AN INNOVATIVE HYDRAULIC DRILLING RIG FOR MARGINAL FIELDS DEVELOPMENT: OPERATIONAL RESULTS AND FUTURE EVOLUTION

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ABSTRACT

Nowadays the Oil Industry is continuously asking for solutions to improve project profitability. In order to meet this demand, it is important to focus attention on technology innovation, a key factor in cost reduction and production enhancement.
As far as drilling is concerned, the last years have witnessed the big change, still ongoing, in the availability of innovative technologies.
This allows to face today's challenge: to be able to provide cost effective solutions for a variety of operating environments.
Onshore marginal fields exploitation or high risk exploration ventures are two areas that have drawn the attention of many Oil Companies and Drilling Contractors and led to the decision to design and develop a "fit-for-purpose" drilling rig.
Reduction in weight and dimensions as well as enhanced automation to minimize crew, is the focal point of the rig design.
The potential advantages for drilling and work-over operations are great, especially for the development of extreme areas which pose huge technical and economic challenges.
This paper presents the criteria adopted to design a new rig, the G-125, specifically engineered to exploit marginal fields and shows actual results achieved during a 30 months of operations.
The paper also illustrates the future evolution and applications, which include the construction of a more powerful version of the rig and offshore utilization of the "G" series.
This could range from work-over rigs on fixed structures to installation on semis or multi-purpose vessels for light work-over or slim hole drilling in deep water environments.

DESIGN PREMISES FOR A "FIT FOR PURPOSE" DRILLING RIG

Considering domestic operations in Italy, a remarkable number of small prospects have never been exploited because of the limited reserves expected.
Typical reservoir size is up to a few hundred million cubic meters of gas; vertical depth usually ranges from 1200 m to 3000 m and expected production rates generally range from 20,000 to 70,000 S/m^3 per day.
Economic evaluations show that the profitability from the exploitation of these prospects was critical for Oil Companies, mainly because of the critical low profit margins obtainable with standard rigs and technology.
The Drilling Contractor has, at the same time, the necessity to garrison this particular market area to avoid the proliferation of other competitors, preserving and improving the know-how acquired in the past.
In this tight scenario, operating times and daily rates are fundamental for achieving competitiveness; "capex" expenditures are often the discriminating factor that drive the decision weather to drill/complete or not a prospect.
Having assessed these requirements taking also into consideration the number of potential prospects that may benefit from the decrease of the bottom line "capex" and improve profitability for an Oil Company, producing at the same time an added value for the Drilling Contractor, a new project was set-up with a partial funding from the European Community within the framework of the Thermie program.
The driving objectives of the project were:

- Targeted drilling cost reduction for the above outlined scenario of some 30%, depending on well logistics and geometry.
- Fast rig move/rig up-down.
- Reduced number of loads.
- Reduced crew.
- Reduction of the global environmental impact (waste, noise, size and civil works).
- Integration of services (i.e. cementing, casing make up).

Innovation was necessary not only to reduce dimension and volume related to the drilling activity, but also to satisfy the requirements of high mobility and reduced personnel.
The project was undertaken on a step by step approach, consisting of the following stages:

- Setting up a dedicated project team, which include an Oil Company (Eni-Agip), a Drilling Contractor (Saipem) and a Rig Manufacturer (Soilmec)

- Selection and evaluation of a suitable hydraulically driven drilling rig.
  The choice fell on a compact drilling rig, developed by Soilmec (involved in construction of water wells rigs), whose design was technically sound and proven since they have been involved for a long time in severe environmental situations, ranging from desert to arctic.
- Modification of the existing rig to upgrade it for oil field operations.
  Conventional oil-field equipment from an idle drilling rig was adapted to the water well rig, in order to keep investment to a minimum while proving the applicability of the original concepts.
  This first rig was called G-100 and was intended as the prototype from which the engineering required to design the G-125 rig is derived.
- A field testing, which consisted of drilling three wells (2 verticals and 1 deviated), was undertaken to assess the reliability of the basic technological aspects and to obtain indications of equipment efficiency and limits, as well as to draw up of specifications for the new purpose designed rig.
- Based on data gathered from this "rig-appraisal" campaign, a new rig, the G-125, was designed in order to fulfil the long term commitment in exploration/development drilling activity over the prospected scenarios.

The G-125 rig, which was constructed by Soilmec and operated by Saitre (a consortium constituted by Saipem and Trevi, the head group company of which Soilmec is a branch), began the drilling campaign in July 1996; after a testing phase it is presently drilling a series of onshore wells in different parts of Italy.

MAIN TECHNICAL FEATURES

The main features of the G-125 rig are briefly described herein:

- The rig is hydraulically driven and has all its components in a self-contained configuration that is never disassembled.
  Hydraulic powering was preferred because of it's capability to operate more easily and smoothly the functions of the rig ("push'n pull", substructure and mast self-erecting, pipe handling, drill-string rotation, etc.).
  The hydraulic system is compose by following main group assembly:
  - independent hydraulic power unit realized by a special container complete with electric motors, hydraulic pumps, heat exchanger, safety devices, filters and ancillary.
  - hydraulic cylinder for pull up/down inside mast structure.
  - hydraulic motor series and cylinders complete with all control devices to move all services for complete rig functionality.
  - independent hydraulic power pack air operated fitted for rising mast and piston positioning.
- The drilling rig is mounted on a 3-axis semi-trailer, weighing 42 t.
  A hydraulic cylinder operates the telescopic mast, resulting in substantial reduction in weight and height, and making transportation possible on standard road loads.
  When on site, four hydraulic pistons lower and raise the substructure to proper height (up to 6.1 m) directly from the trailer.
  Special distributor provided with flow compensatory in each section to avoid out of balance controls the movement of the four pistons.
  Another couple of pistons erects the mast; both operations require some 45 minutes.
  Rig up/down operations are consequently much easier and faster, compared to a conventional rig; all hydraulic control lines being already in place and connected.
  The mast is self-standing and does not require any wind-bracing.
- The entire system (substructure and mast) is rated for 136 t static load capacity.
  A special feature provided by the hydraulic system allows for a "push-down" action equivalent to a force of 20t.
- Four hydraulic motors drive the top drive, capable of a torque up to 3.600 Kgm at 60 RPM.
  During pipe connections, extending and tilting braces allow the top drive to connect the single joint from the mouse hole, then rise and connect it to the drill string.
  The top drive is also equipped with a special device for casing lifting and make-up: this makes the rig capable of independently perform casing jobs.
  The casing can be run in and filled with mud at the same time.
- Another innovative aspect is provided by the vertical pipe racking system (any pipe can be stored and transported in containers from base to well site) along with the jib crane fitted to the rig.
  A total of 12 containers (each containing 18 x 3½" range 3 drill pipes) is placed on the ground around the drill floor, enough to drill in excess of 3000 m deep.
  The mast is equipped with a cable and sheaves system that allows to double the stroke and the speed of the hydraulic piston.

The rising length provided is 16 m, allowing to handle range 3 casing and drill pipes. The resulting maximum rising speed is 1 m/s.
The rig is also arranged with automatic hydraulic slips and automatic hydraulic power tongs.
Operated from driller's panel, to make-up and break-out from 2 3/8" drill pipe to 8" drill collar, consisting of:

- double hydraulic rotating clamps to close drill pipes and collars joints, max. torque 8.000 Kgm;
- set of hydraulic cylinders for removing the power tongs from well center and parking out;
- vertical hydraulic cylinder to suspend the power tongs at variable position.

Two persons are normally required to handle tubular.

- Four totally soundproof diesel-electric power generators providing a continuous total power of 1600 kW provide the power.
  Furthermore, the hydraulically operated rig does not require standard brakes, which are typically the most difficult source of noise to eliminate.
  As a matter of fact, the maximum combined noise level measured at rig site during operations is 62 dB.
- The rig is equipped with:
  - 13 5/8" x 3000 Psi diverter spool
  - 11" x 5000 Psi annular BOP
  - 11" x 5000 Psi single blind/shear ram BOP
  - 11" x 5000 Psi dual ram BOP
- Three pumps, two of 1000 HP and one of 600 HP, provide optimum performances in all drilling operations.
  The 3rd pump is normally kept as back up (thus minimizing down time) as well as for cementing operations.
  For these latter operations, a bulk cement surge tank and two batch mixer tanks (18 and 7 m3 respectively) are available.
  The rig can independently run cement jobs.
- The mud system is fully integrated into the rig equipment.
  Pit system consists of 3 mud tanks (theoretical total mud volume is 122 m^3) plus an additional 50 m^3 tank, that can be used as a cement/water tank.
  The mud cleaning system includes two dual BRANDT shale shakers ATL 1000, a degasser and an on-line M/V CD 350 centrifuge for fine cuttings.
- Automatic drilling can be easily achieved thanks to the hydraulically based design.
  Constant WOB or, alternatively, a pre-set rate of penetration or a constant torque can be selected by the operator from the control panel.
  The driller controls that set parameters are properly working; alarms can be set along with automatic stop of drilling operations in case of anomalies.
  In case of stuck pipe, pre-determined values of over-pull and/or torque prevent accidental damage of the drill string.
  A special pressure balanced feed system senses the amount of down feed at any instant depending on the formation the bit is drilling and adjust feed automatically and instantly.
- A complete set of sensors control all essential rig functions.
  The on-line drilling parameter data acquisition system displays real time information on the drilling console in the driller's cabin and manages the alarms.
  Drilling data are also displayed and stored on PC's in the tool-pusher's office. Hard copies of the drilling parameters may be produced from playback or real-time data. The same set of data may feed the Company's drilling database in real time.
- The minimum rig crew consists of 10 people for drilling operations: 4 daily (1 tool-pusher, 1 mechanic, 1 electrician, 1 roustabout), and 2 shifts of 3 (1 driller, two assistant drillers).
  Presently the rig operates under a contract that includes extra services (cementing and casing make up).

MAIN ADVANTAGES

Main advantages featured by the G-125 accomplish with the aforementioned project requirements.
The technical advantages provided by the G-125, compared with conventional rigs of same potential, may be summarized as follows:

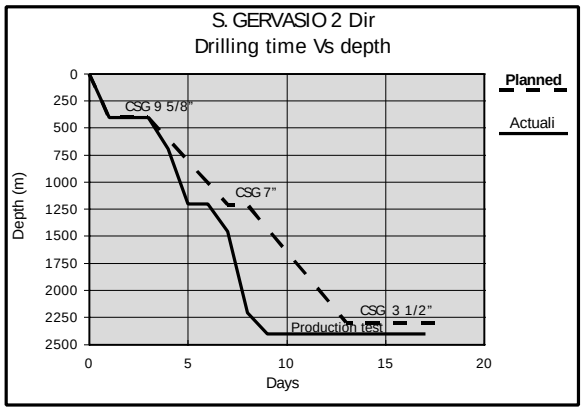
- Rig-up and rig-down, as well as mob and demob time, is reduced by some 35-40%. Assuming a 100 km move, the G-125 needs less than 6 days to complete rig-down, moving and rig-up on the new location. This compares to the average 8 days required by conventional equivalent rig.
- About 28 standard truckloads are required to complete moving, compared with 40 loads necessary for

an equivalent traditional rig.

- The layout of the location can be reduced to 30 m x 30 m, thanks to the reduction in the height of the structure.
- The vertical pipe racking system allows for pre-packed pipe transportation from the base to the well site. This reduces the land space required and the inspection and preparation times at the rig site (casing and tubing running) to a minimum.
- The hydraulic top drive works satisfactorily and gives good performances during fast drilling.
  The tripping times have been cut to a minimum by using its back reaming capabilities at the best.
- Hydraulic regulations generally allow for fine adjustments, constant maintenance and more accurate measurements of drilling parameters such as weight on bit and torque.
  Some tests were made on automatic drilling capabilities with excellent results even in highly deviated holes (over 50°). While tripping out in back reaming the possibility of accurate maximum torque and over-pull pre-setting reduces stuck pipe problems occurrence due to excessive over-pull.
- Extensive automation and enhanced control opportunities optimize the crew composition: in contingency it has been experienced that one only skilled person is capable to run in hole with drill pipe.

FIELD EXPERIENCE

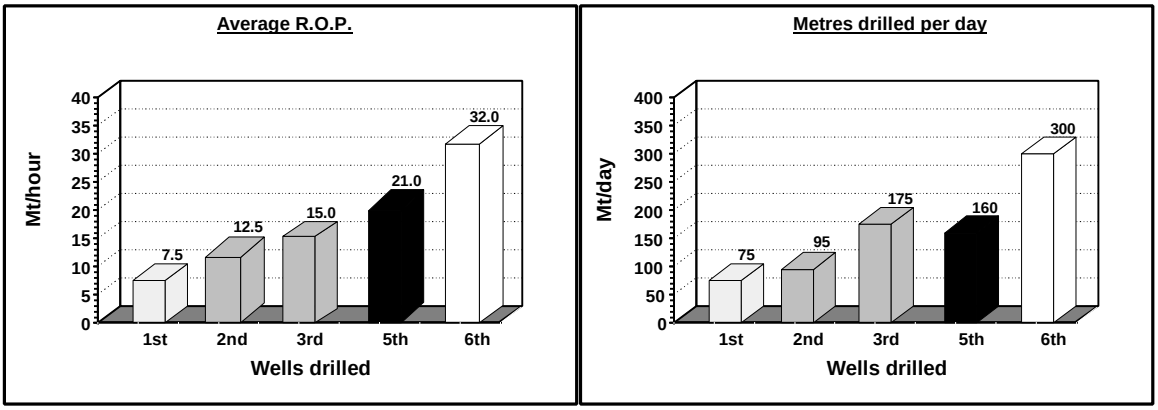
Following its construction in May 1996, the new rig G-125 went on field trials in a series of seven Agip's wells in the northern part of Italy.
Operations on these wells were closely supervised and monitored from the head office in order to provide prompt information and feed back about operability and further improvements.
"Gisolo 1" was the first test well drilled by the rig. It was an exploration, vertical well located in a hilly area. Total depth was planned at 3000 m with $4^1/_8$" hole size. For geological reasons, the 6 $^1/_8$" phase was deepened from 2400 m to 2510 m and it was decided to stop drilling after logging.
Drilling performance was satisfactory in all phases 12¼", 8½" and $6^1/_8$".
Time for casing running and well head operations were comparable to conventional rig performances.
In the "San Gervasio 2 dir." well, a deviated well with a maximum drift of 53°, the total depth of 2400 m was reached in 8 days (190 hours), including three string of casing, instead of the 13 days (309 hours) planned on the basis of the best performances realized in the area.



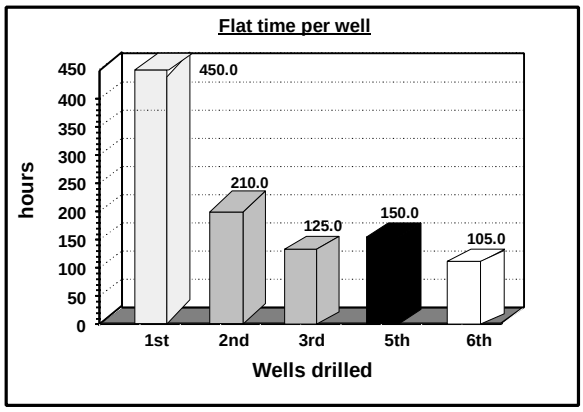
This result corresponds to a reduction of about 40% of drilling time. In this well a compact (or unitized) well head has been used along with 2" Coiled Tubing completion for dual concentric production, in order to:

- reduce time for wellhead operations;
- enhance safety (no BOP disconnection);
- move the rig to the next location as the production casing is run and cemented (a cheaper CTU will finish the job).

Performance recorded in the fourth (Cortemaggiore 57) and in the fifth (Barzaniga 1) wells is not comparable with the other wells, because different hole diameters and other experimental drilling tools were used.
Over the other five wells, R.O.P. increased from 15 to 35 m/hour and meters drilled per day increased from 75 to 300.



On the other hand, flat time was reduced from 450 hours in the first well to less than 120 hours in the last one (including wellhead/BOP, casing and cementing operations, tripping, down time etc.).



In these first wells a learning curve can be clearly seen, both in terms of the drilling performance and of flat time.
A drilling costs reduction from 12% to 24% compared to the cost estimates based on traditional rig.
The G-125 rig, after a drilling campaign conducted in Central and South Italy, where seven wells have been drilled and where good drilling performance were confirmed even in this new area (in the last well drilled, bottom of $8^1/_2$" section at 1261 m, was reached in 18 days instead of 30 days planned), is back in North Italy last September and is currently operating in Po Valley.
Particular attention is now given to the operating performances, especially for the package services provided by the rig, which are casing running and cementing operation.

REMARKS

The G-125 drilling rig is based on innovative concepts in order to make marginal fields development economically viable. It has those characteristics that allow for easy and fast mob/demob; thus a wells where drilling time is short if compared to moving time is the ideal application.
The rig layout allowed for reduction in the area dedicated to the rig site.
This smaller area and the soundproofing made the rig more suitable for applications in environmentally sensitive and populated areas.
The rig automation and the reduced number of personnel turned in to both safer environment and a better performance.
The economic analysis demonstrates the good results obtained; the learning curve and the use of complementary technology (unitized wellheads and CT completion) can further improve the benefits.
The G-125 rig has been built with the highest safety standard in order to improve the efficiency in drilling operations.
Due to the innovative system, personnel working on the rig had to modify its approach to the new concept, especially concerning tubular handling.
The new practice took a little time and, at the beginning of the operations there were some accidents. After this initial "training period", the measures taken to improve safety brought the crew to achieved the primary aim and the learning curve shows that only two minor accidents in two year operations occurred.

FUTURE EVOLUTION

A continuous optimization process is currently underway, both in terms of operational performance, personnel training and rigs site management.
Thanks to the good results and experience gained with this first version of the hydraulic drilling rig (practically a prototype), the drilling contractor (Saitre) that managed the G-125 in this first application has undertaken the construction of a more powerful version of the rig based on the same concepts and principles.
The new rig, named G-200, has been completed last December and is now ready for operations.
This new unit improves the characteristics of the "G" series, offering further advantages in terms of technical capabilities, environmental protection and safety aspects.

THE G-200 HYDRAULIC DRILLING RIG

- One of the main features is the significant reduction in the location area in comparison with conventional units, a characteristic already shared with the G-125.
- The entire system (substructure and mast) is rated for 181 t static load capacity and is designed to drill up to 4000m.
- The telescopic mast is constructed of high tensile steel, electrically welded and composed by the two following sections:
  - main base section with inside the guides to slide the telescopic section;
  - telescopic section, sliding inside the main base section;
- The independent power pack unit is composed by:
  - nr. 1 independent explosion proof group assembled in soundproof special container, complete with 2 power units each composed by:
  - nr. 1 electric motor 500 kW 60 Hz;
  - nr. 2 hydraulic piston pump (one for pull up/down and the other for power swivel rotation);
  - nr. 1 hydraulic piston pump for services;
  - nr. 1 vane pump for powered rotary table;
  - nr. 1 vane pump for serve controlled devices;
  - nr. 1 vane pump for filtration and cooling.

  The containerized unit is completed with:
  - nr. 1 oil tank, 3.000 lt. oil capacity:
  - nr. 3 air-oil cooler with 105 kW each exchange capacity.

  Both the power units are connected with "hydraulic compound system", in order to permit the drilling operation still in case of damages of one unit at half rate.
- A semi-automatic pipe handler has been introduced that completely eliminates the need of human intervention on the rig floor, during all activities of handling pipes.
  This implies several advantages such as increased safety, time saving and constant quality of all repetitious operations, independently on weather and/or personnel conditions.
  The modular pipe vertical container is composed by:
- nr. 8 vertical container racks especially designed to recover drill pipes and drill collars as follow:
  - 3.200 m 3 1/2" range 3 drill pipe;
  - 500 m 5" range 3 drill pipe;
  - 180 m 4 3/4", 6 1/2", 8" drill collar.
- nr. 1 central pivoting mast on roller bearing, completes with hydraulic power unit and control board.
- nr. 1 operator cabin incorporated on pivoting mast structure at drilling floor level.
- nr. 1 set of hydraulic cylinder and wrench for drill pipe and drill collar radial and vertical handling.
- nr. 1 special hydraulic arm for drill pipe stabilization in vertical position.
- nr. 1 special hydraulic device for mast rotation.
- nr. 1 special hydraulic crane inserted in mast top head, 4.000 kg lifting capacity.
  The total storage depends on the size and length of drill pipes used.
  The bottom part of each container is constructed in order to fix and dismount very quickly the container elements, when necessary.
- Four totally soundproof diesel-electric power generators providing a continuous total power of 2800 kW provide the power.
  The diesel engines, with a soundproofing degree equivalent to 60 decibels, are provided with a special electronic combustion control system that guarantees a low atmospheric pollution, in line with the most stringent national and international regulations.

For the first time in Europe, alternating current is applied to drive the drilling rig. This solution includes the use of A.C. standard motors for the entire rig functions (mud pumps, hydraulic packs, etc.). In particular, the Power Management System is continuously monitoring four different parameters (voltage, current, power and frequency) and automatically ensures the proper distribution of power.
This allows the best utilization of the power in all operative conditions, with a consequential reduction in fuel consumption (up to 20%) and a significant improvement in safety during drilling operations.
A software program is installed in the dog house, with an improved data acquisition system able to guarantee communication with more than 20 PLCs "working" on the rig. The operator has therefore the possibility to control all the drilling parameters (mud level, top drive revolutions, pump strokes, penetration rate, pressures, etc.) and also the power production and distribution, as well as the proper functioning of every essential unit device.
Automation and technical innovation go hand in hand with greater professionalism on the part of the operators whose job will change substantially so they become more and more oriented towards the management of complex industrial processes.

- It's worth mentioning the flexibility of the mud circuit that is built in modules. Its capacity can be varied by adding or removing modules (tanks) according to operating requirements, without modification of the circuit.

Once again the challenge accepted by the design team was to work bearing the client's point of view in mind, in order to create a drilling rig complete with the accessory services that would make it simple and reliable to run.
Offshore applications of the same principles featured by the "G" series rigs are under evaluation.
Range of applications span from for work-over rigs on fixed structures or Tension Leg Platform to the installation on semis or multi-purpose vessels for light work-over or slim hole drilling in deep water environments.
This latter application is especially appealing because of the benefits in terms of reduction on the deck loads provided by the slim-hole technology coupled with the specific features of the "G" series rigs.

CONCLUSION

The G-125 has been designed in order to meet and to exceed the demanding technological requirements that characterize onshore drilling activity today, especially in term of integration of services.
A global approach to the productive process it is necessary to reach this objective.
The interdisciplinary co-operation between Company and Contractor has made the fulfillment of this innovative drilling rig possible. It has a competitive benefit, drilling medium and shallow depth wells, in terms of performance and economic returns.
To sum up, reduction in weight and dimensions as well as enhanced automation to minimize crew, is the focal point of the rig design.
The potential advantages for drilling and work-over operations are great, especially for the development of extreme areas, which pose huge technical and economic challenges.

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