CHAPTER SIX

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GEOPHYSICS SO MAGNIFIQUE DEFINES SCHLUMBERGER TECHNIQUE

INTRODUCTION

Schlumberger technique is indeed magnificent when it comes to the application of geophysics to oil field problems. You undoubtedly remember that the science of geophysics is simply the measurement or description of geological features and/or formation parameters in situ (in place) through physical measurements. Schlumberger has, indeed, been very successful in this particular discipline and in so doing has become the most successful wire line company in the entire world. Their corporate motto or slogan was and, I assume still is, **"To help our customers find and produce more oil and more gas more efficiently".** To that end they have committed many times the normal corporation's investment in research to find new and better ways to measure critical geological parameters applicable to the search for oil and gas as well as in the development of appropriate hardware to provide those required services. This resulted in the evolvement of a strong research group as well as a capable engineering group to support field operations.

Schlumberger was founded by two brothers, Conrad and Marcel in France in the early days of the oil industry. I don't remember the date but it seems it was in the twenties if my old bean is serving me correctly. You'll have to have pity on me and remember I'm writing all this from memory and am not taking time to dig up facts, which would make things a little more authentic. I believe I'm close. Anyway, there wasn't much market for their electrical measurements in defining ore bodies, their original idea I believe, and so they came to the United States to apply it to oil wells in the early thirties (maybe). Their electric log proved valuable as a means of correlating geologic horizons from well to well. Although such original measurements may have inferred the presence of oil or gas, there was no real means to calculate water saturation, as was described in chapter five. Obviously they were successful and their meager beginning has now become the worldwide corporation it is today. Those brothers instituted much, if not all, of the basic management philosophy, which I served under during my working years. Policies, such

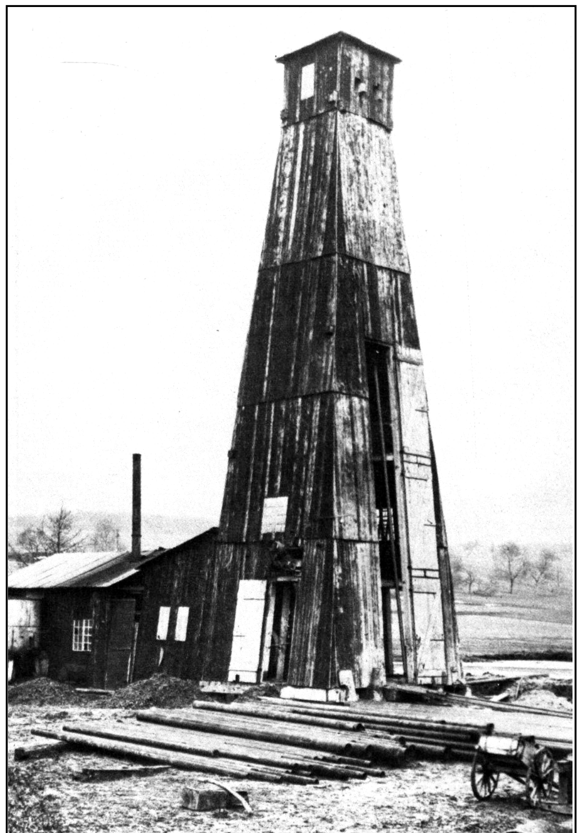

Figure 6-1 Dieffenbach # 2905, rig #7, the well in Pechelbronn, France, site of the 1st electric log, recorded on Sept. 5, 1927.

as, hiring only college graduates as field engineers, requiring long field hours, having a strong pay scale and heavy research investment, etc. were all in force from the company's foundation long ago.

A LITTLE SCHLUMBERGER HISTORY

I stumbled across an old booklet I was given, while still with Schlumberger, titled, "SCHLUMBERGER, THE FIRST YEARS". It doesn't exactly validate my memory but it does indicate I wasn't far off with some of the dates I just mentioned. I thought I would include a few pictures and comments from that booklet to lay a foundation for later comments. They may not be exciting but I believe you will find them curiously interesting. Now, here are the quotes from the booklet.

"To help our customers find and produce more oil and more gas more efficiently".

THE SCHLUMBERGER BROTHERS

"Both Conrad and his brother Marcel were born at Guebwiller in Alsace. Their father, Paul, was in the textile business. Conrad, born in 1878, was six years older than Marcel. He went to the Ecole Polytechnique in Paris and then to the Ecole des Mines where he was later appointed professor of physics in 1907. Marcel Schlumberger was graduated from the Ecole Centrale as a mechanical engineer and later worked for a mining company."

Figure 6-2 Logging a well in Pechelbronn, France in the 1920s.

At the Ecole des Mines Conrad began to study an approach to geophysics based on resistivity of rocks. The wide range of resistivity values which he measured in the laboratory encouraged him to continue this research."

ELECTRICAL EXPLORATION

I'll continue with information from the booklet but not as quotes. Conrad made his first surface measurements of rock at the family estate in 1912. Later in 1913, he demonstrated that surface measurements of resistivity could be correlated with underground geology. Apparently he outlined the extension of a fault in Normandy as well as a pyrite ore body in Sain-Bel, Rhone. In 1914 he successfully discovered an extension to a copper ore body at Tilva Roche near Bor, Serbia. About that time World War I caused the cessation of his work while he served in the French army. In 1919 he resumed his experiments and was joined by Marcel. Apparently, their work wasn't commercially successful until about 1923 but their father, Paul Schlumberger, had financed their work. Now, let me share another quote from the same booklet, which may be of interest.

"The year 1923 was an important date for Schlumberger. Conrad resigned from the Ecole des Mines to devote his entire time to the new venture. In Rumania a map of resistivity made it possible to delineate the contours of the salt dome of Aricesti. This was not only the first salt dome to be delineated by surface electrical prospecting but it was also the first oil productive salt dome to be mapped by any geophysical technique. For Schlumberger it was the first major successful survey made for an oil company and marked the beginning of Schlumberger oil field activity."

THE WORLD'S FIRST ELECTRIC LOG

"On September 26, 1927, a Schlumberger crew ran the first electric log ever recorded in a drill hole. That event completely changed the course of Schlumberger." That is to say, their full efforts were then applied to oil wells. The crew who ran the log was composed of Henri Doll, Conrad's son-in-law, Charles Scheibli and Roger Jost.

"The method was painfully slow. Measurements were made point by point; instruments were raised and lowered by a hand winch. The significance of the log was immediately apparent when it was compared with drillers' logs from other wells some distance apart. The characteristic resistivity patterns could be correlated easily giving a clear picture of the geological formations of the area."

WELL LOGGING ABROAD

In 1929, well logging crews were sent to the United States as well as to Venezuela and the Soviet Union. Apparently, logs were run in Texas, California, Oklahoma and Louisiana but little interest was raised because of the depression and the plentiful supply of oil. Consequently, Conrad and Marcel withdrew from the USA. Interest continued, however, in Venezuela and the USSR. Now here's another significant quote.

"While the field crews were struggling to get recognition for the new oil field service, a very important discovery was made in 1931 that would greatly increase the effectiveness of well logging. It was found that a natural voltage was generated at the level of permeable beds in a borehole filled with drilling mud. Though still a somewhat misunderstood phenomenon, it would allow permeable and impervious beds, such as sand and shale or limestone and shale, to be differentiated quite clearly. The combination of self-potential and resistivity measurements was of much more value than the resistivity log alone in locating oil and estimating production possibilities. This greatly helped Schlumberger to successfully introduce the radically new technique of logging in the middle of the depression."

The Royal Dutch Shell group in Venezuela brought Schlumberger back to the U.S. in 1932. Success was immediate with the combined SP and resistivity log and by September 1934, they had 40 employees with 11 trucks and 12 engineers. They grew rapidly and I joined the company just 21 years after that in July 1955. In that time span (1932 to 1955), technical advancement was rapid and the services I witnessed that first year were much improved as well as more extensive in number.

It was found that a natural voltage was generated at the level of permeable beds in a borehole filled with drilling mud.

Now, a few words about figures 6-1 through 6-4 which are photos taken from the booklet I mentioned. Figure 6-1 is the drilling rig on the first oil well ever logged in the world, i.e. the Dieffenbach No. 2905, which was accomplished in 1927 as noted. Note the derrick is made of wood. It was powered by a steam engine housed in the building just behind it. In the foreground is extra drill pipe lying on the ground and to the right, you might notice drill pipe being pulled through the tall door. Modern rigs, of course aren't enclosed except in special circumstances such as extreme cold or within city limits to meet ordinances. They do, however, have a V-door through which the drill pipe is hoisted when needed which is the equivalent of the door you see in the photo.

Figure 6-3 William Gillingham & a Schlumberger truck logging a well near Houston, Texas in 1934.

In the next photo, figure 6-2, is a similar rig but it includes an early logging unit. Notice the winch is being cranked upward by hand. The resistivity measurements at that time were still made while the down-hole equipment was stationary. Typically, they took a reading every meter, about 3 feet, and plotted it on a strip chart opposite the depth of the tool. You might also notice a fresh snowfall, which must have made things a little miserable in those days.

SUCCESS IN THE UNITED STATES

As already indicated, Schlumberger was successful in their second attempt to serve the oil companies in the United States. Figure 6-3 was taken near Houston, Texas at a well site in 1934. Obviously a good deal of improvement was made in the years, which had intervened. By this time the winch and recorder were both mounted on the truck. Furthermore, the truck engine could now drive the winch, as evidenced by the chain drive from the rear axle hub to the winch. If you look closely, you can see the back wheel is jacked up into the air to allow the wheel to turn while truck engine is driving the winch. You might also notice two braces behind the truck sticking into the ground. In later years, these were called spades and were secured in the ground to prevent any truck movement toward the well as line weight or tension increased. I have a little story related to those contraptions, which I'll share with you in chapter nine. As noted in the photo, the engineer doing the recording was Bill Gillingham who was president of Schlumberger, USA when I joined the company. It seemed to me that having higher management evolve from within the field ranks was a distinct advantage in that they understood the field engineer and the problems he faced. Bill Gillingham was quite congenial when he appeared at Schlumberger socials in conjunction with a school or other meeting. I remember a joke he told to a group I happened to be in at such a school. It went something like this.

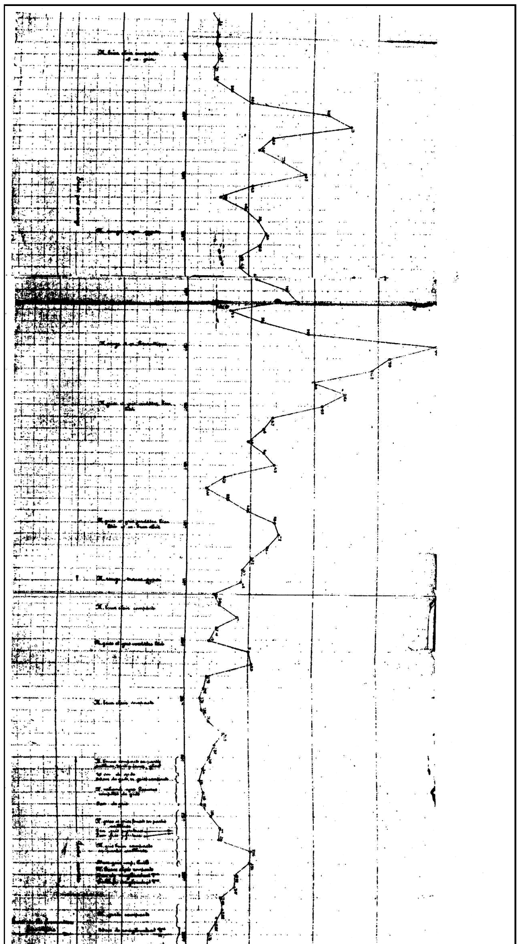

Figure 6-4 A copy of a portion of the resistivity log run in the Dieffenbach 2905, the first ever run in an oil well.

"There was a young doctor who graduated from Baylor Medical School, had completed the necessary internship, etc. and finally decided to set up practice in a quiet little Texas community. Now, it seems he was specializing in treatment of homosexuals as well as hemorrhoids for which he immediately began to advertise. Up went his shingle stating,

'Dr. Smith - Specialty Services for Homosexuals and Hemorrhoid Sufferers'.

Of course the residents in this conservative little town felt that his sign was a little too blatant and took their feelings to the town fathers. Not wanting to offend the new doctor, these gentlemen asked him in a friendly manner if there wasn't some way he could rephrase his sign and still meet his advertising needs. The young doctor gave the problem a little thought and quickly came up with another sign, which he posted the next morning for the town's citizens. It read something like this,

'Dr. Smith - Providing Medical Services for Queers and Rears'.

Of course, that didn't meet the town fathers' approval any more than did the first and they quickly let it be known that a change would be necessary. This kind of disgusted and upset the young doctor but after contemplating the problem for a couple of days he finally came up with a shingle he felt would satisfy his need to advertise and yet one the town couldn't fault him for. The next morning residents were greeted with a sign that stated his specialty in very simple terms. It said,

'Dr. Smith - Specializing in Odds and Ends'.

Needless to say, he got a big laugh including mine. I had to admit it was funny and probably would have roared even if he wasn't the President of the company.

REPRINT OF THE FIRST LOG

Figure 6-4 is a copy of a portion of the log run on the Dieffenbach 2905 in 1927, the first resistivity log run. The SP, which was such a big advantage, didn't appear until 1932, you'll probably remember. Although it may not be readily apparent, on that first log, each horizontal line represents one meter or 39.27 inches. Each vertical line is one-ohm meter^2/meter, the chosen unit of measurement. Notice the value of resistivity measured is listed at each point and they are then connected with a line to provide the log trace. Apparently no scale was provided at the top. Keep in mind that each measurement was taken with the sonde stationary. Once in position, they had to adjust a couple of rheostats or variable resistors to balance the bridge they were working with. A continuous recording was still a ways in the future. You might also observe that all writing is in French. So, if my explanation in the rest of this chapter comes across like French to you, the reason should be quite obvious.

PERSONNEL

The work ethic was still well among Schlumberger field employees during my years. Those looking for a forty hour week quickly fell by the wayside because of the long hours required. Payment according to productivity was factored into the salary structure. Over all payment and benefits were among the top offered to engineers graduating from college, as was opportunity for advancement. Such philosophy attracted not only hard working but also a bright and hard-nosed group of field engineers from which management ranks drew their candidates. Consequently, they assembled and constantly renewed a management group composed of high achievers that moved up through the field ranks. Schlumberger's demand for quality and hard work as well as commitment to the corporate motto became a part of every successful field engineer's developing psyche. All of this has apparently paid off in that Schlumberger has remained successful over the years, weathering all the economic down turns of the industry during my time, and it seems, they have apparently remained so judging from all the information I receive.

MANAGEMENT PHILOSOPHY

One of the very attractive fringe benefits offered employees was a retirement package made up of both profit sharing and a pension. The profit sharing plan required no employee contribution during my tenure, and Schlumberger would contribute up to 15% of one's salary depending upon the corporation's yearly profit. In by far the majority of years, I received full contribution. All of this has proven a blessing to me, allowing me to live comfortably since retirement. Later, they added a pension plan, which was obviously well designed and managed because it has remained solvent over the years and even appears to be gaining strength. The last comment stems from reading their annual statement and having received three raises since retirement rather than suffering pay cuts, as many retirees seem to grapple with. For all of this, I am extremely grateful and have a continuing feeling of good will towards that corporation I spent over thirty years with. The integrity of its officials was above reproach.

I continue to admire their management philosophy in spite of the rigorous demands often placed upon employees. Such philosophy was honest and direct during my time and I always knew what was expected of me. I felt a high degree of integrity involved with their decisions, a characteristic that seems less and less prevalent among corporations as well as society at large today. I attribute the strong retirement benefits I am now enjoying to those ethics, which served as a foundation for their management philosophy. Though I may not have agreed with everything I experienced, I felt I could trust the policies and decisions made over the years as being fair and just. Well, enough of management philosophy and my retirement check and on to geophysics, a most interesting and honorable discipline.

WINCH AND RECORDING UNITS

After a little head scratching and associated pondering of the problem of presenting the geophysical techniques employed by Schlumberger, I decided to divide the business I so enjoyed into three parts or chapters, that is, an introductory chapter which will include a description of various winch and recording units with which I am familiar, a chapter addressing open hole measurements or those made before casing is run and yet a third one describing cased hole services. There is some overlap in the winch units used in open-hole and cased-hole services as well as in some of the services provided. Even so, when I considered the volume of material involved, it seemed best to allow a separate chapter for the winch and recording units and to concentrate on the measurements and other services utilized in uncased and cased holes in the latter two. So, we begin with the winch unit and its recorder, which are used on every trip to a well.

TRANSPORTATION OF MEN AND MATERIAL

A typical crew needed to run the services in open and cased-hole situations was composed of three people, i.e. an engineer and two operators. The engineer was in charge of the operation and carried out all communication with the customer, as well as being responsible for any significant decisions, regarding the operation. He had the responsibility of seeing that all critical equipment ordered by the customer was loaded on to the wire line unit prior to its departure. The wire line or winch unit was manned by the two operators and had special compartments for supplies, tools to be run into the well, surface control equipment and auxiliary devices that might be needed.

The engineer traveled to and from the well site via an assigned auto, which he utilized in other responsibilities as well. It also provided flexible transportation when necessary to allow crews to leave a winch unit at the well while they found a café or motel to eat and rest during lulls in the operation. Because crews were on call 24 hours a day and often worked around the clock, it was important to take advantage of opportunities to eat a decent meal or sleep in a bed when possible. As you shall see, when I relate some personal experiences, we often existed at the well site munching on crackers and Vienna sausage while washing the same down with black coffee. Sleep at the well site consisted of taking turns in the sleeper for the operators with the engineer trying to relax in the back seat of his car. Thus, sleep came when one was dead tired and meals were taken when the stomach growled so loud it interfered with the recorded data. Thus, waiting time at the well-site, provided the crew with the time necessary to get a genuine meal and, if sufficiently long, an opportunity to sleep in a motel with a real bed.

Of course, we couldn't predict the length of waiting time nor could we predict its occurrence. As a result, we managed to take advantage of each and every such opportunity with an effort to satisfy the most urgent need of the moment. We might make a quick trip to town, eat and then come back to sleep until we were called or we might just simply sleep if time was short and/or distance to the nearest restaurant was too great. I have eaten five meals a day as well as just one or even none because of such circumstances. Ah, the joys of life in the field. How it tests your resolve for the engineering profession. Did I really go to school an extra five years for this opportunity?

THE LOGGING TRUCK

As you have seen, the original logging units were crude at best and provided little or nothing in the way of comfort or protection for the crews operating them, i.e. figures 6-2 and 6-3. As time

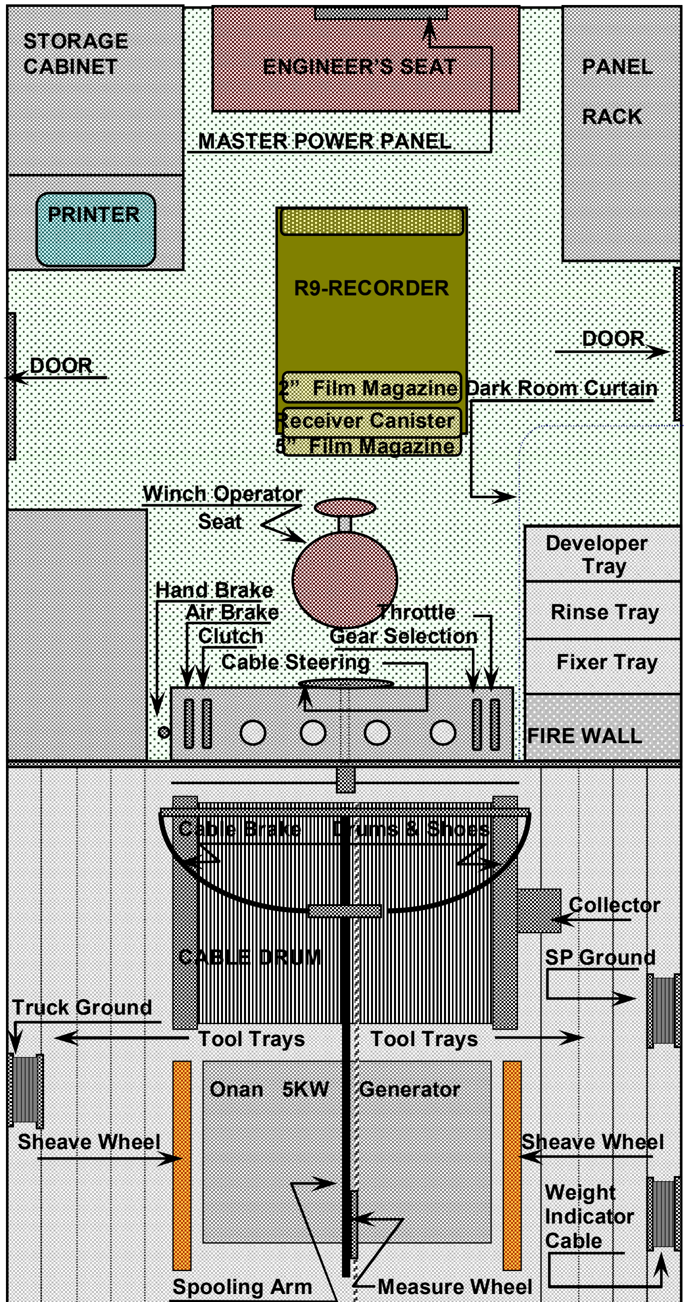

Figure 6-5 A plan-view of a logging truck through most of my years with Schlumberger.

moved along, improvements rapidly appeared and by 1955, when I was employed, the logging truck had evolved into a rather nice mobile laboratory, at least for those days. In figure 6-5 a plan view of a typical unit is depicted. Although all details can't be filled in, most critical items are shown. Schlumberger gave their trucks numbers according to a given production series. The floor plan is essentially that of a 500 series, a 1500 series, a 2500 series, a 4500 series and finally a 7000 series truck. There were also a 700 series and a 1700 series truck, which differed in floor plan but otherwise provided the same features. Each series of trucks was an improved version of the preceding one with increased capacities of various kinds. But, enough of that, let's get on with a tour of the basic floor plan shown in figure 6-5. These luxurious quarters might astound you with their plush carpeting, world art, soft music, etc; ha-ha.

THE WINCH COMPARTMENT

The firewall, as indicated at the right center of the diagram, separated the truck bed into two parts, i.e. the recorder cab and the winch area. The latter was exposed to the elements, although it was partially protected by tarps, while the recorder cab was enclosed and heated when needed. Air conditioning didn't come along until the arrival of the computer age, which was well after I left the field. Let's consider the winch area first.

Thus, sleep came when one was dead tired and meals were taken when the stomach growled so loud it interfered with the recorded data.

The cable drum or winch for raising and lowering tools into the wells was powered by the truck engine and by 1955 was coupled to the engine via a PTO or power-take-off unit. The truck auxiliary transmission was placed in neutral while the main transmission was coupled through the PTO to the winch drive. The operator running the winch had a three-speed transmission with reverse available at the winch console. This, coupled with the main truck transmission and an air throttle, provided winch speeds of about 600 feet per hour to maybe 50,000 feet per hour. Thus, one could run at about 1000 ft/hr for radioactive logs, 8000 ft/hr for electric logs or 20,000 ft/hr when coming out of the hole after a log was complete. The spooling arm guided the cable on to the drum so as to keep it neat and tightly packed and was controlled by the winch operator through the cable steering wheel. A unique cable system transferred steering wheel movement to the spooling arm allowing it to move back and forth across the drum as needed to align the cable. The drum brakes were large bands applied against the brake drums on either end of the cable reel. They could be controlled by a hand or air brake. The air brake was used when stationary and the hand brake when slowing the descent of a tool into the hole. The collector was composed of a set of eight brushes (one for each cable conductor and one for ground), which provided electrical connection between the moving cable and the stationary recorder cab. The logging cable included seven conductors, six of which were wound in helix fashion around the seventh acting as the core. Intervening space was filled with filler material to provide a solid mass of conductor and insulation. Around this mass two layers of steel wire were wound in opposite directions of one another, which provided the necessary strength for support of the various tools, which were run. (See figure 6-29) Typical open hole logging cable size was initially 9/16" and later 15/32". The latter size allowed more cable to be placed on a drum and thus increased depth capability but still provided the necessary cable strength. Cased-hole applications generally required a single conductor, which allowed smaller cables and still meet necessary strength requirements. They were typically 7/16" down to 3/16" or even 1/8th for the various service conditions. Small diameters were extremely important when working under pressure, as you shall see in chapter eight, which deals with perforating operations, as well as production logging. Such operations are carried out under pressure.

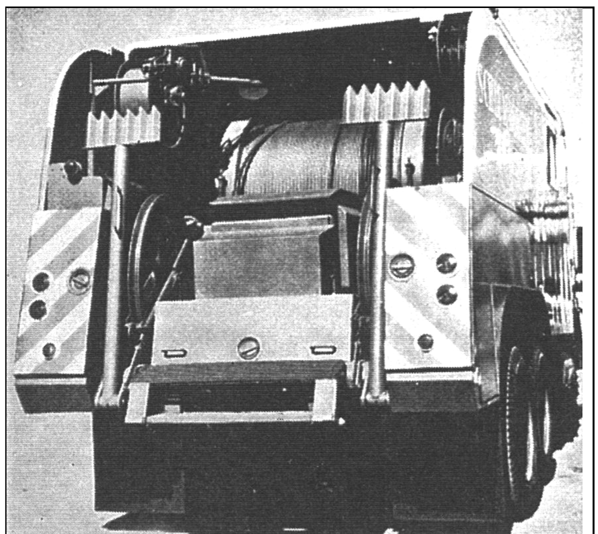

Figure 6-6 Rear view of a typical Schlumberger logging truck around 1962.

You will notice 3 small spools of cable mounted along the sides of the truck in the rear section which are labeled, truck ground, SP ground and weight indicator cable respectively. These are also visible in figure 6-6, which I added as an after-thought. The first, a truck ground, was used to ensure the truck chassis and the rig-floor were kept at the same potential when working with explosives. Small differences could result in the detonation of a gun on the surface under the right conditions. This helped ensure such an incident couldn't happen. The second spool, SP ground, provided a return for the SP circuit to mother earth, which was necessary in recording that particular signal. We'll talk about it in chapter seven. The third spool provided connection to a weight indicator, which was installed at the rig and measured the line tension of the steel logging cable. As you shall see, such information was essential in determining tool movement or lack thereof with all its associated inferences. The engineer was constantly monitoring the weight indicator as the tool traversed the borehole.

Each truck had a generator to supply the electrical requirements of the services run. In the early years it was a 3.5 KW gasoline driven generator and was later upgraded to a 5.0 KW diesel generator. With the advent of the computer controlled equipment and its necessary air conditioning, it was raised again, I believe, but to what power level I can't say. They were built by ONAN and were so referred to throughout my career. The ONAN compartment is visible in figure 6-6 as well.

Figure 6-6 is the best picture I could find of the truck spades, as they were called. These devices were used to prevent the truck from being pulled towards the rig by the high line tension often experienced. Once the truck was in position, they were lowered and planted firmly in the ground. Any pull on the cable simply planted them a little deeper and prevented any truck movement. This was important both from a safety standpoint and a depth accuracy standpoint.

At the rear of the truck were two compartments, which opened to the racks where the down-hole tools were carried. The doors are shown in figure 6-6 and the slots in figure 6-5. These slots were big enough to handle a 3 5/8" tool and were about ten feet long in most cases. Some devices exceeded 10 feet and the units had 3 or 4 slots capable of holding a 14-foot tool. These slots were primarily for transportation and were designed to prevent tool problems. As the use of electronics increased, it became necessary to hold the tools firmly to the truck to minimize tool damage from rattling around while negotiating rough roads. This was done through air bags, which were inflated once the truck was loaded. These bags held the tools firmly to the truck chassis, which drastically reduced the G forces they experienced during transportation. In very cold climates, the racks were also heated which improved surface calibrations and tool reliability. Keep in mind that the down hole tools in such areas might experience temperature ranges from 60 below zero (Fahrenheit) to + 350^{o} F. These severe environments required thoughtful care of our logging tools as well as having the best designs that were possible.

Keep in mind that the down hole tools in such areas might experience temperature ranges from 60 below zero (Fahrenheit) to + 350 ^{o}F.

The sheave wheels, whose use I'll explain a little later, were latched down to the truck bed alongside the Onan and transported to and from location. They were utilized in rigging up such that the tools could be run into the well with the least amount of effort. Now, let's move inside the recorder cab.

THE RECORDER CAB

Besides containing the controls for winch operation, the recorder cab also provides a means of operating the down-hole tools, processing the various measurements made, recording them versus depth in the well on photographic film, developing that film and providing the customer with any number of prints. Thus it is, in reality, a mobile laboratory for geophysical measurements. We'll take a little time to discuss each of these functions so you'll be better equipped to digest the many escapades which I experienced as I sat on my little behind betwixt the panel rack & printer with the power panel behind me and that marvelous machine called an R9 recorder before me.

Let's begin with the console provided for the winch operator directly in front of the firewall. This console had several dials or meters, which allowed the winch operator to monitor critical functions. There were many more than the four I have illustrated. I'll try to list the meters, at least to the extent I can remember them. First there are monitors for the main truck engine such as a fuel gauge, an oil pressure gauge, a temperature gauge and an engine RPM meter with their obvious purposes. Then there are three meters for the winch, which provided cable speed in feet per hour, cable tension in pounds and also the presence of a magnetic mark on the cable every 100 feet.

We'll discuss the latter one in detail under depth control but let me just say here that the mark was set to occur at a specified number such as 75', 175', 275' etc., which the engineer could control. By doing so during the logging operation, he could keep the depth of the various logging anomalies, which occurred on the film, accurate within the bounds provided by the cable measurement system.

Cable speed is important to note while logging. Each log type had a designated speed for optimum results. Also, tool speeds had to be noted and controlled, as well, when the tool approached obstacles in the well such as a casing shoe, the rams in a blow out preventer or maybe just a known tight spot.

Cable tension is monitored for several reasons. It increases with tool depth and weight and is also affected by such things as borehole size and mud weight in addition to viscosity. Consequently, normal values depend on the borehole environment as well as the depth of the well. In a given well, a normal weight is established when moving upward and anomalous conditions are referenced to it, i.e. when the tool is floating or dragging. Normal weight will typically be 500 pounds or so at the surface and maybe 2500 to 3000 pounds at 10, 000 feet. When logging, an increase in weight means the tool or cable is sticking and the engineer can take certain preventative actions to minimize the possibility of a fishing operation. We'll talk about that particular logger's bane in more detail later. When going in the hole the winch operator has to be sure the tool is falling as fast as the cable is un-spooling. If it doesn't, the cable may develop loops and actually tie its self in knots, which leads to all kinds of unhappy circumstances. Consequently, he monitors and utilizes the cable tension as a guide and may stop and move the tool upward to compare the indicated` weight with a normal value at that depth. He also monitors it closely when approaching a casing shoe or the surface pressure equipment to be sure the tool doesn't accidentally catch on something. One has to react very quickly when that happens to prevent pulling the tool off with its ensuing fall to the well bottom. I have a personal story to tell in that regard at a later time. You can see that winch operation requires an alert and knowledgeable operator. No sleeping on the job, please.

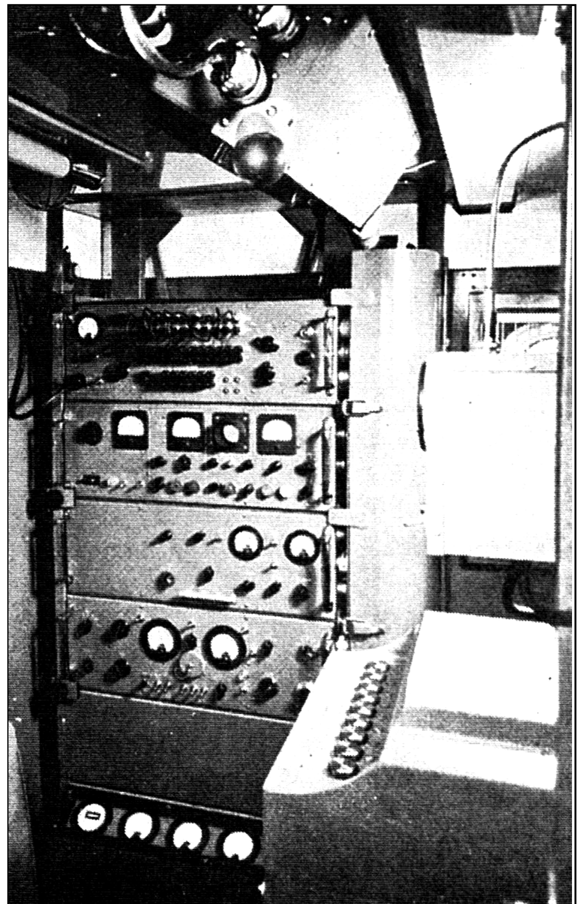

Figure 6-7 The engineer's recording area in a 1500 series logging truck in 1962.

You'll notice in figure 6-5 a device labeled cable steering. It is, in fact, a steering wheel, which the operator uses to move the spooling arm back and forth across the drum and assure a smooth spool. There is also a throttle to adjust truck engine speed with, a gear selection lever to choose the desired winch gear, a winch clutch which engages the PTO to the engine, an air brake for use when the winch is stopped and a hand brake to control winch movement when engaging the clutch or letting the winch free wheel while going in the hole. The latter would be used much like the foot brake of a car while the air brake would be the equivalent of its emergency brake. The operation of the winch is much like the operation of a car with a standard transmission on a hill in that the throttle, hand brake and clutch have to be coordinated as the operator moves up hole from a stopped position. To go down hole, one can engage the winch and un-spool the cable with the engine or he can free wheel. That is, the operator allows the weight of the tool and cable to pull the cable off the drum. In so doing, he controls the winch movement with the hand brake. This is fine on shallow holes or short distances in any hole but extended use in deep holes can over heat the brakes much like a truck's brakes with a consequent loss of control. Needless to say, that is a no-no like loss of truck brakes on a hill.

The dark room and developing trays are just to the left of the winch operator. Notice there are three trays, one with developer, one with rinse water and one with fixer. A dark blue curtain on a track could be pulled around the area to shut out all undesired light. Within the compartment a red developing light was available for the person developing the film. The film canister from the recorder was opened in the dark room and the film processed therein. Typically, the developing water was heated to 70 degrees Fahrenheit and the film rapidly rolled and unrolled within the water for four minutes to provide the developing. It was then moved to the rinse water and rinsed a couple of times. From there the operator moved it to the fixer and rolled it through that solution several times until the background was clear which took about four minutes as well. Once again it was rinsed to rid the film of the fixer solution and then run through a squeegee to eliminate the water. As it emerged from the squeegee, it was wiped with a chamois to assure all water droplets were removed. This hastened drying and prevented unwanted fixer spots, which degraded print quality. Believe it or not, we were concerned about the appearance of our product as well as its technical integrity. A good deal of effort was made to produce eye-appealing prints.

To the right of the winch operator was a storage cabinet for various supplies. In the bottom there was space for the tools to extend into the cabinet and thus accommodate the longer sondes. Another storage cabinet and a shelf for the field printer stood to the right of the engineer. The latter used a high intensity light to expose the ammonia sensitive paper and burn off all areas not shielded by black traces or spots. After being exposed, the paper was run through a developer unit where ammonia fumes turned the shielded traces blue or black depending upon the paper used. Typically we ran several field prints of each service at the well site for the geologist and/or engineer to evaluate the well and make an early decision. He might call the office for additional instructions in some cases after viewing a field print. Sometimes such instructions led to additional services.

This set up is clearly shown if figure 6-7 which also illustrates my little cubbyhole where I spent many an hour.

To the left of the engineer was the panel rack, which would handle about four different panels at a time along with a main power supply and so called gang switch panel used to program cable and recorder hookups. For a given service, the engineer might typically use two or three panels for surface control of a set of down-hole tools. These were connected together via a cable system on the right side of the rack and the measured output signal was sent to the optical recorder known as an R9. This set up is clearly shown if figure 6-7 which also illustrates my little cubbyhole where I spent many hours. This is an older photo, (late 50's vintage) and shows only the electrical survey panel and a microlog panel in the main rack. You can see another panel hung from the ceiling over the engineer's head. That is the tension device panel, which had meters on the front for the engineer to monitor and also fed two meters on the winch panel for the operator. It receives measuring data from the tension device mounted between the elevators and the upper sheave wheel.

This system worked well through all my years in the field because the services run were relatively simple and the required panels were fairly easily combined. However, by the seventies, more and more services were being combined and run on a single trip in the hole. This required the interconnection of multiple panels. Field problems began to occur through faulty cables, which developed through excessive handling, incorrect hookup or simply failure to bring along the proper cables. With computers coming on strong, a system built around such a control device was the obvious way to go. Such computer-controlled surface systems began to arrive in the field in the late seventies and, by the early eighties; almost all logging units, on and off shore, were converted. Even so, my experiences in field units occurred with the older panel systems and consequently this is the environment from which I'll relate my stories. It definitely dates me but then, I never claimed to be one of the yuppie generation, much less a computer geek.

Right behind the engineer's seat was the power distribution panel, which controlled the Onan and supplied power to lights, a. c. outlets, the winch operator's console and a main power supply at the bottom of the panel rack. Directly above and to the front of the engineer was a tension device panel (not shown in figure 6-5) but clearly displayed in figure 6-7 which controlled and processed the signal from the tension device on the rig floor. Tension meters were provided for both engineer and winch operator. The engineer could glance up and monitor both total line weight or tension and incremental weight. The latter was useful in various operational procedures and particularly those involving mechanical sampling. It provided a measurement of pull over normal line tension and thus tool drag and/or release tension. My, how I talked to that unit at times.

Directly in front of the engineer was the R9 recorder as you saw in figure 6-7 which derived its name from the nine galvanometers utilized to record the logging data. The device was really an electro-mechanical marvel and served well from the early fifties to the late seventies. Because it was utilized in so many different ways on the job, I will describe it in more detail in a section all of its own. It was, indeed, a marvelous machine.

THE R9 RECORDER

The heart of the R9 recorder was the nine-galvanometer mirror system utilized to record the various signals processed by the control panels as a function of depth in the well. Everything else in this complex machine was peripheral in nature in that they combined to produce a film grid upon which the galvanometer traces were accurately recorded as to depth and appropriate units of measurement. The finished product was a photographic film of variable length having a grid of three tracks containing the necessary galvanometer traces along with a depth track, which accurately portrayed the desired signal versus depth in the well. Figure 6-8 illustrates a portion of a typical film from a hypothetical electrical log. I don't intend to explain the log at this point but only to illustrate the product, which displayed a given measured signal versus depth. This will help you understand individual logs or records of the various geophysical measurements that are described in greater detail in chapters 7 and 8. As mentioned earlier, the truck also had a printer on board with which any number of field prints could be made, according to a customer's needs. He could then make decisions regarding well operations in a quick and efficient manner.

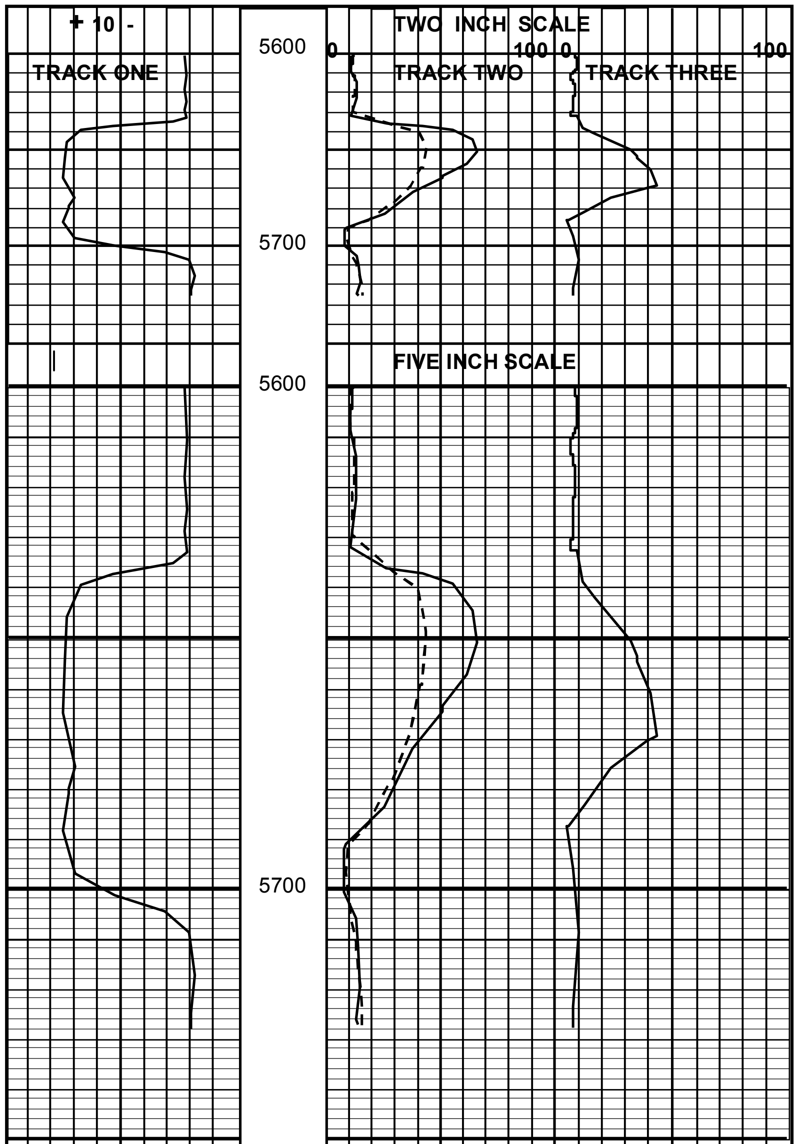

Figure 6-8 An illustration of R-9 recorder film on scales of 2 inches per 100 feet and five inches per 100 feet.

THE FILM RECORD OR LOG

First, let's look at the grid or the lines that make up the graph upon which the galvanometer traces are recorded. Notice, there are both horizontal and vertical lines. The horizontal lines indicate the depth of the tool in the well relative to the surface while the vertical scale, i.e. length of film representing 100 feet, is variable and is selected by the engineer as desired. Also notice, I have chosen to illustrate two different vertical scales in the figure, i.e. 2 inches per 100 feet and five inches per 100 feet. Fifty and 100-foot lines are the darkest in density, ten foot lines next and 2 foot lines the lightest. The latter only occur on the five-foot scale of the figure. This allows easy determination of the depth of a particular anomaly or that portion of the galvanometer trace, which is being considered for log correlation as well as for the accurate definition of zones of interest, which require a more detailed analysis.

Vertical lines define the amplitude of the particular curve being recorded and are scaled in units compatible with the particular measurement that is being made. I have shown three different scales for the curves, which are involved. Notice that every fifth vertical line is a heavier density like the 100-foot lines. They represent zero, 50% and 100% of the full scale respectively. Thus, the film grid has three recording tracks in which data can be displayed from the galvanometers being used. Each track contains 10 major divisions which can be further resolved into tenths through eyeball estimation.

In track one, each major division represents 10 millivolts, the unit used to record spontaneous potential. Since only differences between the readings of various zones or lithology are of importance, the track has no absolute scale. We would subtract the reading at about 5715 from that at 5660 and determine a value of about 55 millivolts or 5 ½ large divisions for the zone, which deflects to the left.

The other two tracks have absolute scales of 0 to 100 ohm meters per meter squared, the unit of measurement for resistivity. In track two the dotted curve registers about 43 ohms and the solid about 65 ohms while in track three the curve registers a maximum of 48 ohms. It's not important at this point to explain what all this means but only to illustrate that each curve or galvanometer trace can be read at any depth to determine values of resistivity, SP (spontaneous potential) or other parameters being recorded in the well. Determining where and how to read the value of a given curve can be an art all to itself and can become an important part of the interpretation of well logs. We'll talk more about that in the discussion of the various individual geophysical services with each of their respective recordings. Now that you've seen some aspects of an actual recording, let's take a look at the device itself, which not only records the data but also constructs the grid for depth and amplitude scales.

THE R9 RECORDING HARDWARE

I mentioned that the curves result from the traces that the various galvanometers make on the film as it passes in front of the beams of light emanating from the mirrors of each one of them. The mirrors are the equivalent of a needle on any meter, which is commonly used by humanoids, that's us, I believe. Just as the temperature of a car engine or the amount of gasoline contained in a tank are indicated by a needles and meters, so are the values of various geophysical measurements indicated by the position of a mirror mounted on a galvanometer. In fact they work on similar principles but one has a needle that swings back and forth while the other has a mirror that moves. The mirror, however, has the ability to reflect light and expose film and thus produce a permanent record. Consequently, we engineer types don't have to remember or write down all the readings we see as the tool moved up some 10,000 feet of bore hole because, you see, we engineering types are messy writers and can hardly remember our names let alone all them thar numbers. When you add writin to the job, yere askin an engineer to get somthin dun ya might term chaos.

In an effort to clear up this muddy little explanation of mine, I'll utilize my simple mind to draw a couple of simplified diagrams of the R9, which will either help clarify the issue or else cast you into complete confusion (my locale for the last 30 years) in regard to its operation. Now, take a look at figure 6-9 and 6-10 but, mind you, before you throw down the book and/or faint in sheer terror, let grandpa Tom assure you that he will take you on a tour and explain the many gadgets which are contained therein. That may not help and it even may be quite possible that the less technically inclined among my posterity, will have to be dragged through it kicking and screaming, "I don't want to know all that baloney". How some ever, just keep in mind that you're trying to see what made grandpa Tom tic and a little sacrifice on your part is the least that can be expected. After all, you got some of them thar genes, like it or not, and in the long run, you'll be better off learning how to deal with them right now before they take you too far off the path of normalcy.

As of this writing, dealing with them is emerging as a distinct possibility. Yep, gene modification is becoming the in thing. By the time you read this story, such an option may be a reality. I can see it being advertised now, something like this, "If you worry about your progeny because of past pranks of your progenitors, simply contact our web site at http//:www.genemachine.com. We offer a variety of personalities, temperaments, intellectual abilities and looks including curly, kinky or straight hair as well as simply bald heads". Of course, you're probably out of luck, having already had some of these traits established by your progenitors of which I am one. How some ever, you may be able to design the perfect kid who, of course, will find his/her parents unsuitable because of their imperfections. To do so, you must realize it is essential that you understand me, your jolly old grandpa, so as to know how and where to upgrade. So, pay attention, ya hear? Neither grandpa nor you want to repeat this stuff. Now, let's take the tour.

As we make the tour, we'll be bouncing between the two diagrams. So, be diligent in comparing my remarks to the proper figure. From the outset, I might just as well tell you that the diagrams aren't meant to be accurate in detail or scale. My gray matter has become too old and gray for that to matter. Rather, they are meant only to explain principles and concepts, which might help you, the reader, better understand this optical electro-mechanical marvel grandpa refers to as the R9 recorder.

"If you worry about your progeny because of past pranks of your progenitors, simply contact our web site at http//:www.genemachine.com."

DEPTH INFORMATION

Of obvious importance is the depth information that allows the recorder to match geophysical readings to tool depth in the well. That information comes in via the recorder drive from the so-called measuring wheel and is shown in both diagrams. The wheel is accurately calibrated such that its circumference is exactly one foot. As one foot of cable passes between it and an associated pressure wheel, it rotates one revolution and couples that information to the recorder via a system of drive shafts and several u-joints to the indicated recorder drive. The information enters a gearbox located at the bottom of the recorder, which then supplies the

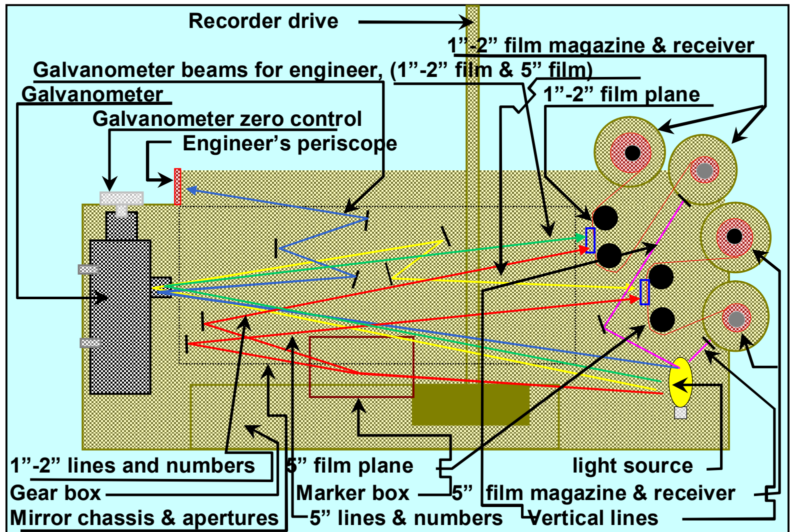

Figure 6-9 A cross-section of the R-9 Recorder illustrating film paths and the light source with its multiple paths for film monitoring and exposure at the film planes from grid lines, depth numbers and galvanometer traces.

necessary drive to the two film spools, the marker box and a depth meter. The latter is located on the R9 but not shown and allows the engineer to monitor the indicated tool depth. It's much like an odometer or mileage indicator on a car only it's calibrated in feet. The marker box (figure 6-9) generates both the horizontal lines and the depth numbers, which are printed on the film. The darker lines at 10' and 50' intervals are simply a series of rapidly generated 2' horizontal lines, rather than one, to produce the darker line. The gear selection knobs determine the film drive for the magazines and receiver cans. (See figure 6-9). Notice that one or two inch film is selected with one knob and five or sixty inch film with the other (figure 6-10). With the exception of the 60", each can be multiplied by five with the times five knob next to them. The up-down knob is the equivalent of a forward-reverse gear with no clutch being needed to complete the transfer of drive from the measuring wheel to the selected film cans. In most cases logs are run from the bottom upwards in the well, insuring smooth tool movement in the well, thus in the up position. Basic or primary logs are run on two scales, i.e. 1” and 5” or 2” and 5”. The smaller scale is useful for correlation purposes and the larger for analytical purposes. These will be described in more detail later. The 60” scale is for the dipmeter tool, where detailed correlations are necessary and will be covered in chapter 7,

OTHER CONTROLS

Other controls illustrated on the R9 (figure 6-10) are the lamp on/off switch, the light intensity knob, the galvanometer beam break knob, the galvanometer mechanical zero knobs and the film movement indicators. The recorder lamp was kept on all the time to allow the engineer to monitor the tool. When film was to be recorded, it was turned off momentarily (off/on switch) to load the film and then turned back on as recording was started. Thus it provided the film exposure and its intensity was adjusted, surprise, surprise, by the light intensity knob. The galvanometer beam break was utilized to eliminate undesirable galvanometer excursions at the beginning and end of some logs. The mechanical zero controls, one for each galvanometer, allowed the engineer to properly position the light beam from the galvanometer

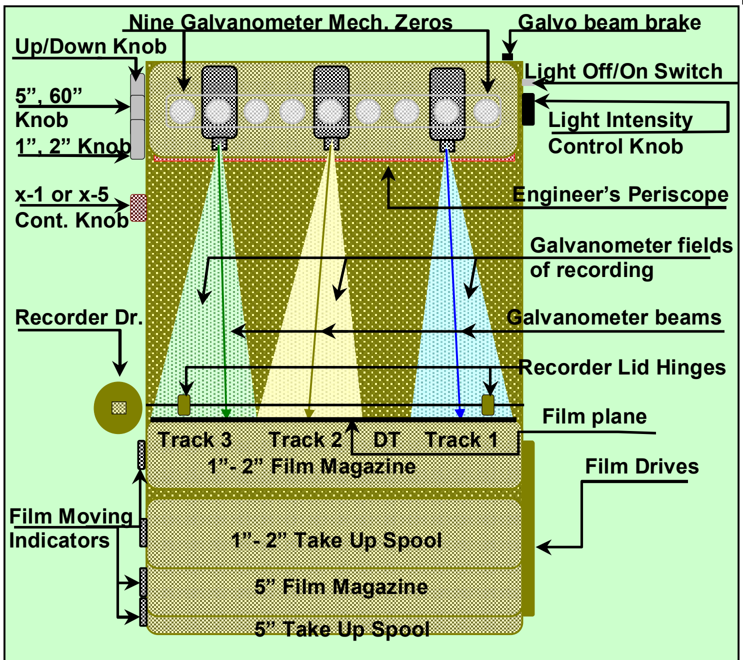

Figure 6-10 A plan view of the R-9 Recorder, illustrating various primary controls and features.

on the film grid. Finally, the film movement knobs (four) allowed the engineer to monitor film movement to ensure the recording was being recorded properly, i.e. no jerking or stopping, which would indicate erratic film motion and consequently an unacceptable log.

One didn’t want to record for a couple of hours and find out that the film hadn’t moved smoothly or not at all. If such happened and all that wonderful information wasn’t recorded properly, provoked inquiries occurred from the customer. It meant more work for Schlumberger, considerable lost time and thus a less than satisfied customer. None of these, of course, promote company or customer relations.

GENERATING THE FILM GRID

That pretty well covers the essential controls, so let’s move on to the recording of information in the appropriate track (one, two, or three) of the film grid and at the appropriate depth on the indicated depth scale. We’ll begin with the production of the grid. The vertical lines are controlled by apertures of appropriate size placed in the path of a light beam emanating from the bulb towards the two receiver cans (see figure 6-9). The size of the aperture controls the exposure and width of the line. Each aperture device has 32 holes or apertures of appropriate size to produce the necessary 32 vertical lines on each film. The aperture devices are indicated by black lines in the path of the magenta light beams directly in front of the cans. Mirrors required to properly guide the beam to the 1 or 2” can are designated by black lines.

Producing the horizontal lines is much more complicated. They must be placed at the proper depth relative to the numbers exposed on the film and also be varied in intensity so as to be distinguished as 2’, 10’ or 100’ lines. This is accomplished in the marker box indicated, once again, in figure 6-9. It contains a numbers disk, which is synchronized to the depth meter and produces the appropriate number at the proper depth. It also produces horizontal lines in synchronism with the numbers such that a 100’ line is produced when a 100’ number shows up. In between it produces one 50’ line of the same intensity, eight 10’ lines somewhat lighter and forty 2’ lines. Adding a 100’ line to that makes a total of fifty lines produced each 100’ of hole for the 5” film. The 2” and 1” films only require lines every ten feet of hole. The galvanometer traces also have to be aligned to print their information on depth with the horizontal lines, requiring a complex system of mirrors (the mirror chassis) and a lens in front of the film planes to properly focus lines, traces and numbers, to provide the sharp definition needed.

DEPTH ALIGNMENT

Both the film plane and the focusing lens are illustrated in figure 6-9 with the little blue rectangles as lenses and the flat area across which the film moves for recording as the film plane. My crude drawing would indicate a difference in depth at the lens for the lines/numbers as compared to the galvanometer beams. Actually, they would be superimposed at that point. You can appreciate the precise alignment required to achieve such recording accuracy. Much of this is done in manufacture with some adjusting by the technician on the job. Coupling this with the required apertures and shutters, which determine beam size and recording mode, one can appreciate my earlier comment in which I called the R-9 an optical electromechanical marvel. Indeed it was and produced a very clean sharp record on film from which prints could be produced for the customer. Once again, I emphasize that I couldn’t possibly illustrate the internal complexity of this device and any mirrors, etc. shown aren’t meant to be accurate in size, placement or any other feature but only to illustrate principles of operation. Hopefully, even in their crude form, they will help the reader gain an appreciation for the complexity of this device. The finished product would amaze you with its sharpness and clarity.

THE DATA GALVANOMETERS

Now let’s move on to the galvanometer beams in figure 6-9. Light rays from the bulb strike the mirrors of all nine galvanometers though some may be unused off screen. Those in use, of which I have shown one, reflect a light beam to both 1”-2” film and the 5” film as well as the engineer’s periscope. The beam moves across the film grid whose production was just described as well as across a grid in the engineer’s periscope. The latter grid is precisely aligned with that which is drawn on the film so the engineer can monitor the recording at all times. This allows him to make judgments regarding tool operation, tool movement and the type of formation, which the tool is passing by. It also allows him to mechanically zero the galvanometers at precisely the right place on the film grid and calibrate each device being run. This is the equivalent of calibrating the needle position on any voltmeter, ohmmeter, etc. that one might use for quantitative testing so as to establish accurate values. The beam of light from the galvanometer is the equivalent of a needle on any meter. Consequently, the mirror controls its swing across the film. Figure 6-10 illustrates the arc through which it moves. Obviously nine such arcs, needles or whatever could be recording at a given time but usually four to seven or eight is the norm. The recording arc is illustrated over one track or each galvanometer trace is confined to one track by appropriate shutters. In some cases, a galvanometer may be allowed to record over two or even all three tracks, again by shutter control. The three tracks and the depth column or track are designated in figure 6-10. Similarly, the engineer’s periscope is illustrated in both figures in red. It, in fact, contained a red filter, which eliminated all light waves but red from entering the recorder and thus unwanted film exposure.

FILM MAGAZINES

Each film magazine (1”-2” & 5”) is initially filled with a 150-foot spool of blank film. With the magazine installed on the recorder, the film is threaded through the rollers across the film plane and secured to the take up reel in the receiver can. Prior to recording, the recorder light is shut off and sufficient film is spooled up by hand to assure unexposed film is in position and the winch operator begins to move the tool up hole. The light is turned on with the correct intensity, appropriate zeroes are recorded and

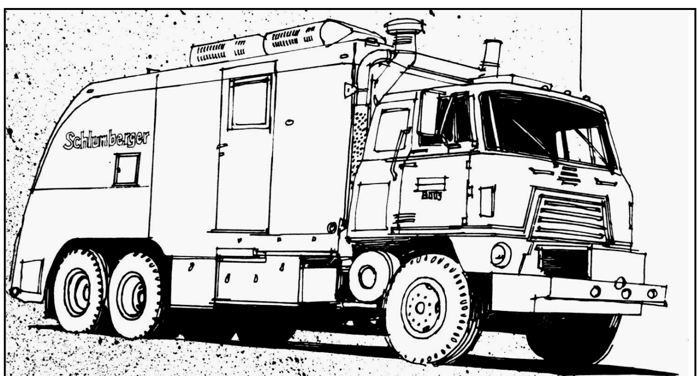

Figure 6-11 An illustrative drawing of an 8000 series truck with a CSU recording and control system.

the switches are then set to the record position, all before the tool actually begins to move off bottom. This allows the engineer to see and record the first tool movement or pick up as we called it, which represents total depth of the well or at least the depth at which the tool stopped. After completing the log, the recorder light is turned off and extra film is rolled up into the receiver can to be sure all pertinent recording is contained therein. The film is then cut within the receiver can by a knife-edge cutting mechanism, which frees it for developing and prevents unwanted exposure. In the cutting action the knife blade also closes the opening in the can for reception of the film, protecting the film from exposure until opened. The film is then developed in the dark room as described earlier.

Well, that completes my two-bit tour of the R9 and its many gadgets. It should prepare you for

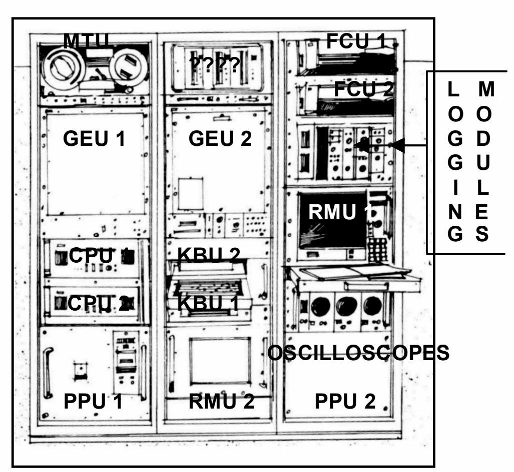

Figure 6-12 A drawing of the CSU or Cyber Service Unit, which is a computerized recording and control system.

some of my experiences later on, which bring laughter and tears, at least to my eyes. Yes siree, some were painful and some funny, which punctuated my many hours in the cockpit observing that marvelous machine, the R-9.

THE CYBER SERVICE UNIT

During my last couple of years in the Rockies, Schlumberger began applying computers in the field operation. Having run across a drawing of such a unit in my material from Houston, I decided to include a photo of it as well as the 8000 series truck which was the backbone of the land based logging fleet at that time. The drawing of figure 6-11 illustrates the logging truck, which could carry sufficient cable to log a well of 25,000 feet or so. The recorder cab was rearranged and the CSU was placed against the front wall of the recording cab next to the truck cab. It occupied most of that wall. Air conditioning appeared in field units for the first time with the CSU because of the need for accurate control of its environment. Needless to say, the engineer and operators were grateful recipients of that particular feature. I spent my field days in sweat and dust with management having little concern over my personal comfort. Of course, being reared in ignorance of such amenities; lowered my expectations somewhat and I was, as you know, “fat, dumb and happy”.

Figure 6-12 illustrates the Cyber Service Unit or CSU. The photo depicts such a unit for a cased hole or production service truck. As I remember, all electronic components were contained in duplicate because of the need for back up, should a failure occur. It may be that only the more critical ones were backed up because I don’t see duplicates of all components. Then again, the open-hole logging unit may have been configured differently with additional back up. In any case, I have tried to identify the various electronic units as best I can for your edification. I’ll try to explain the function of each so you can get an idea of the whole integrated system.

Starting on the left top, you see the MTU or magnetic tape transport. All data was recorded on tape as well as on film, which provided for computer-generated interpretations of results or “Cyber Products”, as I believe they were called. There is no back up to this unit shown. I remember a back up, however on open hole logging units. For some reason they don’t consider it necessary on the cased-hole units. By the way, I’m not sure of my alphabet soup designations of the various electronic units. This old bean never dealt closely with them and I can only come up with my best guess as guided by designations of earlier instruments. The next compartment down housed, what I remember as, the general electronics unit or GEU. Its back up is immediately to the right. Just below the GEU are CPU’s 1 & 2 or central processing units. They, of course, house the computers or brains of the whole system. Below the CPU’s is the PPU 1 or power panel unit, which supplied all power to the surface equipment as well as down-hole cartridge power and required power for opening or closing tools or shooting guns. At the top center is a unit I don't recognize and can't seem to shake the cobwebs regarding its purpose. Below GEU 2 are the two keyboard units for communication with the CPU's. Below them is what I believe to be the spare film monitor unit, which I have designated as an RMU (recording monitor unit). It may have been an FMU or film monitor. At the top of the right bay are the two film canister units or FCU whose designation is questionable. Of course, you might ask; "What isn't, regarding my nomenclature"? Next in line are the individual control modules for the required services. A different one is needed for each service type such as induction resistivity, sonic, etc. Typically, a logging truck carried modules for whatever services were commonly run in their area. If a special or unusual tool was to be run, that module was added for the job. Next is the active RMU or FMU and below that oscilloscopes for monitoring signals from down hole such as the sonic or radioactivity signals arriving at the surface. Below the oscilloscopes is empty space I believe but somewhere in hiding there should be a second PPU. Not knowing where, I so designated this space. Well, let's get back to equipment of my era and that which is general in nature to the operation.

DEPTH MEASUREMENTS

I have already referred to the need for accurate depths on the log or finished product and to some extent just how that was accomplished in the R9. Remember, the depth information came into the R9 via the recorder drive from a measuring wheel, which was as close to one foot in circumference as one could make it. However, it was subject to wear (you know; steel against steel) and what may have been very accurate when received would soon change with use. Also, a 0.001 foot error or 0.1% in the wheel's circumference would translate into 10 feet at 10, 000 feet of depth. That's significant. Additionally, one logging truck might have 0.1% error and another 0.2% error, resulting in depths dependent upon the logging unit used. This could create completion problems, correlation problems and even analytical problems for the geologist and log analyst. A better mousetrap was needed. Some companies used a large clumsy wheel mounted on the rig floor, which probably had a circumference of 10 feet. That reduced the built in error of the wheel by a factor of ten. Unfortunately, there were other problems associated with such a wheel. If not handled carefully or damaged in any way, its accuracy could change. Also, if not kept absolutely clean during the job, mud could build up on it and change the circumference. This was particularly true in cold weather.

CALIBRATED LOGGING CABLE

To get around such problems and improve accuracy by another factor of ten, Schlumberger chose to use a calibrated logging cable with marks every 100' which could be observed at all times during the job. The percentage error in a calibrated 100' interval was then 1% of that of the measuring wheel and the wheel could be constantly adjusted during the job to match the line. Thus, the measuring wheel, whose accuracy was referenced to the calibrated line, drove the recorder. Such a line could easily be calibrated to within less than 0.1 feet in 100' or less than 0.1%. In the example previously given, such an error would translate to a tenth of a foot at 10,000'. The system was great and became the standard of the oil industry. The depths recorded by Schlumberger were considered better than driller's depths considering the many problems involved. Accurately calibrating the cable required both care and control because of the many factors inherent to the business which influenced both cable and drill pipe length. Such problems would not be obvious to the uninitiated so, let me sight a few.

1. Drill pipe or cable tension. Both drill pipe and cable stretch when subjected to weight and/or drag. Such stretch can be significant. At 10,000' such stretch may be 10' or more.

2. Mud properties. Mud weight affects the buoyancy of logging tools. Their tendency to float increases with mud weight.

3. Human error in calibration and/or measurement. Drill pipe is measured standing in the rack by roughnecks with a 100' steel tape. Though the tape is accurate, sloppy measurements of each stand, communication errors from roughneck to driller, addition problems and shear boredom of making some hundred or so measurements, all add to the potential for error in the driller's log.

4. Method of measurement. If drill pipe is measured under tension, i.e. while hanging in the hole, it will be significantly longer than if measured in the rack after being disconnected from the down hole string. Thus, a well determined to be 10,000 feet deep by measuring

the drill pipe in the rack will, in all reality be more like 10,010 or 10,015 feet in actual depth because of drill pipe stretch. It is extremely awkward to measure drill pipe under tension and it adds to the drilling cost of the well. Consequently, the industry has standardized on measurement of drill pipe standing in the rack.

If all rigs measure the same way, the error is consistent and will not affect geologic maps and

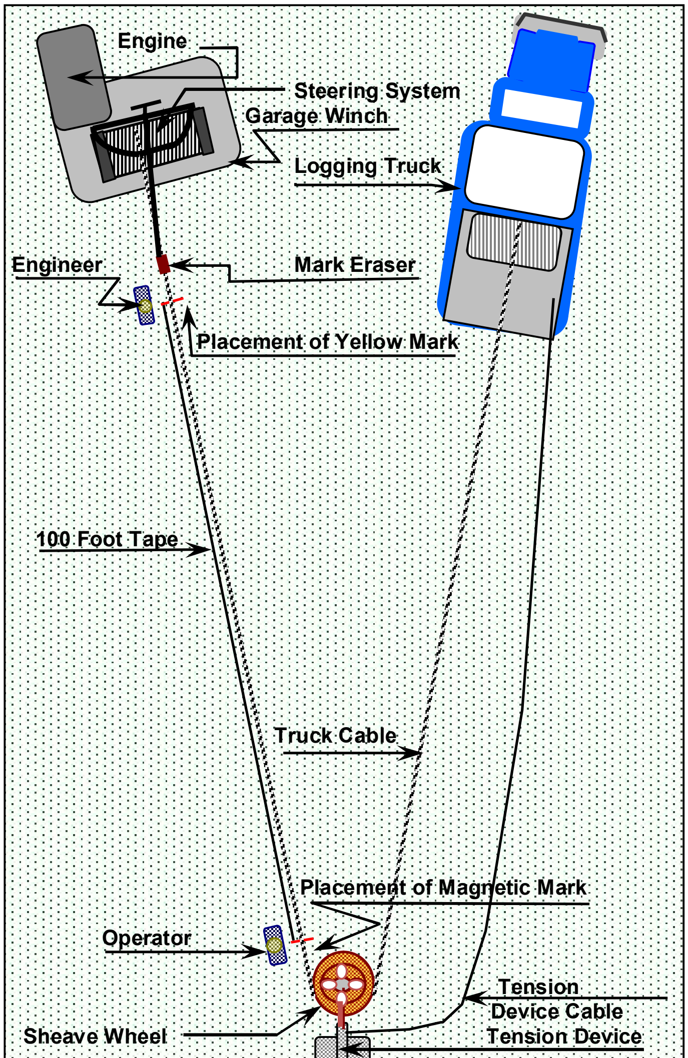

Figure 6-13 An illustration of the original system used to calibrate logging cable when I began work.

cross sections. We don't really care about the exact depth but we do care about depth relative to other wells and the accuracy of later completion services. As a result, Schlumberger chose to calibrate their cables to match drill pipe measured in the rack rather than under tension. We will have more to say on that subject later.

Well, I think I covered the main factors and, if I left out a few, I'll probably think of them later. That may not excite you but it's one of those things you do when you get old. Things don't pop into your mind like they used to. As a result, you just wait until they do and if they don't, like Ronald Reagan, you simply forget about them. So, I'll move on to calibrating our cable and maybe include a few of the problems involved.

CABLE DESCRIPTION

Schlumberger logging trucks carried a spool of steel cable, which expanded from six to seven conductors about 1965 or so. Originally the six conductors were wound around a central core in a helix fashion, giving them the solid support necessary to withstand the hydrostatic pressure they would under-go. The core eventually became the seventh conductor as the demand for more conductors grew. All space between the conductors was packed with solid insulation type material to form a rather rigid clump of conductors to support the steel sheath. The latter was composed of two layers of stranded steel wires described earlier. The inner layer had something like 10 or 12 strands and the outer about 14. The physical construction of the cable allowed it to stretch to a significant degree without armor wires or conductor wires breaking. As an afterthought, I have depicted such construction in figure 6-29, which you may want to refer to. There, I also describe the splicing process in more detail.

The stretch per 1000 pounds of tension was a known characteristic, which was designed into the cable. Each engineer had a field manual, which contained graphs of stretch versus tension for every cable type he might use. Thus, if the tool was at 10,000 feet in the hole and the tension meter read 3000 pounds, he could determine exactly how much the cable had lengthened, a standard operational procedure, which we'll talk more about later.

At either end of the cable a so-called rope socket was built which allowed both electrical and mechanical connections to be made to the cable. The truck end was hooked to a collector with eight sets of electrical brushes, which provided connection to the surface equipment. The down-hole end was connected to a universal 10 conductor head, which I'll also describe in more detail later. For now, let's get on with the cable measurement procedure.

A typical spool of cable was 20,000 feet long although they could be obtained longer and shorter. A new spool of cable would be spooled onto the truck and each end prepared for either the collector or U-head (universal head). Then the truck would be moved to the measuring area, which contains a second winch, which was termed a garage winch or skid unit. Its purpose was to provide support for cable repair and measurement. Figure 6-13 illustrates how the garage winch and truck winch were utilized in measuring cable. You might also consider what kind of marks will be placed on the cable. Will they be visible or detectable in some other way? Initially, a visible mark was used in the form of a shim woven into the strands of armor in the cable. That method had many drawbacks and was eventually replaced by magnetic marks, which could be detected with a sensitive coil placed next to the cable. They could also be erased and renewed as necessary. During logging, a detector, mounted next to the measuring wheel, monitored all the marks that passed by; thereby allowing the engineer to be constantly aware of the depth at which they occurred. Now, in the following explanation you will want to refer to figure 6-13.

MANUALLY MARKING CABLE

To measure the truck cable, some cable was backed off the truck by hand and threaded around a sheave wheel mounted to a dead-man or post, which was secured in the ground. The truck tension device was used to couple the sheave wheel to the post and thus provided a means of monitoring cable tension in the truck. From the sheave wheel, the cable is run to the garage winch and secured to the drum, after being run through an erasing coil. The latter removes all old marks as the cable passes through it and is spooled on to this drum. It is spooled under tension to the desired point on the truck cable where the marking is to begin. On a new cable this would be near the top end, maybe 500 feet from it, which has been moved to a point directly in front of the garage winch. The engineer then made a yellow mark with a wax pencil, which constituted the starting point.

The truck operator then began to pull the cable back on to the truck winch with the garage winch brake so set that the cable is under 1000 pounds tension. When the yellow mark reaches the operator near the dead-man, the winch is stopped with 1000 pounds tension still on the cable. The operator placed one end of a 100 foot invar steel tape on the yellow mark while the engineer pulled the tape tight and measured off exactly 100 feet. The tape was removed and while the engineer made another yellow mark denoting 100 feet, the operator at the other end quickly ran a strong hand magnet around the cable at the first yellow mark thus magnetizing it. When done, he would signal the operator on the truck winch who would quickly pull another 100 feet of cable on to the truck and set the brake with 1000 pounds tension once again. The process described previously was then repeated and additional cable pulled on to the truck. This process was continued until less than a hundred feet of cable was left unmeasured. As the cable on the garage winch neared the end, it had to be pulled slowly and carefully as the last one hundred feet came into play. You see, the end was secured to the garage winch drum. Once this last mark was placed on the cable, the remainder was pulled off by hand and the distance to the cable end carefully measured. The last mark then became known as the first mark because it was now the first mark to go into a well. Its distance from the end of the cable was recorded for use at the well. The value could be anything from a few feet to 90 plus feet but always less than 100 feet. It was common practice to cut a few feet off and build a new rope socket to improve reliability.

MARK ERASER

You have probably noticed the mark eraser near the garage winch. A strong AC current was run through it during the marking process, which effectively erased all old marks and any stray marks that might be on the cable for one reason or another. It was used with a new cable to erase any false marks and on remark jobs; the old marks were nicely cleaned off. The policy on cable maintenance was to mark the cable once a month to the depth of the deepest well logged that month. Cable left on the drum was stable and the old marks were still good. Cable, which went in the well, could, however, stretch or even contract depending upon the age of the cable and the number of times it was run in the hole. In fact, in the early days (1955 to 1960), we measured stretch and shrinkage and plotted the same, mostly because it was interesting though not too useful. A typical year old cable would show stretch from 10,000’ to 15,000’, stability (little or no change) from 5,000’ to 10,000’ and shrinkage from zero to 5,000’. If cable was shrinking very much, it needed to be replaced because of inner armor rust which would lead to breakage at something less than the cable tension rating. We typically cut off all cable that had shrunk more than one foot per thousand to eliminate the possibility of the cable breaking at a relatively low tension.

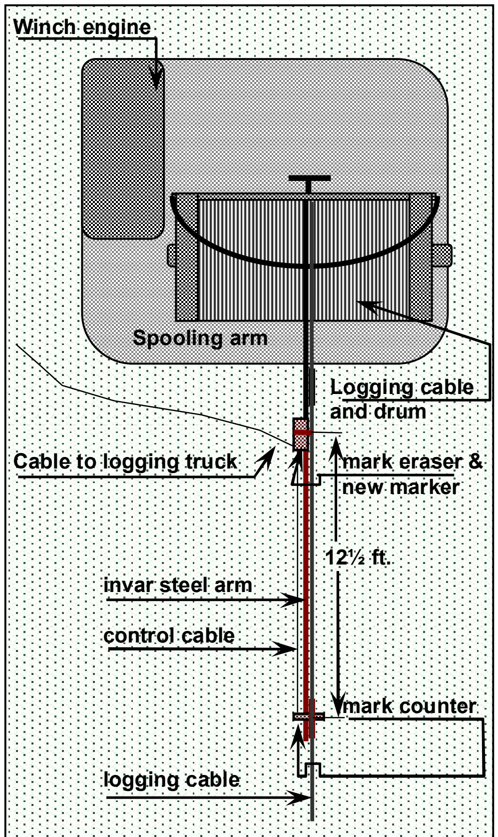

Figure 6-14 Automatic marking device's setup and application.

CABLE MEASUREMENT RECORDS

We also kept a record of the change throughout the cable, which could be referred to if depth accuracy became an issue. In addition, when running a second or third log on a well, which had been drilled deeper, our policy was for the last run to be within three feet of the depth of the earlier log. If not, we corrected to their depth, ran the new log and then re-logged the whole well at the depths determined by the last run unit. Upon return to the garage, we then measured our cable to determine which unit was correct and submitted the last log to the customer. Needless to say, Schlumberger engineers paid close attention to depth accuracy. All of this effort to maintain depth accuracy proved of great worth, in that our depths were usually taken as true, even when in disagreement with the drilling records or any other wire-line company's measurements. We were the standard and it wasn't unusual for drillers to check with us as soon as the tool came off bottom to verify their own depths.

THE AUTOMATIC CABLE MARKING DEVICE

In the sixties, an automatic marking device was developed which not only sped things up but also made it possible to mark at the well site. The latter was important off shore because the cable couldn't be brought in every thirty days for marking as on land. Until its development, depths in offshore wells frequently left much to be desired. In the following, I'll briefly describe it as well as illustrate its setup in figure 6-14. The overall configuration was still that shown in figure 6-13.

Further investigation, so I later heard, proved the drilling crew had been taking their Totco measurements in the dog house and manufacturing apparent deviations under five degrees.

The automatic marking device (AMD) utilized a 12½-foot arm, which was attached to the end of the spooling arm of the garage winch. On the near end was the necessary marking circuitry and on the far end a simple mark detector. A marking panel, which was located in the logging truck, controlled the device. As the cable came off the drum, old marks were erased and new marks installed. Accuracy was maintained by the manufacture of the invar steel arm on which the marker and mark detector were installed exactly 12½ feet apart. The unit determined 100 feet by counting to eight, a very easy thing to do with digital circuitry. The process went something like this.

As marking was started, the device would begin by placing a small or weak mark on the cable. As that mark moved to the detector 12½ feet away, it would be picked up and counted. When the seventh mark was counted, the marker would be signaled by the panel to make the next one a large or strong mark, which would occur at exactly 100 feet. Strong marks could be detected by the logging truck's marking detector while weak one could not. Thus, as far as the truck cable was concerned marks (strong ones) were being placed on it every 100 feet. The number 12½' was used because of the digital nature of the system, which, of course, is one eighth of 100 feet.

Such a device was very advantageous. On land it made all marking jobs the same without the engineer accuracy variable factored in. It also kept you out of the blistering sun of Texas and the fifty-mile an hour sub-zero winds of Wyoming. Yes, it was advantageous. Off shore, it allowed the cable to be marked anytime when a tool was being run in the hole. There was little or no wasted rig time and marking was consistent and regular which drastically improved the quality of well depth recording in that environment.

A CASE FOR DEPTH ACCURACY

Now, let's talk a little about the need for depth accuracy and what elements went into it. First, there is the need for geologic accuracy. Logs are compared to those of nearby wells through correlation, which we'll demonstrate in chapter seven, and the upper surface of a given horizon or formation is mapped with contours (remember chapter five). Depth errors on any of the wells produce errors in the accuracy of the top of the inferred formation. This can produce both exploration and development problems including such things as coring and testing points.

Second, depth is measured during drilling breaks via both open-hole (uncased) logs and when running completion logs. Unfortunately, they all seldom agree. Who is right? As I said, Schlumberger had the name for depth accuracy and it was an embarrassment when we were proven wrong. We guarded that recognition like our family name. Open-hole logs were the standard and later logs on the same well were always adjusted to that depth standard.

Third, vertical depth to a given horizon is dependent upon how straight the borehole is. Borehole deviation of 1 degree would result in 1 foot of vertical error in true depth at 10,000 feet. Similarly, a deviation of 5 degrees would result in a 38-foot error. That is appreciable and can't be tolerated where accurate geologic data is needed. Figure 6-15 will clarify the problem.

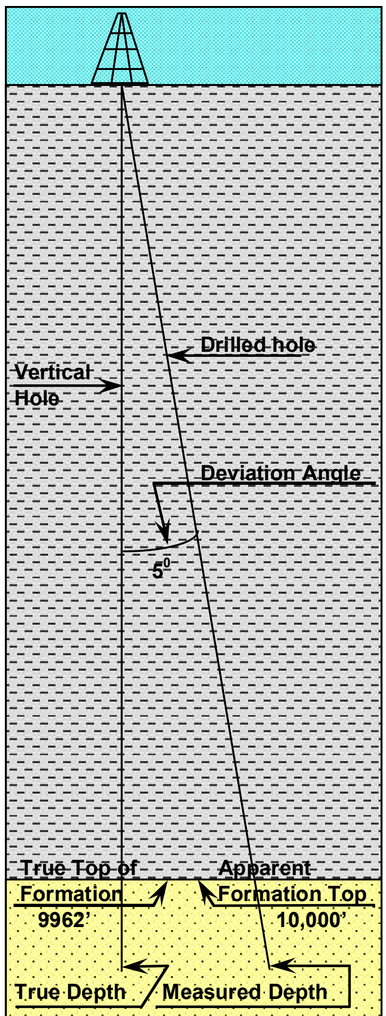

Figure 6-15 Well depth error due to borehole deviation.

Obviously, wells must be drilled near vertical for reliable depth data. Drilling contracts always specify the maximum allowable deviation, which is typically 1 or 2 degrees. If geologic data is not of prime importance, specifications may be relaxed to 5 or 10 degrees but I've never seen anything more specified where a straight hole is needed.

I remember logging a development well one time, near Rock Springs, Wyoming, where the expected top of the Almond formation, came in much too deep. Consequently, the geologist asked me to run a directional survey and the results showed the hole to be 45 degrees off the vertical, even though the specifications called for no more than 5 degrees deviation. Further investigation, so I later heard, proved the drilling crew had been taking their Totco measurements in the dog house and manufacturing apparent deviations under five degrees. The geologist commented:"You get what you pay for". The operator had used the cheapest drilling company he could find to minimize water flood costs. The drilling company had to drill the borehole fast to realize a profit and obviously ran way too much weight on the bit. That speeds up drilling but creates havoc with borehole deviation. So, they just ignored that and made the Totco read what they wanted to meet contract needs.

By the way, when I plotted the bottom hole position of this particular well (a part of our services), it proved to be within 50 feet of another well and should have been more like 460 feet away. The new well was worthless and had to be side tracked to straighten it up.

You'll remember, The Totco was run each time the drill pipe was pulled to change bits. It was dropped down the pipe and timed so that it measured the deviation only when it hit bottom. When the pipe is pulled, the Totco is retrieved and the deviation read. This reading of deviation only, i.e. no direction, then became part of the drilling record, which was examined closely by the operator and others with vested interest in the bottom hole position of the well. If the deviation was within the contract terms, little more was done with this particular information.

MEASUREMENTS AT THE WELL SITE

To kind of wind this depth measurement topic up, I guess I'll take you through the procedures we followed at the well and try to explain why all that was really necessary. It gets kind of involved, so naturally I'll need a few drawings to explain some of the concepts I want to explain. I think maybe I'll just toss in a couple of photos too which show a logging truck and an off shore unit. They are a little out of date (the truck is a 1948 version and the offshore unit a 1960 version) but they illustrate the principles of both and the truck also has a typical rig behind it. They probably won't help with the explanation much but they'll add reality through component identification, so you can get a little better mental perspective of what I'm talking about.

PREPARATION AT THE WELL SITE

Consider figure 6-16, a photo of a truck getting ready to log a well in the 1950 era. Judging from the scenery and the sky, the event could well be taking place in the Rocky Mountains somewhere. I've seen similar locations from Montana to New Mexico and all points in between. Judging from the rig, I would place it in Cody, Wyoming because of the enclosure built around the monkey board or derrick hand's station. The truck is what Schlumberger called a 700 series truck. Other than having a kind of old appearance compatible with mine, it appears much the same as the ones I rode myself. In fact, my first truck was a 700 series, which I served on in Wharton, Texas in 1955 through 1957. I was assigned another in Rock Springs, Wyoming until 1959. So, they seem kind of homey to me. The winch arrangement was basically the same as later trucks but the recorder cab was arranged somewhat differently than what I described earlier. I have a personal story to tell about that later which, along with my stupidity, resulted in my smashing a vertebra and ending up in a cast some eight or nine weeks. But let's get on with the picture for now.

Looking at the rig, you'll notice they are still circulating or conditioning the hole for logs. You can see there is no drill pipe in the rack and the Kelly is in the hole when you examine it closely. Remember your lesson on drilling rigs back in chapter 5. Of course, my drawing shown therein and any resemblance it may have to a real drilling rig, is strictly coincidental. The rig in the photo of figure 6-16 looks as though it could pull triples (three joints of pipe at a time) and so the monkey board enclosure is roughly ninety feet off the rig floor.

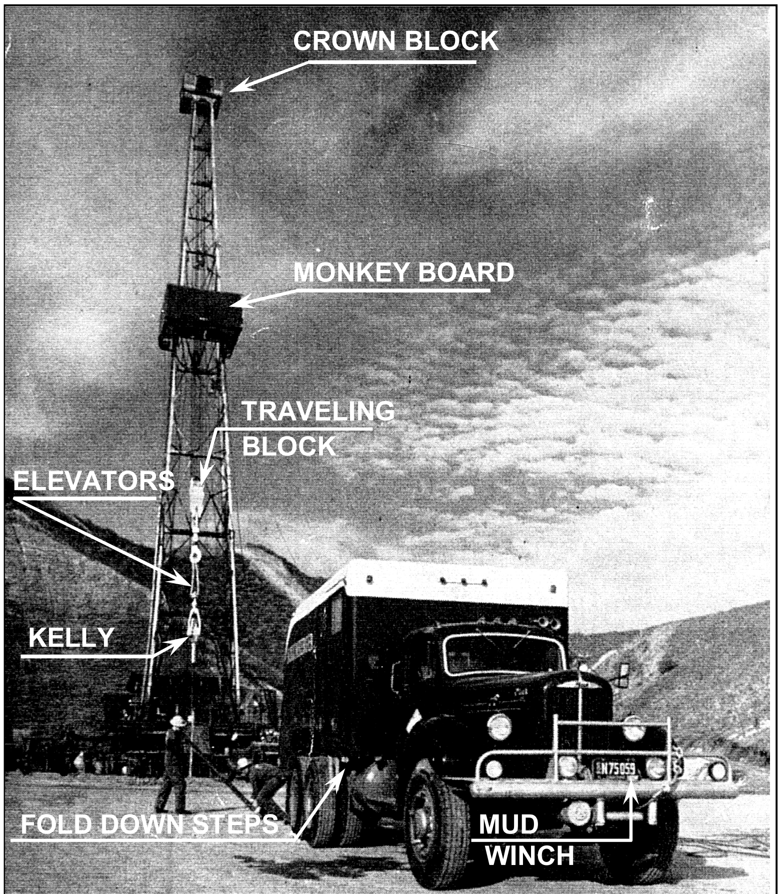

Figure 6-16 A Schlumberger logging truck with the crew preparing for a job, probably in Elk Basin, Wyoming.

I believe that I mentioned some time earlier that the derrick hand usually rode the elevators up to his station as well as down. Most of those guys were rather nonchalant about the whole thing. They'd step on at the rig floor and hold on with one hand going up and they stepped off at the monkey board in one smooth motion almost before the driller shut down the draw works. I've seen them also slide down a stand of drill pipe rather than ride the elevators down. Of course, that's a no-no as far as safety is concerned and we didn't see it in later years and particularly so when OSHA came to the oil field.

Most of those guys were rather nonchalant about the whole thing…. I've seen then also slide down a stand of drill pipe rather than ride the elevators down.

The operators are preparing the equipment for the job. They'll unload all tools to be run as well as the various components necessary to rig up or configure the cable and tools such that they can be readily lowered into the well. All of this is done after the truck is properly positioned at the end of the catwalk and lined up with the hole. It's hard to say where the engineer is. He may still be on his way, taking a quick snooze or conferring with the geologist. Since no car is visible, it is likely the first is the case.

Notice the truck utilizes a chassis with dual wheels and tandem axles. You can barely see the fold down steps leading into the recorder cab on the left side of the truck. A similar set is on the right side. They pull out from underneath the recorder cab and then drop into position. You can see how high the door of the cab is from the ground, roughly 4 feet I'd say. Keep this in mind for a later story of mine, which took place in Sublette County, Wyoming one cold and windy night. Of course, all nights were windy and most of them cold in that state. You will then see how this young man took the butt of that experience and what he learned in the end or from his end.

AN OFF SHORE UNIT

I only throw in an off shore unit here so you can compare it with a truck. These units were mounted on the offshore rigs when they rig up on location and weren't moved off until a series of wells was completed. An off shore rig is a crowded place with space being at a premium. Consequently, the unit was made no bigger than necessary. Auxiliary equipment was stowed in boxes in some out of the way place. Logging equipment was taken in each job by boat for preservation purposes as well as for maintenance. The off shore environment is tough on equipment and drilling crews have little concern with it when Schlumberger isn't there. It's just in their way and they are apt to place it anywhere. The recorder cab is the equivalent of that on a truck and protects man and equipment from the elements when Schlumberger is on location. Panels were brought to the unit for each job in special boxes designed to protect them en route. Down hole tools were also transported to the rig each time on specially designed pallets, which minimized mechanical shock due to handling. Upon arrival, the crew always installed and checked all equipment before the rig was ready for them to be sure all was in working order. Lost time due to equipment failure is expensive to the well operator, particularly so off shore.

THE BRIDLE AND U-HEAD

I have pointed out four items of interest one of which identifies the winch engine, one the cable spooling arm and the other two which pertain to our depth measurement problem that we are about to get into. The cable needs an adapter or head, which will connect to the tools quickly and reliably. This head is termed the universal head or U-head because it connects to any standard logging tool. You can see it in the picture of figure 6-17 right in front of the cable. It is connected to the cable with a so-called torpedo. In some cases the U-head includes a bridle, which is about an eighty-foot piece of cable with the conductors on the outside instead of the inside of the steel cable. It allows the bridle to have electrodes installed on it, which we'll talk about in chapter seven. In any case, the bridle and U-head then connect to the cable with the torpedo. The torpedo is designed to mechanically connect the two rope sockets of the cable and the bridle as well as provide protection for the wires inside to prevent any physical damage during the operation. The wires protruding through the rope sockets have insulated connectors at the ends, which keep the conductors from shorting out in the mud. We end up with the cable we have marked as well as a universal device or head that allows it to be quickly and reliably connected to any tool we might need to run in the hole as shown pictorially in figure 6-18.

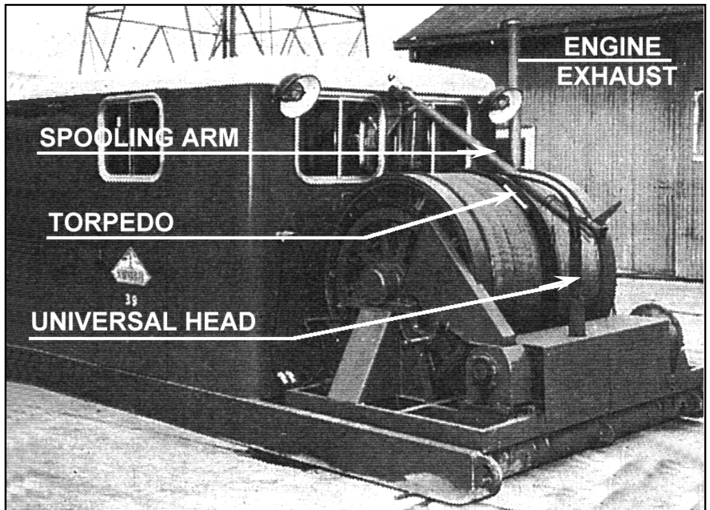

Figure 6-17 A pre-CSU-era offshore logging unit mounted on a skid and complete with cable

MEASURE POINTS AND FIRST MARKS

Besides illustrating the cable, bridle and U-head, figure 6-18 also shows the relationship of the first mark and the measure point of the tool. The measure point of the tool is that point on the tool, which responds to the particular measurement being made. As you will see, it varies in position depending upon the type of tool being used and is typically a few feet from the bottom end of said tool. Knowledge of its relationship to the first mark on the cable is essential for accurate depth measurements. I have arbitrarily shown it as being 4 feet from the bottom of the tool. I have also arbitrarily shown the bridle length to be 80 feet from U-head to the torpedo and the distance of the last cable mark to the torpedo as 35 feet. Knowing that the distance from our U-head connection to the measure point of the tool is 10 feet, we can quickly determine the distance from measure point to the first mark on the cable through simple addition. The result is 125 feet. This distance would change for other tool types but we only need it for the first device run in the hole. That device establishes the depths and is called the primary log. Depths of all other logs are made to agree with it. Thus, it is essential that the engineer be absolutely sure the depth of his primary log is correct.

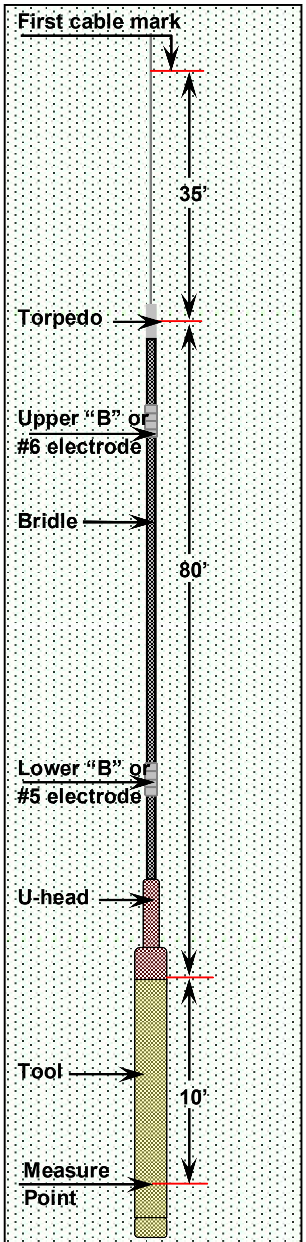

Figure 6-18 An illustration showing the relationship of the first mark to the tool measure point.

Now, as a quick review, remember the distance of the first mark to the torpedo is determined when the cable is marked and is recorded for future reference. Also the bridle is measured and its length from torpedo to U-head is also recorded for reference. Finally, the distance from the U-head to the measure point is standard for like tools but differs between tool types. The engineer has that number in his operations manual. We'll show you just how this information is used a little later on.

You may have noticed the extra two electrodes I conveniently slipped over without explanation, which are located on the bridle. These were originally devised for the electrical survey, a log we'll discuss in chapter seven, but they also have great utility for other services. Consequently, we'll make reference to them from time to time, as it seems pertinent when we talk about such services.

RIGGING UP AT THE WELLSITE

"Rigging up" is the term used to describe truck positioning at the well along with the configuring of cable and tools such that they can be readily run in and out of the well. It seems important to describe this operation here to some degree. Later descriptions of depth measurements, as well as personal experiences, will then have more meaning. I have already made reference to the truck being positioned at the end of the catwalk. This is desirable for tool access to the catwalk and also allows the winch operator to readily see the rig floor during operations. Typically, the truck is placed (spotted) just to the left of the catwalk and aligned such that a line through the long axis of the truck will intersect the rotary table or top of the well. This is necessary for proper spooling of the cable. The cable spools more easily too if the truck is about 150' or more away from the rig floor. You see, the angle encompassed by the spooling arm decreases with distance from the floor and this means less effort on the part of the winch operator to smoothly wind the cable back on to the drum as logging ensues.

Sheave wheels (special pulleys and expensive ones I might add), which I have mentioned earlier, are used to bring the cable coming off the winch in a horizontal attitude to a vertical attitude, or in line with the hole. This is illustrated in figure 6-19. We'll refer to it as the rig up procedure is described. Let's begin with each element of hardware involved.

THE LOWER SHEAVE

The tie down chain secures the lower sheave to the blow out preventer stack, as indicated. The chain is tested to 20,000 pounds to ensure its integrity when the cable is under load. The chain is secured to the sheave wheel with a special clevis while the other end is wrapped around the BOP stack, tied in a couple of knots and then taped to the chain to prevent it from coming untied. Should it come untied during an operation, the wheel will come rolling right down the cable into the back of the truck, that is if said cable isn't severed in the process. Such has happened and, needless to say, excitement reigns. In addition, customers may get mad, the boss too and the crew's behinds will get chewed until raw and that's for sure.

UPPER SHEAVE

The upper sheave is hooked to the tension device, which will monitor the cable tension. The tension device is then locked to the T-bar whose top end is latched into the collar of the elevators. The cable connecting the tension device to the truck is secured out of the way to prevent it being damaged. The upper sheave is raised high enough to allow easy entrance and exit of the hole during operation. This is typically a distance of 80 feet or so on most wells.

SOME RIGGING UP DETAILS

Prior to rig up, the operators have placed all necessary equipment on the catwalk in positions most advantageous for efficient rigging up. Sufficient cable has been spooled off the truck to allow the slack necessary to raise sheaves into position. Once the rig is ready the driller and rough necks move the sheave wheels, etc. to the rig floor with the cat line under the direction of one of the two operators. The sheave hanger or T-bar with tension device and upper sheave attached is placed in the elevators and secured. The lower sheave is raised to an appropriate height with the cat line and the latter is tied off. It will hold the sheave in place when cable is slack. The tie down chain is then threaded through the rotary table to the rig cellar where an operator secures it to the BOP stack as described a little earlier.

Next, the U-head is threaded through the sheaves and held stationary as the upper sheave is slowly raised to the desired height. The driller sets the brake on the draw works to be sure the sheave stays at the selected height and the U-head is then dropped to the catwalk to be attached to the first tool to be run. That tool is then raised from the catwalk to a vertical position as shown in that bodacious little drawing of mine, which is illustrated in figure 6-19. Oh what fun it is to try to reproduce those strange thoughts pictorially that run through my head as I write about them.

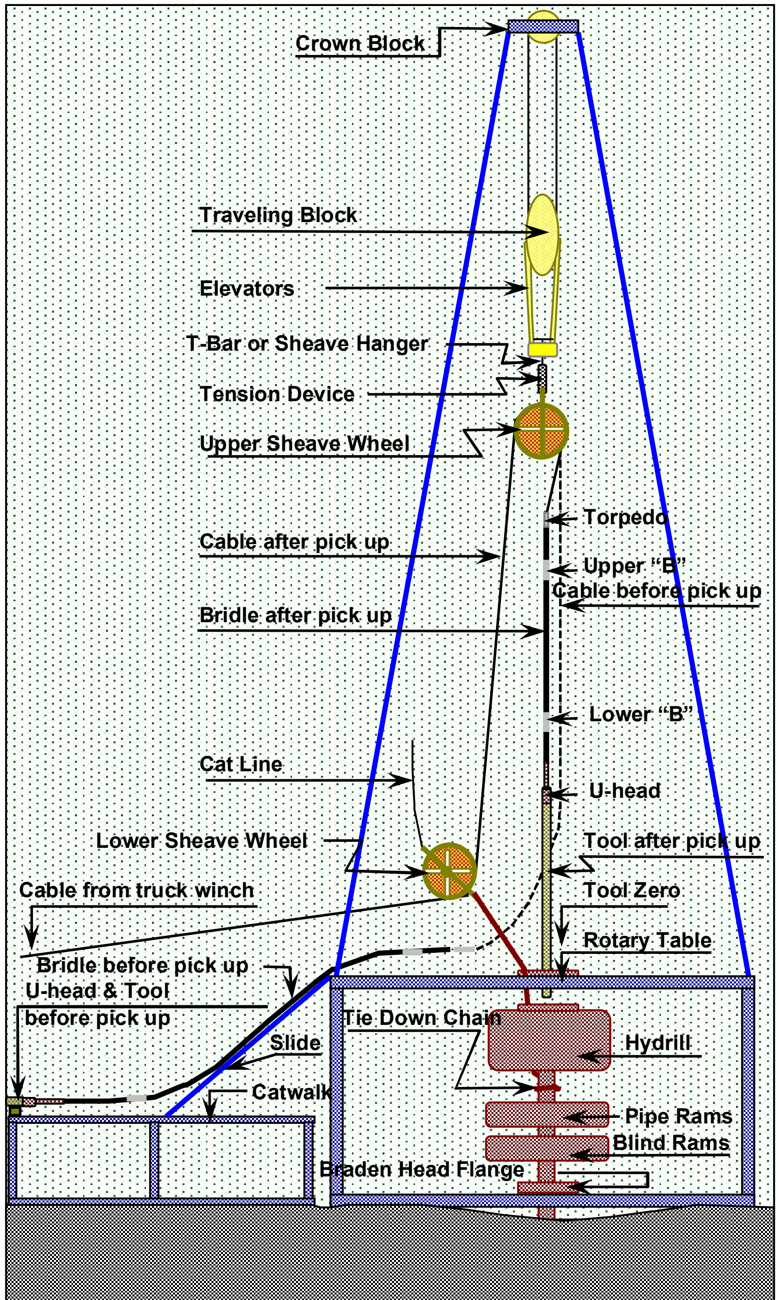

Figure 6-19 A drawing illustrating the configuration of Schlumberger equipment at the well with a tool both lying on the catwalk and also in the derrick; about to be zeroed.

AN OLD MAN'S JOY

Boy, I have more fun making these drawings than a kid with a triple ice cream cone. It matters not what others think of my artwork because, in my mind's eye I see exactly what I'm trying to explain. Each little strut as well as each cross member is there in plain sight though they may be invisible to you. Isn't the imagination great? I can see the logic and beauty of my drawing, as well as its organization while you see nothing but confusion. I understand quite clearly what I'm trying to explain while you mutter and wonder just what all that babbling is about. To me, my signals are clear and direct; to you they are lost in the background noise of your amusement and disinterest. I revel in my imaginary talent while you wonder if I've gone mad. Ah yes, the wonder and mystery of one's God given imagination. Truly, it is a gift to protect us from the cruel reality of the world. Boy, I better shut up or I'll never get finished with this chapter, let alone the book. So, let's continue with the mundane once again.

THE MECHANICS OF ZEROING THE TOOL

Let's see, where were we? I believe we had just picked the tool up from the catwalk. In such a case the engineer usually runs the winch while the operators handle the tool. It must be done slowly and carefully to keep the bridle from jumping a sheave or slipping out of the wheel groove between the frame and wheel. This has the nasty tendency of ruining the bridle and usually requires the crew to change to the spare bridle, about a half hour's effort. You need not worry; I've been there. Once the tool is hanging vertically, the engineer lowers it to the point where the tool zero coincides with the rotary table. This is typically one foot in the hole or one foot below the Kelly bushing or the point from which all depth measurements are made in the well. The Kelly bushing is used as "well zero" because it's the only practical place for the rig crew to reference their measurements to. No, it's not in the well or even at the top of the well. Nobody cares anyway, as long as everyone measures the same way. Remember, we subtract out such error in the construction of maps, etc. which are referenced to sea level. All we have to have is the zero point and the ground elevation and we are in business. Well, we are rigged up and have the tool zeroed, so let's get on with depth measurements. Be sure and stay awake; I don't want you to miss such interesting stuff. You'd never forgive me.

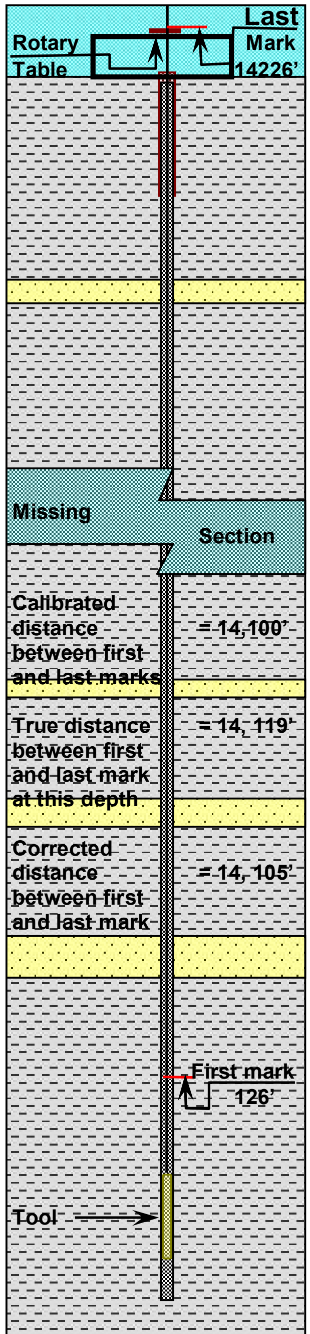

Figure 6-20 An illustration of cable stretch adjustments.

DEPTH MEASUREMENTS

When the tool zero is even with the rotary table, the engineer places the depth meter in the truck at one foot in the hole or makes it register 1'. The Kelly bushing has been set to one side with the Kelly and isn't visible. Besides, even I can add 1 and zero and get the right answer, 10, correct? Any of you chillen that think I'm wrong can surely add and qualify for further instruction.

CATCHING A WELL MARK

The next step is to catch the first mark at the well. That should be 126' or the same number we talked about (+1') after cable measurement or as shown in figure 6-20. I'm assuming, of course, that the bridle is the same and so is the tool length. We catch it or identify it to verify its accuracy because it is the only permanent reference we have. When I say, "at the well", I mean an operator takes a portable mark detector, identifies the mark and it is slowly lowered into position by the engineer. If it agrees with what he expected, everything is hunky dory; if not, he has to resolve the problem before proceeding. Normally, it is as expected. So, let's be optimistic and assume the best. This number is written down on a data sheet for later reference.

Now then, ya'll being my posterity and thus, somewhat brighter than normal, you have probably already figured out that this system is kind of clumsy. Every time the engineer wants to check a mark, he can't have an operator running to the well to do so. It's simply not practical. There's two ways around this predicament. We could mount a detector even with the rotary table and connect it to the truck so we could monitor the well mark whenever we desired or we can simply see what depth the marks are ringing at the truck when we know the mark at the well is correct. It's a different number but we can use it for control. The first option was used in South America while we Americanos used the latter. Thus, we observe at what depth a mark registers at the truck immediately after observing the well mark and such knowledge replaces the well mark. We'll arbitrarily pick the truck mark as 181'.

Now then, an observation is in order at this point. The distance from the rotary table to the truck via the cable path varies with rig set up, i.e. how far the truck is from the well, how high the upper sheave is positioned, etc. Furthermore, that distance can change during the job. Under normal conditions such change is two or three feet less at the bottom of the hole than at the surface. We can account for that without any problem but should the blocks move, i.e. slip, a few feet or simply be moved by the driller, the mark at the truck becomes useless because we don't know how much error has been introduced. This is why the mark observed at the well is so critical. Any change in the distance between rotary table and truck regardless of cause, has no bearing on the well marks. If we have determined them accurately, we can set our meter correctly at the bottom of the well regardless of whether the blocks have slipped or not because such changes don't affect that number. It's our guarantee to depth accuracy regardless of any slipups by the driller or any undesired truck movement, etc.

So, with about 14,000' of hole to traverse, the engineer simply takes out ½ a foot for each thousand feet of hole and he ends up with 181' when the tool arrives at that depth.

CATCHING A SECOND MARK AT THE WELL

About 200' from the bottom of the hole, the engineer catches another mark at the well. The last two digits should be the same if all is well. That is, with the surface mark at 126', the second well mark might be 14,226' or some similar number because all our marks on the cable are exactly 100' apart. Thus, if it differs from the correct value, the engineer makes the meter read correctly. Some of you are probably saying, ah ha, I caught you because I know the cable has stretched and the marks aren't exactly 100' apart. That's the problem with having brighter than normal posterity and particularly when one has been sniffing too many aromatic hydrocarbons like me. Now, how in the world am I going to get out of this one? Well, I may have to stretch the truth, somewhat like the cable, but I'll do my best to compensate and explain the situation for you.

MAKING STRETCH CORRECTIONS

You may remember, I mentioned stretch charts earlier. All the different sized cables have their own stretch characteristics as described by a graph, which we referred to as stretch charts. In fact there are two for each major cable. One is designed to match real stretch, as related to cable tension and provides true depth. The other is designed such that cable measurements match drill pipe measurements. Remember, the drill pipe has been measured in the rack, i.e., without the tension of the drill pipe string affecting it. See figure 6-25. I think I mentioned earlier that measuring drill pipe under tension is a slow arduous task and would significantly increase the time required to accomplish the job. Consequently, the industry standardized on the former system of measuring the pipe in the rack. Considering my earlier remark that all mapping depths are referenced to sea level, I repeat that the method makes little difference as long as consistency reigns.

So, the engineer reads the cable tension from the tension meter we talked about, notes his depth meter, and enters the proper chart **(i.e., cable stretch calibrated to match drill pipe measured in the rack)** with both tension and depth. Voile, the apparent amount the cable has stretched is given and he adds that amount to the 14, 226' he had just set the meter at. Let's say the stretch is five feet. He now sets the meter to read 14, 231'. (Note, in figure 6-20 I have also indicated true distance between first and last marks as being 14,119 feet, **which would have been established to match drill pipe measured under tension)** If that chart were used, the well depth would be recorded as 14 feet deeper than that obtained with our usual procedure. Now, let's get back to truck mark selection. Next the engineer will observe a truck mark which would typically be 7 or 8 feet greater than the surface mark of 181'. That number includes the cable stretch and the changing cable distance between truck and rotary table. We'll say it rings at 188'. Remember, we now have 3500 pounds of tension whereas there had been only about 500 at the surface. Now, we are ready to log. By the way, we have a bell that rings every time a mark is detected as well as a meter that it registers on. This also alerts the engineer in case he's dozing off a little, maybe in la-la land or thinking about the wife and kids.

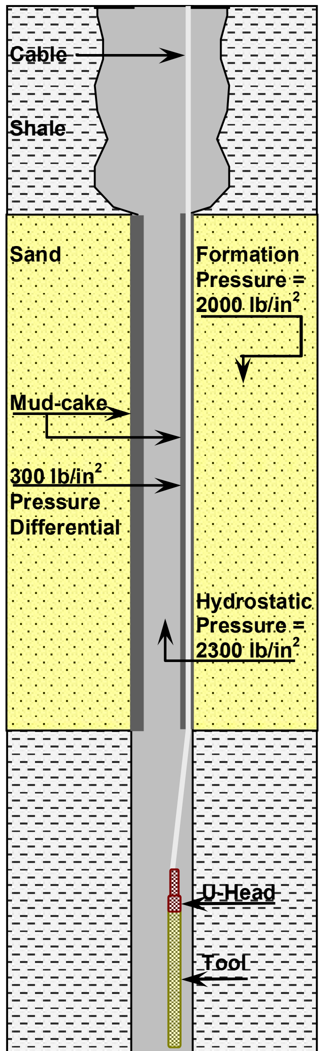

Figure 6-21 An illustration of cable differentially sticking.

As the winch operator moves the tool up the hole from bottom, the bell in the truck is now ringing every time the number XX88' passes by on the depth meter. We know that the correct number is going to be 181' when we get near the surface because we determined that earlier. So, with about 14,000' of hole to traverse, the engineer simply takes out ½ of a foot for each thousand feet of hole and he ends up with 181' when the tool arrives at that depth. The system works well and is sufficiently accurate. What more could be desired?

I mentioned earlier that the primary log or first log run becomes the depth standard. This is the log where marks are determined at the well as we just described. Depths of subsequent logs on the same trip to the well are tied into or made to match the first log. Basically, the engineer logs a short section with the later log and compares anomalies in his periscope to those on the first log or we might say he correlates the second or later log to the first one. Because the first one has set the standard, the engineer simply makes the second one agree as far as depths are concerned, a process called tying in. He notes the bell or depth at which the truck mark occurs on this log and utilizes it throughout to maintain proper depth. He also checks anomalies at regular intervals during logging, as continuing assurance of depth consistency

GOING FISHING

You will want to read this portion of chapter six carefully while looking for flaws, because I've already warned you there might be something fishy considering the title. I promise, however, not to lie but maybe exaggerate just a little, sort of like a normal fishing story. You might be wondering what in the world fishing has got to do with the oil business. Is grandpa gonna tell us about some neat fishing streams he came across out thar in the oil patch or maybe about some beautiful lake he came across as he wandered in them thar hills in search of a remote drilling rig? Then again, maybe he's just setting us up for more of his exaggerations. Well, I have seen some pretty streams in my time with, I suspect, some mighty nice trout lurking in their depths. How-some-ever, I never had time to stop unless, of course, I was on days off. Even then, I had to set up a picnic or camping trip with Esther and the kids to take advantage of such places. No, in this case, I'm not speaking of trout fishing or bass fishing or anything like that. I'm talking about big fish that sell for thousands of dollars. Talk about quality! Man, such fish often go for $50 a pound or even more. You find them in deep holes and I mean really deep, like 10,000 or 20,000 feet. You may wonder, is he going to shift to his off shore experiences now or just exaggerate some story in the Rocky Mountains? But now, are you interested? Well, hold on tight because I'm going to take you for a real ride.

THE OIL FIELD FISH

When oil field personnel speak of going fishing, you'll notice it's always with a tear in the eye but not one of happiness. Why, because, such fishing experiences are nothing but work. You don't get paid any more and, in Schlumberger's case, you lose money. You see, a person could be somewhere else making money for the company and hence, one's self. Consequently, we refer to a fishing trip as a fishing job, and I do mean job, which term you will understand soon enough. You see, any piece of drilling equipment, testing equipment or logging equipment that becomes stuck in the hole and won't budge with standard operating procedures is termed a fish. The tactics used to retrieve such an animal vary with the quarry, its size and the circumstances, which lodged the sucker therein. I could probably write quite a bit on fishing for drilling equipment and testing devices but that's not what my story is about. It's also not what I spent my time doing when I was "going fishing". No, my efforts always involved the retrieval of Schlumberger equipment, which was expensive and hard to replace. You see, you can't go down to the local hardware store and buy a new induction tool or other logging device. We couldn't just pick up the phone and order one from headquarters in Houston either. We had to wait in line with priorities established according to need. Consequently, our loss (if we didn't get the tool out) was more than just the price of the tool. It had to be measured in terms of lost business because of inability to provide the desired service. It also might involve a radioactive source of some kind. Such things made "going fishing" for Schlumberger serious business and we paid close attention.

SOURCES OF FISHING JOBS

I don't suppose that it's too surprising to find out that tools sometimes get stuck in oil wells that are being drilled. After all, there can be a lot of rather nasty circumstances associated with fishing for such despicable critters. So, let me explain a few things that lead to fishing jobs regarding Schlumberger tools.

First, you have carelessness. That's one you don't want to be responsible for but it does happen. An example would be "not paying attention when bringing a tool out of the hole". The tool hangs up on a ledge such as the bottom of surface casing, the BOP rams or some other protrusion. Before the winch operator can shut things down the weak point rating of the U-head is exceeded and it parts letting the tool drop to the bottom of the hole.

Another example of carelessness is allowing the cable to get ahead of the tool while going in the hole. In most cases a tool will drop nicely at twenty thousand feet an hour and no problem occurs. Sometimes, however, the tool may strike a ledge and stop. If such goes unnoticed by the winch operator, cable may fall past the tool developing kinks, knots and even balls. These get wedged along-side the tool and, you guessed it, the tool is stuck tight.

A second cause may be debris, which can fall in on top of the tool while logging and catch the tool in a bind by lodging between the tool and the wall of the hole. If the operator can't shake the tool loose, a fishing job follows. We do our best, however, to prevent such a situation.

Third, certain types of rock (clays) have a tendency to swell and decrease the borehole diameter to something less than bit size. Though it was big enough to get through to start the log, two hours or so later when the device returns to that depth, the clays have swelled and the diameter is too small for the tool to come back through. If you're lucky, you can drop back down and work on the tight place by alternately raising and lowering the tool to ream out the diameter a little until it can squeeze by.

Fourth, differential sticking may grab the tool or, more likely, the cable, while logging. This is probably the most common cause of Schlumberger fishing jobs. To better understand it, refer to figure 6-21. There I have shown a rather thick water sand of, let's say, 50' with thick mud cake buildup. This occurs with relatively high water-loss drilling mud. In the case described, the sand has a reservoir pressure of 2000 pounds per square inch while the mud column hydrostatic pressure is 2300 pounds per square inch, a rather typical situation. This leaves a differential pressure of 300 pounds per square inch between well bore and formation. However, the mud cake has sealed off the formation and no more filtrate can enter the sand at his particular point in time.

Stability reigns and all is well, unless the cable cuts through the mud cake. When that occurs and the mud cake is closely packed around the cable, that same differential pressure now occurs across the cable rather than having the hydrostatic value on all sides. Thus, we now have 300 pounds per square inch of force pushing the cable into the wall of the hole. If the cable is ½ inch wide (typical) and fifty feet of it is in front of the sand, then we have about 1800 pounds per foot pushing the cable into the wall. When that occurs, we aren't going anywhere and the weeping and wailing and gnashing of teeth begins. We have a fishing job on our hands. Believe you me, a $20,000 tool may be a more valuable trophy than a measly little trout but it surely isn't as much fun landing it. It's like snagging your fishing line in a stream after a nice fish has a hold of the hook. Somehow we have to get a hold of the fish or, in this case, free the line from the snag. One doesn't want to break the line and lose the fish. Such a job doesn't pay any bonuses and it's long and tedious. Besides that, we'll have to splice cable, build a new bridle and maybe repair the tool when we return to the shop. Oh well, as they say; "It's all in a day's work", or maybe I should say in three days work. So how do we get out of this mess? Is there any easy way? I didn't find one in my 30 odd years of oil field service.

THE CUT AND THREAD OPERATION

I mentioned the weak point a while ago. I wasn't referring to one of my weak points but to the weak point designed into the U-head. It has a specific function, which you're about to learn of. It is designed to break at a specific tension depending upon design and cable strength. For our logging cable we generally used a weak point rated at 6500 pounds. It is installed in the U-head and consequently, if cable tension at the U-head exceeds that value, VAROOM, we are free but the tool isn't. We lost the fish. Of course, when the cable is stuck, as in our example, of figure 6-21 we aren't going to pull free. We may pull the cable in two, pull down the rig or suck the truck down the well but that cable isn't going to move. So we got to figure out how to get it free. You see, customers are kind of picky about their wells and any cable left therein has a tendency to mess things up. It's to their benefit and ours to get the cable and tool out. So we work together to accomplish the job.

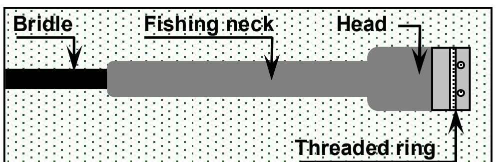

Figure 6-23 The Schlumberger Universal Head or so-called U-Head.

This is where the cut and thread operation comes in. It is so successful in retrieving fish that we utilize it even when the tool is stuck and we could pull off and clear the well of our cable. Often the operator will suggest pulling off when we know it's the tool that is stuck. However, if we do, anything may happen to the tool. It may slide further down the hole. It may tilt to one side in an enlarged section of hole. If the latter occurs, experience tells us the odds are against retrieval and the tool will have to be cemented in the hole. Consequently, in uncased holes we always recommend the cut and thread operation. In a cased hole the situation is different and we often do pull off. The operator then goes in with drill pipe and an overshot, grabs hold of the tool and brings it out rather quickly, in comparison to the cut and thread operation.

OVERSHOTS

Now is a good time to talk about the overshot I just mentioned. Such an animal is used in virtually any fishing operation. About the only exception is when fishing for cable or something similar. So, consider figure 6-22, an illustration of a Bowen overshot, one which we used in our cut and thread operations. Over-shots exist in many different sizes and forms to meet particular needs. They all include some type of

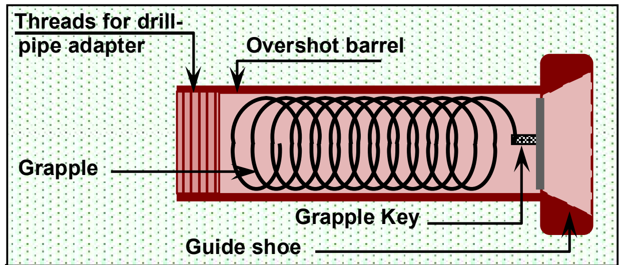

Figure 6-22 Simplified drawing of a Bowen Overshot with grapple and guide shoe.

helix shaped grapple, which engages the fish when the overshot slips over it or some portion of it. The barrel not only contains the grapple but also controls its expansion and contraction. Thus, when the barrel slips over the fish the grapple expands to accommodate it but when the barrel is pulled back upwards, the internal surface design of the barrel causes the grapple to contract and its knife-edges cut into the material composing the fish and hold it firmly. The grapple key is held in place by the guide shoe and holds the grapple firmly in position. The fish can only be released by rotating the drill pipe and overshot barrel which essentially unscrews the grapple from the fish. The guide shoe guides the overshot over the fish as it approaches it and the threads on the top end are hooked to the drill pipe through an adapter. As I indicated, there are many different types of over-shots designed to fish for specific tools. I am most familiar with

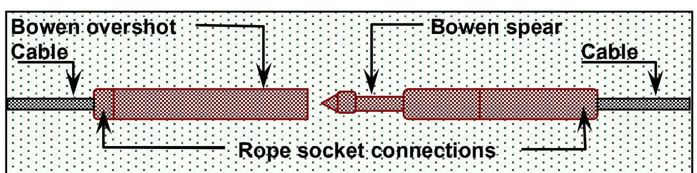

Figure 6-24 Simplified drawing of Bowen quick connect cable equipment for cut & thread jobs.

the Bowen overshot and have been unfortunate enough to have used it numerous times. We'll be talking about it more a little later on.

THE BELL HOUSING

Figure 6-23 illustrates the bell housing of a universal head connected to a bridle. The bell housing has two distinct parts, i.e. the fishing neck and the head. The threaded ring is part of the head and provides the physical connection of the tool head to the U-head. The grapples of figure 6-22 are specifically designed to grasp the fishing neck of the U-head when it is slipped into the barrel. This allows the drill pipe to reliably engage the logging tool to pull it out of the hole. The grapples are released by rotating the tool in a counter clockwise rotation, i.e. basically unscrewing it.

BOWEN FISHING ADAPTERS

Now, let's consider one more piece of Bowen equipment that Schlumberger took advantage of. It is the so-called spear and overshot used to mechanically connect the two ends of the logging cable together during a fishing job. This is illustrated in figure 6-24. Prior to the cut and thread operation, the cable is cut and the overshot hooked to one end with a so-called rope socket and the spear connected to the other with a similar device. The spear obviously fits inside the overshot and can be easily connected and released as needed during the operation. We'll describe the process a little more during an overview of this activity. Of course, with the down-hole cable pulling at about 2000 to 3000 pounds, the procedure is closely controlled in both time and method.

SHE'S PULLING TIGHT

From time to time, the logging engineer will be kind of lost in his work, watching those neat little galvanometers dance across the screen, while wondering if that resistive zone he just passed is going to have any decent porosity. All seems calm and the job is going just fine when all at once the winch operator yells, "she's pulling tight". The first reaction of any normal engineer is to utter a quick prayer kinda like, "Come loose baby, come on loose", as he glances up at the tension meter, hears the truck engine groan a little and the line weight begins to build. He will quickly observe the tool response to see what it is telling him. If a caliper is in the tool string, he may observe a decrease in borehole size indicating a tight spot. If so, he may elect to pull only a thousand pounds or so before dropping back. Sometimes a tool can be worked through such a situation. In any case, he'll shut down the recorder because there is no point in wasting film. Also, he'll have to overlap the previously recorded film a hundred feet or so if they are fortunate enough to break loose. Assuming there is no tool indication of the problem, the engineer may elect to continue pulling. He has to make the decision as to how hard to pull before shutting down. The weak point is going to part at about 6500 pounds above line weight, give or take a little. To keep a little safety margin, we might raise the weight as high as 5000 pounds, hoping all along that the sucker will come loose.

All seems calm and the job is going just fine when all at once the winch operator yells, "she's pulling tight".

Although we got a big one on the line, this kind of fishing is no fun. We aren't interested in returning with a story of how long we had to play that lunker and how hard she fought. No sirree, I should say not, the less it takes to land that baby the better. Assuming the worst, we might shut the winch down at 5000 to 5500 pounds above line weight. That might be about 7500 or 8000 pounds total tension in a 10,000 or so foot hole. Once shut down the engineer would observe the line tension for a while before slacking off. With luck, the tension might slowly drop off indicating the tool is moving ever so slow. If that happens, the tool may well pop loose in a few minutes. What a relief that is, when one is so lucky. It makes an engineer appreciate the boredom of a smooth job wherein the trips in and out of the hole are without incident and a top quality product is delivered to the customer in record time.

Well, since I'm telling the story and am determined to describe a fishing operation, you can be sure there won't be any good fortune today. So after a little while the engineer would mutter, "Let's find out where she's hung up". The winch operator would then slack off to maybe ten feet or so below the point the tool began to pull. He would then have the winch operator pick up to normal line weight and stop. With that accomplished, he'd then instruct the operators; "We'll need to take a stretch measurement every thousand pounds of line tension up to 5000 over normal line weight. That will give us the shallowest point at which the equipment is hung up".

MEASURING CABLE STRETCH

The engineer would then grab some chalk, a pad and a pencil along with his operations manual and head for the rig floor with the other operator. Once there, he'd make a chalk mark on the cable just even with the rotary table. Next, he would signal the operator to come up to

1000 pounds additional tension and stop. At that point another mark would be made and the distance or stretch measured between the two. The stretch is then tallied opposite the 1000-pound value of cable tension. He continues this procedure for four additional 1000-pound increments of tension, marking the line with chalk at each stop and measuring the stretch. He then tallies up the results on his little note pad or even in his head, no less.

He will then select the stretch chart for the particular cable mounted on the truck from a group provided in his Operations Manual and enter it with both observed stretch and tension. From the chart he can determine just how much cable is stretching, or in other words, the highest point in the well at which the cable is stuck. You see, the cable may be differentially stuck, or key seated as it is often termed and if so, the tool itself may be free. Let' assume this is the case (take a look-see at the situation of figure 6-21).

Well, now the engineer at least knows the depth at which his gear is hung up. If he is lucky, a primary log has been run prior to this predicament. Let's assume it has and he spots a thick water-sand as is shown in figure 6-21 near the depth indicated by the stretch charts. If that is the case, he now understands the problem better and can predict the depth at which the fish is apt to come free.

WAITING ON FISHING TOOLS

If the tool is stuck, the next step would normally be to place the cable tension at 5000 pounds or so above line weight once again and hold it with the winch brake after notifying the well operator's representative and ordering out the necessary fishing tools. The crew then waits with the line under tension, hoping for that miracle until the fishing tools arrive at the well.

Schlumberger engineers, you see, have to be optimists. We feel sure that the cable and/or tool will come loose before we have to make that fateful cut. You would be surprised how many times that is the case. In my experience, such an act of God seems to occur roughly fifty percent or so of the time.

It's similar to the situation we often found ourselves in with our dog Charlie. He loved to have tug of wars with anyone who is sucker

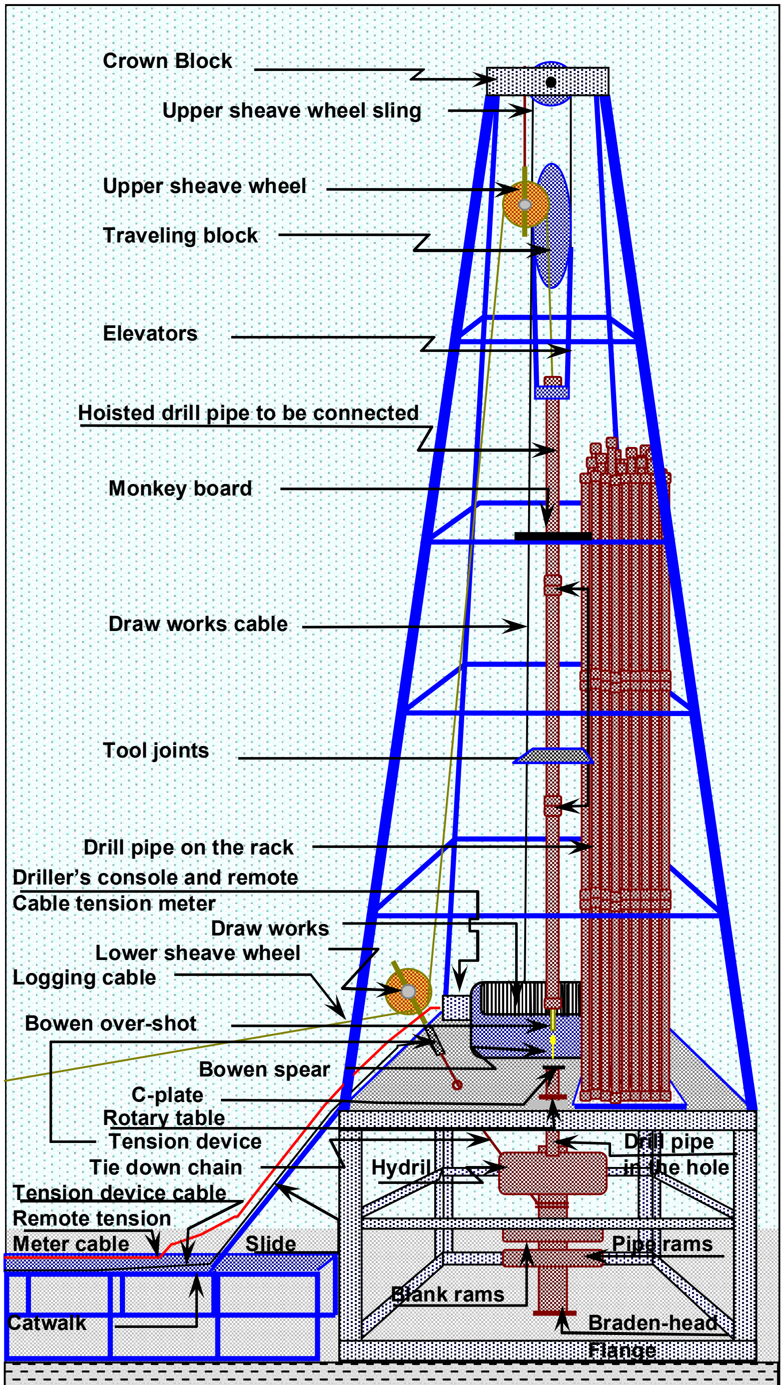

Figure 6-25 A simplified drawing of Schlumberger's equipment configuration during a cut & thread operation.

enough to pull on the other end of the rope. Well, Charlie's an optimist and keeps a bind on the rope. Invariably, the sucker who took him on (a situation similar to our fish) gives up and Charlie wins and we, of course, hope so too.

In most cases it will be a few hours before the fishing tools arrive anyway and tension over such a time span often breaks the fish loose. One can spot the gradual slipping or movement of the tool by observing the weight, which will gradually decrease with that slipping process. Should that happen, the winch operator builds it back to 5000 pounds above line weight so as to keep a maximum tension on it. Once the tool begins moving slowly, it usually comes loose. The word usually is significant because, as someone once said, "Baby, it ain't necessarily

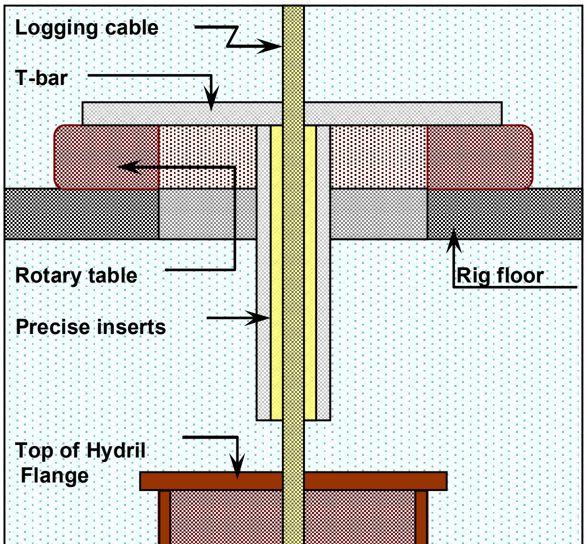

Figure 6-26 An illustration of a T-bar being used to secure the cable at the rotary table.

so". And, unfortunately, my story won't permit that because it would have to end there. I intend to describe the fishing operation whether you want to read about it or not and consequently, the tool is still hung when the fishing tools arrive.

RIGGING UP FOR FISHING

Rigging up for the fishing operation would be difficult to explain without the aid of a diagram. Also, you probably remember just how much fun this kind of artwork is for me. It's more like assembling tinker toys than art and consequently appeals to the engineering mind.

ART WORK

The difficulty comes in convincing the reader that my creation actually resembles a rig or whatever I'm trying to describe. However, the advantage I have is that few of you really understand what such electromechanical devices look like anyway. Thus, you almost have to accept my word that the visual image before you does, in fact, represent what I describe it to be, even though your imaginative powers find it difficult to swallow. So, do your best to find the hidden reality within my creation; trying much like you did looking for hidden creatures within those puzzle pictures of your childhood days. Now, let's move back to our figure 6-25, an illustration of a rig during a fishing operation.

One more comment about my work of art. The truly astute reader will realize that something about the floor arrangement of my little rig in figure 6-25 is wrong. Relative to the catwalk, the draw works is rotated 90 degrees. Similarly, the stacked drill pipe is on the right of the diagram or to the back of the rig floor. That's not kosher, ya know. The open face of the draw works should be facing the V-door and the catwalk while the stacked drill pipe should be on the left of the diagram or to the front of the floor next to the V-door. We could solve the whole thing by placing the catwalk in front of the rig but there's no room and the slide would mess up the view of the rig cellar. I've also made the stand of drill pipe being hoisted by the draw works somewhat larger than the other stands in the rack. I had to in order to get the Bowen cable coupling spear and overshot to show up. Other than that I've tried to keep relative sizes reasonable.

Consequently, as with many other things in this book, I have taken the liberty of placing things as I thought convenient and adjusting size as required by my limited artistic ability. Such acts don't change the principles involved and besides, it's my book. I just didn't want the more artistically and mechanically astute of my posterity to think I didn't know better. I've spent about seventeen years to date in writing this thing and trying to portray myself as somewhat competent and don't want to mess it up now.

CUTTING THE CABLE

Once the decision has been made to begin the cut and thread operation, the first thing the Schlumberger crew does is cut the cable and in so doing, taking special precautions not to let the lower end slip down the well. Consequently, Schlumberger has included with the fishing gear a so-called T-clamp for the cable. It has precise inserts placed in the cable channel, which will grab the cable without damaging it but securely enough to hold several thousand pounds tension. See figure 6-26 which illustrates the manner in which the cable is secured. Before cutting the cable, normal tension is applied, the T clamp put in place and, of course, the tool in the hole is shut down, i.e. all power is removed from the cable.

Once the clamp secures the cable, excess cable is backed off the truck to provide slack on the rig floor. The cable is cut about 8 to 10 feet above the rotary table (depending upon well depth) with a special cable-cutting tool included with the fishing gear. Too much excess cable above the rotary table slows the operation and too little will result in the cable end gradually being pulled into the hole. You see, as the cable is pulled into the center of the hole by the descending drill pipe, the distance to the U-head from the rotary table is increased causing the cable end to move towards the well opening. Should it move

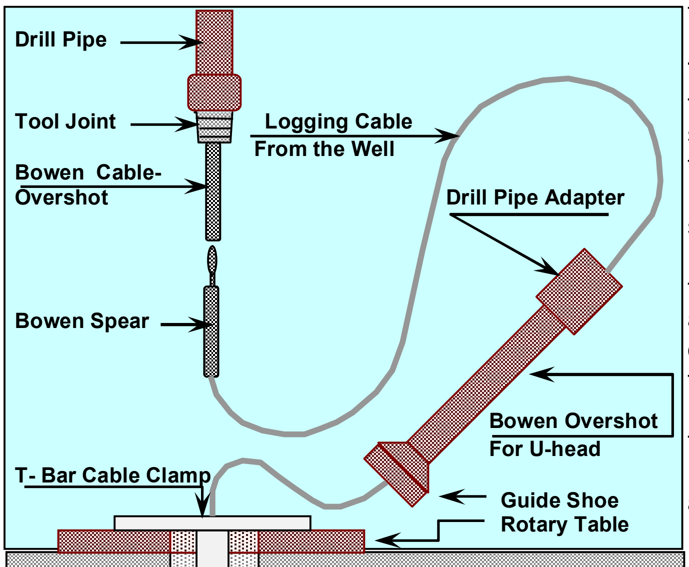

Figure 6-27 A drawing illustrating the process of threading the Bowen spear through the Bowen U-head overshot and latching it to the Bowen cable overshot prior to running the drill pipe in the hole.

below the rotary table or even into the drill string in the hole, the rig crew can no longer latch and unlatch the cable ends. I suppose if that happened, we could utilize a Schlumberger torpedo and add cable before it was too late.

The cable from the well is then threaded through the Bowen overshot, which is to engage the fishing neck of the U-head (see figure 6-27 as well as 6-22). The Bowen spear of figure 6-24 is then attached to that same piece of cable coming from the well. The threading operation is necessary because the ID (internal diameter) of the overshot will not allow the spear to pass through. You might think that's kind of dumb but the design is on purpose. If the bottom piece of cable & spear should somehow get loose, it can fall no further than the overshot and can be retrieved by coming back out of the hole. The Bowen cable overshot is then attached to the cable coming over the sheaves or the truck end. These installations are secured with rope sockets and locking nuts which make the arrangement capable of holding any tension that might be applied to the cable.

REVISING THE SHEAVE POSITIONS

The upper and lower sheave wheels have been removed from their normal positions and the tension device now secured to the lower sheave. A sling made of special heavy cable is attached to the upper sheave and will be used to secure it to the crown block. The logging cable is threaded through the sheave wheels, which will now be re-installed for the fishing operation. The derrick hand now rides the elevators up to the crown with the upper sheave secured to their side as well. He installs the upper sheave wheel to the crown block and the driller then lowers him to the monkey board. The lower sheave is secured with a chain to the BOP stack as before but through an opening in the rig floor other than the rotary table. Weights have been place around the cable just above the Bowen cable overshot which are sufficient to make it drop through the drill pipe. The Schlumberger personnel and rig crew are now ready to begin the fishing operation, which will probably last at least 8 or 10 hours for the typical fishing job on an average well.

BEGINNING THE OPERATION

Well, finally we are ready to start in the hole, some 12 hours or so after becoming stuck and we are looking forward to another 10 or so. No wonder we don't like fishing jobs, huh? A Schlumberger operator will operate the truck winch, another will be on the floor to signal the winch operator and the engineer will be watching line weight along with the driller and will communicate with the well operator and drilling crew as needed. You see, there really is no expert for this particular operation; because it occurs rather infrequently, thank heavens. Unexpected problems may arise and decisions have to be made quickly to keep from cutting the cable and making things worse than they are. If any unusual symptoms occur, the action is stopped and the problem evaluated before proceeding. You should note that in figure 6-25 the driller has a remote tension device meter, which he observes while lowering a stand of pipe into the hole. The red cable connects it to the truck tension device. This allows the driller to determine if any unusual tension is being placed on the cable by the drill pipe. If such should occur, the cable might be cut which will complicate the operation. Believe me, we have enough trouble now and don't really need any more difficulties being added to our woes.

RUNNING IN THE DRILL PIPE

The driller and crew begin by hoisting a stand of pipe (no drill collars are used) as illustrated in figure 6-25. Actually the one shown isn't the first because we also have one resting comfortably in the hole. Anyway, it swings into position above the rotary table, the winch operator sucks the cable up until motioned to stop by the floor operator. That's the proper height for the derrick hand to grab the cable overshot and place it in the hanging pipe. The winch operator notes the depth meter reading in the truck for future reference. The derrick hand signals the floor operator when ready and he, in turn, signals the winch man. The brake is then released on the winch and the overshot and weights drop through to the floor. Once the overshot appears at the bottom end of the pipe, the spear is connected. Again the winch operator notes the depth meter reading. Figure 6-27 depicts the first connection of spear and overshot as well as connecting the drill pipe adapter with the overshot to the drill pipe. Once the Bowen cable overshot is connected to the spear, the slack is slowly taken out of the logging cable, as the drill pipe and overshot combination is being lifted into place by the driller. The adapter is secured to the drill pipe with the rig pipe-tongs.

With cable slack taken out, the first stand of drill pipe is lowered into the hole. The slips are set to hold the drill pipe in the hole (remember chapter five on drilling) and a roughneck places the C-plate on top of the pipe. Take another gander at figure 6-25. The driller begins raising the blocks immediately for the second stand. The winch operator slacks off on the cable allowing the bottom of the spear to rest on the C-plate.

The cable overshot is then disconnected from the spear and the winch operator sucks the cable back to the top of the derrick for placement in the next stand. Having made note of the winch depth with the overshot at the right height, he is able to stop it exactly in the right place for the derrick hand to place it in the second stand. By the time the cable overshot is

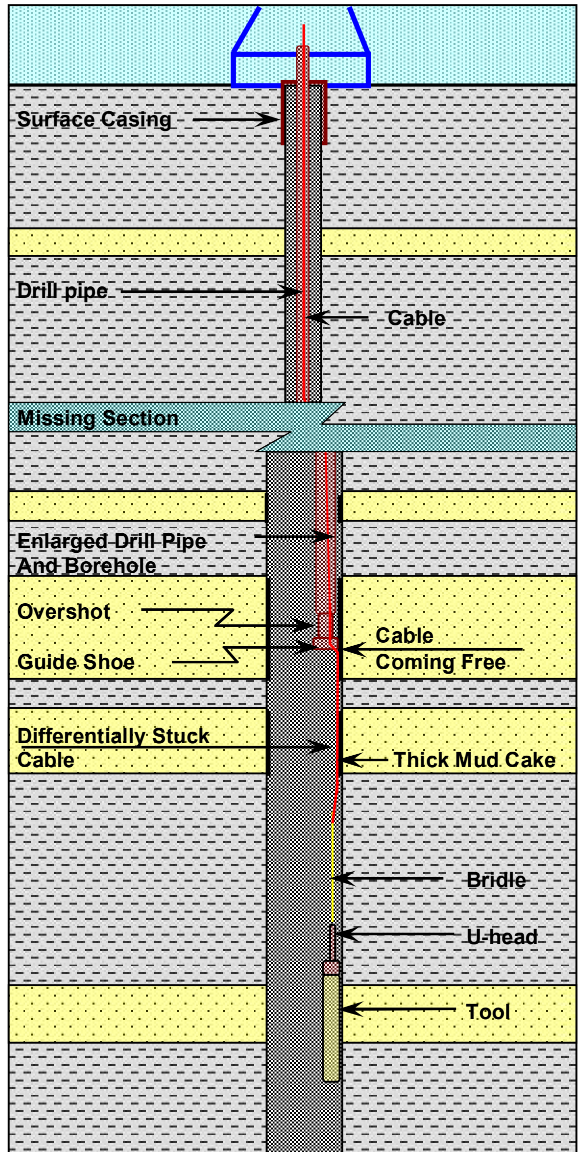

Figure 6-28 A drawing illustrating the process of freeing differentially stuck cable from the mud cake with the drill pipe.

properly positioned, the derrick man has latched on to another stand of drill pipe which swings in over the hole and is made ready for connection to that held at the rotary table.

The overshot and cable are dropped through the pipe, which has been positioned directly over the C-plate and about 6 inches above the top of the spear. As the overshot emerges a roughneck snaps it on to the spear once again that protrudes from the stand in the hole.

The winch operator picks up on the cable to normal weight (no cable slack allowed), the driller drops the hanging stand into the box of pipe in the hole and floor crew makes up the threads. The roughnecks tighten the joint with the tongs, pull the slips and the driller quickly lowers the blocks until the top of this stand rests a foot or so above the rotary. The process just described is repeated again and again with the engineer watching the line tension to be sure the cable in the hole is not being pulled downward by a kink or something.

With the fish at about 10,000 feet it will take roughly 110 repetitions of the described activity to get to it. The first few stands go slow while everyone is getting the swing of things. After a while the rhythm is established and the operation moves smoothly along. There shouldn't be anything to worry about until the overshot in the hole nears the key seat (differentially stuck) depth although such may have moved up hole since the original stretch measurement. That's why the engineer monitors the cable tension, i.e. to detect increased tension due to additional key seating. (I'm using the term key seat, though not technically correct for the situation because it's simpler than the differential sticking point).

ENGAGING THE FISH

As the key seat depth is approached, the driller carefully lowers the pipe while observing the cable tension. As the key seat is engaged, or the cable is being pulled out of the mud cake, small increases in weight will be observed. The driller may move the pipe up and down to facilitate the freeing of the cable. Consider figure 6-28 to better understand how the guide shoe pulls the cable away from the wall and out of the mud cake. Note the bottom end of the drill string has been enlarged to make things easier to see. My color scheme may not be the best but it does help individual items stand out from background colors. Besides, I like them even if ya'll don't.

The tool is free in the diagram, so once the guide shoe passes the last sand showing the cable to be differentially stuck, the tool can be moved. This would be indicated by a drop in weight and would have been foreseen by a knowledgeable engineer. To validate the situation the cable is raised until the cable overshot approaches the monkey board and then lowered again to its normal position. The tool may be two or three thousand feet below the key seat and it's a waste of time to continue with drill pipe to get to the tool, if indeed it is free. Instead, we would leave the last stand of drill pipe sitting in the rotary, pull the slack from the cable and secure the cable with the T-bar. The cable overshot and spear are then placed on the floor and the cable is cut on each side. With that done it is then tied in a square knot to be pulled on to the truck a little later in the operation.

Of course, the T-bar is removed before starting up the winch. The knot is then pulled tight and the ends taped down so they can pass over the sheave wheels. The cable is pulled on to the truck very carefully until the knot is wrapped on the drum. The winch-man then sucks the tool up to drill pipe depth. Before pulling it into the overshot, he shuts down the winch to allow the driller to break circulation (begin pumping mud down the pipe) for a few minutes until we are sure the overshot is clean. If debris were lodged in it the U-head might not enter and/or be held securely. We don't want any slipups here because too many hours have already gone into the job. With that done, the winch operator pulls the U-head into the overshot with a tension of four or five thousand pounds to plant it firmly in the grapples.

Next, we verify the fish is secure before parting the weak point. This is accomplished by having the driller move the drill pipe fifty or sixty feet to verify the tool is locked in. If it is, slack appears in the cable. With the tool secure, the pipe is lowered back to the rotary table and the slips set. The T-bar is placed on the cable once again and the elevators attached to it. The weak point is then parted with the draw works. The cable and bridle are then sucked out of the hole and both are spooled on to the truck. This takes some careful spooling since the knot kind of messes up the job. Next, Schlumberger rigs down and gets out of the way of the drilling crew while they bring the fish out of the hole.

LANDING THE FISH

The reader might think Schlumberger's job is done at this point. That's hardly the case. We get to rest a while as the rig crew brings the tool to the surface but it's up to us to handle the tool once it breaks through the rotary table.

Usually the rig crew will be pulling a wet string. That is the mud in the pipe won't drain out the bottom end fast enough and when the drill pipe connection is broken, SWOOSH the ninety-foot stand drains on to the rig floor bathing anything and anybody in sight. Usually they place a shield around it once the connection is loose and before the driller lifts the stand to be placed in the rack. In this case they can't (at least until the last minute) because they have to chain out, a process I tried to explain in chapter five.

That slows the operation and makes the wet string a little nastier. You see, spinning the rotary to unfasten each stand would unscrew the fish from the overshot and our effort would have been in vain. The down-hole string can't be rotated at all. I explained that process back in chapter five but a little review wouldn't hurt. It goes something like this. After a stand is pulled and the connection loosened with pipe tongs, the spinning chain is wrapped around the bottom tool joint of that stand. As the driller applies pull to the chain from the draw works, the roughnecks hold it firmly to the pipe and the friction of the chain spins the ninety-foot stand hanging in the elevators. As they break the stand loose, the mud begins to spew but they hurriedly place the shield around the pipe before the driller picks it up. Even so they get splattered and then some.

When they are pulling the last stand, the Schlumberger crew is on the floor ready to handle the tool. If a radioactive source is involved, we clear the floor and handle the removal of said source according to accepted procedure. This means having the appropriate shield for the source on the floor as well as the necessary handling tool. The engineer will remove such a source with the help of an operator and place it in the shield. Shield and source are then taken from the floor before any other work proceeds. Once all sources are removed, the rig crew will break the overshot loose while the logging crew supports the tool. The tool may be laid down on the catwalk as one piece or placed in the rat hole for disassembly depending on its length. The individual pieces are loaded on the truck and finally, we are free to go. The operator may elect to condition the hole and try again for logs. If so we get another truck on location and the job is completed.

SPLICING THE CABLE

Unfortunately, the repercussions of the fishing job are still reverberating when we arrive at the shop. Hopefully there are no impending jobs, which require the truck to be placed back on line, like right now. The crew will probably clean the truck up, the engineer will complete all necessary paper work and a cable splice will be set up for the next morning. Not too many men are expert enough to splice a cable. Usually the mechanics were trained in the art and if you were lucky, one resided at your location.

In any case, the truck would be set up with the garage winch just like a measuring job (figure 6-13) and the cable pulled down to the square knot. Any questionable cable would be cut out before splicing and then the mechanic would proceed. Eight hours would usually suffice for a normal splice and then another measuring job would be in order. Also a new bridle with its appropriate weak point has to be built, which takes a few hours. Finally, the truck is back in operation and is placed in rotation with other units. Such experiences as these, I believe, cured me of my desire to go fishing. Even beside a quiet stream, the thought of fishing sent shivers up my spine. So, I began to buy the little suckers like disenchanted cartoon fisherman.

CABLE CONSTRUCTION

A few words about the cable construction seem in order at this point. You probably remember the cable is constructed of seven conductors (at least the later versions), which are surrounded with two layers of steel strands, which make up the armor and provide the mechanical strength of the cable. Six conductors are wound tightly around the seventh to provide a rather solid cylindrical surface on which the inner armor will rest. See figure 6-29 which illustrates both a cut-a-way view and a cross section. Even with my art, the picture or illustration should explain its construction more clearly than the words, which follow. Of course, that might not be the clarity of the art as much as the foggy nature of my words. The number seven conductor acts as a core to provide the necessary mechanical support for the other six. At one time number seven was nothing but filler material but as demands for additional signal paths increased, it was converted to a conductor.

The inner armor layer has two fewer strands than does the outer and each strand is also slightly smaller in diameter. This results in a slightly smaller cable cross-section or diameter at this point, allowing the outer layer of armor to fit snugly over it. All void or empty space within the inner armor or cable proper is filled with appropriate material called filler. The filler's function is to provide a solid and perfectly smooth cylindrical surface for the inner armor wires to rest on as a support so they can't be bent or broken. Likewise, any specific portion of the material will not have to bear extra pressure.

The inner armor wires are wound around the core or conductor group in a helix fashion and clockwise direction if one was looking up the cable. The outer armor wires are also wound in a helix fashion on top of the inner armor but in a counter clockwise direction or opposite to that of the inner. As tension increases on the cable the armors squeeze down on the core evenly throughout the cable increasing its rigidity and strength. Having two layers of armor wires wound in opposite directions prevents the armor from unwinding and losing its composite strength. It also decreases its tendency to stretch and insures better depth measurements.

SPLICING THE CABLE

Figure 6-29 illustrates the complexity of the cable in both an electrical and mechanical sense. It takes little imagination to see that the job of splicing the cable is going to be an involved process. The cable splice is made over a total distance of 100 feet with no two wires or armor wires connected at the same point.

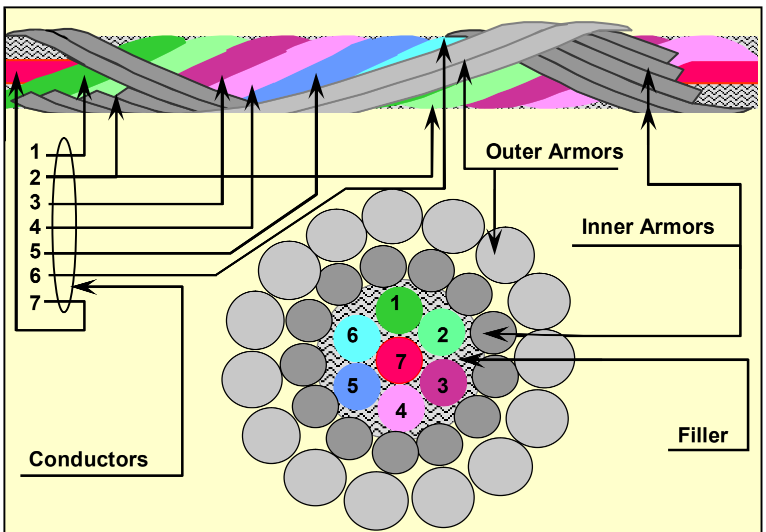

Figure 6-29 Simplified longitudinal & horizontal cross-sections of armored logging cable construction.

First any questionable cable, which might be damaged, is eliminated. The armor wires, both inner and outer, are then unwound some thirty feet back on either side of the cut. Each end of the cable, i.e. the core or conductor group, is carefully held in small vices and the individual wires unwound along with the filler material. The center conductor or #7 is connected and insulated first. Next each conductor in sequence is cut to slightly different lengths so that when connected to the other piece of cable the individual conductor splices will be staggered over about a foot of cable. This minimizes the tendency for wire connections to increase the cable diameter. In so doing, the wires are wound around the center conductor similar to the untouched cable. With that completed, filler material is replaced and the individual inner armor wires from either end are rewound around the core, cut to the proper length and welded. The armor wires are cut such that welds are staggered over fifty feet of cable. Obviously, the welds must be secure but contain no extra metal to enlarge the diameter. Such would prevent the outer armor from lying smoothly on top and could also damage the insulation of individual conductors. Finally, the outer armor wires are rewound and welded in a similar manner but in the opposite direction. The cable is carefully checked for both continuity and insulation and if it passes, the splice is pronounced complete.

MEASURING THE CABLE

Obviously, the cable marks on the drum side of the splice no longer apply because of the section cut out during the splice. Marks below the splice or nearer the head will also be in error because of the tension and resultant stretch suffered during the fishing job. Consequently, the cable is pulled onto the garage winch (see figure 6-11) and remarked beginning from some mark already on the cable but deeper than the splice. It is unnecessary to mark the full cable. It is marked in a similar manner to that described earlier and a new first mark obtained for depth measurements. With that complete, the engineer reports to the manager and other interested parties that his truck is now back on line waiting its turn to log.

Cable strength suffers very little because of a splice due to the cable design and construction as well as the manner of splicing. Thus, life goes on with the spliced cable. Considerable expense is prevented through such practice. One or more splices can be made in a cable during its lifetime or even one cable becoming a composite of two.