Objective
The goal of this section is to provide a basic understanding of the various components of a well log. Covered will be basic information of the header, the scales observed and a brief overview of the calibration procedures. Details of the log curves will not be covered, as this will be the topic of future lectures.

Header information
The first page of the log contains basic information about the well. This “header” information can be divided into three broad categories: 1) location, well name and elevations, 2) mud measurements, and 3) depth measurements. Figure 1 is an example of a log header. A description of each item is given below.

Log Header information:
1. Logging company name and log name.
2. Well identification, including the operating company, well name and number, and field, county, and state where the well is located.
3. Well identification typed or printed perpendicular to the heading's main orientation for filing purposes.
4. Exact well location according to the system used in the state. The most common designation uses the section/township/range system.
5. Other logs and services run in the well (for completeness and quick reference).
6. A permanent depth datum and its elevation. The permanent datum is selected so that rig removal does not result in a loss of depth reference. The API recommends that the top surface of the surface casing's upper flange, called the Bradenhead flange (BHF), be used as the permanent reference plane. Some operators use ground level (GL) or mean water level (MWL) as the permanent datum.
7. The datum from which the log depth is measured and its elevation above the permanent datum. The API recommends that all logs be measured from the rotary kelly bushing (KB).
8. The datum from which the driller's measurements are made. The kelly bushing is also recommended for these measurements.
9. The exact elevation from sea level of the ground level, derrick floor (DF), and kelly bushing. These elevations are helpful in constructing subsurface structural maps and cross sections.
10. The run number. Each time the logging tool is run in a well, the run is assigned a number. The run date and other measurement environment data pertaining to the run are listed. Space is provided for four runs. The lower portion of the heading is duplicated to record additional runs.
11. The depth of the bottom of the hole at the time of logging according to driller's and logger's measurements, respectively. The driller's and logger's measurements of depth usually differ by a few feet, mainly because they use different means of
determining depth. The driller uses the length of the rigid drillstring, while the logger relies on the length of the flexible logging cable.

12. The depth of the top and bottom of the interval logged.
13. The casing size and the depth according to driller's and logger's measurements. The section of the well above the logged open hole is cased.
14. The bit size used to drill the borehole being logged.
15. The type of drilling mud in the hole at the time of logging. Also listed is the mud density in pounds per gallon, mud viscosity in Marsh funnel seconds, pH, and fluid loss in cubic centimeters per 30 minutes.
16. The source of the mud sample used to determine the properties listed in Item 15. The API recommends that a circulated mud sample be used. This sample is collected from the circulated flow stream immediately before circulation is stopped and the drillstring is retrieved to prepare for logging. The API also recommends that samples collected from mud tanks (pits) not be used because they may be nonrepresentative.
17. Measured mud, mud filtrate, and mudcake resistivities at corresponding temperatures. The resistivity values are given in ohm-meters and the measurement temperature in degrees Fahrenheit.
18. Mud filtrate and mudcake resistivities either measured or calculated at bottomhole temperature. The sources of $R_{mf}$ and $R_{mc}$ values have to be indicated. "M" is usually used to show that the value is measured on a sample; "C" is usually used to show that the value is calculated or determined from a chart.
19. The value of mud resistivity at BHT, usually estimated with a chart.
20. Time (in hours) elapsed between the end of mud circulation before logging and when the logging tool reached bottom.
21. The temperature indicated by the maximum-recording thermometer used during the run.
22. The logging truck or equipment number and the truck's base of operation.
23. The names of the logging company and operating company representatives. The logging company representative is in charge of the logging operations. The operating company representative witnesses the logging operation to ensure that the logging program is executed according to company plan and that log quality meets company standards.

Remarks section:
   a. general remarks
   b. mud data for two additional samples for the particular run.
   c. Scale changes made during logging
   d. Detailed equipment data
Figure 1 Basic log header (Taken from Bassiouni, 1994)
 Formats and Scales

Well logs are merely graphic representations of various tool responses in regards to depth. The API log grid is the standard format used for recording well-logging measurements in the petroleum industry. The total width of the "log grid" is 8.25 inches. It is organized into three curve tracks and a narrow depth column for depth numbers. One track is on the left side of the depth column and two or more on the right (Fig. 2). The tracks are 2.5 inches wide and the depth column is 0.75 inches wide. Each track can be divided into its individual grid scale. All tracks are on the same depth scale.

![Figure 2. Examples of standard log format for linear grid scales](image)

The numbers that appear in the depth column represent vertical depth. The most common vertical depth scales are:

- 1 inch of log = 100 ft of hole
- 2 inch of log = 100 ft of hole
- 5 inch of log = 100 ft of hole

For comparison, figure 3 is an example from Prudhoe Bay of the 2" =100’ and 5” = 100’ depth scales. The 1-in. and 2-in. scales are usually used for correlation purposes. And, they are occasionally referred to as "correlation scales". The expanded scales are available for detailed log analysis and interpretation of particular log sections. On the 1-in. and 2-in. depth scales, each major division indicates 100 feet of hole. Each subdivision indicates 10 feet of hole. On the 5-in. scale, each subdivision indicates 2 feet of hole.
Figure 3. Two log sections over the same interval in a well from Prudhoe Bay. Top: 2" = 100 ft. scale, bottom: 5" = 100' scale.
Three types of grids are available: linear, logarithmic and split grid. The linear grid (top diagram of figure 4) represent functions that have straight line or corresponding relationships of constant value. Frequently superimposed scales are required to meet the entire range of the data. Track one (1) is always linear. The center diagram of Fig. 4 illustrates the 4-cycle logarithmic grid in tracks 2 and 3. Logarithmic scales are usually used for resistivity curves, since they provide a greater dynamic range of values. A common resistivity scale range is 0.2 to 2000 ohm-m. The bottom diagram illustrates the 3-cycle logarithmic or split grid. Here, track 2 is logarithmic and track 3 is a linear presentation. The track 2 logarithmic scale allows a slightly more accurate reading of low resistivity values.

Figure 4. Various grid scales (Western Atlas, 1992)
Two examples comparing grid scales for resistivity measurements are shown in figures 5 and 6, respectively. In figure 5, the left track shows gamma ray readings on a linear scale. However, the resistivity measurements are shown on both a hybrid and logarithmic scales. Observe the log scale provides improved definition to the data.

Figure 5. Laterolog recorded on both hybrid and logarithmic scales through the same zone. (Schlumberger, 1972)

The second example (Fig. 6) again illustrates the better resolution of resistivity measurements on a log scale vs a linear scale. Low resistivity values at a depth of 3050 to 3100 feet are difficult to discern on the linear scale but can accurately be read on the log scale. In both log sections, the left track is the SP curve on a linear scale. Note the SP is not absolute scaled since the SP deflection is measured.
Figure 6. Comparison of induction electric log (linear) to the dual induction log (log) (Hilchie, 1978)
Figure 7 is an example of an old electric log with all tracks on linear grid scales. Superimposed scales are necessary since the magnitude of the resistivity measurements vary significantly. A further issue is the lack of depth adjustment in these old logs. That is, the lack of memory in the equipment results in the inability to compensate for the distance between the measuring points on the tool. Several examples are identified on the log.

Figure 7. Example of old electric log.
Figures 8 to 11 are examples of log formats and scales for a variety of porosity logs. All tracks are linear scaled. The left track consists of the gamma ray (scaled in API units) and caliper (scaled from 6 to 16 inches) measurements. Porosity is scaled increasing to the left; therefore the porosity measurement; i.e., sonic velocity, bulk density or neutron counts are scaled to correspond to this increasing direction.

Figure 8. Example: Gamma ray and caliper measurements on linear scale in the left track. Sonic travel time is on a linear scale in the middle and right tracks.
Figure 9. Example: Gamma ray and caliper measurements on linear scale in the left track. Density porosity and bulk density are on a linear scale in the middle and right tracks, with the density correction only in the right track.
Figure 10. Example: Gamma ray and caliper measurements on linear scale in the left track. Neutron porosity and count rate are on a linear scale in the middle and right tracks.
Figure 11 Example: Gamma ray and caliper measurements on linear scale in the left track. Density and neutron porosity curves are on a linear scale in the middle and right tracks, with the shaded areas indicating the presence of gas.
Calibrations

Logging companies perform three levels of tool calibrations to ensure accuracy of the measurements:

1. shop calibrations
2. before survey calibrations
3. after survey calibrations

Figure 12 is a typical calibration record for a dual spaced neutron tool.

![Calibration records]

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**DUAL SPACED NEUTRON II SHOP CALIBRATION SUMMARY**

PERFORMED: 16:33:18 05/26/90  
LAST SHOP CALIBRATION: 13:57:49 04/25/90

SERIAL NUMBER: 108731  
MODEL: DSNT-A

SOURCE NUM: 96  
CALIBR NUM: 36

TRUCK UNIT NUMBER: 51711  
PROGRAM VERSION: 1.11

PERFORMED BY: WHITE

**PRIMARY CALIBRATOR**

<table>
<thead>
<tr>
<th>Measured</th>
<th>Calibrated</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>RATIO</td>
<td>6.447</td>
<td>6.487</td>
</tr>
<tr>
<td>POROSITY</td>
<td>24.311</td>
<td>24.128</td>
</tr>
</tbody>
</table>

**FIELD CHECK BLOCK**

| CHECK RATIO | 6.550 | 6.518 |
| CHECK POROSITY | 24.828 | 24.642 |

---

**DUAL SPACED NEUTRON II BEFORE SURVEY FIELD CHECK SUMMARY**

PERFORMED: 19:54:16 06/ 5/90  
LAST SHOP CALIBRATION: 16:33:18 05/26/90

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<th>FIELD</th>
<th>UNITS</th>
</tr>
</thead>
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<td>6.518</td>
<td>6.542</td>
</tr>
<tr>
<td>CHECK POROSITY</td>
<td>24.642</td>
<td>24.754</td>
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**DUAL SPACED NEUTRON II AFTER SURVEY FIELD CHECK SUMMARY**

PERFORMED: 18:51:08 06/ 6/90  
LAST SHOP CALIBRATION: 16:33:18 05/26/90

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</thead>
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<td>6.476</td>
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<tr>
<td>CHECK POROSITY</td>
<td>24.754</td>
<td>24.446</td>
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</table>

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**PLS-II CALIBRATION SUMMARY TABLE**

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<tr>
<th>SERVICE or SIGNAL</th>
<th>SHOP</th>
<th>BEFORE</th>
<th>AFTER</th>
<th>CHANGE</th>
<th>TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAMMA</td>
<td>247</td>
<td>238</td>
<td>240</td>
<td>-2</td>
<td>+/- 9.0</td>
</tr>
<tr>
<td>DSN POROSITY</td>
<td>24.642</td>
<td>24.754</td>
<td>24.446</td>
<td>0.308</td>
<td>+/- 0.9</td>
</tr>
<tr>
<td>BULK DENSITY</td>
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<td>2.163</td>
<td>2.150</td>
<td>0.005</td>
<td>+/- 0.015</td>
</tr>
<tr>
<td>DENSITY CORRECTION</td>
<td>8.013</td>
<td>0.006</td>
<td>0.006</td>
<td>-0.002</td>
<td>+/- 0.015</td>
</tr>
<tr>
<td>DENSITY PE SHORT</td>
<td>4.725</td>
<td>4.678</td>
<td>4.649</td>
<td>0.029</td>
<td>+/- 0.3</td>
</tr>
<tr>
<td>DENSITY PE LONG</td>
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<td>3.946</td>
<td>3.842</td>
<td>0.103</td>
<td>+/- 0.3</td>
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<tr>
<td>CALIPER VALUE 1</td>
<td>8.000</td>
<td>8.058</td>
<td>8.076</td>
<td>-0.018</td>
<td>+/- 0.5</td>
</tr>
</tbody>
</table>

---

Figure 12. Calibration records
Of importance is to verify that all three numbers fall within the specified tolerances listed on the bottom of the figure.

Question
Read the difference between the “Before" and “After” survey calibrations for the neutron tool in Figure 12.

a) Are they within allowable tolerances?

b) What effect will the drift have in terms of changes in the logged parameter, neutron porosity?

The need for log quality control is of primary importance while acquiring the data at the wellsite. Erroneous data will lead to poor decisions and potentially economic disasters; thus while at the wellsite several quality checks can be examined. First is to view the calibration checks on the log. Calibrations are the only completely objective verifications of log quality available. Learn what they mean and how to use them. Second, the depth-related log measurements will include one or more repeat sections, usually about 200 ft. These repeat sections indicate consistent tool operation and should be examined carefully on every log.

A repeat section of 200 ft or more should be required except in unusual circumstances. Properly functioning resistivity tools, run under conditions that are within their capability, will nearly always repeat very well. Radioactive tools should also repeat within their statistical limits. Remember that excessive logging speed will result in poor repeats of radioactive logs.

Aside from equipment failures, factors which could cause poor repeats include: washed out holes, variable tool centering, tool rotation, the presence of metallic 'fish' in the borehole, and comparing an up log with a down log (which may appear quite different with some types of logs, such as the temperature log).

Repeatability with an earlier log run may also be affected by time-related phenomena, such as changing invasion profiles. Invading filtrate can penetrate deeper, migrate vertically, accumulate as "annuli," or dissipate with the passage of time. The log response, particularly of the shallow reading devices, may continue to change for many days after the well is logged. Such changes can be troublesome, but from the viewpoint of log quality they are usually recognizable; the changes occur only in the invaded sections, not in the shales or other impervious rocks.