AADE-05-NTCE-42

# Enhancing Drilling Rig Efficiencies by Applying Benchmarking and Continuous Improvement Techniques

Hugo Valdez, Jurgen Sager, Transocean

This paper was prepared for presentation at the AADE 2005 National Technical Conference and Exhibition, held at the Wyndam Greenspoint in Houston, Texas, April 5-7, 2005. This conference was sponsored by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author/s of this work.

**Abstract**

Practical and straight-forward application of continuous improvement and benchmarking techniques to monitor, document, analyze and detect best practices during the drilling process can result in improved operational efficiency and well construction performance thus reducing well costs significantly.

**Introduction**

Since the early days of offshore drilling when operators mounted land rigs on piers jutting several hundred feet into lakes, bays and coastal waters, mechanization and automation have gradually changed the way oil wells are drilled.

In those days, the rotary table, kelly and rig tongs constituted the basic equipment on the rig floor. Efficiencies were driven more by human factors than by equipment as it was the same on all the rigs.

When the industry began moving into deeper waters, the necessity for more efficient methods, systems and approaches to minimize manual labor and to overcome the exposure to harsh environments was considered a high priority.

Consequently, drilling rig technology evolved from the traditional rig floor configuration of slips and tongs to the highly sophisticated mechanized multi-activity designs found on the latest generation of semisubmersibles and drillships[1].

Significant improvements in safety have been achieved by using more mechanized and automated equipment along with a higher-skilled work force, but in the Operator's perspective the speed of some critical path operations, particularly those involving moving of steel (drill pipe, casing, and tubing) into and out of the wellbore, have been slowed down to some extent.

In studying this phenomenon, it was noted that rigs with exactly the same capabilities have performed differently when operating under similar conditions. An internal benchmarking program was put in place in order to continuously identify, understand, compare, measure, and adapt best practices from MODUs anywhere to help a particular drilling rig improve its performance.

This paper describes how a rigorous approach to performance benchmarking with documented target objectives, user-friendly and meaningful reports, critical process and task analysis can help to identify non-value added activities and performance gaps within the well construction process, so proper actions can be taken in order to improve the operational efficiency of a particular drilling rig.

**Benchmarking**

Benchmarking is a process of continuously comparing our performance against recognized leaders[2-3]. It is a business practice that leads to increased competitiveness because as soon as one individual or organization realizes there is someone else doing the same thing but better, it becomes a "competitive necessity for survival" to learn 'why' and 'how' and then take steps to change.

**Key Steps**

After a thorough analysis of 25 wells drilled in the deepwater U.S. Gulf of Mexico, several variables related to the well construction process were separated, classified and statistically treated in order to detect the degree of influence on overall well construction time and identify who between the operator and the contractor has responsibility for each performance (See Figure 1).

Those components under the control of the drilling contractor, including unrestricted drillpipe tripping, riser running and retrieval, casing running, and blowout preventer (BOP) and surface equipment testing are called "Key Steps" and these represent more than 30% of well construction time[4]. Therefore, material improvement in any of the Key Steps represents an opportunity to reduce critical path timelines and total well costs to the operator (See Figure 2).

**Contractor's Model for Benchmarking**

The primary elements of the Benchmarking and

Continuous Improvement methodologies[5-6] were combined to generate the model depicted in Figure 3.

*Collect Performance Data.* Daily operational data is input into the company's proprietary Intranet-based reporting system, Global Reporting System (GRS).

Communicating the exact definitions to field operations personnel to enable the collection and analysis of comparable data is crucial to ensure the quality and consistency of the information extracted from the system.

Detailed coding entry protocols with precise start and stop times have been defined for each of the Key Steps and distributed to the rig crews (See Figure 4).

*Identify Best-In-Class Performance.* Report routines have been created within GRS to enable personnel at the rig site and at shore-based offices to easily extract the data and convert it to meaningful information through the generation of reports and charts (See Figures 5, 6 and 7).

Performance review can be done on a real-time basis. Preliminary trends and best-in-class performance can be easily identified on the reports and targeted process and benchmarking partners can be proposed for further study.

*Analyze Processes.* Once the process and the benchmarking partner have been selected, a benchmarking project plan is prepared. The plan includes the schedule of activities to be performed, the definition of critical metrics, a more detailed data gathering plan, and a location visit plan.

*Identify Best Practices.* During this stage, the information is processed and thoroughly compared. The team will look for breakthroughs in practices, identifying "gaps" and root causes of better performance so a future state solution (Best Practice) can be defined and implemented.

*Adopt Best Practices.* Once the feasibility study has been done and it has been concluded that the future state-solution is viable, then the implementation plan is executed.

Proper coordination of all the areas involved in the implementation is required to ensure a smooth transition to the new process and an incident-free operation once the change is completed.

*Monitor.* The drilling systems affected by the change will have to be observed in an operational environment and a "true" assessment of the system reliability and performance will be made.

By monitoring the progress, new opportunities can be detected and new goals can be established. The entire cycle is then repeated and the loop is completed again and again in a continuous process.

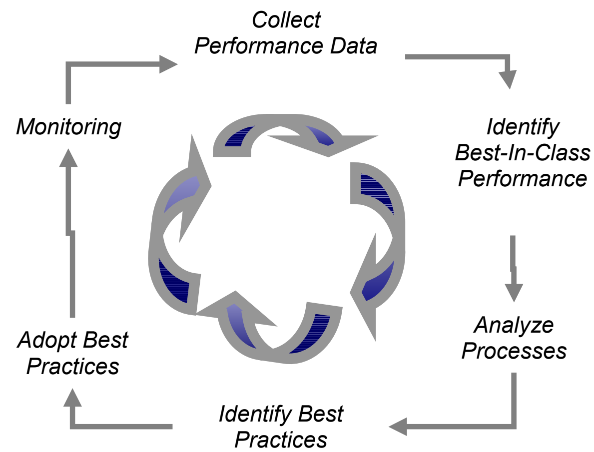



**Fig.3 - Benchmarking Process.**

**Establishment of benchmarks**

With the early stages of accurate data collection completed, it was possible to establish target benchmark expectations. These targets were defined as a standard or point of reference for measurement.

By providing ranges or averages, benchmarks enable a drilling rig to compare performance in the Key Steps with other MODUs (See examples in Table 1).

| Tripping operation | Low (ft/hr) | High (ft/hr) | P10 Benchmark |
|---|---|---|---|
| DP Tripping POOH non-restricted | 1600 | 2800 | 2400 |
| DP Tripping RIH non-restricted | 1400 | 2500 | 2100 |
| Run Conductor Casing | 55 | 150 | 95 |
| Run Surface Casing | 270 | 1000 | 650 |
| Run Intermediate Csg (<13") | 550 | 1780 | 1390 |
| Run Riser and BOP (include test) | 230 | 300 | 280 |
| Pull Riser and BOP | 260 | 420 | 370 |

**Table 1. Example of established benchmarks for tripping of tubulars (ft/hr).**

Benchmarks are subjected to periodic revision, typically every year, so the latest information collected can be statistically processed and new targets and performance baselines are identified.

**Case study No.1- Drill Pipe Tripping Improvements on Enterprise-Class Rigs.**

Initial data collected from 25 drilling operations in the Gulf of Mexico showed some interesting differences in performance for each of the Key Steps monitored.

The differences in tripping speed (ft/hr) of three identical Enterprise-Class drillships (DADS1, DADS2 and DADS3) outfitted with the same pipe handling equipment and working under similar operational conditions was of particular relevance (See Figure 8).

We identified the 'Best-In-Class' performing rig for this particular operation (DADS1) and set up benchmarking team to analyze the process in more detail.

**Process Analysis**

The best-in-class rig DADS1[7] was selected as the benchmarking partner by the DADS2 operational team who eventually invited the DADS3 rig team to join the group.

A letter was sent to the benchmarking partner, explaining the details of the project and requesting that an individual be identified as the location interface.

*Benchmarking Team*. The team consisted of five members assigned to benchmark the drill pipe tripping process by assuming the following roles:

- One team leader from the rig interested in the study, in this case DADS2.
- One member of the sister rig invited (DADS3).
- One process expert (Toolpusher).
- One expert from the Engineering Support Group.
- One facilitator.

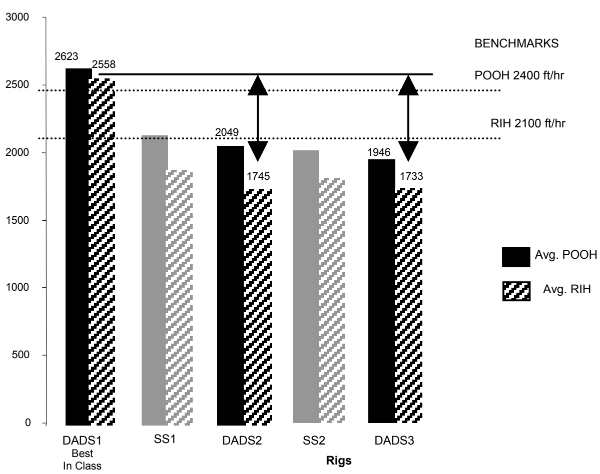



**Fig. 8 - DP tripping (Non-restricted). Arrows shows the difference in performance for three identical drilling rigs.**

*Project plan.* The members of the team met to elaborate the project plan and the schedule of activities to be performed in order to complete the benchmarking study.

Some of the major activities defined are:

- Definition of key comparisons and critical metrics for the process under study.
- Collection of information from internal sources and 3rd party vendors.
- Request for assistance to 3rd party vendors on tracking the elements of equipment involved in the process.
- Ensure the equipment calibration parameters are kept in good shape and coordinated with the rig.
- Explanation to the rig crews about the purpose of the benchmarking study and request information and data as necessary.
- Visit to the rigs (DADS2 and DADS3) to perform a preliminary analysis of the Tripping Process (See Figures 9 and 10) and document the actual performance of the key elements for future comparison with DADS1.
- Visit to the rig selected as benchmarking partner (DADS1) and look for breakthroughs in practices.
- Identify 'gaps' and root causes of better performance.
- Develop a future state-solution.
- Presentation of the future state-solution to top management.
- Implementation of improvement opportunities.
- Monitor results.

*Critical metrics*. A list of specific key measurements and comparisons was elaborated in order to make a thorough assessment and analysis of the elements comprising the tripping process, e.g., drill line specifications, drill pipe specifications, drawworks speed, PRS traveling time, tripping time slips to slips, etc.

*Improvement opportunities*. After monitoring the process on rig DADS1, it was detected that the main driver of high performance during tripping operations is the consistent use of the retracting capability of the block which allows its hoisting and lowering while the PRS and the Iron Roughneck perform operations concurrently in the well center.

The original design of the Enterprise-Class rigs contemplates the use of this feature without any problem (as demonstrated by DADS1), however the drilling crews on the other two sister drillships showed some concerns regarding the sheave arrangement (driven by PRS and block orientation) and the potential side load induced by retracting the blocks which could result in accelerated wear of the components. They did not recognize that the up/down movement of the empty retracted blocks became the critical path component in the handling process, impacting overall efficiency.

After proper technical assessment and feasibility study were completed, DADS2 and DADS3 proceeded to implement the improvement opportunities (which include the use of a new 6x26 dyform drill line) and started consistent use of the retracting capability of the block

*Results obtained.* Significant improvement in tripping speeds on DADS2 and DADS3 ranging from 25% to 30% (See Figure 11) was observed after implementing the improvement opportunities.

*Savings for the operator*. The benefit to the operator as a result of the benchmarking study was calculated as follows.

- ✧ The rig DADS3; POOH 203,886' of pipe in 83.8 hrs and RIH a total of 200,095' of pipe in 91.1 hrs - this was after 44 days of operations since the rig started retracting on Well #1.

Previous Avg. POOH = 1,946 fph vs 2,434 fph for 203,886' on Well #1 = 25 % Improvement

Previous Avg. RIH = 1,733 fph vs 2,196 fph for 200,095' on Well #1 = 27 % Improvement

Total of 403,981' of pipe tripped on Well # 1 in non-restricted DP category in 44 days of operations.

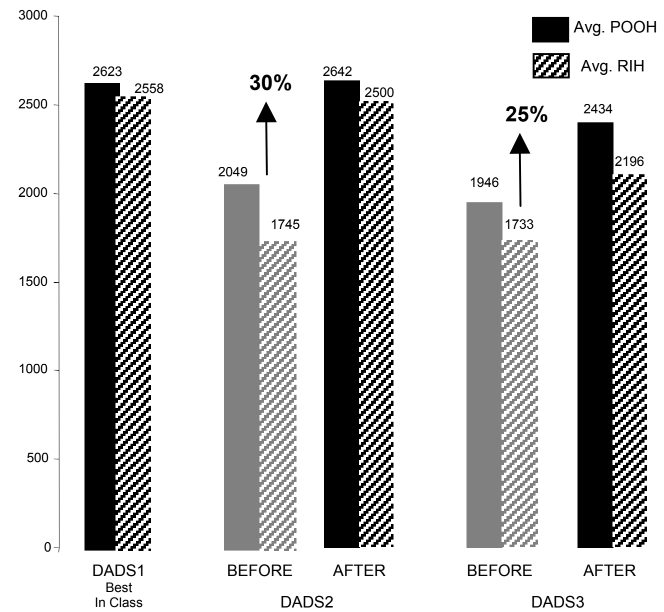



**Fig.11 - DP tripping (Non-restricted), after implementation of improvement opportunities.**

We calculated the following savings by comparing tripping speeds recorded before and after the implementation of improvement opportunities, assuming $400K/Day of total "Spread" costs including the drilling rig,:

- ✧ Dollar Savings to the Operator:

POOH Savings = [(203,886')/ (1,946')] – 83.8 hrs = 21.0 hrs or 0.88 Days @ $400K/Day = $352 K

RIH Savings = [(200,095')/ (1,733')] – 91.1 hrs = 24.5 hrs or 1.02 Days @ $400K/Day = $408 K

Total Savings = $760K achieved in 44 days (1.46months).

Therefore, the projected annual cost savings to the operator from improved tripping rates = $6.2mm.

It is important to mention that the savings are for unrestricted tripping only. We can expect additional savings during restricted tripping operations as well.

**Case study No.2 Tripping Drill Pipe Improvements on Pathfinder Class Rigs.**

Similar study was performed by the teams on the Pathfinder-Class drillships (DS1 and DS2) located in the U.S. Gulf of Mexico.

A detailed sequence of tripping operations was developed and represented in a Gantt chart (See Figure 12).

Based on the chart and after several iterations on the sequence, it was noted that drawworks operations constituted a restriction in the process (See upper part on Figure 12).

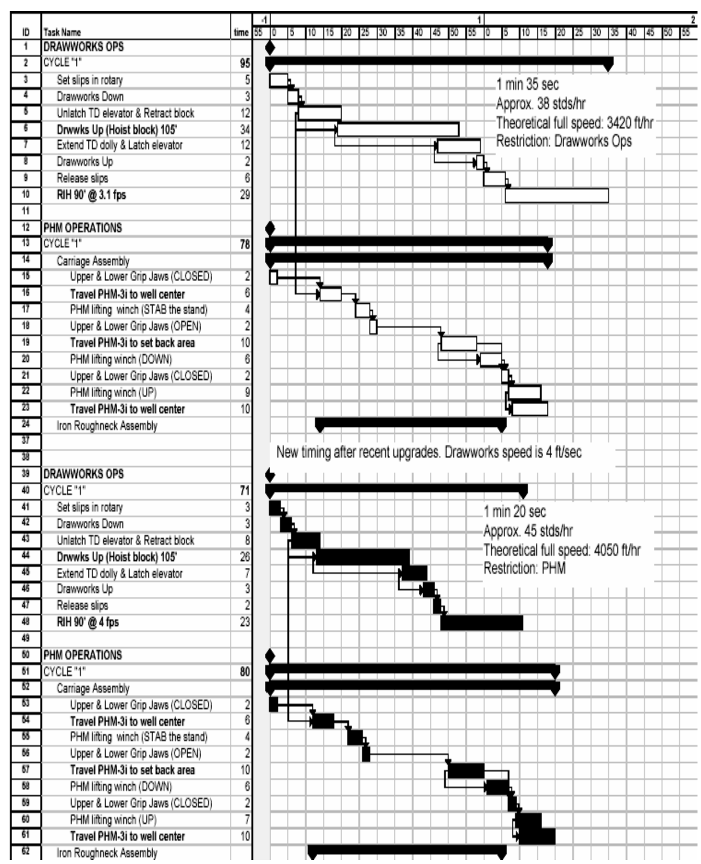



**Fig.12 - Sequence of operations for a single DP Tripping event on DS1 before and after drawworks upgrades.**

With the participation of the Engineering field support group, vendors and the DS1 rig team, several changes on the drawworks system were suggested in order to make the operation more efficient.

After the implementation of such changes on DS1 the drawworks speed enhanced from 3.1 ft/sec to 4.5 ft/sec (See lower part of Figure 12) and the average DP tripping speed improved by 25% (See Figure 13).

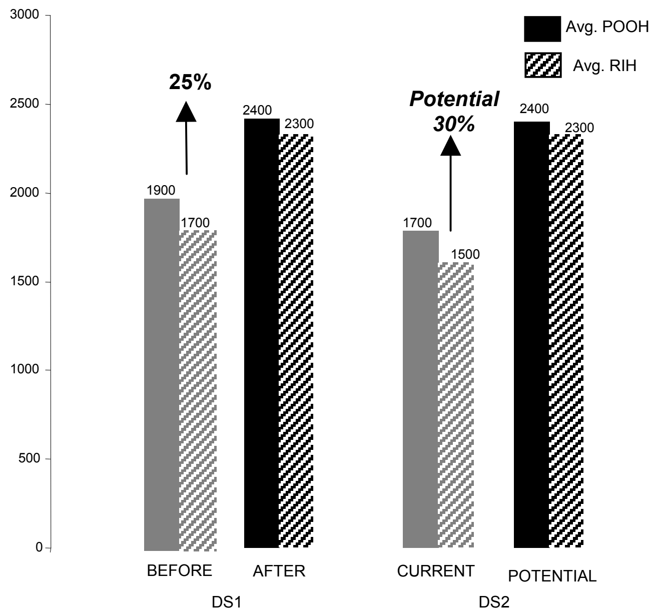



**Fig.13- Improvements on DS1.**

DS2 will implement the same drawworks changes so we estimate the same potential improvement in tripping speed.

**Case study No.3 Process Improvements on Express-Class Rigs.**

Express-Class semisubmersibles (TASS) were launched in 2001; the three ultra-deepwater rigs were expected to deliver drilling efficiencies through their innovative Tri-Act derrick and other newly designed systems.

Additional efficiencies have been gained after benchmarking the operations of the three rigs in different regions of the world. Several lessons learned and opportunities were discussed in an open forum and specific actions were defined in order to improve the overall efficiency of the units.

The *Cajun Express,* which is located in the GoM, has implemented some of these actions. The rig team supported by the Engineering group, assessed the rig performance during one year of operations and compared it against other two units deployed in Brazil and West Africa.

Drill pipe tripping has been improved as a result of changes in the pipe-handling system and changes to the drawworks software which allows more efficient acceleration and deceleration of the block.

Figure 14 shows the average DP tripping speed for each of the Express Class units as recorded until the end of 2003 and the latest results for the Cajun Express after the changes and upgrades.

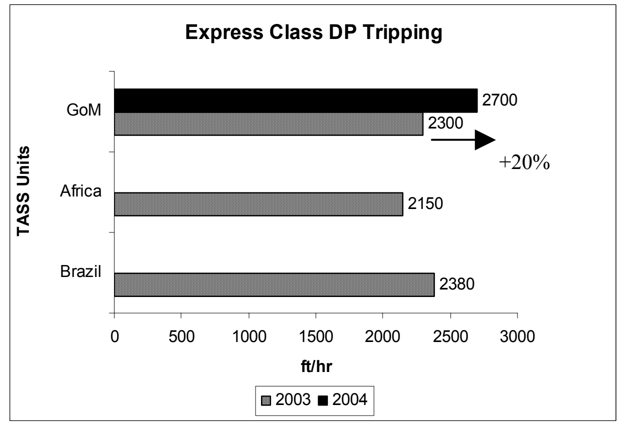



**Fig. 14 - Express Class rigs - DP tripping (Non-restricted).**

**Drill Pipe Tripping - Regional perspective.**

After evaluating the benefit and contribution of individual performance-improvement initiatives, specifically for the DP tripping process, we have noted a positive evolution and an upward trend for the average DP tripping speed for the 59 wells drilled in the GoM between January 2003 and September 2004. Tripping speeds in the overall GoM fleet have improved approximately 20% in 2004 as compared to performance in 2003 (See Figure 15).

Improvements by rig class are also notable during 2004 (See Figure 16). We will set new benchmarks and goals for 2005 based on these new achievements.

**Conclusions**

1. Benchmarking is a process that requires extensive planning, measurement, comparison, and analysis. However, implementation of lessons learned and process improvements gained from the process can yield long term positive results.

2. Most lessons learned from other rigs, even if the other rigs have different characteristics and capabilities, can be used in combination to produce ideas and recommendations that represent pragmatic and value-added opportunities for all rigs.

3. MODU operations carried out on a daily basis can benefit from the type of continuous improvement methodology and critical process analysis described above.

4. Rig crew proficiency is enhanced by their being involved in analyzing and improving routine rig operations.

5. Savings to the operator can be significant considering all of the time sensitive costs associated with deepwater operations. Even discrete improvements in selected drilling processes controlled by the contractor can represent an important reduction in total well construction costs.

**Acknowledgments**
The authors wish to express their appreciation to the Transocean rig management teams for their support in the implementation of this project. Special thanks to Dirk Kolnsberg, Terry Ridgway, Tran Ngoc and Steve Woelfel for their contributions in the analysis of the drill pipe tripping process, and to Bill Ambrose, Tim Lee and Ibukun Keji for their invaluable input and feedback to create the coding entry protocols in GRS.
Finally, we want to acknowledge the comments and suggestions provided by Steven Newman, Chris Young and Guy Cantwell on some of the concepts and words used in this paper.

**Nomenclature**

*BHA = Bottom Hole Assembly*
*DADS = Dual Activity Drill Ship*
*DP = Drill Pipe*
*DS = Drill Ship*
*GoM = Gulf of Mexico*
*GRS = Global Reporting System*
*HSE = Health, Safety & Environment*
*KDF = Key Drilling Factor*
*MD = Measured Depth*
*MOC = Management of Change*
*MODU = Mobile Offshore Drilling Unit*
*POOH = Pull Out of Hole*
*RIH = Run in Hole*
*ROP = Rate of Penetration*
*SS = Semi Submersible*
*TASS = Triple Activity Semi Submersible*
*Tri-Act = Triple activity*
*TVD = True Vertical Depth*
*WD = Water Depth*

**References**

1. Keener, C., Keji-Ajayi, I. and Allan, R. *et al*.: “Performance Gains with 5th Generation Rigs,” paper SPE/IADC 79833 presented at the 2003 SPE/IADC Drilling Conference, Amsterdam, Feb. 19-21.

2. Harrington, H.J.: *High Performance Benchmarking* ,McGraw-Hill Co. Inc., New York, NY (1996) 15.

3. Damelio, R.: *The Basics of Benchmarking,* Quality Resources, New York, NY (1996) 29.

4. Newman, S.L., Sager, J. and Valdez, H. *et al*.:”Deepwater Performance – By the Numbers,” Hart’s E&P Magazine (May.2004).

5. Pande, P.S., Neuman, R.P. and Cavanagh, R.R.: *The Six Sigma Way* McGraw-Hill Co. Inc., New York, NY (2000) 19.

6. Deming, W.E.: *Out of the Crisis,* The MIT Press., Cambridge, MA (1986) 183.

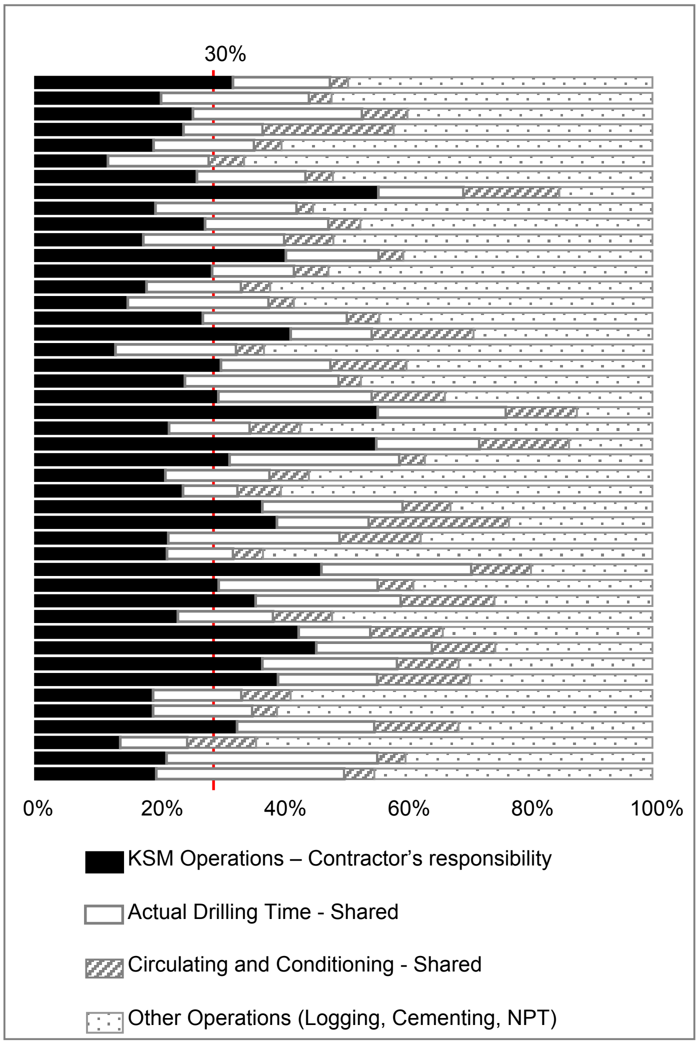
7. Transocean Offshore: *Discoverer Enterprise Dual Activity Drilling Manual* Transocean Internal Publication, Houston, TX (1999) Section 4, p1.

8. Bourgoyne Jr., A.T., Chenevert, M.E., Millheim, K.K. and Young Jr., F.S.: *Applied Drilling Engineering*, Second Printing, SPE, Richardson, TX. (1991)

## Support Tables and Figures

| Drilling contractor's responsibility | Shared responsibility | *Operator's responsibility* |
|---|---|---|
| ♦<br>o<br>o<br>o<br>o<br>o<br>o<br>o<br>***Activity***<br>o<br>o | ♦<br>o<br>o | ♦ *WD/ MD/ TVD*<br>♦ *Horiz. Disp.*<br>♦ *Mud Type*<br>♦ *Mud Weight*<br>♦ *Hole Diameter*<br>♦ *Bit Type*<br>♦ *BHA's*<br>♦ *#Csg Strings*<br>♦ *Csg. type*<br>♦ *KDF's*<br>o *Shallow flow*<br>o *Shallow gas*<br>o *Hydrates*<br>o *H2S/CO2*<br>o *Salt drilled*<br>… |
| ♦ *HSE Duties*<br>♦ *Rig Maintenance*<br>♦ *Rig Crew Training*<br>♦ *Housekeeping*<br>… | ♦ *Horizontal Displacement*<br>♦ *Drilling Parameters*<br>o *WOB*<br>o *RPM*<br>o *Pump Rate*<br>… | |

## Fig.1 - Key Steps identification.




## Fig. 2 - Key Steps as % of spud to end of logging.

| PERFORMANCE SET | | OPERATION SET | START POINT | END POINT | GRS Coding MAIN | PRIMARY | SECONDARY |
|---|---|---|---|---|---|---|---|
| POSITIONING | 1 | Running Anchors or Deploy Transponders | Start Deploying Transponders / Running Anchors | Calibration and Positioning Completed | Moving | Positioning | All |
| | | | | | Moving | Run Anchors | All |
| | | | | | The Master/Captain must report the time in the Daily Operational Report | | |
| PREPARATION & PRE SPUD ACTIVITIES | 1 | Pre-Spud Activities | Start preparing rig floor to P/U tubulars | Finish PU tubulars, BHA & related stuff | Drilling | Pick-up | BHA |
| | | | | | Drilling | Pick-up | Drill pipe |
| | | | | | Drilling | Rig-up/Nipple up | Drill Floor Equipment |
| | | | | | Sidetracking | Pick-up | BHA |
| | | | | | Sidetracking | Pick-up | Drill pipe |
| | | | | | Sidetracking | Rig-up/Nipple up | Drill Floor Equipment |
| M/U BHA | 1 | R/U to P/U BHA | Start to rig up floor to handle BHA | Ready to handle first BHA component | Completion | Rig-up/Nipple up | Drill Floor Equipment |
| | | | | | Drilling | Rig-up/Nipple up | Drill Floor Equipment |
| | | | | | Sidetracking | Rig-up/Nipple up | Drill Floor Equipment |
| | 2 | M/U Bit, components and RIH | P/U first BHA component | Last BHA component below rotary | Completion | Pick-up | BHA |
| | | | | | Drilling | Pick-up | BHA |
| | | | | | Sidetracking | Pick-up | BHA |
| BREAK AND LAYOUT BHA | 1 | R/U to L/O BHA | Start to rig up floor to handle BHA | Ready to handle first BHA component | Completion | Rig-up/Nipple up | Drill Floor Equipment |
| | | | | | Drilling | Rig-up/Nipple up | Drill Floor Equipment |
| | | | | | Sidetracking | Rig-up/Nipple up | Drill Floor Equipment |
| | 2 | Break out BHA components and Bit | L/O first BHA component | L/O last BHA component | Completion | Lay-down | BHA |
| | | | | | Drilling | Lay-down | BHA |
| | | | | | Sidetracking | Lay-down | BHA |
| DP TRIPPING RIH (non-restricted) | 1 | Tripping | First DP stand made and lowered | Tag first restriction / enter open hole | Drilling | RIH: Non-Speed Restricted | All |
| | | | | | Sidetracking | RIH: Non-Speed Restricted | All |
| DP TRIPPING POOH (non restricted) | 1 | Tripping | Start POOH / inside casing | Last DP joint clear from rotary table | Drilling | POOH: Non-Speed Restricted | All |
| | | | | | Sidetracking | POOH: Non-Speed Restricted | All |
| DRILLING | 1 | Drilling hole | Bit on bottom and start to make a new hole | TD reached | Drilling | Drilling | Making Hole |
| | | | | | Sidetracking | Drilling | Making Hole |
| CIRCULATING | 1 | Circulating | Stop drilling, start circulating & Conditioning | Complete circulating & continue operation | Completion | Circulating | All |
| | | | | | Drilling | Circulating | All |
| | | | | | Sidetracking | Circulating | All |
| | | | | | Fishing | Circulating | All |
| | | | | | Lost Circulation | Circulating | All |
| | | | | | Well Control | Circulating | All |
| | | | | | Well Testing | Circulating | All |
| RUNNING RISER & BOP'S | 1 | R/U to run riser | Start R/D PHE and R/U to run risers and BOP's | All hydraulics connected and gimbals ready for first joint of riser | Completion | Rig-up/Nipple up | BOP/Riser |
| | | | | | Drilling | Rig-up/Nipple up | BOP/Riser |
| | 2 | Move BOP to spider beams | Start to skid BOP to under well center | BOP under Well Center, 1 joint (stand) made up | Completion | Skid | BOP |
| | | | | | Drilling | Skid | BOP |
| | 3 | Run BOP / Risers | P/U 2nd joint (stand), make up & lower BOP | Land out last riser joint in spider | Completion | Run Riser | BOP/Riser |
| | | | | | Drilling | Run Riser | BOP/Riser |
| | * | *Pressure Test During Deployment* | *Start rig up for test* | *Finish rig down after test* | Completion | Pressure Testing | Riser |
| | | | | | Drilling | Pressure Testing | Riser |
| | 4 | Run Slip Joint and Install Diverter | P/U first Pup Joint | L/D Diverter Running Tool | Completion | Run Riser | Slip Joint |
| | | | | | Drilling | Run Riser | Slip Joint |
| | 5 | R/D Riser Equipment | Start R/D Riser Equipment | Rig floor clear and ready for next operation | Completion | Rig down/Nipple down | BOP/Riser |
| | | | | | Drilling | Rig down/Nipple down | BOP/Riser |
| PULLING RISER & BOP'S | 1 | R/U to pull riser | Start R/D PHE and R/U to pull risers and BOP's | All hydraulics connected and gimbals ready for retrive | Completion | Rig-up/Nipple up | BOP/Riser |
| | | | | | Drilling | Rig-up/Nipple up | BOP/Riser |
| | 2 | Recover diverter and L/D Slip Joint | Unlatch diverter | L/O last Pup Joint | Completion | Pull Riser | Slip Joint |
| | | | | | Drilling | Pull Riser | Slip Joint |
| | 3 | Pull Risers and BOP's | Pull out first riser joint | Stack on beams | Completion | Pull Riser | BOP/Riser |
| | | | | | Drilling | Pull Riser | BOP/Riser |
| | 4 | Move BOP to storage position | Start to skid BOP to storage area | BOP secured in storage area | Completion | Skid | BOP |
| | | | | | Drilling | Skid | BOP |
| | 5 | R/D Riser Equipment | Start R/D Riser Equipment | Rig floor clear and ready for next operation | Completion | Rig down/Nipple down | BOP/Riser |
| | | | | | Drilling | Rig down/Nipple down | BOP/Riser |
| RUN CONDUCTOR CASING | 1 | R/U to run casing | Start R/U casing tools | Shoe & float joint made up | Drilling | Rig-up/Nipple up | Casing |
| | 2 | Run Casing and land out on GRA | Start lowering shoe joint through rotary table | Land Conductor well head housing in the GRA | Drilling | Run-Casing | All |
| | 3 | Run Spud BHA | Release the Conductor handling tool | Lock CADA tool to WHH | Drilling | Pick-up | BHA |
| | 4 | Run Casing and casing hanger on landing string | P/U Casing on Landing String | Tag Mud Line | Drilling | RIH: Non-Speed Restricted | Landing String |
| | 5 | Jetting Conductor and landing GRA | Start Jetting in the Conductor | Land GRA | Drilling | Jetting | Cementing Casing |
| RUN STRUCTURAL or INTERMEDIATE CASING | 1 | R/U to run casing | Start R/U casing handling tools | Shoe & float joint made up | Drilling | Rig-up/Nipple up | Casing |
| | | | | | Sidetracking | Rig-up/Nipple up | Casing |
| | 2 | Run Casing Joints | Start lowering shoe joint through rotary table | M/U Well Head to last casing joint | Drilling | Run-Casing | All |
| | | | | | Sidetracking | Run-Casing | All |
| | 3 | R/U to run casing on Landing String | Begin R/D Casing handling tools | Finish R/U Pipe Handling Equipment | Drilling | Rig-up/Nipple up | Casing |
| | | | | | Sidetracking | Rig-up/Nipple up | Casing |
| | 4 | Run Inner String/BHA | Start Running Inner String/ BHA | Land out and engage WHH | Drilling | Pick-up | BHA |
| | | | | | Sidetracking | Pick-up | BHA |
| | 5 | Run Casing on Landing String | P/U Casing on Landing String | Tag Mud Line/WH ready to enter in Csg/hole | Drilling | RIH: Non-Speed Restricted | Landing String |
| | | | | | Sidetracking | RIH: Non-Speed Restricted | Landing String |
| | 6 | Run Casing on Landing String and Land out the same | Enter casing/hole below ML | Land out Casing in WH/GRA | Drilling | RIH: Speed Restricted | Landing String |
| | | | | | Sidetracking | RIH: Speed Restricted | Landing String |
| BOP SUBSEA TEST (Conventional Test) | 1 | Test BOP as per procedure | Start running with Test Plug | Test Plug on Surface | Completion | Pressure testing | BOP |
| | | | | | Drilling | Pressure testing | BOP |
| | | | | | Sidetracking | Pressure testing | BOP |
| BOP SUBSEA TEST (for Rigs w/Test Rams) | 1 | Test BOP as per procedure | Start Spacing out to WH | Open Test Rams ready to continue operations | Completion | Pressure testing | BOP |
| | | | | | Drilling | Pressure testing | BOP |
| | | | | | Sidetracking | Pressure testing | BOP |
| SURFACE EQUIPMENT TEST | 1 | Test Surface Equipment | Start R/U to test surface equipment | Finish R/D test equipment | Completion | Pressure testing | Drill Floor Equipment |
| | | | | | Completion | Pressure testing | Other Well Control Equipment |
| | | | | | Drilling | Pressure testing | Drill Floor Equipment |
| | | | | | Drilling | Pressure testing | Other Well Control Equipment |
| | | | | | Sidetracking | Pressure testing | Drill Floor Equipment |
| | | | | | Sidetracking | Pressure testing | Other Well Control Equipment |

Running Conductor Casing

| Step | Start Point | End Point |
|---|---|---|
| R/U to run casing | Start R/U casing tools | Shoe & float joint made up |
| Run Casing and land out on GRA | Start lowering shoe joint through rotary table | Land Conductor well head housing in the GRA |
| Run spud BHA and land out CADA tool in WHH | Release the Conductor handling tool | Lock CADA tool to WHH |
| Run Casing and casing hanger on landing string | P/U Casing on Landing String | Tag mud line |
| Jetting Conductor and landing GRA | Start Jetting in the Conductor | Land GRA |

**Fig. 4 - Coding entry protocols for Key Steps and an example of starting and ending points defined for running conductor casing.**

## Performance Tracking Report

*Performance Improvement with Uncompromising Safety*

**Performance Set :** KSM-Tripping

| Operations Set | Rig name/ Well name |
|---|---|
| **POOH - Rate -f/h** | **2222.76** |
| **Section 2** | 1690.45 |
| Drilling/POOH: Non-Speed Restricted/ALL | 1690.45 |
| **Section 3** | 2210.29 |
| Drilling/POOH: Non-Speed Restricted/ALL | 2210.29 |
| **Section 4** | 2371.04 |
| Drilling/POOH: Non-Speed Restricted/ALL | 2371.04 |
| **RIH - Rate -f/h** | **2204.7** |
| **Section 3** | 1894.22 |
| Drilling/RIH: Non-Speed Restricted/ALL | 1894.22 |
| **Section 4** | 2246.41 |
| Drilling/RIH: Non-Speed Restricted/ALL | 2246.41 |

Printed : 20-Oct-2004
GRS-OnLine

**Fig.5 - Example of performance report – DP tripping.**

## Performance Tracking Report

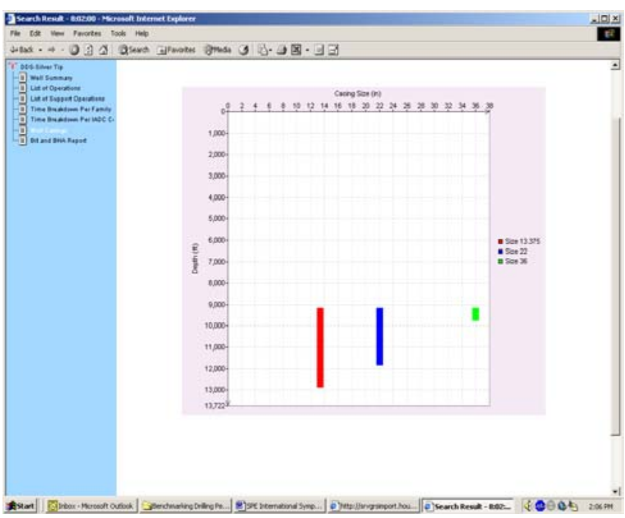
*Performance Improvement with Uncompromising Safety*

**Performance Set :** KSM-Run Riser/BOP

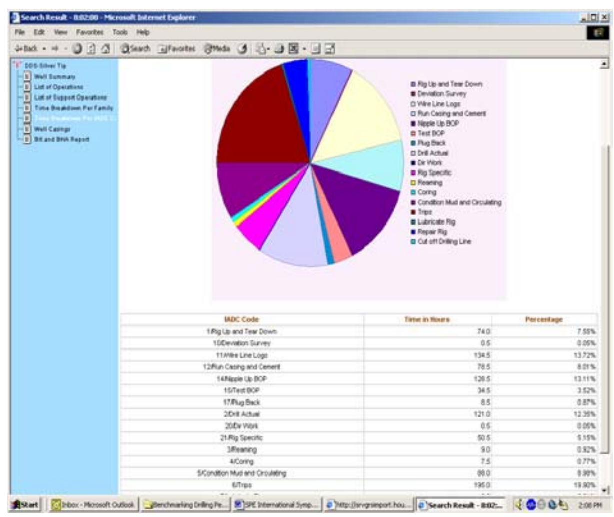
| Operations Set | Rig name / Well name |
|---|---|
| **Rig up to run riser - Time** | **11** |
| **Section 2** | 11 |
| Drilling/Rig-up/Nipple up/BOP/Riser | 11 |
| **Run BOP / Riser - Rate -f/h** | **312** |
| Drilling/Run Riser/BOP/Riser | 312 |
| **Land BOP - Time** | **0.5** |
| Drilling/Run Riser/Land BOP | 0.5 |
| **Install Diverter - Time** | **1.5** |
| Drilling/Rig-up/Nipple up/Diverter | 1.5 |

Printed : 20-Oct-2004
GRS-OnLine

**Fig.6 - Example of performance report – Riser operations**



*Casing strings*



*Time breakdown per IADC code*

**Fig. 7 - Example of performance reports on screen.**

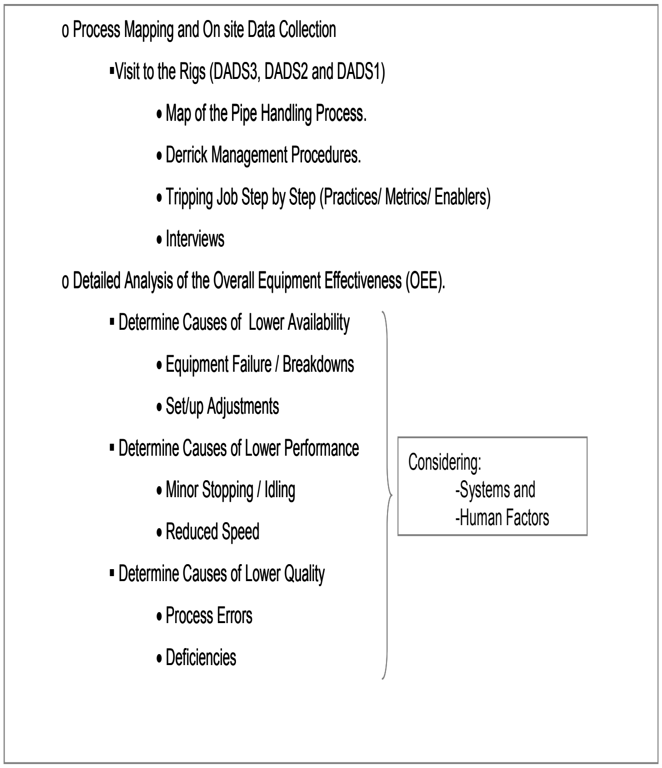



**Fig. 9- Data and information gathered from the rigs during the benchmarking study.**

DP Tripping POOH

Typical sequence of Operations (dry trip) / Non-Retractable Mode

| | | Equipment | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Operations | Drawworks | PS-30 | AR-3500 | PRS-5 | BX Elev | Fingerboard | Parameters needed from E-Drill |
| 1 | Pre-Task Safety Meeting | | | | | | | |
| 2 | Ensure the working set of elevators and power slips are properly dressed for the appropriate pipe size | | | | | | | |
| 3 | Dress the PRS-5 with the correct upper and lower jaw assemblies | | | | | | | |
| 4 | Rig Up the Iron Roughneck | | | | | | | |
| 5 | Latch the elevators on the stump in the rotary to trip the pipe out of the hole | | | | | X | | Functioning time (a) |
| 6 | Remotely actuate the power slips and unset same | | X | | | | | Functioning time (b) |
| 7 | Hoist the pipe out of the hole and position the connection for the stand at +/- 3' above rotary. | X | | | | | | Hookload / Block Speed / Travel Direction (up) / Travel time / Pipe Length / Stand Length |
| 8 | Remotely actuate the power slips and set same | | X | | | | | Functioning Time (c) |
| 9 | Slack off the blocks to verify setting | X | | | | | | |
| 10 | Approach Iron Roughneck to rotary | | | X | | | | Position / Travel time |
| 11 | Drive PRS to the stand in well center | | | | X | | | Position / Long travel time / Arm travel time |
| 12 | Engage the stand and close the lower guide, roller jaws and the upper guide | | | | X | | | Functioning time (d)/ Tubular diameter |
| 13 | Open the elevators and continue to slack off the blocks | X | | | | X | | Functioning time (e) |
| 14 | Engage IR and Break out the connection | | | X | | | | Break out time |
| 15 | Close the PRS lower gripper jaws | | | | X | | | Functioning time (f) |
| 16 | Hoist the PRS and stand of drill pipe to clear the box connection | | | | X | | | |
| 17 | Drive the PRS to the appropriate finger board position | | | | X | | | Long travel time / Arm travel time |
| 18 | When the PRS-5 is clear from the well center zone the block assembly is lowered to rotary | X | | | | | | Hookload / Block Speed / Travel Direction (down) / Travel time |
| 19 | Rack back and close the fingerboard finger to secure the stand in derrick | | | | X | | X | Finger position / Finger closed functioning time (g) |
| 20 | Latch the elevators on the stump in the rotary to continue POOH | | | | | X | | Functioning time (h) |
| 21 | Remotely actuate the power slips and unset same | | X | | | | | Functioning time (i) |
| 22 | Drive the PRS returning to well center for the next stand. | | | | X | | | Long travel time |
| | Re-start cycle from Operation No.7 | | | | | | | |

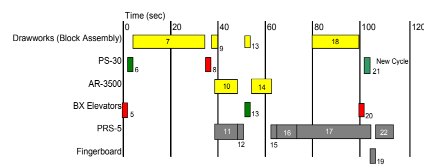



**Fig.10 - Example of the sequence of operations for POOH in non-retractable mode.**

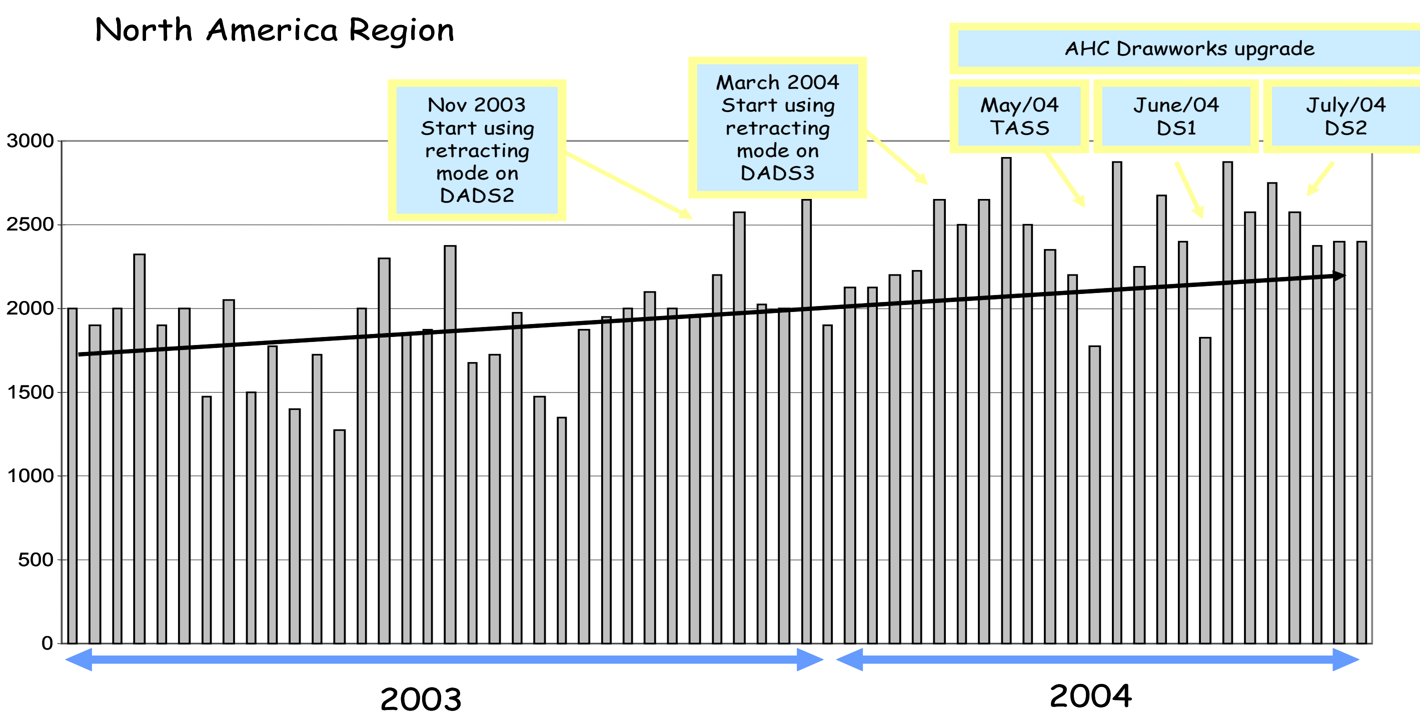



**Fig. 15- Drill pipe tripping speed evolution.**

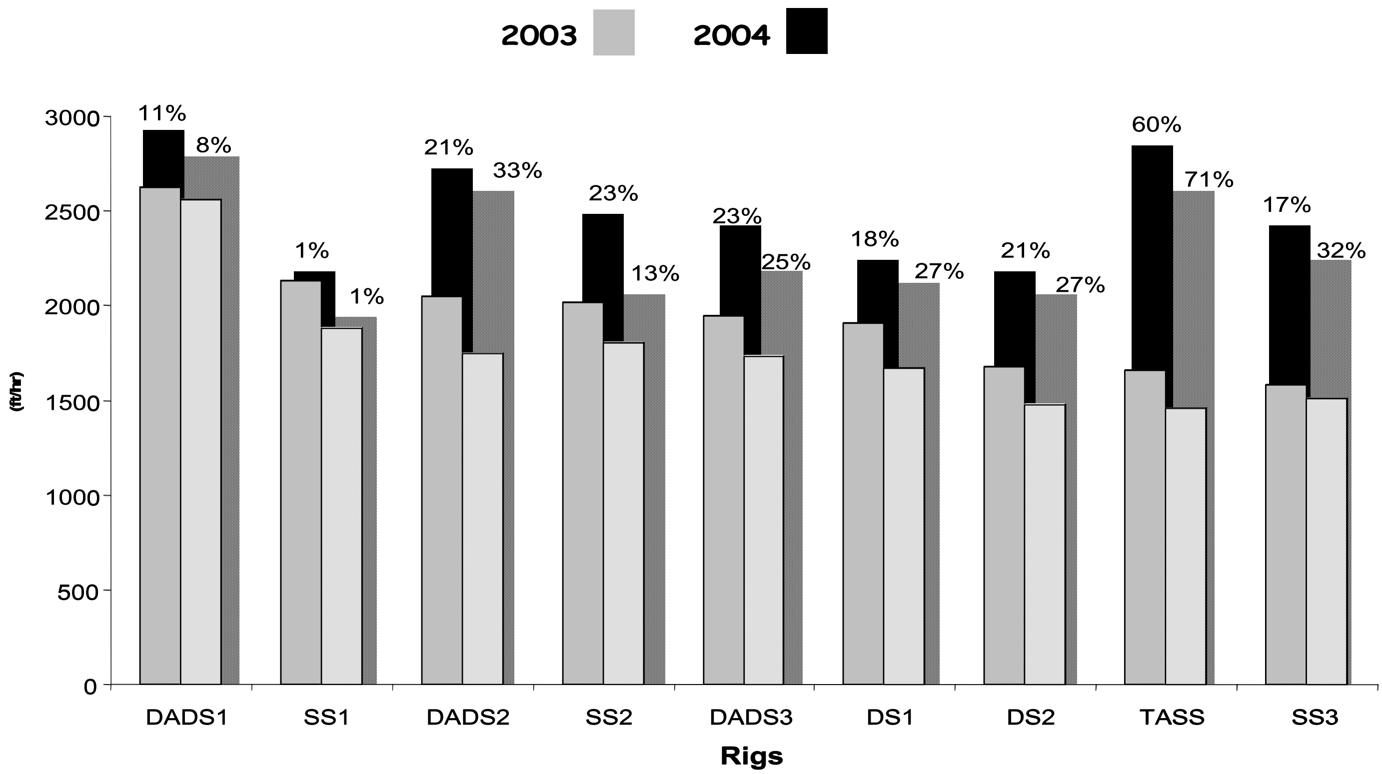



**Fig.16- Drill pipe tripping speed improvement by rig class.**