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# Applications of Data Analytics and Statistical Models to Limit Mud Losses: Case Histories from the Rumaila Field, Iraq

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## Abstract

Lost circulation has been known as common phenomena to cause wellbore instability problems and impede drilling operations. The direct and indirect unwanted consequences of lost circulation are mud losses, non-productive time, formation damage, inefficient hole cleaning, loss of formation evaluation, additional casing strings, kick, collapse issues, mechanical stuck pipe, bit damage, wash pipe, and the possibility of abandoning well.

This paper presents case histories of field applications of previously developed mud losses mitigation strategies and statistical models for the Rumaila field to mitigate mud losses in the Dammam, Hartha, and Shuaiba formations. The mud losses mitigation strategies and statistical models were applied in fifteen wells drilled in 2018 in the Rumiala field. Nine wells applied the recommended key drilled parameters prior to entering the losses zones and resulted in a significant decrease in mud losses while drilling the Dammam, Hartha, and Shuaiba formations. Only seepage to partial losses were encountered which is a big accomplishment. The other six wells utilized the recommended key drilling parameters after the occurrence of lost circulation. The recommended key drilling parameters should be utilized prior to entering the losses zone and should be maintained while drilling the losses formation. The recommended key drilling should be used to mitigate not to stop mud losses. Once lost circulation occurred, corrective actions have to be used to treat and stop mud losses.

Due to the lack of published studies in regard drilling data analysis of lost circulation events, this work can serve as a substantial resource to be used globally if the characteristics of the formations are the same as Dammam, Hartha, and Shuaiba formations.

## Introduction

Drilling mud accounts for a major expense in drilling oil and gas wells. The drilling mud is circulated through drill-string and drill bit, to remove cuttings from borehole and to enable drill bit performance. Drilling mud is specifically formulated to develop a thin coating on the borehole wall, referred to as a ‘mud cake’ which limits fluid losses to the formations already drilled and exposed in the borehole, as drill bit proceeds deeper and deeper.

The concept of lost circulation or lost returns can be defined as “the partial or total loss of circulating fluid from the wellbore to the formation. It is the loss of whole fluid, not simply filtrate, to the formation. Losses can result from either natural or induced causes and can range from a couple of barrels per hour to hundreds of barrels in minutes. Lost circulation is one of drilling’s biggest expenses in terms of rig time and safety. Uncontrolled lost circulation can result in a dangerous pressure control situation and loss of the well” (Baker Hughes, 1999).

Loss circulation is a significant problem in the oil and gas industry. By industry estimates, more than 2 billion USD is spent to combat and mitigate this problem (Arshad et al., 2015; Alkinani et al., 2019, Alkinani et al., 2018a; Alkinani et al., 2018b). Although lost circulation may occur in any formation, some primary contributors to loss circulation are high permeability weakly consolidated formations, fracture calcium carbonate reservoirs, and depleted aquifer zones. (Al Menhali et al., 2015).

Given sufficient experience in drilling a particular type of formation, it may be possible to avoid or significantly minimize, lost circulation events by controlling mud properties, drilling rate, or other field parameters. However, this requires a high level of experience and study, which is generally not available. For this reason, the industry relies heavily on using methods of stopping or mitigating lost circulation events after they occur (Al-Hameedi et al., 2017d).

This paper presents a real field application of previously developed mud losses mitigation strategies for the Rumaila field, for three formations which are the Dammam, Hartha, and Shuaiba on newly drilled wells in the Rumaila filed (Al-Hameedi et al., 2017a; Al-Hameedi et al., 2017b; Al-Hameedi et al., 2017c; Al-Hameedi et al., 2017d; Al-Hameedi et al., 2017e; Al-Hameedi et al., 2018a; Al-Hameedi et al., 2018b; Al-Hameedi et al., 2018c). The mud losses mitigation strategies, that were previously developed, applied on fifteen newly drilled wells in the Rumaila field.

## Introduction to the Rumaila Field

The Rumaila field is a super-giant oil field located near Basra city in Southern Iraq, and approximately 20 mi (32 km) from the Kuwaiti border. Basra Petroleum Company (BPC), an associate company of the Iraq Petroleum Company (IPC), discovered this field in 1953. The Rumaila field is considered the third largest field in the world. Currently, the field is owned by Iraq and subcontracted to British Petroleum (BP) and China National Petroleum Corporation (CNPC) under Iraq Producing Field Technical Service Contract (PFTSC). BP is an operator of the project with 47.6% while CNPC and State Oil Marketing Organization (SOMO) hold 46.4% and 6%, respectively. As of October 2016, the field produces 1,000,000 barrels per day, from approximately 200 production wells (Al-Hameedi et al., 2017d). **Table A.1** (Appendix A) Provides an overview of the lithology and producing formations in the Rumaila Field. Prior to 2010, the field was under the supervision of Basra Oil Company, and the primary formation for development was the Zubair formation. As of 2010, BP became the operator for this field, and development focus shifted to the Mishrif formation (Al-Hameedi et al., 2017d; Basra Oil Company, 2010; Basra Oil Company, 2011; Basra Oil Company, 2015; Basra Oil Company, 2016; Basra Oil Company, 2017; Basra Oil Company, 2018).

## Approach

Given the number of drilling parameters that affect mud loss and the complex interrelationship between some of the drilling parameters, a drilling engineer is challenged to select the optimum value for each one. The purpose of this work was to develop a more systematic approach to determining the best values for these parameters while drilling the Dammam, Hartha, and Shuaiba formations in the Rumaila field, Iraq. The methodology developed is based on analyzing actual mud loss events while drilling these formations, to develop key statistical models for rate of penetration (ROP), equivalent circulation density (ECD), and mud losses and then setting key drilling parameters. Mud loss events for more than 300 wells drilled in the Rumaila field were identified through reading and summarizing daily drilling reports (DDR), final well reports, and technical report. Critical drilling parameters such as mud weight (MW), ECD, yield point (Yp), plastic viscosity (PV), ROP, strokes per minute (SPM), revolutions per minutes (RPM), flow rate (Q), wight on bit (WOB), and bit nozzles were recorded at the time of each mud loss events. Mitigation strategies and statistical models as well as corrective methods to limit mud losses were developed for the Dammam, Hartha, and Shuaiba formations (Al-Hameedi et al., 2017a; Al-Hameedi et al., 2017b; Al-Hameedi et al., 2017c; Al-Hameedi et al., 2017d; Al-Hameedi et al., 2017e; Al-Hameedi et al., 2018a; Al-Hameedi et al., 2018b; Al-Hameedi et al., 2018c).

The ultimate objective of this work is to apply and test the previously developed mud losses mitigation strategies and statistical models to limit key drilling parameters on fifteen newly drilled wells in the Rumaila field.

## Statistical Models and limiting Key Drilling Parameters for the Dammam Formation

Three statistical models have been previously developed to be used for mud losses predication and limiting key drilling parameters. Equations 1-3 are the models that have been statistically constructed for the Dammam formation, which are volume loss, ECD, and ROP models, respectively. More details on the development of the models are available in the literature (Al-Hameedi et al., 2017a).

$$\boldsymbol{Mud\ Losses = -1950.102 + 1019.371 * MW\left(\frac{gm}{cc}\right) + 808.816 * ECD\left(\frac{gm}{cc}\right) + 0.557 * Yp\left(\frac{Ibf}{100ft^2}\right)} \ldots \textit{(Eq.1)}$$

$$\boldsymbol{ECD = 0.8512 + 0.1723 * MW\left(\frac{gm}{cc}\right) + 0.0071 * ROP\left(\frac{m}{hr}\right) - 0.0000026251 * Q\left(\frac{L}{min}\right)} \ldots \textit{(Eq.2)}$$

$$\boldsymbol{ROP = 1.972 + 0.00648 * SPM + 0.00642 * RPM + 0.462 * WOB\ (Ton)} \ldots \textit{(Eq.3)}$$

The aim of building the above statistical models is to set key drilling parameters that have the chances of avoiding or minimizing lost circulation in the Dammam formation. **Table A.2** (Appendix A**)** illustrates the ranges of key drilling parameters that have to be used to penetrate the Dammam formation as a proactive approach, these parameters were identified and summarized based on reviewing historical data, comprehensive statistical analysis, and constructing statistical models. As a proactive approach, each key drilling parameter has been analyzed separately to estimate the best operating range that will prevent or mitigate mud losses, more details on setting and selecting each key drilling parameter for the Dammam formation are provided in the literature (Al-Hameedi et al., 2017b).

## Statistical Models and limiting Key Drilling Parameters for the Hartha Formation

Using the same approach in the Dammam formation, three statistical models for the Hartha formation have been developed to be used for mud losses predication and limiting key drilling parameters. Equations 4-6 are the models that have been statistically constructed for the Hartha formation, which are volume loss, ECD, and ROP models, respectively. More details on the development of the models are available in the literature (Al-Hameedi et al., 2017c; Al-Hameedi et al., 2018b).

$$\boldsymbol{Mud\ Losses = -1915.757 + 530.782 * MW\left(\frac{gm}{cc}\right) + 1144.376 * ECD\left(\frac{gm}{cc}\right) + 0.582 * Yp\left(\frac{Ibf}{100ft^2}\right)} \ldots \textit{(Eq.4)}$$

$$\boldsymbol{ECD = 0.9895 + 0.125 * MW\left(\frac{gm}{cc}\right) + 0.0068 * ROP\left(\frac{m}{hr}\right) - 0.000009901 * Q\left(\frac{L}{min}\right)} \ldots \textit{(Eq.5)}$$

$$\boldsymbol{ROP = -1.312 + 0.007 * SPM + 0.0124 * RPM + 0.489 * WOB\ (Ton)} \ldots \textit{(Eq.6)}$$

Using the same approach that has been used in the Dammam formation, key drilling parameters were estimated as a proactive approach to combat mud losses in the Hartha formation as shown in **Table A.3** (Appendix A). More details on setting and selecting each key drilling parameter for the Hartha formation are provided in the literature (Al-Hameedi et al., 2018a; Al-Hameedi et al., 2018c).

## Statistical Models and limiting Key Drilling Parameters for the Shauiba Formation

Once again, the same techniques that have been used in the Dammam and Hartha formations, utilized to develop statistical models of the Shuaiba formation. Three statistical models for Shuaiba formation have been constructed to also be used for mud losses predication and limiting key drilling parameters. Equations 7-9 are the models that have been statistically created for the Shuaiba formation, which are volume loss, ECD, and ROP models, respectively. More details on the development of the models are available in the literature (Al-Hameedi et al., 2017d).

$$\boldsymbol{Mud\ Losses = -1985 + 760 * MW \left(\frac{gm}{cc}\right) + 908 * ECD \left(\frac{gm}{cc}\right) + 4 * Yp\left(\frac{lbf}{ft^2}\right)} \ \dots (Eq.7)$$

$$\boldsymbol{ECD = 0.977 + 0.164 * MW \left(\frac{gm}{cc}\right) + 0.00664 * ROP \left(\frac{m}{hr}\right) - 0.00000646 * Q\left(\frac{L}{min}\right)} \dots \ (Eq.8)$$

$$\boldsymbol{ROP = -5.556 + 0.01362 * SPM + 0.01669 * RPM + 0.578 * WOB\ (Ton)} \ \dots (Eq.9)$$

To achieve the same aim in the Dammam and Hartha formations, the above equations in conjunction with data analytics have been unitized to select the best range of key drilling parameters to minimize the mud losses in the Shuaiba formation as proactive action. **Table A.4** (Appendix A) shows the minimum and the maximum range of each parameter to be used to drill the Shuaiba formation. More details on setting and selecting each key drilling parameter for the Shuaiba formation are provided in the literature (Al-Hameedi et al., 2017e).

## Field Applications for the Statistical Models and the Recommended Key Drilling Parameters

The objective of this work to test and apply the statistical models and the mud losses mitigation strategies that were previously developed for three formations which are the Dammam, Hartha, and Shuaiba, in the Rumaila field. Basra Oil Company utilized the findings presented by Al-Hameedi et al. (2017a; 2017b; 2017c; 2017d; 2017e; 2018a; 2018b; 2018c) to drill new wells in the Rumaila field. In this section, case histories from fifteen wells drilled in 2018 will be presented, nine wells used the findings presented earlier in this paper, while six wells didn't use the findings presented in this paper. The nine newly drilled wells using the recommended key drilling parameters showed very good results to mitigate mud losses. The range of mud losses was between seepage to partial losses for all three formations. Encountering only seepage to partial losses in the Dammam, Hartha, and Shuaiba formations is a big accomplishment since non-productive time and cost due to mud losses will be minimized. Therefore, the mud mitigation strategies and the statistical models previously developed are tangibly valuable for minimizing the cost and time of the drilling operations. **Tables A.5-A.7** (Appendix A) summarize the key drilling parameters, recommended by the previous studies, utilized to drill the new nine wells in the Rumaila field, for Dammam, Hartha, and Shuaiba formations, respectively.

The main reason behind the successful mitigation of the mud losses in the nine newly drilled wells is that the crew started and maintained the recommended ranges of key drilling parameters. In addition, the crew carefully monitored the key drilling parameters in order to maintain the same key drilling parameters throughout the entire section of each formation (e.g. Dammam, Hartha, and Shuaiba). As a result, a remarkable reduction in mud losses has been experienced while drilling the Dammam, Hartha, and Shuaiba formations.

On the other hand, higher ranges of key drilling parameters were used initially to drill six wells in the Rumaila field. Severe and complete mud losses were encountered, then the drilling crew tried to use the recommended key drilling parameters to stope mud losses. However, using the recommended key drilling parameters after the occurrence of lost circulation will not stop mud losses since the recommended key drilling parameters are used to mitigate or minimize mud losses not to stop mud losses. The solution, in this case, is to used corrective methods and pump treatments to stop mud losses. **Tables A.8-A.10** (Appendix A) summarize the key drilling parameters to drill the six wells after and before the occurrence of mud losses.

## Conclusions

This paper presents field application of previously developed mud losses mitigation strategies and statistical models for the Dammam, Hartha, and Shuiaba formations, in the Rumaila field. Case histories from fifteen wells drilled in 2018 in the Rumaila field were presented and analyzed. Based on this study, the following conclusions were made:

- The mud losses mitigation strategies and statistical models were applied in nine wells drilled in 2018 in the Rumaila field and showed a significant reduction in mud losses when drilling the Dammam, Hartha, and Shuaiba formations. As a result, non-productive time and cost related to mud losses were minimized.
- The recommended key drilling parameters have to be utilized first prior to entering the losses zone. If higher ranges of key drilling parameters were used first, there is a big potential to have mud losses in the Dammam, Hartha, and Shuaiba formations and utilizing the recommended key drilling parameters will not stop mud losses. In this case, corrective actions have to be utilized to stop mud losses. This was proven by six case histories of wells drilled in 2018 in the Rumaila field.
- Alternatively, given a target loss volume, the statistical models can be used in reverse, to set key drilling parameters to limit losses while drilling. Wells drilled in 2018 in the Rumaila field according to the recommended key drilling parameters, which were developed using the statistical models and data analytics, were successful at mitigating mud losses. Thereby, validating the models developed.
- The mud losses mitigation strategies and statistical models developed for the Rumaila field to mitigate

mud losses in the Dammam, Hartha, and Shuaiba formations can be used to limit and mitigate mud losses for formations with same characteristics.

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## Appendix A

**Table A.1. Lithology in the Rumaila Field (Basra Oil Company, 2011)**

| Formation | Description | Formation Intervals | Problems |
|---|---|---|---|
| DIBDIBA | Sand & Pebble | 200 m or less | High gel strength, sand content, and filtration. |
| L. FARS | Argillaceous Limestone | 200 - 315 m | High viscosity and balling. |
| GHAR | Sand & Pebble | 315 - 440 m | Wash pipe and corrosion. |
| DAMMAM | Dolomite | 440 - 700 m | Lost Circulation due to vugs. |
| RUS | Anhydrite | 690 – 860 m | High contamination of $Ca^{++}$. |
| UMM ER-RADHUMA | Dolomite | 860 – 1310 m | $H_2S$ flow. |
| TAYARAT | Shale | 1300 – 1550 m | $H_2S$ flow. |
| SHIRANISH | Argillaceous Limestone | 1550 – 1660 m | Stuck pipe and low penetration rate. |
| HARTHA | Limestone | 1660 – 1850 m | Lost circulation due to natural fractures. |
| SADI | Limestone | 1850 – 2150 m | Kick due to high pressure. |
| TANUMA | Shale | 2150 – 2200 m | Shale sloughing and collapse. |
| KHASIB | Limestone | 2200 – 2250 m | Formation hardness is high. |
| MISHRIF | Limestone | 2240 – 2390 m | Kick due to abnormal pressure. |
| RUMAILA | Limestone | 2400 – 2490 m | Low penetration rate. |
| AHMADI | Shale | 2490 – 2635 m | Shale sloughing and collapse. |
| MAUDDUD | Limestone | 2630 – 2723 m | Partial mud losses. |
| NAHR UMR | Shale | 2720 – 2990 m | Shale collapse and stuck pipe. |
| SHUAIBA | Limestone | 2990 – 3090 m | Lost circulation due to fractures. |
| U. SHALE ZUBAIR | Shale | 3090 – 3205 m | Shale collapse and stuck pipe. |
| U. SANDSTONE ZUBAIR | Sandstone | 3205 – 3390 m | Low penetration rate. |
| M. SHALE ZUBAIR | Shale | 3390 – 3445 m | Shale collapse and stuck pipe. |
| L. SANDSTONE ZUBAIR | Sandstone | 3445 – 3515 m | Low penetration rate. |

**Table A.2. Recommended Key Drilling Parameters for the Dammam Formation**

| Property | Minimum Value | Maximum Value |
|---|---|---|
| Mud Weight (MW), (gm/cc) | 1.05 | 1.06 |
| Equivalent Circulation Density (ECD), (gm/cc) | 1.06 | 1.075 |
| Yield Point (Yp), (Ibf/100ft$^2$) (Polymer Mud) | 20 | 25 |
| Yield Point (Yp), (Ibf/100ft$^2$) (FWB Mud) | 13 | 15 |
| Plastic Viscosity (PV), (cp) | 6 | 10 |
| Weight on Bit (WOB), (Ton) | 5 | 10 |
| Strokes per Minute (SPM) | 100 | 110 |
| Flow Rate (Q), (L/min) | 1760 | 1936 |
| Revolutions per Minute (RPM) | 55 | 65 |
| Rate of Penetration (ROP), (m/hr) | 5 | 8 |
| Bit Nozzles | Without Nozzles | Without Nozzles |

**Table A.3. Recommended Key Drilling Parameters for the Hartha Formation**

| Property | Minimum Value | Maximum Value |
|---|---|---|
| Mud Weight (MW), (gm/cc) | 1.12 | 1.13 |
| Equivalent Circulation Density (ECD), (gm/cc) | 1.13 | 1.15 |
| Yield Point (Yp), (Ibf/100ft$^2$) (Polymer Mud) | 20 | 24 |
| Yield Point (Yp), (Ibf/100ft$^2$) (FWB Mud) | 13 | 15 |
| Plastic Viscosity (PV), (cp) | 9 | 14 |
| Weight on Bit (WOB), (Ton) | 7 | 13 |
| Strokes per Minute (SPM) | 100 | 120 |
| Flow Rate (Q), (L/min) | 1760 | 2112 |
| Revolutions per Minute (RPM) | 60 | 70 |
| Rate of Penetration (ROP), (m/hr) | 5 | 9 |
| Bit Nozzles | Without Nozzles | Without Nozzles |

**Table A.4. Recommended Key Drilling Parameters for the Shuiaba Formation**

| Property | Minimum Value | Maximum Value |
|---|---|---|
| Mud Weight (MW) (gm/cc), | 1.15 | 1.16 |
| Equivalent Circulation Density (ECD), (gm/cc) | 1.16 | 1.18 |
| Yield Point (Yp), (Ibf/100ft$^2$) | 12 | 13 |
| Plastic Viscosity (PV), (cp) | 12 | 15 |
| Weight on Bit (WOB), (Ton) | 10 | 14 |
| Strokes per Minute (SPM) | 80 | 90 |
| Flow Rate (Q), (L/min) | 1408 | 1584 |
| Revolutions per Minute (RPM) | 55 | 65 |
| Rate of Penetration (ROP), (m/hr) | 2 | 4 |
| Bit Nozzles | Without Nozzles | Without Nozzles |

**Table A.5 Examples of Newly Drilled Wells Using the Recommended Key Drilling Parameters for the Dammam Formation**

| Well No. | MW (gm/cc) | ECD (gm/cc) | Yp (Ibf/100ft$^2$) | PV (cp) | SPM | RPM | WOB (Ton) | Q (L/min) | ROP (m/hr) | Type of Losses |
|---|---|---|---|---|---|---|---|---|---|---|
| RU-461 | 1.05 | 1.06 | 21 | 6 | 100 | 55 | 5 | 1760 | 5 | Seepage to Partial |
| RU-462 | 1.06 | 1.07 | 23 | 7 | 100 | 65 | 7 | 1760 | 6 | Seepage to Partial |
| R-653 | 1.06 | 1.075 | 25 | 9 | 110 | 65 | 8 | 1936 | 8 | Seepage to Partial |
| R-654 | 1.05 | 1.065 | 22 | 7 | 110 | 60 | 6 | 1936 | 6 | Seepage to Partial |

**Table A.6. Examples of Newly Drilled Wells Using the Recommended Key Drilling Parameters for the Hartha Formation**

| Well No. | MW (gm/cc) | ECD (gm/cc) | Yp (Ibf/100ft$^2$) | PV (cp) | SPM | RPM | WOB (Ton) | Q (L/min) | ROP (m/hr) | Type of Losses |
|---|---|---|---|---|---|---|---|---|---|---|
| R-612 | 1.12 | 1.13 | 20 | 9 | 100 | 65 | 8 | 1760 | 5 | Seepage to Partial |
| RU-443 | 1.12 | 1.13 | 22 | 10 | 120 | 70 | 13 | 2112 | 9 | Seepage to Partial |
| RU-444 | 1.13 | 1.14 | 21 | 11 | 100 | 65 | 11 | 1760 | 8 | Seepage to Partial |

**Table A.7. Examples of Drilled New Wells Using the Estimated Key Drilling Parameters for the Shuaiba Formation**

| Well No. | MW (gm/cc) | ECD (gm/cc) | Yp (Ibf/100ft$^2$) | PV (cp) | SPM | RPM | WOB (Ton) | Q (L/min) | ROP (m/hr) | Type of Losses |
|---|---|---|---|---|---|---|---|---|---|---|
| RU-474 | 1.16 | 1.18 | 12 | 13 | 80 | 55 | 11 | 1408 | 2 | Seepage to Partial |
| R-656 | 1.16 | 1.18 | 12 | 14 | 90 | 60 | 13 | 1584 | 4 | Seepage to Partial |

**Table A.8. Examples of Newly Drilled Wells Started with High Ranges of Key Drilling Parameters for the Dammam Formation**

| Well No. | | MW (gm/cc) | ECD (gm/cc) | Yp (Ibf/100ft$^2$) | PV (cp) | SPM | RPM | WOB (Ton) | Q (L/min) | ROP (m/hr) | Type of Losses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R-618 | Before Losses | 1.07 | 1.09 | 31 | 12 | 145 | 75 | 13 | 2552 | 12 | Severe |
| | After Losses | 1.05 | 1.06 | 20 | 7 | 100 | 60 | 6 | 1760 | 6 | Complete |
| RU-431 | Before Losses | 1.065 | 1.09 | 32 | 14 | 135 | 80 | 12 | 2376 | 11 | Complete |
| | After Losses | 1.05 | 1.07 | 24 | 9 | 110 | 65 | 9 | 1936 | 7 | Complete |

**Table A.9. Examples of Newly Drilled Wells Started with High Ranges of Key Drilling Parameters for the Hartha Formation**

| Well No. | | MW (gm/cc) | ECD (gm/cc) | Yp (Ibf/100ft$^2$) | PV (cp) | SPM | RPM | WOB (Ton) | Q (L/min) | ROP (m/hr) | Type of Losses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RU-468 | Before Losses | 1.14 | 1.16 | 27 | 15 | 130 | 80 | 16 | 2200 | 12 | Complete |
| | After Losses | 1.12 | 1.13 | 21 | 10 | 100 | 60 | 7 | 1760 | 5 | Complete |
| R-623 | Before Losses | 1.15 | 1.17 | 31 | 17 | 140 | 90 | 18 | 2464 | 14 | Severe |
| | After Losses | 1.13 | 1.15 | 24 | 13 | 120 | 65 | 12 | 2112 | 8 | Severe |

**Table A.10. Examples of Newly Drilled Wells Started with High Ranges of Key Drilling Parameters for the Shuaiba Formation**

| Well No. | | MW (gm/cc) | ECD (gm/cc) | Yp (Ibf/100ft$^2$) | PV (cp) | SPM | RPM | WOB (Ton) | Q (L/min) | ROP (m/hr) | Type of Losses |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RU-403 | Before Losses | 1.18 | 1.2 | 15 | 18 | 100 | 70 | 15 | 1760 | 6 | Severe |
| | After Losses | 1.16 | 1.18 | 13 | 15 | 90 | 65 | 14 | 1584 | 4 | Severe |
| R-597 | Before Losses | 1.19 | 1.21 | 17 | 20 | 110 | 75 | 16 | 1936 | 8 | Complete |
| | After Losses | 1.15 | 1.16 | 12 | 13 | 80 | 55 | 10 | 1408 | 2 | Complete |