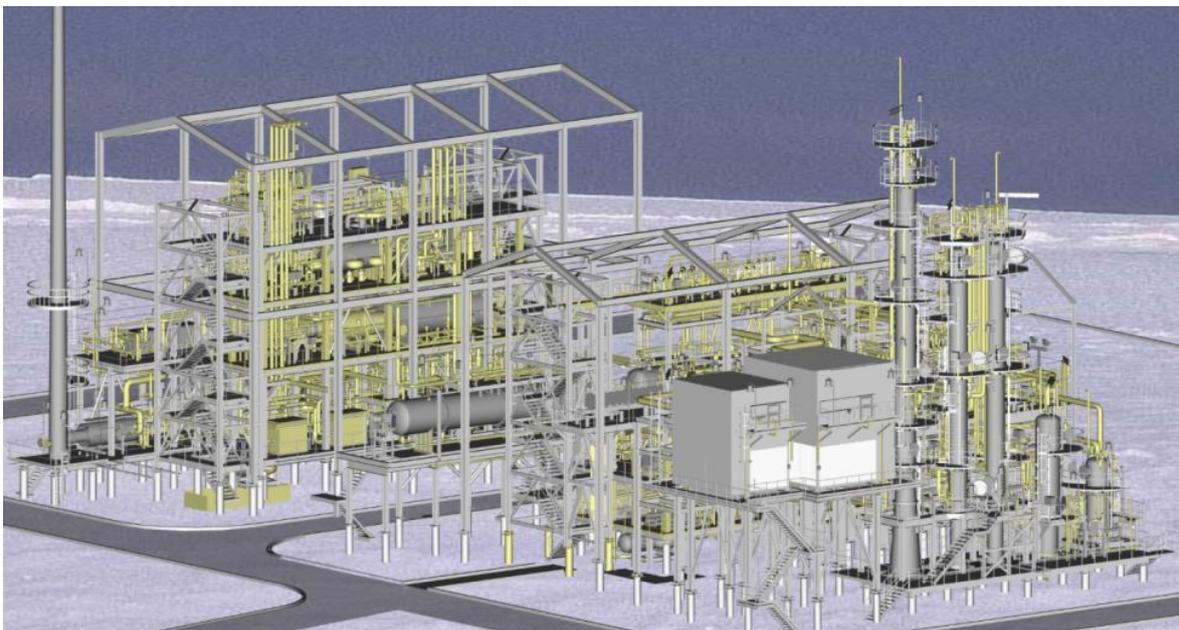


Fig. 9: GSU-SRU 3D model view

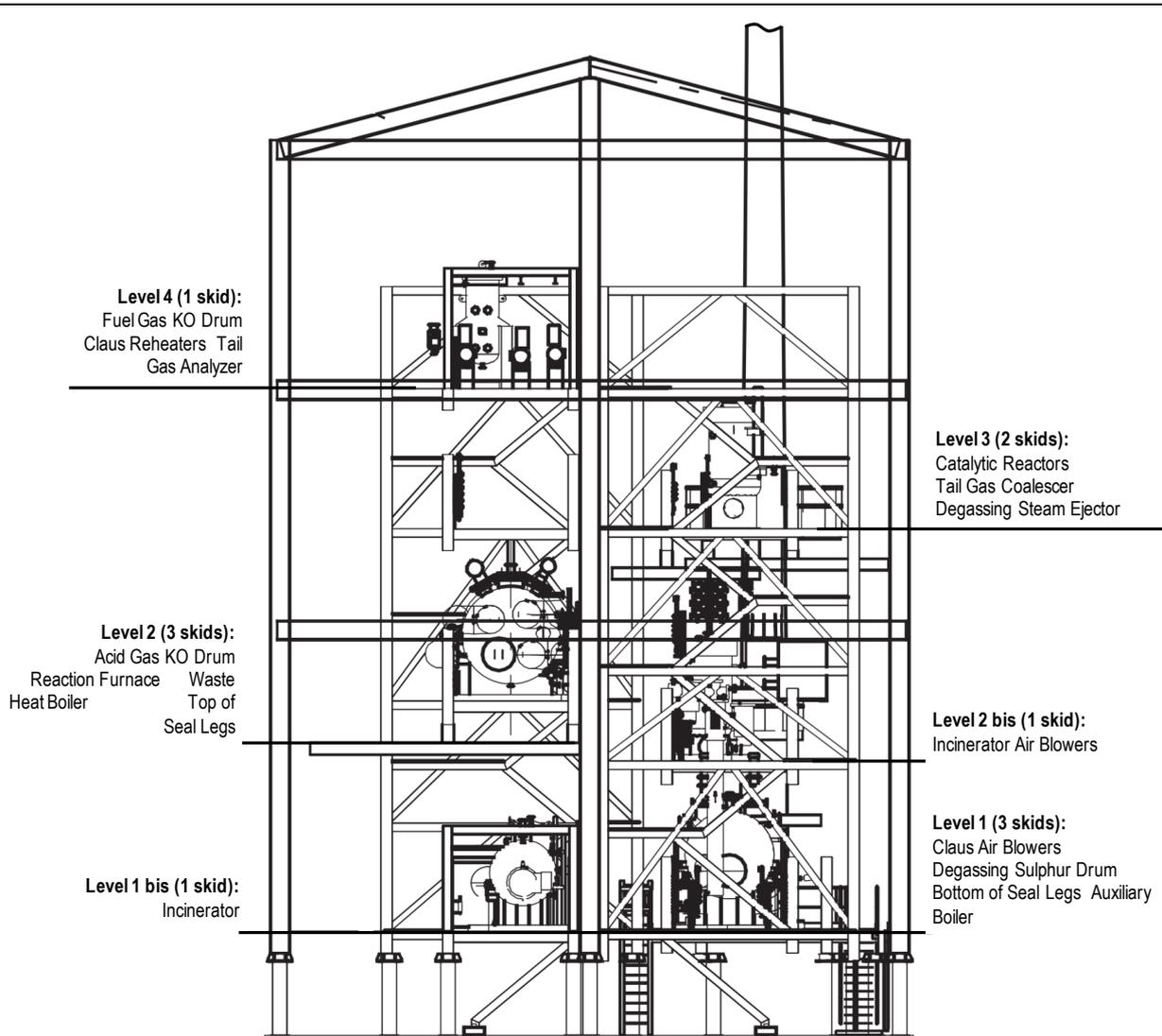


Fig. 10: SRU side view

Winterization challenges

The unit is exposed to extreme arctic conditions illustrated in Table 1.

Table 1 Project climatic conditions	
Absolute minimum temperature	-48°C
Absolute maximum temperature	+32°C
Average as per 5 most cold days temperature	-42°C
Average as per most cold day temperature	-46°C
Average as per most cold period temperature	-28°C
Annual average temperature	-4.9°C
Annual mean wind velocity	4.2 - 6.1 m/s
Maximum wind velocity	38 m/s
Snow depth	0.8 to 1.2 m

The extreme arctic climate (minimum ambient temperature is -48°C , maximum wind velocity is 38 m/s) exposes the unit to potentially high heat losses. Due to geometric considerations, small capacities SRU are more exposed to heat losses than high capacities SRU. Indeed, the ratio surface / volume of lines and equipment exposed to ambient air increases when the unit capacity decreases, amplifying the heat loss per amount of process gas for small scale SRU. This observation is illustrated in Fig. 11.

The Reaction Furnace and the Incinerator are especially exposed to heat loss due to high temperature in the combustion zone. The heat loss has been assessed for a range of SRU capacity considering the following conditions:

- Ambient temperature: -48°C
- Furnace chamber temperature: 1085°C
- Acid Gas composition (molar basis): 70% H_2S , 29.3% CO_2 , 0.5% CH_4 , 0.2% C_2H_6
- Weather shield, 100 mm shell gap

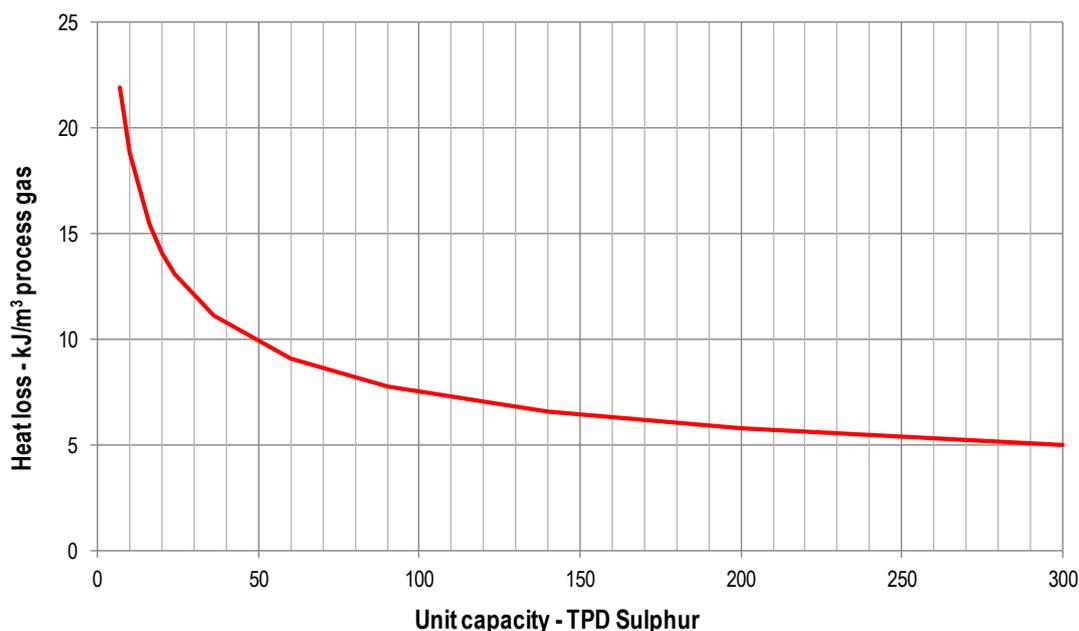


Fig. 11: Estimated heat loss (kJ/m^3 process gas) vs. unit capacity

For given climatic conditions, the process gas flowing through a 20 TPD SRU Reaction Furnace would be subject to 2.8 more heat loss than in a 300 TPD SRU Reaction Furnace. That ratio can roughly be extrapolated to the SRU main equipment and pipes.

An in-house calculation was performed to evaluate the heat loss applied to the gas from inlet battery limit to the Incinerator of a 20 TPD capacity SRU, according to climate conditions. Results are illustrated in Table 2 and Fig. 12.

Heat Loss (kW)	Extreme cold climate (-46°C , 38 m/s)	Temperate climate (38°C , 2 m/s)	Drop (%)
Lines	24.6	12.2	-50%
Reaction Furnace	36.0	33.9	-6%
Other Equipment	3.5	2.4	-31%
Supports	19.6	2.4	-88%
TOTAL	83.7	50.9	-39%

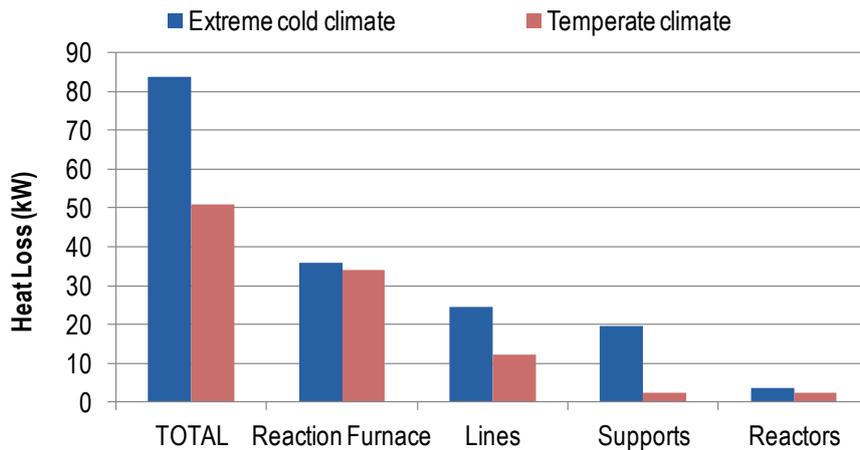
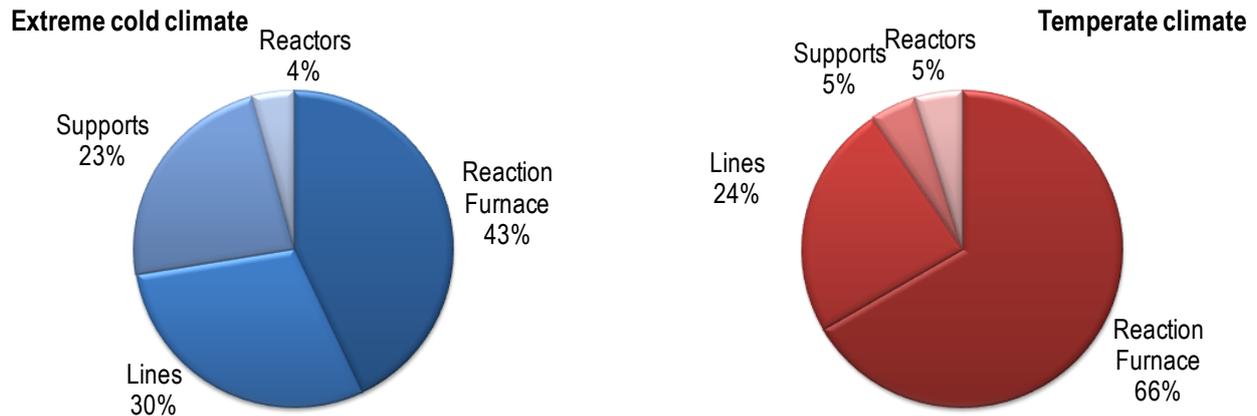


Fig. 12: Heat loss repartition

For a 20 TPD sulphur capacity SRU, the global heat loss is 65% higher with an extreme cold climate than with a temperate climate. The difference is particularly pronounced for the process lines and for the piping and equipment supports. Supports form thermal bridges between equipment and module structure and conduct the heat released from the core unit to the environment towards the structure. In other words, the module structure acts as a finned heat exchanger. This effect is emphasized when the wind chill effect creates convection on the steel structure.

Sulphur freezing point is 119°C: any locally solid sulphur aggregation could quickly degenerate into more extended plugging and potential requirement for unit shutdown.

The SRU modules were covered with wind breaker panels that purpose is to conserve the unit heat and suppress the effect of wind.

The panels act as a shelter that protects the unit from blizzard, heavy snow falls or ice accumulation responsible for cold spots.

The panels also maintain the heat released inside the module, thus increasing the ambient temperature around the equipment and reducing the heat loss. Still, it facilitates routine operation and maintenance.

Regarding the Reaction Furnace and the Incinerator, it is certainly forbidden to cover the shell with regular insulation material; otherwise the skin temperature would rise above carbon steel mechanical stress limit. A weather shield is provided and it was carefully designed to envelop the whole surface of the furnace to avoid cold spots (Fig. 13). It is equipped with adjustable louvers.

Particular care was taken during design phase to avoid cold spots and freezing at any point of the unit:

- Acid Gas KO Drum and Fuel Gas KO Drum are equipped with an external steam coil to avoid excessive water or hydrocarbon condensation.
- Each of the Claus Air Blowers is installed in a specific hood (acoustic enclosure) for winterization purpose. Enclosure is equipped with an air fan for inside temperature monitoring. The motor fan starts-up if the inside temperature rises above 15°C. In addition to that, the Claus Air Blowers are supplied with a special synthetic gear and bearing oil that allows cold start-up.

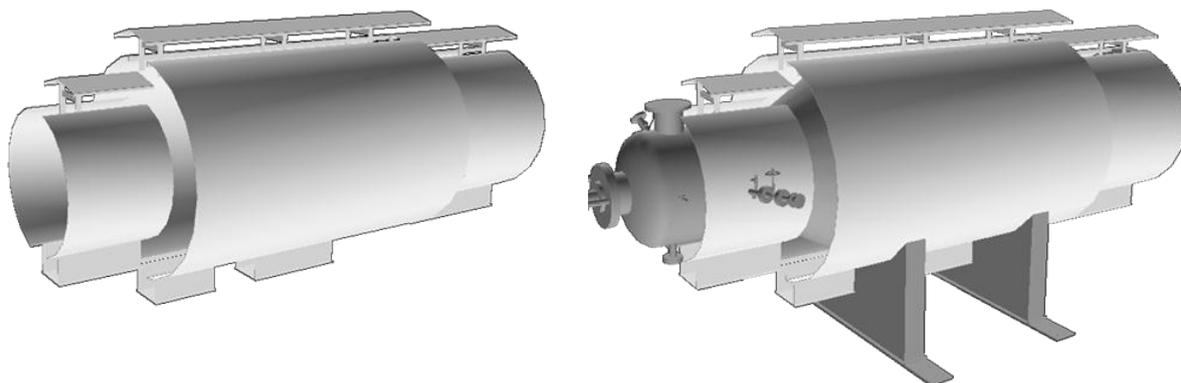


Fig. 13: Reaction furnace weather shield

- Catalytic Reactors are equipped with an external steam coil to compensate for heat losses.
- Tail Gas Coalescer is equipped with an external steam coil and a steam jacket at the lower part to avoid sulphur solidification.
- Degassing Sulfur Drum is equipped with internal and external steam coils to compensate for heat losses and avoid sulphur solidification.
- All process, utility and effluents lines including on-line equipment (valves, strainers...) are electrically heat traced and insulated.
- Orifice plate type flowmeters are replaced by vortex and coriolis type flowmeters. These are more convenient to trace and insulate.
- Level transmitters and gauges, bodies of control valves, on/off valves and PCV's, and pressure safety valves are electrically heat traced and insulated.
- Control valves actuators are provided with insulation blankets.
- All field indicators (pressure, flow, temperature) and all analyzers are installed inside heated enclosures.
- The air coolers of the GSU are fitted with an air recirculation hood adjustable with automatic controlled louvers and heated by a hot oil coil.

The winterization philosophy required the installation of additional devices and several design adaptation. The choice of a modular construction in an adapted workshop was an asset for installation of the electrical heat tracing, heating coils, insulation and all other winterization devices.

CONCLUSION

According to one project drivers and context, modularization can play a key role in reducing investment and schedule. Owner will fully benefit from modularization when the project location remoteness suffers lack of manpower, or when the extreme climate area restricts working efficiency. Most of future Russian associated petroleum gases flaring reduction projects are typically candidate to modularization. A successful modular experience requires Contractor's ability to manage complex design, logistic and construction challenges. Because small scale modular sulphur recovery units are particularly exposed to heat losses, advanced winterization solutions have to be provided to allow proper operation and performance guarantee. The modularization strategy has allowed PROSERNAT to manage this complex construction remote from the plant location and its harsh working conditions.

Strong from its licensor extensive know-how and numerous modular construction references, PROSERNAT is fully qualified to provide high quality solutions to its customers.

References

1. Central Dispatch Office of the Russian Fuel and Energy Industry (CDU TEK).
2. US Energy Information Administration