

Utilization of Big Data Analytics for Effective Refinery Operations

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ABSTRACT

Refinery Equipment and process units are increasingly instrumented with sensors and the desire of equipment operators for real time monitoring is fuelling an explosion in data, and much of these data relates directly to equipment performance and reliability. Therefore, since refineries generate a wealth of data on equipment, maintenance frequency, unit performance, process parameters, costs and even more, it becomes pertinent to properly harness this huge chunk of Big Data in ensuring optimum productivity since refinery operations are now swimming in data units with a shift in product mix to swiftly integrate petrochemicals. In this light, traditional data analytics tools such as spreadsheets are general purpose and not specifically designed for extracting valuable time-series refining data which may include inefficiency signatures, process problems and potential equipment failure. This paper therefore critically looks at improved ways of effectively utilizing Big Data from refining operations relative to Refinery inefficiency sources including waste heat, steam systems and furnaces, delayed coker, reformers and distillation units which produce huge volumes of data that are stored in disengaged information systems and utilizing them in building data models that would aid reliability of operations. To achieve this goal, this paper adopts a research Methodology that introduces an approach that reduces the mitigating factors in visualizing refining time-series data, which is achieved by reducing the sensitivity of the variables thereby reducing and addressing energy inefficiency locations that would have taken longer durations to identify. This further promotes quicker decision-making timeline that favours the volatile crude oil markets thereby creating an opportunity for refiners and process engineers to improve their profit margins considerably. This novel approach introduced and developed reveals that advanced analytics on Big Data by refiners could enable them extract actionable insights from data. Then, quickly analyze and compare these process parameters such as flow data, column temperature, boiling point curves, inlet and output temperatures and pressure drop trajectories which is further reconciled over the model for analysis through a visual overview of the process through time. Consequently, developing a pattern-based anomaly detection technique to determine the actual state of process equipments and possible emergence of process problems with real-time trends giving signatures for possible track deflection and leaving solid digital footprints of production data using cloud technology.

Keywords: Data Analytics, Refining, Process Equipments, Process Parameters.

INTRODUCTION

Big Data Analytics has indeed been a growing trend generally and has now been hugely instrumental in oil and gas operations; ranging from the downstream, midstream and the upstream sectors, with each of these sectors having a unique usage package. However, Big Data Analytics is a fairly new domain that has even a more increasing value in the oil industry due to its applications in vital areas of this industry and more precisely refining operations. In the light of the above, Petroleum refining is an integral part of the down stream sector of the oil industry and refining involves the process of separation of

the different fractions/products in crude oil by standard operating temperature and pressure from the distillation column at various product specifications emanating from different tray levels.

However, Big data transformation is also improving the energy and chemical products that sustain daily life around the world. Specific Refineries in Africa specifically Nigeria (PHRC, KDRC, WRPC) are indeed not fully working at optimal levels due to several issues that ranges from equipment failure, poor maintenance culture and quite a number of disruptive process operation issues. However, these operational deficiencies can directly affect and impair the direct overall output of refinery products, and therefore leading to a reduction in the total refinery capacity and consequently not meeting up with the customer demands.

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In the light of the above, amongst several refineries in Africa and Nigeria specifically, the Port Harcourt Refining Company Limited was born with the construction and commissioning of 35,000 barrels per stream day (bpsd) hydro-skimming refining in 1965 by a consortium of British Petroleum and Shell. It was then known as BP/Shell Petroleum Refining Company of Nigeria Limited. In 1972, the Refinery was expanded to 60,000 BPSD capacity and renamed the Nigerian petroleum Refining Company Limited (NPRC) after acquisition of 50% shares of the company by the Federal and regional government of Nigeria. The ability to maintain the prescribed Barrel per stream day was based on proper operational procedures of the refinery. In this regards it is noteworthy that a flow of data swirls around refinery operations hence creating huge chunks of relevant Big Data that could be effectively utilized in understanding the functionalities of refining operations while also enabling the process engineers to make better decisions.

AIM AND OBJECTIVES

The aim of this paper is to utilize a new software algorithm orchestrated through quality programming that can be used in the efficient analysis of big data obtained from the work-flow of operations in refining process.

However, the objective of this research paper is to; utilize data and clean these data to ensure that the required output is sustainable over time, and consequently as a follow up technique, run these data on the model through the algorithm developed to ensure that the feed back mechanism yields accuracy through the model and then gives enhanced instructions on the next line of action that would enhance optimum productivity.

LITERATURE REVIEW

BIG DATA ANALYTICS

Overall, it is evident that the exploration and production industry can find solutions to its aching productivity issues by embracing the effective use of Big Data. The petroleum industry is no stranger to large volumes of data. Operating in arguably the original sensor-based industry, oil and gas companies have for decades used tens of thousands of data-collecting sensors installed in refining facilities to provide continuous, real-time monitoring of refining operations. These companies closely monitor the performance of their operational assets. They also conduct advanced physics-based modeling and simulation to support operational and business analytics and optimization. Today, organizations are capturing a greater volume and variety of data, at a faster velocity, than ever before. In addition to sensor data, this big data includes large volumes of semi-structured and unstructured data—ranging from high-frequency production

measurements, which quickly add terabytes of new data (Chan, 2013).

The E&P industry, which incorporates upstream, midstream and downstream processes, is recognised as one of the first sectors to identify and understand the countless possibilities which Big Data could bring to the private sector (Cowles, 2015).

While the concept of Big Data is relatively new to certain industries, it is not new to the petroleum & petrochemical industry, as Big Data's inherent ability to uncover invisible trends and patterns has long been exploited by this industry (Dyson, 2016). However, even though P&P companies are investing increasingly in information technology and analytics, Martin, (2015) as noted in Dyson (2016), in comparison to the P&P industry's interest in innovation-orientated sectors like the tech sector, the interest shown for maximising the opportunities put forward by Big Data has been slow moving.

After all, Big Data is the oil of the new economy and the P&P industry is one where small improvements in efficiency and productivity can result in significant economic gains (Cowles, 2015).

Oil & Gas upstream sector is a complex, data-driven business with data volumes growing exponentially (Fleblowitz, 2012). Upstream organizations work simultaneously with both structured and unstructured data. They must capture and manage more data than ever and are struggling to store, analyze and get useful information from these huge volumes of data. Under these conditions, the traditional analysis tools would fail but with the appropriate infrastructure and tools, Oil & Gas companies can get measurable value from these data and this is part of the aim of writing this paper on the "Utilization of Big Data Analytics for Effective Refinery Operations".

Therefore, With the introduction of the right technology solutions, refining compaies can move beyond traditional real-time monitoring to more agile real-time prediction. By rapidly analyzing incoming refining and process data - and applying that information to refinery models in real time—that can generate tactical insights that help increase refinery operations, product output and production performance while preventing problems from uprising. By quickly searching and analyzing a large volume and variety of data, refineries can substantially improve strategic decision making that can improve processes. To capitalize on these opportunities, many oil and gas companies are dopting new IT solutions designed to address the specific challenges of big data. They need solutions that can analyze a wide variety of data types—including numerical data streaming from plant sensors and unstructured data from pumps, distillation

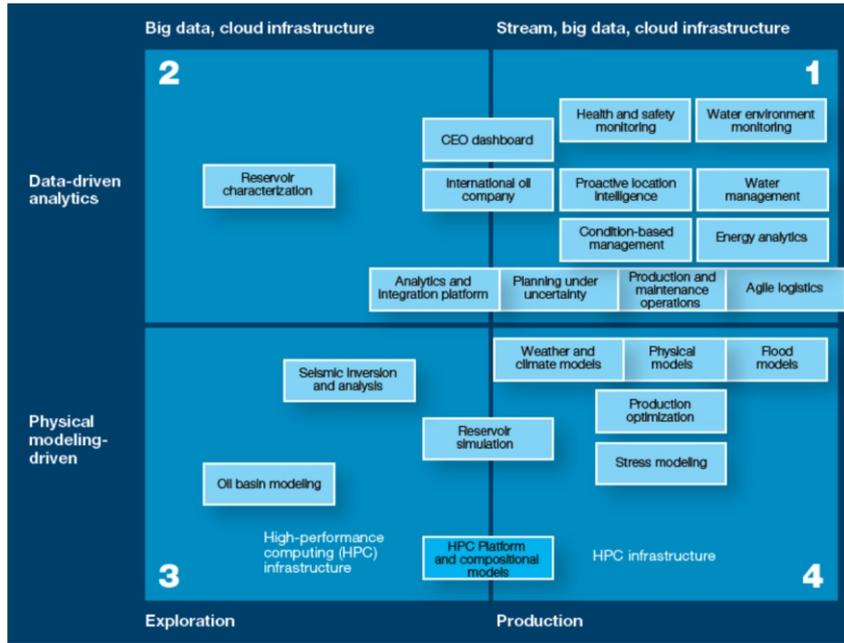


Figure 1: Data Driven and Physical Modelling Analytics.

columns, and other sources. They must enable searches of big data repositories to help companies quickly identify and visualize information among vast quantities of structured and unstructured data, and deliver results to support time-sensitive processes. Currently, most companies fail to exploit the true potential of Big Data owing to a lack of collaboration, limited access to industry leading Big Data-related computer programs and software processing tools, lack of data integration and lack of human capital with the knowledge and skills to apply Big Data techniques (Dyson, 2016).

The effective exploitation of Big Data can undoubtedly help P&P companies gain new insights, enhance business value, improve bottom lines and attain a true competitive advantage (Feblowitz, 2012). Moreover, given that the

P&P industry is prone to high-risk, Big Data analytics can help the industry to automate high-cost, dangerous or error-prone tasks, which will result in improved safety via minimised risks to human lives (Martinotti, Nolten, and Steinsbø, 2014).

In fact, Chevron estimates indicate that a fully optimised digital oil field can result in 8 per cent higher production rates and 6 per cent higher overall recovery rates. (Ahmar, 2016).

However, recent reports indicate that the O&G industry is lagging in terms of its adoption of Big Data kivi (2017) with low oil prices deterring O&G companies from investing in data scientists who can help the industry make the most out of Big Data. In contrast, some authors argue that plummeting oil prices are indeed creating a stronger

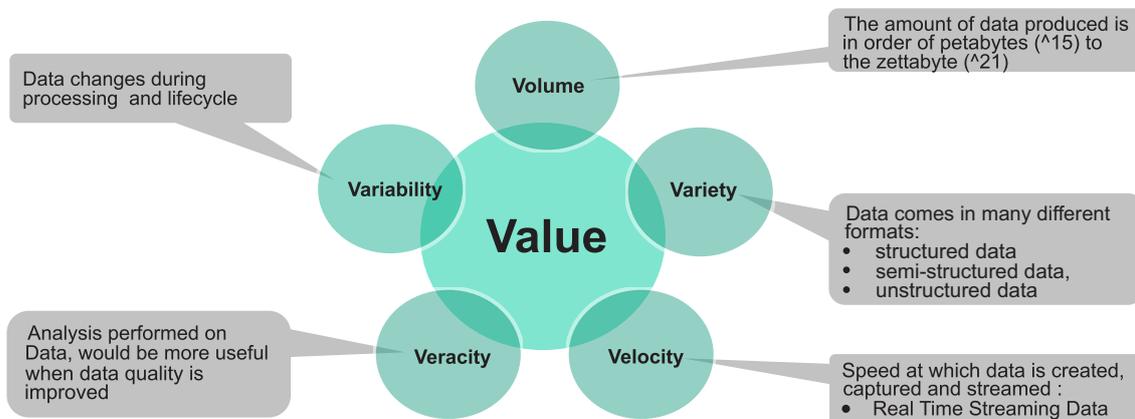


Figure 2: The Value Metrics of Data Analysis (Jacques, 2016).

demand for numerous Big Data-led innovations and investments which can deliver increased levels of operational efficiency and automation (Boman et al., 2015).

Data existing in different formats, associated with different refinery equipment, can now be freely shared and analyzed without an expensive transformation to a relational database.

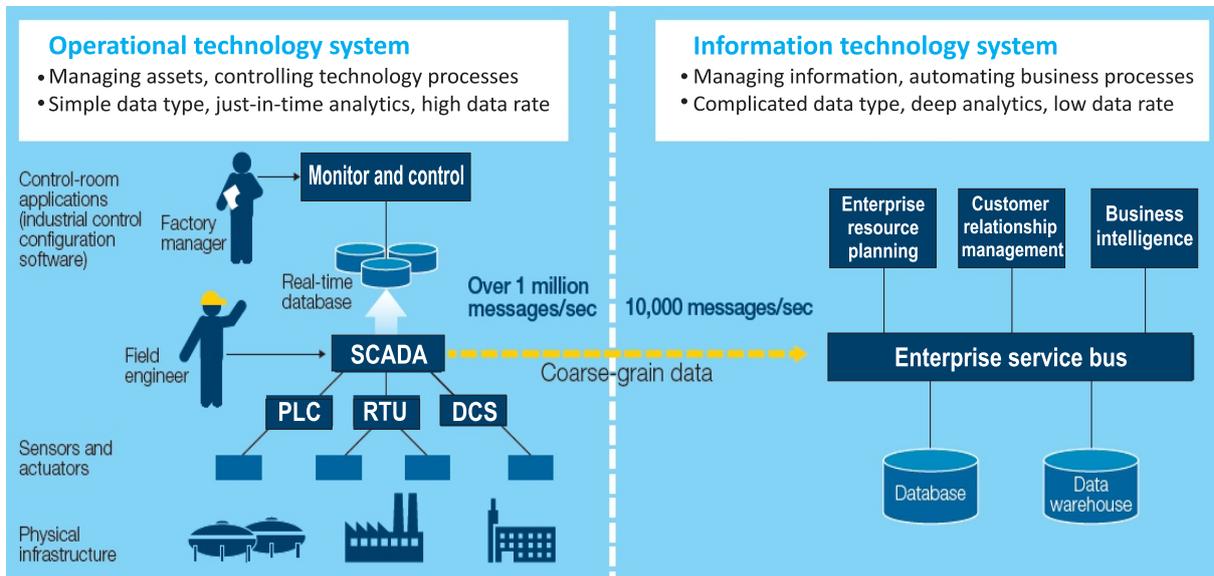


Figure 3: The Operational Technology System and The Information Technology System.

METHODOLOGY

BUILDING THE BIG DATA ANALYTICS ALGORITHM FOR REFINERY OPERATIONS

The big data platform provides a broad portfolio of solutions and capabilities designed to help the refining industry capitalize on the potential of big data to optimize operations, improve business performance and facilitate effective, strategic decision making. This platform-based approach allows refineries to adopt this fit-for-purpose solution that address specific challenges or goals and then easily add capabilities in the future.

In the industry, only a small fraction of data exists in relational format. The majority of data is in tagged, flat-file format or organized according to specific standards. Because there is such detailed characterization of equipment, there is no easy way to convert this data into a relational format. Building the algorithm through C-sharp based on a simple network will indeed help process industries and refineries to appropriately collect, process, analyze and manage this large volume and variety of data. Hence as further entailed in this paper, big insights can be obtained for effective refining and therefore, the refineries can ingest and analyze not only these structured data from relational databases but also complex, unstructured data that those relational databases cannot accommodate. The software utilized analyzes all of this data in its native format, without imposing a structure.

ALGORITHM ARCHITECTURE APPLICATION IN REFINERY PRODUCTION SYSTEM

Big Data is of great interest to production and refinery operation work. Being able to predict future performance based on historical refining production results, can be used to shift assets an equipment to more productive areas in a running refinery that constitutues of Area 1-5. Refining rates can be improved across board, as well, by integrating production data to provide self-service intelligence to process engineers.

(I) REFINING PERFORMANCE FORECASTING: The Algorithm through C-sharp (#) would be interfaced for Forecasting production performance and therefore when there the expectation does not meet a predetermined production threshold flags are raised for immediate remediation procededures.

(II) REAL-TIME PRODUCTION OPTIMIZATION: The real time Algorithm architecture and process control systems combined with analytics tools will help the process engineer to optimize resource allocation and prices by using scalable compute technologies to determine optimum product pricing. They also, help to make more real time decisions with limited engineers on the field.

(III) REFINERY EQUIPMENT MAINTENANCE: Predictive maintenance is not a new concept for the oil and gas industry if you ask a refinery maintenance executive. In the various streams of the oil industry, if pressure, volume, and temperature can be

collected and analyzed together and compared with the past history of equipment failure, advanced analytics can be applied to predict potential failures from the new algorithm developed. Additionally, many operations are in remote locations, so being able to plan maintenance on critical assets is important, especially if work requires purchase of specialized equipment. Technicians often use

incorporated in the software developed to avoid associated downtime. In line with this, for efficient refinery operations a cross-section for data analysis of facility equipments in refineries would enable data utilization prior to storage. As a result, the model can be refined to suit prevailing issues and consequently the veracity of data and make quick decisions.



Figure 4: Pneumatic Crude Control Valve.



Figure 5: An Actuated Crude Refining Valve.

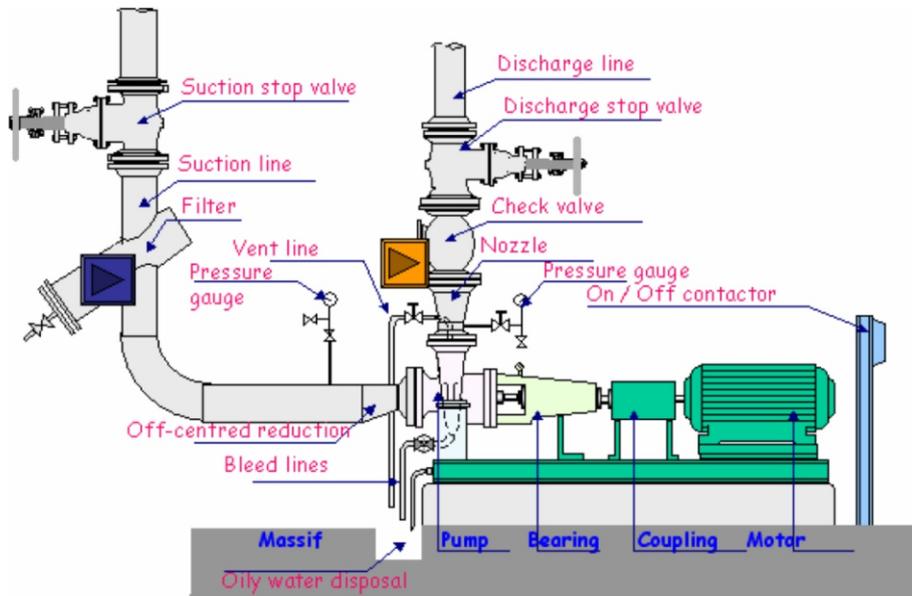


Figure 6: A Refinery Centrifugal Pump That Generates Qualitative Big Data Per Time.

data collected from pumps and wells to adjust repair schedules and prevent or anticipate failure. Better predictive maintenance also becomes possible to ensure smooth running of refinery operations.

(IV) ALGORITHM ARCHITECHTURE PREVENTS INCESSANT DOWN TIME: A vivid Understanding of how maintenance intervals are affected by variables such as pressure, temperature, volume, shock, and vibration so as to prevent failure are fully

OPTIMIZING DATA WAREHOUSING WORK-LOAD

The software utilized entailed an integrated data warehouse appliance that enables refineries to conduct deep, complex analytics on large-scale data volumes, from the production data collected from the plant. With an innovation in the architecture through a robust C-sharp programming (#), the System for Analytics supports rapid analysis of hundreds of terabytes of relational

information, enabling exploration of more variables in production data, by finding more patterns in operational data and delivering results faster than before.

IMPROVED OPERATIONAL ANALYTICS FOR DATA VERIFICATION

Big data presents important opportunities for enhancing the efficiency, safety, productivity and cost-effectiveness

of oil and gas operations. Yet it comes with an array of operational technology challenges that often impede the use of big data for operational gains. One which is the challenge of cleansing and verifying data generated by sensors on equipment, as erroneous data can lead to poor conclusions during surveillance and impair decisions based on models which would be dynamic.

Through the utilization of c# programming in the course

Table 1: Operating Conditions For The Crude Charge Heater.

PROCESS OPERATING PARAMETERS	Operating Variables	STANDARD OPERATING CONDITIONS
Total Flow rate	894.3m ³ /hr	894.3m ³ /hr
Inlet temperature	226 ^o C	(223-226) ^o C
Outlet Temperature	353 ^o C	(352-355) ^o C
Inlet pressure	16.5kg/cm ² g	(16.3-16.7) kg/cm ² g

Table 2: Crude Distillation Unit Desalter Process Variables.

PROCESS OPERATING PARAMETERS	OPERATING VARIABLES	STANDARD OPERATING CONDITIONS(SOC) BENCH MARK
Inlet Temperature to Distillation Unit	25 ^o C	(24-29) ^o C
Desalter Mixing Valve Pressure drop	1.80kg/cm ² g	1.80kg/cm ² g
Desalter Inlet Temperature	137 ^o C	(134-139) ^o C
Desalter Pressure	16.0kg/cm ² g	16.0kg/cm ² g
Desalter Outlet Temperature	129 ^o C	(128-130) ^o C
Desalter Injection Water Flow Rate	49.6kl/hr	49.6kl/hr
Inlet Temperature to Preflash Drum	202 ^o C	(200-210) ^o C

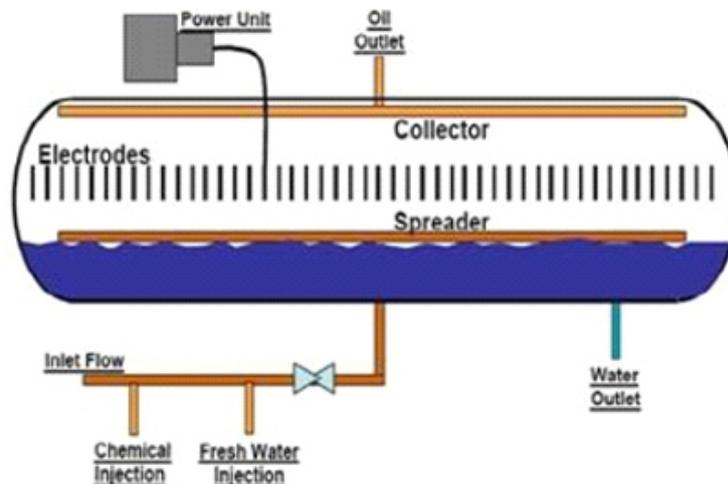


Figure 7.0:A Schematic of a Crude Desalter.

Table 3: Sample Products and Flowrate.

PRODUCTS	FLOWRATE(Kl/hr)	Lv %
Total Flow rate	993.7	100
Whole Naphtha	300.1	30.2
Kerosene	140.1	14.1
LDO	233.5	23.5
HDO	43.7	4.4
ATM. RESIDUE	276.3	27.8

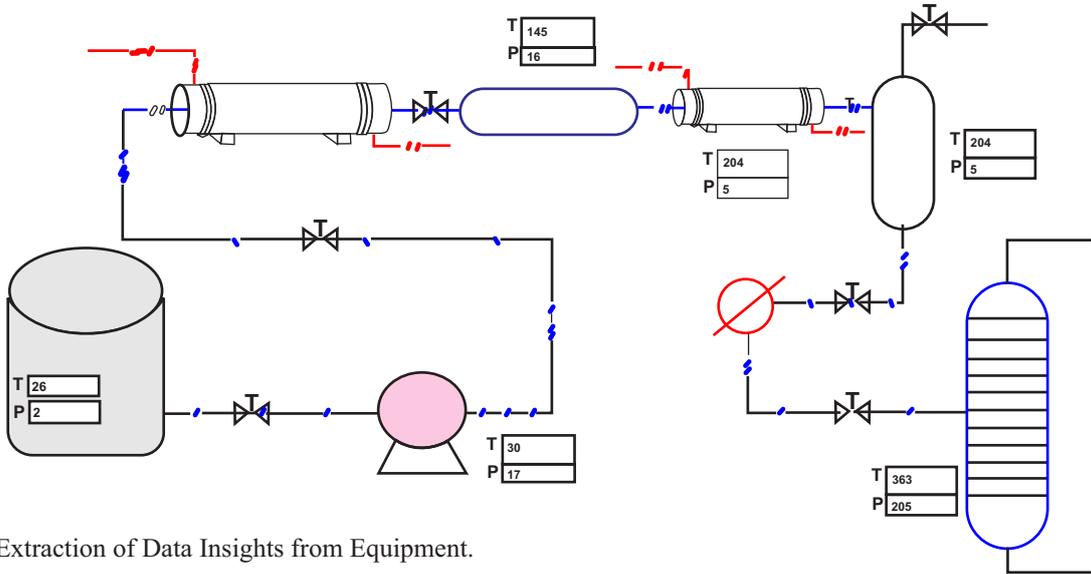


Figure 8: Extraction of Data Insights from Equipment.



Figure 9: Digital Data Representation of operating conditions.

of the work, we were able to develop a schematic algorithm to enable the extraction of data insights from the various refinery equipment and hence develop a data representation mechanism for the various production phases. However, using the desalter as a prime template, key operational standard conditions were appropriately keyed in while programming to also help generate consequent operational conditions for several other equipment knowing that process operations work sequentially.

CONCLUSION

The widespread availability of inexpensive sensors has driven unforeseen possibilities in the Industrial sector. And with the incorporation of programming with specific languages, modern assets are now data enabled and can easily relate with oil and gas operators. The popularity of the application of data analytics has also engaged solid oil and gas business outcomes. This fully gives oil and gas companies, much like any other industry sector, the potential to perform greater analytic analysis and obtain business insights from such data.

A clear example of this new opportunity lies in remote daily oil and gas operations both upstream and downstream. Many remote operations centers now have rich operation capabilities that extend well beyond mere monitoring to include broad remote management and onsite reporting capabilities. This in turn allows for much more timely reaction to problems and opportunities, and enables a more proactive management approach to assets. To add to this, greater automation of asset performance can be achieved as these assets become smarter and control logic is pushed closer to the asset. New sensors and technologies, such as video analytics and streaming data analytics, are enabling an increased number of assets in the refining industry to demonstrate the capability of executing discrete autonomous decisions.

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