Drill Labs, Inc. Training Program

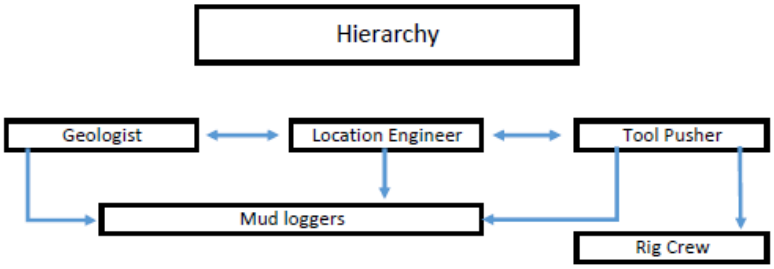
The Job of Mud Logging

The process of mud logging requires you to record data for each and every foot for thousands of feet. It may seem monotonous, but once you understand what we do, you will come to realize how important it is. Computers have come a long way in relieving much of repetitive nature of our tasks. Tasks that require Geology, math, observation and computer literacy make it a job that bridges a gap from those on a rig working with their muscle to those working with their heads. Here's the fancy job description for the position you are training for:

Hydrocarbon detection specialists. We monitor numerous parameters of an exploration drilling operation (oil or gas) which provides both geological and operational data to assist in the safe, and successful completion of our clients prospects (finding hydrocarbons).

So who's your boss on the rig?

A practical description of the organization chart for rig is presented below. We are the eyes and ears of both Geologists and Engineers, who both serve as our clients. Yes, this presents us with that age old problem of too many chiefs not enough Indians, but as a night logger it is simplified. The unit pusher is your boss. We have also provided you with a "Field Policy Manual" to act as generalized FAQ for "how we do things" for both you and our "Pushers" to follow.

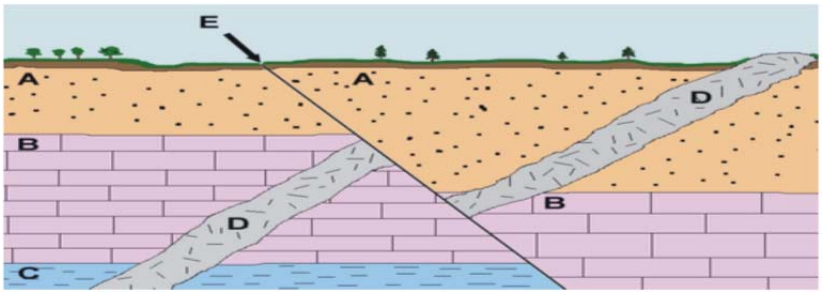


We as mud loggers basically have 3 bosses. Geologist, Location Engineers and Tool pushers. The Geologist is the one paying us, but we are responsible to all three depending on the subject matter. Tool Pusher is over the rig personal and safety around the rig. The Location Engineer is responsible for carrying out the well plan. So we are responsible to all three. We deliver information to help all three. Keeping safety in mind with our other duties.

Everyone at one time or another starts a job they know nothing about and because our jobs require many disciplines it can seem overwhelming at first. We all start out that way. This job will be no different. This manual will attempt to break these tasks down into job fundamentals and by providing a short overview of each with reference to detailed material contained in later chapters.

Communication….

Over millions of years, from tectonic movement to erosion, soil is laid down on top of other soils and sand. These deposited layers, are then pushed, compressed, faulted and lifted from what was once a nice orderly layering into a mixed puzzle requiring seismic surveys, Geologist,

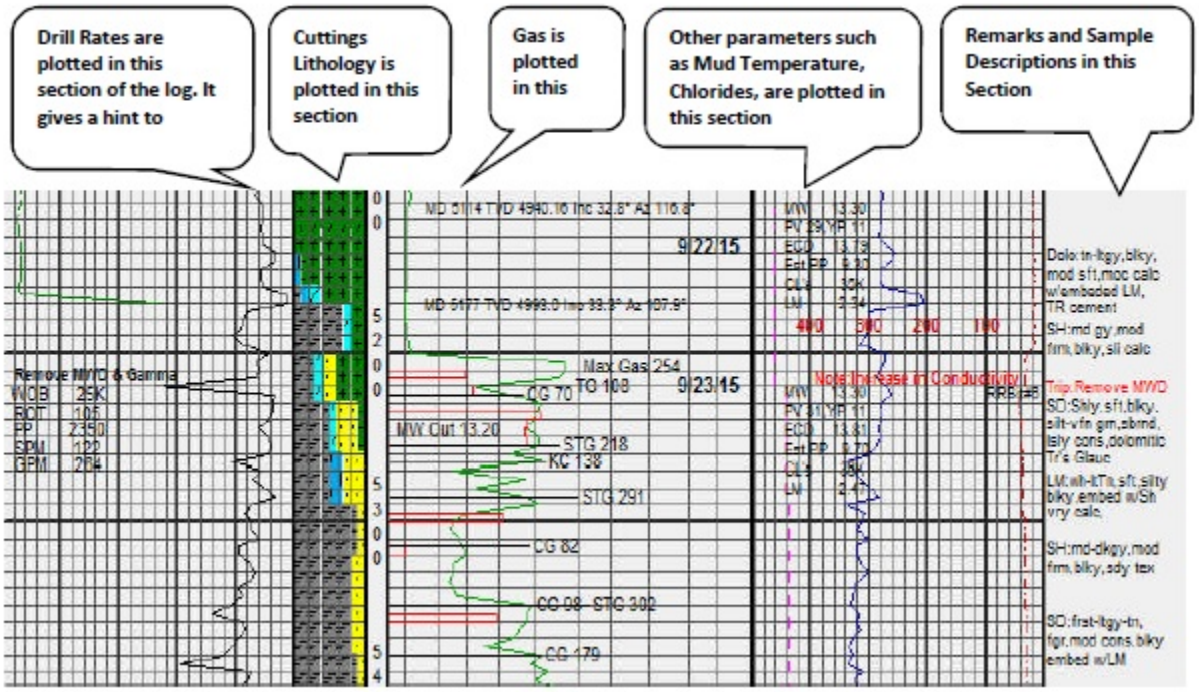


correlation wells (other wells drilled in the area) and mud loggers to decipher. So in a very real sense we go back in time the deeper we drill a well. The makeup of this layering, which can't be directly observed, is hinted at by your observations and is communicated to our clients. Unlike a lot of jobs, on a well site, this one puts you in the middle of many of the processes on a well. Your logging unit is an information hub helping to solve that mixed up puzzle of geology. Hand in hand with discovery is the communication of what's learned. Our job requires us to communicate with the people in charge on location and at the oil company's headquarters. From data feeds to our website to morning and afternoon reports, mud logs, show reports and announcements over rig PA systems, everything you do is about the communication of what you have discovered, to the people who are the decision makers. One of our mantras is written on the side each of our units "Get Connected"

You will start with the basics, from collecting samples (bit cuttings), to learning what they are and how they are important to the prospect. We put this information in a graphic form called a Mud Log for the geologist to interpret.

The mud log when properly documented will tell the story of not only "What" was drilled but also "How" it was drilled either successfully or unsuccessfully. It can be thought of as a

chronological, scaled, historical record of the drilling of this well.



A good analogy: You are told to drill a hole through a wall that consists of different materials. As you place the spinning drill against the wall you drill fairly quickly through the dry wall on the outside. This is confirmed by looking at the shavings falling to the floor as a white powder. Then the drilling slows down, but you are pressing using the same force. Wood starts to show as you progress, next it's even slower and you note the cuttings have changed to steel. We in a very real sense do this same thing as we match drill rates (1st column above) to the lithology (2nd column) that we see coming up out of the hole to hydrocarbons, such as natural gas (3rd). All then plotted at the correct depth noted.

The lithology (samples, cuttings) depiction will show where they came from depth wise and what they consisted of, as a percentage of total lithology.

Our gases parameters will show if there are gases, how much, and what mix of gases (chromatograph).

Monitoring the gases also serves as a function of safety. As gas increases we keep the people on the location informed so steps can be taken to keep the conditions safe for the personnel on location. This also facilitates the drilling of the well in a timely manner making it more cost effective. One day saved can mean from tens of thousands (land rig $15,000) to hundreds of

thousands (marine) of dollars saved per day. Let's face it who doesn't like saving money right. The oil company is the same way.

We collect information from many different sources and tests. How that information is used and what affect it might have on drilling operations, we will discuss in later chapters.

There are wonders under our feet. Hidden by time and thousands of feet of soil and rock. Jackson, Ms. has a volcano under it. There are places where there is enough CO2 trapped underground to fill billons of canned soda. Great mountains of salt push to the surface creating islands in marsh. You of course will see the earth in geologic times scales. There is not much room for creationism geology in this job. 160 million years ago is a few thousand feet away from where you currently are standing. Confusion can rule. It's a puzzle remember, but never be afraid to ask a question. That's the best way to learn. The more you know the easier your job will become.

Sample collection

The first thing you will learn is how to catch samples from the shakers. Shakers are basically screens that are vibrating. The screens filter the solids such as sands and shales out of the mud as it returns from down the hole. These are called the cuttings. The bit drills loosens them and the mud brings them to the surface. We can calculate where they came from using "Lag".

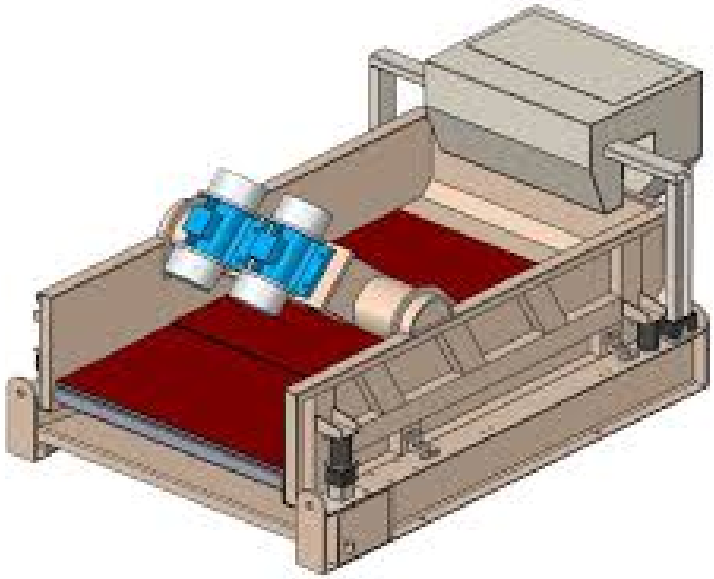
Thinking back to our wall drilling analogy, now the wall is 20 foot thick. When we drill a foot of it we could put a stop watch to the beginning and end of that foot (ROP). We can calculate this rate of drilling instantly when the foot is completed. But what about the cuttings? They still maybe 19 foot inside the wall and have not yet reached us. The method by which you marry these cuttings, when they do come out, to that footage rate, ROP, that we calculated is what we call "LAG". On a drilling rig we do this by counting the strokes of the mud pumps that circulate the drilling mud. When it does come out we collect this material, put some away, clean a smaller sample, and use tests and a microscope to identify and check for any trace of hydrocarbons.

Hydrocarbons are natural gas or oil or a mix of both. Examination using Ultra-violet light will fluoresce the liquid hydrocarbons in our cuttings sample. The color of this glow can determine quite a bit about the type hydrocarbon (gold -→ orange). It's similar to walking into a bar with a white shirt and a room lit by black light. How to clean the cuttings will depend on the type of mud use to drill the hole.

Water base muds only require using water to clean them. Oil base mud requires solvents to remove the diesel fuel from the cuttings so they can be examined. Consistency is the key here. Cleaning the cuttings the same way each time and getting your samples from the same location on the shakers generates consistent cuttings for observation. These observations are placed on the mud log as a percentage of each elements makeup of the total lithology for that foot. (sand 50%, shale 40%, lime 10%)

Once the mud has gone through the shakers it is returned to the Circulation System in the pits, where it is checked and re-pumped back into the hole and the cycle starts all over again.

Below is an image of a shaker. There are many different types but they all do the same thing.



Circulation System

Just like the human body has a circulation system that pumps blood through the body and back to the heart, the rig has a circulating system that pumps the mud back to the pits. Figure 6 below is a basic diagram of the circulation system of a rig. The main thing you need to know is how the mud is moves around the rig, from the pits through the pumps to the standpipe and down the hole all using the force of the mud pumps. After it's forced up and out of the hole it crosses the shakers. That's where we come in.

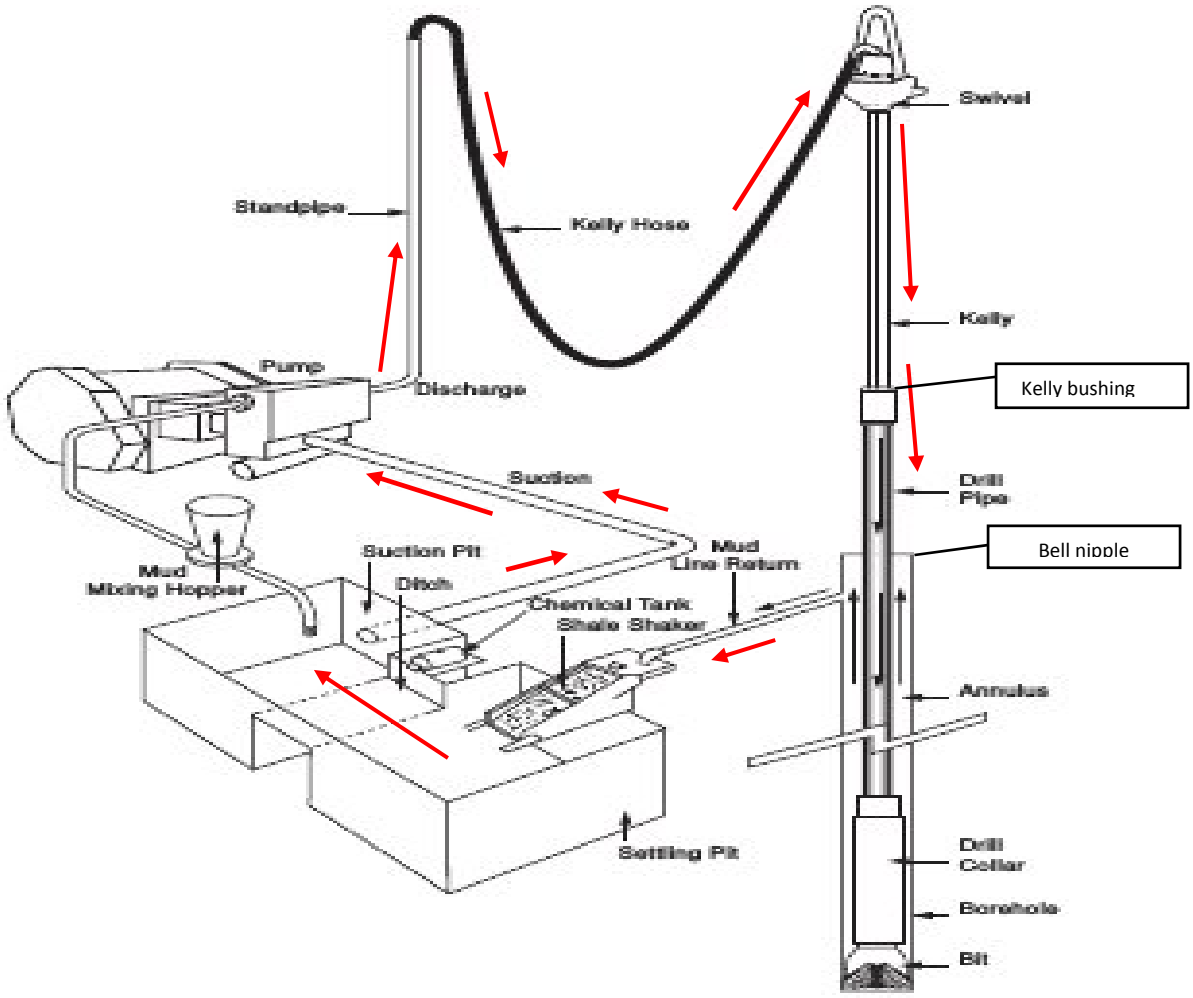


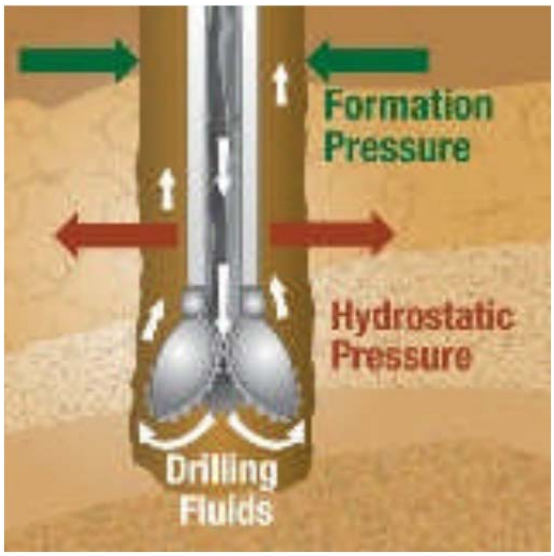
Figure 6 Circulating system

The Mud

It's called mud for a reason. It looks like mud. Sometimes it will be thick and sometimes it will be thin.

You will hear the term **"Mud Weight"** all the time on a drilling rig. Just as when you pick up a gallon of water it has weight. A gallon of fresh water weights 8.3 lbs. Salt water is 8.66 lbs./gal. In order to make water base muds have a heavier density per gallon, chemicals are added to the water that dissolve into it and increase it weight. It's the same as adding powdered chocolate to milk. The more you add the thicker it gets and heavier it gets. The mud reacts the same way. Depending on the gas amounts and other drilling parameters the

mud weight will be increased as well gets deeper. Sometimes the weight is predetermined in a drilling plan submitted at the beginning of the well sometimes the well conditions will change that plan. More detail is available later in this manual under the “important fluid properties”. Characteristics of the mud also have effects on the well bore. One affect the mud has is to cool the bit. Think about the act of drilling a piece of steal. The bit gets very hot and dulls quickly. The mud acts as a lubricant to cool the bit and help it last longer. Also it moves the cuttings up and out of the hole for us to do our job (sample collection). Another is it resists the inward pressure exerted by the surrounding formation and keeps it from collapsing the hole. It’s an equalizing of force.



The mud is pushing back against the walls of the well bore preventing it from collapsing. Filling the hole with drilling mud pushes back with an equal force which stabilizes the hole. This pressure is called “Hydrostatic pressure” and is represented in Lbs./gallon which you will note is the same unit that mud weight uses. This makes a well bore where the Mud Weight is = “Hydrostatic pressure” theoretically stable and additionally maximizes drill rates. In practice a whole host of factors change this and make “balanced drilling” the holy grail of oil & gas exploration. You will learn more about this in the “Math” section.

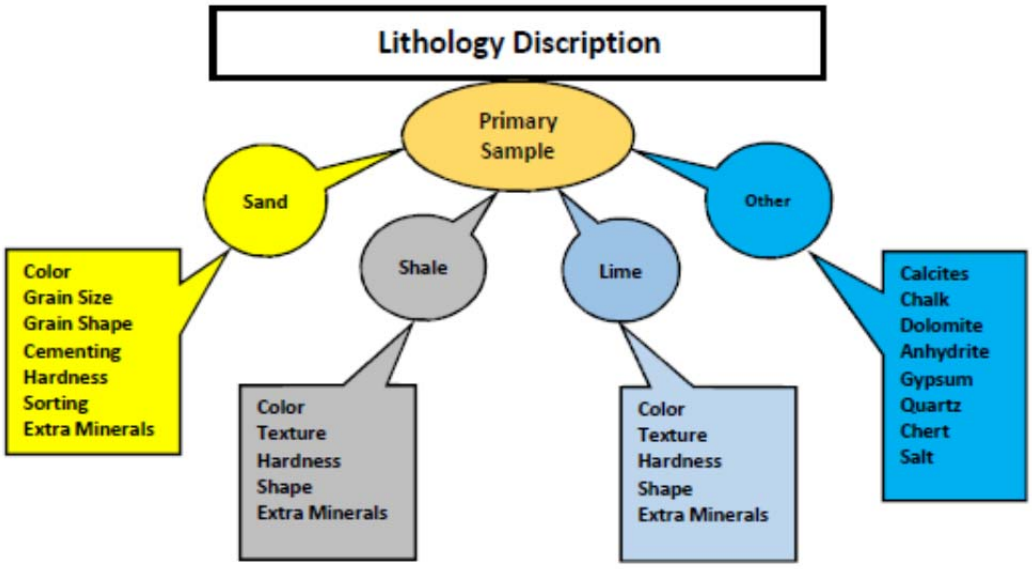
Formation Recognition

Once you made a trip out to the shakers and retrieved the cuttings, and cleaned a smaller representative sample, it’s time to describe them. No it’s not “Dirt”, its history. It can tell a story all by itself. Once you have the sample under the microscope, what do you see? Some things are easy. Loose large grain sand is easy to spot, but what else is there? What is hiding

among those boulders you ask as you look through your microscope? Sometimes you will see fragments of sea shells, sometimes there may be other things mix with the sand you don't recognized. Start by learning that sands can be loose or consolidated. Consolidated sands are clumps, bound together by another material. Sometimes loosely, and sometimes well consolidated (hard to break apart). There is a flow chart to go through to help with this process in the section under formation recognition. For instance those sea shells noted earlier, they are actually "Lime". To test lime reacts (bubbles) to certain chemicals. We use Hydrochloric Acid (HCL) in deluded amounts to check for Lime and what is called Calcareous materials. Lime, chalk (a form of Lime), Calcites are all calcareous materials and react, bubble, to HCL. Learning to gage a percentage of sand in your formation between 0 - 100%, is part of what we do, but there are tests that can quantify these percentages. You will also learn about "Shales". With "Shales" **Size does matter.** If you start to see increases in size of the shale cuttings it means something different is happening to the formations being drilled. This is an indication that the "Formation" pressure may be increasing and requires attention with mud weight increase. In rare occasions this is something that has to be dwelt with immediately.. It's a bit like being an archeologist. You find something. You identify it then note its position relative to everything else all to tell a story.

When we drill into a section that we detect may have hydrocarbon in it a whole reporting process is started and relayed to Geology and Engineering. Notes are made on your regular log and an additional log is started for this "Show" section. **"Show"** logs are more detailed (scaled as 5"=100' of wellbore) than our regular log. This expanded section or zone gives additional space for gas and/or oil descriptions, Chromatography and other observations. A log and report are started and maintain during the whole depth interval of the suspected "Pay Zone" and details conditions before, during and after the section drilled are noted. Later when the hole is completed an e-log will be performed by another service company which uses direct sensing devices to quantify this zone for production. So in a very real sense you as loggers are the guys who are the prospectors, the one guy that gets to shout Eureka!

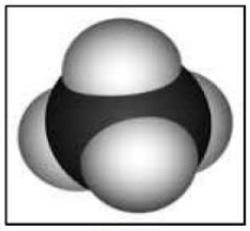
We need a consistent method of notation in order for us to relate this Geology. These descriptions are in abbreviated form and placed on the last track of our mud log. The descriptions follow a predetermined form and are listed below. In this manual you will find a section on "**Abbreviations**" to help standardize the descriptions from one logger to another. Get use to writing your descriptions and using abbreviations to describe what you see. Below is a basic chart showing just a few things you will learn about the cuttings and what to look for when identifying them.



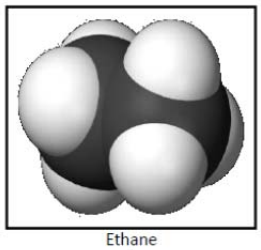
There are quite a few different types of Geology and Minerology tasks but with time and experience you will learn to recognize them. We also employ a computer microscope for pictures which opens up the possibilities of sharing the identification process with your fellow loggers and Geologists. More specific Lithology terms can be use (examples **Oolitic, or Arkose….)** and will be outline in the **Lithology** of the manual.

GAS

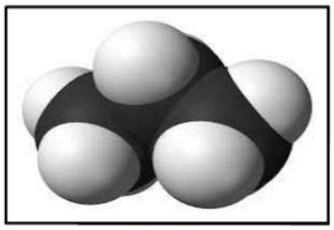
The natural gas component of the hydrocarbons we a searching for are really made up of a mixture of gas types, molecules, with increasing physical size and goes as follows C1 - (methane) C2- (ethane) C3- (propane) C4- (butane) C5- (pentane). This increasing physical size will be important to remember as we discuss the Chromatography analysis we do. This analysis will give us the ratio of these gases.



Methane



Ethane

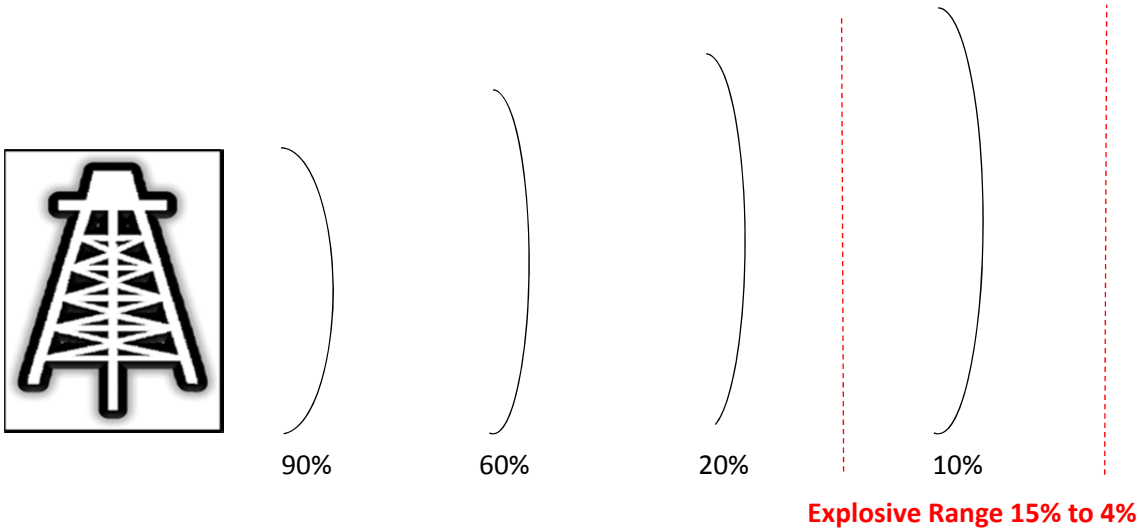


Propane

What is a Unit of Gas?

A "unit" of gas is a representation of an amount of natural gas from the well bore and comes from the gas detection equipment in our unit. Gas has a unit of measure called a "unit" (I know, confusing). A certain number of units will equal a percentage of gas for a volume of space. The scale we use is from 0 – 5000 units. With 5000 units being 100% gas. So if the reading is 5000 units its 100% gas, 500 units would be 10 % gas, and 50 units of gas is 1%. Think of it in terms of the percent of a mixture in a room. If the room had 5000 units you and I could not survive as there would be no air to breath. Change that to 200 units in the room and the room could go boom! To give you an idea of **the Explosive Range** of gas, it can start somewhere between (4% - 14%), depending on conditions. Different studies say different percentages. To be safe use the lowest in your mind for references. So, on our units this is equivalent to around 200 units. This is a gas to air mixture, but on an open air location and with all types of gas coming out of the hole, with some lighter than air and some heavier than air, (staying close to the ground) it's really hard to say. The volume we deal with is not a danger to us. As the small volume of sample that is brought back to the unit for the gas detectors is contained and if it is not it gets instantly mixed with a much larger volume of air contained in our unit. (Note all gases detectors are vent to outside) When gas gets to a level of 200 units notify the proper personal and advise them of this fact for safety reasons. For the purposes of formation evaluation we are really looking for a percentage of change of our gas readings. A change from 30 units to 60 units is significant as it represents a 100% change in the formation gas. **Always call out gas readings when you hear the Mud weight called out over the PA system.**

Distance from the source and concentrations of gas can vary in open air situations. Be aware Concentrations are greater closer to the source. Ignition range may propagate out from the source depending on wind direction and concentrations. Distance can change with concentration. Example below



The Dino Camera System

This system is a small digital microscope camera system. It can take images of your samples and store them in the computer. Always try to get a good representative picture of the sample, unless there is something in particular you wish to point out. There are standard settings and calibrations in the manual for this. But get use to using the camera. These images are uploaded for the benefit of our clients. If you're not sure what something is take a picture and label it. Set the sample aside so they can be reviewed by the Unit Manager or other loggers**.**

Learning the Math

There is a lot of math with this job. Calculating lag, pressures, dimensions and volumes, angles and azimuths all have their place in mud logging. Learn and practice the math. If you ever wondered why you took Geometry and Algebra, well this is it. You will learn to use these formulas and calculations in the math section of this manual. Understanding and being able to work these calculations (though some are now done by our computer programs) is fundamental to this job. You will be asked a lot of times by rig personal and oil company personnel for information from these calculations. They expect the results instantly. They aid in drilling of the well and safety of all aboard. There are a lot of tools and other programs and excel sheets that can aid in these calculations. Learn them and how to use them they can be of great value once you understand how they work and what information you are looking for. Never be afraid to ask questions or get help.

Log Standard

Over the years Drill Labs has developed a standard for their logs. Not all logging companies draw their logs the same way. We EXPECT all loggers who work for Drill Labs to follow our log standards, no matter how they might have learned. We should not be able to tell by the data presentation where one logger stopped working and another started. With all things there are exceptions and you will find that different Geologist may want data presented differently in some cases. Our aim is to satisfy the customer, but the log standard is your basic guide to what goes where and how often.

You will learn how to input data and assign file names using our award winning Geoview program. Save your logs using our standard naming conventions as well as doing regular backups to an external drive or use in printing the jobs final prints. This back up structure is important and should include only one copy of the final data.

We have the ability to draw many different kinds of logs. Examples of which are 1MD, 5TVD, 1PP, 1EFT and many others. Questions such as: What parameters go on each type? What size text to use where? How should the file be named? What colors to use? Line styles? Scaling? They each can be referenced to our Log Standard.

Reports

Night loggers keep up with and preform duties that require reporting generally once and at the end of a tower, but because most of the principles (Geologist, Company Man, & Tool Pushers) have been happily a sleep all night the morning report always gets a higher level of scrutiny. **Morning Reports** can be transmitted via email and/or hand distributed to rig personal. Knowing when these reports are due will give you time to get them completed. Generally the company representative (Co. Man) on location and Rig Tool Pusher are the ones that require these reports and logs hand delivered and placed on their desks. You should start preparing for your report around 4:30am. This gives you time to gather the required information, fill out the reports and print copies. You will learn how to fill these out, print them and logs using Geoview, Excel. Time sheet reports go into the office and are fundamental to getting paid. The government requires we fill these out as our official time record. Time sheets also provide a summary of the daily operations of the drilling process and rig

activity for quick reference. Data for all these reports may have to be gathered from third party sources. The **Direction driller**, or **MWD** (who plot the direction and distance the well is going in), Mud engineer are all examples of personnel on location providing us with this survey and other drilling data.

Try to arrange a daily time to retrieve these items from them and other sources. In some cases data may have to be converted before we can use it on logs. Converting a **LAS data file** to a **CSV** for use with GeoView is an example. All this can take considerable time and many times occurs while you continuing to keep up samples and actively drilling. Take the gathering process one step at a time, and give yourself ample time for completion.

Reserves

This section is added to our introduction to mud logging because in the Gulf Coast there is a saying *"a sand formation will contain either or all of three things OIL, GAS, or WATER (fresh or salt) but it's never nothing."* The determination of all water in a sand it not a good thing, as you can imagine, the oil company would rather one or both of the first two. This is very general statement but water can or may show in three ways. Its cooling effect on the mud, its conductivity (how well it carries an electrical charge) or its salt/chloride (parts per million) content determined from a test. So sands formations can act as containers for the gas & oil we are looking for or can act just like the surf line at an ocean side beach. A short description may help bring this fact into better focus, because for many oil and gas reserves are as "great pools" or voids under the earth waiting to be drawn from. This is NOT true.

The beach down close to the water is always a different color than the beach higher up the slope. Plus, when you walk along the surf line you will note that each foot step changes the sand around your feet. It may seem to get light in color. What is happening here? Water! Your weight is squeezing out the water between the sand grains. The beach line contains hundreds of gallons water per square meter and this water lies between the very small spaces between each grain of sand. The same is true underground in oil and gas deposits. The whole oil field lives between the grains of sand or some other formation.

Equipment Trouble Shooting

So where does all our data come from? Sensors and wires that run all over the rig. This is the part of our job that requires a DIY, good with tools handyman. We will attempt to teach good rig up and wiring practices. Proper installation of sensors will insure you are not always out repairing items or rerouting wires. Making sure wires are out of the way and in an area which is least likely to impart damage. Sometimes if there is a problem it's a matter of the process of elimination, and sometimes there is an easy fix. Diagnose the problem, check the connections, visually inspect. Learn to use a voltage meter. Learn our color coding. Check for continuity.

This process can save you a lot of time and trouble when looking for damage in the wire. It's not always evident when a wire is broken inside a cable. The wire might have been stretched or something crushed it making breaks hard to find. These things happen with all the equipment and repairs that go on around a rig. That is why it is best practice to put you lines next to or attach them to something that will be a buffer, or in some way protected your gas and sensor lines.

There are 4 colored wire in each set. Go to one end and twist 2 together and do the same with the other set. Go back to the other end and set the volt meter on the Ohms setting. Test across two of the wires you have connected and read the meter. If it reads “0” the wires you are testing are good. If there is a high number then one of the two wires is bad. Check your connections in the umbilical box. The umbilical line is where all the signals come together. So if everything seems to have quit working this might be the first place to look. Visually inspect the Umbilical line as you walk back to the unit. But if you still haven’t found the problem move inside and check connections in the Orange box. The signal modules in the orange box might have a grounding problem or be turned off or disconnect. They could be damaged as a result of a lightning strike or high power surge from damaged wires.

The signal modules take analog signals that come from the outside sensors and the inside gas detectors and turned into them into digital signals for the computer to read. These are called “A to D” converters and also act as a circuit breaker for the compute. If the module is still good then there may be a problem getting the signal to the computer. Check the wiring diagrams, for the modules contained in our equipment manual. Make sure you have good connections to them. If the problem still persists then it could be a computer issue which will require checking the settings in you Geostar computer. Get in the habit of asking yourself what just changed or occurred that could have caused my troubles. Learn a systematic approach to trouble shooting. Generally most issues can be fixed onsite and don’t require a call to operations. Don’t let it frustrate you, as it seems to always happen when the weather is bad, its dark and your tower is almost over.

Testing

So, **Chlorides** is just one of the properties of the mud. Testing is required and this process can tell you if you have an influx of salt water in the mud from a sand formation. In some cases the mud will be cut (lightened/ weight less per gallon). It can be due to gas or water adding to the well bore. Generally there will be a Mud Engineer on location and you can ask them to check the mud for Chloride increases. There are other properties should be familiar with. One is the **Sand Content**. Testing for this can be found in the section on Chlorides. You are measuring how much sand is in a given amount of mud after running it through a set screen size. Testing this smaller sand grains that can go through the shaker screens and remains in the mud helps you determine how much sand may be trapped in the circulation system of the rig. This information is also on the mud engineer’s daily report, which we retrieve. But knowing how to do the test helps in the understanding of the rig processes and is needed when no Mud Engineer is available.

Shale density can be referred to as the density of the shale. It would be like having a feather and a piece of iron the same size one weights more than the other. They are both the same size but the molecules are more compacted in the iron. You are basically weighing the difference in a column of fluid. That fluid is thicker as you go down the column. So the Shale will stop a point and you measure that point in the column. This information is them put into the GeoStar computer and on your reports. Shale Density is a special service and we charge extra for it because of the chemicals required to set up and maintain the Density Column that gives us this number. It is not something we do very often but you need to know how to set up the column and maintain that it can be done.

Summation

We gather information. And combine it and make it useful. The more information you have the better you are able to understand what is happening on location and with the well. I have found over the years that most of the time you will know more about what is going on with the rig and the well than any one individual around you. In most cases you will be talking with the Geologist and Engineers and have a better idea what is really going on before anyone else. So think of it this way “On location you are the central information keeper”. Your mud log will become the historical record for this well. You **can’t** put everything on the Log but use the pertinent information and keep it as simple as possible. Someone may decide to drill another well next to it in the future. Your mud log will be indispensable in drilling that well or other wells in the same area.

We are the masters of relating information to the Geologist and others. You will be working with another logger and team work and communication are key. Take the time to go over the events of the evening and any pertinent detail and information with your counterpart. He will do the same. Helping each other when there are problems is just part of the job.