Master Thesis

The Ideal Rig

Chair of Drilling and Completion Engineering

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Approval date:

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Abstract

Today's drilling industry uses different types of rigs (multi-stand, rack and pinion) where different levels of mechanization help rig personnel with certain tasks such as making/breaking tubular among others. The question arising is which type of rig, in combination with the well to be drilled, and the processes taking place is most efficient. This specifically relates to material flows and workflows which take place.

In this thesis the material flows (tubular, mud, material etc.) and work steps in different – so called "work centres" will be analysed with the objective to optimize such flows and processes ending up with minimum waiting times and a continuous flow of material.

The main reason is to avoid "Invisible Lost Time" and "Non Productive Time" particularly for parallel processes; this makes it necessary to come up with a better rig layout, improved logistics and communication paths, as well as better interaction between crew members. Furthermore this thesis is aiming for a better rig organization. This means that the quality of the Tool Pushers job needs to be improved; therefore the concept of administration software for drilling rigs is presented.

Kurzfassung

Heutzutage werden von Bohrkontraktoren verschiedene Arten von Bohrtürmen betrieben (multi-stand, rack and pinion), wobei der unterschiedlich hohe Grad an Mechanisierung dem Personal bei verschiedenen Aufgaben hilft, wie zum Beispiel dem Festziehen bzw Lösen von Schraubverbindungen am Bohrstrang. Die Frage die sich daraus ergibt ist, welcher Bohrturm, in Kombination mit welchem Bohrloch und den dabei ablaufenden Prozessen, bezüglich Arbeit- und Materialfluss am effizientesten ist.

Des weiteren wird in dieser Arbeit der Materialfluss (Rohre, Spülung, Material etc) und die Arbeitsschritte in so genannten „Arbeitszentren“ analysiert, mit dem Ziel diese Flüsse und Prozesse zu optimieren, um am Ende minimale Wartezeiten und einen kontinuierlichen Materialfluss zu haben.

Der Hauptgrund ist die Vermeidung von „Invisible Lost Time“ und „Non Productive Time“ im speziellen für parallele Prozesse. Daraus ergibt sich ein besseres Layout des Bohrturms, bessere Logistik, bessere Kommunikation und ein besseres Zusammenspiel der Crew Mitglieder. Des Weiteren versucht diese Arbeit die Organisation eines Bohrturms zu verbessern. Dies soll mit der Steigerung der Qualität des Jobs eines Bohrmeisters erreicht werden; dafür wird das Konzept einer Verwaltungssoftware für Bohrtürme vorgestellt.

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1 Introduction

A rig is not only a steel structure with the ability of drilling wells. A rig can also be seen as a factory and like a factory, different processes are necessary, materials and equipment are delivered/ shipped and different people with different jobs are needed to finish the rigs product, a well. If a rig can be seen as some sort of manufacturing plant, it can also be divided in workcenters. Also the processes are similar, because the workers transform raw material (input), in goods that can be sold or in a semi-finished goods (output), which need to be processed further. Consequently it is normal to as the question, if goods in less time and better quality can be produced?

To achieve such this goal, all processes in a workcenter need to be determined and their duration need to be measured. The suggestions made, decrease NPT, ILT, costs and increase quality, efficiency, earnings and reputation. Once implemented and further investigated, the perfect result would be to generate more products, with higher quality, in less time, compared to the pre-optimization state. Now, one can come up with the conclusion, that the company has a better functioning manufacturing process, but the focus was only on the workers and workcenters. Maybe there is also some improvement potential in the administration and what about the same situation on rigs?

If processes should be optimized on a rig, one first needs to know where these processes take place. Therefore this thesis will identify every workcenter (rig floor, pipe rack etc.) of the rig which is relevant to material flows (pipes, tools etc.), as well as the processes taking place in each workcenter to use or modify such materials. Based on identified workcenters and optimized material flows, an ideal rig layout with ideal workcenters and corresponding workflows will be developed.

Today's drilling industry uses different types of rigs (multi-stand, rack and pinion) where different levels of mechanization help rig personnel with certain tasks such as making/breaking connections etc. The question arising is which type of rig, in combination with the well to be drilled, and the processes taking place is most efficient?

This circumstance (different rig types) can also be seen as an opportunity, because the next question is: are there certain processes on a conventional/rack & pinion rig with an outstanding performance, compared to the other rig type and is it possible to modify this process in a way, for using it on the other type?

Furthermore, not only the processes the crew is responsible for, should be analyzed and optimized; as mentioned above also the rigs administration is investigated further because there is great potential for improvement. This fact is due to the authors experience as a Tool Pusher, who was facing inefficiency, delays, ILT, NPT and LTI's. The question asked is, can this job be optimized, speaking in terms of increasing the quality and efficiency of the work? Moreover can ILT, NPT and especially LTI's be avoided?

Why is it so important to optimize the rigs administration? In "Tool Pusher" the word push can be found, he/she is responsible for pushing people forward and encourage them to perform better. Next he/she should show/tell the crew what the following job is and how this job is executed in a safe and efficient way.

Once the processes for the crew are analyzed, optimized and implemented, the Pusher has one of the most important tasks; he/she needs to monitor the proper execution of these workflows, since optimized processes are useless, if the crew "decides" doing it the old fashioned way. Therefore it is important to optimize the rigs administration - shorten the time the Pusher sits in front of his computer - because he cannot supervise the crew and recognize the relapse into their old habits, if he/she is struggling and wasting time in his/her own job.

The solution therefore could also be in this thesis, because it is tried to develop the concept for a software package which should improve the quality of the Pushers work and make it way more efficient.

This means that not only the workers and their work- and material-flows, in the different departments of the 'factory' rig are under investigation, but also the administration needs to contribute to the process of trying to find the ideal rig.

2 Process and Process optimization

2.1 What is a process

Before talking about process optimization, a process needs to be defined. Some definitions are as follows:

- A process is an organized sequence of activities turning defined input into defined output. ([1], p. 77)
- A process is activated by one or more precipitating events, consists of different activities and leads to a result. ([5], p. 9)
- A process is a series of activities initiated by customer requirements, with its goal, creating exactly customer desired results. ([1], p. 77)
- Or, a process is a cohesive, logically structured and self-contained complex number of operations, which are necessary in handling an economically relevant object. ([2], p. 6)

A company's output performance depends on processes, leading to three key elements a process consist of.

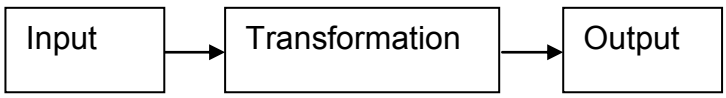


Fig. 1.1 Process elements ([3], p. 59)

Transformation refers to a series of operations, respectively a combination of different production processes, having the following goals: turning provided resources into results or to increase the value of the input. ([3], p. 59)

To avoid mixing up process and project, the definitions are as follows:

Process: all related actions and operations that are necessary to produce a specific good or service. [28]

Project: a temporary plan, to create a unique product, service or result. [28]

2.1.1 Process Attributes

Characterization of processes is done by looking at their attributes:

- **Set off events**
  It takes one or more events to start a process. ([4], p. 15)

- **Defined start- and endpoint**
  A process has a clear startpoint (Refers to the very first workstep in a process: process-starting-activity. This activity is started by a set off event) and also a clear endpoint (Refers to the very last workstep in a process: process-closing-activity). ([5], p. 1)

- **Sum of recurring activities**
  A process is a summary of different activities which result in a defined product or a defined service, meaning that there is a direct relation between the frequency of repeating a process and the frequency of set off events. ([4], p. 15). “The difference between activity and task is that a task is a well-defined work assignment usually assigned to one person. Related tasks are grouped to form activities.”
  (http://www.chambers.com.au/glossary/task.php, 01.08.2015)

- **Measurable output**
  The output of a process is the product/service of inspection. It is tested whether the job performance meets the defined specifications (weight, height…) or the customers’ requirements. ([4], p. 15)

- **Process-closing-activity**
  One or more events are closing a certain process; these events on the other hand are the process-starting-activities of the following process. ([4], p. 15)

2.1.2 Process Determination in Organizations

An organization consists of lots of processes and many of them are interconnected which each other. Structuring those is done by trying to link different skills and resources together in categories. Competitiveness of organizations is secured by having actual process chains, with parameters, adjustable as soon as something changes in the organizations environment. This leads to the following model of primary and secondary processes. Speaking in general terms a primary process is one which is creating value, like the generation and marketing of goods and services (innovation-, productplanning- or distribution-process). But an efficient work progress does not only need primary processes; some help is required in the form of infrastructure processes. These, for customer usually invisible processes are called secondary or support processes. A clear discrimination is not always possible. Depending on its goal one organization defines a certain process as primary and another one as secondary. ([3], p. 55f). Another definition of processes in organizations is done by Weiss. ([6], p. 22f) He differentiates between performance- and development process.

- **Performance processes**
  These processes are an interaction of different activities and tasks, which are necessary to produce output like goods and services for the organizations customer. According to this model competitiveness of an organization is secured by its performance processes. ([6], p. 22f) Performance processes can be further split up:

  a) *Core process*

     A company only consists of a few core processes, which can be derived directly from company's strategy. ([7], p 36)

     Core processes provide the basis of business and existence of a company ([6], p. 109)

     A core process covers all operational activities, which contribute to a company's value adding procedure. ([8], p 7)

b) *Support process*

Under support process one understands all activities and measures which support a company's output (core process) and a company's management (management process). ([6], p. 53)

c) *Management process*

These are all superior and corrective processes which link core and support process together and initiate development processes. ([6], p. 54)

- **Change processes**

  These processes are useful for changing people, groups or organizations. New parameters and new potentials for performance processes are created. With the help of development processes transformation of people starts, leading to the next step: constant adjustment of performance process parameters. Long-lasting competitiveness of an organization highly depends on the parameters that are changed with development processes. It is very important to choose the right development procedure to guarantee an organizations success in the future and so one can see that performance and development processes heavily depend on each other. ([6], p. 23f)

  The problem now is, to combine the above mentioned processes in a way that all wishes, expectations and requirements of a company's customers can be fulfilled.

2.2 What is Process Management?

Process management is a sustainable concept of different procedures, responsibilities, IT-backings und cultural measures, having one goal: Guarantee an effective and efficient process organization in a company. ([9], p. 26)

Process management tries to derive all processes from the strategy of the company or organization, with respect to output it is creating: goal-oriented, output-driven processes which need to be maintained, directed and regulated.

But the bigger a company, the more processes and also the more complex they can get. Therefore process management should help, not to lose track. ([10], p. 13)

The concept of agile process management adds agility to process management. Process management provides structures and techniques to handle repeatable business processes and agility is the possibility to react immediately in real time to unforeseeable circumstances that occur in those processes. Agile process management moves processes out of a pre-defined and predictable processes box into handling difficult cases that elude traditional formalized process management techniques. ([29])

2.2.1 Goals of Process Management

One goal of process management is to increase efficiency and effectiveness resulting in higher customer satisfaction, higher productivity and also a better performance. But it is not only about the company itself, also the people working there need to improve themselves, as a result another target can be established: learning. Hence individual learning is as important as a “learning company”. ([3], p. 36)

Process management also aims for an improved value chain, which should be at an optimum for every company. So it is necessary to adapt and improve at a constant rate. A very important point is, to eliminate non value-adding activities and to decrease process costs. ([4], p. 17)

2.2.2 Benefits of Process Management

The following list gives an overview of benefits a company can gain from process management:

- Regulations for responsibilities of different things: who is in charge for this particular thing/process etc.?
- Reduce interfaces and friction losses.
- Improve transparency of processes in an organization.
- Different procedures are enhanced in efficiency and speed.
- Motivations of co-workers increase.
- The management is going to be relieved.
- Standards are introduced.
- Secure quality and improve it on a constant basis. ([11], p. 11)

2.2.3 Tasks of Process Management

According to Jung ([4], p. 16 f) the main tasks of process management are:

Process identification

Identify all processes acting in a company, with a special focus on the ones most responsible for the company's success (key-process). By doing so a company-specific process structure is defined and can now be displayed to everybody in the company.

Process analysis

Now, those mentioned key-processes are reviewed and investigated further, in order to build a target value and writes down how an optimal key process has to look like. This means to identify the correct order of activities per process and also the right order of processes. The next step is to compare these optimal processes with actual ones and sees what needs to be changed, to transfer; existing and not optimal working processes into optimal ones.

Development of measuring systems

The purpose of key-processes needs to be defined clearly, in a way everybody understands. To reach this goal it is necessary to come up with key performance indicators (KPI) as well as measurement systems.

Continuous improvement of processes

According to reach preset goals it is required to steer the process in a way that, quality, costs and duration are improved continuously and satisfy the company's customers. If at some point the preset goals are reached one needs to define new challenging goals. ([4], p. 16 f)

2.2.4 Process Map

A process map is a graphical display of all processes working together in a company. It's an overview not only of processes but also of how they are structured, where they are located and from which all success relevant processes can be distinguished. ([12], p. 57 f)

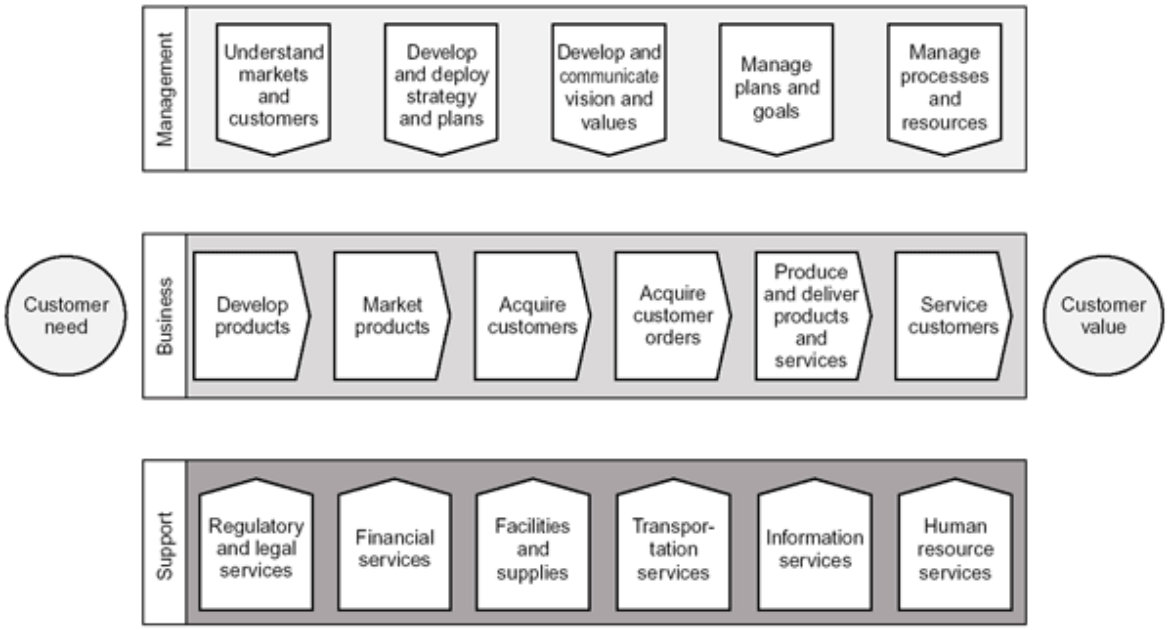


Fig. 2.1 Example for a process map (core processes are named business processes) ([13])

The different processes in a company/organization are interconnected with each other and they also depend on each other. For displaying these connections and interfaces a process map is used. As mentioned before, it gives an overview of all processes, how they cooperate and how they are connected with customers. Also external partners, like suppliers can be added. At measuring points, where two or more processes meet it is suggested to watch performance at a regular basis, to ensure quality is kept at a high level or is continuously improved to reach a high level. ([3], p. 60)

2.2.5 Key Performance Indicators

Acquisition of data is done by key performance indicators (KPI). Due to the fact one is using these indicators for process- and company-control, it is necessary having very detailed indicators. The principle behind acquisition of such indicators is the so called top-down-principle which can be seen in the following figure. ([4], p. 72)

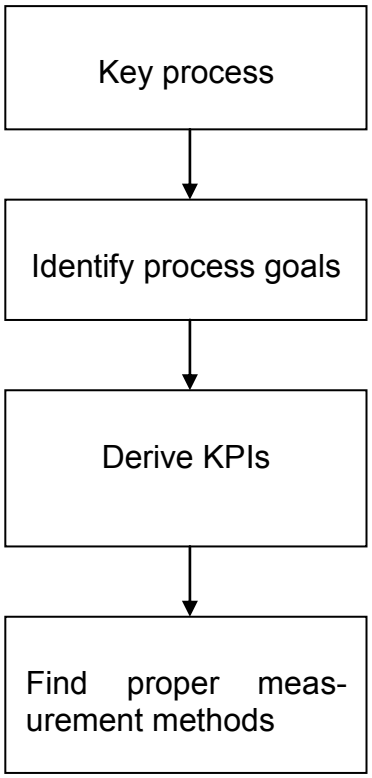


Fig. 2.2 Development of process orientated KPIs ([4], p. 72)

Key process

Starting point for key performance indicators are key processes. As mentioned before, a key process is a major contributor for the company's success.

Define process goals

The goals which are linked to key- and their sub processes need to be defined clearly. That's why formulating these goals should be done in written form and from the customers' point of view. In this particular case a customer is a receiver of different services or goods that are produced within a process.

Derive key performance indicators

The next step after the written formulation of goals is, to derive key performance indicators from that. Those build the basis for steering processes in the right direction. According to that the degree of target fulfillment can now be quantified. Of course newly introduced systems of classification numbers need to be tested, afterwards adapted, completed and fine-tuned. This is a procedure done steadily because it is not so easy to find the right numbers at the beginning.

Find proper measurement methods

The collection and analysis of data has to be done at the highest possible level of efficiency. To eliminate errors in surveys, it is a good idea to acquire these data automatically. Following points have to be considered during the development of a process orientated KPI system:

- Take the company's business strategy as guidance.
- Also take the process structure as guidance.
- Need for a detailed description of a process' performance.
- Use interface between two or more processes as a measurement point.
- Quality before quantity.
- Developing a classification system is teamwork.
- Come up with efficient performance indicators.
- The used KPI system needs to be checked periodically. One is looking if it is still valid and if it is still delivering the desired quality. Also if conditions change for some reasons the system needs to be adapted. ([4], p. 77 f)

Three factors of success are universally valid in every company: time, quality and costs. On that basis a list (Tab. 2.1, Universally valid identification numbers) was developed with also universally valid performance indicators, which can be used for general classification of nearly every process.

Universally valid key performance indicators	
Time	• Cycle time • Handling time • Ratio between handling- and cycle time • Avoidable time included in cycle time (down-, transport-, waiting-, repair-, post-processing- and set up time) • Reaction time • Punctuality rate
Quality	• First pass yields • Process capability index • Output (willful- and material-waste) • Error rate (intern/extern) • Complaint rate • Process-volume
Costs	• Cost of failure • Costs of appraisal • Costs due to misperformance • Employee productivity

Tab. 2.1 Universally valid performance indicators

During development of a KPI system, one needs to focus on: keeping it straight and simple. It is not helpful having lots of indicators which are inexpressive. Therefore it is better to have a small amount of indicators with a high quality. It is recommended to establish objectives for performance indicators, because these build the basis for controlling. If a process needs more than just indicators, one has to watch carefully how interconnected they are. ([14], p. 139)

3 Methods of Process Optimization

A company or an organization requires constant monitoring and furthermore constant adaption due to changing environmental conditions. Further developments and/or improvements are built on existing structures therefore practice will always inspire new ideas to improve processes. So it is essential to investigate errors, vulnerabilities and problems which reduce the effectiveness and efficiency. ([15], p. 187)

In order to steer processes it is recommended to use an appropriate performance measurement system, like the previously mentioned key performance indicators. Continuous improvements cannot be applied off the cuff; it is more a conceptual model. ([4], p. 93) Best suiting methods for process optimization and process performance improvement are the following ones:

- Total cycle time (TCT),
- Kaizen and
- Process reengineering

Process efficiency is reduced by problems, weaknesses and errors, so one uses these three methods to identify and eliminate them. ([3], p. 344)

By closer looking at these three possibilities one finds out that a so called PDCA-cycle is used in every one of them, this cycle can be seen in Fig. 3.1.

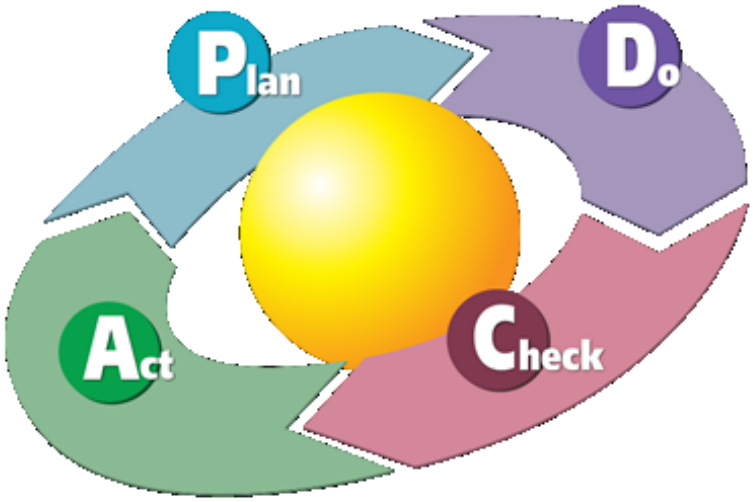


Fig. 3.1 PDCA cycle ([16])

PDCA stands for:

Plan: Each process needs to be planned completely before its actual implementation.

Do: The process is realized as planned.

Check: Process operation and its result are checked; by using target-actual comparison any discrepancies should be identified.

Act: The found discrepancies are now eliminated and processes can start again – taking PDCA cycle into account again.

This never ending cycle allows creative, as well as, analytical thinking. Once an improvement is successful, new developments and improvements are defined, based on previous ones. Main acting people in such a cycle are: Kaizen-Teams who get help from, the accounting department, which provides information about how effective a new implemented step is. ([3], p. 266 f)

3.1 Total Cycle Time (TCT)

TCT, starts by breaking down process-barriers and eliminating non-value adding processes. Therefore the entire business processes as well as all sub-processes need to be considered. Performance should be pushed and increased permanently, which means to remove all barriers reducing cycle time.

Significant features are:

- Determine and get rid of barriers, interfering with process operations.
- Measurement of how effective barrier-removal was, by using the following performance indicators:
    a) Process-time,
    b) Process-quality and
    c) Reduction of delivery time.
- Compare measurement with target.

One differentiates between general, process and culture-barriers: ([3], p. 346f)

General	Process	Culture
• Missing parts • Missing information • Missing material	• Duplication of work • Complex procedure • Waiting time	• Vague goals • Changing priorities • Collaboration problems • Poor customer orientation

Tab. 3.1 TCT barriers ([3], p. 346f)

Barriers are collected by process-teams, rated and afterwards it is decided which barriers are removed at what time, followed by an analysis of the reasons.

TCT is based on four steps:

1. Depicture a process
2. Define targets
3. Determine barriers, rate and get rid of them
4. Measure of improvements.

These impacts are achieved with TCT:

- Increase in process performance
- Use problem-finding-potential of employees,
- Increase in employee's motivation and identification
- Improved cooperation and teamwork
- Increase in customer orientation. ([3], p. 534)

3.2 KAIZEN

KAIZEN has its roots in Japan, is composed of the words KAI (change, transformation) and ZEN (for the better) and means systematic and continuous improvement. The target of KAIZEN is to avoid errors and eliminate inefficiencies, it focuses on customers, staff and processes. The companies customers are defined as improvement targets, processes are *improvement objects* and employees are *improvement protagonists*. KAIZEN's starting point are expectations and requirements of internal and external customers. Internal refers to different departments of a company. The main purpose is to avoid production errors and negative aftereffects (one department tells the previous one if there is a failure) and external customers are the consumers. Improvements are aiming for an increase in customer-satisfactions. The key question is how processes can be improved in order to achieve an optimal result?

Knowledge and skills of employees are crucial for success because they should:

- Co -know,
- Co -think,
- Co -create and be
- Co –responsible.

KAIZEN's core points are:

- Well practiced process-steps are constantly questioned.
- Identify and eliminate waste.
- Planning and implementation of measures which will achieve a company's defined process goal(s)

It is also necessary to adapt the company's internal suggestion scheme (For instance Q- or Stop-cards at a rig) or in case there is none, install one. ([3], p. 353f)

3.3 Process Reengineering (PR)

PR is defined as fundamental rethinking and radical redesigning of essential business processes. Afterwards work should be done better and costs should be reduced as well. Fundamental questions are asked like; do the mission need to be realigned, are the strategic goals within the mission and who are the customers? Now it is possible to find out that the company is working on debatable conjectures. Especially when it comes to customer needs and wishes. ([17] p. 6)

Reengineering recognizes that an organization's business processes are usually fragmented into sub processes and tasks that are carried out by several specialized functional areas within the organization. Often, no one is responsible for the overall performance of the entire process.

Reengineering maintains that optimizing the performance of subprocesses can result in some benefits, but cannot yield dramatic improvements if the process itself is fundamentally inefficient and outmoded. For that reason, reengineering focuses on redesigning the process as a whole in order to achieve the greatest possible benefits to the organization and their customers. (Business Process Reengineering Assessment Guide, US general accounting office, p. 7)

Keyword: fundamental

First of all it needs to be defined what a company has to do and afterwards one decides how it should be done. If PR is used nothing is taken for granted. It ignores what is and only focuses on what should be.

Keyword: radical

In the context of business reengineering radical redesign means developing completely new ways to get the job done. Therefore it is necessary to ignore all existing structures and procedures. PR is about completely redesigning the company and not only improving, modifying or extending a simple business process.

Execution of PR can be divided into four phases, which are briefly explained below.

Phase 1: Selecting a process

Reengineering a process begins with selecting what should be redesigned. For this purpose it is necessary to name the basic business and corporate processes in terms of core competencies. These are usually determined according to their activity and not by their organizational unit. At the end somebody needs to choose between:

- Processes with an already known malfunction,
- Processes which have a special meaning for the company,
- Processes whose redesign is feasible, or
- Processes whose redesign would be crowned with a high probability of success.

Phase 2: Work in and understand the process

The selected process is investigated for: function, procedure, results, performance and is afterwards evaluated. Familiarization is necessary to understand its elemental functions as well as seeing requirements from the customers point of view. A detailed analysis is skipped due to redesign the process. At this state using benchmarking can be helpful to gain new perspectives.

Phase 3: Redesign

The new designed process combines several tasks in their natural order and should consist of as few different processing steps as possible.

Phase 4: Implementation

Since PR represents a fundamental change, introducing a new designed process affects almost all areas and aspects of an organization.

What can go wrong?

- An old process is just optimized, not redesigned.
- There is no focus on business processes.
- There is still a willingness to be satisfied with minimal results.
- Implementation of PR is hindered by a company's current corporate culture.
- The person in charge does not have a clue about PR.
- There is no clear separation of PR and other improvement programs.
- One focus' only on the redesign phase. ([18], p. 36 f)

4 Different Phases of Process Optimization

Process optimizations objective is to sustainably improve a company's competitiveness by adapting all workflows to customers' requirements. Main goals are shortening of cycle time and improvement of process quality. ([3], p. 204)

The main difference between process reengineering (PR) and process optimization is that PR tries to radically rethink a process while process optimization tries to continuously improve the current situation. ([5], p. 35)

In any case process optimization can be divided in following phases:

1. Preparation
2. Potential analysis
3. Actual state
4. Process design
5. Implementation
6. Efficiency control

4.1 Preparation

Before starting a measure for organizational design or re-design, it is necessary to determine goals for the measure itself as well as for the company. Furthermore, people involved need clear defined criteria on which they work. ([2], p. 108) Formulating and developing process goals can be done by five principles shown below:

a) **Specified goals**
   Goals are formulated concrete and result orientated.

b) **Measurability**

   Every process design needs to have a result which can be measured, therefore it is necessary establishing goals which can be measured.

c) **Derivability**
   Best practice is if every goal can be connected to strategic goals, so a strategy can be realized.

d) **Realistic goals**

   The formulation of a goal should show how this goal can be implemented with respect to methodology, procedure, resources, etc.

e) **Deadline**
   A goal should be achieved before deadline is reached. Furthermore teams should be established. If a process covers more than one department, one person in charge of every department is required. As employees of each department have highest process-knowledge and –experience, these teams are the centre of improvement. ([19], p. 35f)

4.2 Potential Analysis

Potential analysis is about getting to know a company's current competitive situation this is done by using the view of the customer, a competitor and that one of the own company.

a) Customers view

Customers view answers the question, what a customer wants from the company. What criteria is he looking for and how process-relevant are these criteria? The more efficient customer requirements are met, the higher customer satisfaction and the more successful a company is. To satisfy customers one needs to implement their requirements correctly. ([3], p. 47)

b) Competitors view

The competitors view shows, how good a company's major competitors handle customer criteria, mentioned above.

c) Company's view

The company's view helps to identify core competencies and its analysis gains information about a company's performance. Additionally, it is shown which processes are relevant for competition and if those can be optimized? ([12], p. 54 f)

4.3 Actual State Analysis

Primary target of actual state analysis is to picture current structures and processes of a company. Based on collected data, a list with all vulnerabilities and potentials is created and should be as accurate and complete as possible. ([2], p 179) It is important, to have a clear picture of all processes in a company due to modeling and representation. Therefore a map is prepared, giving information about where to find a specific process and also about how this one is connected to other ones. Then, the process to be optimized is excluded by defining an exact start- and endpoint. ([12], p. 56)

Best practice is to use a flowchart. Because of their concise presentation process orientated thinking is encouraged. The following figure shows simple symbols used in process modeling.

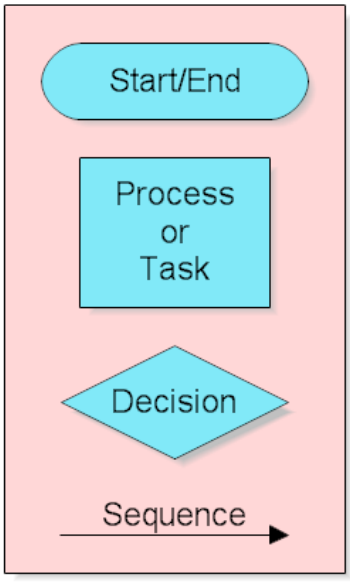


Fig. 4.1 Flowchart objects, ([20])

Such a flow chart should cover the following aspects:

- **Input/Output**
  What conditions have to be created for a process or which results will be created and are these used in following processes.

- **Process steps**
  Which steps are executed, who is responsible and which event is initiated? What kind of information or material is transported further?

- **Interfaces**
  How is a process connected to other ones? Information or goods are exchanged at interfaces, but in what form? How can process interfaces be described and what is contributed to the overall result?

- **Sequence and frequency**
  Are above mentioned steps running parallel or sequentially and how many steps per unit of time are there?

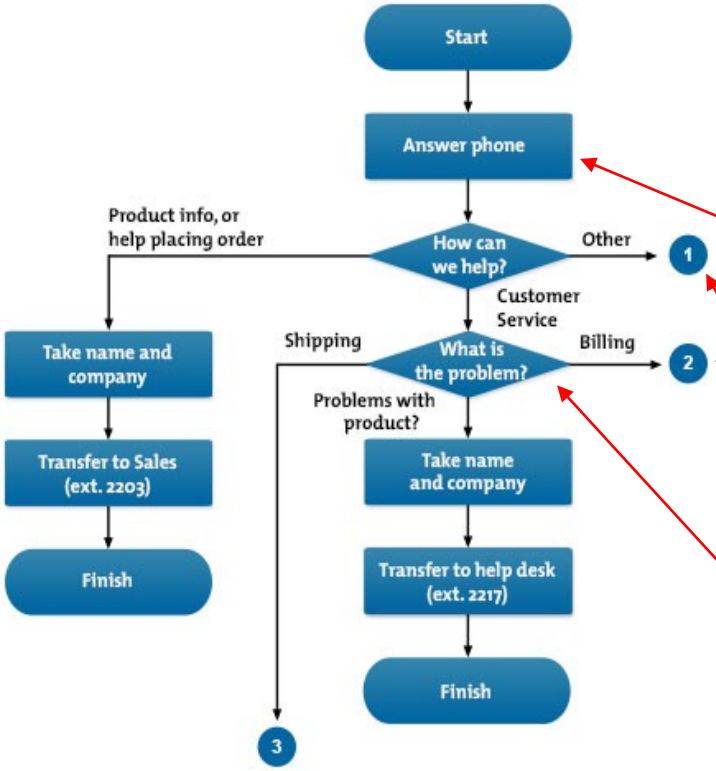
- **Branch points and variation**

  Are there branch points within a process and which variations arise from these?

- **Time and costs**

  Amount of time per process needs to be analyzed, as well as costs for each step. ([12], p. 65 f)

The following Figure shows the actual state analysis of a phone call process



Input, a customer call

Output, helping the customer

Steps, all rectangles

Interfaces

Sequence, steps running sequentially

Branch points

Time, as long as the call takes

Fig. 4.2 Simple phone call process, ([30])

4.4 Process Design

Based on the actual state, a target concept is worked out, the process is redefined stepwise. This phase requires constant focus on previous set optimization goals. Below mentioned points are expected from management as well as employees:

- Increase in revenues,
- Saving costs,
- Streamline workflow,
- Reduction of planning time,
- Reduced processing time,
- Higher currency of information,
- Better communication between departments,
- Minimize waiting times

Also customer and market demands on new target concepts

- Higher product and process quality
- Greater customization and improved customer loyalty
- Accelerated communication between market partners
- Greater process transparency
- Increase in market share due to faster response on market developments

Individual activities are checked to increase customer benefit and added value. This involves revision of already created flow charts by the project team. Failures and unnecessary work steps are identified and together one looks for more efficient and effective handling. Furthermore, interfaces between different departments are checked carefully, because optimizing transition minimizes losses and misunderstandings. Here it is essential having a written documentation due to keep on track. ([19], p 56 f)

Feasibility of realistic target and ideal model needs to be kept in mind for all improvements. Watching an ideal model can be helpful finding new ideas, realization on the other hand would be an unacceptable waste of resources. Having a detailed target model is important for the estimation of resulting costs, quality, quantity and time. As previous mentioned, identification and definition of core processes is crucial for introducing a model. Also target contribution of all sub-processes and individual activities of a company have to be analyzed and non value adding ones eliminated. ([2], 203 f)

4.5 Implementation

Now the newly designed processes come to life but there is no ideal way for doing so. Instead, under consideration of substantive, political and cultural conditions of existing organizations, appropriate measures need to be selected and combined usefully. ([2], 269 f) Implementation success depends on people who are associated. Therefore an effective change-manager has to have following attributes:

- Good social skills,
- Result and goal orientation,
- Shoulder risk of failure,
- Believable goal commitment,
- High implementability even if it’s uncomfortable for all involved. ([12], 172 f)

During implementation one will face resistance because there is no change without it. Reasons for that are fear of new improvements and uncertainties. Creating acceptance requires an honest and trustworthy communication. Also people who are directly affected, are involved more closely. The best thing to create acceptance is of course, having success and a positive result. ([2], 278)

4.6 Efficiency control

Introducing performance indicators is essential to demonstrate effectiveness and efficiency of processes. Furthermore they show how the impacts of change in performance, influence economic results. These indicators also collect information about the actual performance level and how its development looks like. Customer satisfaction is most important when it comes to process effectiveness and most important for process efficiency is cycle time, meeting deadlines, process-quality and –costs. That is why they should be used as standard parameter.

Continuous measurement and control of process performance takes a predefined and implemented measurement system. This purpose requires sound information about the measurements, like e.g. frequency, type and location. To achieve a high degree of technical coordination and acceptance it is necessary to establish this system in close cooperation with the process team.

Efficiency control is about deviations between actual- and target value. Terms and conditions are verified by which effectiveness and efficiency of processes depends on. The shorter measuring intervals are the faster respond on deviations and the greater learning potential is. ([3], 278 f)

6 The Ideal Rig

The target is to optimize costs and time, especially to avoid ILT and NPT. Because a lot of studies concerning a decrease in ILT and NPT have been made in the last years due to ~ 10 – 25% NPT and ~ 30% ILT of overall well delivery time and cost [34]. In the end a drilling sequence should be finished faster and cost less than before. The “Ideal-Rig” is about the ongoing processes on a rig. Selected workcenters and especially the processes happening there are investigated. Furthermore the insufficiently working work- and material-flows are checked for ILT and NPT. If one of these can be found, suggestions are made to avoid them. If these two factors can be avoided, the rig runs more efficiently which results in a decrease in running costs. In order to do that, a rack & pinion rig and a conventional one are compared with each other. It is investigated if there are any synergies, if one rig can be optimized by using technology from the other one or if the same processes are working insufficiently on both rigs.

This thesis does not cover rig move procedures or some works like changing pistons, liners or valves at a pump. Also BOP work after cementation is not covered. The reason for that is that rig move procedures depend on rig configuration. Pump and BOP work needs to be done on every rig but there are differences between the rigs. This is due to different pump manufacturers and BOP types and configurations. Of course this is quite an improvement potential, and due to different manufacturers, rig owners should have a careful look at their fleet. The first thing to save costs is a standardized fleet. This means every rig of the fleet has the same pumps, BOP, crane, catwalk etc.

Such a procedure saves costs because there is only one type of pump, therefore one can use the spare parts from one manufacturer on every rig. The fleet owners do not have to order small amounts of spare parts from different manufacturers, but instead larger amounts from one manufacturer. This saves shipping costs and if one is buying a large amount, there is also the possibility of negotiating a better price.

7 The Rigs

7.1 Description, Rack & Pinion Rig

The rig is equipped with hydraulically operated slips (only for DP and HWDP) and elevator. Hook load capacity is roughly 400 tons. Due to absence of a monkey board on a rack & pinion rig no stands can be stored on the rig floor. Since every pipe has to be brought to the rig floor separately, the maximum useable pipe length is about 46 [ft] ~ 14 [m] which equals a Range III drill pipe.

The flexible box on box system makes it possible to adapt the rig easily to almost every location. Resulting in a smaller footprint of 36 m 34 [m] compared with a conventional rig of 40 x 55 [m], this makes it possible to move such a rig in ~6 days compared to ~7 days on conventional one.

Another advantage is that if the rig needs to be skidded also the mud pits, pumps and generators can be skidded as well. Therefore only connections like the flow line, the high pressure hose between pumps and standpipe, choke- and kill-line, etc need to be removed. The pipe rack can be moved with the forklift only the hydraulic connections need to be removed.

Figure 7.1 and 7.2 show a rack & pinion rig, a short description of the components can be found below:

- Rack & pinion system fixed to mast.
- Top drive system, with six gear wheels mounted in the back, moves up and down along mast's rack & pinion system.
- Pipe handler mast carries the weight of pipe handler and also works as guidance.
- Pipe handler grabs drill string components, turns them vertically or horizontally and gets them from rig floor to pipe rack or vice versa. Also, pipe handler is moving along a rack & pinion system.
- Pipe rack at ground level (with help of a forklift): pipes are placed here during RIH. During POOH, pipe-handler places pipes there and after cleaning, forklift grabs and brings them to their storage area or box.

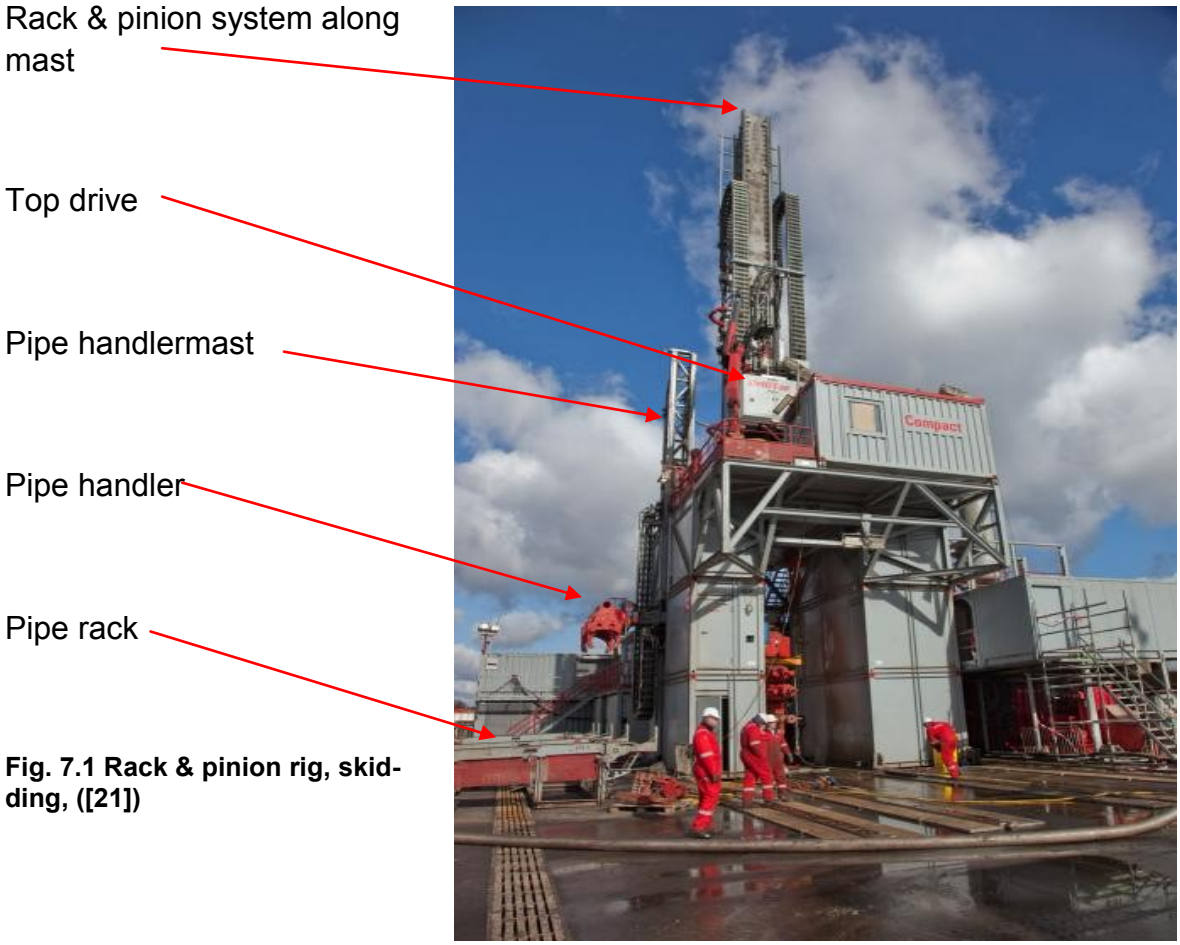


Fig. 7.1 Rack & pinion rig, skidding, ([21])

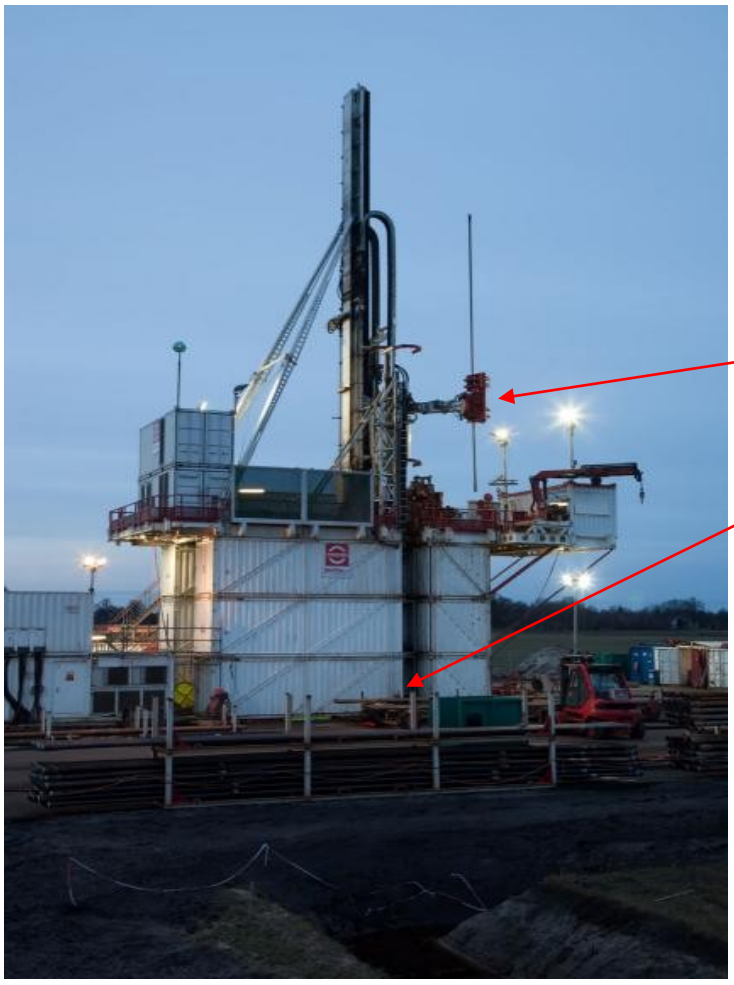


Fig. 7.2 Rack & pinion rig during POOH or RIH, ([21])

Best view of the handling concept gives Fig. 7.3 because at this sequence one can see the stepwise movement of the Pipe handler:

Wait in Position

Swing in

Grab pipe

Swing out

Turn pipe horizontally

Lay down pipe

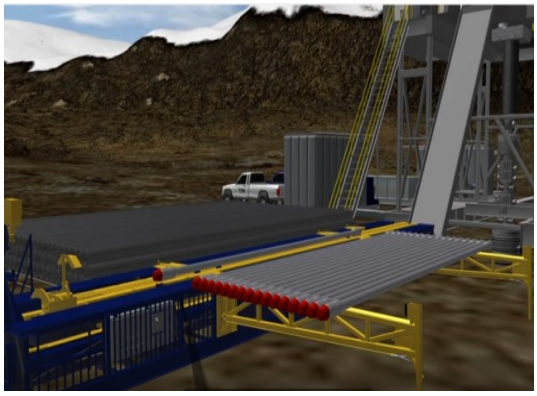
Lay down pipe

Fig. 7.3 Sequence of POOH, ([22])

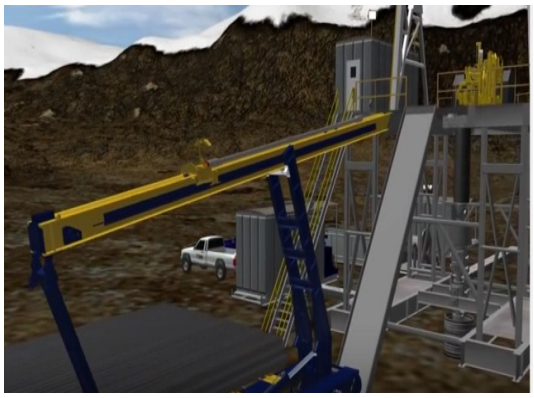
7.2 Description, Conventional Rig

A 400 tons conventional rig (capable of 90 [ft] stands) should be widely known, so there is no need to go in detail here, but a short sequence of how pipe handling works can be seen in Fig. 7.4. and 7.5. The rig is equipped with hydraulically operated slips and elevator as the previous one. But in absence of a pipe handling system also a hydraulically operated catwalk is installed.

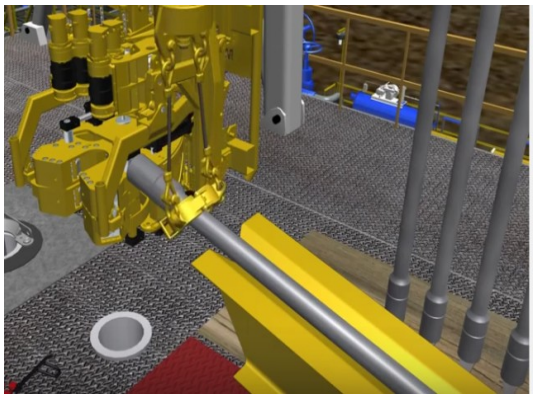
Hydraulic operated catwalk



Pipe is placed on catwalk



Transport to rig-floor



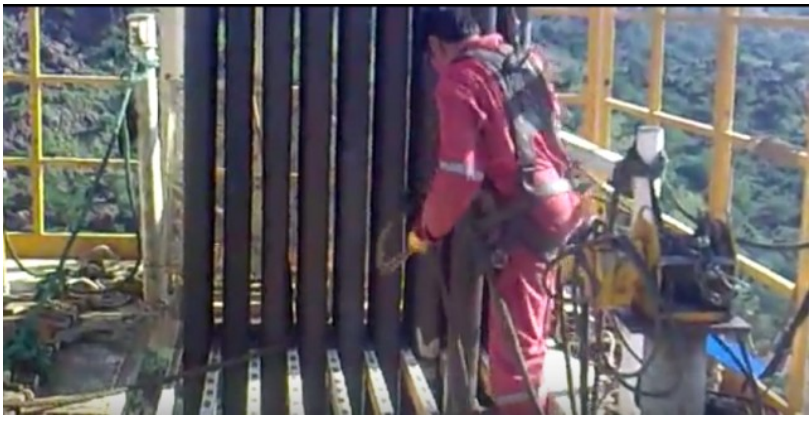
Elevator closes around pipe

Fig. 7.4 Sequence of hydraulic catwalk, ([31])

Derrickman stacks back pipe

Derrickman secures stand with rope

Elevator opens and stand is pulled in



Stand is pushed into fingers and secured

Fig. 7.5 Sequence of POOH, ([32])

8 Comparison, Conventional – and Rack & Pinion Rig

In this chapter a conventional and a rack & pinion rig are compared (time vs. depth diagram) in terms of tripping time. The first case (Fig 8.1) is the ideal case; this means that every section is drilled without the need of an extra roundtrip. The second case needs an additional trip per section (Fig 8.2) and the third case, two additional trips per section (Fig 8.3). The reason why the making and breaking of a BHA at a R&P rig takes longer, due to the assumption that an overweight BHA (OW) is run which exceeds the weight limit of the pipe handler. This makes it necessary to lift up and lay down the BHA with a mobile crane which needs to be rigged up and down (calculated with 2 [h] longer per lift up and lay down).

8.1 Input Data

Besides the input Tabs 8.1 – 8.5, the sum of rig up/down logging-, casing- and cementing equipment, BOP work and WOC is assumed with 75 [h] after reaching TD of each section.

Well and drilling data		
CSG Depth [m]	ROP [m/h]	BHA length [m]
1100	50	26
1980	10	36
3297	8	31
3520	4	41

Tab. 8.1 Well and drilling data

Connection/ tripping data					
Drilling connection slip to slip [min]	Tripping connection slip to slip [min]	RIH		POOH	
		Cased hole [m/s]	Open hole [m/s]	Cased hole [m/s]	Open hole [m/s]
2.5	2	1	0.5	0.5	0.5

Tab. 8.2 Connection/ tripping data

Casing data			
		RIH	
Pipe length [m]	Connection [min]	open hole [m/s]	cased hole [m/s]
12	2.5	1	0.5

Tab. 8.3 Casing data

Conventional Rig		
Move [d]	pipe length [m]	Stand length [m]
7	9	27
	BHA make up [h]	BHA break out [h]
1st BHA	2	1
2nd BHA	3	2
3rd BHA	3	2
4th BHA	3	2

Tab. 8.4 Conventional rig data

R&P Rig		
Move [d]	pipe length [m]	Stand length [m]
6	13	13
	BHA make up [h]	BHA break out [h]
1st BHA	4	2
2nd BHA	5	4
3rd BHA	5	4
4th BHA	5	4

Tab. 8.5 Conventional rig data

8.2 First scenario

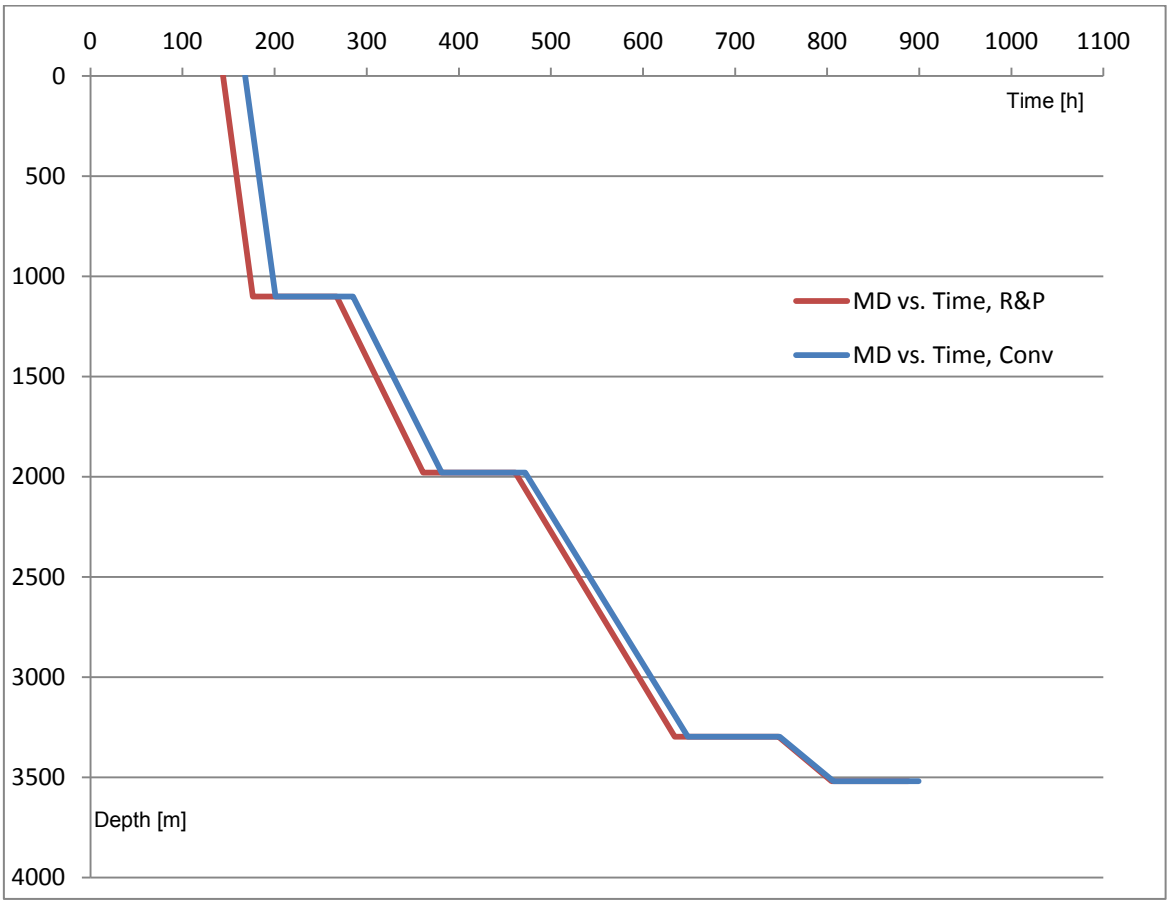


Fig. 8.1 No additional trips, ideal case

The bit runs presented in Tab. 8.6 show that if there are not additional roundtrips per section necessary; a R&P can finish the well in almost the same time even an overweight BHA is run, due to a faster rig move.

The overall durations for this well are:

R&P rig, OW:	916 [h]	38 [d]
R&P rig:	900 [h]	37.5 [d]
Conventional:	899 [h]	37.5 [d]

Runs	Depth [m]		Duration R&P [h]		Conventional [h]
	From	To	OW BHA	BHA	
1	0	1100	38.6	34.6	36
2	1100	1980	111.7	107.7	106
3	1980	3297	197	193	189
4	3297	3520	86	82	73

Tab. 8.6 Bit runs, first scenario

8.3 Second scenario

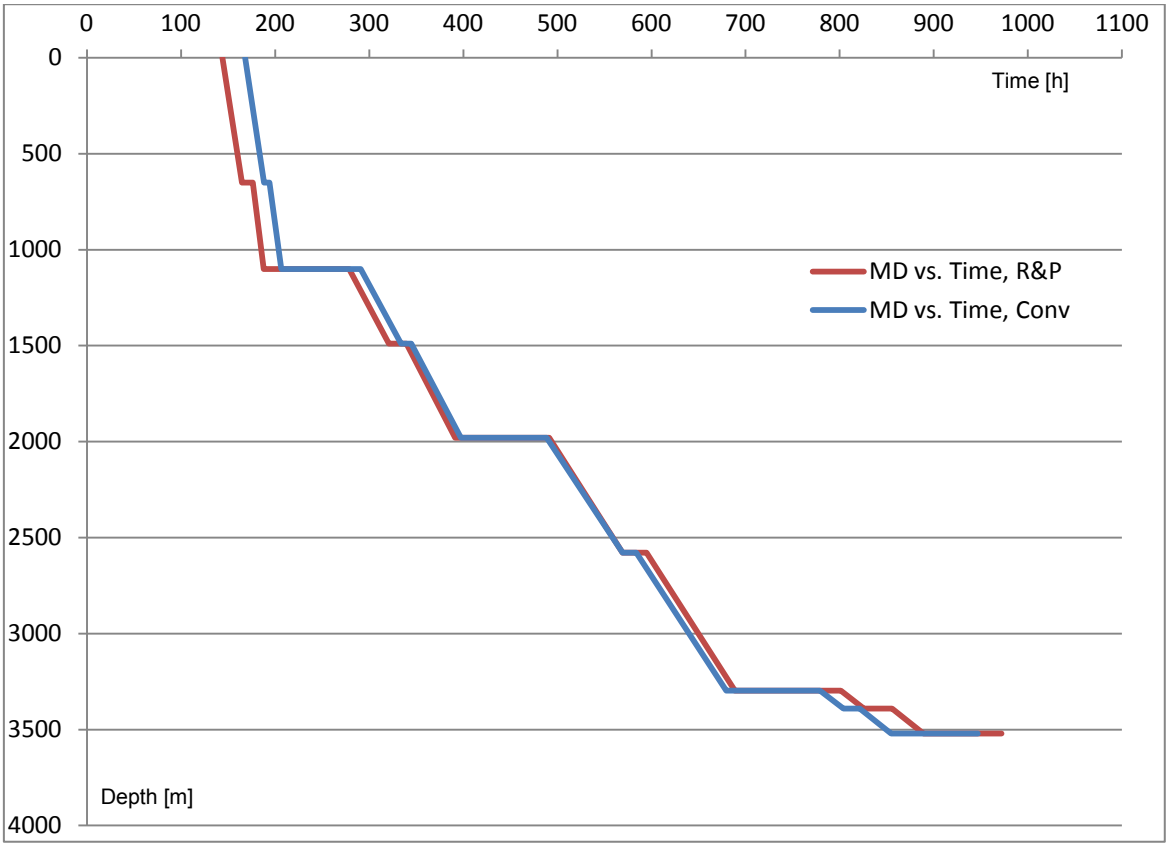


Fig. 8.2 One additional trip per section

The bit runs presented in Tab. 8.7 show that if there is one necessary additional roundtrip per section, a R&P rig running an overweight BHA is two days slower compared to a conventional rig. Taking in consideration the faster move it lost 3 days overall.

The faster move also answers the question, why a R&P running a non overweight BHA and a conventional rig can finish the well in almost the same time.

The overall durations for this well are:

R&P rig, OW: 988 [h] 41 [d]

R&P rig: 956 [h] 39 [d]

Conventional: 947 [h] 39 [d]

Runs	Depth [m]		Duration R&P [h]		Conventional [h]
	From	To	OW BHA	BHA	
1	0	650	26	22	22
2	650	1100	24	20	19
3	1100	1489	58	54	52
4	1489	1980	72	67	64
5	1980	2579	100	96	93
6	2579	3297	121	117	111
7	3297	3390	52	48	39
8	3390	3520	64	59	50

Tab. 8.7 Bit runs, second scenario

8.4 Third scenario

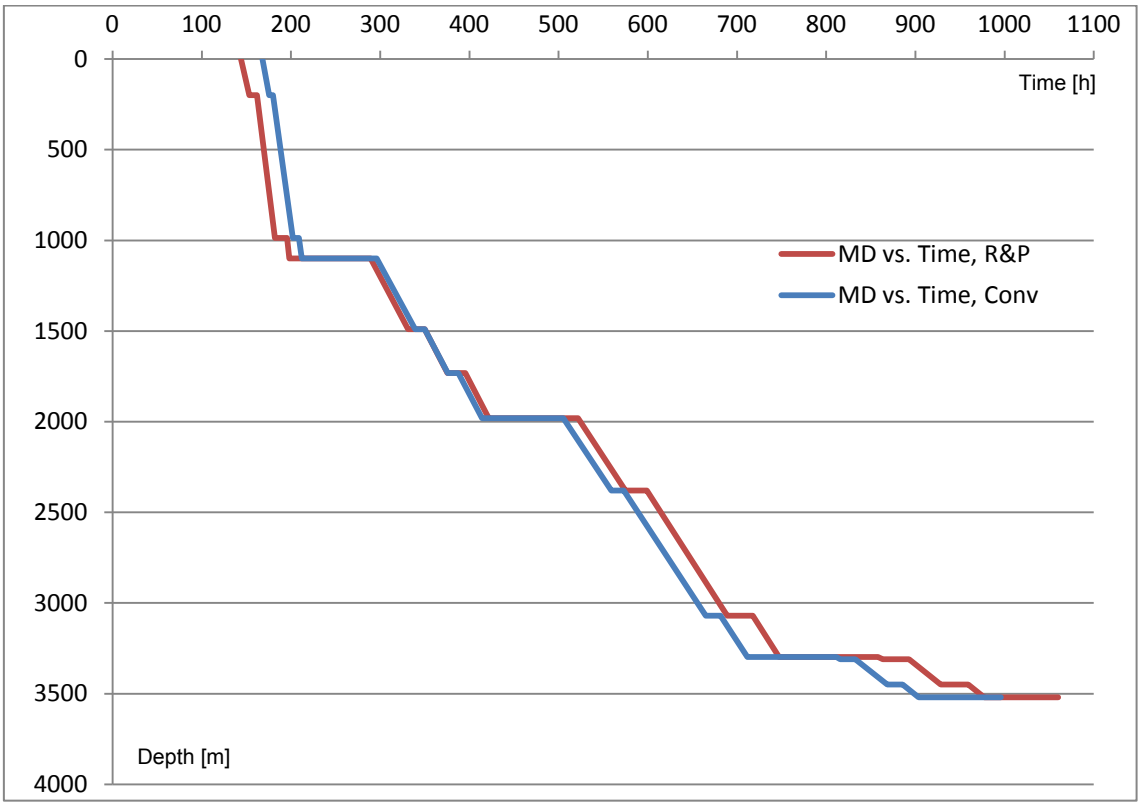


Fig. 8.3 Two additional trips per section

The bit runs presented in Tab. 8.8 show that if there are two necessary additional roundtrips per section, a R&P rig running an overweight BHA is 3.5 days slower compared with a conventional rig. But also a non overweight BHA slows down a R&P about 1.5 days. This leads to the conclusion that although a R&P rig can be moved faster, each additional roundtrip slows down the rig significantly.

The overall durations for this well are:

R&P rig, OW:	1088 [h]	45 [d]
R&P rig:	1040 [h]	43 [d]
Conventional:	996 [h]	41.5 [d]

Runs	Depth [m]		Duration R&P [h]		Conventional [h]
	From	To	OW BHA	BHA	
1	0	200	13	9	9
2	200	987	31	27	27
3	987	1100	16	12	10
4	1100	1489	58	54	52
5	1489	1731	44	40	37
6	1731	1980	47	42	38
7	1980	2379	74	70	65
8	2379	3069	116	112	106
9	3069	3297	56	52	46
10	3297	3310	33	29	18
11	3310	3450	65	61	52
12	3450	3520	48	44	35

Tab. 8.8 Bit runs, third scenario

8.5 Summary

If only tripping speed (with the assumption of an overweight BHA and a necessary mobile crane) is compared, the general conclusion is that the more trips necessary, the slower a rack & pinion rig. This leads to one recommendation for operators running a R&P rig: an overweight BHA needs to be avoided by all means.

Because if there is no hydraulic catwalk present and an increased number of trips are required, the operator slows himself down unnecessarily.

The result is a longer overall duration for finishing the well and more days mean more day rates needs to be paid by the operator.

9 Actual State Analysis, Selecting the Workcenters

First step of actual state analysis was to find so called *workcenters*, material flows at those centers and which processes they include. The flowcharts in the appendix sections A1.1 – A1.3 (rack & pinion rig) and A2.1 – A2.4 (conventional rig) helped with the identification; a sample of such a chart can be seen in Fig. 9.1 which shows the processes on the rig floor of a rack and pinion rig and in Fig. 9.2 the materials coming in/out can be seen.

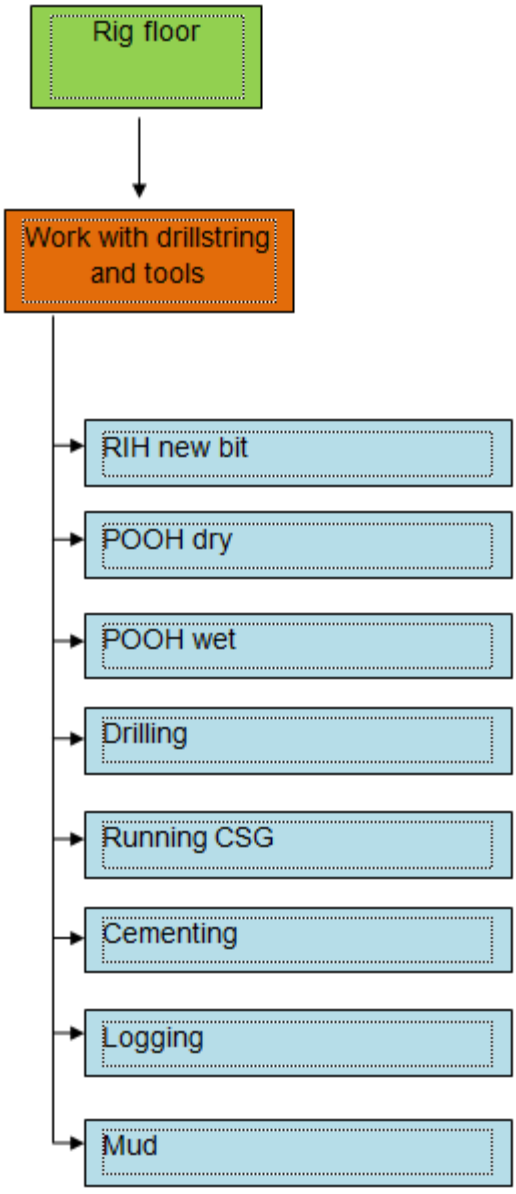


Fig. 9.1 Ongoing processes, rig floor, R&P rig

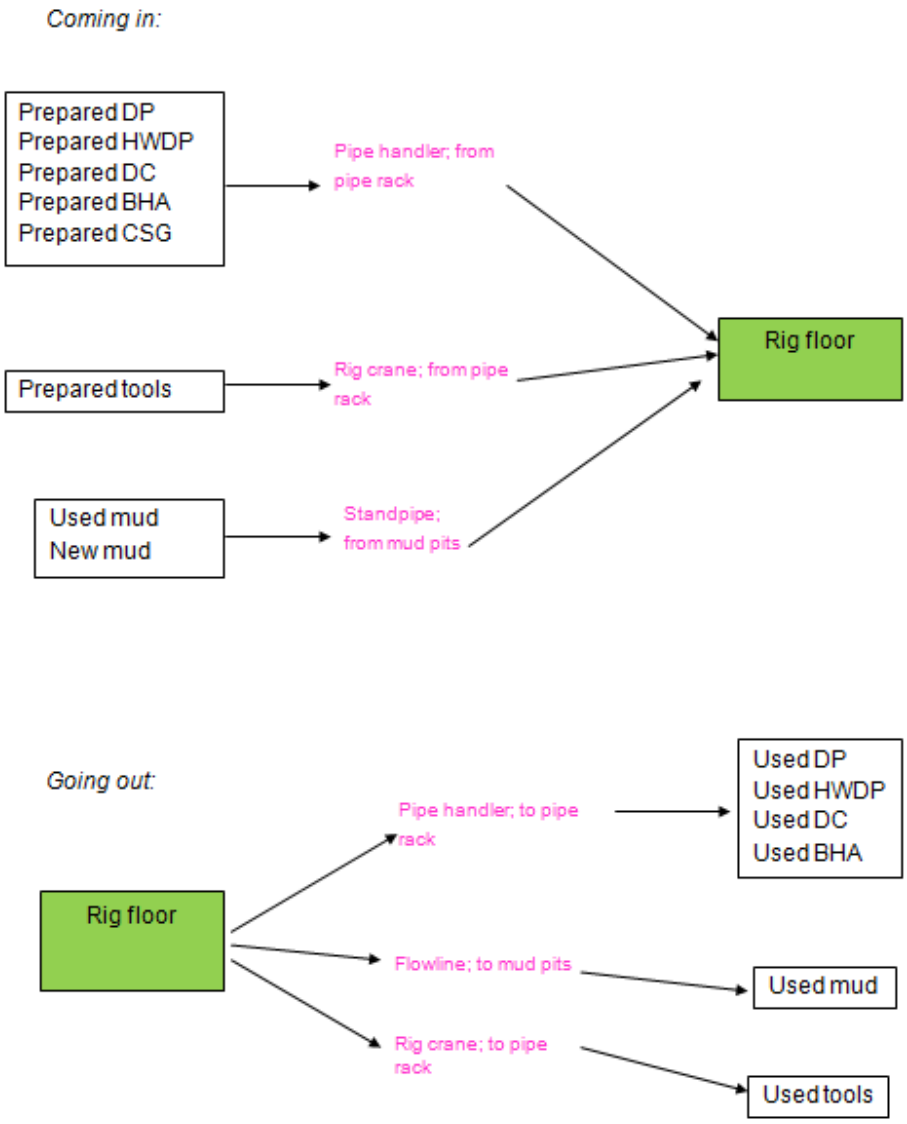


Fig. 9.2 Materials flowing in and out, rig floor, R&P rig

These flow charts made it possible to come up with the workcenters listed in Tab. 9.1 as well as the ongoing processes listed in Tab. 9.2, rack and pinion rig will be abbreviated to RP and conventional rig to CR.

Rack & pinion rig	Conventional rig
• Pipe rack • Rig floor • Mud pits • Equipment storage	• Pipe rack • Rig floor • Mud pits • Equipment storage • Floor rack

Tab. 9.1 Workcenters

Workcenter	Process	Rig
Pipe rack	Prepare equipment and pipes: • New equipment from supplier, warehouse, etc. • Used equipment from storage area onside or from rig floor	RP, CR
Rig floor	RIH new bit RIH new bit new string RIH new bit used string POOH dry, stack back POOH wet, stack back POOH dry, back to pipe rack POOH wet, back to pipe rack Drilling Running Casing Cementation Logging Mud	RP CR CR CR CR RP, CR RP, CR RP, CR RP, CR RP, CR RP, CR RP, CR
Mud pits	Solids control Prepare new mud	RP, CR RP, CR
Floor rack	POOH RIH	CR CR
Equipment storage	Equipment from the mechanic, electrician as well as all other tools are stored	RP, CR
Tool Pusher office	Rig administration	RP, CR

Tab. 9.2 Ongoing Processes

Where these workcenters are located (container/office of the Tool Pusher is not displayed, because it can usually be found next to the locations entrance) on a conventional rig can be seen in Fig. 9.3 and on a R&P rig in Fig. 9.4.

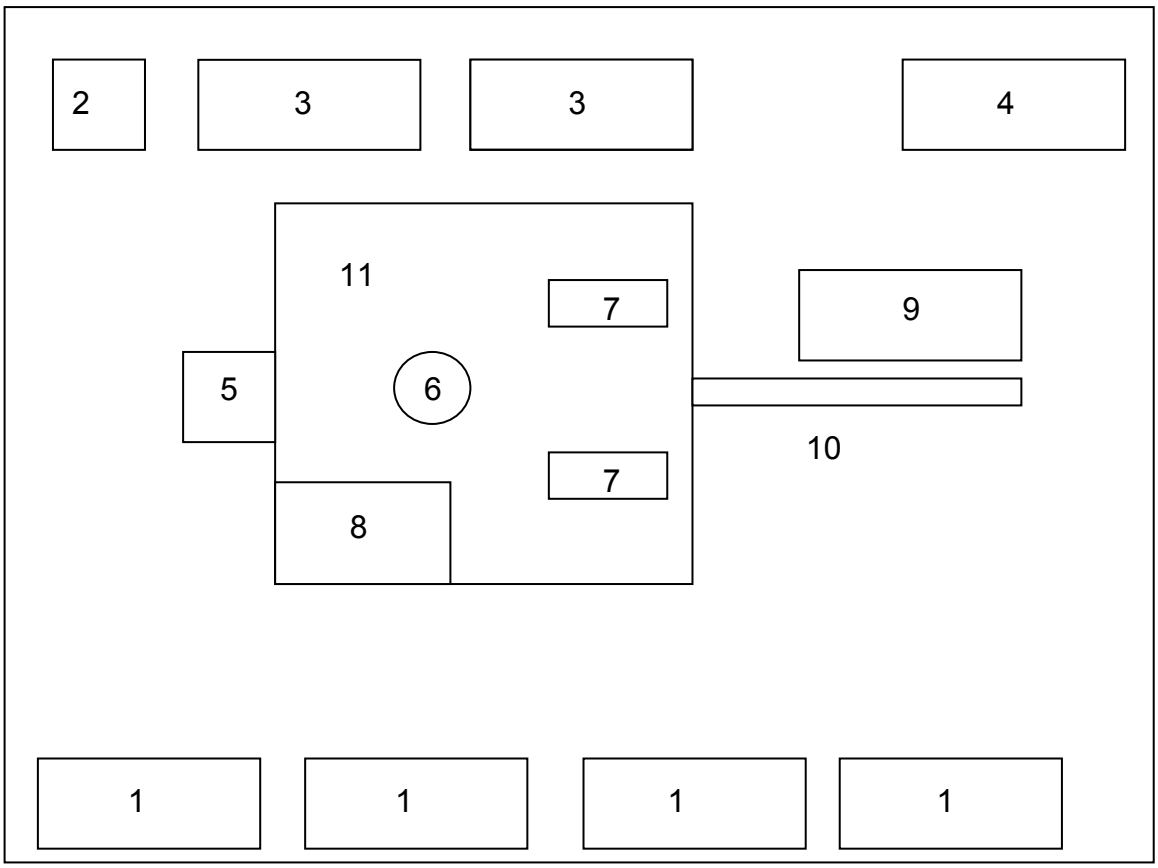


Fig. 9.3 Schematic rig layout top view, conventional rig

1 Equipment storage Ccontainer, pump-, rig-, mechanic-, electrician-equipment
2 Mudpumps
3 Mudpits
4 Mud chemicals storage
5 Drawworks
6 Rotating system, drip pan, bell nipple and BOP is below
7 Floor rack
8 Driller cabine
9 Pipe rack
10 Hydraulic catwalk
11 Rig floor

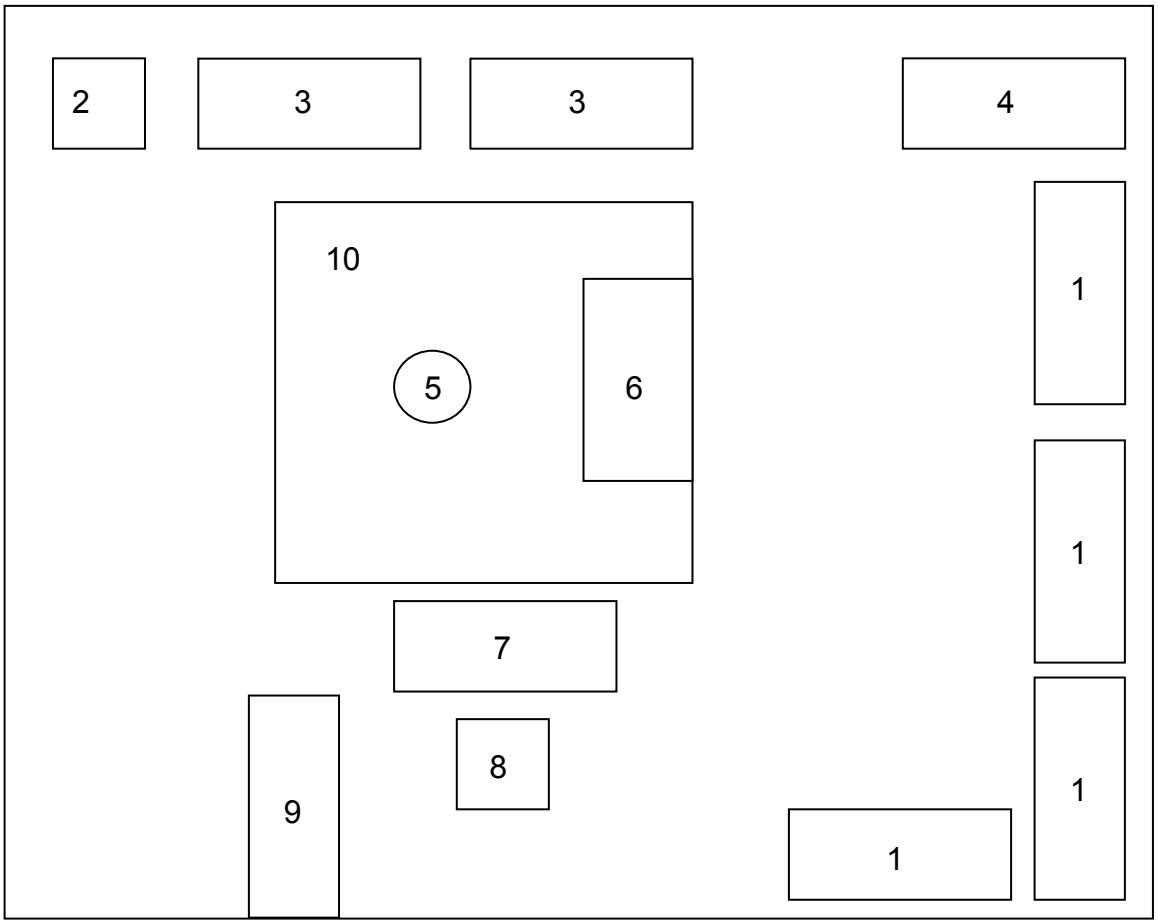


Fig. 9.4 Schematic rig layout top view, rack & pinion

1 Equipment storage container, pump-, rig-, mechanic-, electrician-equipment
2 Mudpumps
3 Mudpits
4 Mud chemicals storage
5 Rotating system, drip pan, bell nipple and BOP is below
6 Driller cabine
7 Pipe rack
8 Fork lift
9 Pipe storage boxes
10 Rig floor

These workcenters were chosen because they have one thing in common: most of the material flow of a rig is handled in these centers, besides the Tool Pushers office where the rigs administration happens.

Pipe rack

Every drillstring component as well as every piece of service equipment has to pass the ground rack, otherwise they cannot be used on the rig floor. The people working at the ground rack take care of the transport from ground level to rig floor.

Rig floor

Every component which is delivered from the ground rack, as well as the mud from the pits is processed here. The ongoing processes on the floor vary between two extremes: a lot of work to do and almost nothing to do. Especially if one compares drilling and tripping.

Mud pits

Like the pipe rack, all of the mud and every mud additive has to pass through. Another point is that without a proper solids control the well can be lost.

Equipment storage

Every container and area where equipment is stored, like the containers for the electricians and mechanics equipment, the tool shop container or the area around the rig where huge pieces of equipment can be stored

Floor rack

It can only be found on a conventional rig and without this rack not a single stand could be stored on the floor. In absence of a floor rack every single pipe needs to be brought back to the ground rack.

Tool Pushers office

In this container/office the rig is administrated regardless what type of rig. In this workcenter no material flow is present but instead a flow of information.

It can be argued that there are more locations on a rig which could be named work center like the dog house, BOP console, choke manifold etc., but this thesis focuses on every day operations and tries to improve these processes, not special ones like circulating out a kick, where special procedures exist. During every day operations the choke manifold is not used at all. Same is valid for the BOP control panel which is only used during a kick or if there is no string in the hole to prevent things falling into the well.

Furthermore the term dog house is used slightly different on every rig. This can be the floor tool shop, the driller cabin, meeting-, break-, coffee- and changing room or a combination of all these things.

Therefore it makes no sense to classify the doghouse as work center. For instance in some countries like Germany, the Netherlands or Austria a dog house could never be used as changing room because it is not allowed to enter a drilling location without personal safety equipment.

10 Investigation of the Workcenter Pipe Rack

10.1 Material Flow

Tab 10.1 gives an overview of what material is flowing in the workcenter pipe rack and which material is flowing out. The main process here is to prepare the equipment either for using it on the rig floor or storing it on location or sending it back to the supplier.

Inflow			
New	DP, HWDP, DC, BHA, CSG, tools	From	Suppliers tool shop, Storage area on site
Used	DP, HWDP, DC, BHA, tools		Rig floor, Storage area on site
Outflow			
Prepared	DP, HWDP, DC, BHA, CSG, tools	To	Rig floor
Used	DP, HWDP, DC, BHA, tools		Supplier Storage area on site

Tab. 10.1 Material flow, pipe rack

10.2 Casing/Drillpipe measurement

The first problem concerns both rig types. If a new casing (CSG) or drillstring arrives at location it needs to be measured (length and inner diameter). The author can tell from experience that such a measurement can take between 3 and 4 hours and afterwards the Tool Pusher needs roughly an hour for preparing a tally.

The measurement procedure looks like this; the drilling location needs to have a storage area, where the pipes can be unloaded from the trucks and processed further. The pipes are laid down on wooden planks to protect threads and the two thread protectors per pipe need to be removed.

This can be very time consuming especially if protectors are screwed on with a machine and threads are lubricated heavily. Afterwards every piece of pipe gets a number starting with one, ending with xxx. Important here is to use a water resistant pen because of rain, snow, etc.

Length is measured and written on every pipe but one also needs to write a tally with pipe numbers and lengths. Second thing to look after, is the pipes inner diameter. A plastic cylinder with an attached string and a slightly smaller diameter than the actual pipe diameter is pulled through every pipe. If it goes through every pipe without getting stuck, the inner diameter is alright and they can be used. Next step is to screw on thread protectors again.

The actual problem here is that two crewmembers are occupied and cannot do any other work. Once they are done, a third person (usually the Tool Pusher) needs to make an Excel-list, depending on how many pipes there are and especially on how readable the measuring person's handwriting is, it takes some time. This list is later used as input data for rig computers and of course a copy is given to forklift driver, driller, pusher and operator. Everybody should always know what pipe is currently RIH, especially for drillers a tally is very important. These people are responsible for the correct order of pipes, for that they should check every pipe number and list number. Most failures occur if lots of pup joints are used and driller relies on forklift driver and vice versa.

The next problem, failures in measurement cannot be ruled out, because it can always happen that the measurement team does not know CSG/DP length definition and add the pipe pin in their measurement as well. If it happens that pipes arrive much later as scheduled, every further step is delayed as well, since a CSG cannot be run before it is not measured.

Summarizing CSG/DP measurement:

- Time consuming
- Can delay every further step
- Error-prone
- Need to have a sufficient storage area at the drilling location

10.3 Pipe handler

This problem only refers to rack & pinion rigs, because it can happen that an operator wants to run a BHA which exceeds the pipe handlers' weight limitations. If this is the case, one needs a mobile crane next to the pipe rack to lift and of course lay down BHA. This crane first of all needs to arrive punctually and be rigged up. The author can tell from experience that this procedure takes roughly 2 hours each time. Before the heavy lift, of course a safety meeting has to take place. Then BHA is mounted with soft slings to the crane hook. During lifting it needs to be guided with ropes and wind always be kept in mind.

A BHA that exceeds pipe handlers' weight limitations is usually a bit longer compared to Range III DP's. That means the BHA has to be guided very accurately, to not hit rig parts or even worse, hurt somebody. Once the BHA is through rotary table and slips and safety clamp are set one has to wait until the mobile crane is rigged down, because it is blocking pipe rack.

After a well section is drilled successfully, the BHA has to be removed from rig floor. So above described process starts again in reverse order.

Summarizing Pipe handler:

- People can get hurt
- Time consuming, pick up and lay down combined, roughly 6 hours
- Every further step is delayed
- Rig can be damaged

11 Investigation of the Workcenter Mud Pits

11.1 Material Flow

Tab 11.1 gives an overview of what material is flowing in the workcenter mud pits and which material is flowing out. The main process here is to prepare and maintain the mud as well as maintain and clean the solids control equipment.

Inflow			
New	Mud and mud additives	From	Mud from supplier Additives from storage area on site and/or silos
Used	Mud		Rig floor, flow line
Outflow			
New Used	Mud	To	Rig floor, pumps, stand-pipe
Used	Mud and cuttings		Mud to supplier Cuttings to processing plant of mud supplier

Tab. 11.1 Material flow, pipe rack

Problems with the mud pits can occur at both rig types, because it does not matter which rig is used, processes here are equal. Usually there are no troubles during normal rig operations, difficulties start if one needs a lot of mud in very short time. This is due to lost circulation, a kick or unexpected change in rock type. If such a situation occurs, the man who is normally working alone at the pits, needs help immediately, so at least 2 – 3 crewmembers are occupied.

New mud needs to be prepared as instructed by the mud-service-company. For example barite, comes in big packs of 5 tons (if not stored in silos), so a forklift driver is needed.

But in the case there is no forklift driver for some reason (unloading truck etc.) it gets worse. Depending on where at the location mud additives are stored, crew members need to carry every sack used (~ 25 kg) on their shoulders or has to use a wheelbarrow, which needs to be loaded/unloaded. As a result of rushing from the storage area to the mud pits and back, a crewmember can fall downstairs and hurt himself. In such a situation risk of injury is increased.

Even if a forklift driver is available it is not an easy operation. A 400 tons rig is equipped with a suction pit capacity of roughly 80 to 100 m^3. If this is all gone or needs to be replaced, one is facing a very time consuming task. Especially at a remote location, where water needs to be stored too, it can get troublesome. Maybe a crewmember misreads the tank level sensor and one finds out that only half the water which should be in place is actually there.

Due to the fact that it can get confusing during the mixing procedure, there is always the risk of a spill. It can happen that a crewmember accidently opens or closes the wrong valve and one maybe loses a substantial amount of freshly prepared mud.

Summarizing Mud pits:

- People can get hurt
- Time consuming
- Every further step is delayed

12 Investigation of the Workcenter Rig Floor

12.1 Material Flow

Tab 12.1 gives an overview of what material is flowing in the workcenter rig floor and which material is flowing out. The main process here is to work with the tools and pieces of the drillstring.

Inflow			
Prepared	DP, HWDP, DC, BHA, CSG and tools	From	Pipe rack
Used, new	Mud		Mud pits
Outflow			
Used	DP, HWDP, DC, BHA and tools	To	Pipe rack
Used	Mud		Mud pits

Tab. 12.1 Material flow, pipe rack

All the other workcenters process their materials only to get them on the rig floor and due to this dependency it suffers most from delays. This is not so much the problem on a conventional rig because once the entire string is in the derrick the pipe rack is not used. But on a R&P rig floor with no possibility of stacking back pipe it can get troublesome if the pipe rack is either full or empty.

In the case that there is a problem at the mud pits and circulation has to be stopped both rig floors need to stop their processes too. The same is valid if essential equipment is missing and therefore the work has to be stopped.

This leads to the solution that there always has to be continuous supply of materials and equipment. Therefore maintenance problems (which require the stop of the ongoing process on the rig floor) need to be detected at an early stage because then the mechanic/electrician can find the optimum moment for their repair, during wait on cement for instance.

This is only valid for the case that the maintenance work can wait that long; if not there is no other solution than shutting down the operation. Best practice would be if the repair can be done during the ongoing processes which of course cannot always be done that easily because of safety concerns.

13 Investigation of the Workcenter Equipment Storage

At a drilling location a lot of various things can be found:

- Loads of drilling equipment
- Wellhead equipment
- Rig spare parts
- Devices for electrician and mechanic
- Service companies stuff
- Chemicals
- Forgotten hand tools
- Garbage (wood, metal, plastic, organic, hazardous), etc.

All of this and a whole lot more can be found in various amounts in sometimes very surprising places. A new location commonly comes with a new layout-plan but this plan only focuses on the rig itself, mud pits, workshop-, storage-, office- and camp-container. That means above mentioned stuff can be placed wherever enough space is found. Therefore the pusher is in charge to ensure, what is placed where. Even more important, he has to remember, where everything is.

13.1 Inventory

Usually a list is handed out and a time frame of about four weeks is set during which a crewmember is trying to find everything requested. But not only rig parts need to be counted, also electrician and mechanic get a list for their things. Occurring problems can be:

- Person in charge is not working accurate and mistakes are made.
- Items that cannot be checked like: agitators which are fixed to the bottom of mud tanks or hopper pumps mounted so close, making it impossible to identify a serial number
- Time consuming: the crewmember is occupied and cannot do anything else. Even more affected are electrician and mechanic. If there is more important work to do, nobody cares about inventory. But at some point it has to be done, especially if one is close to deadline. Now, even more mistakes happen, because people just rush through their list and do not take it seriously.

Summarizing Inventory:

- Time consuming
- Error prone
- Costs for new ordered equipment, which is not necessary. These items were ordered due to a person who was not working accurate and just kept saying that something is missing even if it was there.

14 Investigation of the Workcenter Floor rack

14.1 Material Flow

Tab 14.1 gives an overview of what material is flowing in the workcenter floor rack and which material is flowing out. The main process here is storing the drill string.

Inflow			
Used	DP, HWDP, DC, BHA		Rig floor
Outflow			
Used	DP, HWDP, DC, BHA		Rig floor

Tab. 14.1 Material flow, floor rack

Due to the drill string is only secured in the fingers; to prevent falling into the derrick, no improvement potential was found.

15 Investigation of the Workcenter Tool Pusher Office

15. 1 Material Flow, Certification

Tab 15.1 gives an overview of what material is flowing. The main process here is to find the right tools.

Inflow			
Used, new	Down hole equipment, slips, dog collars, fall protection equipment, chains, lifting devices….	From	Certifying company
Outflow			
Used, new	Down hole equipment, slips, dog collars, fall protection equipment, chains, lifting devices….	To	Certifying company

Tab. 15.1 Material flow, certification

Drilling equipment needs to be certified at regular intervals; this means finding out if the actual state of a tool corresponds to the guidelines and if a safe operation mode can be ensured. Only a few companies are allowed to certify, which makes it necessary to tell them in advance, what tools are delivered. The certifier sets up a schedule and afterwards one knows when the tools are sent back. This is relevant because, the equipment which is checked at the moment needs to be replaced with rental equipment. Following steps explain how such a procedure looks at location.

1. The Tool Pusher has a list with everything that needs to be checked and hands it to a crewmember which should find these items on location and pack them on a wooden pallet.
2. The person tries to find everything at location, which is no problem if one is looking for an annular preventer for instance, but smaller things like, dog collars, slips, saver subs, kelly cocks, XO's etc. can be difficult to find, since a rig is usually equipped with more than one thread type.
3. The person finds some things on the list, are these items the right ones? Therefore serial number is checked, if one can find it and if it is still readable.
4. The person finds everything and let the Pusher check it, usually something is wrong and the process of trying to find some parts starts all over again.

The problems here can be:

1. The Pushers list is not accurate because it is only an Excel list, with toolnames, serial numbers, thread types and date of last inspection. It can happen that:
   a) A pusher made a mistake during filling out this Excel-sheet but did not recognize it.
   b) For some reason the tool is not at location anymore, but nobody knows, where it was sent to because there is no delivery note present
   c) It is there, it is found, thread type is correct, but the serial number is different and nobody knows that there is second tool, or it is the right tool but nobody knows about a change in serial number

d) Since last inspection the tool was not used and therefore does not need to be checked (this circumstance can be identified by two white painted rings around the tool)

2. The person looking for tools, cannot find the right ones but some other ones, where no certificate is present and nobody knows since when these items are at location.

3. After several running hours and excessive wear of a XO for instance, the serial number is grinded out and it is not possible to identify it.

4. The person looking for tools is not working accurately and just says that the requested items cannot be found. The Pusher trusts the person and does not review it.

How such a XO looks like before it is worn out can be seen in Fig. 6.6. One can see a longitudinal recession with the engraved serial number and thread types. Equipment which is used down hole or on the rig floor is usually exposed to wear, stress, temperature and/or abrasive drilling fluids, this makes the number unable to read.

Fig. 15.1 XO, NC 50 box, 2 7/8 pin ([24])

Summarizing Equipment certification:

- Time consuming
- Error prone
- Costs for rental equipment

15.2 Material Flow, Weekly Checks

Weekly checks are necessary because it is tried to find out if certain consumption material is available in sufficient quantities, Tab 15.2 gives an overview of what material is flowing. The main process here is to find the right materials.

Inflow			
New	Soft s Soft slings, in different weight ranges, Soft iron rings, in different diameters, Pump parts, like liner, piston, suction- and pressure valves, Thread grease, Lubrication for elevator, iron roughneck, etc.	From	Supplier
Outflow			
New	All material mentioned above is consumed	To	Various locations of the rig

Tab. 15.2 Material flow, certification

Checking these goods and a whole lot more, is very important, but often neglected due to time consumption. But for instance, if BOP-stack is nippled-up, and it is found out that there are no soft iron rings anymore, the Pusher is in big trouble, because he is responsible for performing weekly checks and also keeping a list with previous mentioned goods up to date.

That is why he should do the check or at least hand over this job to a crewmember/night-pusher, if he has no time. After counting the rigs supplies it is once again the Pusher who needs to order everything that is not available in sufficient quantities.

Summarizing Weekly checks:

- Time consuming
- Error prone
- Every other step is delayed due to missing parts

15.3 Substitute Pusher, Electrician, Mechanic

This is not a material flow but a flow of information. It can happen that Pusher, electrician or mechanic have to leave location due to illness or for some other reason, in such situation a substitution is needed. As long as nothing special takes place, there are no problems. But if for instance one is facing: broken hydraulic hoses, broken electric motors and non-routine drilling operation, like coring, problems start and grow bigger immediately, if no correct hand over was done. Electrician and Mechanic needs to find spare parts and tools in tool shops they are not familiar with. Furthermore they need to know how the broken hoses/motor should be exchanged without causing additional damage. But if there is a severe problem and they do not know what to do, one needs to call the maintenance crew of the company. Depending on where the rig is located, getting there can be a long trip and in the meantime the rig is at a standstill.

Coring on the other hand is the pusher's problem. As mentioned it is not an everyday operation, this makes it possible that, nobody of the drilling crew has ever done coring. Also such a job is a little different from rig to rig. The pusher has to ensure nobody gets hurt, nothing is damaged and that the core is retrieved successfully. Therefore one needs to know, how such an operation is done, especially how it is done safely. Also at the pre-job safety meeting he needs to know what he is talking about and all questions need to be answered correctly.

Summarizing Substitute Pusher, Electrician, Mechanic:

- People can get hurt
- Rig can be damaged
- Time consuming
- Every further step is delayed

16 Improving the Workcenter Pipe Rack

16.1 New Casing/Drillpipe Measurement

A short problem review:

Time consuming: Because at least two crew members are occupied and cannot do any other work.

Delay of further steps: Because too much time is wasted during the measurement. Another reason can be that there is a delay in delivery or even worse, a combination of both.

Error-prone: Because there can be failures in measurement and/or writing/reading mistakes.

How can these problems be avoided? Measurement errors can only be avoided by double checks. That implies that two crew members measure the lengths and record them. Once done, two other crew members measure again and now there are two sets of lengths, with (hopefully) the same numbers. If the lengths of some pipes do not match, these ones need to be measured again.

This solution occupies more men and takes longer. For instance, one detects that the length of one pipe does not match the previous measurement. Based on the new process design it needs to be measured again, but this particular pipe is number 162 of a CSG-string with 2500 m. Getting there takes its time, especially if the pipes are not lying next to each other but, because of narrow space, above each other.

This design is not working out, that is why the following design should be applied.

All necessary measurements should be done at the manufacturer's tool shop, because:

1. There is enough space.
2. Every pipe can be measured immediately after production. This means after every assembly line, a certain tool measures the length and before or afterwards a plastic cylinder is automatically pulled through. Such a procedure is much more accurate than using a measuring tape on location and, even more important, it is much faster.

   This means the manufacturer needs to install new machineries, which of course cost money. But he can call a higher price due to better service and furthermore he is not selling only one string to one customer. The company buying the string needs to pay more but safes a lot of time and in addition money. One is paying more, but the savings should compensate the higher price.
3. If a new string is ordered and loaded on trucks for delivery, just-in-time-principle is applied. Therefore it is necessary to load the pipes in correct order. For instance the last pipe on the first truck is that one with the CSG-shoe, because it is the first one RIH.

   Best practice would be if the pipes are not stored at location anymore but instead: delivered, loaded on pipe rack, protectors unscrewed, transported to rig floor and RIH. This makes it possible to have a smaller drilling location ending up with a reduction in costs, because one does not need to build an unnecessary large location.

   A tally is sent in advance and if required transformed into an Excel-sheet, as input data for the rig computers.

The bottleneck is that delivery needs to be flexible. For instance the section which should be cased took two days longer to drill and in addition it is Sunday 2 am, December 25th. Even at such dates, there has to be a person at the manufacturer's office who can be called and of course at least two truck drivers are necessary.

Even though there is a bottleneck, the improvements are as follows:

- No delay of further steps because no measurement is necessary and since just-in-time principle applies, there are no delivery delays. In addition 3 to 4 hours are saved each time a string needs to be measured. In the sample well presented in chapter 8 which needs 4 casing strings, the savings are between 12 and 16 hours
- No measurement errors.
- No personnel costs for the measurement process and the process of writing a tally
- No ILT, because the time can now be used for other, more important things. Of course it needs to be controlled carefully what the crew is doing, because it does not improve the overall drilling process if they use the saved time for breaks.

16.2 New Pipe Handler

A short problems review:

People can get hurt: Because of working under a suspended load.

Time consuming: Because of waiting on crane. The crane needs to be rigged up/down directly in the pipe rack area, blocking this area for further work.

Delay of further steps: Because of waiting on crane. The crane needs to arrive punctually on location.

Damage of rig: Because of wind and not proper working. BHA on the hook can be caught by a gust of wind and hit the rig. This scenario should be avoided by guiding BHA with ropes, but if the wind is too strong and the guiding person loses grip, damage to the rig can be done.

The problem is not the crane process itself, the problem in the first place is that a crane is even needed. Avoid a crane order can only be done by:

a. lighter BHA to avoid exceeding weight limitations of the pipe handler.
b. a different method of getting BHA on the rigfloor.

According to point a. a BHA can only get lighter if it is “cut” in more than one piece. Therefore it is screwed apart from each other, but making up or breaking out a BHA on the ground without an iron roughneck is almost not possible unless very unsafe tricks are used.

It is also not recommended to screw apart a BHA without the manufacturer’s permission because damage on the inside can be significant. At the end, getting a BHA lighter is no easy task.

According to point b. can a BHA brought to the rig floor without pipe handler- or crane-usage? Yes, but the rig floor layout needs to be redesigned completely. Figure 15.1 shows the current rig floor layout in top view and figure 15.2 shows the redesigned rig floor.

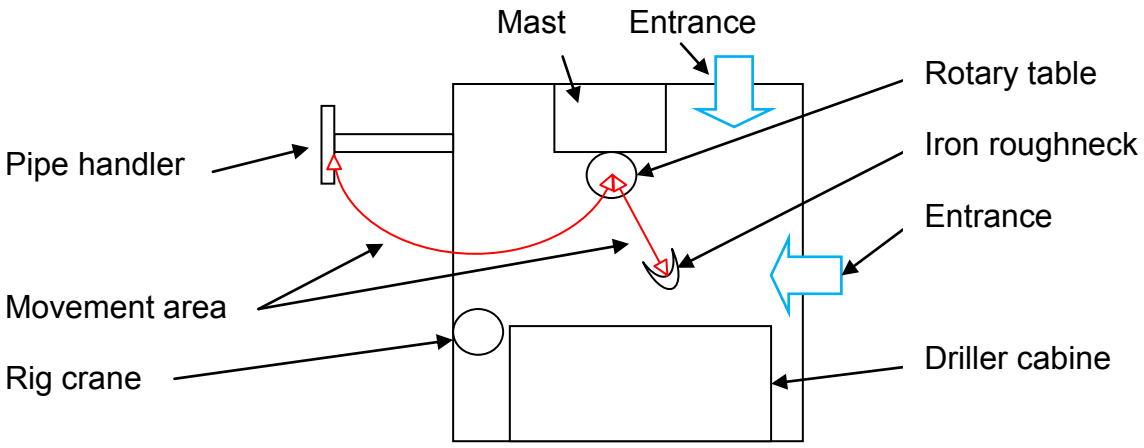


Fig. 16.1 Current rig floor layout, top view

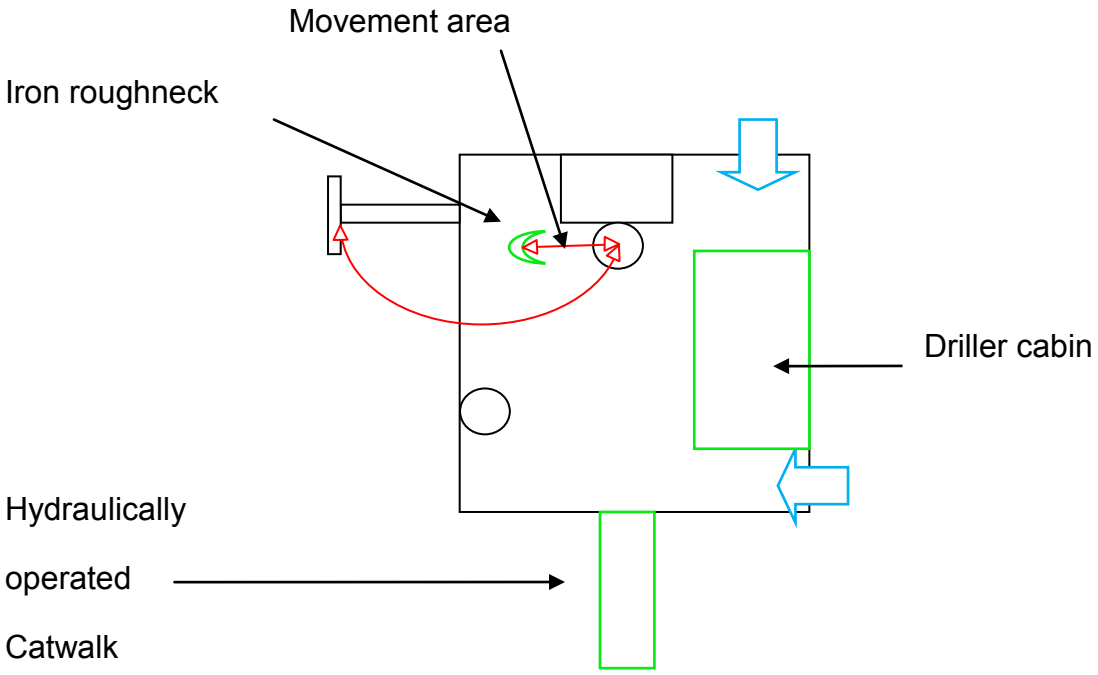


Fig. 16.2 Redesigned rig floor layout, top view

Both figures show that the pipe handler and its movement area cannot be changed also the mast and rig crane are still on the same position. But the driller cabin and iron roughneck change their positions. A hydraulically operated catwalk delivers the overweight BHA's to the rig floor. A sample picture of such a device can be seen in Fig. 15.3

Fig. 16.3 Sample picture of a hydraulically operated catwalk, ([23])

If the catwalk is not in motion and on the ground a BHA is placed on it with the help of a fork lift, but before that a hoisting plug needs to be screwed on. This Figure shows the catwalk in motion because the upward position is completely horizontal. Once this position is reached, the shoe pushes the BHA towards the rotary table. The top drive waits in its lowest position with swung out bails and open hydraulically operated elevator, which closes around the hoisting plug. Afterwards the top drive moves upwards and slowly swings in the bails until the BHA is directly above the rotary table. The BHA is RIH and secured with safety clamp and slips. This process is exactly the same one as on a conventional rig.

Such a redesign corresponds with the process optimization type, "Business reengineering". Therefore it makes only sense if a rack & pinion rig is newly built because these changes on a rig which is already in use are not possible.

The problems will be: the rig's static loads (driller cabin, iron roughneck), rewiring electric cables, reinstalling hydraulic hoses as well as the change in entrance (new stairs need to be built).

There are some things that need to be considered if a catwalk is installed:

- What max. weight can be lifted?
- What max. BHA diameter can be lifted?
- What is the max. lifting height?
- Does it have its own power supply (diesel engine), or can it be connected to the rigs hydraulic system?
- Is it moveable (trailer mounted) or not?

If the rig needs to drill a series of wells in one row, one has to make sure that the catwalk is connected to the rig. Because if one well is drilled after each other, a hydraulic operated skidding system is used. This makes it possible to push the rig from well to well and of course the catwalk should be pushed as well. If this is not possible, one needs to find a moveable catwalk. Such device needs to offer the necessary requirements and in addition is trailer-mounted, so it can be pulled by a truck. This provides another advantage. A drilling company knows in advance what wells are drilled and what material is used, because such data has to be provided by the operator. If these wells do not require an overweight BHA, the hydraulically operated catwalk does not need to be installed because the pipe handler is capable of every pipe used. Of course the same is true for a non moveable catwalk, if it is not needed, there is no need to install it.

There is also a reason against it, because one can argue, that, if the catwalk is only used a few times, why should the construction department design a whole new rig?

The answer therefore is pretty simple. Not only does it improve BHA handling; the new design makes it even possible to operate the iron roughneck from the driller cabin. This increases the safety on the rig floor significantly, especially if a fully automated iron roughneck is used. Those devices can handle drill pipes and casings, have stubbing guides, can find the tool joints on their one and also have a

mud bucket attached. Such an iron roughneck would be the Weatherford TorkWrench 10-100 All-in-one System. ([25])

Installation of a hydraulically operated catwalk improves the following:

- No harm of people because no one works under a suspended load.
- No waste of time, because one knows in advance if a catwalk is necessary to install or not. There is no need any more to wait until a mobile crane is rigged up and down which saves roughly 4 hours each time an overweight BHA is run. In chapter 8 the two rig types are compared in terms of tripping speed and the saved time varies between 17 hours (ideal case) and 92 hours (worst case).
- No rig damage, because no suspended loads can hit the rig due to gusts of wind.

17 Improving the Workcenter Mud Pits

A short problems review:

People can get hurt:	Because of falling downstairs, due to running and carrying mud additives
Time consuming:	Because of mixing 80 – 100 m³ mud takes its time.
Delay of further steps:	Because of waiting on mud preparation.

This problem cannot be solved everywhere (speaking in terms of location), because the new process only works in non remote areas. The drilling location itself needs to be in a certain distance from the mud service company's plant. The reason for that is that the fastest way to get new mud without preparing it on location is, to have it delivered. But this works only in areas which have access to streets and are not remotely operated. Otherwise a delivery of mud is not possible. The next thing to consider is the preparation time of the mud: in the case this time is shorter compared to the delivery time, it makes no sense to have mud delivered.

Assuming the plant is next to the drilling location and therefore delivery time is shorter than mixing time, the mud service company needs to be fully flexible because lost circulation can happen any day at anytime, for that reason the mud company always needs to have personnel working at the plant and also truck drivers on standby.

If it is possible to find a company providing such service, and it is close enough to the drilling location, the following things would be improved:

- No harm of people, because they do not need to run and bring mud additives to the hopper and according to that, do not fall down stairs.
- Reduced loss of time, because preparation of the mud on site takes much longer than to call the company and get the mud delivered to the rig.
- Since several important factors like mud type, mixing capacity of the mud pits, volumes of the well and mud pits influence the preparation time on site, the exact amount of saved time is very difficult to quantify. But a general conclusion is; the higher the density of the new mud and the higher the volume of mud which needs to be mixed, the longer it takes.

18 Improving the Workcenter Equipment Storage and Tool Pusher Office

In this chapter the concept of storage software for a drilling rig is presented which makes it possible to improve the Workcenters equipment storage and Tool Pusher office. A short problem review follows below:

Time consuming:	Because of people need to find the right tools, drilling/rig equipment and/or spare parts.
Error prone:	Because of people who are not working correct and because of wrong instructions.
Delay of further steps:	Because of missing parts.
Costs:	Because of rental equipment and/or not needed new equipment.
People can get hurt:	Because of wrong instructions were given.
Damage of rig:	Because of wrong instructions were given.

Smart storage is the idea of warehousing software for drilling rigs. It should run on the pushers- electricians- and mechanics-computers as well as on the computers in the office. Especially the people who work in the bookkeeping- purchase- storage- and safety-department need to have access to the system. They have to deal with the annual inventory, orders from the rig and safety issues. But of course not everybody has full access to it. For instance, the people from the safety department do not need access to the chapter *Equipment.* This is also a safety issue because no one should be able to change data if he/she is not authorized to.

18.1 Requirements for SmartStorage

It is required that every rig in the fleet has a reliable internet connection, so that the rigs can check the data of each other, as well as the people working in the office can check the data of every rig, but both of them have only access to special data.

Furthermore it is necessary that every tool on the rig can be identified clearly but the engraved numbers especially at down hole tools wear out; therefore it is hard to identify them. The first problem is to find a better system than engraved numbers.

The solution could be RFID-chips which are placed in the longitudinal recession (where the serial number is engraved) and covered with a steel plate. It has to be determined however if that is even possible.

- Is it legal to place a chip at drilling tools and is it legal in every country or only in a few?
- Is it legal to weld a steel cover over the longitudinal recession?
- Is the chip temperature resistant?
- Is it possible to place rig-tongs or the blades of the iron roughneck, directly over the longitudinal recession, without damaging the chip?
- Is the chip working under a steel cover and temperature resistant paste?
- Is it possible to read the data of the chip ("pistol-shaped-hand-scanner") if it is covered with a steel plate?
- Is the scanner ex-proof, dirt and impact resistant (oilfield-proof)?
- Is the scanner easy to operate?

Best practice would be that every new tool is sent to the workshop of the company, where the RFID's are placed on the tools and tested if they work properly. Afterwards the tools are added in the database and sent to the rig.

One also needs a special container with shelves (different sizes and heights) in it and opening side doors which make it possible to get out heavy tools from the shelves with the forklift.

The container is used to store every tool of the drill string (which is not used at the moment). The clue is that every shelf space has an EAN code that needs to be scanned if a tool is stored there, this means that the RFID chip corresponds with the EAN code and because of the database it is possible to know at any time where the tool is. This means unnecessary loss time due to searching for tools can be avoided.

The future workflow therefore should look like this:

- Anybody who takes out a tool from a container needs to scan the tool.
- The system now “knows” that the tool is not at its place. The scanner needs to be programmed in such a way that information can be sent to the tool, if it is active, which means working (recording of running hours) or at maintenance/recertification (no recording of running hours)
- Once the tool is back either from maintenance or from down hole, it needs to be ready for storage (clean, threads greased, protectors screwed on)
- The person who returns the tool needs to scan the tool as well as the EAN of the storage position on the shelf.

The basic program structure of SS can be found in the following Figure: 18.1 and a detailed description afterwards.

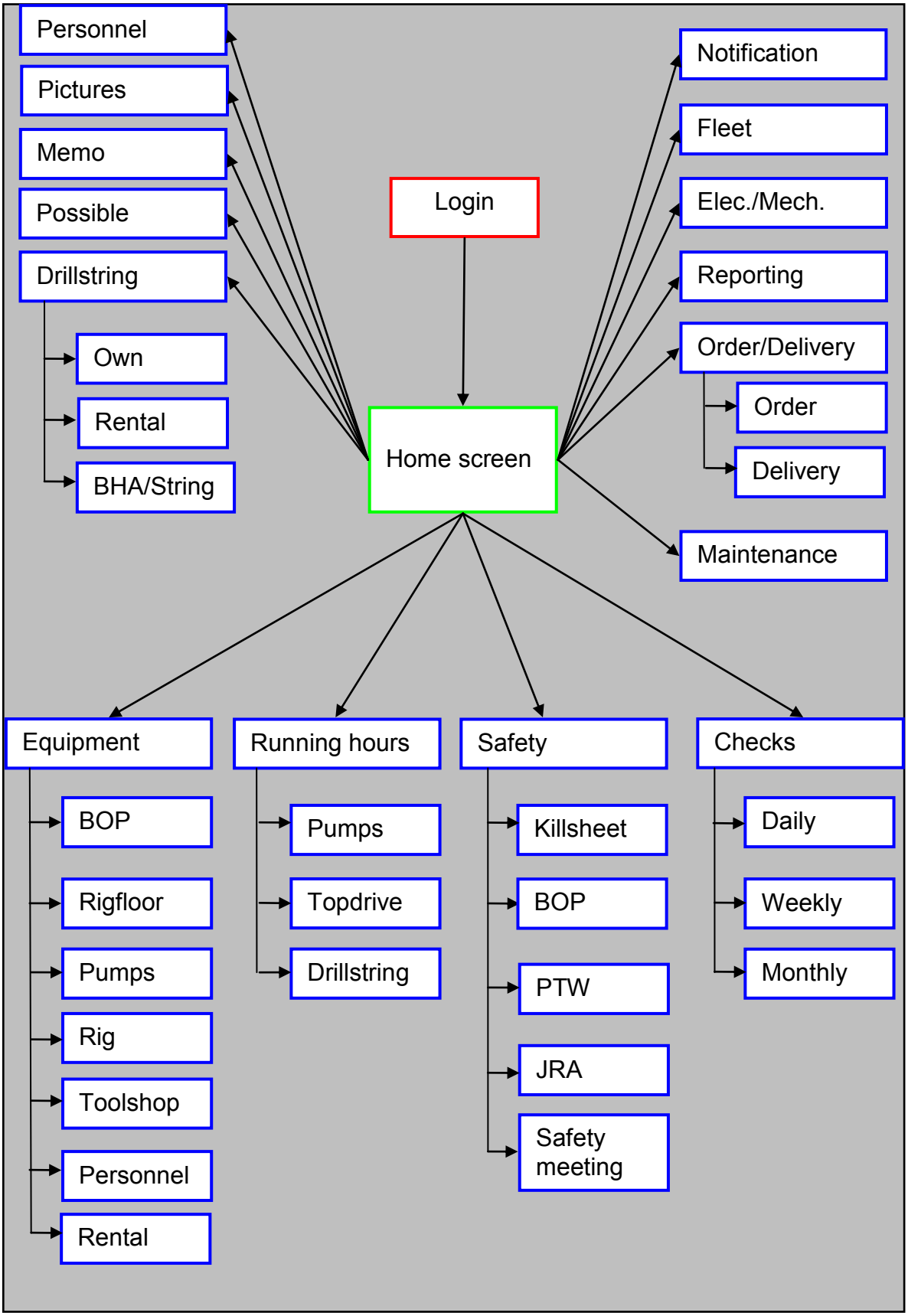


Fig. 18.1 Layout of SmartStorage

As one can see, it is necessary to log oneself into the program. This is important because if a mistake happens, one can see from the logs, which person is responsible for it. Of course this feature could be used as a spying tool on every employee who has access, but it is strongly recommended not to do so and only use the logs if something went wrong.

The blue rectangles which are hit by an arrow can be seen as buttons at the home screen on which one can click on and a submenu opens. The same principle applies for the four buttons at the bottom: clicking on them opens a set of further buttons/menus and from there one reaches the respective function.

The description itself starts with the button *Drillstring* and is continued counterclockwise.

18. 2 The Menu “Drillstring”

This menu covers all tools from the bit to the top drive system (automated kelly cock is the last piece of the string). This means, behind the button *Drillstring* and its sub buttons hide two databases with all the equipment, one for the rental and one for the own equipment. Because usually a drilling company does not own all tools necessary to drill a well, equipment needs to be rented from a third-party-company. To avoid confusion, rental equipment is always added here, because confusion starts if the tools were rented 3 months ago, should be given back now and nobody can remember which tools are the right ones.

The menu *Drillstring* should also give a short overview of how many and which DP/HWDP/DC’s are on site, split up in own and rental ones. This overview should be directly displayed in *Drillstring* without furthermore clicking. An example of how such an overview should look like is given in Tab 18.1.

Type	Size	Range	Connection	Amount	Notes	Own	Rental
D.C.	x	x	x	0		0	0
H.W.D.P.	5"	3	NC 50	14	From Rig 70	10	4
	5"	2	NC 50	1		0	1
	3 1/2"	3	NC 38	28		0	28
D.P.	5"	3	NC 50	98	Incl. 1 damaged (#227)	98	0
	5"	PJ	NC 50	3		0	3
	3 1/2"	3	NC 38 VAM EIS	116		0	116
	3 1/2"	PJ	X	0		0	0

Tab. 18.1 Pipe overview

The database for company owned equipment also needs to have a certification-counter. This counter warns the Tool Pusher if a certain tool needs to have the next inspection. If this tool is relevant for the current drilling process a spare one needs to be rented. Since organizing a spare tool takes its time, the counter should warn the Pusher 3 to 4 weeks before the inspection date. Such a warning should pop up at the Desktop even if the Tool Pusher is not logged into the system so that he knows that something is not ok. After logging in the Button *Notification* needs to blink in red (or some other color). By clicking on *Notification* he gets the message about the tool but the flashing red light stops only if he sets a checkmark next to it and every other message.

If something is wrong afterwards and the logs are checked, one can see, the Pusher set a checkmark at (date and time), but has not done anything further.

The menu *Drillstring* also includes a tool, which helps the Pusher to set up a new BHA. If the BHA is changed one needs a new BHA list. A BHA list is made of every tool/pipe a BHA consists of, starting with the bit and ending with HWDP's, an example of how such a list should look like can be seen in Fig. 18.2

Bottom Hole Assembly No: BHA 04

Company:	MarkusOil	Rig Contractor & No.:	Markus Drilling, Rig 66	Depth (in):	m	Date (in):	
Well:	XYZ 12	Field:	XYZ Field	Depth (out):	m	Date (out):	

BIT DATA

Item	Bit No.	Size inch	Mfr.	Type	Serial No.	Nozzles	TFA [in²]	Gauge Length	Depth In [m]	Depth Out [m]	Bit Length
0	2	9 1/2	ACME								

BHA COMPONENT DATA

Item	Description	Ser.-No.	Weight [kg]	ID [mm]	OD [mm]	FN [m]	OD FN [mm]	Connection dowm	Connection up			Length [m]	Total Length [m]
1	Stabi			63	240			B 6 5/8" Reg	B NC 50			0,33	0,33
2	Motor			114	171			P NC 50	B NC 50			7,79	8,12
3	Float sub			51	171			P NC 50	B NC 50			0,94	9,06
4													
5													
6													
7													

Fig. 18.2 BHA list

Important to know is, from which point the operator wants to measure the total length, rotary table or ground floor, therefore the distance between rotary table and ground floor is added or subtracted.

This list can be also used for the CSG run, therefore the Bit data is skipped and the first BHA component data is the float shoe.

This list can only be used for making up BHA/CSG, an entire Drill/CSG string is done as follows. Due to the premade equipment list, all drill pipes are in the system already. And one also know in which order they are RIH because they are stored in “Boxes” on a rack&pinion rig and on a conventional rig one also knows, at which position each stand can be found. Of course that the database for the equipment (here the drill string itself) has to be made very accurately, speaking in terms o length, pipe No. and order. The length of the BHA is automatically taken from the BHA list, so it is important to make the BHA list first. Another reason for working accurately is that the rigs computer system uses these lists and works with them.

An additional function should be that the BHA and DP list can be printed, because operator, driller, forklift-driver and Pusher need to have one. How such a list looks like can be seen in Tab. 18.2

No.	Pipe No.	Length [m]	Total length [m]	Type
0	**BHA 04**	**26,94**	**26,94**	**BHA 04**
1	252	13,23	40,17	5" DP
2	39	13,19	53,36	5" DP
3	153	13,20	66,56	5" DP
4	56	13,21	79,77	5" DP
5	92	13,24	93,01	5" DP
6	129	13,23	106,24	5" DP

Tab. 18.2 DP list

18.2.1 Requirements for the Menu "Drillstring"

The database itself should have the following columns:

No./ Name/ Serial No./ Dimensions/ Amount/ Sketch / Last inspection/ Next inspection/ Storage/ Active/ Certificate

- Dimensions is split up in: Length/ OD/ ID/ Threads/ OD Fishingneck
- Sketch needs to show all dimensions of the tool, even the depth of float sub, in which the float valve is installed.
- Active is a box where a checkmark can be set, to identify if a certain tool as currently working as part of the drill string.

  If a tool is active, it is automatically taken to the menu *Running Hours* where the running hours for every active tool are recorded. But it depends on the tool, what data is recorded. For instance all pipes, XO's etc. are sensitive to rotation from the Top drive, but a saversub is sensitive to the amount of connections, that are made with it. If a tool is not in use, it needs to be cleaned, greased and stored in the right place.
- Storage is the position where the tool can be found, for instance in container A, shelf 3, position 25 a 5 inch saversub with the connections pin&box NC 50, can be found.

18.3 The Menu “Equipment”

In this menu every other not drillstring related tool can be found, even the rig itself. All submenus are also databases, having the same main columns like the *Drillstring* database: No./ Name/ Serial No./ Dimensions/ Amount/ Sketch/ Last inspection/ Next inspection/ Storage/ Active/ Certificate/Picture

“Equipment” splits up to the submenus:

- BOP

  In this menu not only every BOP part can be found but also the spaceout. This is a drawing of the actual BOP configuration. It should be possible to change parts of the drawing by drag&drop because maybe the next well to be drilled requires a different BOP configuration for which it needs to be adapted.

  The spaceout requires precise measurements from the rotary table to every part of the BOP. Also necessary is to name every part, know the pressure ratings and the dimensions. Also very important to know is which softiron ring (BX ??) is used for which connection.

  Also the choke line (coflex-hose) and kill line (usually made out of chicksans) is listed here, every piece of pipe from the pump manifold to the BOP stack (list of all serial numbers and names in the right order).

  But also a drawing of the choke manifold with all necessary data as well as all details concerning the Koomey unit can be found in this menu.

- Rigfloor

  This menu covers all parts that are used on the rig floor, slips, dog collars, bails, elevators, tongs, iron roughneck, TD etc, basically everything that needs to be certified at some time. Therefore hammers or crowbars for instance are not listed.

- Pumps

  This menu covers all parts concerning the pumps, pistons, liners, valves, pop offs etc. Mud pumps are a vital part of a rig, therefore all pump parts should be in a separate container. Once again with shelves, this makes it possible that every component can be found at the same place indicated by the database.

- Rig

  This menu covers all parts of the rig itself, substructure, shaker, hopper-pumps, mast, draw works, etc. As long as something is not changed out, this database is only for inventory reasons.

- Toolshop

  This menu covers only the expensive tools, because it makes no sense to list every nut here. Therefore such tools like the Hytorq, battery-powered screwdriver or angle-grinder can be found here. The storage system could work in the toolshop-container as well, but this makes it necessary that every crewmember brings back the tool he took.

  To avoid self-responsibility of the crew every expensive tool is secured with a RFID chip combined with a scanner station at the door of the container. This is more or less the same principle like the ant-theft-device in shopping malls. Of course the pusher does not know who took it, but at least he knows what is missing and which shift was responsible.

- Personnel

  This menu covers the PSE (personal safety equipment). It is necessary to have a few PSEs available at the rig for visitors or because of damages to the overalls or helmets. These things are stored in Fort Knox, which is an oilfield term for a secured container (the Pusher has the only key) with things that happen to be stolen very often: PSE, new tools, detergent, coffee, milk but even more important, also fall protection equipment is stored here.

- Rental
  This menu is for all other rental equipment that is not drill string related, for instance an additional lighting tower or an annular preventer, due to the inspection.

18.3.1 Requirements for the Menu “Equipment”

If it is possible to use RFID chips without any problems, they should be used. But of course there are still questions that need to be answered first, for instance, where to place an RFID on slips or dog collars? But maybe this could also work with EAN codes. That point needs to be tested first.

If not already in the company’s use a container for pump parts (recommended at least a 30 ft container) and a Fort Knox (recommended a 10 to 16 ft container) need to be bought.

Every database with certifiable equipment needs to have a certification calculator. Also every database with inventory relevant equipment needs to have an inventory function.

18.4 The Menu “Running hours”

Extremely important for the pump equipment is a function where the daily running hours are recorded, the same applies for wash pipe and swivel. For the pump parts and wash pipe the circulation hours are relevant and for the swivel the rotation hours. This is a very important function, because all these tools can only work for a predefined amount of time/rotations etc until their next inspection. Therefore also a message should pop up in *Notification*, so that the Pusher knows he has to take actions.

In this menu the running hours of the rig and rig equipment is recorded. Best practice would be if SmartStorage takes over these numbers automatically from the rigs software. In case such a link between these two programs cannot be established the input needs to be done manually. Of course if one is doing the input by hand, one always has a certain error in the data. It makes a difference if the system records the running hours automatically and exactly (how many rotations per minute for instance) or if the Pusher does the input (some sort of average value) at the end of 12 hours shift.

The menu *Running hours* does not necessarily require the submenus: Topdrive, Drillstring and Pumps. These menus should be more like tabs (compared with and internet browser). The most important thing is the previously mentioned problem, if the input has to be done by hand, there should be a table where the running hours are entered every hour.

This means, the input itself (for everything) is done at the first page of the menu “Running hours” and by clicking through the tabs one can see how these effects the tools.

The following list shows what affects the tools:

- Washpipe circulation hours
- Swivel rotations
- Saversub connections
- DP meters drilled
- HWDP/DC/XO rotation and reaming hours
- Pump parts Pump running hours

The input table Tab. 18.3 should look like this: the running hours are entered and automatically assigned to the correct tools. As one can see there has to be the possibility of multiple entries with a time step of an hour. The simple reason therefore is that the Pusher takes these numbers from the daily drilling report made by the driller and on this paper the time steps are one hour.

Time	Operation	Rot/min	Meters drilled	Rotation & reaming hours	Circulation hours	Connec-tions
06:00 – 07:00	Drilling	70	75	1	1	2
07:00 – 08:00	Reaming	50	0	1	1	0
08:00 – 09:00	POOH	0	0	0	0	15

Tab. 18.3 Input table

The pump hours are a little different, because they are taken directly from the pump control software and the problem is that it is usually one value for the whole day. This would be no problem but the pump hours affect (assuming a triplex pump), 3 liners, 3 pistons, 3 suction valves and seats and 3 pressure valves and seats and these things are not worn out at the same time. This makes it necessary that single things can be set to zero running hours (respectively the running hours after the change) if they are changed but the other ones need to keep counting the hours.

Pump 1									
Date	Hours	Liner	Piston	Suction Valve	Pressure Valve	…..	……	…..	….
01.06.2015	18	18	18	18	18				
02.06.2015	20	5	38	38	38				
03.06.2015	10	15	48	48	48				

Tab. 18.4 Pump input table

As one cans see in Tab. 18.4, on the 2nd of June the liner was changed, and the new one was only used 5 hours. The table itself is not accurate because (assuming a triplex pump) 2 liners, 2 pistons, 2 suction and pressure valves are missing.

18.4.1 Requirements for the Menu "Running hours"

The data provided from the daily drilling report needs to be correct; therefore the Driller is in charge to enter the correct dataset. The entered data should be automatically assigned to each tool.

The first thing one can see in this menu is the input table and in the tabs one can see the specific evaluation for the tools. *Notification* should blink in red if a tool reaches 75 – 80 % of the maximum so the Pusher knows he has to take action. The maximum itself should only be entered from the warehouse manager of the company because he needs to have all relevant data.

The reason for *Running hours* is that, the operator wants to have equipment that is ok and like the other equipment, the drill string needs to be certified as well. Therefore one needs to have a full documentation about the running hours, because there are different regulations for recertifying (API standard DS-1 Volume3, and the North Sea standards NS-1 and NS-2). Each of these standards is slightly different, and it depends on the operator which one is used. The regulations differ in the amount of drilled and reamed meters as well as mud type, temperature range etc., but the drilling company has to accept the standard and certify their drill string according to the used regulations.

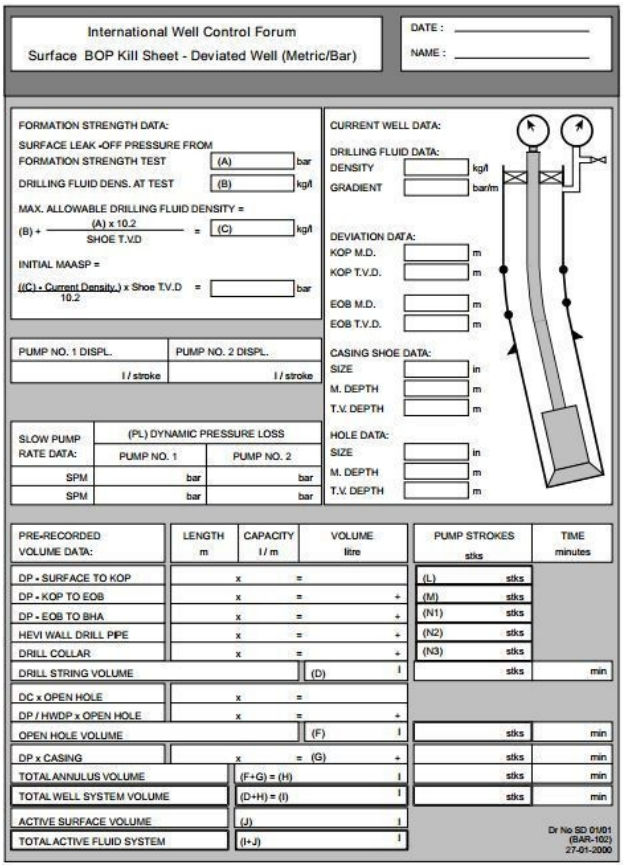
If there was no standard, every drill pipe would need to be recertified every six month, no matter if the pipe was used or only stored.

18.5 The Menu "Safety"

In this menu all safety matters can be found, *Safety* splits up in the submenus: Kill sheet, BOP, PTW (permit to work), JRA (job risk analysis) and Safety Meeting.

A kill sheet is one of the most important things on a rig because it can save life's. A kick can happen all the time, which is why the kill sheet always has to be up to date. The kill sheet itself is taken directly from the IADC/IWCF homepage and added to this subchapter. An example of a kill sheet can be seen in the sequence Fig 18.3 – Fig 18.5. That is a special one for deviated wells, but different ones are available: vertical/deviated and SI/oilfield units. There also needs to be the possibility to print the kill sheet. Due to its importance a kill sheet should be widely known therefore it is no need to explain how it works in detail.

Next to the kill sheet a document for the kick drill should be available, because such a drill needs to be done regularly and the drill document must be stored as hardcopy in the Pushers office. The company's own kick-drill-sheet should be available here.



International Well Control Forum
Surface BOP Kill Sheet - Deviated Well (Metric/Bar)

DATE :
NAME :

FORMATION STRENGTH DATA:
SURFACE LEAK -OFF PRESSURE FROM FORMATION STRENGTH TEST (A) bar
DRILLING FLUID DENS. AT TEST (B) kg/l
MAX. ALLOWABLE DRILLING FLUID DENSITY = (B) + (A) x 10.2 / SHOE T.V.D = (C) kg/l
INITIAL MAASP = ((C) - Current Density) x Shoe T.V.D / 10.2 = bar

CURRENT WELL DATA:
DRILLING FLUID DATA: DENSITY kg/l; GRADIENT bar/m
DEVIATION DATA: KOP M.D. m; KOP T.V.D. m; EOB M.D. m; EOB T.V.D. m
CASING SHOE DATA: SIZE in; M. DEPTH m; T.V. DEPTH m
HOLE DATA: SIZE in; M. DEPTH m; T.V. DEPTH m

PUMP NO. 1 DISPL.	PUMP NO. 2 DISPL.
l / stroke	l / stroke

SLOW PUMP RATE DATA:	(PL) DYNAMIC PRESSURE LOSS PUMP NO. 1	PUMP NO. 2
SPM	bar	bar
SPM	bar	bar

PRE-RECORDED VOLUME DATA:	LENGTH m	CAPACITY l / m	VOLUME litre	PUMP STROKES stks	TIME minutes
DP - SURFACE TO KOP	x	=		(L) stks	
DP - KOP TO EOB	x	=	+	(M) stks	
DP - EOB TO BHA	x	=	+	(N1) stks	
HEVI WALL DRILL PIPE	x	=	+	(N2) stks	
DRILL COLLAR	x	=	+	(N3) stks	
DRILL STRING VOLUME		(D) l		stks	min
DC x OPEN HOLE	x	=			
DP / HWDP x OPEN HOLE	x	=	+		
OPEN HOLE VOLUME		(F) l		stks	min
DP x CASING	x	= (G)	+	stks	min
TOTAL ANNULUS VOLUME		(F+G) = (H) l		stks	min
TOTAL WELL SYSTEM VOLUME		(D+H) = (I) l		stks	min
ACTIVE SURFACE VOLUME		(J) l			
TOTAL ACTIVE FLUID SYSTEM		(I+J) l			

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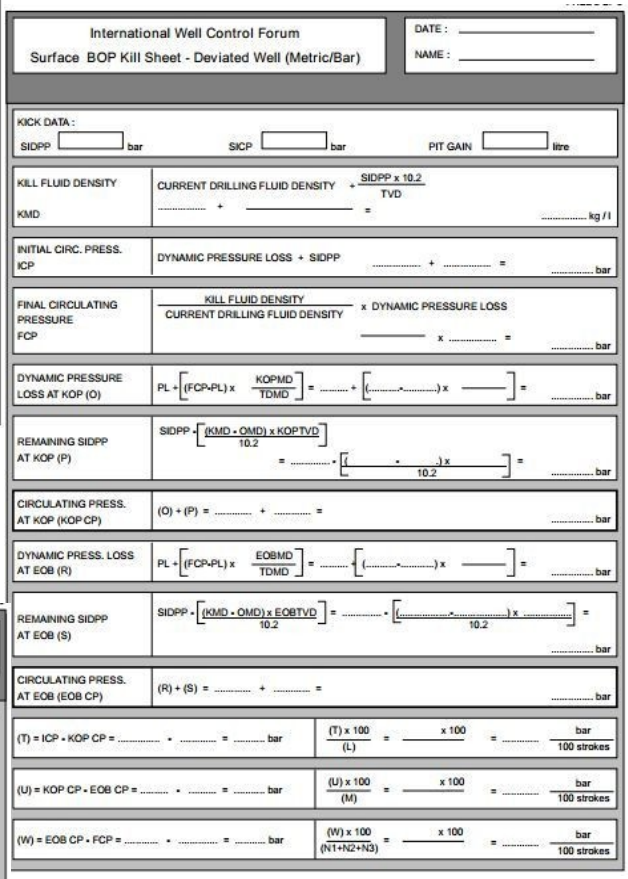
Fig. 18.3 Killsheet 1, ([26])



International Well Control Forum
Surface BOP Kill Sheet - Deviated Well (Metric/Bar)

DATE :
NAME :

KICK DATA : SIDPP bar; SICP bar; PIT GAIN litre

KILL FLUID DENSITY — KMD: CURRENT DRILLING FLUID DENSITY + SIDPP x 10.2 / TVD = kg / l

INITIAL CIRC. PRESS. ICP: DYNAMIC PRESSURE LOSS + SIDPP = bar

FINAL CIRCULATING PRESSURE FCP: KILL FLUID DENSITY / CURRENT DRILLING FLUID DENSITY x DYNAMIC PRESSURE LOSS = bar

DYNAMIC PRESSURE LOSS AT KOP (O): PL + [(FCP-PL) x KOPMD / TDMD] = + [(-) x] = bar

REMAINING SIDPP AT KOP (P): SIDPP - [(KMD - OMD) x KOPTVD / 10.2] = - [(-) x / 10.2] = bar

CIRCULATING PRESS. AT KOP (KOP CP): (O) + (P) = + = bar

DYNAMIC PRESS. LOSS AT EOB (R): PL + [(FCP-PL) x EOBMD / TDMD] = + [(-) x] = bar

REMAINING SIDPP AT EOB (S): SIDPP - [(KMD - OMD) x EOBTVD / 10.2] = - [(-) x / 10.2] = bar

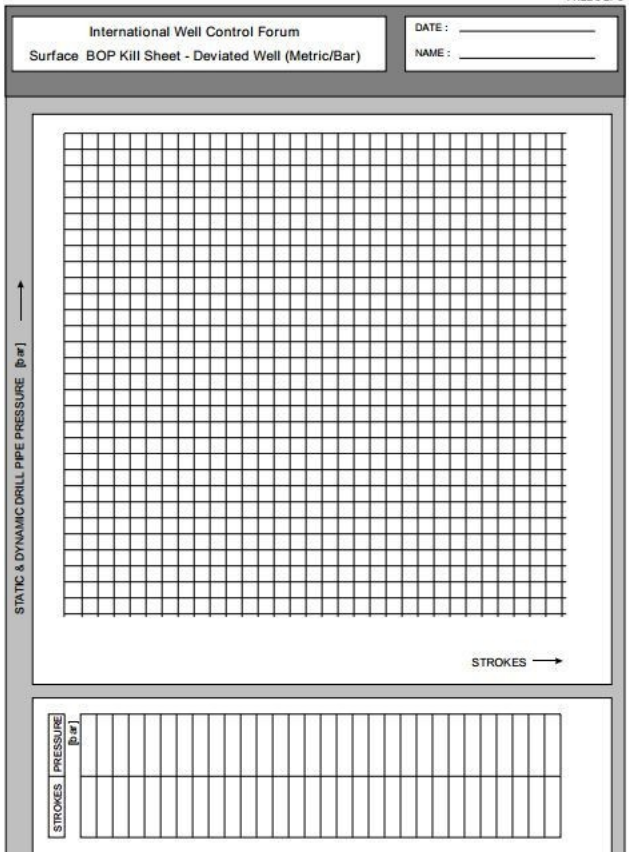
CIRCULATING PRESS. AT EOB (EOB CP): (R) + (S) = + = bar

(T) = ICP - KOP CP = - = bar; (T) x 100 / (L) = x 100 = bar / 100 strokes

(U) = KOP CP - EOB CP = - = bar; (U) x 100 / (M) = x 100 = bar / 100 strokes

(W) = EOB CP - FCP = - = bar; (W) x 100 / (N1+N2+N3) = x 100 = bar / 100 strokes

Fig. 18.4 Killsheet 2, ([26])



International Well Control Forum
Surface BOP Kill Sheet - Deviated Well (Metric/Bar)

DATE :
NAME :

STATIC & DYNAMIC DRILL PIPE PRESSURE [bar]

STROKES

STROKES | PRESSURE [bar]

Fig. 18.5 Killsheet 3, ([26])

The next submenu in *Safety* is BOP. The BOP needs to be tested,

1. when installed.
2. after setting each casing string.
3. prior to entry into a transition zone.
4. not less than once a week.
5. repairs that require breaking a pressure connection.

If any of those situations occur, the driller has to perform the test. The test procedure is slightly different at every rig, this means the rigs currently used procedure needs to be reviewed (verified) and should be afterwards available in this submenu. A change in the procedure itself needs to be discussed with the company's safety department and comply with local requirements.

The Permit to work submenu is up next.

The objectives and functions of such a system can be summarized:

ensuring the proper authorization of designated work. This may be work of certain types, or work of any type within certain designated areas, other than normal operations

making clear to people carrying out the work the exact identity, nature and extent of the job and the hazards involved, and any limitations on the extent of the work and the time during which the job may be carried out

- specifying the precautions to be taken including safe isolation from potential risks such as hazardous substances and energy sources.
- ensuring that the person in charge of a unit, plant or installation is aware of all the work being done there
- providing not only a system of continuous control but also a record showing that the nature of the work and the precautions needed have been checked by an appropriate person or people
- providing for the suitable display of permits
- providing a procedure for times when work has to be suspended, ie stopped for a period before it is complete

- providing for the procedures or arrangements for work activities that may interact with or affect any of these activities
- providing a formal hand-over procedure for use when a permit is issued for a period longer than one shift or when permit signatories change
- providing a formal hand-back procedure to ensure that any part of the plant affected by the work is in a safe condition and ready for reinstatement

(Guidelines on permit to work systems, International Association of Oil & Gas Producers, January 1993, p.1, http://www.ogp.org.uk/pubs/189.pdf)

A permit is issued by the Tool Pusher, who is the only person on a rig allowed to issue a permit. There are different types of permits, they are given for:

- cold work, for instance: work with chemicals the crew is not familiar with
- hot work, for instance: welding, grinding etc in the ex-zone
- pressure system work, for instance: any pressure test, BOP work
- electrical work, required for any work that is performed on any electrical equipment
- explosive/radioactive work, required whenever explosives or radioactive sources are used, logging, perforating
- confined space entry, required whenever the upper body or head enters a confined space, cleaning the mud tanks, work in the cellar.
- work at heights

A permit system is usually used on every rig; this means that the permits need to be verified before they are available in this menu. The permits should be ready to use, only the name of the Pusher, worker and DSV/NSV as well as the actual date should be left blank. There also needs to be an area where these guys can sign, one signature to start the work and the other one if the work is done.

The next submenu is the JRA one. A JRA can also be called JSA (job safety analysis) or JHA (job hazard analysis). To start such an analysis a job or task with potential hazard is selected. Also uncommon or not very often performed jobs qualify therefore, for instance such a job would be coring.

- The job or task is then split up into steps and every step should cover a major task.
- To do a JRA effectively and successfully every potential hazard within every step must be named and written down. One also needs to identify every potential source of energy. All possible hazards should be identified; therefore the environment next to the rig should be taken into consideration as well.
- After identifying the hazards, one decides what procedures are required to eliminate, control or minimize hazards, that could lead to injuries, accidents, damage to the rig and environment.
- Every Crew member can write a JRA, but it needs to be reviewed verified and signed before the job is executed. JRA's are very important for new crew members, because they get knowledge about how a job is performed and elevates their awareness. ([27])

The last submenu in *Safety* is Safety meeting. Standard safety meetings should be covered here, for instance running casing, cementation or logging. There is no need to always fill out a safety meeting sheet for routine operations. Such a paper is printed, with the important steps already on it. The Pusher has to read these steps in front of the crew and casing crew for instance and make sure everybody understood, what he just said. Afterwards every participant needs to sign.

Safety meetings should be done:

- if the crew is changed to inform them what happened in their time off
- every time a new shift starts to work, this means at least twice a day. There is no need to make an unnecessary long meeting; the crew only needs to be informed about, what will happen during their shift.
- every time a non routine job should be executed.

18.5.1 Requirements for the Menu “Safety”

All mentioned documents need to be correct, therefore they should not be implemented in SmartStorage without overseeing them carefully. Double check principle should be applied. No document should be just taken over without the “ok” and signature of the company’s safety officer, this means he/she needs to have a signature pad, for instance from the company Signotec [33].

It should be possible to modify the text of a JRA for instance, because there is always a possibility that something was overseen. But if somebody has modified the text an automatically generated email is sent to the safety officer.

Of course these systems operate online, therefore if one rig of the fleet comes up with a new PTW, JRA or safety meeting it can be sent automatically (after careful review) to every other rig of the fleet.

For instance if the system is not online:

A rig needs to take a core but nobody did such thing before. The Pusher calls the office and wants to know if another rig of the fleet has done coring before and therefore has a JRA available. The office calls or sends a mail to the other rigs and asks for information. If the Pusher can be reached immediately, he has to look up his JRAs to find out he does not have one.

Depending on the number of rigs in the fleet, this procedure could take a while. That is why the system should operate online, after a review every rig has the same information and no time is wasted.

18.6 The Menu “Checks”

In this menu all the things can be found that need to be checked on a regular basis. The inspection intervals vary from one day to one month, therefore this menu is structured into three submenus: Daily, Weekly and Monthly.

Examples of what could be stored there are:

Daily: diesel, water, etc

Weekly: coffee, milk, etc

Monthly: soft slings, soft iron rings, insert blades (iron roughneck and slips), etc

It depends on the company what they want to have exactly in this menu. It is clear that coffee and milk are important to keep up the crews good spirits, but they are less important than a missing soft iron ring during BOP nipple up.

The design of the menus is a simple table with the name of the product, the quantity and the storage place. One could also implement a notification that warns the Pusher if the amount of a certain product is at a minimum.

18.6.1 Requirements for the menu Checks

Best practice would be, if the monthly and weekly checks are only done once, to get the current amount of products. Afterwards every crew member who took a soft sling for instance, should tell the Pusher how many and which item it was. But without constant observation of the crews this system will fail, because people simply forget to mention it.

Maybe one could improve this situation with a scanner. At the place where these products are stored, a pistol shaped hand scanner (mentioned previously, dirt-, impact-, ex-proof and easy to operate) needs to be put in place. Every time a crew member takes something he scans the EAN code. The scanner as well as SmartStorage itself is online, this means the system knows immediately, somebody took a 5 tons soft sling and adjusts the stock level. But once again the Pusher has to be sure that the crewmember does not forget about the scan process.

The only other way possible is that the Pusher needs to perform all checks on his own or let a crew member count. Even so there is no guarantee that these checks are really done.

Therefore, this menu could be helpful, if everybody does his or her work correctly and responsibly.

18.7 The Menu “Maintenance”

Studies show that ~ 14 % of NPT [35] are related to maintenance issues, which is realistic since a lot of things on a rig need to be maintained and/or function tested on a regular basis. This can be greasing the top drive, elevator or iron roughneck but also mandatory function tests of the generators, hydraulic power packs, the chock manifold, well closing system etc.

This menu provides an overview of all the equipment that needs to be maintained.

18.7.1 Requirements for the Menu “Maintenance”

For every maintainable piece of equipment the manufacturer of the rig has to provide a list and detailed sketches of the equipment which clearly show the maintenance operations that need to be conducted, including the service intervals.

After the implementation of the data (also the sketches need to be stored together with the description) the system alarms the Pusher 1 – 2 days before equipment needs to be maintained. This is necessary to find the optimal point to perform the maintenance work without interrupting the normal rig activities (if possible). For instance greasing all parts of the pipe handler during tripping is not recommended.

Additionally there needs to be the possibility to set a checkmark after the work has been performed. Also the name(s) of the responsible personnel should be included in case of an equipment failure. If such a failure should occur and investigations show that it was due to poor or even no maintenance, the company can more easily take the appropriate steps to avoid problems in the future.

18.8 The Menu “Order/Delivery”

This menu is about the rigs order and delivery system with its submenus of the same name. In Fig. 18.6 one can see the 2 submenus but each of these submenus splits up into Rig, Mechanic and Electrician

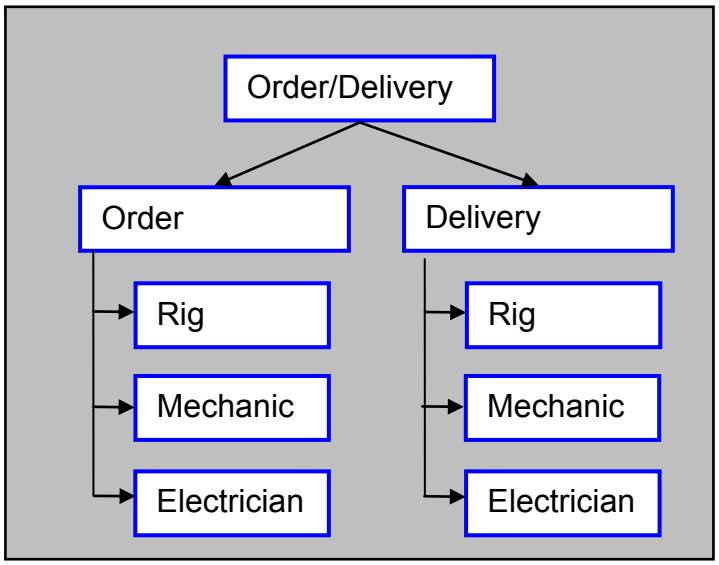


Fig. 18.6 Order and delivery

The rig, the mechanic and the electrician have their own order and delivery submenu to prevent mixing up the different orders/deliveries, the functions in the menu are the same.

There is a blank order form (should be printable) with a standard, non-changeable layout which is given to every rig in the fleet. The only field which is editable is the address. The date is filled in automatically as well as the consecutive number. *Delivery* registers every order automatically; which means every ordered item can be seen in a table. This table has additional functions:

- A column where a checkmark can be set to mark every delivered item. However this makes it necessary to control all deliveries carefully with the order form to know what goods are missing.
- A column to enter the delivery date.

- A column to enter the date of the reorder. Maybe a function could be implemented that SmartStorage reorders articles automatically if they were not delivered within 3 – 4 weeks, for instance.
- A column to set a checkmark if an article is undeliverable; otherwise SmartStorage is going to reorder this article every 3 – 4 weeks.

The Pusher who is responsible for the orders of the rig has additional functions. He is the only one who could also make a delivery note for goods that are sent away from the rig. This form should also be not changeable besides the addresses. Another thing the Pusher can do with SmartStorage is the delivery note management. Almost every delivery the rig gets is equipped with a delivery note. The original one is stored in a folder and a copy is going to the rig manager (RM). The RM signs it and afterwards it is sent to the office and finally the accounting department pays the bills.

The part with the accounting department cannot be skipped, because the Pusher does not pay the bills. But one could try to scan every delivery note and make a *.pdf file out of it. This file is sent via email to the RM, he needs to have the possibility to sign it (virtual signature) and send it directly to the accounting department. In *Delivery* should be an extra column, where the *.pdf's can be added with drag and drop stored. There is no need to put the original one into a folder and a copy etc. Such a procedure safes time, paper and of course money, but of course it has to be made sure that those procedures comply with the legal requirements.

The electrician and mechanic write their orders in their order forms, but the Pusher is the one who first has to check the orders and afterwards sends them to the suppliers. This should be no problem because he has access to every menu. Electrican and mechanic need only access to their stuff and not to *Drillstring* for instance.

18.8.1 Requirements for the Menu “Order/Delivery”

There needs to be a table with all necessary suppliers, because the order form is equipped with a drop down menu. This means one needs to add the address only once and afterwards just press the button and it is automatically placed on the order form. Such a menu could be helpful especially if the Pusher often orders from the same supplier. But on the other hand adding new suppliers should be very easy and also the electrician and mechanic can add new suppliers if necessary.

A delivery needs to be checked carefully together with the order and the delivery note. Therefore the Pusher is responsible to either do it himself or hands over the check to a reliable crew member.

The next table contains photos from things on the rig that are needed but not essential for the rig itself. These things should be:

- the type-approval certificate for every vehicle on the location, forklift, crew bus, etc
- the type plate of the washing machine and dryer
- the type plate oven and freezer
- the type plate water coolers (if not rented)

Pretty much everything that cannot be repaired by the rig electrician and/or mechanic needs to be listed. That is because if something breaks down for instance the washing machine, one does not need to pull over the washing machine to be able to read the type plate.

If the washing machine breaks down, the Pusher calls the service company and can immediately tell their mechanic what type of machine it is.

18.9 The Menu “Reporting”

In this menu all drilling and rig related reports can be found and maybe one could implement an e-mail program as well. But on the other hand SmartStorage runs on Windows operated computers therefore one could simple use Outlook or LiveMail.

Usually there is a computer in the Pushers office as well as in the Driller's. On the Driller's computer certain software can be found that is used for creating the IADC daily drilling report, Rimdrill for instance. The report itself is stored as *.pdf and is only available on the Drillers computer. This makes it necessary to have a rig network. If such a connection does not exist, also SmartStorage is not working properly. Assuming such a connection exists; SmartStorage should automatically take the report (after it is finished) from the memory location on the Drillers computer and transfer it to the Pushers computer. Afterwards he gives the report the correct name and chronologically stores it in the correct folder.

There is also the possibility of creating NCR's (non conformity reports), with a template (looks the same on every rig of the fleet). After the Pusher finished the report and clicks on the "send" button, the office as well as every other rig in the fleet gets the report. The reports are stored in this menu and if a new one arrives the button *Reporting* on the home screen starts to blink in red, for instance.

18.9.1 Requirements for the Menu "Reporting"

Once again the base of SmartStorage is the online function, without an Internet connection the software is not working properly. Therefore the company has to provide a suitable connection, with satellites for instance, if the rig is operating in remote areas, where no connections to cell phone antennas or cable networks are possible. One also needs to make the NCR-template first and set it in a way that only the date, the name of the person who is creating it and the report text itself can be changed and every other thing like rig name is locked. Another requirement is that the program needs to find the right file (daily drilling report) on the Drillers computer and use the right folder on the Pushers computer for storage.

18.10 The Menu “Electrician and Mechanic”

The menu *Electrician and Mechanic* are two separate menus, one for the electrician and one for the mechanic but the functionality of these two are the same. Therefore the following explanation is valid for both of them.

This menu is like the menu *Equipment* for the Pusher; it is an inventory management system, with the difference that not only RFID chips are used but also EAN-codes. For large and expensive tools RFID chips are used and for smaller ones like hydraulic seals the EAN of the packing is used. Due to similarities with *Equipment* the product needs to be scanned as well as the EAN of the shelf where the product is stored.

Once the articles are in place and its position is saved with the help of SmartStorage it should be no problem to find articles. For instance a substitute electrician is replacing the actual one due to vacation. Of course something breaks down on the rig, the new electrician needs to replace a certain part at the top drive. Instead of looking around and trying to find what he needs, he can use the “Search” function in SmartStorage.

A search can be done by the EAN (just scan the old part, to know where the new one is) or catchphrases (if no EAN is available). An additional function that could be implemented is the availability of circuit diagrams of the whole rig.

18.10.1 Requirements for the Menu “Electrician and Mechanic”

One of the most important requirements for this menu is that the EAN of the packing needs to be scan-able with the scanner used on the rig. But this function is worthless if there is no storage space available.

This means that the electrician as well as the mechanic need their own container (or they share a larger model) with sufficient storage facilities (shelves, cupboards etc.). Best practice would be everybody gets a desktop, computer and scanner, so that they can work independently from each other. This means that the mechanic does not have to wait until the electrician finished his work at the computer or is done with using the scanner.

But on the other hand everybody is responsible for his workplace and scanner, therefore playing around with scanner and possible damage, has to result in punishment (buying a BBQ for the day- and nightshift, for instance).

The problem with this point is that the electrician as well as the mechanic cannot be controlled by the Pusher, they have so many tools and products to work with, and the Pusher cannot know them too. So they have to take care about their equipment on their own. This means that electrician and mechanic need to be accurately working people, who take care of their stuff and do not fool around with it. Because after their turn is over and the next electrician or mechanic takes over, the system needs to be up to date and ready to use, without any failures due to sloppiness.

Best practice of handling a delivery for these two guys should look the following.

- The Pusher hands over the order form.
- M/E (Mechanic or electrician) have a look at the delivery note and check if everything is ok. They should not only check the documents but also the goods itself (right amount, undamaged etc)
- When it comes to storage, the article EAN is scanned and afterwards the EAN of the empty space at the shelf. SmartStorage now knows exactly which article can be found where.
- If something was ordered but not yet delivered the Pusher needs to know so he can put it on the reorder list in the menu *Order/Delivery*. The important question is, if an item should be reorder at the same supplier or bought somewhere else? This problem can only be solved, by simply talking to each other.

18.11 The Menu “Fleet”

This menu is about the other rigs in the fleet, more precisely it is about the equipment of the other rigs. This means that the menu *Equipment* is presented here, but not the rigs own one but a list of equipment of every other rig. The equipmentlist should be up to date because every Pusher is told to work accurately.

This menu also saves time, because one does not have to call the office and explain the situation to them, for instance a generator is needed for the move. Afterwards an office guy would call every Pusher on their rigs to ask if they have the required generator. If yes, he would need to organize a transport and tell the other Pusher he found something etc.

SmartStorage skips the office part and the Pushers can directly communicate bewith each other and so precious time is saved.

18.11.1 Requirements for the Menu “Fleet”

The only requirement for this menu is that the equipment list of the other rigs cannot be changed. This means if the Pusher of rig A looks for a heater, in the equipment list of rig B, he cannot change a single line in the other rigs equipment list. Compared to a computer system this would be the ROM compared to RAM.

18.12 The Menu “Notification”

The menu *Notification* can also be seen as “to-do-list”, because all relevant information of the rig is displayed here and the Pusher is forced to take action. For instance:

- If there are only 4 weeks left until the certification of a certain tool expires
- If the IWCF/IADC certificate of the driller expires
- If ordered articles are not delivered yet and now the system asks, if they should be reordered
- If there are only 3 soft iron rings of a certain dimension are left and should be reordered
- If another rig in the fleet came up with a new JRA
- If the running hours of the suction valves of pump 1 are reaching their maximum.
- If rental equipment needs to be returned
- Etc.…

As one can see this menu is very important and to make sure the Pusher always checks the menu, he has to set checkmarks otherwise the information does not stop blinking red. The time and date of the checkmark are stored, for further investigation if something goes wrong. For instance the rig is running out of thread grease, the system warned the pusher, he sets a checkmark but took no further action. Since everything has been documented, he can be directly approached and questioned by his supervisor.

The system also stores information about the login of the Pusher, if he is logged in and “Notification” is blinking, why didn’t he open the menu and checks why it is blinking.

18.12.1 Requirements for the menu Notification

An important part of this menu is that the software developer of SmartStorage has worked correctly and that the right notifications are displayed at the right time.

There also should be no such thing as, the Pusher sets a check mark but “Notification” does not stop blinking.

The message itself is displayed (even if a checkmark is set) until the system recognizes that something changed. For instance: The Pusher orders new buckets of the previous mentioned thread grease, but the message is left in the system until the new grease is at the location and the EAN is scanned.

The system now “knows” that enough grease is in stock again and deletes the message.

18.13 The Menu “Personnel”

This menu is about the personnel of the rig, especially about their trainings (IWCF, gas) and also about what they are allowed to do, like operating a forklift or the rig crane, for instance.

The look of the menu itself is like an Excel-spreadsheet, the first column should be the Name of the employee, followed by the birth date, cell-phone number and current address.

Afterwards a very important column can be found, it is the cell- or landline-number of the person who should be called in the case of an emergency. The following columns are for the trainings, where only checkmarks are set. For instance, is the guy allowed to operate a forklift? Yes, then a checkmark is set. Maybe one could make these cells a little bigger and add the permission as a *.pdf file as well as the date for the next exam. This date is processed by SmartStorage and pops up in *Notification* if the certificate is expiring in the next two months.

The following points need to be filled by hand:

Name, Position, Birthday, Address, Phone, Emergency phone number

The following points need to have the possibility to set a checkmark, enter the date by hand and add the certificate by drag&drop. All of them need to have drop-down menus, where one can change between yes and no or the different IWCF levels.

IWCF	Level	Certificate (*.pdf)	Next Exam
Forklift	Yes/No	Certificate (*.pdf)	
Rig crane	Yes/No	Certificate (*.pdf)	
Manitou*	Yes/No	Certificate (*.pdf)	
Gas course	Yes/No	Certificate (*.pdf)	Next Exam
Respirator	Yes/No	Certificate (*.pdf)	Next Exam
Firefighter	Yes/No	Certificate (*.pdf)	Next Exam
First aid	Yes/No	Certificate (*.pdf)	Next Exam

**Manitou is the name of a company manufacturing and selling rotating telehandlers, besides a lot of other things.*

18.13.1 Requirements for the menu Personnel

The main problem with this menu is that the input data is very sensitive, which means one needs to work very carefully and avoid failures that lead to a loss in personnel data. Maybe one could save this special menu, with an additional password, that means that only the Pusher and the HR department at the office have access to it and nobody else, especially not on the rig.

Additionally the link between the date of the next exam and the menu *Notification* has to work without failures.

18.14 The Menu “Pictures”

This menu is about the photos taken on the rig. Photos are made often to document damages of the rig, report unsafe situations or a picture of a certain tool is taken for the guys working in the office etc. etc.

The problem is that there are a lot of pictures and they are always stored somewhere (temporary folders, folders at the desktop…) and after a couple of days new ones are made and nobody remembers where the old ones are. Another possibility is that one needs to find a picture from the previous location. Without a smart system the Pusher keeps on searching pictures and wasting precious time.

The solution could be the menu *Pictures*, because every photo taken on the rig is stored here except if the pictures report a damage of equipment. If this is the case their needs to be a link to the menu *Equipment* and the pictures are stored in the same column where all the other equipment data can be found. Some previous work needs to be done first, before any picture is stored. If the rig is at a new location, also in this menu a new folder for this specific location needs to be created. Due to the functionality of a Windows Desktop that step should not be a problem.

To speed things up, every time the camera is connected to the computer and SmartStorage is running, the folder of the last location should open itself automatically. In this folder and already created subfolder with the actual date can be seen (also automatically created by the system), now by the use of drag and drop the pictures are copied into this folder.

The schematic can be seen in Fig. 18.7, but of course the subfolders are not visible unless they are activated by a double click. As one can see they can be renamed, but the date is fixed.

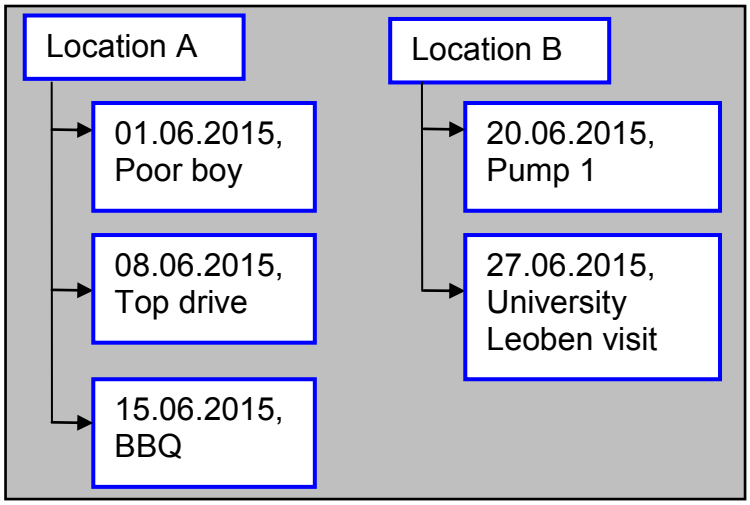


Fig. 18.7 Menu "Pictures"

18.14.1 Requirements for the Menu "Pictures"

There is only one requirement for this menu; it has to work like a Windows Desktop, therefore it needs to be possible to:

- Create new folders, for new locations
- Generate new folders with the actual date automatically, once the camera is connected
- Rename folders, but the actual date remains unaffected

With the help of this menu the picture management should improve significantly because all pictures are stored in the same menu. There is no need to search the whole computer for pictures that were taken 2 months ago.

18.15 The Menu “Memo”

This menu works like a notepad and can help to avoid piles of paperwork and also avoid the loss of memos. Very often important information is written on a piece of paper, due to chaos and stress in the office this paper gets lost within other papers and at the end the paper is forgotten and the information is lost. If important information is written in *Memos* it cannot get lost until it is deleted by the Pusher.

With the help of this menu information is not getting lost anymore and the Pusher as well as the whole crew can work more productively.

18.15.1 Requirements for the Menu “Memo”

The menu itself needs to be an extreme downgraded version of MS Word. Therefore just a simple sheet of (virtual) paper with lines is shown and with a click at the beginning of the line, the Pusher can write his memo. Maybe one could add a function to highline very important information with colors. The only problem with this menu is that, a lot of people working on the oilfield are not capable of the ten-finger-system (maybe a Touchpad could help).

18.16 Smart Storage, Summary

If SmartStorage can be brought to work without failures and the people on a rig accept it, a couple of things should improve.

Time consumption: Wasting time, due to finding the right downhole tools, equipment and other spare parts, is no problem anymore. If SmartStorage is operated correctly and the Pusher works accurately, he should always know where everything can be found.

Furthermore the Tool Pushers office time is reduced. As the author can tell from experience the Tool Pusher is sit-

ting 9 – 10 hours in the office dealing with administrative stuff. This means he/she can only look after the rig in 20 – 25% of a 12 hours shift. This is a very small amount of time considering the Tool Pusher is responsible for the entire rig and its operations. Therefore the office time should be decreased to roughly 6 hours or 50 % of a shift, because otherwise he/she has no chance to recognize all the ongoing things. Especially when it comes to maintenance, recognizing a problem at an early stage is essential.

Error prone: Fewer failures should happen now, because with the help of JRA's and experience from other rigs, the guys on the rig are told how something is done correctly, in case they have not done such things before.

Delay of further steps: There should not be a delay anymore due to missing parts. That is because one knows where the parts are if they are on location and SmartStorage is used. If they are not on location due to a delay in delivery, one now knows that too, because of the order and delivery system.

People can get hurt/

Damage of the rig: The Problem with these two points is that SmartStorage cannot really avoid that people can get hurt or that the rig is damaged. But it can be avoided that wrong instructions are given, because all JRA's from the fleet are available on every Pusher computer. If an unclear situations occurs the first step is always, have a look at the JRA's if the same or similar problem has already happen on another rig.

Costs: The costs should be decreased;

- Because less time is needed to find something, therefore more time can be used to actually work.
- Because of almost no delays anymore.
- Because one can increase the day-rate for the operator, due to a faster overall project.

19 Summary

In the beginning the theory behind process optimization is explained, what a process is and that it needs to be clearly defined including a start, an endpoint and all relevant steps between these points.

Therefore the right process which should be optimized needs to be identified and analyzed. Due to the interconnections and dependencies of different processes in a company, these analyses are done by the use of a process map which displays all these connections. One also needs to measure the effects of a newly created process on the company. This makes it necessary to define key point indicators and watch their changes carefully so that the process can be steered in the right direction.

Afterwards methods are presented of how process optimization can be done on a rig. The company wants to save money with the new processes and therefore has to decide if either small steps of a process are continuously improved or if the old process is eliminated and a completely new process is introduced. Each of these methods has its advantages and disadvantages. In the following chapter the different phases of process optimization are presented.

The next part and chapters of this thesis are about process optimization on drilling rigs; therefore a rack & pinion rig and a conventional rig are compared with each other. The focus lies on possible synergies, exchange of technology between the rig types for optimization and on the question if there are processes which are inefficient regardless of the rig used.

The first chapter introduces the two different types of rigs which are both capable of operating about 300 tons hook-load. The rigs are compared in terms of tripping speed; therefore several time vs. depth charts were made focusing only on tripping speed assuming that an overweight BHA is run on a R&P rig which exceeds the pipe handlers weight limitations. This method was chosen to find how much time is wasted only because a mobile crane is used to do the heavy lift.

A number of process maps and flow charts (Appendix sections A1.4 – A1.16 and A2.5 – A2.22) focusing on the material transport on a rig were made followed by the actual state analysis which is based on these charts. This means that every work center at a rig which is relevant to material transport is identified as well as all processes taking place there. But not only the rigs and their technical insufficiencies are investigated, a closer look is also taken at the rigs administration, which is the job of the Tool Pusher. In the work center Tool Pusher office no material flow happens but instead a flow of information.

All occurring problems in these work centers are listed and described in detail especially why a certain process needs to be optimized. Despite one (the pipe handler problem can only happen at a rack & pinion rig) all other inefficient working processes occur on both rig types.

The following part tries to redesign the previous listed processes or come up with complete new ones so that efficiency can be increased, ILT and NPT can be decreased.

20 Conclusion

The goal of this work was to decrease the costs and time necessary to drill a well, as well as to avoid ILT and NPT. In order to reach these goals, a number concepts and suggestions were developed and presented.

The first suggestions results from the comparison of a R&P rig with a conventional one in terms of tripping speed, assuming a BHA is run which exceeds the weight limitations of the pipe handler of the R&P rig. Therefore a mobile crane is needed to lift up/lay down the BHA with the outcome that every lift up and lay down needs 4 hours of extra time.

One of the solutions was that the operator needs to avoid running an overweight BHA by all means. An alternative solution was that the contractor needs to come up with a slightly different rig layout, which makes it possible to attach a hydraulic catwalk. As long as one of these two suggestions is not applied, there is a loss of both time and money. Assuming 8 roundtrips to complete the well, a whole day rate is wasted for lifting up and laying down the BHA.

Additionally, there are no renting costs for the mobile crane anymore, no costs for clearing and making the area usable again and no repair costs as a consequence of damages made by the crane.

The next suggestion affects both rig types because both of them need to measure their casing- and drillstring before it is run in hole. The problem is that two crewmembers are occupied 3 – 4 hours and an additional hour is needed by the Tool Pusher to prepare the tally. A concept was presented, where the string is measured at the manufacturer's plant, a tally is sent in advance and the string is delivered just in time. Since crewmembers are no longer occupied with the task of measurement, they can do more important work, like tagging tools, if SmartStorage is used, or maintaining the rig.

Additionally, the drilling location does not need to have a casing storage area, resulting in a smaller location, resulting in less location building costs. Another advantage is that there should be no errors in measurement anymore. If for any reason a measurement mistake happens, the responsibility for that lies with the manufacturer.

In the next section the focus was on the improvement of the process of mud mixing, which again is valid for both rig types. If circulation is lost, in the presented concept the mud service company is called and new mud is delivered with trucks and not mixed by the crew anymore. This means no LTI's due to stressful work conditions, no mixing errors and no failures in operating the mud pits.

The problem is that the saved time cannot be determined because a lot of influencing factors exist. This includes the total volume (well and tanks) which needs to be replaced, the used mud type and the mixing and storage facilities on site (number of hoppers, diameter of hopper lines, number of mud silos). The general conclusion was, that 80 – 100 m^3 mud (surface capacity) can be replaced much faster with mud delivery (~30m^3/truck) than mixing the entire volume by hand. Mud needs to be delivered whenever it is possible because during the mixing procedure the rig is at a standstill and therefore producing NPT.

SmartStorage is the concept of storage software for drilling rigs no matter if a conventional or a R&P one is run. The software supports the Tool Pusher in terms of equipment storage/certification, regular inventory, safety, order and delivery etc. This means that equipment renting costs as well as the costs for buying the equipment can be decreased, because the Pusher knows where everything is and unnecessary orders can be avoided.

The main goal is to decrease the Tool Pushers time in the office and to get him/her more time on the rig because maintenance is a major contributor to NPT. The Tool Pusher is responsible to check maintenance intervals and oversee how the works are carried out. Recognition of a problem at an early stage results in smaller maintenance costs and reduced amount of NPT. Additionally the number of LTI's can be decreased because the Pusher can pay better attention and control if every crewmember is working due to the company's safety standards.

At the end SmartStorage is not only the concept of storage software but the concept of rig administration software.

The thesis successfully showed some of the major problems on drilling rigs which are responsible for loss of time and money. The presented concepts to approach these problems would be the first steps to effectively improve the performance of drilling rigs, which should be in the interest of all stakeholders. Of course they

have yet to be implemented in real-ife drilling rigs to make their value visible in every day operations. In order to bring these concepts to life, major investments are necessary on existing rigs.

The currently low oil prices around 50$/bbl (September 2015), could be seen as a chance for contractors to work on new, more efficient processes in terms of cost and time to realize the ideal rig.

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[33] http://www.signotec.com/produkte/unterschriften-pads/, 16.09.2015

[34] http://www.spegcs.org/events/1170/, 15.08.2015

[35] http://insights-on-business.com/chemicals-and-petroleum/more-drilling-more-productivity-more-production/#_ftnref2, 01.09.2015

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24 List of Abbreviations

BHA	bottom hole assembly
BOP	blow out preventer
CSG	casing
DC	drill collar
DP	drill pipe
DSV	day supervisor
HWDP	heavy weight drill pipe
ID	inner diamedter
ILT	invisible loss time
LTI	loss time injury
NPT	non productive time
NSV	night supervisor
OD	outer diameter
POOH	pull out of hole
RIH	run in hole
XO	cross over

Appendix

A1 Rack & Pinion Rig

A1.1 Workcenters, Pipe Rack (PR) at Ground Level

Rack and pinion equipped with: automated elevator, automated slips and pipe handler. Therefore the workcenters are:

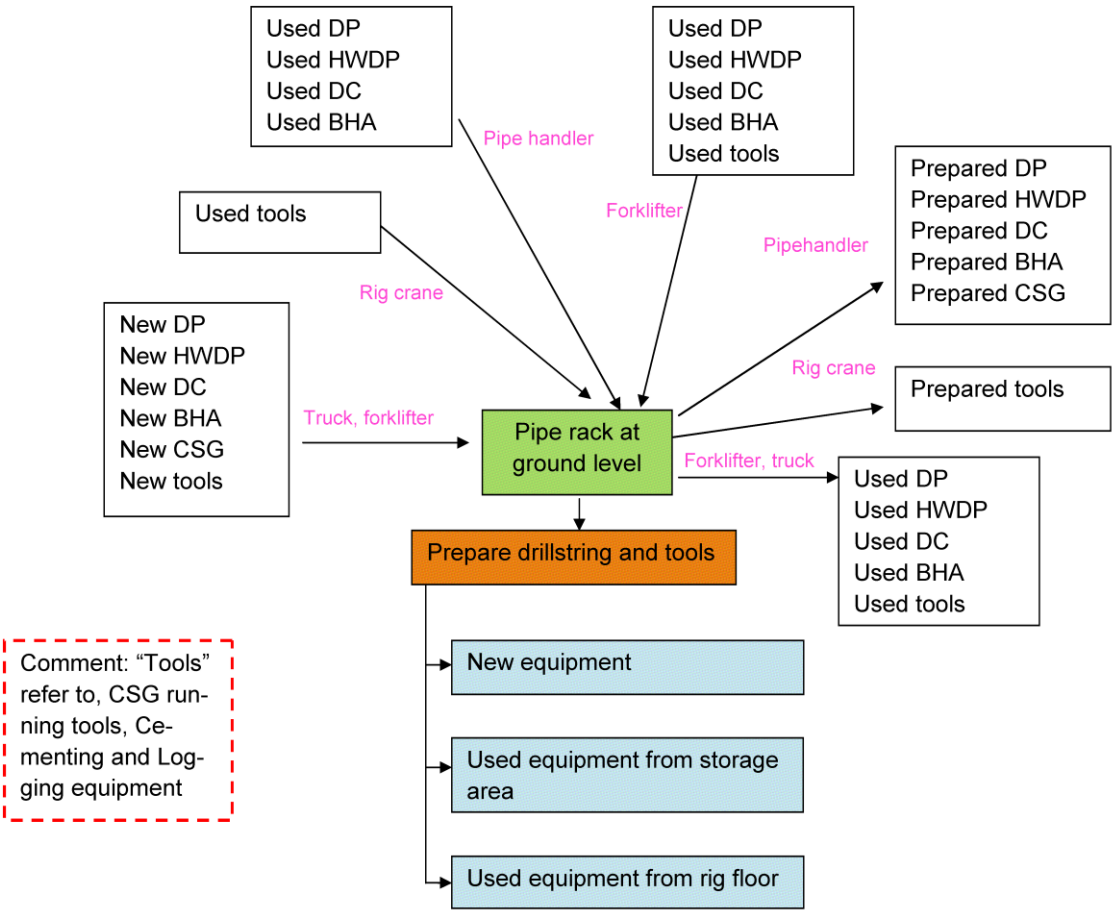
1. Pipe rack at ground level
2. Rigfloor
3. Mudpits

Key:

- Workcenter in green
- Main process in orange
- Sub process in blue
- Transport in pink

1. <u>Pipe rack at ground level</u>

What's going in and out and what's going on there



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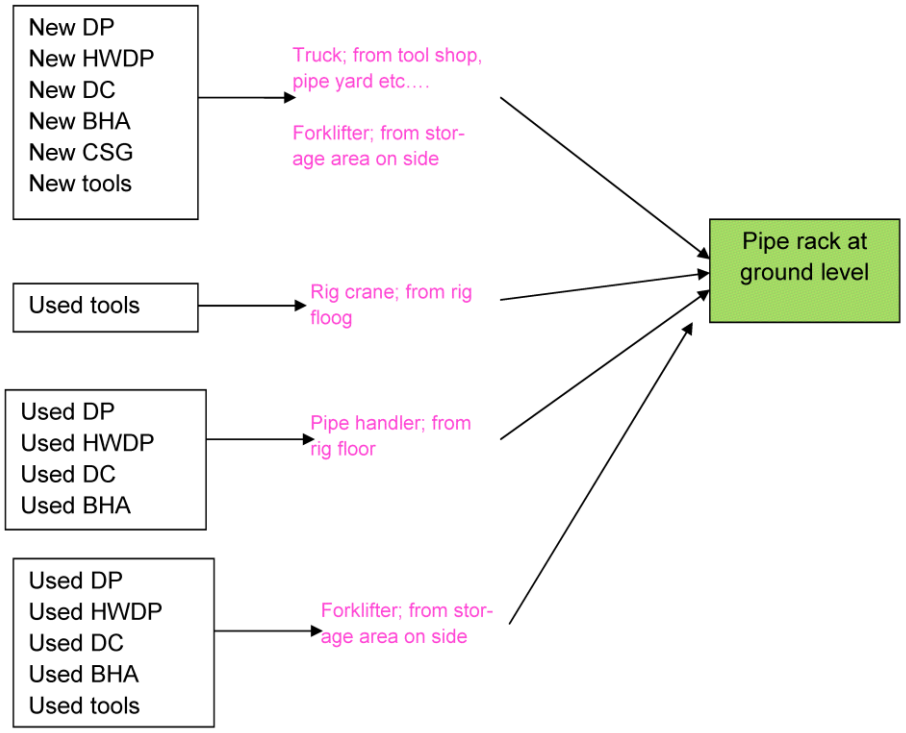

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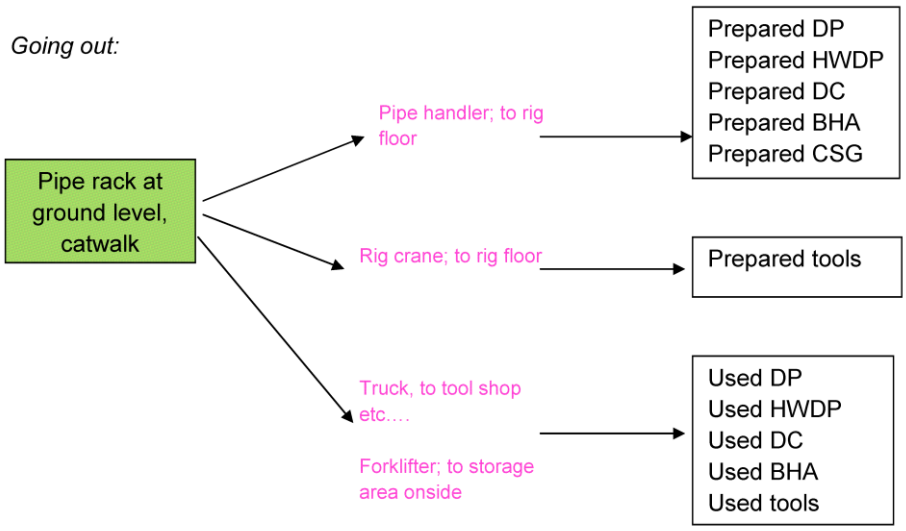
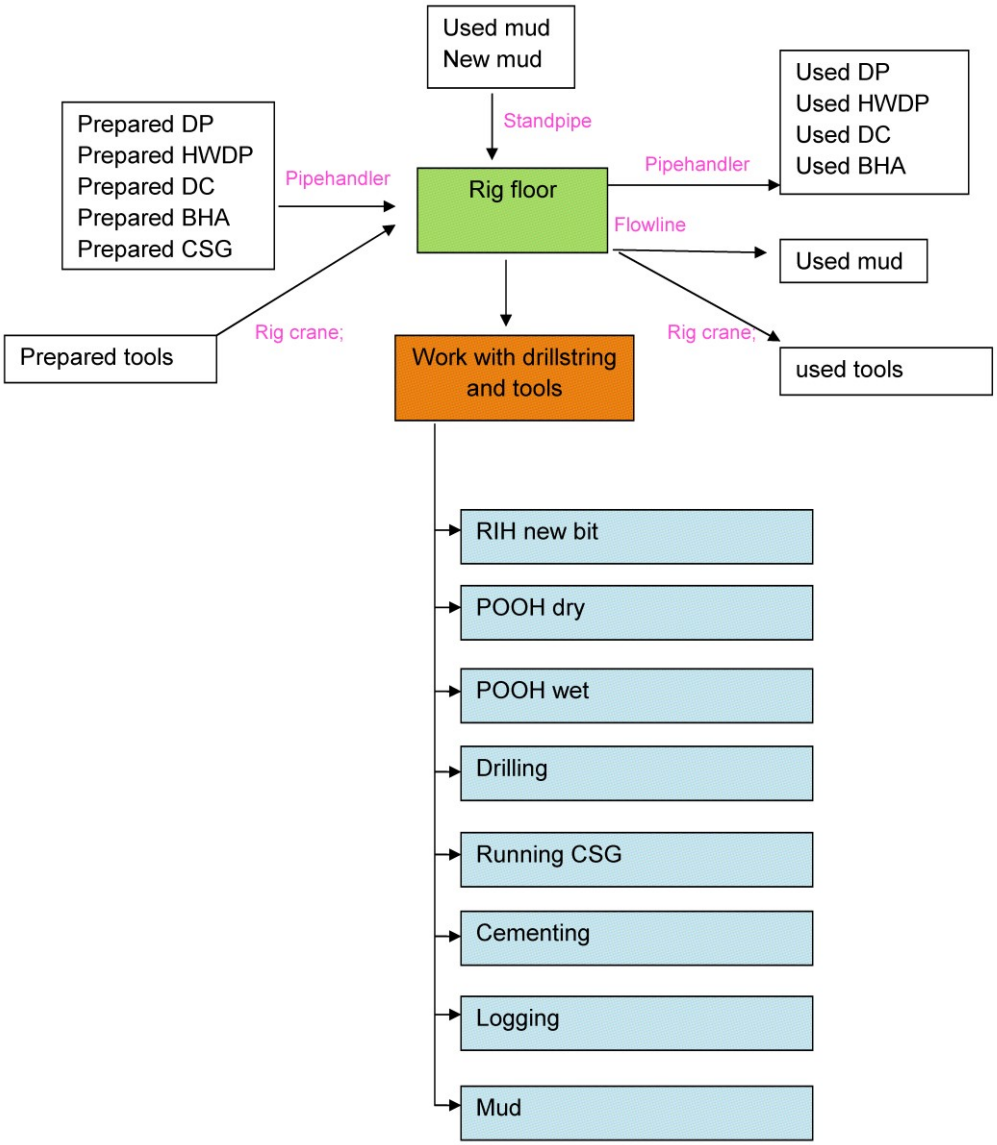


A1.2 Workcenters, Rigfloor (RF)

2. Rig floor

What's going in and out and what's going on there



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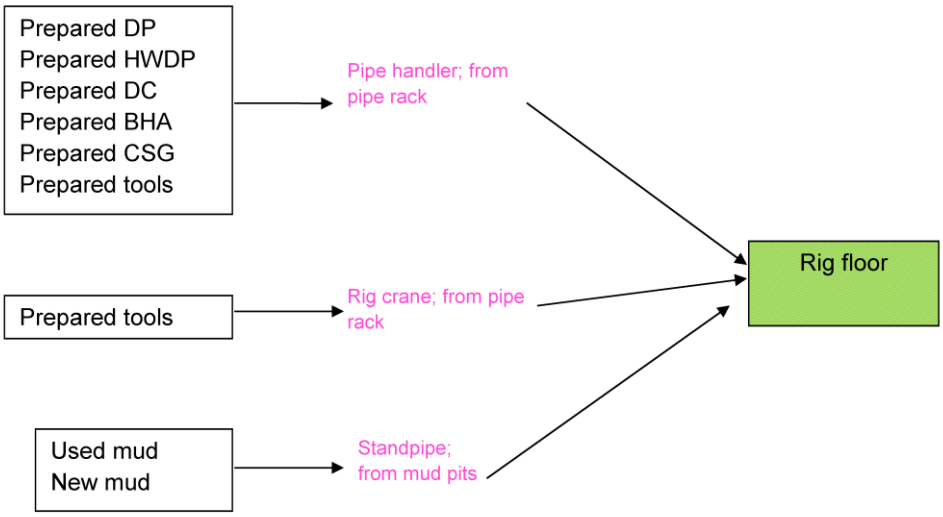

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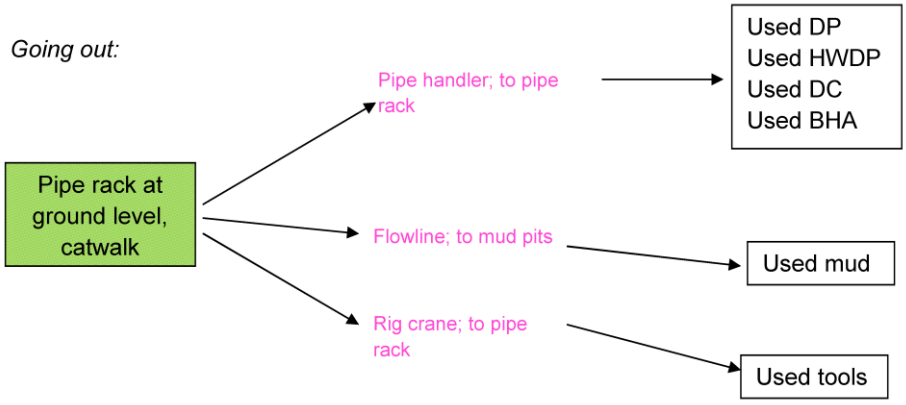
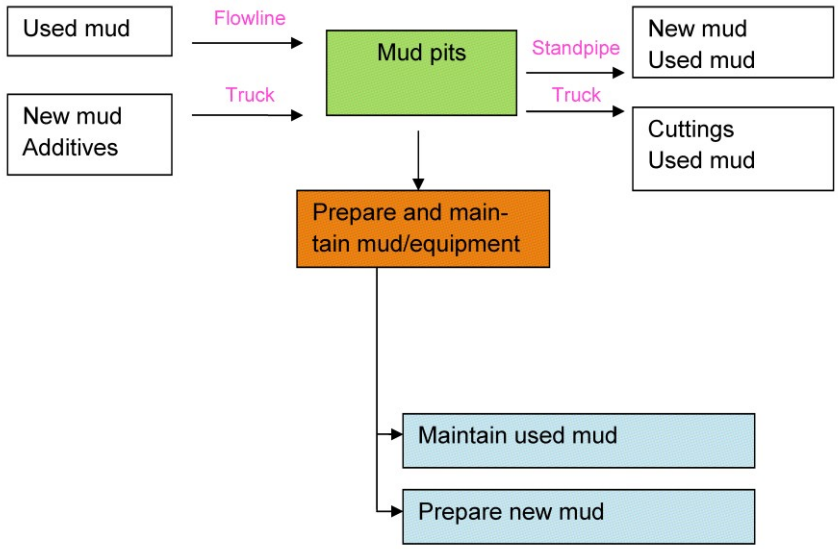


A1.3 Workcenters, Mud Pits (MP)

3. Mud pits

What's going in and out and what's going on there



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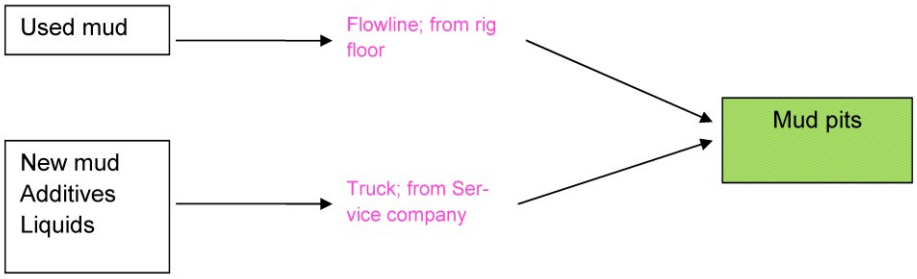

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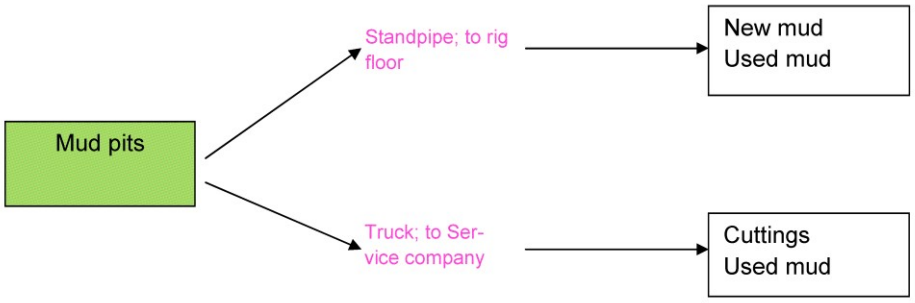


A2 Conventional Rig

A2.1 Workcenters, Pipe Rack (PR) at Ground Level

Conventional equipped with: automated elevator, automated slips and hydraulic cat-walk. Therefore the workcenters are:

1. Pipe rack at ground level
2. Rigfloor
3. Monkey board, Pipe rack at rig floor
4. Mudpits

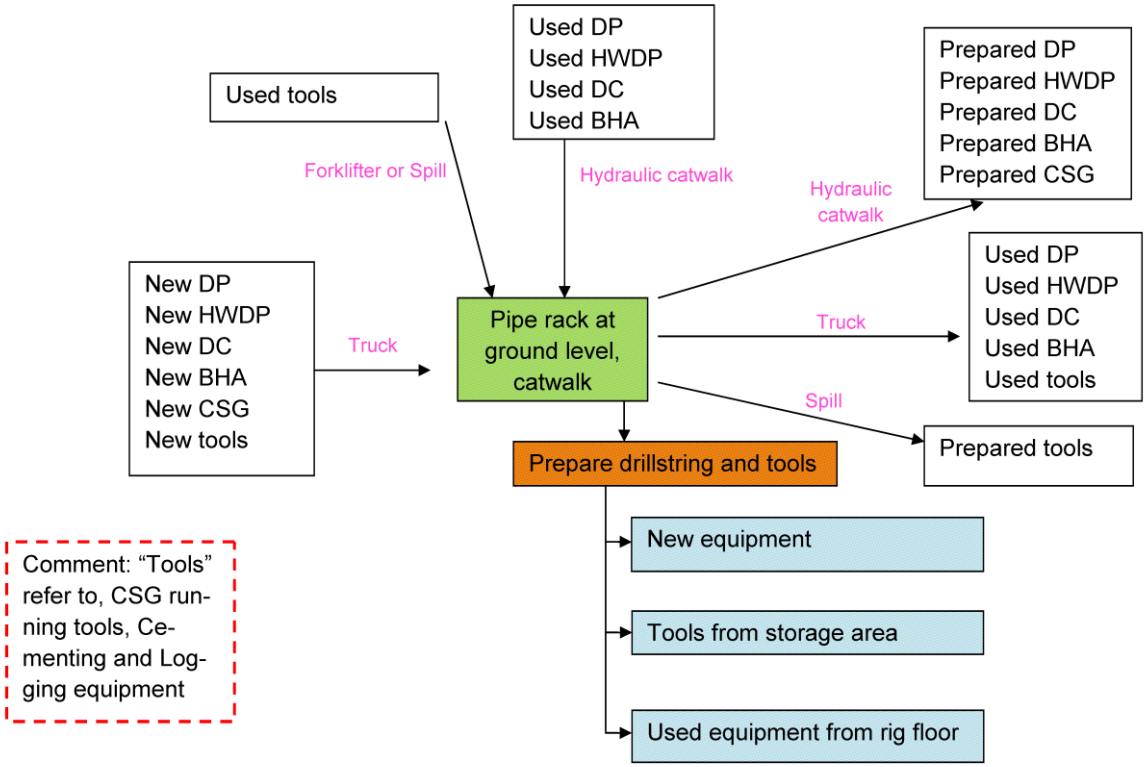
Key:

- Workcenter in green
- Main process in orange
- Sub process in blue
- Transport in pink

Workcenters marked in blue, processes in green and transport in pink

1. <u>Pipe rack at ground level</u>

What's going in and out and what's going on there



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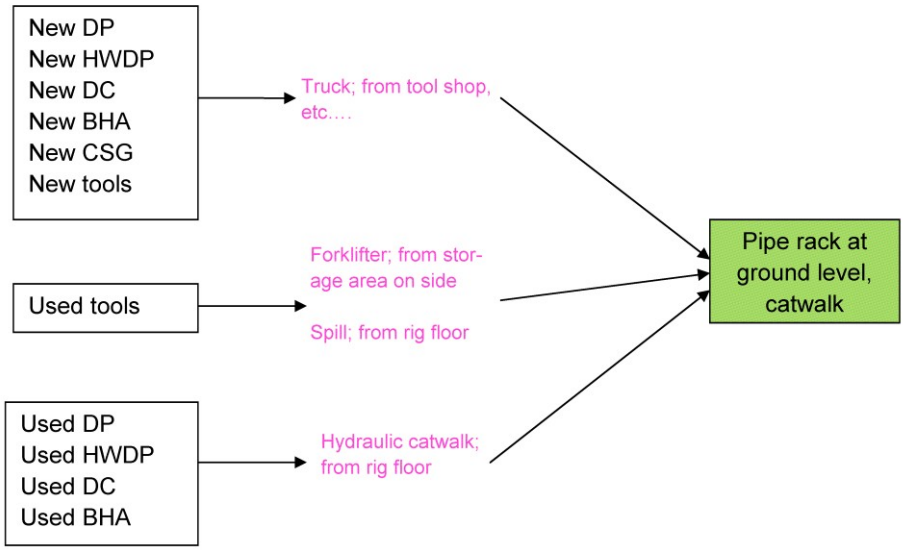

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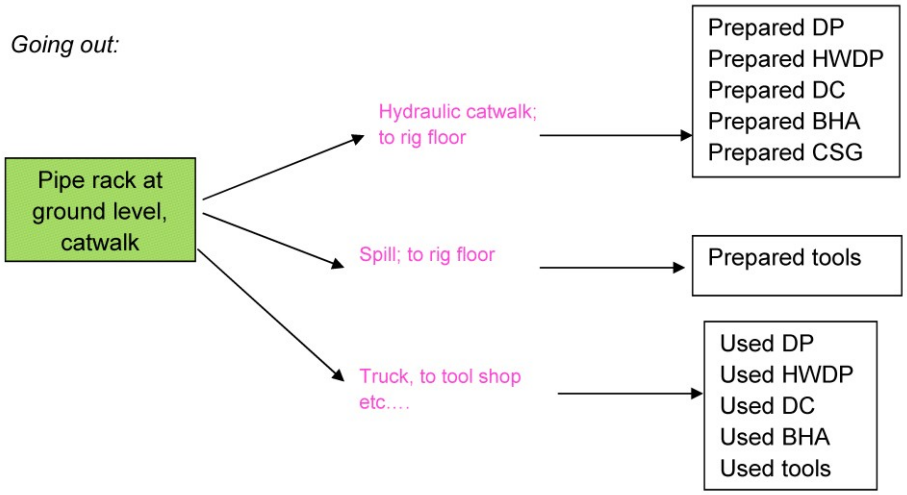
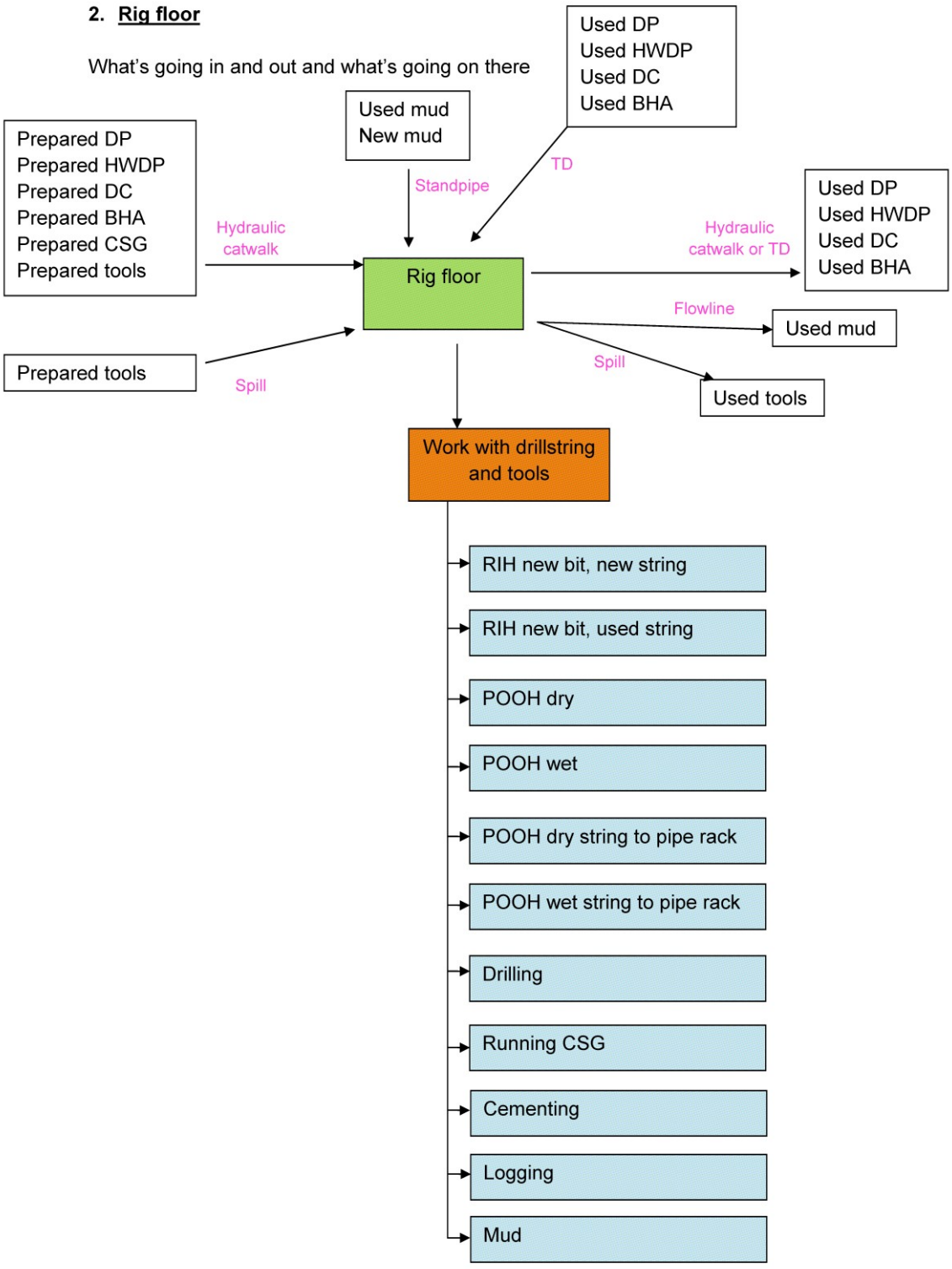


A2.2 Workcenters, Rig Floor (RF)



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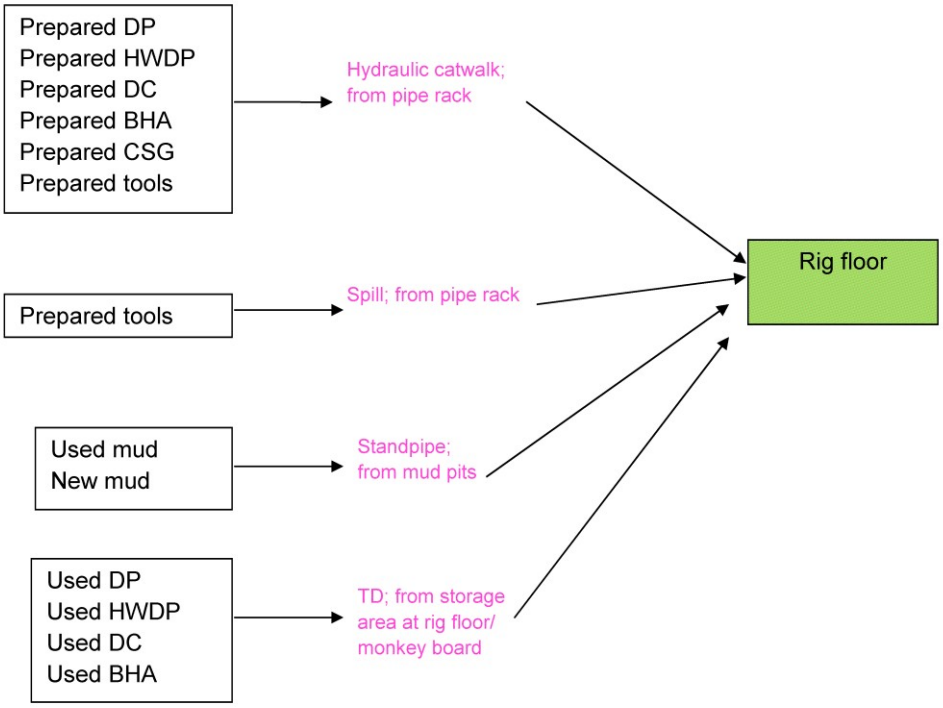

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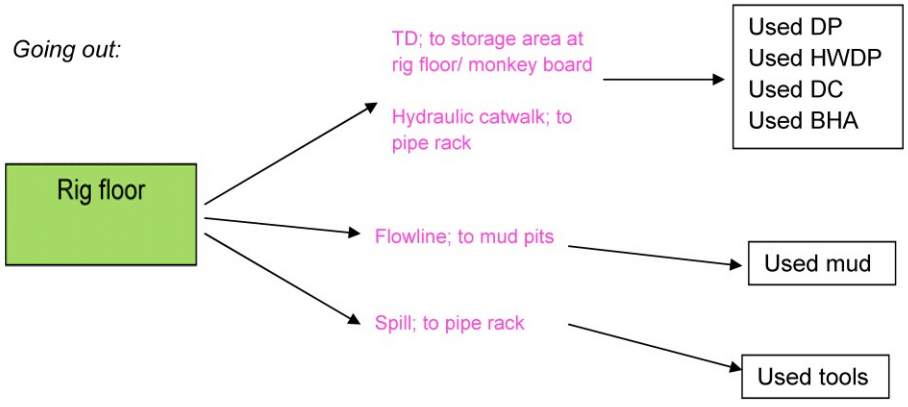
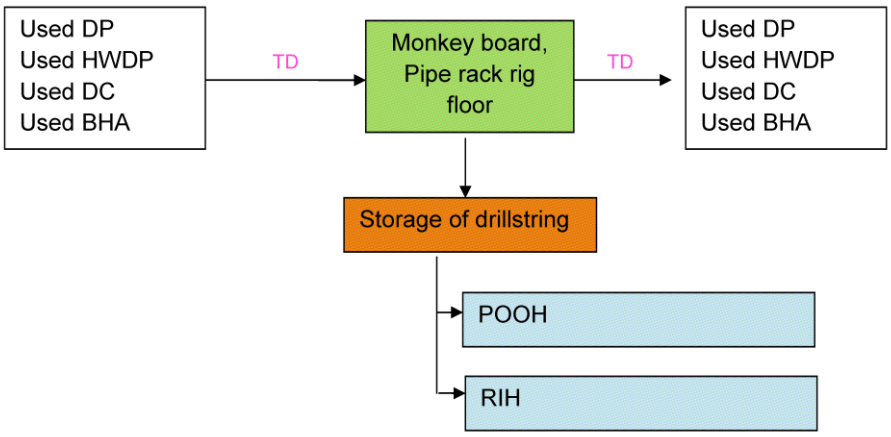


A2.3 Workcenters, Monkey Board (MB)

3. Monkey board, pipe rack rig floor

What's going in and out and what's going on there



Transport

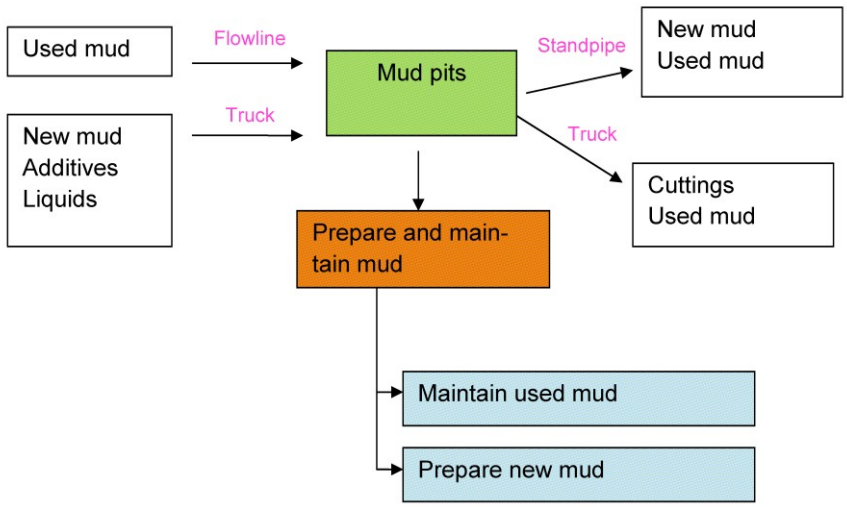
Coming in:

Going out:

A2.4 Workcenters, Mud Pits (MP)

4. Mud pits

What's going in and out and what's going on there



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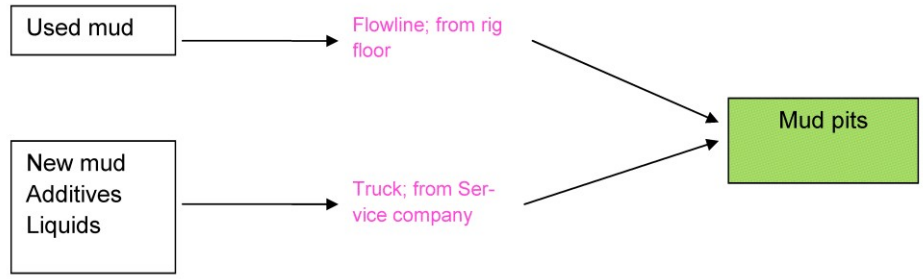

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