Companies providing services in the oilfields do not possess suitable equipment maintenance programs, and are not qualified enough to tackle equipment maintenance. Usually, equipment returning from work sites is just washed and painted, and is then ready to take subsequent assignments. Thus, only lip service or facelift service is provided to the equipment as neither specialized inspection nor performance evaluation of its mechanized components are made. Also, no minute observations of their myriads of parts are done. This approach of service providers just show that they want simply to shy away from the real problems developing with the constant use of equipment, and lack of their maintenance in the real sense. The approach enhances equipment availability, but diminishes equipment durability and reliability. As per records held internally, a contemporary oil service company incurred huge revenue loss to the tune of $300000 during a period of seven months only due to the mal-functioning and non-performance of the equipment. This paper dwelled at length on the characteristics of Total Quality Management (TQM), its approaches and scope. It also stresses TQM based maintenance program that encompasses structured communication channel and employee empowerment to redress the malady of equipment maintenance in the forms of downtime and equipment failures. The paper suggested the use of various TQM tools in order to resolve the issues of equipment maintenance are coming across management levels.

**Keywords:** Total Quality Management (TQM), Petroleum industry, Equipment maintenance and management

**INTRODUCTION**

The petroleum industry which is often referred as oil and gas industry and is used to perform exploration activities, extraction, refining, transporting, and marketing petroleum products that include fuel oil and gasoline or petrol. Petroleum is of utmost importance to the whole of the world for the industrial civilization maintenance in its present configuration. For Asia and Europe, 32% of their energy consumption
comes from oil, and that figure for Middle East is as high as 53%. Oil accounts for the energy consumption to the level of 44% in South and Central America, 41% in Africa, and 40% in North America. More than 30 billion barrels of oil are consumed by the world every year. Thus, the importance of petroleum products cannot be overemphasized. Hence, it is imperative that the industry go on developing and producing to meet the ever growing demand for petroleum products worldwide (Petroleum industry).

**Research Motivation**

The oil and gas sector due to versatility of its very nature of work demands deployment of heavy equipment and devices besides a huge posse of manpower. The drilling, exploration, extraction, and even refining, transporting, and marketing of petroleum products require the use of heavy machineries, equipment, devices and transport vehicles. The processes involve rotating equipment, atmospheric storage tanks aboveground, pressure vessels, piping systems, and many more. The proper designing and maintenance of equipment are essential for uninterrupted and unhindered functioning of the industry all over the world. This equipment is amenable to normal wear and tear in addition to damages and breakdowns that may cause immense loss in terms of money and human sufferings. Thus, proper planning for their maintenance is imperative to get the industry going (Glomacs Training and Consultancy). The oil and gas sector suffers from equipment malfunctioning, equipment under performance, and equipment breakdowns leading to monetary loss of billions of dollars besides credibility dilution. These all happen due to improper and poor equipment maintenance. Hence, this research paper focuses at finding a comprehensive solution to equipment management and upkeep in the oil and gas industry.

**Research Questions**

It is worth mentioning, even at the cost of repetition, that oil and gas industry requires deployment of large equipment during its entire operation right from exploration, extraction, refining, and transportation. The frequent breakdowns and stoppages are the order of the day due to poor maintenance regime of the devices, machineries, and equipment. The very nature of work of the industry requires highest efficiency from men and materials. All types of equipment howsoever sophisticated and well built are subject to wear and tear, and deterioration in built up as well as performance that may lead to occasional stoppages, and if not taken care of properly may cause serious breakdowns (Perrons and Richards).

**Research Aims and Objectives**

As evident from discussions under study motivation, and the particular aim and objective of this paper are to find a viable, all encompassing, and holistic approach to equipment maintenance for uninterrupted operations and consistent development of the industry. This treatise focuses on Total Quality Management (TQM) approach for oil and gas industry equipment management. It is a holistic approach aiming at all round improvement in every department of the organization leading to well equipment maintenance, and gradual development in equipment management. It is pertinent to take note of signs of wear and tear or deterioration visible at the incipient stage. One of the objectives and aims of this paper is to present facts on the basis of analyses that equipment
maintenance on an ongoing process is imperative. One needs to be pro-active rather than reactive to keep the industry running (Perrons and Richards). In addition, this paper dwelled on a case for TQM based program of equipment maintenance that stresses workforce empowerment and communication channel that is well structured to suit an oil and gas service company. The foundation of this program is management approach. It discusses the present system of equipment maintenance and TQM based equipment maintenance program (Hmida, Gaspard and Lee).

RESEARCH PROBLEM
The crux of the research problem is that service companies associated with oil and gas industry are ill-equipped to handle the maintenance issue. Mainly the upstream gas industry can make significant headway in asset maintenance by adopting philosophies and strategies, especially with respect to offshore platforms and remote pipelines, learnt in the space and satellite sector. The risk and failures associated with oil and gas industry are immense, and the technical challenges are complex and demanding technologically as in space and satellite sector. Secondly, in both these sectors, assets are hard to access, and opportunities for servicing are limited. They both have their operations in harsh and not so congenial atmosphere, and have the enormous task of maintaining assets and equipment that are subjected, due to their nature of work, to the wearing out and degradation of components. Lastly, lifecycles of equipment and assets usually extend to decades, and so, these demand long term planning for their maintenance.

Principles of maintenance have their implications for over 15000 oil and gas platforms and pipelines extending to several thousands of miles all around the world. These assets and equipment need inspection and maintenance activities are worth of several million dollars every year for ensuring that these have not been so far considerably affected by a variety of potential complications like corrosion, mechanical vibration, or soil movements on the seabed. However, emphasis till now has been on enhancing production and increasing ultimate recovery (Farid, 2006). Most businesses including oil and gas services require various complex equipments to manufacture products and provide services to customers (Yeh, Kao and Chang). The present maintenance strategies adopted by oil service companies are not in commensurate with the ever increasing magnitude of complex equipment maintenance. Primary causes of failures of equipment performance are improper, ineffective, and dubious quality control procedures, and lack of skilled personnel and planning. Service companies working in oil and gas fields must evaluate the cost involved in proper maintenance and the breakdowns. The rent per day of a rig hovers around $150000 per day in the Gulf of Mexico, and equipment failures entail heavy monetary losses (Hmida, Gaspard and Lee).

RESULTS AND DISCUSSION
Typical equipment maintenance plans encompass fixed time, run-to-failure, condition based preventive maintenance and design out. Run-to-failure refers to activities undertaken on non-critical equipment. This kind of the maintenance plan has been prevalent since long, and is not cost effective due to the unpredictability of machine damage and downtime. Fixed time, also called planned maintenance, is a widely
utilized maintenance plan, and its efficacy is the most if this plan is executed on the equipment showing signs of deterioration at the end of the stated life. Condition Based Maintenance (CBM) refers to power tool utilized to improve downtime reduction and reliability. It is based on the assumption that most of the failures do not happen instantaneously, but take place over a period. CBM measures equipment conditions, and requires human force to use his senses like hearing to sense possible problems. Preventive maintenance refers to periodical inspection and corrections if any required, prior to stoppages and failures. However, evaluation of maintenance cost and penalty cost arising out of equipment failure needs to be done before hand.

Preventive maintenance prevents failure of equipment and enhances life of the equipment. Design out is a process of repeatedly solving occurring equipment failures, and it reduces maintenance issue by redesigning equipment. Design and maintenance engineers work hand in hand to locate and scrutinize root cause of the maintenance problems, and accordingly redesign the equipment (Hmida, Gaspard and Lee).

It is through TQM that these equipments could be well maintained, and industry does not run into trouble. TQM is an all encompassing approach which aims at all round and consistent improvement in every aspect of an enterprise. It brings about radical changes progressively in practices, structures, attitudes, and systems. It goes beyond product quality approach, involves every functionary of the organization, and takes into account every function such as communication, administration, manufacturing, distribution, planning, training, and many more. The US Naval Air Systems coined this term in the early part of 1980s, and the TQM has since then assumed several meanings, and encompassed various facets of the organization. TQM includes direct involvement and commitment of the topmost level executives in setting up goals of quality and policies, and resource allocation and monitoring of results. It also makes those involved to realize that fundamental changes are required for the transformation of the system that may relate to equipment maintenance. It requires initiatives from the very beginning, and adjustment of strategies as per the changing needs of the consumers, stakeholders, and all other external forces. Under TQM environment, supervision is substituted by leadership, and every individual feels motivated to perform his best leading to cost effectiveness in the endeavor. It facilitates the development of team culture, eliminates distances among departments and sections, and promotes self improvement measures as education and training for all concerned (Total Quality Management).

Through the last decade, the improvement in mechanized rig systems has impacted the deployment of new technologies and the adaptation of modern advanced equipment. A number of deep-water drilling rigs have maximized operational efficiency by using equipment remotely controlled in the exploration of oil. The designing of drill pipes is also changed to improve penetration rate. The fast development of newer technologies is compelling service companies to equip existing workforce with the necessary knowledge by imparting training; employ new highly talented and skilled employees, and update management and organizational systems. (Hmida, Gaspard and Lee).
All equipment needs to be designed to have a life cycle within which these are expected to perform, but these require constant maintenance and repair to keep these in top performing mode. The concern is how to maintain proper equipment to get optimum performance from these in oil and gas industry. Principles of maintenance have their implications for over 15000 oil and gas platforms and pipelines extending to several thousands of miles all around the world. These assets and equipment need inspection and maintenance activities are worth of several million dollars every year for ensuring that these have not been so far considerably affected by a variety of potential complications like corrosion, mechanical vibration, or soil movements on the seabed. However, emphasis till now has been on enhancing production and increasing ultimate recovery (Farad, 2006: Perrons and Richards).

The complexity of equipments coupled with their maintenance problems is compelling various agencies to take these equipments on lease instead of buying them. The onus of maintenance lies with the lesser. However, the problem of equipment maintenance is very much there in the arrangement (Change-Yeh, Kao and Chang). As it is not feasible to outsource production streams, but planning and resources preservation are imperative to minimize stoppages and breakdowns. On getting signs of equipment being rusty and underperforming, initiatives have to be taken at once and immediately to forestall stoppages and breakdowns. It is significant how much time it takes to the organization to react regarding maintenance aspect of equipments. The engineers and technicians report the matter to concerned officials who take decisions regarding the maintenance problem of equipment. Those at the helm are usually least concerned with the maintenance problem of equipments already functional and it could be addressed by novel TQM practices (Yeh, Kao and Chang).

The TQM based program of equipment management focuses on condition monitoring and equipment maintenance. Involvement of one and all in the maintenance and upkeep of equipment is the cornerstone of TQM philosophy that aims at maximizing output and profit by achieving customer satisfaction (Barlow). The concepts of TQM are also applicable in equipment maintenance with culture of the organization being its area of concern. It is a dynamic, perpetual, and continuous improvement process that requires all kinds of resources, human, financial, and technological to achieve optimum utilization of man and material. It has no end goal or destination as such, and is a way of life of the organization (Hmida, Gaspard and Lee).

The present organizational structure of maintenance management is termed as functional, and has a management structure which consists of the president, operational managers, engineers, supervisors, and many more. The message emanating from the department is hard to percolate to other sections or high ups, and inordinate delay happens in actual action for maintenance. The supervisors are possessive of equipments and often reluctant to part with them to other departments for maintenance purposes. Whereas TQM based program requires the involvement of one and all, and hence, the chances of delay in communication is minimal. Also, the decision making is made easy by the active association of one and all (Padhi). There is a well defined role for employees of various stages; the tools to be employed, and the organizational structure to be had. Table 1 represents tools in relation to various tasks.
The program of TQM ensures quality of products and services to the level of requirements. It is a holistic approach and encompasses the following as its basic concepts.

1. Everyone is a supplier and customer.
2. Processes and programs are problems, not people.
3. Production quality and services is the responsibility of every employee.

Figure 1 delineates the organizational structure of an organization which has adopted TQM program.

The employees of each stratum are oblivious of their well defined role and responsibilities, and accountable for their actions. Hence, there develops a team culture within the organization, and everyone takes responsibility and claims recognition based on his performance. The dissemination and percolation of knowledge and information are easy and straight. Employees are encouraged to share ideas, and get involved in the process. The Gantt, as well as flow charts for communication and resultant problem redress, should be straight without any barriers (Hmida, Gaspard and Lee).

Table 1: Problem and Task Identification and Relevant TQM Tools

<table>
<thead>
<tr>
<th>Problem</th>
<th>Task</th>
<th>TQM Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disjointed Structure of Management</td>
<td>Implantation chain-command System</td>
<td>Prepare Gantt/or Flow chart</td>
</tr>
<tr>
<td>Unclear Authoritative Limits</td>
<td>Identify Responsibilities</td>
<td>Prepare Table for Responsibility</td>
</tr>
<tr>
<td>Improper communication System</td>
<td>Development of well defined communication System</td>
<td>Gantt/or Flow chart</td>
</tr>
<tr>
<td>Lack of Responsibility by employee to resolve Issue</td>
<td>Restructure EmployeesManagement Team for Empowerment</td>
<td>Develop Quality Assurance Network</td>
</tr>
</tbody>
</table>

Table 2: Distribution of Responsibilities by Effective TQM Environment

<table>
<thead>
<tr>
<th>Structured Positions</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>President</td>
<td>Philosophy to Support TQM</td>
</tr>
<tr>
<td>Operation Manager</td>
<td>Performance Monitoring System for Reorganization and Initiatives of Reward for Achievements and Quality Assurance</td>
</tr>
<tr>
<td>Engineering Manager (EM)</td>
<td>Monitoring for reliability of equipment and effective design systems as well as supply maintenance.</td>
</tr>
<tr>
<td>Quality Assurance Manager (QAM)</td>
<td>Monitoring for TQM implementation, Development of quality procedures and Effective maintenance System.</td>
</tr>
<tr>
<td>Job Supervisor</td>
<td>Monitoring for job evaluation as well as performance of equipment, Provision of customer satisfaction system by feedback mechanism.</td>
</tr>
<tr>
<td>Departmental Manager</td>
<td>Eliminate barriers within the section, Decision making, and Imparting Training programs</td>
</tr>
<tr>
<td>Departmental Supervisor</td>
<td>Promoting teamwork by building teams and keep effective feedback system, decision making, and imparting trainings as well as reward system for employees</td>
</tr>
<tr>
<td>Departmental Worker</td>
<td>Enhance sense of acceptance for responsibility within the team</td>
</tr>
</tbody>
</table>
4. Problem fixing is of no use. Problem must be prevented.
5. Quality is measurable, and so, it must be measured.
6. Improvements in quality should be consistent and continuous.
7. The standard of quality should be defect free.
8. Goals are amenable to requirements, and cannot be negotiated.
9. It being perpetual; life cycle costs matter; not front end costs.
10. The involvement and leadership of management are mandatory.
11. There are planning and vision for quality improvement.

Thus, TQM is not an ongoing process or program, but a life style of an organization or enterprise (Pettersson and Marte).

The results of TQM program implementation is a consistently developing and thriving organization like a well-oiled machine. There exists a close coordination among the different level functionaries of the organization. Everyone is, and feels, involved, takes responsibilities, shares knowledge and ideas, and coordinates and cooperates to achieve the intended goal. Even the highest rung functionary is equally concerned. The TQM environment favors direct and straight communication preventing delay in action.

On the economic front, too, changes are positive and tremendous in terms of profit. With minimization of stoppages and breakdowns due...
to ever evolving equipment maintenance planning, the uninterrupted use of the equipment ensures hefty returns on this front. A rig is leased out on an average rent of $60,000 to $150,000 per day, hence, rejection of the equipment due to under performance or breakdowns may bring huge reduction in earnings. The consistency and continuity of planning give rise to innovative ideas suited for ever evolving changes due to newer technologies developing. Hence, the oil and gas industry can immensely benefit from the adoption of TQM approach. Rodney et al., developed novel strategic models for TQM as presented in Figure 2 TQM sustainability and lifecycle can facilitate in enhancement of dynamic operation and maintenance within the organization. In addition, this model reflects real life problem and solution that can be exercised by the quality manager.

CONCLUSION
This paper is based on the assumptions that oil and gas industry service companies are not adequately equipped with resources to handle the issue of equipment maintenance, and TQM approach is the answer to this problem of equipment maintenance and management. The usual practice of these companies is to provide only a facelift to the equipment when it returns from a job, and make it available for further assignments without inspecting its real conditions in terms of wear and tear. The lack of early diagnosis of the problem aggravates the damage leading to layoffs, and stoppages. These all entail economic loss besides credibility dilution. As per research report, oil and gas company suffered a loss of $300,000 in seven months owing to under performance or non-performance of its equipment (Hmida, Gaspard and Lee).

The petroleum industry, also called oil and gas industry, is engaged in the extraction, exploration, refining, marketing, and transporting fuel oil and gasoline which is the source of energy up to 32% in Asia and Europe, 53% in Middle East, 44% in South and Central America, 41% in Africa, and
40% in North America. The world consumes more than 30 billion barrels of oil every year produced by the world’s oil and gas industry, the importance of which cannot be overemphasized. Hence, it is imperative that its equipment maintenance be of the highest degree so that its equipment is in uninterrupted use.

The research questions of this paper are addressed including how to manage economic, technical, or organizational barriers to achieve high standards of maintenance; how to take into account long term cost of maintenance and serviceability in design decisions; and how to handle impediments for proactive reactions instead of reactive actions in equipment maintenance to cut downtime in oil and gas industry. There are numerous equipment maintenance plans such as fixed time, run-to-failure, condition based preventive maintenance and design out, but TQM is the suggested for equipment maintenance in oil and gas industry. TQM is an all encompassing approach to the maintenance of equipment, and it ensures uninterrupted service from it. It is designed to bring about progressively radical changes in attitudes, structures, practices, and systems. In contrast to traditional methods of equipment maintenance, TQM process consists of a well defined role for various categories of employees, appropriate tools to deployed, and organizational structure conducive to close coordination, communication, and cooperation among employees. It promotes involvement of one and all. Everyone takes responsibility and corners glory on achievement. TQM environment favors direct communication to obviate delay in action and resultant stoppages and breakdowns. It represents an ongoing process which becomes the lifestyle of the organization. The oil and gas industry can benefit immensely with models of TQM approach.

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