SUSTAINING AND RAPID RESPONSE ENGINEERING IN THE RESERVOIR SAMPLING AND PRESSURE GROUP OF THE COMMERCIAL PRODUCTS AND SUPPORT ORGANIZATION AT SCHLUMBERGER SUGAR LAND TECHNOLOGY CENTER

A Record of Study

by

BRADLEY GRAY KERR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF ENGINEERING

December 2006

Major Subject: Engineering
College of Engineering

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ABSTRACT

Sustaining and Rapid Response Engineering in the Reservoir Sampling and Pressure Group of the Commercial Products and Support Organization at Schlumberger Sugar Land Technology Center. (December 2006)

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This record of study investigates twelve months of engineering industry experience, a required internship of the Doctor of Engineering degree program at Texas A&M University. The internship company was Schlumberger Limited. The record of study begins with a brief introduction to the company. Three projects undertaken by the intern during the internship are discussed. The projects show how a wide variety of knowledge, both technical and practical, is required to solve engineering problems. Issues facing newly graduated engineers in industry are discussed. Issues facing newly graduated engineers exposed to industry for the first time are quite different than a traditional engineering curriculum has prepared them to encounter. Industry today is demanding a well-educated engineer capable of tackling technical problems in several areas as well as engineers with the ability to easily communicate and interact with others and develop leadership potential. Academia, industry, and society all have a highly influential role in developing engineers. The engineer must consider the interaction of technology and society when searching for a solution to optimize the benefit to all. The study further investigates academic challenges as well as the declining number of engineers, international competition, industry responsibility, and observations made during the internship period. Research has shown that in the next few year as the Baby Boomer generation of approximately 77 million people begin to retire, the next generation of approximately 44 million will have difficulty keeping up with technical and scientific demands. Industry demand for science and engineering graduates is beginning to overwhelm academia's ability to respond and produce. Few U.S. undergraduates are continuing education in graduate schools. This leaves a large student population base to be filled by international students. U.S. citizens accounted for only 35-percent of the total number of doctoral degree recipients in science and engineering during the 2005 academic year. Observations made during the internship period will be used to make recommendations to both industry and academia to help align industry demands and academic abilities in order to produce engineering graduates that are ready to accept the vastly different challenges encountered in industry.

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INTRODUCTION

The Doctor of Engineering program at Texas A&M University prepares men and women to work at the highest levels of the engineering profession. The program emphasizes solving practical engineering problems facing the world today and prepares its graduates to balance the interaction between technology, society, and industry. After completion of an extensive technical and professional development degree plan, the engineering intern enters industry and completes a twelve-month internship whereby learned knowledge is practiced. This record of study is one of the requirements of the program used to document experiences acquired during the internship period. An overview of the internship parent company, Schlumberger Limited, is discussed.

Three projects completed during the internship are discussed. The projects were chosen for discussion based upon the driving force requiring the project, the level of engineering involved, and the variety of technical and professional challenges faced in developing a solution. Technological advances in business require direction by persons with both high technical competence and an understanding of the social, political, and institutional interactions. After spending twelve months in industry, shortcomings in education and industry support for education became apparent. These shortcomings, backed by several discussions found throughout historical references, are discussed and supported with research and statistics based upon recently graduated engineers.

This record of study follows the style of the ASME Journal of Engineering for Gas Turbines and Power.

Finally, challenges experienced by the intern during the internship are discussed. Few problems or obstacles encountered during the internship were of a technical nature. The toughest challenges for the intern stemmed from interaction with an environment vastly different from previous experience in academia. The value of knowledge and study outside a technical discipline was made acutely clear. The intern learned to appreciate the knowledge gained through practical experience. The gained knowledge is viewed as a compliment to an excellent education at the academic level. In addition, much is still to be learned to perform in industry with the highest level of professionalism.

INTERNSHIP COMPANY

Schlumberger History

The origins of electrical well logging date back to 1911. Conrad and Marcel Schlumberger then started what has today grown in to Schlumberger Limited.
The first drilled-hole electric log ever recorded was run on September 5, 1927. That event set Schlumberger on a new course and gave the petroleum industry a powerful new exploration tool. Schlumberger Well Surveying Corporation was founded in Houston, Texas in 1934. Schlumberger Limited has grown into the leading oilfield services company supplying technology, project management, and information solutions that optimize performance for customers working in the international oil and gas industry. Schlumberger Oilfield Services supplies a wide range of products and services from formation evaluation through directional drilling, well cementing and stimulation, well completions and productivity to consulting, software, information management and IT infrastructure services that support core industry operational processes.

Schlumberger Oilfield Services, a division of Schlumberger Limited, is made up of three major groups each containing three segments. Reservoir Characterization contains segments concentrating on Drilling and Measurements, Testing, and Wireline Formation Evaluation. Production is divided into Well Services, Completions, and Artificial Lift. The Reservoir Management group encompasses Integrated Project Management, Data and Consulting Services, and Schlumberger Information Systems. These services are provided throughout the world across five Areas, North America, Latin America, Europe and Africa, Middle East and Asia, and Russia. The global management of Schlumberger Limited is unique. The five areas are further broken into 28 GeoMarkets made up of the various countries contained in the respective GeoMarkets. Greater detail about Schlumberger and its many programs and commitments can be found on the public Schlumberger website www.slb.com [1]. In the following section, the internship site, Schlumberger Sugar Land Technology Center, containing Sustaining and Rapid response, is discussed.

INTERNSHIP SITE

About SPC

The following discussion will focus on the internship site, Schlumberger Sugar Land Technology Center (SPC), and the sub-organization containing the internship, the Commercial Products and Support department (CPS). The mission of CPS is to provide the field organization a dedicated project team for the development of customized products, solutions, and improve existing commercial products by positively impacting their quality, improving their reliability, reducing their cost, and managing their obsolescence. The departments within CPS include Sustaining and Rapid Response, InTouch, and Quality. Sustaining provides engineering support to improve product quality and reliability, reduce manufacturing costs, and developing solutions to problems encountered both by the field organization and manufacturing. Rapid Response is a provision to the field organization, a dedicated project team for the development of customized solutions. Rapid Response projects are low risk customization and enhancement of existing products in limited production for a specific market.

The internship assignment was as a shared project engineer between Sustaining and Rapid Response in the Reservoir Characterization Segment. The structure of reporting is shown in Fig. 1. The interrupted lines in the structure of Fig. 1 indicated secondary reporting functions. A figure showing the management structure of SPC may be found in Appendix B. The internship assignment included overseeing the daily operation of one mechanical designer and one mechanical technician. In the next section, the tools experienced during the internship are discussed. The tools listed are those tools that are the responsibility of the Reservoir Sustaining and Rapid Response groups. All work during the internship was in support of the MDT Tools.

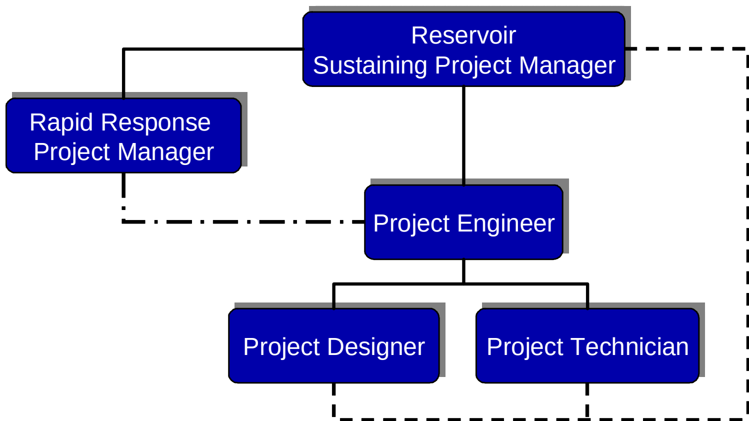


Fig. 1 Internship Department Organization

MDT Tools Overview

In most businesses, information improves cost effective productivity. In the oil exploration and recovery business, the more that is know about reservoir conditions, the more likely production efforts can be optimized. A valuable tool used in meeting this goal is the Modular Formation Dynamics Tester (MDT). The MDT is a field proven tool that has been designed, analyzed, improved, and redesigned by Schlumberger engineers to provide accurate and valuable reservoir information. The MDT tool provides fast and accurate pressure measurements, permeability and permeability anisotropy, fluid sampling and downhole fluid analysis, and micro-hydraulic fracturing. The MDT tool features a modular design that allows for customization on the job site to meet specific requirements. The following is not a comprehensive list of all services and options available. The list is only mean to give the reader a general appreciation for the complexity and capability of the tools experienced during the internship. The following list contains tool descriptions that are largely copied from MDT Modular Formation Dynamics Tester [2].

1. Power Cartridge Module
The modular reservoir power cartridge (MRPC) module converts AC power from the surface to DC power for all the other modules in the tool.

2. Hydraulic Power Module
The modular reservoir hydraulic power (MRHY) module contains an electric motor and hydraulic pump to provide hydraulic power for setting and retracting the single and dual probe modules.

3. Single Probe Module
The modular reservoir single probe (MRPS) module contains the probe assembly, with packer and telescoping backup pistons, pressure gauges, fluid resistivity and temperature sensors, and a pretest chamber. The MRPS module also contains a strain gauge and an accurate, high-resolution, quick response CQG gauge.

4. Dual Probe Module
The modular reservoir dual-probe (MRPD) module contains two probes mounted diametrically opposite each other. When combined with the MRPS module, it forms a multi-probe system capable of determining horizontal and vertical permeability. Running multiple probe modules enables monitoring pressure communication between adjacent formations during an interface test in vertical or horizontal wells.

5. Sample Chamber Module
The modular reservoir sample chamber (MRSC) module is available in three sizes: 1, 2.75, and 6 gallons. These modules are used to capture large samples or to capture reservoir fluid for later disposal for environmental purposes.

6. Multisample Module
The modular reservoir multisample (MRMS) module allows the collection of high-quality PVT samples. Up to six formation fluid samples can be collected with a single MRMS module. The MRMS module can use two types of sample chambers that easily detach from the tool for transfer to a PVT laboratory. A similar bottle, the single-phase multisample chamber (SPMC), is positively over-pressurized by a nitrogen charge to ensure that the sample remains in single phase all the way to the surface.

7. Single-Phase Sample Module
The modular reservoir single-phase sampler (MRSS) module is used to collect single-phase samples and bring them to surface at, or above, reservoir pressure. The MRSS consists of three separate modules; a control module, a module containing sample bottles, and a nitrogen chamber module, which is the basis of the MRSS pressure maintenance system.

8. Pumpout Module
The modular reservoir pumpout (MRPO) module is used to pump unwanted fluid from the formation to the borehole so representative samples can be taken. It is also used to pump fluid from the borehole into the formation for minifracturing or into the flowline for inflating the dual-packer module.

9. LFA Module
The live fluid analyzer (LFA) module utilizes visible and near-infrared light to quantify the amount of reservoir and drilling fluids in the flowline. Light is transmitted through the fluid and measured by the LFA spectrometer. The amount of light absorbed by the fluid depends on the composition of the fluid.

10. CFA Module
The composition fluid analyzer (CFA) module utilizes near-infrared optical absorption spectrometer to determine the concentration of methane, ethane-propane-butane-pentane, heavier hydrocarbon molecules, water, and carbon dioxide.

11. Dual-Packer Assembly Module
The modular reservoir packer assembly (MRPA) module uses dual inflatable packers set against the borehole wall to isolate a 3-to-11 foot interval of the formation. This module provides access to the formation over a wall area that is much larger than a typical formation tester probe. This larger area allows fluids to be withdrawn at a higher rate without dropping the pressure below the saturation pressure.

12. Controlled Flow Module
The modular reservoir controlled-flow (MRCF) module is a chamber where the flow rate is accurately measured and controlled. It is used to create a pressure disturbance that is large enough to produce a measurable pressure response at monitor probes. The MRCF can also be used for performing large-volume pretests and sampling operations that require an extremely low flow rate or drawdown.

An additional module recently developed is the Quicksilver Probe Module. The modular reservoir quicksilver probe (MRPQ) module contains a single probe assembly with concentric packer elements that operate through two independent flowlines. With this module, two pumpout modules and two fluid analysis modules are utilized to retrieve samples with little or no borehole fluid contamination. This is achieved by developing concentric conical flow paths. The outer cone is a guard flow that discards a mixture of reservoir and borehole fluids while the inner cone provides pure reservoir fluid.

The tools briefly described above were the subjects of work during the internship. All projects completed by the intern in Sustaining and Rapid Response were design modifications of the above tools. In the next section, three projects completed during the internship on the MDT tools are discussed. The projects in the next section were chosen for discussion based upon the varying levels of complexity and intern involvement.

INTERNSHIP PROJECTS

The three projects discussed in this section will convey the technical nature of the work completed during the internship. The intern contributed to many more projects than are discussed in this record of study. The projects below were chosen to show the varying levels of technical knowledge exercised during the internship. In the following sections, the solid models and cross-sectional drawings have been adapted from Schlumberger.

Release Washers

The release washer, Fig. 2, is a small sub-assembly of the multisample tool. The current release washer is a multi-part washer held together by a metal band, C in Fig. 2, and connected to a release mechanism, B in Fig. 2, attached between a pair of resistors, A in Fig. 2. Before a sampling job begins, the valves are spring loaded and locked in place by a release washer such that for each sample bottle, one valve is closed and one valve is open. When a sample is desired, a signal is sent downhole to the release washer from the surface. The signal passes through the resistors on the release washer creating heat. The heat from the release washers is used to melt a solder joint, B in Fig. 2, which releases a tripwire and coiled spring, D in Fig. 2. The release washer breaks into three pieces that are pushed away from the valve stem by radial force generated at the angled interface of the release washer and the valve stem, E Fig. 3. A compression spring installed on the valve stem actuates the valve and either opens or closes the flow path from the main flowline to the sample bottle. Each sample bottle is connected to a main flowline via two valves, one normally closed valve, and one normally open valve. The parts of the valve assembly are labeled in Fig. 3, release washer A, valve stem B, valve body C, and compression spring D.

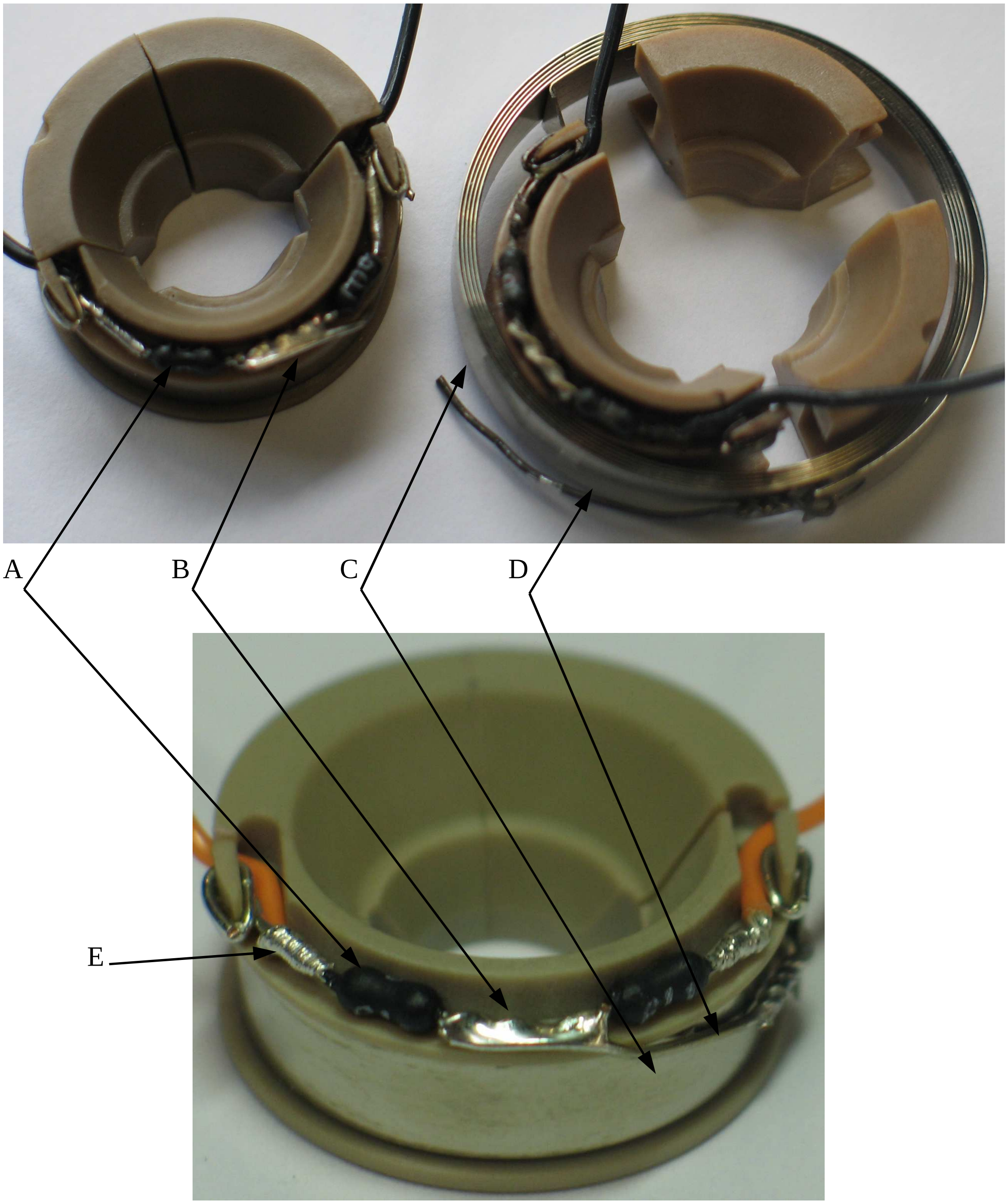


Fig. 2 Release Washer

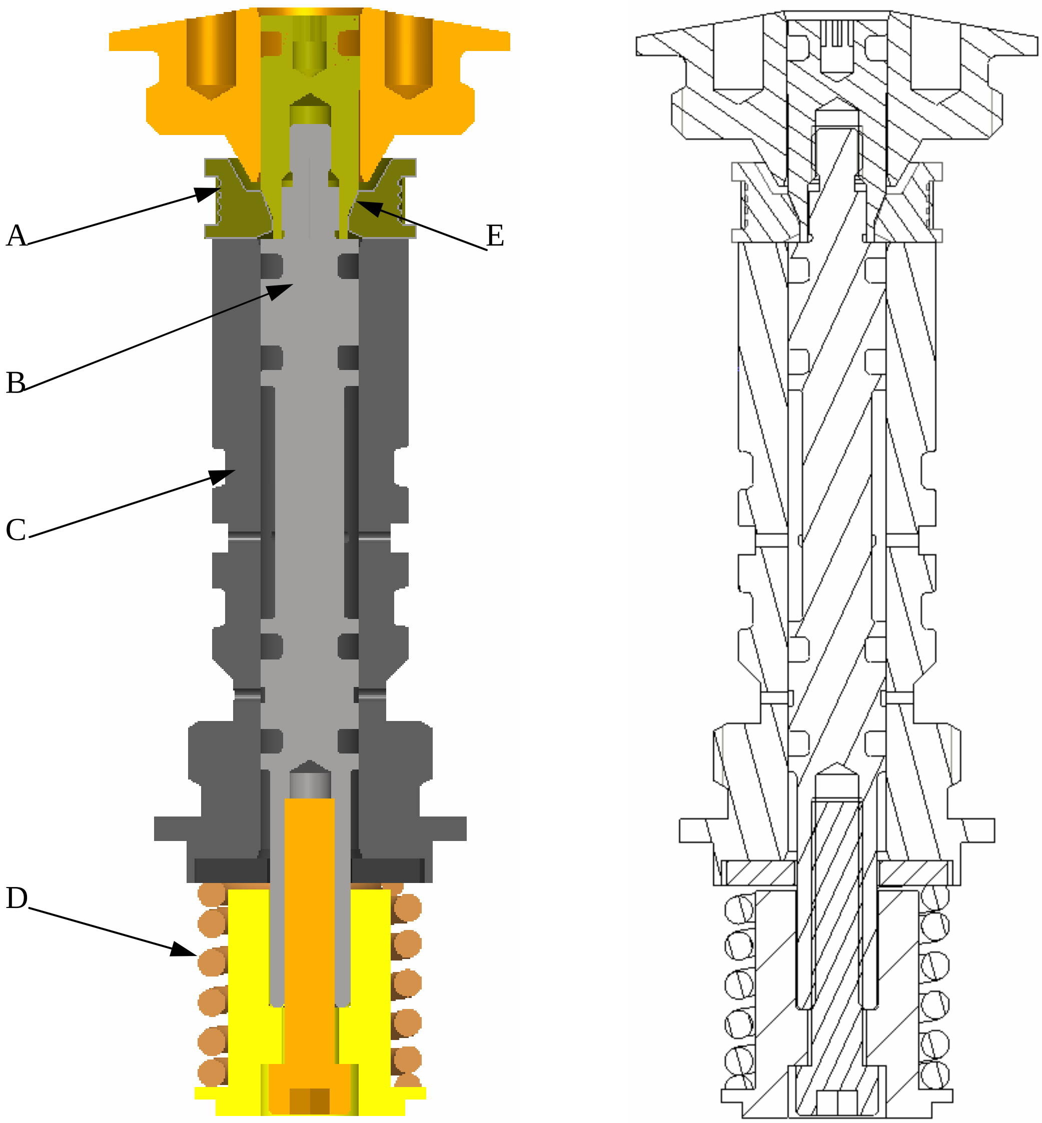


Fig. 3 Release Washer Valve Assembly

Figure 4 shows a cross-section of the multisample valve block with two valves installed. One valve is shown it an un-actuated state, the other is shown in an actuated state. Figure 5 shows a close view of the same valves installed in a multisample block with the fluid flow path indicated. The flow path through the valve is blocked in the un-actuated position.

The mechanism of release and capability of the release washer to achieve desired function was not of question in this project. The washer functioned as designed, however, the reliability and repeatability of a successful actuation was far less than desired. Several outside vendors were given basic specifications, both functional and financial, and asked to provide alternatives. Schlumberger engineers worked closely with the engineering groups at the outside vendors to develop a mutually acceptable product considering functionality, manufacturability, deliverability, reliability, and cost. Only a portion of the total project life cycle is discussed, the portion with which the intern was directly involved. The intern was responsible for qualification and field-testing that would lead to several problems requiring investigation and modification before a final product would be released and announced as a commercially available replacement. The following discussions are those problems, analysis, and design changes with which the intern had direct interaction.

The intern's first involvement was during qualification testing. The release washer assemblies were assembled in a valve test fixture and then exposed to a representative downhole environment. The release washers were qualified and sent in large numbers to the field locations for field-testing and feedback. A significant point is that after initial qualification and verification of design, most major failures can be

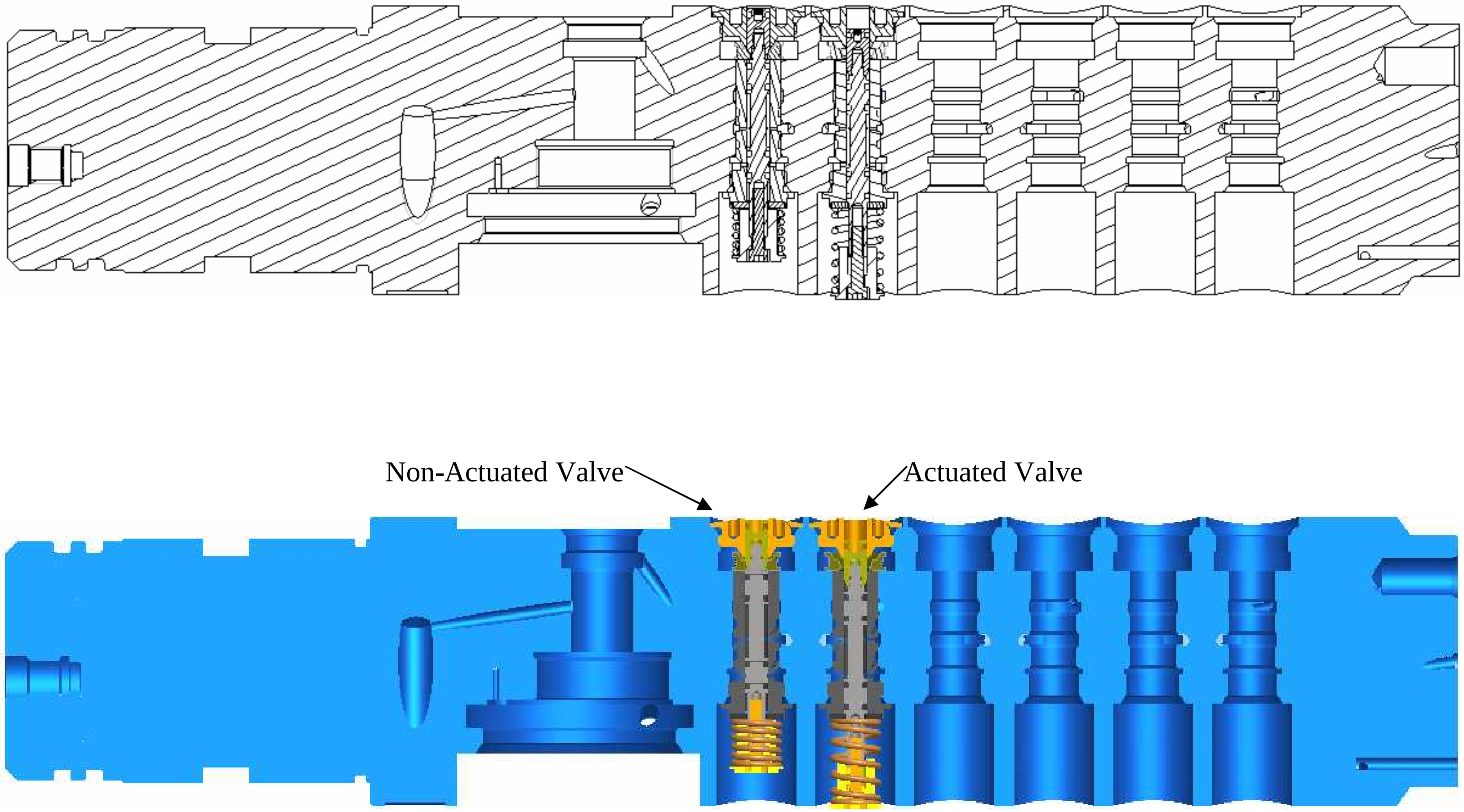


Fig. 4 Cross-Section MRMS Block with Valves Installed

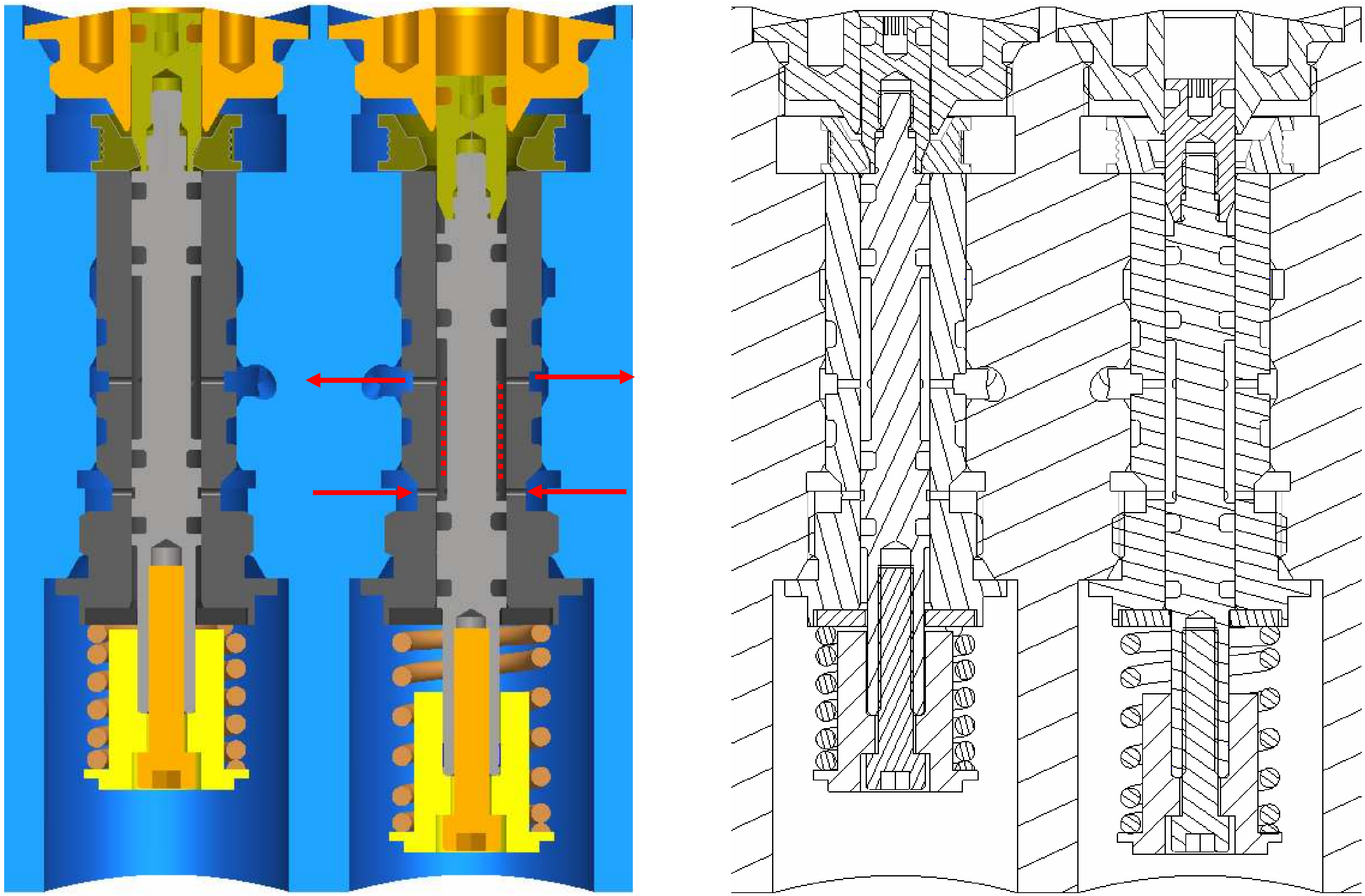


Fig. 5 MRMS Valves

attributed to a change in process. Many changes in process are driven by efforts to decrease cost. However, as is the case with the release washers, a process change can lead to a product that responds to hostile downhole environments in an unexpected manner. The following is a brief description of the problems encountered and the action taken by the intern in conjunction with manufactures to correct the non-conformance.

In order to decrease manufacturing cost, a change from individual machine made pieces to injection-molded pieces was desired. When this change was made, the same material for injection molding was specified as was being used in the machining process. However, the heat and pressure required to mold the molten material changed the post-process material properties of the release washers. During subsequent testing the washers began to stick to the valve body even after the retention mechanism had been activated. This blocked the valve from actuating and caused samples to be lost. The original cause was thought to be an edge interface issue where the washer meets the top of the valve body as shown at location A in Fig. 6.

The washer was thought to deform under temperature and pressure at this interface and the edge of the valve body would provide a radial force that kept the washer pieces from moving outward and releasing the valve actuator. A relief feature was added to the bottom of the washer to remove the interface contact area. A new production run of washers was molded, however, the sticking issue continued. Upon further investigation, deformations to the interface surface of the release washer where the valve actuator rests were discovered, shown at B in Fig. 6. At high temperatures, the material would become soft and allow the angled portion of the valve actuator, B in Fig.

6, to deform the release washer. The deformation decreased the radial force on the release washer and increased the downward force causing the washer to become stuck in position. The washers became stuck in position after only a few hours of exposure to high temperature. A material with higher yield strength was introduced and no additional sticking issues occurred. This raises questions about the necessity of the geometry change. Although the change added an additional mitigation factor to the design, the time and cost associated with the change may not have been necessary. However, at this point in production, removing the relief would propagate additional testing, cost, and questions from the end users as to why the physical geometry has changed even though there are no perceived problems.

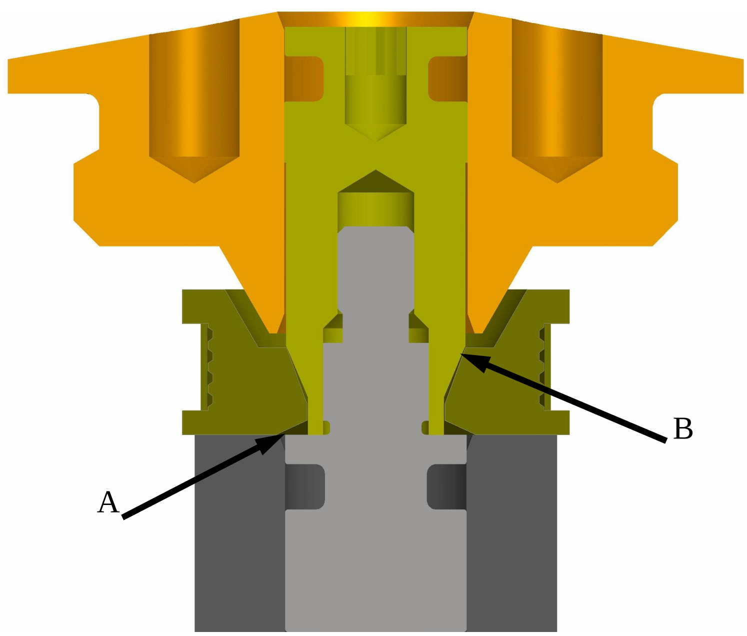


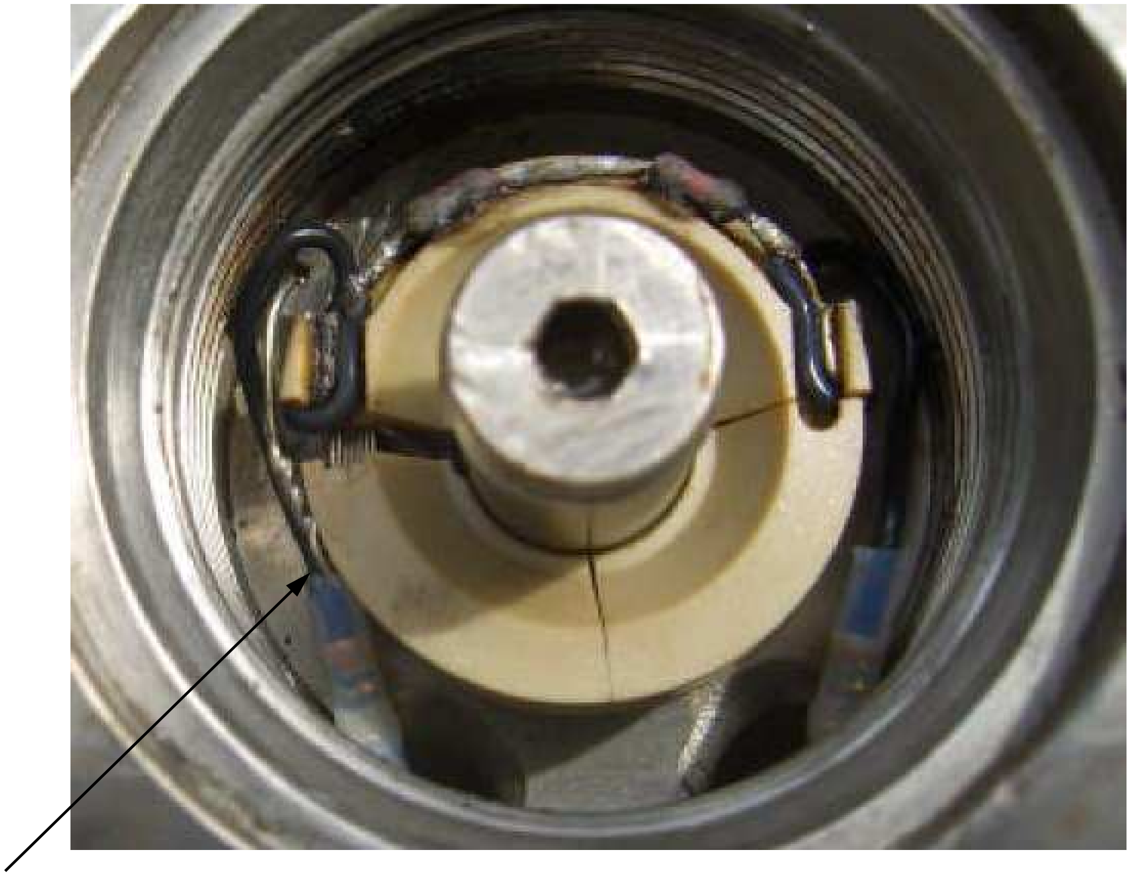
Fig. 6 Release Washer and Valve Cap Interaction

An additional problem found was premature release of the trip wire solder joint. During engineering testing the resistors were attached to electrical leads using a high melting point (HMP) solder, while the release washer tripwire joint was connected using a silver solder. During production, both ends of the resistors were tinned using the HMP solder, D in Fig. 2. When the tripwire was attached to the resistor assembly using silver solder, this joint became contaminated, E in Fig. 2. At high temperatures, the tripwire would release and the valve would actuate prematurely. The contamination was confirmed utilizing a scanning electron microscope and X-ray refraction. The remedial action was to use only silver solder on all joints to mitigate the possibility of possible contamination.

All resistors come from one manufacturer. They are purchased several thousand at a time and subjected to thorough testing and inspection. Approximately half of the resistors are deemed unacceptable. In this particular instance, the resistors passed all screening tests, but when functionally tested in the tools, failures began to appear. The resistors would not last long enough to heat the solder to the melting point before becoming an open circuit, no longer passing current. There had been no apparent process change and screening tests were being passed at approximately the expected rate. Upon further investigation, a process change was discovered at the manufacturer of the resistors. Internal to the resistors is a wire winding. Without changing the measured value of resistance provided, this winding can vary in wire size and spacing. The manufacturer changed the machine and location where the resistors were made. At the new facility, the resistor wire size and winding spacing had changed. A request for the previous design was implemented and no further problems of this nature occurred.

Installation errors have also lead to failed sample retrieval. During field use, the tripwire and retention spring have been shown to contact and hang on the feedthru pins that supply signal to the resistors, see Fig. 7. This is attributed to improper installation. Testing showed that significant interference between the release washer and the feedthru connection is required to cause a catching incident. The trip wire can lodge between the retention spring and insulation on the feedthru connector and prevent the release washer from actuating. A process to minimize the overhang of insulator material was implemented at the manufacturing facility and specific instructions on installation using a feeler gauge to ensure spacing were directed to the field organizations.

After all issues had been satisfactorily resolved, qualification testing and field testing completed, the release washers were made commercial and turned over to the manufacturing group. During this final stage of product release, questions arose regarding quality control of future orders. The manufacturer had been testing two out of every 98 washers produced at maximum temperature for 100 hours. The legitimacy of this number became a point of contention. Military Standard 105-E was applied given that the manufacturer would supply 96 units with a 99 percent chance of success using the reduced testing criterion of the standard. This resulted in a final quality control test of five assemblies out of every 101 tested at maximum temperature for a period of 24 hours. This time is representative of actual downhole exposure and all previous failures had occurred very early in the testing process.



Tripwire Caught on Feedthru Insulation

Fig. 7 Release Washer Installed

The previous release washer design had a release rate of approximately 89% over the life of the design. Given the financial and reputation cost to Schlumberger this reliability is unacceptable. The design discussed here has provided just over 99% success. This project required substantial improvement with minimal design change. This project required the intern to link many different functions such as innovative design, cost saving manufacturing, experimental design, and qualification testing in order to produce a product with exceptional reliability at an acceptable cost to the field organization. The resulting product is a reliable release washer that far exceeds the previous design in reliability. Previous generation release washers had a success rate around 89%; today the field enjoys a successful firing rate of slightly over 99%. Feedback from the field organizations has been extraordinarily positive. The increase in reliability will save millions in lost revenue yearly and will reinstate client confidence in Schlumberger services and products.

MDT Compression Calculator

This project was requested by personnel in field locations. It was chosen to show how traditional engineering methods and analysis were applied during the internship to develop an approximation method for maximum tool loading based upon well characteristics. In this project, the intern investigated past research in tool string failure by buckling and material failure at the MDT module interfaces. The intern used a combination of past research and classical engineering failure theory to program an Excel macro calculator to suggest approximate limits of operation for MDT tool strings.

Wireline tools are sometimes required to operate in conditions whereby wireline conveyance is not practical. Such is the case with highly deviated wells or horizontal wells. In these tough logging conditions (TLC), the tools are conveyed using a variety of methods such as drillpipe, coiled tubing, or tractor systems. This project takes into account the condition that requires substantial axial loads be applied to the tool string during operations or retrieval. The maximum allowable load is not an easy limit to forecast. Many factors influence the load determination such as well temperature, well pressure, bore size, deviation, tool string length, and drilling fluid weight. Additionally, since the tools under consideration are long columns with varied and complicated crosssections, a suitable failure criterion is difficult to define. The MDT Compression Calculator includes many of the above factors as well as field experience, engineering testing, and theoretical finite element analysis to provide guidelines for field reference. Destructive testing of tools at specified conditions is not feasible. As field experience is gained, the calculation method may be modified to represent the actual performance of the tool string under compressive loading more accurately.

The original MDT tools were rated to work in wells with up to 20,000-psi pressure and 350˚F. Throughout several years of operation and modifications, the limits have been increased to 25,000psi and 400˚F. This increase was due to market demand and field experience. With the increased limits came the need to revisit the recommendations for applied compressive load. The specifications available were previously only calculated at a specific and limited number of operating conditions. The field organization desired a more functional method for determining the limitations for multiple combinations of well conditions including the expanded 25,000-psi and 400˚F operation limits.

Compressive loading of drill strings and other tubular structures in boreholes of various sizes and inclinations is a highly researched area. Several failure theories and methods of prediction based upon various forms of buckling have been proposed. In the case of the MDT tools, field experience has shown that buckling is not the first indication of damage if large axial compressive loads are applied. Rather, internal components at the interface of the individual modules of the MDT tool string joints are the first to be deformed permanently.

These interface areas were used as the basis for the failure criterion of the module and implemented in the compression calculator. Figure 8 shows the cross-section of a typical MDT module joint. This view shows many of the electrical and fluid communication passages and interfaces within the modules. Figure 9 shows a simplified joint showing only the parts of concern for the compression calculator, the Upper Block A, Lower Block B, Thrust Ring C, and Threaded Ring D. To accommodate pressures above 25,000psi, the interface was redesigned to redistribute the forces. However, the compression calculator was developed to give field locations a general guideline for tools with the standard connection interface details that may experience pressures up 25,000psi.

With field experience, FEA analysis, and engineering testing reports, tool string buckling as a failure concern was foregone and only material yield at the module interface of the two blocks and the thrust ring was considered. The force applied by the hydrostatic pressure, axial loading due to TLC, and any force developed by bending of the tool in the well bore was considered. Previous work by Thomas [3] investigated Euler buckling and Elastic Support buckling as limits for generic tool strings in deviated wells. Thomas [3] suggests that the Euler approach should be viewed as a lower bound and the elastic approach as an upper bound of allowable compressive loading. These two methods were considered along with the material yield condition at the module interfaces. However, buckling failure was later removed from the analysis and only the material yield condition based upon pressure, added axial force, and bending was considered.

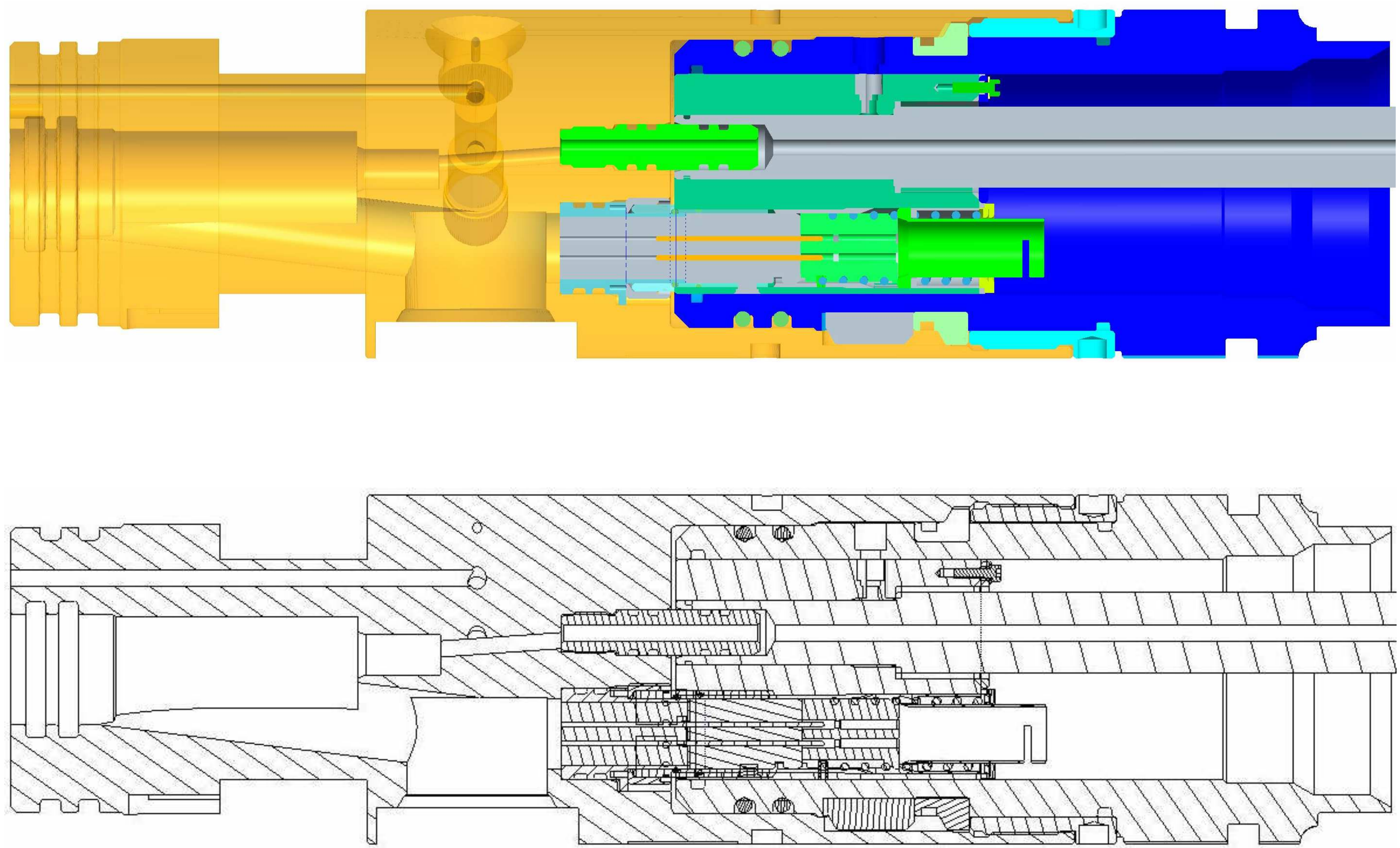
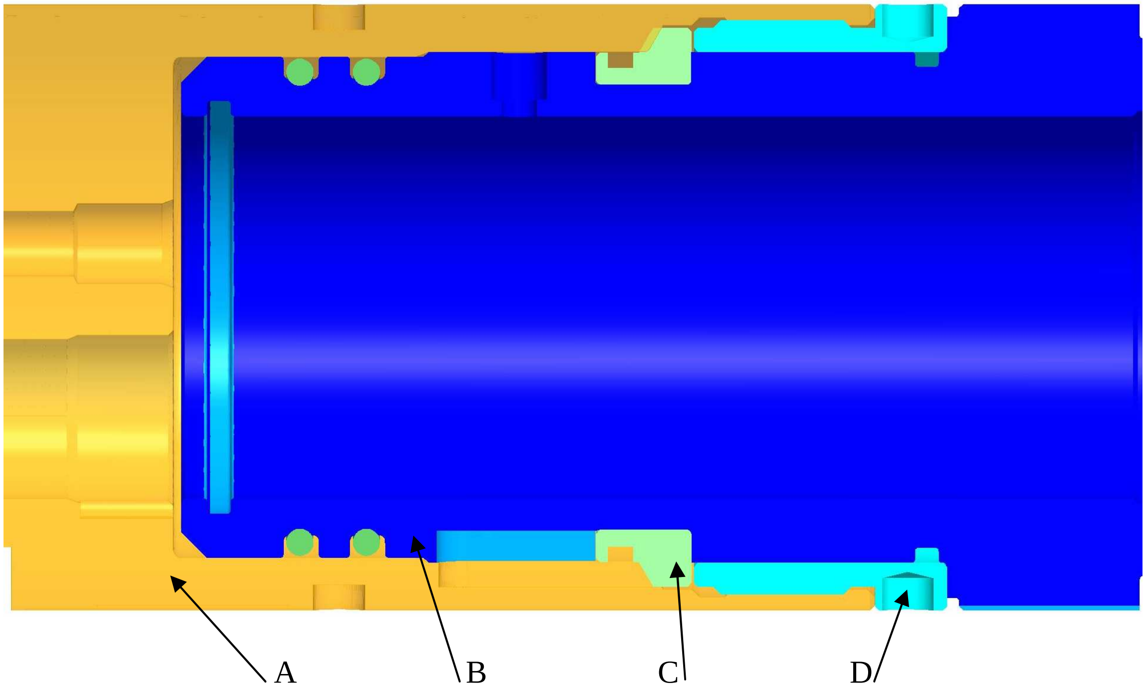


Fig. 8 MDT Tool Joint



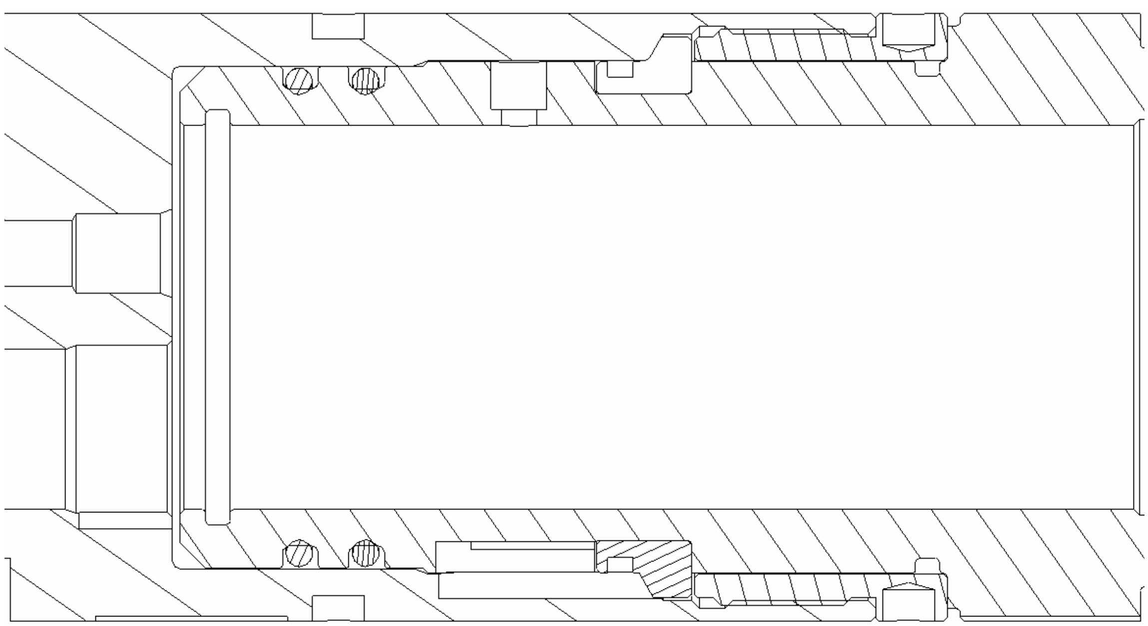


Fig. 9 Cross-Section MDT Tool Joint

The compression calculator uses temperature, hydrostatic pressure, average borehole deviation, well bore diameter, tool length, modulus of elasticity, and yield strength as variables. The modules of elasticity and yield strength are compensated for temperature changes from 68˚F to 450˚F. See Fig. 10 for a graphical representation of bending induced on a tool string in a deviated well. The tool centerline represents the neutral axis of the tool string, assuming the tool string is conformed to the center of the well bore curvature. Since the approximate deviation of the well bore is known from drilling logs, the radius to the centerline of the tool is found assuming the tool is conformed to the curvature of the well bore. Deviation is reported as degrees per 100 feet of well bore. Using well deviation and the tool string length, the angle theta occupied by the tool is found. A deflection distance is defined as the distance from the center of curvature of the well bore to a straight line that connects the endpoints of the tool string. Assuming a simply supported beam, the second area moment, equivalent transverse load, maximum moment, and bending stress can be found. The Von Mises effective stress for a biaxial stress state was used to calculate the stress and allowable compression before yield of the MDT module interface components for a set of given well bore and tool conditions.

In order to distribute the compression calculator quickly and easily, an Excel based macro was written to perform the calculations. As feedback from field locations is received, the compression calculator will be modified to predict allowable compressive loading more accurately. Future work exists in this area with the introduction of a new generation of downhole tools with expected pressures and temperatures near 35,000psi and 500˚F. A similar calculation tool will be required, however, with a redistribution of forces due to a design change at the module interface, the area of failure is now unknown. Field experience will be heavily relied upon to determine the areas of concern within the new generation of downhole tools.

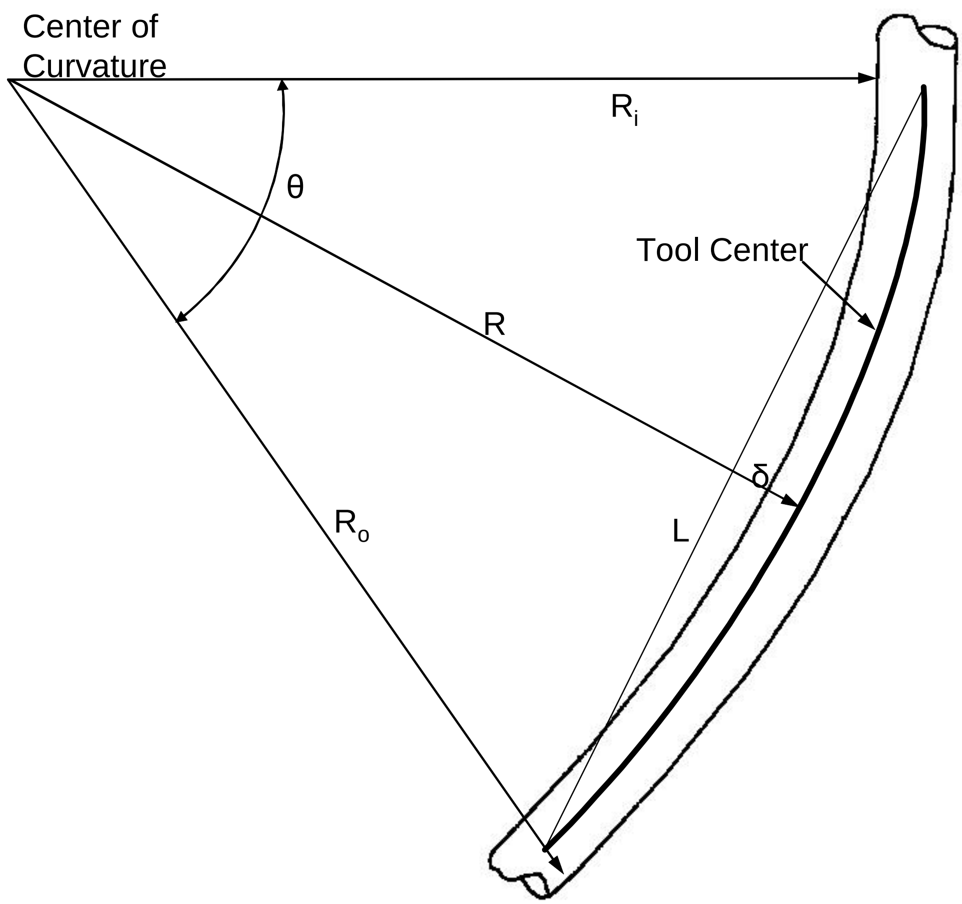


Fig. 10 Tool Deflection Due to Well Bore Curvature

Displacement Unit

This project was driven primarily by market competition, and requested by a field location. Design, testing, and initial production were carried out by Rapid Response. In this project, the intern took on a more active role in the complete cycle of product development. The intern was tasked with verifying design, creating solutions, designing concepts, obtaining manufacturing quotes, building prototypes, testing new products, documenting the entire process, and ushering the prototype through testing and commercialization.

In some particular oilfields, high overbalance or low mobility is present requiring high-pressure downhole pumping in order to pump reservoir fluid from the formation to the borehole. The drilling fluid serves multiple purposes such as lubrication, removal of cuttings, and creates a pressure dam between atmospheric pressure and reservoir pressure or between reservoir zones of various pressures. When drilling in unexplored fields or new formations, exploration companies tend to be conservative regarding safety with well control issues and use a high weight drilling fluid to create high hydrostatic pressures and high overbalance. If true pressures and samples are desired in such conditions, pumping against the differential pressure between reservoir and borehole is required. Pumping may also be used when sampling or pressures are desired in reservoirs containing heavy fluids or in formations where reservoir fluid mobility is limited.

Competition was the driver of this project. Competitors exchanged successive product releases, each with slightly higher pumping capability. An original request to pumping against 7000psi was fulfilled. A few months later, competition released a pump with a 9000-psi rating. Clients in the area began to prefer the competitor for this reason. Another request was made to produce a pump to out-spec the competition. The request was again fulfilled and a pump with a 10,500-psi rating was developed.

The pumpout module contains an electric motor driving a variable displacement hydraulic pump. The output from this hydraulic pump is feed into a dual-piston displacement unit shown below in Fig. 11. The parts of the displacement unit labeled in Fig. 11 are, A cylinder, B piston, C magnet, and D piston shaft. The outer cylinder volume is filled with hydraulic fluid from the variable displacement pump through a valve in the end of the cylinder. The inner cylinder volume is filled with formation fluid through a flowline that connects at the center of the displacement unit. The displacement unit is double acting. As one cylinder volume is evacuating fluid, the opposite volume is being filled with fluid. The hydraulic and formation fluid flows are controlled by a network of solenoids and valves. As the pistons near the end of the stroke, a magnetic sensor detects the proximity of the pistons and sends a signal to the solenoids and valves that causes the hydraulic fluid and formation fluid flow to reverse. The major issues with increasing the output pressure of the displacement unit include the differential pressure across the seal in the center of the displacement unit and the reduced flow rate of the displacement unit. The previous displacement units were used as starting concepts for the modular reservoir displacement unit (MRDU).

This concludes the technical portion of the record of study. Non-technical challenges made major contributions to the internship. In the next section, non-technical experiences of academic studies and the internship are discussed as well as observations of the internship made by the intern regarding relationships between academics, industry, and society.

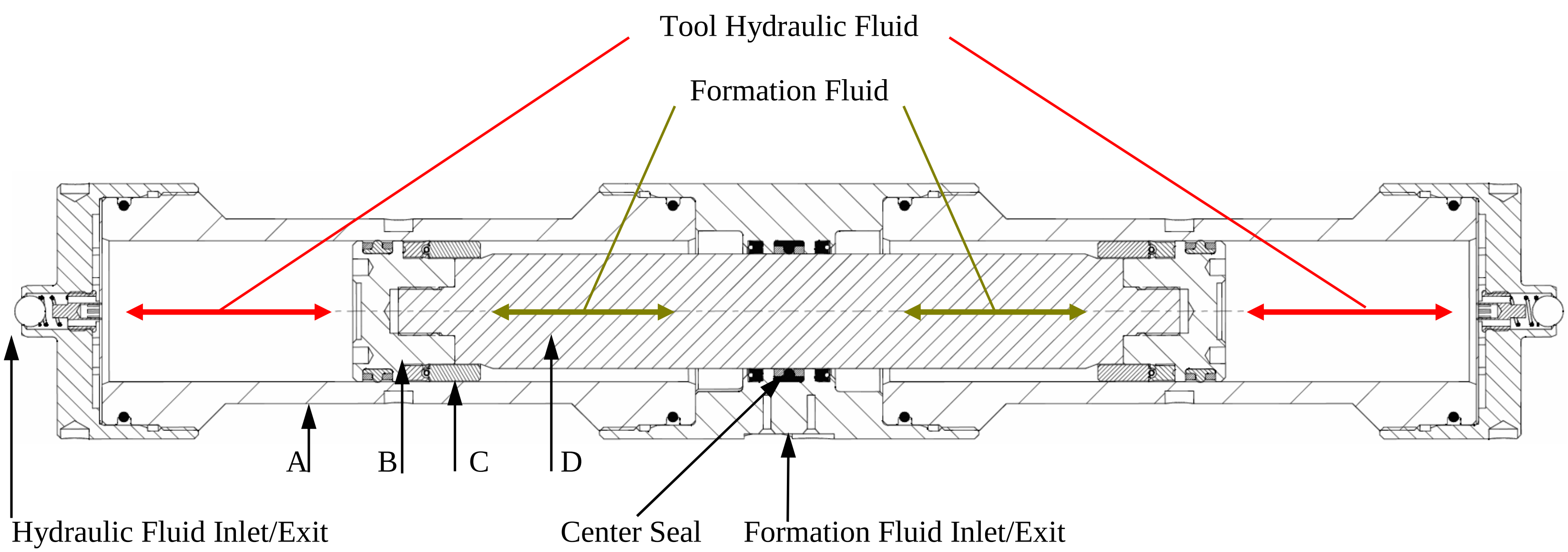


Fig. 11 Cross-Section Displacement Unit

SOCIETY, INDUSTRY, ACADEMIA, AND THE ENGINEER

The premise of the doctor of engineer degree is to produce engineers capable of working at the highest levels of professionalism in industry. In recent times, technically trained engineers and scientists have been called upon to develop a better understanding of how their work influences society. Superior technical knowledge also requires an understanding of the interaction of industry, society, and academics. This section is included in the record of study to discuss some of the interactions and challenges the intern experienced during academic study and the internship period.

Pletta contends that in the past engineers were, “content to produce only the technological innovations the public desired and requested” [4]. Recently, engineers have become more aware of the impact their technological innovations have on society. The engineering profession is under continual change as a reaction to social and industrial demands. Specifications and requirements for performance and curricula have recently shifted toward practice-oriented structures. This requires a greater ability to exercise leadership in all domains influenced by engineering, society, government, and industry. There is an increasing demand for engineering professionals that can reduce large amounts of information efficiently, identify variables, and analyze systems that have significant interactions with both sociological and technological aspects. Several institutions have begun to develop programs to help fill the void and promote a more completely educated engineer; such is the premise of Texas A&M University’s Doctor of Engineering program.

“At a workshop of the National Academy of Engineering in 1990, the participants forecasted an engineering environment in which engineers must combine technical competence with a deep understanding of social, political, and financial systems and constraints” [5]. Currently the only solution available to produce engineers with all these competencies is to proceed with a significant amount of graduate education whereby engineers are allowed to develop skills to fill the exacting requirements set by academics, industry, and society. While mixed discipline graduate programs will increase the marketability and desirability of new engineers, engineering education beyond the normal four years is optional.

Much has been researched and written over the years regarding the necessity of change in engineering education to meet the needs of industry, keep up with foreign competition, and produce independent, capable, well-educated, cross-functional engineers. A sort of cyclical system exists whereby industry, economic, and society demands are eventually fulfilled by newly educated engineers. One variation of this cyclical system from Yoshisato [6] is shown in Fig. 12. The interactions shown, as well as some of the recently debated topics concerning engineering talent in the U.S., are discussed in the following sections. An attempt has been made to provide a view of both sides of the various debates by including first-hand experiences encountered during the internship with previous research and articles supporting arguments. The sections to be discussed include academic challenges, international competition, the decline of engineers, and industry’s responsibility.

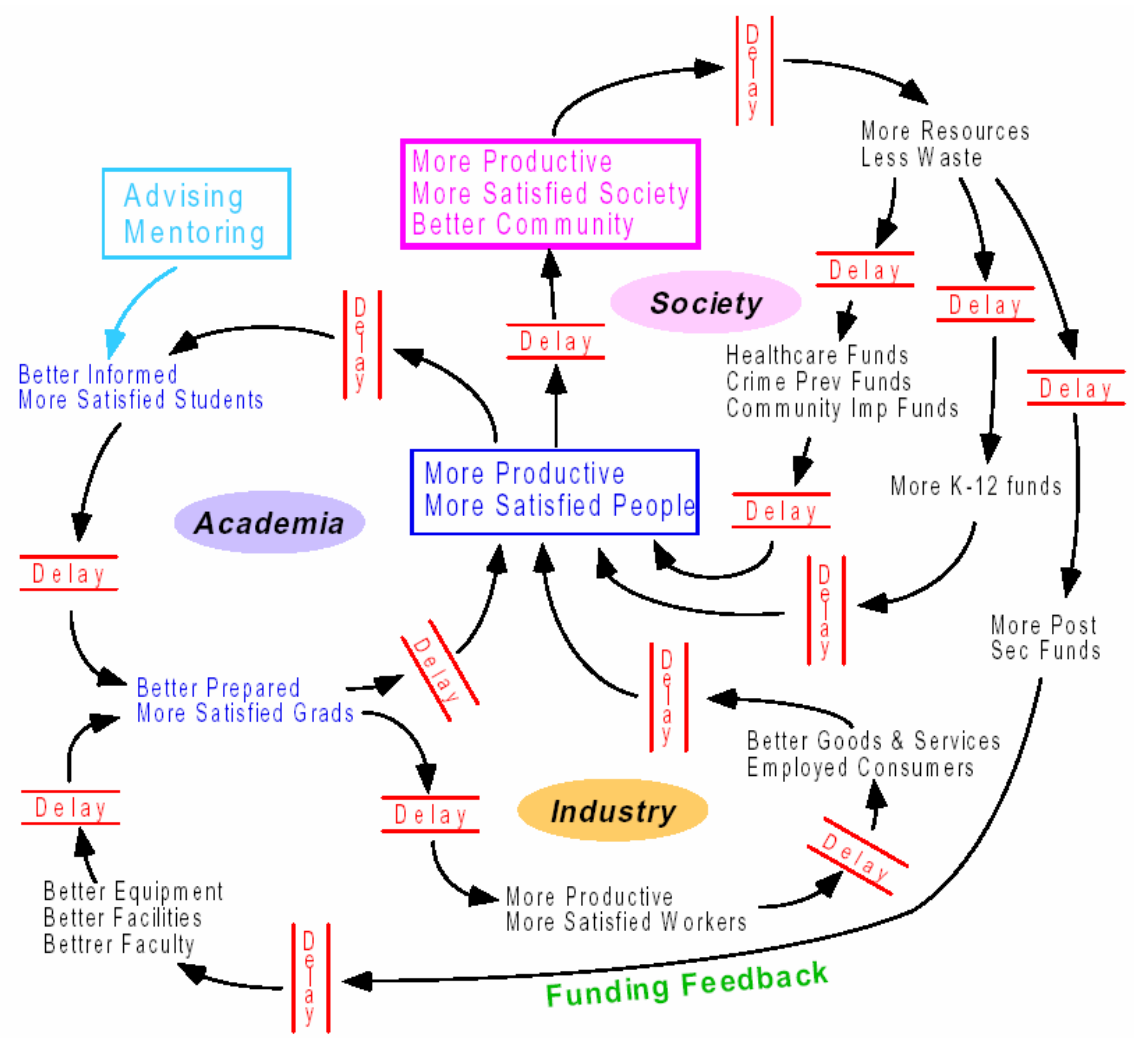


Fig. 12 Feedback and Cyclical Interaction System [6]

Academics

The premise of higher education today is vastly changed from the now historical philosophical education, derived from social sciences and humanities, upon which higher educational institutions were founded. Throughout history, education can be seen as a maturation process that shows the ability to focus on and accomplish a long-term goal. Education is now becoming a necessary condition to support societal demands, expectations, and economic growth. As a necessary path to a career in engineering, academic education carries a great burden of the nurturing of an early engineer. Academic influence does not start only at the collegiate level, but stems from early education, cultural influences, and even economic trends.

One opinion regarding early education proposed by Abbot is that, “a very large portion of the primary and secondary educational system graduates in the United States are not functionally literate” [7]. “A report released by Achieve, a nonprofit organization that helps states raise academic standards, contends that we have institutionalized low performance through low expectations” [8]. There are indications that the problem is related to American social culture. Two interrelated issues arise if culture is accepted as a cause of poor performance. “One is the poor job being done by the public educational system at both the elementary and secondary levels; and the other, which permits the first to exist, is a cultural problem: an undemanding attitude that prevails in society in general, and with parents in particular with regard to education and achievement” [7]. Defining a culture problem is difficult. Those encapsulated by cultural norms do not see the differences or problems perceived by other outside the cultural area. People within a culture have been conditioned to respond to outside stimuli in a certain manner. Enacting change within a culture to the extent necessary to influence a culture’s response requires significant effort and time. Cultural change imposed by outside influences will be resisted. In discussing cultural issues, Abbot contends, “We are dealing here with philosophy and with value judgments on issues about which almost everyone has preconceived notions that are culturally determined by background, education, and inclination" [7]. Generally, American culture dictates equal treatment and opportunity for all. Equality is rooted in the very basis upon which the American society and culture have been developed and evolved. A major issue that exists in industry is also becoming commonplace in education, the equal treatment of un-equals. One perceived problem is that equal educational opportunity may be illogically believed to lead to equal performance.

Primary education has been diluted to a point such that the majority of students should be able to pass a defined minimum standard that is based upon the average student. When these average students arrive at colleges and universities, some may require remedial action to bring them up to collegiate education levels. Sometimes students enact this effort willingly and without direction. However, oftentimes the faculty must adjust coursework to rehabilitate students and bring them out of a state of mediocrity. Some believe that in today's educational system mediocrity has become the accepted norm. Yet this acceptance of meritocracy is not necessarily a desired course of action in academics but rather a guided acceptance based on politics and a defined minimal average that lead to mediocre students. Students that do overcome mediocrity in education once reaching the collegiate level are suddenly exposed to another deeply political issue, the engineering curriculum.

Engineers are being asked more and more to fit into traditionally non-engineering rolls. Engineers are being asked to participate in areas outside strictly technological rolls such as public policy. Although the need for more socially in-tune engineers is a know requirement, the means by which to fulfill this need is not as clear. How the current engineering curriculum should be modified to meet the ever-changing demands and expectations of academics, industry, and society is a point of contention that has been under debate and criticism for as long as an engineering curriculum has been in place. With an already time constrained curriculum, how can the current requirements be modified without significantly changing the time required to graduate or without decreasing emphasis on classical engineering courses? University curriculum is constantly under review.

Some programs both within the broad discipline of engineering and in other non-engineering disciplines have re-structured the curriculum to a mandatory five-year program or a mandatory graduate degree in order to practice at a professional level. This would seem to be a logical step in meeting the demands for more engineers and better-educated engineers. However, international competition, the fear of declining enrollment, concerns over the economic position of the U.S. as a technological leader and the upcoming mass exodus of engineering talent expected as the U.S. Baby Boomer generation nears retirement will continue to stifle this idea in the near future. These obstacles are discussed in later sections.

Social, political, and communication skills are more valued in industry interactions than they are in engineering schools, according to O’Neal [5]. Academia has recognized the importance of non-technical interactions. Changes in curriculum and expectations of students have been introduced to better acclimate engineering students to non-technical expectations. This leads one to the rational decision that engineers need more exposure to the humanities such as history, economics, communications, and a myriad of business related education. In today's professional world, the softer skills promoted through social sciences and humanities are no less important than technical skills. Traditionally an engineer has an aptitude for analyzing but substantial effort may be required to improve other professional skills. O'Neal [5] expresses the opinion that too few humanities are being taught to undergraduate engineers. However, no solution is proposed as to how to maintain the technical level of today's engineers while including additional humanities and plan for new technical courses that will be required as technology develops and new methods of engineering propagate in industry and society. Graduate education whereby in-depth engineering education as well as soft skills can be further honed is not a consideration for most students. "To lead an organization, particularly a large one, skills are required in the basic three P's: problems, people, and purpose" [9]. These skills are related to the soft skills gained through professional development disciplines outside the technical realm of engineering. Lack of these soft skills becomes a problem later in the engineers career when a choice to remain technical or move to a managerial roll, which requires greater soft skills, is presented.

Engineers are often presented a dilemma some 3-to-7 years after entering industry, remain in a technical capacity, or move to a managerial role, as promoted by Kocaoglu [10]. Most engineers have not however acquired the skills necessary to be competent in a managerial position. Some fail and return to a technical capacity while still yet others adapt and learn the necessary skills to be an effective leader. "Most Americans would probably be surprised to learn that more S&P 500 CEOs received degrees in engineering than any other field. Engineering based CEO's greatly outnumber their liberal arts, business or law counterparts" [11]. "The chance to move up keeps people happy who might otherwise burn out. People who are able to solve problems are going to do that in a lot of different roles and succeed, says Kenneth L. Havlinek, a longtime R&D engineer and now the technology manager for Schlumberger's Sugar Land Technology Center" [12].

Dunn states, "Recent academic research shows that engineers have a far better chance of making it to the boardroom than any other category of professional" [13]. For example, "engineers and scientists outnumber accountants three to one among top executives" [13]. Yearly research published by SpencerStuart [14] supports this claim. "Yet according to research, manufacturing companies headed by accountants and non-technical graduates distinctly outperform those run by engineers" [13]. The substantial number of engineers in industry leading positions predicates the necessity for well-educated multi-functional engineers. This should implement some concern within academia and industry. Traditional leaders that have helped develop a strong technological economy are becoming less available.

Today customers are more demanding and more sophisticated. As international competition increases, companies must be lead by individuals that understand financial and business aspects as well as manufacturing, materials management, and the engineering process in a complex project. In Braham's opinion, "An engineer is particularly adept at understanding and adapting to today's changing international competition" [9]. In addition to the advantages gained through engineering education, Braham says in order "to advance into top management, engineers are advised to broaden their background" [9]. Many faculty are aware of the necessity to educate engineers beyond only technical study and strive to incorporate soft skills into traditional engineering academics. However, faculty sometimes does not fully understand what industry and society demand.

An additional academic challenge is the perception of what industry requires in a new engineer. "Although the trend in engineering is for faculty to have more limited industrial experience than previous generations, the value of industrial experience is significantly underappreciated" [6]. "This lack of practical industrial experience provides the advisor with a limited, and sometimes distorted, view of industrial practice and industry expectations of students" [6]. This lack of practical experience, exposed primarily through the slow response of academics to change under the influence of industry and society becomes most obvious to the engineer after the first few months of employment outside the realm of academia. Limited industrial experience does not degrade the ability of faculty to teach traditional engineering courses. Industrial experience is exposed through the methods and topics faculty use to convey technical and non-technical knowledge and experiences to students.

Beyond academics and the interaction of academics and industry is the competition imposed by international students. Competition arises in the number of international students being produced in international countries as well as those educated in American universities.

International Competition

In recent years, political debate has arisen concerning international competition in the shear numbers of engineering, science, and technology graduates produced by some of the major emerging economies of today as rivals of the U.S. economy. The most public debates generally cite the large number of recent graduates from China and other Pacific Rim countries as the major threat to U.S. engineering talent. “China has increased the number of engineers it graduates by 126% over the last five years with a factory-like approach to education” [15]. Quantity usually comes at the cost of quality. Many debates have focused solely on the numbers of graduates without considering the quality of education or the impact to the local economy. Debates in U.S. politics focus only on the exacting numbers and the assumption that more is better. Although a larger number of technological and scientific graduates would presumably lead to a larger number of advances, one could argue that a slightly fewer number of graduates with a more complete education may produce just as many advances.

Another lesser point of contention is the number of international students versus U.S. students receiving graduate education at U.S. institutions. Recent graduation statistics clearly show the trend of large numbers of international students receiving U.S. degrees. “Foreign students typically have fewer opportunities and see a U.S. education as their ticket to the U.S. job market and citizenship” [15]. The most recent publicly available research compiled for the yearly Survey of Earned Doctorates, 2004, provides detailed statistics on Doctorates. The following are selected highlights of the SED report [16]:

- The 419 universities in the United States that conferred research doctorates awarded 42,155 doctorates during the 2003-2004 academic year (the eligibility period for the 2004 SED), an increase of 3.4 percent from the 40,770 doctorates awarded in 2003, and the highest number since the all-time high of 42,647 in 1998.

- The number of doctorates awarded by broad field in 2004 was greatest in life sciences, which conferred 8,819 Ph.D.s. The numbers in the other broad areas were 6,795 in social sciences; 6,635 in education; 6,049 in physical sciences and mathematics (combined); 5,776 in engineering; 5,467 in humanities; and 2,614 in business and other professional fields.

- Women received 19,098 doctorates, or 45 percent of all doctorates granted in 2004. This is very similar to last year’s percentage for women. Women earned 50 percent of the doctorates granted in life sciences, 55 percent in social sciences, 52 percent in humanities, 66 percent in education, and 46 percent in business/other professional fields. In physical sciences and engineering, they constituted 27 percent and 18 percent, respectively.

- In 2004, 51 percent of all doctorates awarded to U.S. citizens went to women, the same percentage as 2003, marking the third consecutive year U.S. women were awarded more doctorates than their male counterparts.

- U.S. citizens received 67 percent of all doctorates earned in 2004 by individuals who identified their citizenship status (94 percent of all doctorate recipients identified their citizenship). The People's Republic of China was the country of origin for the largest number of non-U.S. doctorates in 2004, with 3,209, followed by Korea with 1,448, India with 1,007, Taiwan with 703, and Canada with 601.

- The percentage of doctorates earned by U.S. citizens ranged from lows of 35 percent in engineering and 52 percent in physical sciences, to highs of 88 percent in education and 79 percent in humanities.

At Texas A&M University, graduation rates for the 2005 fiscal year indicated a similar trend. International students comprised 66% of all masters degrees awarded in engineering, 70% of those awarded in mechanical engineering, 86% of all doctorates awarded in engineering and 95% of all doctorates awarded in mechanical engineering, Texas A&M graduation statistics [17]. The SED report states that the growing numbers of doctorates awarded to foreign students on temporary visas has accounted for virtually all of the overall growth in the numbers of doctorate recipients since 1974. With political influences on educational spending and scrutiny over U.S. governmental budgets, one would expect this to be a greater point of contention in the future, particularly given that most U.S. universities are non-profit state funded educational institutions.

Differing reports have been presented regarding the number of technological graduates staying in the U.S. "A report prepared for the National Science Foundation showed that the number of foreign-born doctorates who chose to stay in the U.S. increased from 49% to 71% from 1989 to 2003" [15]. Demographics of students graduating from engineering schools and taking industrial positions in science and engineering are largely international students. To compensate for the decreased interest in graduate school by American students, universities have admitted more and more international students. "The result is that in some engineering graduate programs 70 percent, or even more, of the students are foreign-committed to return to their native lands" [18]. This would seemingly lead to short supply of American engineers, however, to date enough international engineers have been able to maintain temporary visas or obtain permanent working rights in sufficient numbers to keep up with demand such that the disproportionate number of international graduates has not been cause for alarm.

There are not enough American citizens to fill the available positions for graduate students. Additionally, given the security constraints surrounding some industry work, outsourcing and off shoring are not feasible options. Some have expressed concern about decreasing the opportunity for international student to enter the U.S. and study. If these students cannot enter the U.S., they will go to other institutions, thereby decreasing the talent pool available to U.S. industrials and the economy. In addition to a reduction in international opportunity, the numbers of American students completing graduate education is declining. The next section investigates some of the reasons and effects of the declining numbers of engineers.

Decline of Engineers

"Science and technology are the engines of economic growth and national security in the U.S., and we are no longer producing enough qualified graduates to keep up with the demand" [8]. Various reasons influence the declining numbers such as economic performance that relates to availability and quality of job offers that tempt students away from graduate education. American undergraduate engineers are simply not motivated to continue graduate level work. Some industry representatives have taken notice of the dwindling number of engineers that are U.S. citizens. This is most concerning to those in national security sensitive areas. "According to the Bureau of Labor Statistics, the number of electrical engineers, mechanical engineers and industrial engineers is dwindling" [19]. This comes at a time of increasing demand for engineers. Demand is expected to continue to increase as a large portion of the current U.S. workforce nears retirement age. For example, 19% of the employees in the aerospace industry are reported as eligible for retirement, but the decline of technical talent will affect industry beyond technical sectors" [11]. "According to a consultant at RHR

International Co., the country's 500 biggest companies anticipate losing half their senior management in the next five to six years" [12]. There will be tough technological, political, and social obstacles to overcome in the coming decade as the 77-million U.S. baby boomers begin to retire. The younger generation, totaling approximately 46 million, required to support and replace the retiring generation will be strained for resources. The need for experienced management in the near future is hindered further by large efficiency cuts made in the 1990s that removed several middle management positions. Workers affected by the cuts of the 1990s are skeptical and have become less loyal to companies. "At the same time, business has gotten tougher, and companies are counting on their people to be flexible enough to move at today's accelerated pace, yet creative enough to excite consumers around the world -- a tall order for a group that is already doing more than ever" [12]. Another consideration is that approximately 25-to-40 percent of available engineering graduates choose to enter professions outside the engineering discipline such as law, medicine, and business. Given this fact, it appears as though the decrease in technically trained engineers may influence more than just technological advances. The impact of decreasing numbers of engineers may well reach into the socioeconomic structure.

Some would argue however that the decline of engineers is not as problematic as industry suggests. These are however, the same proponents that say the Asian explosion of engineering graduates is not as alarming as industry and politics would have the public believe. In a supply and demand economy, shortages usually lead to price increases for the available products. "If there were a shortage of engineers, salaries should have risen, yet in real terms, engineering salaries have actually dropped" [15]. This leaves the question of why are American students not pursuing engineering education and what can be done to mitigate the decline of engineers in the U.S. Most U.S. students do not feel as though there is enough financial benefit associated with postgraduate education. Passing on an opportunity to begin to become financially stable by entering industry only to spend an additional 2-to-6 years at an education institution is a difficult decision. In today's job market, the industrial experience gained in the two years required to obtain a master's degree are valued by industry just as much and sometimes more than additional education. In theory, graduate education would lead to higher paying jobs and more opportunities in future assignments. This is not always the case though.

In many ways, the decline of American engineers relates back to the cultural influences of today's students. The students of today were heavily influenced by a time when the U.S. and world economies were rapidly growing. Businesses seemed to blossom and prosper in very short time. The hear-and-now attitude of immediate gratification propagated during this time has been entrenched into local culture thereby influencing recent graduates' decisions. Many students simply cannot see the benefit of continuing education beyond the bachelor's level. Industry has made demands for more engineers with expanded capability. In order to produces more engineers, educated as industry desires, industry has a responsibility to take an active role in promoting and enabling academics and student to fulfill industrial demands. This will be discussed further in the next section.

Industry Responsibility

Industry and society have come to expect a well-educated engineer to be developed within a certain period and that the engineer will possess the necessary attributes to add value to industry. However, industry and society expectations are beginning to outstrip the abilities developed by new engineers under cultural norms. The business community can and should become involved. Some industrial firms have become deeply involved with education. Industry has created scholarships and contributed to existing programs or professional associations that help students pursuing technical degrees. Others have become involved in various industry-educator consortia. Sill yet some universities have developed programs whereby a limited number of highly qualified students are completely funded and often times taught by industry partners. The question of how to produce the well-educated engineers industry desires and society demands still exists. Industry is beginning to understand its role in shaping future engineers to meet the needs of society rather than relying solely on academia to autonomously produce engineers that meet industrial demands.

For scientists and engineers in industry, questions of technological competition drive the necessity to innovate and thrive. Science and engineering have contributed to economic development, security, education, and well-being throughout history. Technology and science are basis upon which improvements to life quality and economic strength have been developed. Industry is beginning to recognize new challenges in future science and technology fields. In order to overcome future challenges and continue to provide life enhancing products society has come to expect, more young people must be inspired to thrive in advanced technology careers. Meeting these challenges is an effort that will require cooperation between academics, industry, and society. In a speech given by Andrew Gould, CEO of Schlumberger Limited, to the annual Asia Oil and Gas Conference, he offered this insight to today's challenges that limit industry's capacity to respond:

> In my opinion, the only serious constraint to a smooth, steady increase in new supply is in the availability of people with proper experience and sufficient technical education. Unfortunately, a shortage exists at almost all levels of our industry. This is the result of the under-investment in new talent, and the discouragement of existing talent, over the last twenty years. Solving the human resources problem will not be possible without a massive cooperative effort on the part of the industry. [20]

Attracting and retaining talent is a key challenge for industry. Academia and industry could and should do more to promote additional education for a larger number of American students. Industry has noticed a decline in American students and has made public the looming problem of replacing a large retiring workforce. Now industry needs to take a leadership role in promoting more graduate education for American students.

In fulfillment of all requirements of the record of study, observations made by the intern during the internship are discussed in the next section. The observations include challenges, frustrations, and lessons learned outside academia.

INTERNSHIP OBSERVATIONS

The following details some observations made during the course of the internship in an attempt to explain some of the difficulties and frustrations experienced by the intern. During the internship period, a far greater number of significant events and interactions occurred than can possibly be discussed. A lesson learned, often a misconception with new engineers, is that engineering in industry is not the same as engineering in academics. One cannot expect to be given a problem that can be simply solved by finding the correct references and mathematical approximations to describe the physical interactions involved and develop a design or idea to solve the given problem. Engineering in industry is achieved by utilizing many different resources intermingled within a complex organization. There does not seem to be any set laws or principals that shape the daily interactions engineers encounter. Within a small-defined group and area of an engineer's experience, some general guidelines for interaction can be found. However, these are not universally applicable, especially in a world of cross-functional education and work experiences with multi-national cultures to consider. The new engineer leaves academia with a sound technical knowledge, and a lot to learn.

During the internship, multiple projects were assigned from different project managers simultaneously. Little guidance was given as to the importance of a project leaving the intern to prioritize projects after discussions with the involved managers. Generally, the projects were somehow inter-related, and after discussions, priority and necessity were established. A perplexing problem existed in that even though the managers were of the same department working on the same product lines and often times utilizing the same resources, the intern found that often times neither manager was fully aware of what their counter part had assigned or was planning for the intern. As a result, organizational conflict developed due to the all too often problem with lack of communication. Although major issues rarely occurred, the common annoyances and minor conflict imposed that could have been mitigated through better communication only leads to frustration of all parties involved. Frustration not addressed can eventually evolve into a more serious conflict scenario requiring substantial effort to resolve. Although this progression of events is not common, the parties evolved must be aware of the possibilities that a common annoyance could covertly escalate to higher order problem.

An attitude altering experience encountered by the intern was in the form of a drastically different workplace environment and project assignments than expected. A substantial shock to work habit and attitude was applied to the intern immediately upon entering industry. Although company training and introductions exist, the new expectations of the intern were so foreign that a complete re-learning of what engineering really encompasses in an economic driven environment was required. A major shift of perception in many areas such as expected breadth of knowledge, independence, financial responsibility, complexity of issues and personnel interactions is experienced. Individual perception shift is not uniformly applicable to all engineers entering industry since different companies of different size and organizational make-up will require a different mix of these and many other factors surrounding an engineering task. Regarding this internship experience, the intern found that detailed and specialized knowledge gained in graduate collegiate studies was rarely utilized. Expectations of the intern's knowledge and capability were expected to be widely varying but not necessarily deeply concentrated in any way more than a good understanding of all concepts along the traditional lines of major academic discipline.

In academic studies just prior to the internship, an emphasis was put upon working in teams. This is an example of how adjustments are made to academics at the request of industry. However, industry experience has shown that the level of independence varies with the project. In academics, a problem is stated and there usually exists one best solution. In industry, a problem may be presented to the project engineer to work on independently or with a team.

Financial responsibility changes in that during academic studies the student is usually left to find the best solution at the best cost. Yet in industry, this function was many times removed from the intern's responsibilities in order to simplify accounting and supply chain management, often leading to acquisition times and costs far exceeding the intern's expectations. The intern was tasked with keeping cost as low as possible, yet when orders were placed the intern had little influence over awarding work or choosing suppliers.

Problems faced in industry are more complex. They are not necessarily more complex in a scientific and engineering manner but in the organization through which the solution is achieved and implemented. In academics a 1-to-3 person team may completely solve, design, order, test, implement, and phase out a solution. Industrial solutions seemed to take longer to develop. Several people must be continuously updated and the intern had only a small part in some of the steps of developing a solution. The large range of freedom and various tasks to be completed in academia during research projects is largely removed. The intern was presented with the necessity to communicate needs and desires to others that would then provide the necessary service to the engineering project. The engineering process in industry is complex and a fresh out academic engineer is not equipped to fully accept the sudden change required to transition to industry engineering, it must be learned.

Many institutions have enacted programs similar to the doctor of engineering aimed at equipping new engineers with the skill necessary to be effective in industry. These programs are not however currently the popular choice among the small number of graduate engineers. Very few students recognize the potential benefit or are even aware of the option of an industry focused practical degree. More graduate engineers enter into industry than any other discipline, and more executive managers tend to have an engineering background than any other discipline. This leaves one to question why more engineers are not being produced from programs such as the Doctor of Engineering program that seem to provide industry with exactly what is desired, a well-educated, cross-functional engineer.

This is partly due to academic institutions not actively advertising or promoting practical engineering degrees. A stark reality is that today's universities are run very much like corporate business. Research faculty are of the perception that students working on industry oriented practical degrees rather than in-depth research oriented degrees will not attract funding. Unfortunately, in today's universities and research institutions, students not directly related to research funding efforts are of little use to academic researchers. Another hindrance to students pursuing education involving both research and industry oriented practical engineering is the reaction of industry to the new engineers.

During the search for an internship site, many potential employers simply did not know how to facilitate a new engineer with such a complete and extensive education. The intern was too educated for entry-level work, yet not seen as experienced enough for anything other than entry-level positions. Industry has been presented with exactly what is desired, a highly effective, well-educated, cross-functional engineer. Yet in general, industry has balked at the idea of implementing such engineers. Most employers prefer to hire students with a bachelor’s or master’s degree. These students have a sound technical background. However, one advantage is that they can still be essentially molded to fit into a particular organization with little resistance. A higher educated engineer requires greater maneuvering room and greater compensation.

Exclusive of degree programs expressly designed to expose the engineer to higher levels of soft skills, most engineers learn the communication and business tactics necessary to excel while on the job. All else being equal, the technical background an engineer gains must provide some benefit as to leadership capability when compared to other disciplines base upon the number of engineers in leadership positions. The point to be conveyed here is that historically, more than any other discipline, engineers have become top industry leaders. Industry is being presented with the opportunity to hire engineers with the exact training and characteristics reportedly most desired. The point that must be made and acted upon is that academia needs to encourage more students to seek out such practical education and industry needs to do a better job of supporting academia and incorporating the engineer into the organizational structure.

SUMMARY

The basis of the Doctor of Engineering program is to prepare individuals for professional engineering careers in business, industry, and the public sector by emphasizing engineering practice, public service, and development of leadership potential. Even after having completed a highly customized degree plan containing both technical engineering coursework and professional development courses, the intern was faced with a significant challenge immediately upon entering the internship. The non-technical interaction became more consuming of time and effort than technical engineering activities. The intern was frustrated by industry's reaction to a new engineer with the educational background afforded to a student through the Doctor of Engineering program. Although this program prepares engineers to meet and exceed industry's cry for a more complete engineer that can go beyond the technical aspects, initial reactions by industry were found disappointing. Industry has become accustom to hiring technically sound engineers expecting to invest substantial time and money to help the engineer acquire other professional skills. This can take anywhere from 3-to-7 years, the time at which most technical engineers are presented a choice of technical or managerial career paths. However, in the case of the Doctor of Engineering graduate, the technical and professional knowledge has already been obtained and industry struggles with placement of these individuals. The intern observed that the internship site initially ignored the additional training brought about by the Doctor of Engineering program. Yet after a few interactions where the intern was able to express a deeper understanding of problems beyond only technological issues, supervisors quickly began to notice a difference in engineering performance.

Although frustrating, this response was not un-expected. Programs such as these are recent relative to traditional collegiate studies. Industry, students, and even faculty have very little understanding of the benefits of such a complete education. Most students choose, or are directed by faculty to pursue, a philosophical-research oriented education. This can be attributed mainly to the limited industrial experience most faculty possess as well as the unfortunate reality that a student pursuing a Doctor of Engineering is of little use to faculty involved in funded research. To break this barrier, industry must become involved in designing and funding education programs such as the Doctor of Engineering. This program has the potential to produce professional engineers that will become leading professionals in the world economy. However to realize the optimum benefit, industry and academia will have to work together to learn their respective needs and capabilities, as well as promote this level of education.

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APPENDIX A

Internship Supervisor Comments

Bradley Kerr has done well in the RS&P Sustaining group. He has been assigned responsibility for resolving Sustaining Requests from the field organization and from the manufacturing group at this location. He has done well at evaluating the request and identifying the underlying issues. He has done a good job of looking at several options for the resolution of the issue, and, after evaluating each option, deciding on the best solution. Identifying the best solution involves considering cost, ease of implementation, reliability, material availability, and many other things. He has demonstrated good management skills in prioritizing tasks, and directing people in the whole process of resolving a Sustaining Request. Bradley is on track for meeting his individual objectives for Sustaining issues, and the group objectives are also on track. In addition to the main focus of the Sustaining group, Bradley has kept up with the other objectives required in the job. He has completed all the required safety training, and has kept all the training certifications up to date. He is up to date on the Advance training, a course of study that gives the new employee a good basic understanding of the different aspects of their job in Schlumberger. Bradley has completed the objectives outlined in his Internship program.

Signed: William E. Brennan III
Project Manager
Sustaining, Reservoir Discipline
Schlumberger Sugar Land Product Center

APPENDIX B

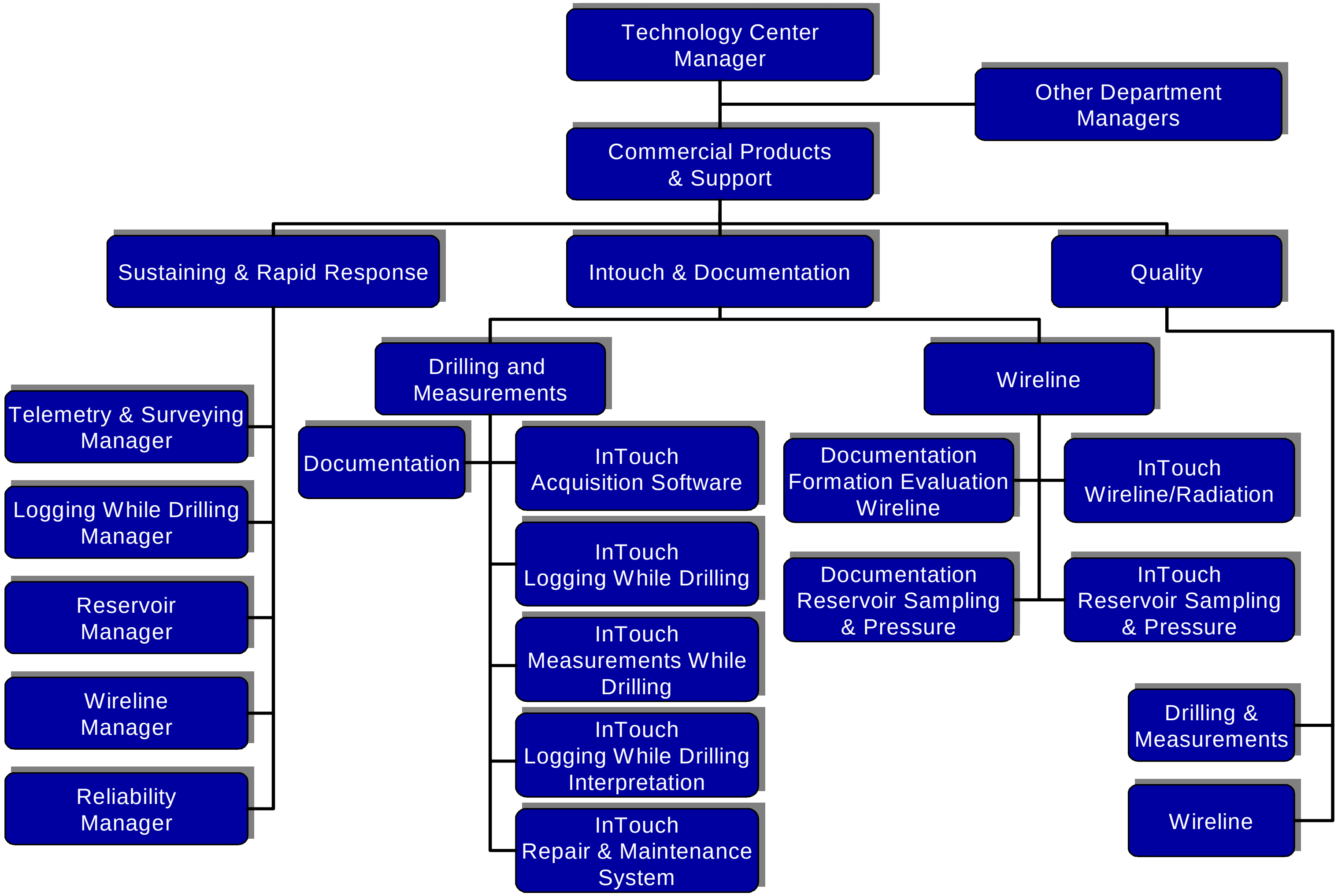

Fig. 13 Internship Site Organization

VITA

Bradley Gray Kerr earned his Bachelor of Science in mechanical engineering from the University of Arkansas in 2002, his Master of Science in mechanical engineering from Texas A&M University in 2004 and a Doctor of Engineering from Texas A&M University in 2006.

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