

Performance Improvements and Process Efficiencies from Simultaneous Operations Utilizing Dual Rig Design

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Abstract

Though many recent drilling advancements provide solutions to drill wells faster, safer, and cheaper than ever before, flat time still remains a significant hindrance to achieving optimal performance.

A simultaneous drilling program taking place within one complete unit is achieved with an innovative dual rig design that combines a primary and secondary rig into one. The secondary rig is capable of drilling the surface section, running casing and circulating mud simultaneously as the primary drilling rig drills the production hole and performs standard tasks and operations. The secondary rig is also capable of safely and efficiently transferring a stand of drill pipe to the primary rig.

In addition, the rig saves time throughout the well, including the entire surface section, casing running operations, tripping, cementing, and skidding. The reduction of flat time and non-productive time maximizes well efficiencies. Furthermore, the solution creates safer working conditions on the rig by removing operations from the critical path of the primary rig's well center.

This method of simultaneous operations and stand transfer is an entirely new concept in the land drilling realm. Utilizing existing equipment reduces the total cost and resourcefully repurposes assets that would have otherwise remained idle. Ultimately, as both operators and drilling contractors look for new and pioneering ways to decrease cycle time while increasing overall performance in an efficient and cost effective manner, the dual rig design represents a significant step change in the drilling industry.

Concept

Years prior to the dual rig design, numerous attempts between the operator and drilling contractor had been made to eliminate nonproductive time. One of the first attempts was offline production cementing and later partnering with the wellhead provider to maintain well control barriers at all times during offline production casing cementing. This initial success gave the operator and contractor a renewed focus to explore other possibilities outside well center. This spawned the idea of running surface casing offline with a 350 ton crane, purpose built rig floor mounted on an existing skidding system, and conventional casing running equipment.

Operator Request

The foundational concepts listed above and the unrelenting drive for innovation inspired the idea of completing simultaneous operations while utilizing a dual rig design in the U.S. land drilling market.

The simultaneous operations performed by the dual rig concept is a common sight in offshore environments. It had never been attempted on land due to cost constraints and standard multi-well pad drilling design, so the concept was studied in-depth to find a viable, sustainable, and cost-effective solution. Initial studies were developed to investigate how to efficiently combine two rigs to perform simultaneous operations as one unit, and it was estimated by operational data that two rigs could save between two and three days per well. Exploring the possible solutions in their entirety led to the initial concept and design of allowing one rig to start drilling even while the other rig still is moving.

Ideally, the project would be done with two new-build rigs of equal capability, but the decision was made to use an existing secondary rig with the operator's primary rig, which was already drilling in the area. This created a cost-effective solution while also taking advantage of idle assets. The original specifications of the two rigs are shown in **Table 1**.

Table 1: Individual Rig Specifications

Specification	Primary Rig	Secondary Rig
Mast	134.5 ft, 750K lb	126 ft, 500K lb
Top Drive Details	TDS-11HT 500 T, 1200 hp	Flex Drive 300 T, 600 hp
Substructure Floor Height	30 ft	24 ft
Substructure Rotary Capacity	750K lb	500K lb
Substructure Setback Capacity	622K lb	300K lb
Mud System Pressure Rating	7500 psi	5000 psi

Layout Development

Simply combining the primary and secondary rigs' respective original layouts could not be done due to increased well spacing constraints. Rig move procedures were taken into account as well. The rigs would be spaced precisely enough to allow for trucking to disassemble from east to west, thus providing a smooth transition from one location to the next. Ultimately, the goal was to logistically use each rig to its maximum potential.

Backyard

After several meetings it was determined to configure the backyard of the secondary rig to allow the solids control company to manage the cuttings bins on both the primary and secondary rig from a single operating point.

A solution was needed to link the high and low pressure mud service to the substructure. A utility manifold was designed to contain the high pressure mud, low pressure mud, the choke system, and the pump back piping to and from the substructure. A central tee with isolation valves on the east and west sides allowed for each section of the manifold to be isolated at a given time. This would allow for ease of rig up and rig down, while not hindering current operations of the other rig. Each of these sections could be added and removed depending on the pad size, with the final dual rig system pad layout shown in **Fig. 1**.

Secondary Rig Modifications

The substructure of the secondary rig underwent four significant changes to accommodate a 32 ft well spacing requirement and the stand transfer system:

- Increasing of the substructure height
- Adaptation to an existing 200 ft skidding system

- Complete relocation of the driller's cabin
- Addition of a pump back mud circulating system

Substructure Height

The secondary rig's original substructure height of 24 ft was increased by installing two 6-ft pony subs. This was done to match the floor height of the corresponding primary rig.

Skidding System

The original skidding length of the secondary rig was 75 feet, with the lower boxes accommodating a narrower skidding track system, and electrical utilities integrated in to the VFD house via an overhead cable bridge. The lower boxes were removed and replaced with replicas similar to the primary rig. The electrical utility system was completely reworked, removing the utility bridge and transferring the utility skid into a large power junction, supplying electrical service to both the substructure and backyard.

Driller's Cabin

To most land drilling personnel, the west side of the substructure is commonly referred to as the "driller's side" and the east is referred to as the "off-driller's side." Completely reversing the two areas of the substructure was a significant change. Not only did this change require significant structural modifications, it also required adjustments to the MCC house, the electrical service routing in the substructure, and the high pressure mud service routing. The MCC was gutted and rewired to accommodate the new 200 ft utility drag chain located on the northern side of the rig. The high pressure piping was rerouted to avoid the electrical service now required by the MCC and driller's cabin above it and still make its way to the 200 ft utility manifold.

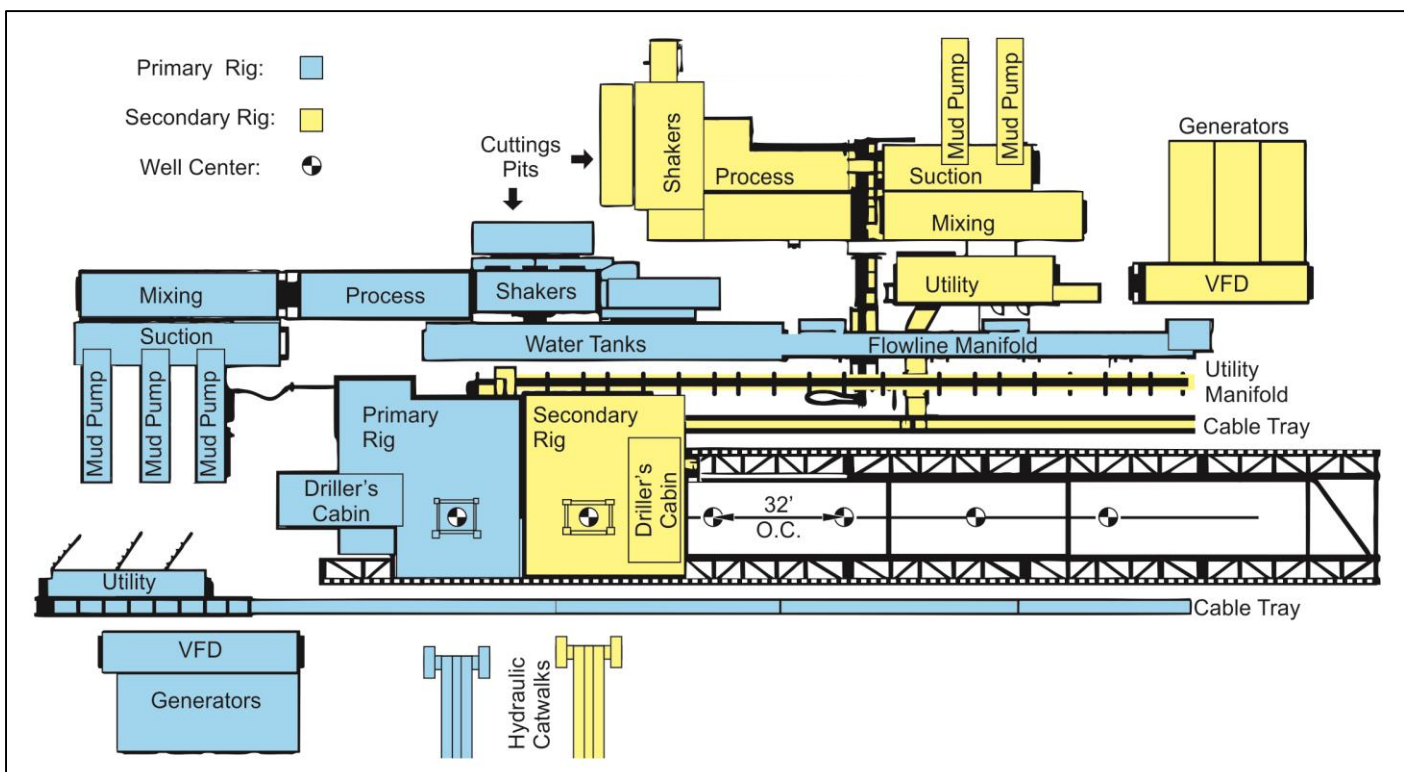


Figure 1: Dual Rig Design Layout

Pump Back System

One of the larger challenges to the design team was the low pressure mud system of the secondary rig. A pump back system would keep both rigs independent of each other while still successfully transferring mud back to the secondary rig's shakers. This pump back system had been used successfully a year prior to the project, however, integrating the system into the secondary rig substructure's trip tanks proved to be another unique challenge. The low pressure trip tank piping was redesigned to accommodate the considerably larger pump back pumps. Along with the pumps, an automated tank level system controlled the volume in each tank.

Stand Transfer System

With the two rigs in such close proximity, the operator determined an additional way to reduce well to well time. If a full 90 ft stand could be transferred from one rig to another, then the secondary rig, originally to be used for casing and cementing, could also aid in tripping out of the hole. This would allow the primary rig to drill ahead and save tripping time.

Several solutions were vetted, considering safety and feasibility of the processes and procedures. One idea included buying a 90 ft hydraulic catwalk for each of the rigs. This required the stands to be laid down and rolled from one catwalk to the next, creating safety concerns. Another idea was to create an oversized mouse hole and transfer the stands utilizing the existing boom pole and floor hoist. This method kept the stand somewhat vertical but required a relatively large angle for the stand to clear the racking board of the primary rig.

Ultimately it was decided to transfer the stand of pipe upright, using a monorail and trolley hoist system mounted above the racking boards. Transfer of the stand occurred as the stand was lifted with a single joint elevator attached to the trolley hoist and transferred through a passageway in each one of the racking boards.

Though ultimately contributing to a cost-effective solution, converting two existing rigs to a dual rig system brought forth challenges that would not have existed otherwise with a new build. New and altered assets led to new procedures being made, which required new methods protecting overall crew safety.

Racking Board

The first structural challenge was to create a racking board passageway for the stand to pass through. This would require cutting a primary structural member needed to transfer loads generated by wind and pipe forces on the mast. These would allow the forces from the cut primary member to be diverted through the gantry structure to the other pin connections on the mast.

Monorail

The second structural challenge was achieving proper monorail placement. If the monorail were attached to both masts, it would be subjected to large forces due to the sway of each from both drilling and the wind. It would also require a method of detaching the monorail to skid the rigs

independently.

It was decided to keep the mast independent by attaching the monorail to the secondary rig's mast. This required the monorail to cantilever out 26.5 ft beyond the side of the mast to present the stand to the well center of the primary rig. At this length, just one degree of rotation in the mast would produce 6 in. of deflection at the end of the monorail. The gantry structure of the primary rig was designed to handle this deflection.

The long cantilever length also limited the hoist capacity to 1.5 T, only allowing for the transfer of drill pipe and not heavy weight drill pipe or drill collars. The stall capacity of the hoist was verified to be less than the structural capacity of the monorail, ensuring the hoist stalls out before the monorail structurally fails.

Mast Raising

The third challenge was raising the mast with the additional weight of the stand transfer system. The racking boards are commonly pinned on with the mast horizontal and raised along with the mast. It was assumed the excess weight from the monorail and the gantry structure would prevent the hydraulic MRCs from raising the mast. The racking boards and mast connections were designed to be attached with the mast in both the vertical and horizontal position. It was ultimately determined that the mast raising cylinders would be able to support the added weight, however, the mast required reinforcement and the top drive required docking at a lower position. These adjustments eliminated the need for a larger crane, further reducing exposure to crew members working at heights.

Safety and Procedures

The design phase of the stand transfer system was significant, but all issues had to be managed in a safe way. Considerable effort was made to identify exposures and remove them through design; exposures that could not be designed out were controlled through the use of procedures and an additional JSA.

As previously mentioned, in order to facilitate the stand transfer between masts, a passageway was created in the side of the racking board allowing stands to enter and exit. This created safety concerns. Significant injury potential exists if the derrickman were to lose control of a stand inside the perimeter of the racking board, or unforeseen issues could occur outside the confines of the board during a transfer.

To reduce the potential for significant injury if the derrickman lost control of the stand inside the racking board, a one-way gate was placed at the passageway along the outside of the board. The gate only allows a stand to enter the board, and the stand can only exit the board if the gate is manually opened. An uncontrolled stand would simply hit the gate and remain within the confines of the racking board.

An equipment malfunction occurring during a stand transfer in between the two rigs could potentially result in an uncontrolled fall of more than 90 ft of drill pipe. To prevent this from happening, an alley way was created in between the rigs with half of the alley attached to each of the racking boards.

This would constrain the uncontrolled stand of pipe and prevent it from falling outside the alley way and racking boards.

The trolley hoist system was selected and utilized primarily with safety measures in mind. The variable stop, start, and travel speeds of the selected hoist prevents converting the 90 ft stand of pipe into a 90 ft pendulum when starting or stopping. The trolley is programmed to travel slower while within the confines of the racking boards, increasing the response time by the derrickman and floorhands. The wireless and compact remote controls allow for extended mobility, creating a clear line of sight as the derrickman transfers the stand. Up to three remotes can be used in this process if additional vantage points are needed, and a horn and light system alerts all on location when a transfer is taking place. The derrickman and floorhands use headsets to ensure clear communication during the transfer.

Construction

Retrofitting existing assets for a new project presents challenges that require extensive planning. Once the project scope and initial design were finalized, a detailed construction schedule was created, tracking the material procurement, fabrication, and modification of over twenty five modular rig packages. The timeline officially began in early January, 2018, with a targeted completion date of June 1, 2018. **Table 2**, below, displays the original milestone breakdown of the on-site portions of the project.

Table 2: Milestone Breakdown

Milestone	Date Completed
Secondary Rig Up	05/02/2018
Secondary Rig Commissioning	05/07/2018
Secondary Rig Down / Trucking	05/14/2018
Primary Rig Components	05/29/2018
Dual Rig System Project Completion	06/01/2018

An aggressive construction schedule required a preexisting lean assembly facility and rig up yard, which significantly contributed to the project's success, with dedicated team members from all areas of all parties involved.

Primary Rig Modification

The casing porch was removed along with all stairs along ODS to create a flat surface to mate with the secondary rig. An additional set of stairs was added along the off-driller's side as the new egress from rig floor. Another set of stairs was added along the drawworks side of the base boxes, exiting on the skid rails. The skid rails were filled with grating to provide an adequate walkway. These tasks were all completed over a period of 48 hours, with a team of 17 welders, on location in the field.

Secondary Rig Modification

The secondary rig was built in 2007, but had been stacked since 2014 due to market conditions in the area. This meant that in addition to the dual rig design modifications, the secondary rig required standardized recommissioning procedures. All structural modifications and the majority of the electrical and miscellaneous utility services were completed at the assembly facility.

Rig Up and Commissioning

After the major structural modifications had been completed, the final stages of rig up and commissioning for the secondary rig included major rig equipment function testing and mud system integrity checks. The equipment operated as designed with only minor issues.

A final on-site pre-move meeting was held at the assembly facility to discuss procedures, logistics, safety, and operational goals. Meeting attendees included the operator personnel, drilling contractor personnel, and all other third party personnel (trucking, solids control, etc.).

The secondary rig was then rigged down and transported to the primary rig's new location. Both the primary and secondary rigs functioned as designed on site, and the stand transfer system effectively completed a series of successful stand transfers. The two separate rigs began operating as a dual rig system.

Continuous Improvement

The initial concept of the dual rig design involved two rigs, utilizing the stand transfer system to drill a faster well. Though it was successful, the stand transfer system was only used through the first two full pads of complete wells. Like many drilling projects, the design and implementation changed over time, and continuous improvement was driven by further increasing cost-effectiveness. This evolved into reducing the flat time of the secondary rig as much as possible.

The dual rig system has undergone changes over the course of its field tenure, not only in equipment and procedures, but in the individual task breakdown for the primary and secondary rigs. Though the stand transfer system is not currently used, the concept and design led to additional time savings and efficiencies through the dual rig system.

Pad Progression

No two pads drilled by the dual rig system have been the same. The pad progression task breakdown, starting at the first full implementation, is shown in **Fig. 2**:

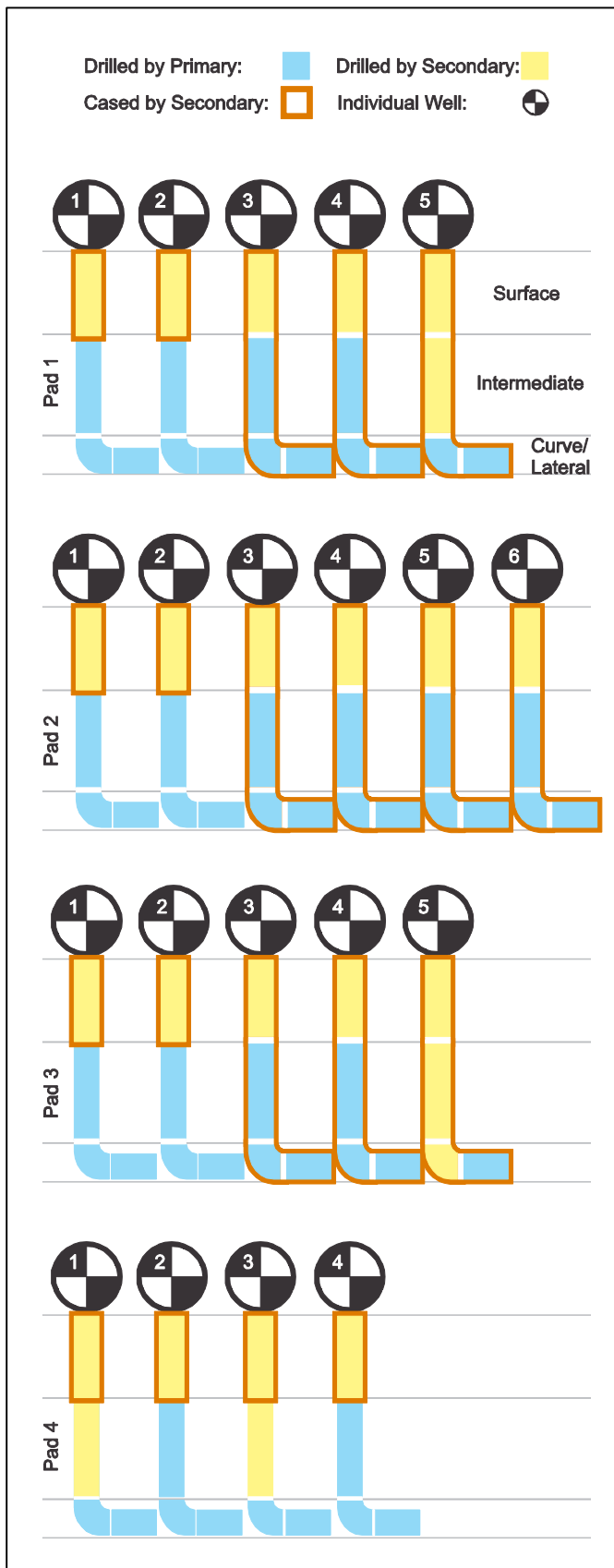


Figure 2: Pad Layout Progression

Drilling Performance

Measuring drilling performance by treating the rig as a single unit negates the supplementary nature of the secondary rig and the increasingly large amount of simultaneous operations occurring on the two individual rigs. Additionally, from the operator's perspective, any tasks performed by the secondary rig are not included in the well's overall cycle time, similar to the time spent utilizing a spudder rig. The more tasks the secondary rig can take over from the primary rig, the faster the well program is completed.

The dual rig system's performance improvements were immediate and translated to a time improvement of over 48%. The time savings continued as the dual rig system completed more wells. The primary rig's spud to total depth cycle time was reduced by over 11% between the first and fourth pad.

Secondary Rig Standby Reduction

Increased utilization of the secondary rig contributes to a lower primary rig cycle time through simultaneous operations. Throughout the implementation of the dual rig system, the average standby time per well (designated by code 21 on the IADC tour sheet) of the secondary rig has improved by nearly 74%, translating to a reduction of 42 hours. The average standby time progression, shown in **Fig. 3**, indicates a clear significant improvement. It is important to note that the values displayed in the chart are the pad averages.

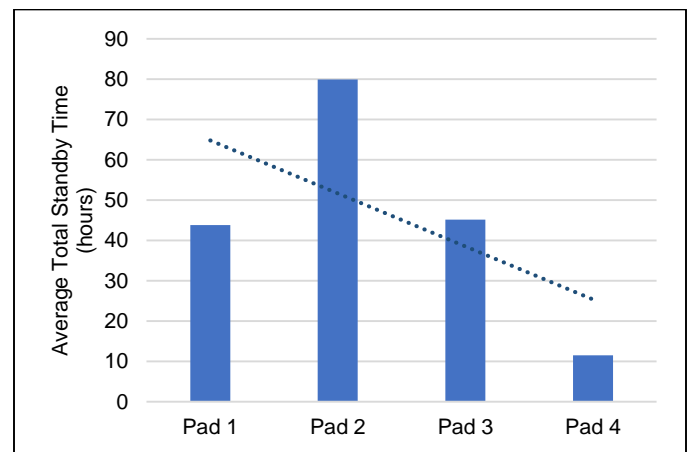


Figure 3: Standby Hours Pad Progression

Additional Flat Time Savings

The dual rig system has seen an additional significant time savings in N/U BOP, test BOP, and N/D BOP time. The operator requires a standard full test every 21 days. With the current average spud to release cycle time, one out of every five tests is a full test. The remaining tests are shell tests, which are significantly shorter in duration, saving an average of 3 to 4 hours.

Rig Personnel

The primary rig has kept a standard six-man crew, along with one rig manager. Originally, the secondary rig started out with a four-man crew and one rig manager. However, as

simultaneous operational activity increased and their standby time decreased, the need for a standard five-man crew became evident.

N/U = *Nipple Up*
ODS = *Off-Driller's Side*
VFD = *Variable Frequency Drive*

Rig Moves

Scheduling a rig move for two separate drilling rigs, working two separate operations as a single unit, on the same pad, involved additional planning, procedures and coordination.

As previously mentioned, the top drive on the primary rig must be lowered from its original transport position in order to raise the mast, adding approximately 10 hours to the total rig move time. A solution was presented by the trucking company to use a custom multi-axle trailer to eliminate the weight transfer issues caused by the relocated position of the top drive.

The secondary rig's move time is significantly affected by the total time spent picking up between 6,500 and 10,000 ft of drill pipe, increasing the total move time by 12 to 16 hours, due to the ST-80's location in front of the drawworks, which inhibits building stands in the mouse hole. Picking up pipe can only be completed online.

Conclusions

The goals of the dual rig design project were accomplished as follows:

- The dual rig system was successfully designed, commissioned, and deployed to the field with a partnership between the operator and drilling contractor.
- A successful stand transfer system was implemented for the first time in a land drilling environment.
- Previously idle assets were refurbished and put back to work.

Tapping into the strengths of each rig has brought forth additional insight into future dual rig system capabilities. Though the term is commonly referred to as overused corporate jargon, the partnership between the operator and drilling contractor created synergy in its most essential form: greater results were achieved through the combined innovative effort of the team than either group could have accomplished on their own.

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Nomenclature

BOP = *Blowout Preventer*
DS = *Driller's Side*
IADC = *International Association of Drilling Contractors*
JSA = *Job Safety Analysis*
MCC = *Motor Control Center*
MRC = *Mast Raising Cylinder*
N/D = *Nipple Down*