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Process and Supply-Chain Optimization for Testing and Verification of Formation Tester/Pressure-While-Drilling Tools

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***Abstract*—**Applying a rigorous process to optimize the elements of a supply-chain network resulted in reduction of the waiting time for a service provider and customer. Different sources of downtime of hydraulic pressure controller/calibrator (HPC) were causing interruptions in the operations. The process examined all the issues to drive greater efficiencies. The issues included inherent design issues with HPC pump, contamination of the HPC with impurities, and the lead time required for annual calibration in the USA.

HPC is used for mandatory testing/verification of formation tester/pressure measurement/logging-while drilling tools by oilfield service providers, including Halliburton.

After market study andanalysis, it was concluded that the current HPC model is best suited in the oilfield industry. To use theexisting HPC model effectively, design andcontamination issues were addressed through design and process improvements. An optimum network is proposed after comparing different supply-chain models for calibration lead-time reduction.

***Keywords*—**Hydraulic Pressure Controller/Calibrator, M/LWD, Pressure, FTWD

I. Introduction

DOWNHOLE pressure measurement is used to optimize the drilling operations, measuring formation pressureand control operation ofrotary steerable tools. This is achieved by using the pressure or formation-testermeasurement/logging-while-drilling tools (M/LWD). To ensure proper functioning of the tool downhole, there is a mandatory requirement to test andverify the working of the pressure sensors in the tool at the HalliburtonDrilling Equipment Maintenance (DEM) centers before the tool string is deployed to the drilling operations in the field. This proves as an effective check to ensure that thecustomers do not have any lost time or non-productive time (NPT).. Halliburton brought forth innovative techniques to optimize the testing/verification of formation tester/pressure-while-drilling tools.

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Fig. 1 Schematic of tool Testing

The M/LWD tool is placed in a high-temperature oven to perform testing/verification against the calibrated high-pressure generating device (HPC), with varying temperatures. The HPC generates high pressures of the order of 40,000 psi, with hydraulic oil as a medium by means of sophisticated pumps present in it (Fig. 1).

Every DEM center (Fig. 2) has a minimum of one unit of HPC.The proper upkeep and maintenance of HPC, in turn, has a direct impact on service quality in field operations. The potential to increase the company's productivity and continuous improvement to reduce the operating cost was targeted by reducing the HPC downtime.

II. Problem Description

The full review of the usage and compatibility of the existing model of the HPC unit was carried out to ensure that Halliburton is using the latest and most reliable technology. A detailed comparativemarket study was initiated to identify the different models available in the market to compare the technical specifications and to study the economic feasibility for replacement of the existing HPCs. Noother model of HPC could be identified as a probable replacement with the existing model of HPC.

This triggered the need to determine the exact reasons for downtime withthe existing HPC units.Constant monitoring of each of the HPC units spread across the globe was conducted, and the results where collaborated to identify the mainreasons for HPC downtime (Fig. 3).The reasons were HPC pressure pump reliability, contamination from debris and HPC calibration.

All reasons for HPC downtime were duly studied and analyzed, and proper solutions are proposed. Among the identified reasons of downtime of HPC, the calibration issue demanded lot of analysis to arrive at the apt solution.

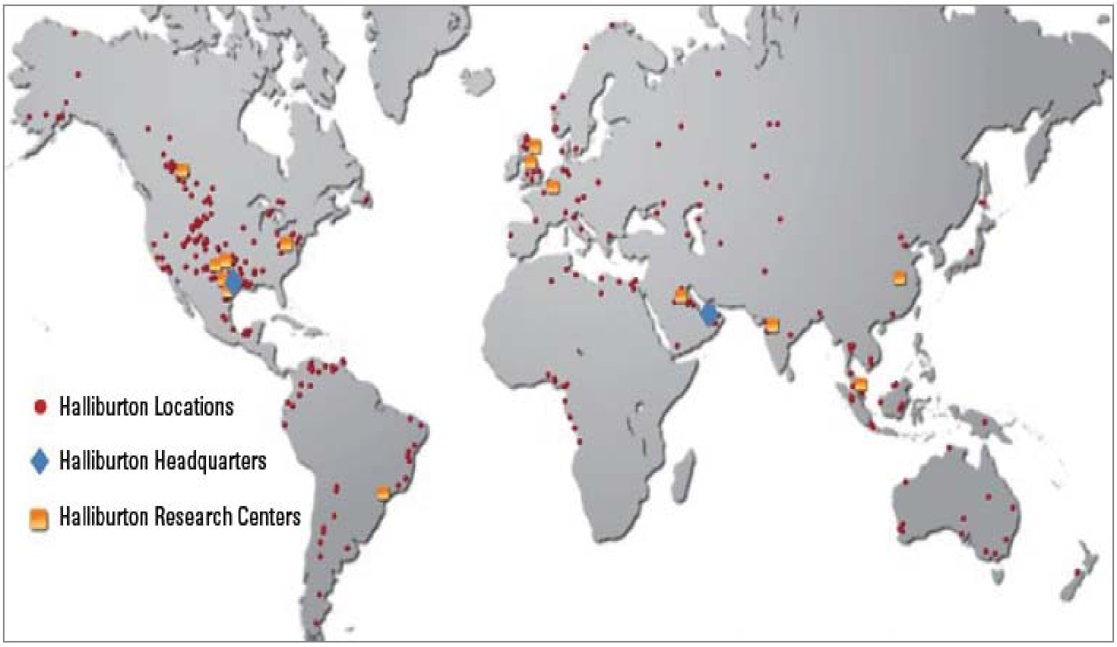

Fig. 2 Global Hallibuton Locations

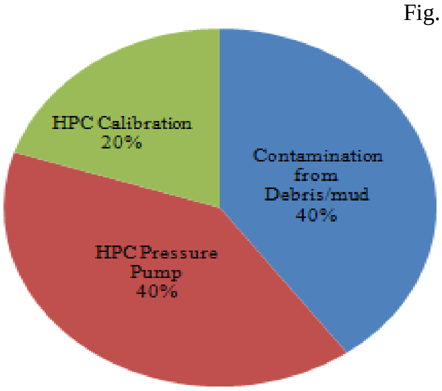

Fig. 3 Reasons of HPC Downtime

III. Solution

A. *HPC Pressure Pump*

The pressure pump comes under the purview of the third-party vendor.Halliburton workedin collaboration with thevendorto introduce back-up rings to the sealing area, thus improving the reliability of the pressure pumps. The resultwill add value to other costumers of the vendor as well.

B. *Contamination from Debris/mud*

The contamination of the hydraulic oil usedin the HPC affects the internal parts of the unit. The source of the contamination (debris/mud) was identified to be the surrounding environment and the dried-up mud inside the pressure sensor tool. This problem is addressed by introducingthe best practicesin the DEM centers across the world.

The need for thorough cleaning of internal parts before verification was re-affirmed. Some oil needs to be drained off/flushed off before verification to remove the contaminants.

A secondary protectionin the form of filter (Fig. 4) is included between the HPC unit and the tool sensor.Ifthe flushing off the tool does notoccur properly, thenthe filter will stop nearly 90% of the debris that was left in the flow line.The filter can be subjected to periodic maintenance, which may include the replacement of the cartridge in the filter.

Fig. 4 Schematic of tool Testing (Improved)

C. *HPC Calibration*

The annual calibration of HPC is a mandatoryrequirement,which is done in strict compliance at a third-party service center (Houston, USA).Currently, when the need for calibration arises, from each DEM, center the HPC unit is shipped to the Halliburton headquarters (HQ)where from it is shipped to Houston (USA) for calibration at the third-party HPC service center. The path followed isdepicted in model I (Fig. 6). The lead time for HPCs to be fully functionalagain at Global DEM locations is around six months (Fig. 5).

There is need to optimize of existing supply-chain network.Thechallenge is in designing an apt network without compromising on the service quality, while simultaneously minimizing the logistical cost incurred[1].

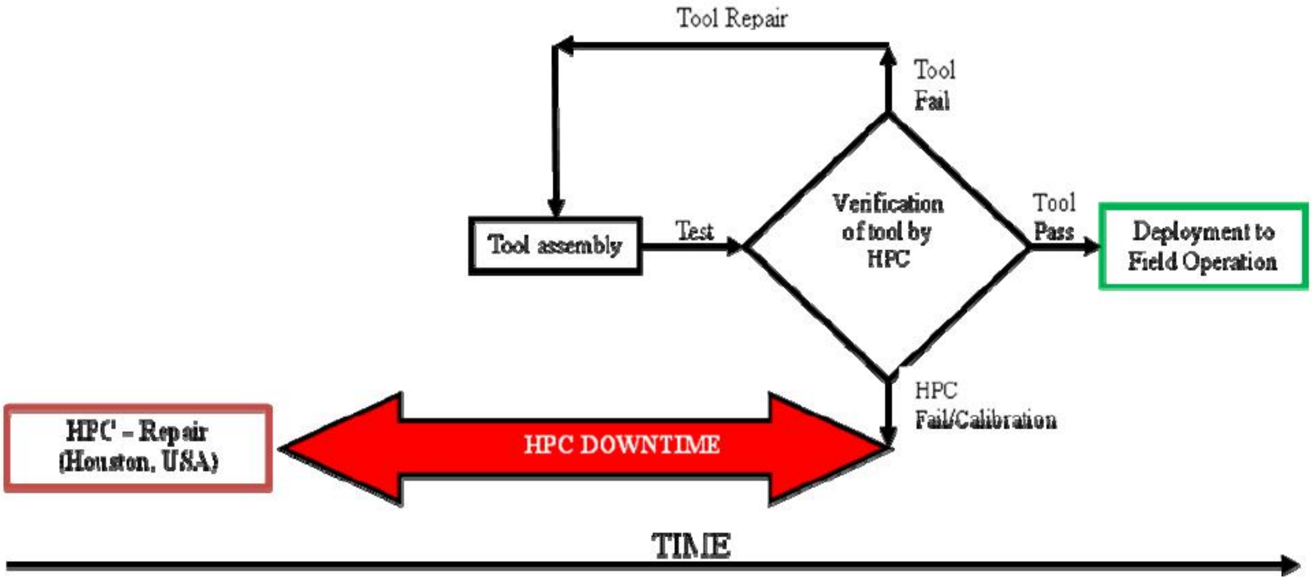

Fig. 5 Time taken for verification/testing of M/LWD Tools

One of the options considered was to purchase the standard calibration equipment at each regional headquarters (RHQ) so that calibration of HPC can be done at the RHQs, thus reducing the logistical cost and lead times drastically. The path followed is depicted in Model II (Fig. 6).It is observed that even though the logistical cost is reduced, there is considerable increase in the initial capital investment and cost for training requirement to the employees,etc. The reduction of logistical costs was also not significantcompared to the next model (Model III).The breakeven point of huge investment in Model II compared to Model III will take longer to achieve[1].

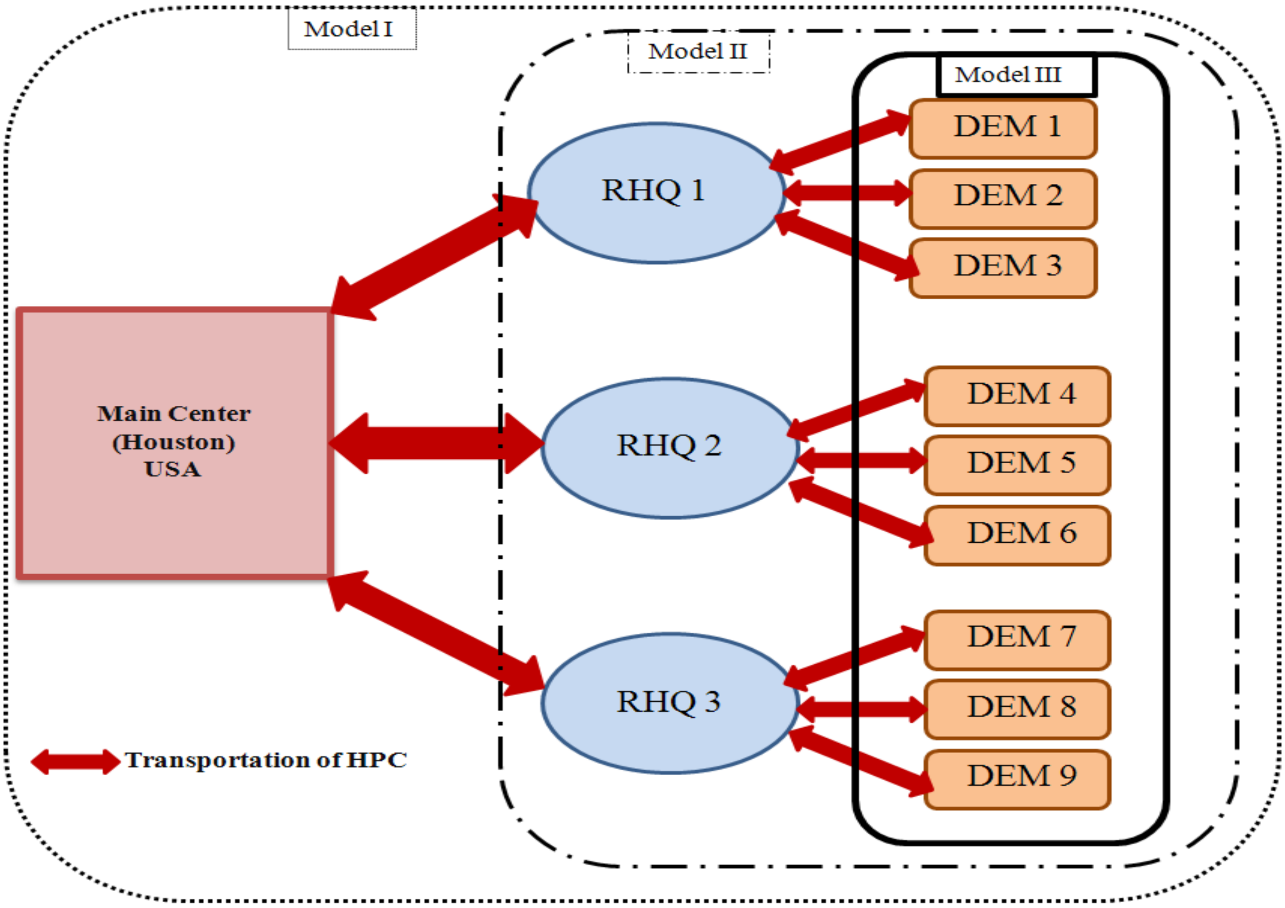

Fig. 6 Supply Chain Models

Model III (Fig. 6) allows the identification of local government certified/approved vendors who can perform the calibration of the HPC units. Here, the interaction with the HQ is not required. This gives more options for DEM locations to choose from the wide array of local government-certified vendors available in the market. This will reduce the lead time and cost involved in calibration.However,keeping the point of service quality in mind, each DEM center willensure that the vendorcomplies with all the regulations. Model III provides better flexibility and improves local control on the lead-time reduction and is best suited without any significant capital investment. The logistical cost is also minimalfor Model III [1].

All three models were evaluated by considering the discounted cash flow analysis [1]. As per the discounted cash flow analysis, the equation for the net present value(*NPV*) is:

$$NPV=C_{0}+\sum_{t=0}^{r} C_t\,(1/1+k)^t \qquad (1)$$

Where, *C* is the stream of cash flow over the next *t* periods, and *k* represents the rate of return. The NPV for different options should be compared when making supply-chain decisions. A negative NPV for an option indicated that the option will lose money for the supply chain. The decision with the highest NPV provides a supply chain with the highest financial returns [1].

In all three models in the analysis, it is cash outflow instead of cash inflow. Thus, the value of *C* will be negative over the years.

When comparing the logistics involved for the different models (Fig. 6)using (1),it is evident that Model III has the highest value for NPV (lowest expenditure over the years).

$$NPV_{III}>NPV_{II}>NPV_{I} \text{ (Logistical expenditure)}$$

When comparing the capital expenditure (CE) involved in the different models, it is evident that Model III has the least value.

$$CE_{III}<CE_{I}<CE_{II}$$

In both the considerations, Model III has the highestnet present value.

The lead time (LT) for Model III proves to be the least (Fig. 6).

$$LT_{III}<LT_{II}< LT_{I}$$

From the above study of discounted cash flow analysis, capital expenditure comparison, and the lead time involved in all three supply chain models, Model III is found to have the least expenditure and lead time. All these results have been assimilated in the below graph (Fig.7).

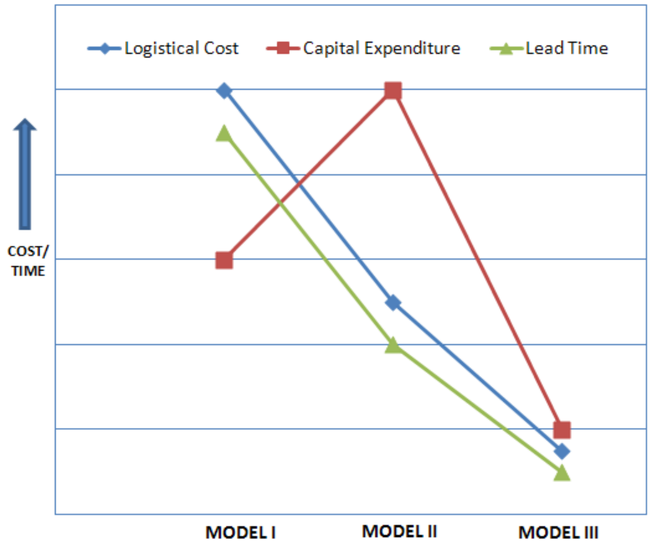

Fig. 7 Comparison of Cost/Time of Supply Chain Models

IV. Conclusion

After the complete market study and analysis,it was concluded that the current HPC model used by Halliburton is best suited for its requirement and, in general, for the whole oilfield industry, in testing/verification of formation-tester/pressure-while-drilling-downhole tools.

To use the existing HPC model effectively, the downtime issues were identified and addressed by suggesting design improvements in the HPC to the third-party vendor and the introduction of best practices for the upkeep of HPC. The process examined all issues to drive greater efficiencies.

The downtime owing to calibration was analyzed, and an optimum supply-chain model (Model III) was proposed after comparing different supply-chain models. This whole process resulted in reduced operating costs andimproved internal efficiencies by faster turnaround of tools and increase in tool utilization. The process contributes to Halliburton's mission of continuous improvement and upholds the philosophy of on time delivery to customers.

The same supply chain model and analysis can be used for similar situations involving the usage of specialized equipment in the industry.

References

[1] Sunil Chopra,Peter Meindl, Dharam Vir Kalra *Supply Chain management, Strategy, Planning and Operation*,Presntince Hall,2008.ch 4,ch 6.