

Supporting Drilling Gains with More Informed Fluids Experts

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Abstract

Historically, the “mud engineer” is the only fluids contractor representative at the wellsite, maintaining effective fluid systems within certain target property ranges. In offshore real-time (RT) operations centers, others follow similar workflows, watching for anomalies. To avoid missing critical drilling events, monitoring should focus on multiple sets of parameters, including the fluids. RT fluid hydraulics monitoring can bridge these silos by interpreting data from the well and concurrent modeling to diagnose fluid system performance as part of the complete drilling mechanism. Fluids monitoring (FM) specialists run RT simulations, communicate findings, and execute situation-specific workflows.

The FM concept was field tested in two areas. Using proprietary software, comparisons between modeled equivalent circulating density (ECD) values and pressure-while-drilling (PWD) equivalent mud weight (EMW) consistently tracked within 0.1 lbm/gal. For a North Sea case, drilling progressed through an intermediate section. An intervention occurred when increased ECD and torque/drag were observed during backreaming, resulting in the suspension of backreaming operations. After circulating bottoms up, a 75% increase in cuttings was observed, highlighting the packoff risk.

In the Gulf of Mexico (GoM), two cases, among many, demonstrate FM effectiveness. The first proved the FM concept was an economically appealing alternative compared to trips for PWD repair or replacement. In the second case, specialists intervened when an operator was “out-drilling” the hole cleaning capacity of its system. The models extrapolated existing conditions to forecast a warning before PWD EMW began to climb.

This paper presents operational aspects of FM, including installation and monitoring options, live inputs and outputs, and field performance data.

Introduction

In most critical well projects, the onshore drilling team will take advantage of diagnostic and monitoring capabilities, which are built in to many of the modern sensor components of the drillstring. Likewise, the drilling log or electronic recorder screen is examined regularly for any indications that a remedial action(s) are required. These sources normally provide the following data:

- Torque
- Drag
- Vibration
- PWD EMW and standpipe pressure (SPP)

Hydraulics, which is linked to each of these, is for many projects the most critical factor to plan and monitor.¹ Along with the typical PWD readout, the industry has recognized the value provided by hydraulic simulation software for planning operations and diagnosing ongoing pressure events.

Drilling Forecast

The use of advanced hydraulics management software has been accepted as an important tool for helping reduce non-productive time (NPT), and it continues to gain use as a proactive solution for helping to alleviate lost circulation and its causes.² Advances in RT hydraulics applications are leading to more accurate and more holistic modeling. No longer are snapshot models of downhole environments the only modeling available. With RT applications, a full and evolving picture of downhole trends is available, allowing engineers to monitor operations within a window of opportunity and instantly observe events occurring within that window. The use of such RT software and the ability to observe in RT ahead of the bit adds a second level of proactive optimization in that, not only is it possible to monitor how drilling with current parameters is affecting the wellbore and its integrity, but also ahead to predict how those parameters will affect the wellbore in the near future.

In addition to running RT hydraulics simulations, FM specialists perform offline simulations based on direct data sources to help predict the optimum drilling parameters for maintaining efficient drilling operations while minimizing any unplanned events. By predicting the optimum parameters based on the most up-to-date wellbore information, the specialists can monitor the drilling operation, noting any events where the parameters drift out of acceptable ranges, and with the use of RT modeling techniques, instantly observe the effects of out-of-range parameters.

Engineering Support

FM uses the RT PWD EMW data and compares them to the RT hydraulics modeling software’s (RTHMS’) simulated

ECD. The simulated ECD is the benchmark of what should be occurring down hole. PWD EMW is the measured value of what is actually occurring down hole. Comparing and contrasting PWD EMW to RTHMS ECD is the primary method for event detection. When PWD EMW “matches” the simulated ECD (see **Figure 1**), everything is going according to plan. When it diverges, based on how it and other parameters change, what is occurring down hole can be determined by comparing the situation to the FM operational workflows.

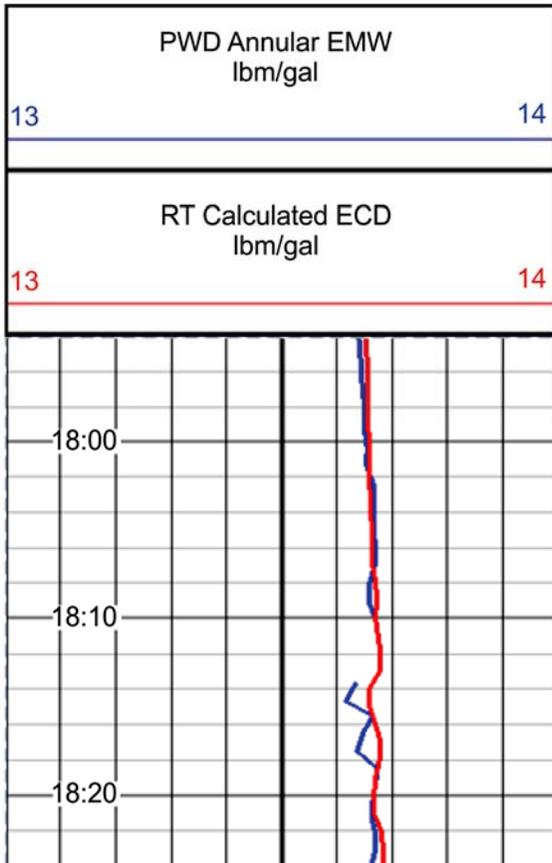


Figure 1: Example of RT log extract, plotting calculated ECD against PWD tool outputs.

The “garbage-in garbage-out” principle of relying on uncertain input values impedes accuracy and has been recognized as a challenge to monitoring. By using RT data being fed directly into the hydraulics modeling software, this uncertainty and the risk of human error for key variables can be reduced. With the addition of regular updates on non-RT variables, modeling of wellbore conditions has been raised to unprecedented levels.

For RT optimization of drilling and fluids properties, it is imperative that the modeling software be accurate and be calculated independently of measured values from downhole PWD tools. The accuracy of this RTHMS program has been validated to within a 1% difference from the value measured

by the PWD tool.^{3,4} All this is accomplished without calibration/correction of hydraulics program outputs to the PWD tool, giving the operator greater assurance of the program accuracy.

The full breadth of RT information available for a well might never be realized unless equal attention is devoted to accurate interpretation. To achieve this in a successful, repeatable manner requires a strong understanding of the fundamental engineering principles at play to produce accurate hydraulic simulations of both the current situation and evolving future conditions. This information is just as vital to the drill team as the current fluid properties and inventory supplied by the diligent mud engineer.

Over the past 17 years, interest in comparing simulated hydraulics results to the actual pressure readings has matured. By fingerprinting the equivalent static density (ESD), awareness was raised of the necessary corrections for compression/expansion of hydrocarbon base fluids. Accurate predictions of downhole rheological behavior allowed for the utilization of predicted ECD to study potential issues on pressure-sensitive well projects.⁵

Timely Alerts

When an out-of-range parameter has been observed, FM specialists activate the FM operational workflows and intervention (or threat level assessment) protocol. This allows them to detect an event, assign the observed event a color code, and take the appropriate actions based on what the workflows indicate (see **Table 1**).

Table 1: Monitoring Threat Level Descriptions

Green Intervention	Normal communications	Verify operations, validate sensor data
Yellow Intervention	Potential threat or impending hazard	Approach swab/surge limits, high predicted ECD/cuttings loads, minor losses
Red Intervention	Immediate threat or hazard	Pack off, influx, lost returns surge/swab exceeds limits

Before starting a job, a collaborative communications plan is agreed upon with the client and put in place to supplement the normal chain of command in an efficient manner. This communications plan designates a point of contact in the client’s organization for all FM communications.

Installation and Setup

The job setup for FM engineers has been developed to allow flexibility in location and data transfer mediums. The location from which the specialists work is generally a real-time operations center (RTOC) environment, either in a client’s office or a contractor facility, but certainly is not limited to either of these. Operations can be performed from

the rig site, if required, if the data connections do not allow remote communications.

Data can be received into the data management system used by FM engineers through standard data transfer protocols, such as Wellsite Information Transfer Specification (WITS) or Wellsite Information Transfer Specification Markup Language (WITSML), if third-party data providers are on the rig or a proprietary data exchange format is used by the FM company when it is the data provider on the rig. It is through these means that data is aggregated into the system database and transferred through LAN or WAN networks by means of a secured connection, allowing FM specialists to provide the FM service.

Data is collected in this manner from surface data logging (SDL), monitoring while drilling (MWD), and/or rig instrumentation systems providers. It is then fed into the database system employed by the FM specialists; from here, the data can be displayed and utilized to run the RTHMS. Calculated data is then written back to the database for display or transfer.

The FM service also utilizes a remote display package, allowing the data to be displayed through a secure link anywhere in the world by means of the internet. This service is provided for client-approved users who receive login credentials to view specific information.

Foreword to Case Histories

Because of confidentiality concerns, sensitive operator data are not discussed in this paper. The cases discussed are for illustrative purposes only. Depths, operators, coordinates, drilling parameters, formations encountered, the presence of hydrocarbons, and other contractors involved are withheld.

UK North Sea Field Test

FM specialists were deployed in the UK to provide RT analysis and optimization of hole cleaning and hydraulics management on a deviated intermediate wellbore section. By employing RT hydraulics modeling techniques onshore, the specialists were able to guide drilling operations in a manner that maintained efficient drilling operations while reducing NPT and time wasted because of poor hole cleaning or unmanaged hydraulics events.

Throughout the 12 ¼-in. section, high rates of penetration were maintained. At several points, inadequate hole cleaning was observed, and communications were made to the rig site providing mitigating actions to prevent continuation of the cuttings buildup. Increasing cuttings loads were being observed throughout the deviated sections, and monitoring ahead-of-bit analysis also showed that the wellbore condition would degrade throughout the rest of the wellbore if drilling continued in the same fashion. An example of this scenario can be seen in **Figure 2**.

Because the fracture gradient allowed for increased cuttings loadings, and most of the cuttings load stayed bedded, the ECD was not predicted to trend outside of allowable values. Recommendations made to the rig site involved a

combination of controlled rate of penetration (ROP) and increased flow rates.

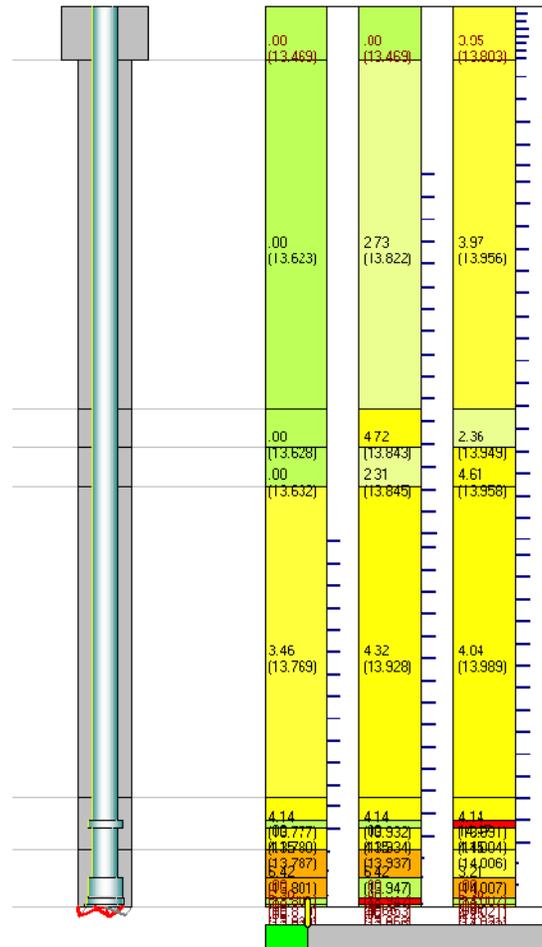


Figure 2: RTHMS output showing wellbore cleaning deteriorating over three stands of ahead-of-bit prediction.

A total of six communications were made to the rig site on hole cleaning throughout the section. However, because of recommendations being followed only when downhole conditions dictated the need for changes, drilling continued in this manner. A short trip was performed before completing the section, which indicated the well was clean.

On returning to drilling operations, drilling commenced with a controlled ROP. Toward the end of the drilling section, divergence between PWD EMW and RTHMS ECD occurred. PWD was observed to be falling lower than the output of RTHMS. The rig was contacted about this issue, and reductions in mud weight were determined to be the reason for the divergence. Offline modeling showed that pump off pressures would approach the pore pressure for the openhole section if these reductions continued. The rig site was informed, and drilling operations continued with lower mud weight.

Drilling continued at a controlled ROP until total depth

(TD). On pulling out of hole, some issues were encountered, with overpulls being experienced; the eventual deterioration of hole conditions necessitated backreaming operations. A discussion with the rig site was initiated, and the presence of pressure cavings was communicated. Hole conditions might have deteriorated because of the presence of cavings, which significantly impacted hole cleaning, and the reduced mud weight might have triggered wellbore instability.

While backreaming the fluids, monitoring specialists continued to closely observe the PWD outputs against the RTHMS outputs and other available data. While monitoring, it was observed that the PWD EMW increased by 0.01 specific gravity (SG) (0.08 lbm/gal) over three stands backreamed out of hole. Also, the PWD signal and value were becoming erratic; this was observed alongside increasing torque and overpull. Further communication was made to the rig site personnel to cease backreaming operations and agree to circulate the hole clean to avoid a possible packoff event. On discontinuing backreaming and circulating the well, an increase of 75% cuttings and cavings was observed at bottoms up. Pulling out of hole continued without rotation or flow until increased drag was observed again, circulation of the well again occurred, and the string was pulled freely. A wiper trip was then performed, which verified the hole as clean. The string was then pulled out of hole to surface.

The large increase in solids returns at surface on circulation plus the continued pull out of hole without issue showed that the issue was identified correctly and remedial actions were sufficient to return operations to productive time quickly.

GoM PWD Replacement

An independent GoM operator began drilling the production interval of a critical well and experienced a PWD tool failure. Because the formation pressure window was narrow, drilling without PWD was not an option. Additionally, a trip for tool replacement would add approximately 15 to 20 hours of NPT; also, the primary formation of the production interval proved “troublesome” on previous wells with extended periods of static exposure. This presented the customer with a difficult set of choices.

During the extensive testing phase performed in the development of the FM service, the developmental team had documented the ability of the RT hydraulics modeling software to simulate ECD accurately and was able to match PWD values to within one tenth of one lbm/gal. This documented reliability and precision led to a draft procedure where the FM service could serve as a temporary replacement for PWD in certain situations.

After conferring with all responsible parties, the operator gave the FM team the green light to perform this procedure and provide simulated downhole hydraulics values for the remainder of the interval.

Drilling continued using the in-hole bottomhole assembly (BHA), with the FM team providing RT ECDs in place of the failed PWD. Drilling proceeded according to program using the originally designed parameters, and the section was drilled

to TD without incident. The drilling team had high confidence in the calculated values from RTHMS, and the robust procedure created by the FM team and effective lines of communication between the customer and FM specialists allowed the avoidance of any NPT or hole problems—even without a functioning PWD in the hole.

GoM Out-Drilling Hole Cleaning Capability

A major operator in the GoM was drilling a 14 3/4-in. intermediate hole section when FM specialists noticed a 40% increase in the ROP without making any other changes to the drilling parameters.

After consulting the RT hydraulics modeling software, it was determined that if the rig continued to drill at this rate, the downhole ECD would approach the casing shoe test limit (**Figure 3**). A yellow intervention was created, and all appropriate parties were notified as per the job communication plan.

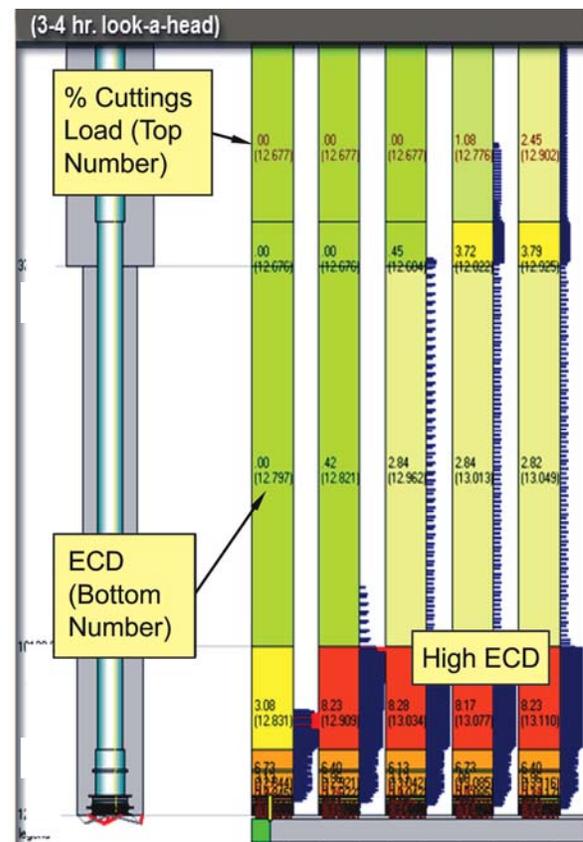


Figure 3: RT hydraulics simulation software output showing wellbore cleaning deteriorating predicted +/-320 feet ahead of the bit.

It was recommended that the rig reduce the ROP by at least 40% to prevent the casing shoe from fracturing. As the rig began to reduce the ROP, the PWD EMW began to climb, which was a clear indicator that the additional cuttings were

building up in the open hole, as predicted by the RT hydraulics modeling software.

Culture Shift

The involvement of ingrained FM specialists in the operator's office space represents a complete contrast to early fluids service models. Where drilling operations were typically supported with one field hand to manage the fluid volumes, treatments, and material requirements, the new approach, including the technical planner and monitoring specialist, takes advantage of improved communication and a "team player" attitude. Applying fluids optimization, in this sense, now means the team takes into account the entire well hydraulics perspective.

Some operators have overcome early resistance to allowing FM personnel access to their data. In all cases, the confidentiality of well data is paramount to building and maintaining the support company-operator relationship. Although these barriers are fairly easy to overcome with legal agreements, when multiple service contractors are involved, issues related to the sharing of information persist.

Another obvious sticking point is the degree to which the FM representative participates in the decision-making process. The authors have had many positive experiences by remaining patient with recommendations and following scripted situational protocols. While advice is most often appreciated, the majority of operators choose their own courses of action.

Market Perspective

Well plans dictate the potential gains FM services can provide. Development projects are usually suited to the task and require sparingly little deviation from the initial program. FM provides value for these projects by optimizing efficiency and improving performance documentation. Exploration wells offer far greater NPT potential. For example, on a rank wildcat, the incoming stream of data requires RT analysis to dependably "see" issues evolving and adapt the plans to make the well successful. Programs are often more vague for these wells and could require substantial changes. FM allows for a fast circuit of contingency planning among the fluids and drilling parameters and serves well to capture lessons learned for improvements on future well plans.

Commercial rates for FM service have usually been based on drilling time coverage and remain linked to the provision of fluids services. As the service evolves, more of a cost differential might be observed between exploration and development, along with incentive contacts based on the goals of the operator's authority for expenditures (AFE). Given the unique ability of FM services to provide advice to decision makers, they enable drill-to-the-limit projects and improvement plans on NPT-laden plays. Linking compensation of the FM team to reduced drilling time provides a logical incentive and ties the gains to both parties.

Heightened Communications

After every significant event impacting health, safety, and

the environment and/or the drilling AFE, conducting after action reviews or some form of tap root analysis is advised. The central idea of these investigations is to uncover any "hidden" factors leading to the events and highlight the causal factors that could be better managed in the future. Studies report that seven of ten mistakes have a communication failure at their origin.⁶ With broader and more timely communication of the hydraulic "health" of the well, it is expected that services such as FM will continue to aid operators in reducing major and minor NPT events.

Conclusions

The following conclusions are a result of this work:

- Every fluids company strives to maintain ideal fluid parameters, yet application services, such as FM, better equip them to improve plans during well development and take a stake in the success and efficiency of the drilling operation in total.
- Wellbore instability can be diagnosed and corrected in RT rather than after an event occurs. The UK case study showed how RT monitoring and proactive holistic hydraulics modeling identified issues with reducing mud weight before related issues were observed at the rig site.
- Accurate baseline ECD modeling provided from a RT hydraulics model, calculated independently of PWD sensor outputs, allowed quicker and more reasoned identification of PWD output trends. The diagnosis of an impending packoff situation in the UK operations showed how small trends that might not be apparent because of erratic sensor outputs or small deviations can be spotted easily compared with other sensor outputs. Catching these small trends can lead to major avoidance of NPT.
- RT ahead-of-bit ECD and hole cleaning modeling can accurately predict the effects of drilling parameters changes and their impending effects on the wellbore. The UK and GoM out-drilling hole cleaning capability case studies both verified the model employed by the FM specialists. The UK model showed how hole cleaning can be optimized while still providing high ROP, which was verified by a clean short trip during the drilling process. The GoM example showed that the predictive model identified increased cuttings loading and increased ECD ahead of the bit, which was verified by the increased PWD reaction. The predictive nature and ahead-of-bit modeling allows for mitigating actions to be quickly composed before operations are negatively impacted by issues.

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Nomenclature

SPP = Standpipe pressure

NPT = Nonproductive time

EMW = Equivalent mud weight

GoM = Gulf of Mexico

AFE = Authority for expenditure (planned well budget)

References

1. Hemphill, T., Murphy, B., and Mix, K. 2001. Optimization of Rates of Penetration in Deepwater Drilling: Identifying the Limits. Paper SPE 71362 presented at the Annual Technical Conference, New Orleans, Louisiana, USA, 30 September–3 October.
2. Mclean, A. Wilde, A., Zamora, M., and Rafferty, M. 2010. The Top 10 Mud-Related Concerns in Deepwater Drilling Operations—Revised after 10 years. Paper AADE-10-DF-HO-04 presented at the AADE Fluids Conference and Exhibition, Houston, Texas, USA, 6–7 April.
3. Green, M., Thomesen, C., Wolfson, L., and Bern, P. 1999. An Integrated Solution of Extended-Reach Drilling Problems in the Niakuk Field, Alaska: Part II—Hydraulics, Cuttings Transport and PWD. Paper SPE 56564 presented at the SPE Annual Technical Conference and Exhibition, Houston, Texas, 3–6 October.
4. Charlez, P.A., Easton, M., Morrice, G., and P. Tardy 1998. Validation of Advanced Hydraulic Modeling using PWD Data. Paper SPE 8804 presented at the Offshore Technology Conference, Houston, Texas, USA, 4–7 May.
5. Stegeman, S., Coles, B., and Rogers, W. 2004. Case History: Hydraulics Modeling Software Help Optimize Drilling and ECD Control with High Degree of Accuracy on Deep, Hot Gulf of Mexico Shelf Well. Paper AADE-04-DF-HO-04 presented at the AADE Drilling Fluids Conference, Houston, Texas, USA, April 6–7.
6. Ross, M. 2010. How Poor Communication Results in Workplace Mistakes. <http://www.digicast.com.au> (Posted Sep 12, 2010).