TQM-Based Equipment Maintenance in Oilfield Service Industries

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***Abstract*-Equipment maintenance programs in oilfield service companies today are not designed to handle complex oilfield equipment. In many instances, equipment that returns from a job is washed, painted, and reinstated for service without any type of special maintenance, inspection, or performance evaluation for its mechanized components. By short cutting the maintenance requirements, equipment availability increases but equipment reliability decreases. According to internal records, a local oil service company experienced a loss in revenue of $300,000 over a seven-month period directly attributable to issues of non-performance of its equipment. This research suggests that a Total Quality Management (TQM) based equipment maintenance program that focuses on employee empowerment and structured communication channel can reduce equipment failure and downtime. Various TQM tools are suggested to deal with the maintenance issues identified in the management level. Maintenance procedures and work instructions are then evaluated with new procedures proposed in the operational level to implement the TQM concepts.**

Keywords-TQM; Oilfield Service Industry; Equipment Maintenance; Organizational Structure; Work Instructions

I. INTRODUCTION

Over the last ten years, development in mechanized rig systems has influenced the implementation of new technology and the adaptation of advanced equipment. For example, many deep-water drilling rigs are currently maximizing operational efficiency through the use of remotely controlled equipment for oil extraction (Morey, 2009), and new drill pipes are also designed for improving penetration rate (Guodong, 2010). Another technology called Top Drive Casing Alignment (T-CAT) is a system for running any sizes of tubular without producing hazardous stabbing-board operations (Dennis, 2005). The rapid development of new technology is forcing oilfield equipment and service companies to train existing employees, hire new highly skilled employees, and update organizational and management systems.

Typical equipment maintenance plans include run-to-failure, fixed time, condition based, preventive maintenance and design out. Run-to-failure is an action typically carried out on non-critical equipment. This type of maintenance has been used for a long time and its cost is high because of unpredicted downtime and machine damages. Fixed time or planned maintenance is the most widely used form of maintenance and is most effective if carried out as equipment starts to show signs of wear at the end of useful life (MR Group UK, 2011).

Condition based maintenance (CBM) is one of the power tools for improving reliability and downtime reduction. It relies on the fact that a majority of failures do not occur instantaneously but develop over a period of time. CBM requires taking some measurement that gives an indication of equipment condition. This technique also requires the operator who routinely works with the equipment to use human senses, such as hearing, to identify changes and possible problems (Tai, et al., 2009).

Preventive maintenance is the inspection and correction of equipment before failure occurs. The cost of maintenance and the penalty cost due to product failure should be evaluated first (Yeh, 2011). Successful preventive maintenance will not only protect equipment failure but also extend the equipment life.

Design out is a method to solve recurring equipment problems and eliminate the cause of maintenance by redesign the equipment. Maintenance and design engineers work together to investigate the root cause of a problem, then a decision must be made between redesigning the equipment or expecting further maintenance (Shikari and Sadiwala, 2004).

The problem with current maintenance programs in oilfield service companies today is that they are not designed to handle the high volume of complex equipment. Primary reasons for equipment performance failure are the lack of proper maintenance, ineffective or non-existent quality control procedures, and the scarcity of skilled maintenance technicians. Because of the effect on equipment reliability due to insufficient maintenance, service companies must seriously consider the cost of proper equipment maintenance vs. the risk associated with equipment failure.

For instance, when one considers that the average daily rental rate for a rig in the Gulf of Mexico is between $60,000 and $150,000 per day for a dynamic positioned drill ship, it becomes obvious that service companies must develop ways to prevent or, at least minimize, equipment failures that result in downtime. According to internal records, the company in our case study experienced a loss in revenue of $300,000 over a seven-month period directly attributable to issues of non-performance of its equipment.

One solution for equipment failure and poor performance (and the resultant downtime) is the implementation of a Total Quality Management (TQM) based equipment maintenance program that focuses on equipment performance and condition monitoring. TQM is a philosophy that involves everyone in an organization in a continual effort to improve quality and achieve customer satisfaction (Summers, 2010; Sharp, et al., 2002). The concepts of TQM have also been applied in maintenance (Galisanskis, 2004) with a focus on organization's culture (Sahu, et al., 2008; Salum and Qin, 2008). TQM can be defined as holistic management philosophy aimed at continuous improvement in all functions of an organization to deliver goods and services in line with customers' needs or requirements (Demirbag et al., 2006). TQM is a long-term perpetual improvement process requiring significant resources, both financial and human. It is a dynamic process - not a static one. It is a continuous effort with no deadlines or target dates. The process can never be considered complete since there is no goal or destination. Hence, TQM becomes a way of life (Mehra et al., 2001).

Industry trends emphasize the past, present, and future of technology and equipment development in the oil and gas industry. The recognition of these developments are important for businesses to provide quality service and customer satisfaction. The acknowledgement of industry trends enables businesses to evaluate the effectiveness of their current business processes and management approach. The future of equipment in the oil and gas industry will require a higher degree of technology and reliability. Equipment maintenance programs will have to be well defined and supported by a committed management team in order to provide effective equipment performance. Although there are many different approaches to equipment maintenance, it is essential for organizations to realize that none is effective without a quality management system.

The objective of this research is to develop a TQM based equipment maintenance program that focuses on employee empowerment and structured communication channel for a local oilfield service companies. The management philosophy is the foundation of this program. This stage highlights two main tasks to implement the program. First, evaluation of current maintenance management is performed. The strengths and weaknesses of the tactics currently enforced by management are evaluated. The next task focuses on the development of TQM based management structure and communication channel. Several TQM tools are suggested in the new program including 1) quality circles, 2) process flow chart, 3) PDSA cycle, 4) Responsibility Table, and 5) Benchmarking. Once the new communication channel is in place, maintenance procedures and work instructions are evaluated at the operational level with new procedures proposed to implement the TQM concepts.

II. CURRENT MANAGEMENT PHILOSOPHY AND ORGANIZATION

The present maintenance management organizational structure is classified as functional, and consists of a management configuration that includes a President, an Operations Manager, an Engineering Manager, and several Department Managers and Supervisors (See Figure 1). Within a functional organizational structure, units are based on distinct common specialties such as manufacturing, engineering, or finance, and are designed around specific functions performed by each unit (Shtub, *et al.*, 2004).

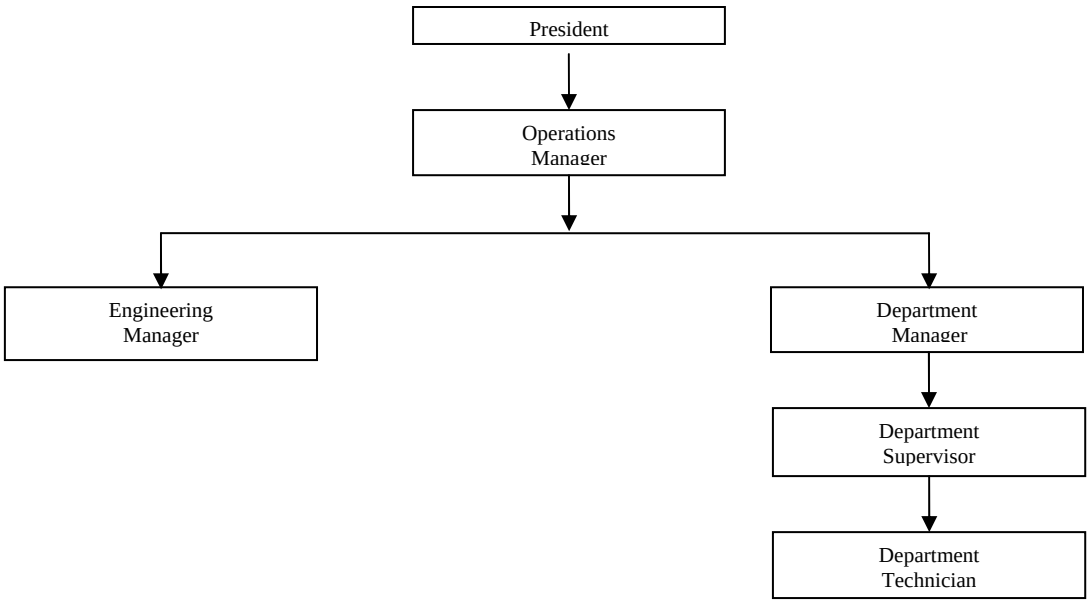

Figure 1 Current Management Organizational Flowchart

Currently the communication of equipment maintenance issues within the organization causes a lot of confusions. For example, maintenance department supervisors receive daily instructions from their respective managers as well as direct orders from the Operations Manager and President. In many cases, maintenance technicians also receive instructions from the Engineering Manager and Operations Manager. Not only the information duplicated, but also the maintenance technicians are often confused and uncertain about the priority of the task to be performed. As shown in Figure 2, current communication

channels allow for inconsistent and unreliable information to circulate throughout the management structure. The sharing of unsubstantiated information creates chaos throughout management because of inconsistencies and misunderstandings. Ultimately, the lack of functional communication channels inhibits the company's overall productivity and efficiency.

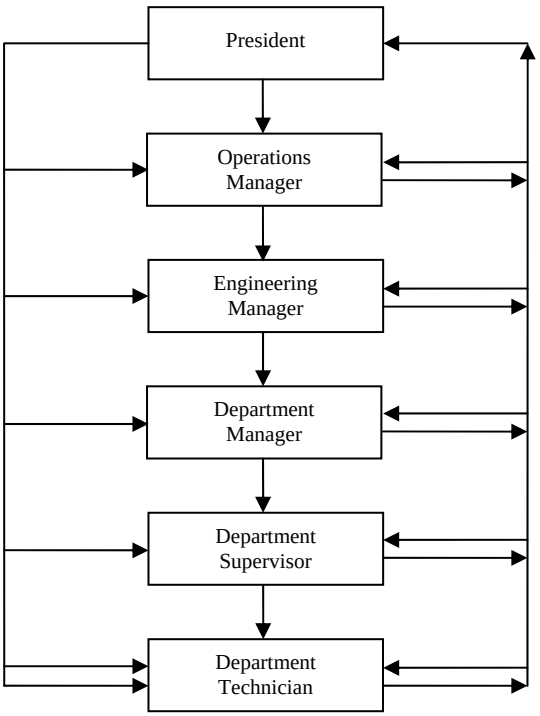

Figure 2 Current Maintenance Communication Flowchart

Because of poor communication, the maintenance activities performed on equipment in various departments sometimes overlap. When equipment fails, the departments and those within the department tend to point fingers as to who is to blame for the failure. When complications with equipment arise in the field or in the shop due to poor maintenance, responsibility goes unclaimed and unacknowledged. Oftentimes, the supervisor informs the department manager that certain department workers are not fulfilling their assigned duties. In turn, managers complain to the Operations Manager and President that there is not a suitable pool of skilled technicians, that the facility size is inadequate, or that the Engineering Department has designed equipment that is too complicated for the average maintenance technician.

The department supervisors are reluctant to submit to other departments certain pieces of equipment in need of repair or modification. Supervisors are possessive of the equipment within their respective departments and rarely cooperate with other departments when specific equipment is requested. The concept of teamwork is unacknowledged throughout the departments. Without a team-approach, departments tend to adopt a defensive attitude that leads to a division among those within the organization. Such attitudes hinder the possibility for management to effectively resolve equipment failures.

In addition to undefined communication channels, there is an unstructured chain of command for establishing goals and decision-making. Department workers, supervisors, and in many cases, even department managers are reluctant to make fundamental assessments and evaluations about equipment. Therefore, the Operations Manager and President make most of the decisions. By directing decision making to a higher level, a pattern develops that reinforces employees' lack of responsibility and empowerment.

In general, the present management approach appears to be in a reactive mode as opposed to a proactive or preventative type mode. The negative issues associated with the current management style include undefined channels of communication, incoherent teamwork philosophies, and an unstructured chain of command for decision-making and establishing goals.

III. TQM BASED MAINTENANCE AT MANAGEMENT LEVEL

The Total Quality Management (TQM) concept will be instituted to address the current management of equipment maintenance issues faced by the service company. Management will adopt the TQM philosophy to support the mission of the organization's equipment maintenance goals. Overall, management's intention will be concentrated on providing products and services that meet or exceed customer expectations and needs, implementing processes that promote doing a job right the first time, developing plans and processes for continuous improvements, and encouraging effective decision making.

Various TQM tools (World Class Manufacturing, 2011) are utilized in this research to develop an effective equipment maintenance program for oilfield equipment and service industry. They include Process Flow Charts (Kemper, et al., 2010),

PDCA Cycle (Sokovic and Pavletic, 2007), Quality Circles (Hutchins, 2008), Benchmarking (Stapenhurst, 2009). Table I summarizes the problems of the current maintenance program, tasks and the suggested TQM tools.

TABLE I TASK AND TQM TOOLS

Problem	Task	TQM Tool
Incoherent Management Structure	Define chain of command	Flowchart
Ambiguous authoritative boundaries	Define responsibilities	Responsibility Table
Unstructured communication channels	Develop communication channel	Flowchart
Employees deny responsibility to solve problems	Empower employees Management team	Quality Circles
Long term performance	Promote Continuous Improvement	PDCA Cycle Bench marking

The TQM philosophy must be an integral part of the new maintenance management concept prior to being introduced throughout the maintenance management organizational structure (See Table II and Figure 3). In general, the President's role is to support the TQM philosophy. The Operations Manager will support the TQM process, oversee quality circles, monitor equipment performance, and recognize and reward employees as deserved. The Quality Assurance Manager will support the TQM philosophy, document procedures and work instructions, monitor documents, make revisions as needed, obtain feedback from quality circles, and measure the effectiveness of the maintenance program. The Engineering Manager will support the TQM process and will encourage engineers to participate in a quality circle, monitor equipment reliability, design maintainable systems, write maintenance instructions, and recognize achievements.

TABLE II RESPONSIBILITY TABLE

Position	Responsibility
President	Support TQM philosophy
Operation Manager	Monitor system performance, recognize and reward achievements, monitor Quality Circles
Engineering Manager	Monitor equipment reliability, encourage participation in Quality Circles, design maintainable systems, supply maintenance instruction
Quality Assurance Manager	Monitor TQM implementation, create quality procedures and work instructions, measure maintenance system performance
Job Supervisor	Monitor job evaluation and equipment performance, provide customer satisfaction feedback to management
Department Manager	Remove barriers within department, make decisions, promote training, recognize and reward employees
Department Supervisor	Build teams and promote teamwork, provide feedback, make decisions, promote training, recognize and reward employees
Department Worker	Work in teams, provide feedback, accept responsibility

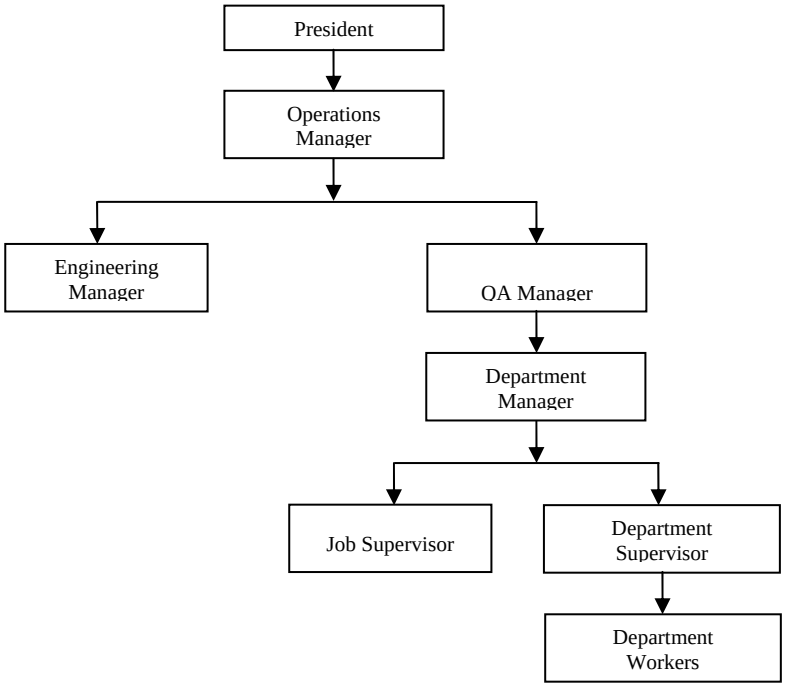

Figure 3 New Maintenance Management Organizational Chart

In the next level, the Job Supervisor is responsible for field activities and returning job evaluation and equipment performance forms to their respective areas within the system. The Job Supervisor provides customer feedback to inform management of customer satisfaction. The Department Manager supports the TQM process, emphasizes coaching, removes barriers among the departments, provides resources, builds trust, provides feedback from quality circles, makes decisions, promotes training of employees, and recognizes and rewards employees for achievements. In addition to supporting the TQM philosophy, the Department Supervisor is responsible for building teams, participating in quality circles, promoting continuous improvement, providing feedback as needed to the department manager, requesting adequate employee training, making decisions, and recognizing achievement. The Department Workers also support the TQM philosophy, participate in quality circles, individually accept responsibility for work performed, and provide feedback to the supervisor regarding equipment performance and condition.

Another tool that will be used by management is a flowchart to clearly define the channels of communication throughout the company. Figure 4 clearly identifies the chain of command, therefore reducing the opportunity for the transmission of unreliable and uncorroborated information throughout management. For example, unless approached by the President, department workers will no longer speak directly to the president regarding equipment maintenance issues. Management will have a defined chain of command that will allow for direct communication between management and individuals who perform maintenance tasks within various departments.

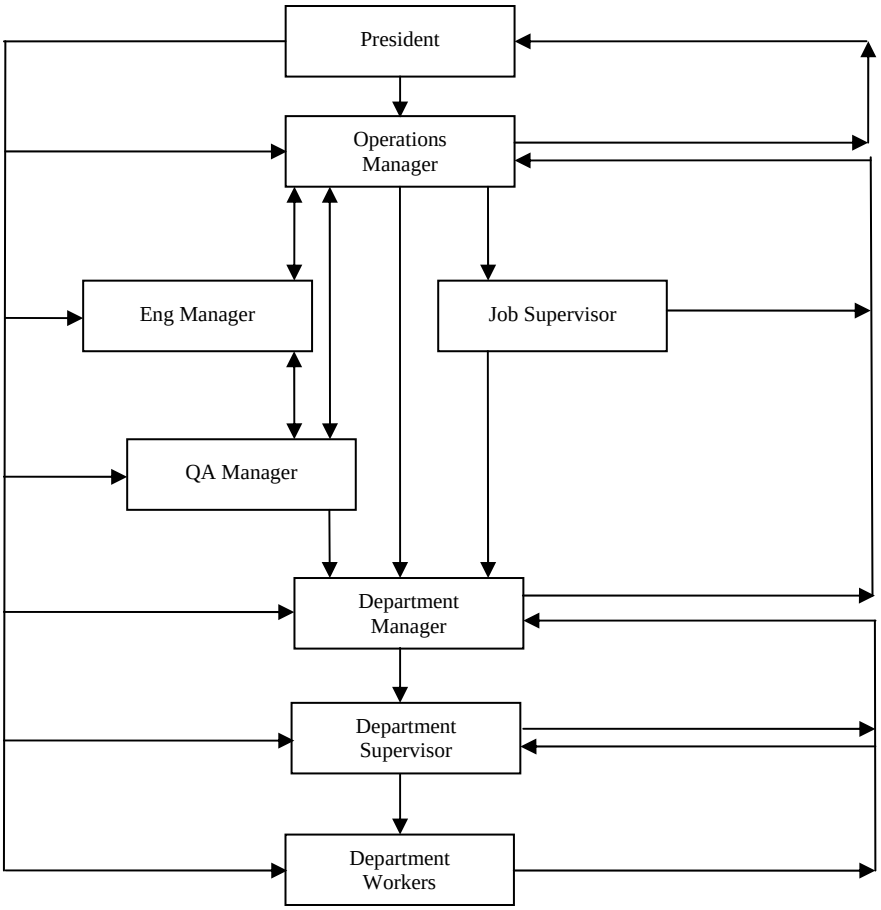

Figure 4 New Maintenance Communication Flowchart

This direct line of communication will allow management to address issues regarding the development of quality procedures in circumstances where time constraints are prevalent. When maintenance technicians observe quality issues that need to be addressed, communication will be directed from the department worker to the immediate supervisor or department manager. If the situation warrants, the department manager has the responsibility to push the issue through the chain of command to reach an ultimate solution. The benefit of structured communication is that relevant problems and issues are addressed within management. In essence, structured communication ensures that all levels of management participate in the maintenance process.

Quality circles will be developed upon a voluntary basis and encourage employees to share ideas where current as well as potential problems can be identified and analyzed and possible solutions can be discussed. Quality circles will establish employee empowerment that will instill a sense of responsibility within maintenance personnel and grant the authority upon maintenance technicians to improve working conditions and solve problems. The flowchart in Figure 5 describes how information derived from a quality circle is submitted to management and implemented for solutions. The flowchart clarifies

the roles of management and quality circle participants. Management will reward quality circle participants by furnishing lunch during circle meetings and recognizing employees who assess potential equipment complications and provide solutions thereto.

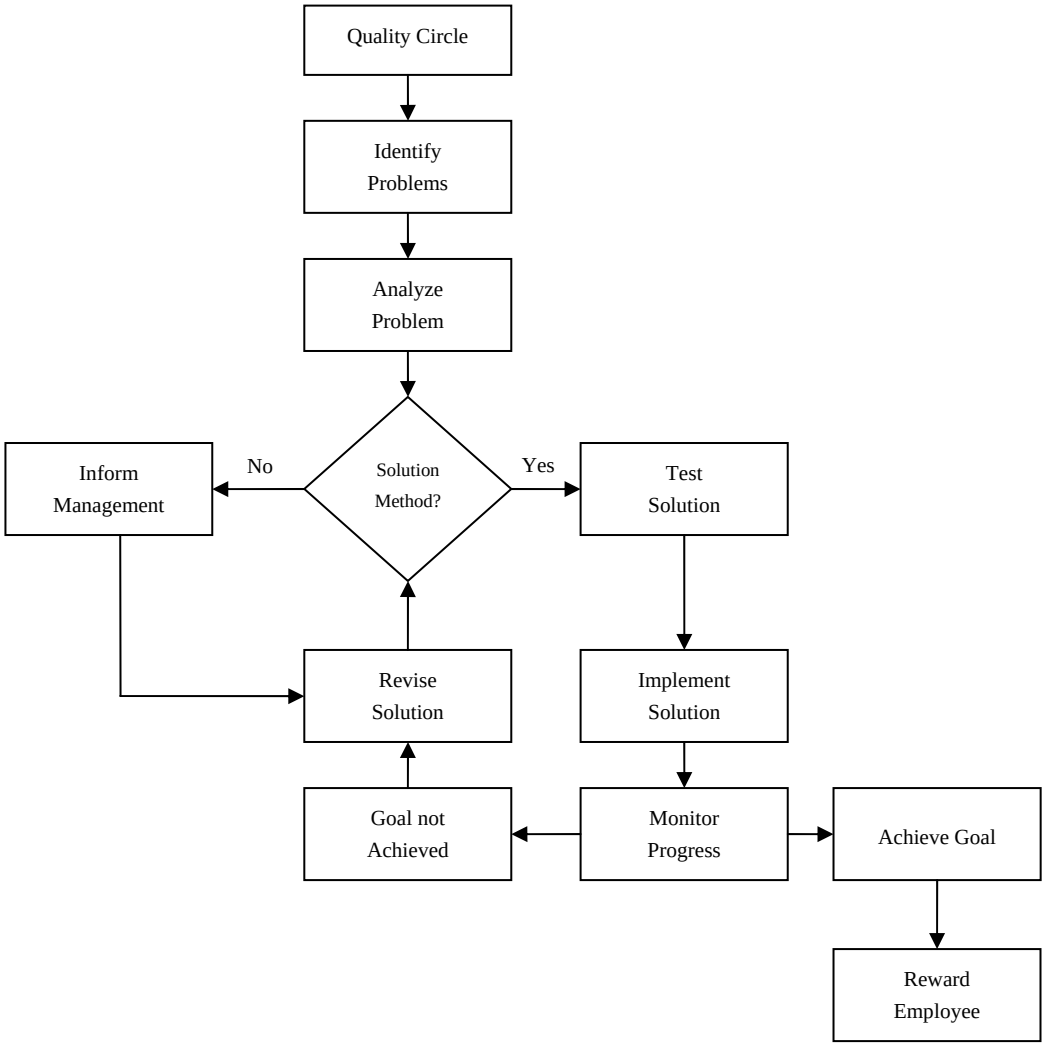

Figure 5 Quality Circle Flowchart

Management will also organize an Operations Management Team to oversee equipment performance issues. The team will consist of managers and supervisors that will meet weekly to discuss operational issues. The operational issues include establishing goals, measuring productivity, monitoring equipment performance and utilizing Deming's PDCA (Plan-Do-Check-Act) for problem solving and improving maintenance.

The PDCA cycle is a tool that will be used to enforce the continuous improvement of equipment, improve operations, and solicit solutions for equipment failures. The PDCA Cycle has four components that include, Plan, Do, Check, and Act. "Plan" initiates problem identification, data collection, analysis, and improvement goals. "Do" represents a trial implementation of a plan. "Check" refers to the evaluation of data to ensure that the plan is fulfilling its expectations and "Act" symbolizes the full adoption of the plan or an adjustment to it.

Benchmarking is another TQM tool that will be a long-term option for management to use to support the equipment maintenance program. Benchmarking is the process of identifying organizations exhibiting exceptional performance and comparing equipment performance among those chosen. Benchmarking allows organizations to learn about and study successful approaches to ensure equipment performance. For each maintenance program component, management will study a company that exhibits superior performance in maintenance or customer satisfaction, make comparisons with the current systems, document the research, and make adjustments to existing procedures accordingly.

Though there are many approaches to quality management, this research focuses on Total Quality Management (TQM). Implementing TQM within a manufacturing environment has proven to be an effective quality management system. Extensive research on TQM has been conducted in manufacturing environments but very little in oil equipment maintenance. This research is unique because it utilizes TQM as a quality management system for oilfield equipment maintenance, to identify industry trends, drive equipment maintenance, and ensure customer satisfaction. TQM tools discussed above will be used to solve equipment problems and ensure equipment performance.

IV. CURRENT MAINTENANCE AT OPERATION LEVEL

At the operation level, the existing equipment maintenance procedures and work instructions were developed to ensure that equipment would receive proper maintenance, thereby increasing equipment reliability in the field. Although the existing procedures and work instructions were written within American Petroleum Institute (API) standards and recommendations, there are several issues that must be addressed. In general, the current procedures and work instructions are primarily focused on equipment integrity and overlook performance that ultimately equates to customer satisfaction. Table III describes and defines the four maintenance procedure categories and Table IV categorizes the problems associated with current maintenance procedures.

TABLE III CURRENT EQUIPMENT MAINTENANCE PROCEDURE CATEGORIES

Scope	Implies setting of requirements; Indicates type of equipment; Specifically names the equipment.
References	Lists internal and external documents used to develop procedures.
Responsibility	Lists positions that are responsible for ensuring inspectors are performing the inspections according to procedure; Positions mentioned are Quality Supervisor and Operations Supervisor.
Requirements	Lists frequency of inspection for Categories I thru IV; General personnel qualifications; Method of handling rejected equipment; Recordation/documentation requirements.

TABLE IV PROBLEMS ASSOCIATED WITH EQUIPMENT MAINTENANCE PROCEDURES

Category	Problem	Task
Scope	Does not recognize reconfiguration/modification of tools	Revise to recognize all equipment
References	Do not include maintenance manuals to address reconfiguration/ modification of tools	Revise to include all maintenance literature
Responsibility	Does not require Engineering Department to update and revise procedures and work instructions affected by equipment reconfiguration.	Revise to include engineering responsibilities For updating procedures and work instructions
Requirements	Uses the ambiguous word “should” in reference to procedures which is misinterpreted by maintenance technicians. Does not incorporate a “flow” of activities for procedure; Inspection Categories I thru IV are mentioned but not defined	Revise to include the term “Shall”
Additional	Lacks categories to effectively address maintenance	Develop new categories

The scope of current maintenance procedures is the first issue to be addressed. The current procedures and work instructions fail to address equipment that has evolved through changes such as mechanization, semi-automation, and remote automation. The company has not modified the maintenance procedures or work instructions to reflect modifications to equipment. Because the guidelines do not acknowledge the modifications, maintenance technicians are uncertain of the techniques necessary to properly maintain equipment.

Another maintenance procedure and work instruction issue to address is the misinterpretation of the term “should” in API standards. The term “should” in API standards implies that the content of each standard can be implemented upon the discretion of the equipment owner or user. Consequently API’s use of the term “should” allows equipment owners to be generic in procedure and work instruction development.

Because the current procedures are unclear about specific measures necessary to properly maintain equipment, additional categories must be incorporated within the program to recognize the actions critical to ensure equipment performance. For example, the requirement category listed in Table V establishes the criteria for the frequency in which to perform a Category II inspection. A Category II inspection must be revised to include real time performance inspections and condition monitoring activities. Real time performance inspection involves simulating job conditions for each type of equipment.

TABLE V API MAINTENANCE INSPECTION CATEGORIES

Category I	Observation of equipment during operations for indications of inadequate performance.
Category II	Category I, plus further inspection for corrosion, deformation, loose or missing components, deterioration, proper lubrication, visible external cracks, and adjustment.
Category III	Category II, plus further inspection, which includes nondestructive examination (NDE) of exposed critical areas and involve some disassembly to access specific components, and identify wear that exceeds manufacture’s allowable tolerances.
Category IV	Category III, plus further inspection where the equipment is disassembled to the extent necessary to conduct NDE of all primary load carrying components as defined by the manufacturer.

Currently, according to casing equipment maintenance procedures, Category I inspections are to be performed by the job supervisor in the field during equipment operation. The results of equipment performance are required to be documented on an equipment performance form. The only time equipment performance is observed for unacceptable performance is during a Category I inspection. If the job supervisor fails to document inadequate real time performance, the maintenance technician is unaware of equipment discrepancies. Consequently, the maintenance technician is oblivious to necessary repair actions prior to the equipment being used on the next job. The current procedures call for a Category II inspection that includes a performance test but the conditions do not simulate real time job performance.

The instruction segment of current work instructions is broad in nature, lacking concise and comprehensible guidance on properly maintaining equipment. Neither the procedures nor the work instructions require specific real time inspections and function testing. A step-by-step maintenance instruction is essential to guarantee equipment performance in the field. Table VI identifies each category and gives a brief description of each and Table VII associates the current problems in the existing equipment work instructions.

TABLE VI CURRENT EQUIPMENT MAINTENANCE WORK INSTRUCTION CATEGORIES

Scope	Establishes instructions and criteria for maintenance; Defines the category level of inspection (i.e. category I, II, III, or IV).
References	List internal support procedures and external documents that support the work instructions.
Responsibilities	Lists positions that are responsible for ensuring that inspections are preformed according to procedure. Positions mentioned are Quality Supervisor and Operations Supervisor.
Instructions	Guide the maintenance technician through each step required to properly maintain the equipment.
Reporting	Leads the maintenance technician to the proper maintenance documents.

TABLE VII PROBLEMS ASSOCIATED WITH CURRENT WORK INSTRUCTIONS

Category	Problem	Task
Scope	Does not exemplify a level of expectation conducting maintenance	Revise to indicate the level of maintenance required.
Reference	Fails to identify manufacturer maintenance manuals and external documents that support the work instruction	Revise to include all literature required to effectively perform maintenance
Responsibility	Fails to recognize all responsible parties associated with inspection	Revise to include responsible parties for updating work instructions
Instructions	General in nature; Fails to recognize reconfigured/ modified equipment	Revise to include all steps required to perform maintenance
Reporting	Fails to identify proper maintenance forms; Does not mention a filing procedure for the forms	Revise to include all maintenance forms required to properly document maintenance.
Additional	Lacks categories to effectively address maintenance	Develop new categories

The current maintenance procedure and work instructions for Category II Inspections are inadequate and must be revised to require pre-job and post-job real time performance. The revisions will include condition monitoring inspections to monitor the equipment's condition and identify specific inspection requirements for mechanized and automated systems. The frequency of the Category III inspection must be increased to a semi-annual basis for all casing handling equipment until experience indicates differently. According to API standard, the frequency of inspection should be established based upon experience. Until enough maintenance records have been generated to validate experience, semi-annual Category III inspections must be performed. Currently, Category IV annual inspections are appropriate to address equipment reliability.

V. TQM-BASED MAINTENANCE AT OPERATION LEVEL

The new equipment maintenance procedures and work instructions focus on the necessity to meet customer requirements by requiring thorough maintenance procedures that ensure reliable equipment performance in the field. The procedures and work instructions must become part of a quality manual. It is important to acknowledge that procedures and work instructions are effective when driven by a quality management system such as TQM. Also, should the need arise for the company to achieve certification, it is imperative to note that the development of the new procedures and work instructions must be in a manner acceptable by International Standards Organization (ISO).

The new equipment maintenance procedures are following ISO 13534 which is the first international standard covering inspection, maintenance, repair, and remanufacture of hoisting equipment for oil industry casing rental tool companies. Unlike API's emphasis on "should", this ISO standard uses the term, "shall", when equipment owners' responsibilities are addressed. The new procedures will contain categories such as revision history, purpose, definition, flowchart, procedure, metrics, quality records, and forms in addition to the categories already established. Table VIII defines the new categories associated with equipment maintenance procedures.

TABLE VIII NEW EQUIPMENT MAINTENANCE PROCEDURES

Scope	Define extent of maintenance activities; Identify all equipment and work instructions affected by procedures
Reference	Identify all documents used to create procedure
Responsibility	Lists all employable positions throughout the company directly associated with maintaining a procedure, associated work instructions, and departments that perform maintenance activities that directly affect the validity of the procedure.
Requirements	Use the term “should” to avoid misunderstanding as to required maintenance procedures.
Revision History	Include date, revision number or letter, description of modification and name of technician who performed the reconfiguration.
Purpose	State intended use of procedure and identifies specific maintenance requirements.
Procedure	Describe all actions necessary for the maintenance program to maintain validity. Indicates frequency of inspection requirements.
Definition	Define and clarify the meaning of every item, action, test, or responsibility that contributes to the effectiveness of the procedure.
Flowchart	Diagram that will show the progress of work activities in a series of operations.
Metrics	Identify and define all associations to the metric system
Quality Records	Define the action/activities requiring documentation to support the procedure
Forms	Identify all documents that support required quality records.

The new work instruction will contain categories that include revision history, purpose, definitions, flowchart, instruction, condition monitoring, metrics, quality records, and forms in addition to those currently established. Table IX illustrates the new categories associated with equipment work instructions.

TABLE IX NEW EQUIPMENT WORK INSTRUCTIONS

Scope	Define extent of maintenance to be conducted; Identify all equipment affected by the work instruction.
Reference	Identify internal and external documents used to create and support work instruction.
Responsibility	Lists all employment positions throughout the company directly associated with maintaining work instruction, performing maintenance, and department activities directly affecting the validity of the work instruction.
Instructions	Describes all steps required to perform maintenance, real time performance evaluations, and function testing.
Reporting	Lists maintenance forms required to properly document necessary maintenance actions
Flowchart	Display the progress of work activities in a series of operations
Purpose	Describes intended use of the maintenance procedure and specifies certain requirements that must be met.
Definitions	Define and clarify the meaning of every item, action, test, or responsibility that contributes to the effectiveness of the work instruction.
Condition Monitoring	Defines tools required to measure the condition of the equipment; Defines upper and lower limits of each condition.
Quality Records	Defines the action or activity requiring documentation to support the work instruction.
Forms	Identifies all the documents that support the required quality records.
Revision History	Identifies the revision date, revision number, description of modification or reconfiguration, and name of maintenance technician.
Metrics	Identify all associations with the Metric System.

Although the equipment maintenance procedures and work instructions have similar categories, it is essential to maintain a two-document approach to maintenance. The primary advantage of having two documents guide maintenance is that the one maintenance procedure can cover many different types of equipment and validate many work instructions. Consequently, there is flexibility to address specific maintenance requirements for equipment equipped for mechanization and automation.

Revision history is another similar feature contained within both equipment maintenance procedures and work instructions. Revision history files will contain documentation on all corrections, improvements, and modifications made to equipment that impact maintenance procedures and work instructions. Revision history documentation will require information such as revision number or letter, description of modification, author of change, and revision date. All revisions to equipment maintenance procedures and work instructions will be forwarded to the respective maintenance departments. Tracking and controlling the revision history of procedures and work instructions will give maintenance technicians the ability to properly maintain equipment.

VI. CONCLUSIONS

TQM implementation is a difficult, comprehensive, and long term process. Leaders need to maintain their commitment, keep the process visible, provide necessary support, and hold people accountable for results. The TQM philosophy will influence management's decisions and actions. Overall, management will adopt a proactive approach to equipment maintenance. A chain of command will be defined to eliminate questionable authoritative boundaries. Also, communication channels will be structured to reinforce the circulation of accurate and verifiable information.

With the use of TQM tools, the concept of teamwork will be encouraged throughout the organization. Employees will not only begin to take pride in work performed on equipment but will also accept responsibility for work performed. An Operations Management Team will be organized to assist in monitoring equipment performance issues. Management will play an active role in the continuous improvements of the predictive equipment maintenance program by monitoring all system components. The next step in building up the TQM based program is to further develop the components needed in the equipment maintenance at the operational level: the quality procedure, the maintenance program, and customer satisfaction program that matches the new management infrastructure.

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