Downhole Measurement: MWD

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Abstract.

Measurement While Drilling (MWD) now becoming an important method of measuring the downhole parameters and transmitting the informations to the surface while drilling in operation at almost real time. The most important application of MWD is for directional drilling, where its eliminates the downtime for directional survey. This paper discussed the engineering aspects of the technology and examples of the applications and future developments of MWD.

Introduction.

MWD is a method of taking the down hole measurement while drilling operation is in progress. The instrument packages placed behind the drill bit in certain type of exploratory oil wells. The downhole assembly are design to measure various downhole geophysical parameters that would normally be periodically measured by wireline surveys taken during interruptions in drilling such while worn bits are being replaced. Since drill rig time is expensive and wireline measurements may take several hours, continuous MWD data may be economic on some type of well drilling operations. Currently the downhole parameters that can be measured are:

i). resistivity,
ii) gamma ray,
iii) hole direction,
iv) hole inclination,
v) tool face angle,
vi) weight on bit,
vii) torque
viii) temperature.

Figure 1 shows the example of MWD log.

Generally, MWD system consist of four important subsystem:

i) Telemetry system to send the downhole data to the surface.
ii) Downhole sensors package to take the measurement.
iii) Power source to powered the transmitter and the sensors instrument.
iv) Surface equipment to receive the information from down hole and put it in a useful format.

Telemetry System.

Theoretically downhole information can be transmitted to the surface by several method such as through: i) the drilling fluid inside the drill pipe, ii) electrical conductors inside the drillpipe, iii) the drillpipe metal, iv) the earth. Unfortunately so far the only system that transmit data through the drilling fluid known as mud telemetry system has proven to be commercially viable.

Drilling Fluid Telemetry.

Telemetry through drilling fluid is accomplish by generating the pressure wave signal in the drilling fluid at the bottom of the hole. The pressure wave travel to the surface of about 4300 ft/sec, depending on mud properties. There are two different pressure wave telemetry system are now used in commercial system:

i) pulse system,
ii) a continuous wave method.

Mud pulse telemetry is a wireless method of transmitting data from the bottom of the well up to the surface. In the downhole tool, measurement data are first converted into binary code. In the downhole mud pulse transmitter, a mud pulse valve move back and forth in the mud stream in accordance with the binary code, and in so doing, induces the coded series of positive pressure pulse in the drilling mud. The negative pressure pulses can be generated by periodically by passing a small amount of fluid from the inside of the drill string to the annulus through the orifice in the drill collar wall. This coded series of mud pressure pulse travels through the mud up the drill string at several thousand feet per second. The pulses are detected by a pressure transducer when they reach the surface. The pressure transducer is installed in the stand pipe. Electrical signal representing the pressure pulse series are fed to nearby digital electronic where the data are decoded and display. Some pulse system have batteries for downhole power while others have mud powered generator. In general, batteries may be satisfactory for routine directional measurement. However, battery may be short if continuous logging is required as in logging formation properties.

The continuous pressure wave is generated by rotating a valve in the mud stream with the frequency fixed. Information is encoded on the pressure wave in digital form and telemetered to surface at a data rate of 2 to 3 binary bits/sec. Maximum operating depth is controlled by wave attenuation in the drilling fluid and by pressure wave amplitude. Attenuation is a function of pressure wave frequency, mud density and viscosity, and sonic velocity in the mud stream. A signal detection and display unit is located at the surface to receive the mud pulse telemetry data, to decode it, and to display the resulting information. The unit consist of a pressure transducer located in the standpipe, which detects the pulses transmitted from downhole tool and the electronic circuits for detecting, filtering, amplifying, decoding and displaying the downhole data.

Sensor Package And Measurements.

The electronic sensors for data measurement are located in the drill collar within a few feet above the drill bit. Since any magnetic disturbance would induce the an error in the measurement, the housing should be manufactured from the non magnetic materials. The major components that are mounted in the downhole assembly are a transmitter or a valve to produce the mud pulses in the\

drilling mud in response to digitally coded signal from sensors, a turbine to provide power for the downhole tool, resistivity sensor, gamma ray sensor and directional sensor. The length of the assembly is between 35 to 45 feet depending on sensors and manufacturer. This integrated assembly transmit the MWD data in form of coded pressure pulses in the drilling mud.

Figure 2 illustrates MWD downhole assembly with its mud pulse transmitter, turbine generator and sensors instrument.

Surface Equipment.

Surface equipment for MWD includes a pressure transducer for signal detection, analog pressure recor er, electronic signal decoding equipment, and digital and analog readouts and plotters. The pressure transducer is mounted in the stand pipe on the rig floor and connected by cable to a display unit. Directional information normally is displayed by digital readout so that the angle, direction and tool face may be read directly.

Figure 3 is a schematic diagram of typical surface instrumentation.

Advantages Of MWD.

The most significant advantage of MWD technology is that it provides downhole measurements and/or interpretations of measurement in almost real time which increase the ability of the engineer to make the timely decision. Furthermore, these measurement are made before any substantial damage to the borehole has occurred and before any damage to the formation arises from invasion. This cannot be done with wireline tools. As downhole measurement such as weight on bit, torque and temperature has never been available before, these capabilities result in better and faster decision concerning drilling operation. MWD also provide safety on drilling operation. While providing a reliable pressure detection and predicting method through the use of the resistivity log, MWD can also be used to detect incipient operational problems such as differential sticking. Drilling efficiency is affected in several ways through the use of MWD. Faster directional surveys result in more time on bottom drilling; more frequent surveys result in reduced risk of being off course. The overall drilling efficiency of bottom hole assembly can be monitored using downhole weight on bit. Geological control can be impacted by using gamma ray and resistivity logs for real time correlation. In some high angle holes, MWD logs may be the only open hole log that can be obtained.

The overall impact of MWD on safety, drilling efficiency, and geological control is improved cost effectiveness in the drilling operation.

Applications Of MWD.

There are many application of MWD since it provided the real time down information. Among them are:

1. Improved control of the well path.

The biggest application of MWD is in directional drilling, where MWD virtually eliminates downtime for directional survey. Since MWD provide the data continuously, the unwanted course deviations are corrected while they are still relatively small. The result is a smoother and more tightly control well path. Good control is particularly necessary when drilling from platforms with a high density of well slots. MWD is also helpful in reaching smaller targets and in intercepting multiple target.

2. Differential sticking.

In the area where the formation pressure is lower than the drilling mud pressure, flow of mud into the formation may occur. This can result in the drill pipe or collars or both being suck against the wall of the well bore and becoming stuck. The longer circulation of rotation is stopped (for example during a wire line survey) the greater the risk of differential sticking. Using MWD system, circulation is maintained through out the survey period, rotation is stopped briefly, thus the risk of sticking is reduced.

3. Detection of abnormal pressure zones.

The short normal resistivity log provides an excellent tool for detection of pressure transition zones from normal to abnormal formation pressure. It is known that resistivity of normally compacted clean shales exhibits an increasing trend with depth; therefore, a plot of formation resistivity of clean shales vs. depth provides a normal resistivity trend line that increases with depth. In abnormally pressure shales, the resistivity usually decreases. The amount of decrease from the trend line can be correlated empirically to estimate pore pressure. Figure 4 is an example of MWD log from the exploratory well illustrating a pressure transition. In this example, the normal pressure gradient trend line was established from the resistivity data higher in the hole and is shown as a solid line. Beginning at approximately 6000 feet, the resistivity begin to decrease relative to the established trend indicating the onset of geopressures. At 7500 feet, the pore pressure gradient has increase to 12 ppg necessitating a corresponding increase in mud density. By using MWD derived pore pressure in real time, the proper mud weight to maintain hydrostatic control can be selected, thus reducing the risk of taking a kick.

Other benefit of using MWD indicated pore pressure is that minimum mud weight for proper pressure control can be used, thereby reducing the risk of lost circulation and increasing drilling speed. This formation pressure estimate also can be used to verify other pressure estimate from d exponent, shale density and cutting size.

WOB and Torque.

In high angle wells, it is difficult to determine the WOB from the surface measurements because of the effect of friction between the drill string and the hole. WOB from MWD help solving this problem by providing a means to maintain needed and desired penetration rate. Torque from MWD provide additional information for determining bit bearing wear and potential sticking. Figure 5 illustrate the example how drilling data and gamma ray log from MWD help avoiding unnecessary trip. It shows that the rate of penetration (ROP) decrease at about the time when erratic torque was observed at the surface. The downhole torque was lower than surface values and relatively more stable. It was also somewhat reduced from previous reading, repeating the characteristic value established in the earlier limestone bed. Examination of the real time gamma log explains the low

ROP as the lithology changed back to the slow drilling limestone. Thus, the identified lithology change, couple with stable downhole torque, explained the low ROP and indicated that the bit was still good. However, the slow ROP, combined with the erratic surface torque, was interpreted by the driller as indicating a dull bit and it was pulled. The bit was in fact still usable and was tripped back into the hole.

Correlation.

The gamma ray log indicates the intensity of radiation which emanates from the formations cut by the borehole. All the sensors in MWD is packed in the drill collar including the gamma ray sensor. The drill collar reduces gamma ray intensity by roughly a factor of five to ten, depending on collar thickness and gamma energy. Loss of intensity could effect accuracy and indirectly bad resolution, since both are a function of total number of count detected in a given interval. However drilling is normally much slower than wireline logging speeds, and this is usually more than compensate for the attenuation by the drill collars, because more time is spent at each depth. Improved resolution result in more of the formation structure and character being revealed. This vertical resolution can lead to better log to log correlation through much more analysis of staratigraphic character of the formation.
Resistivity and gamma ray log are very useful for correlating between wells, especially in sand and shale sequences. Figure 6 shows the comparison between a resistivity and gamma ray log from MWD and wireline log, it illustrate an excellent agreement between those two.

Future Development in MWD.

In general the future development of in MWD system will focus on higher data transmission rate, more measurement, more sophisticated processing of data, higher temperature imit and increase reliability.

Currently the mud telemetry system have a rather slow data rates, in the range of 7 to 50 seconds per word with the resolution of 1 part per thousand. These data rates limit the number of sensors that can be monitor and transmitted within a reasonable time. Even at 7 seconds per word, is limited to about six to nine sensors if it is desired to obtained 1 data point per foot of drilling at penetration rate of 60 to 90 ft/hr. Much effort is aimed toward increasing the data rates. The development of the hardwired electrical conductors system could have the data rate to send the data from an essentially unlimited number of sensors but for now, the application of hardwired system is very expensive so the introduction into drilling industry may be slow.

Development of the sensor to monitor fluid influx into the wellbore for early kick detection will be the primary development in the area of safety. Other formation logs probably will be added as experienced is gained and interest in MWD increases.

Conclusions.

1. MWD systems are reliable and useful additions to the drilling industry.

2. MWD is a cost effective tool particularly when used to survey a highly deviated offshore development wells.

3. MWD has a great potential for improving the efficiency of drilling operation and formation evaluation in the future.

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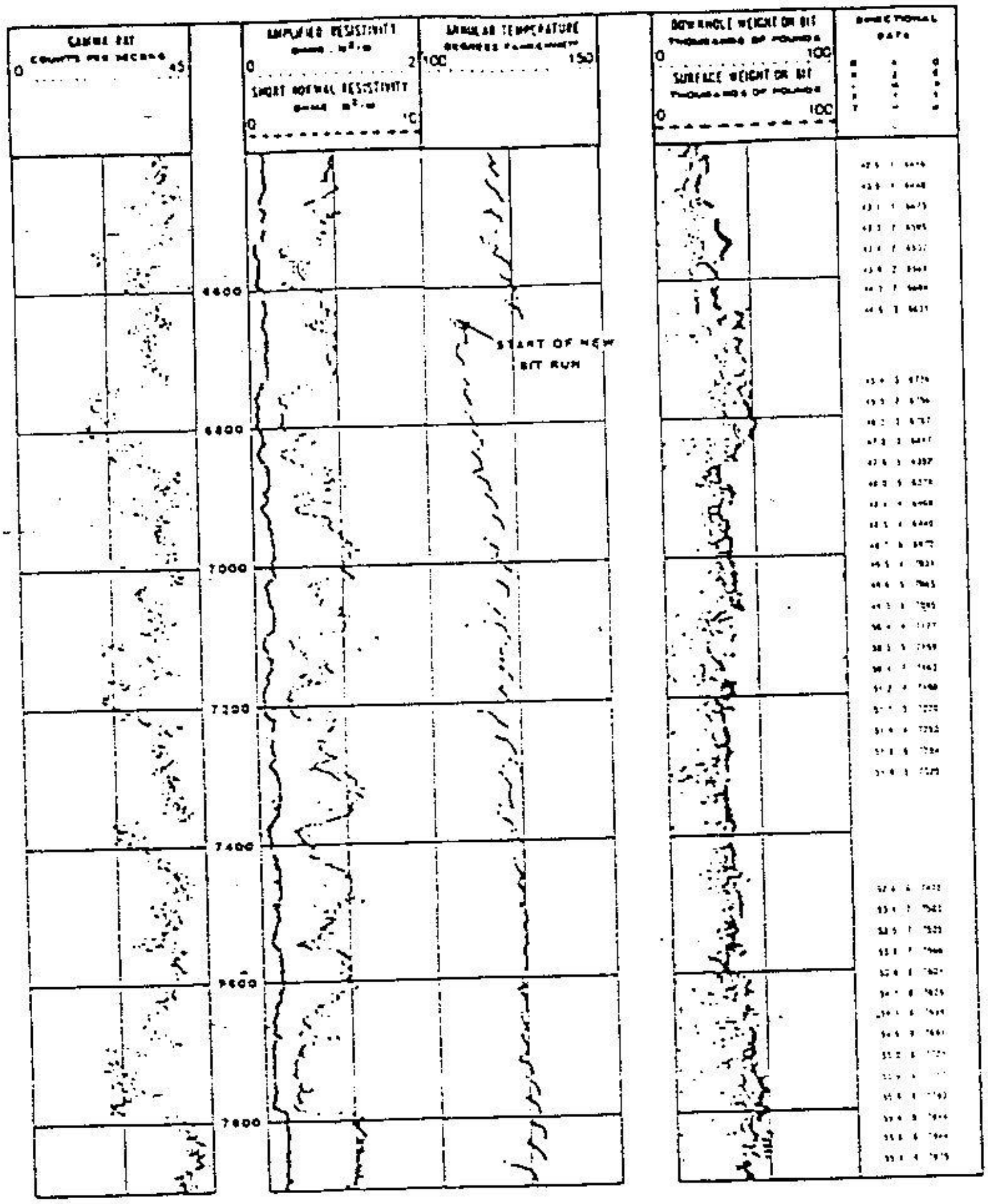

Figure 1
Example of MWD Log

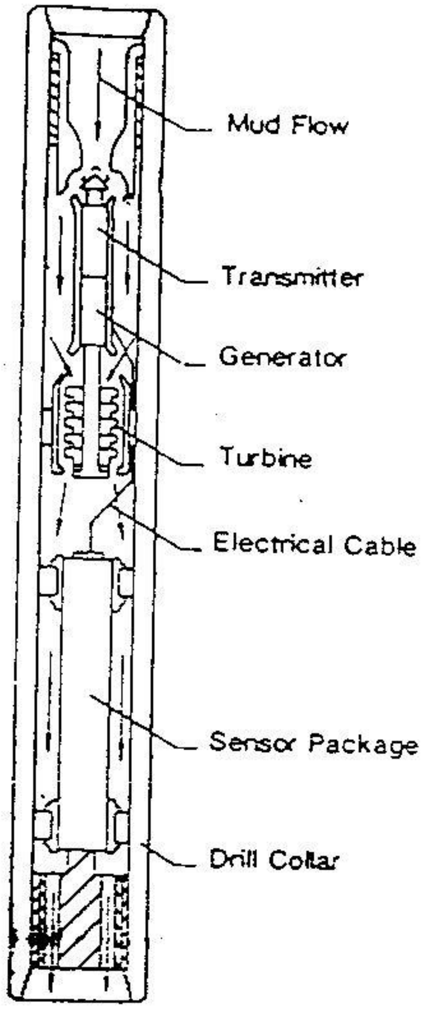

Figure 2
Typical MWD downhole assembly

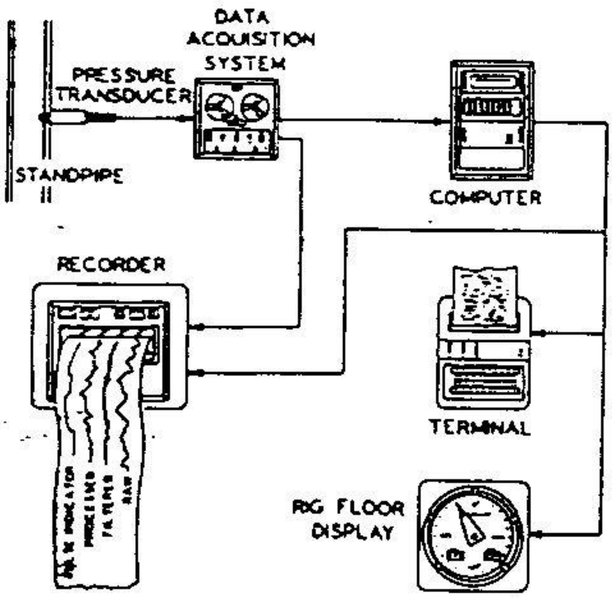

Figure 3
Surface instrumentation

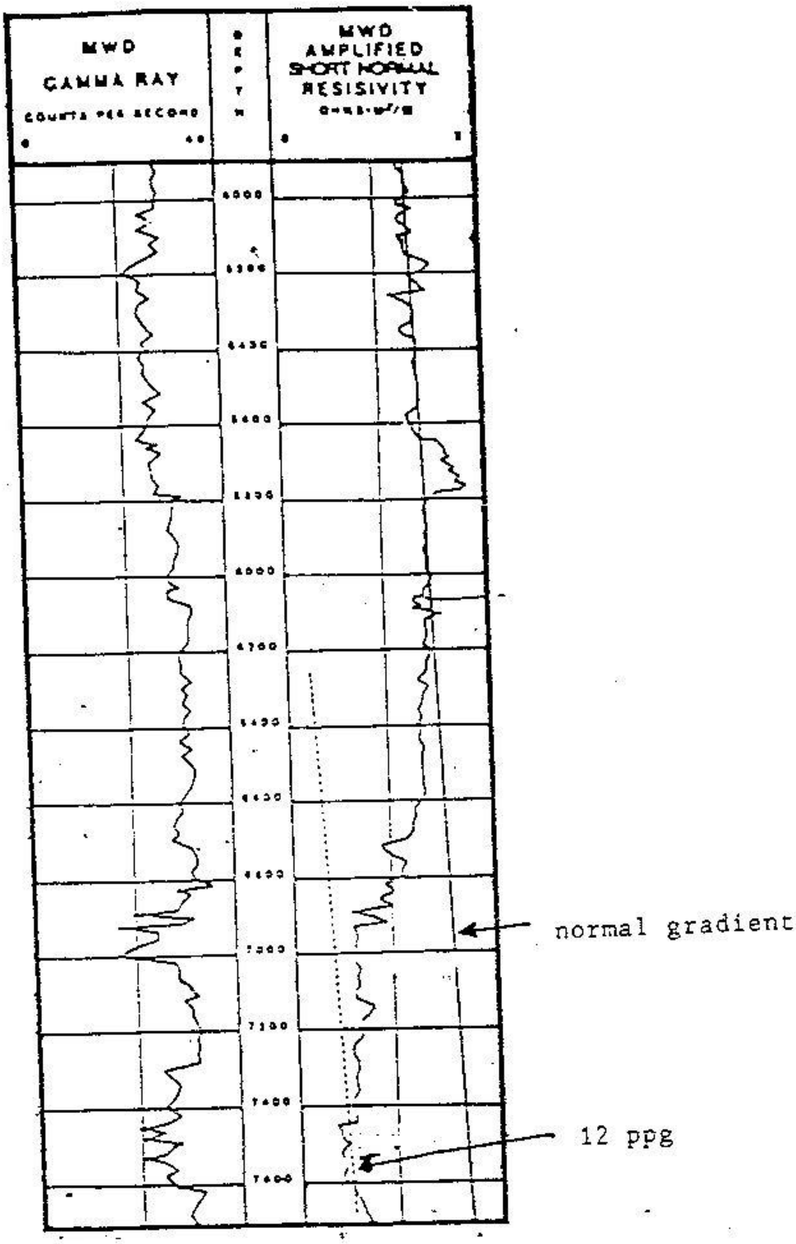

Figure 4
MWD log from isolated exploratory well
showing the resistivity and gamma ray data.

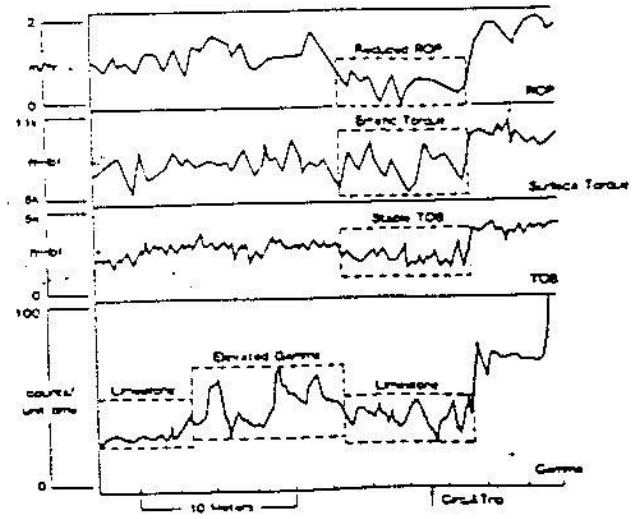

Figure 5
Avoiding a trip

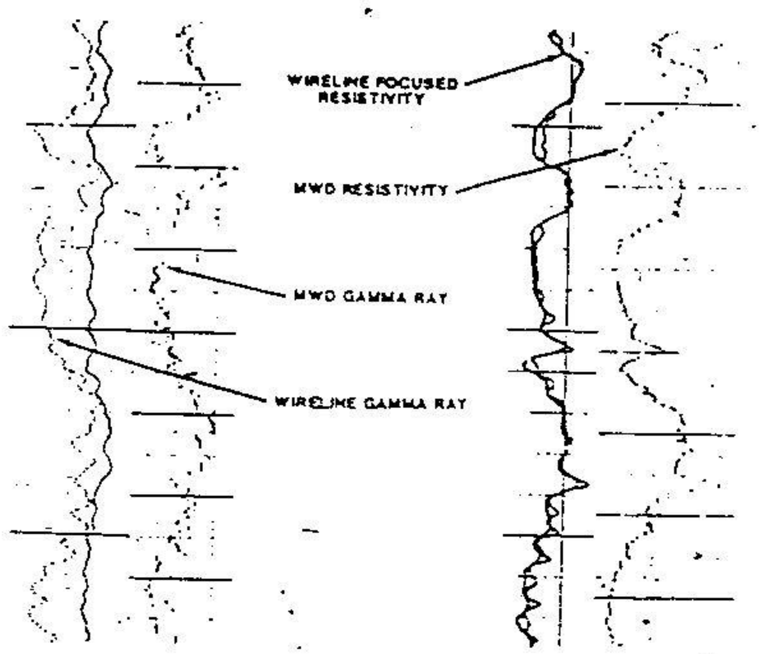

Fig 6 – Comparison between wireline and MWD logs.