EPA Hydraulic Fracturing Workshop, March 10-11, 2011 Arlington, VA 22202

Theme 1: Well Construction

Cementing, Cement Quality Evaluation/Logs and Zonal Isolation for Hydraulically Fractured Wells

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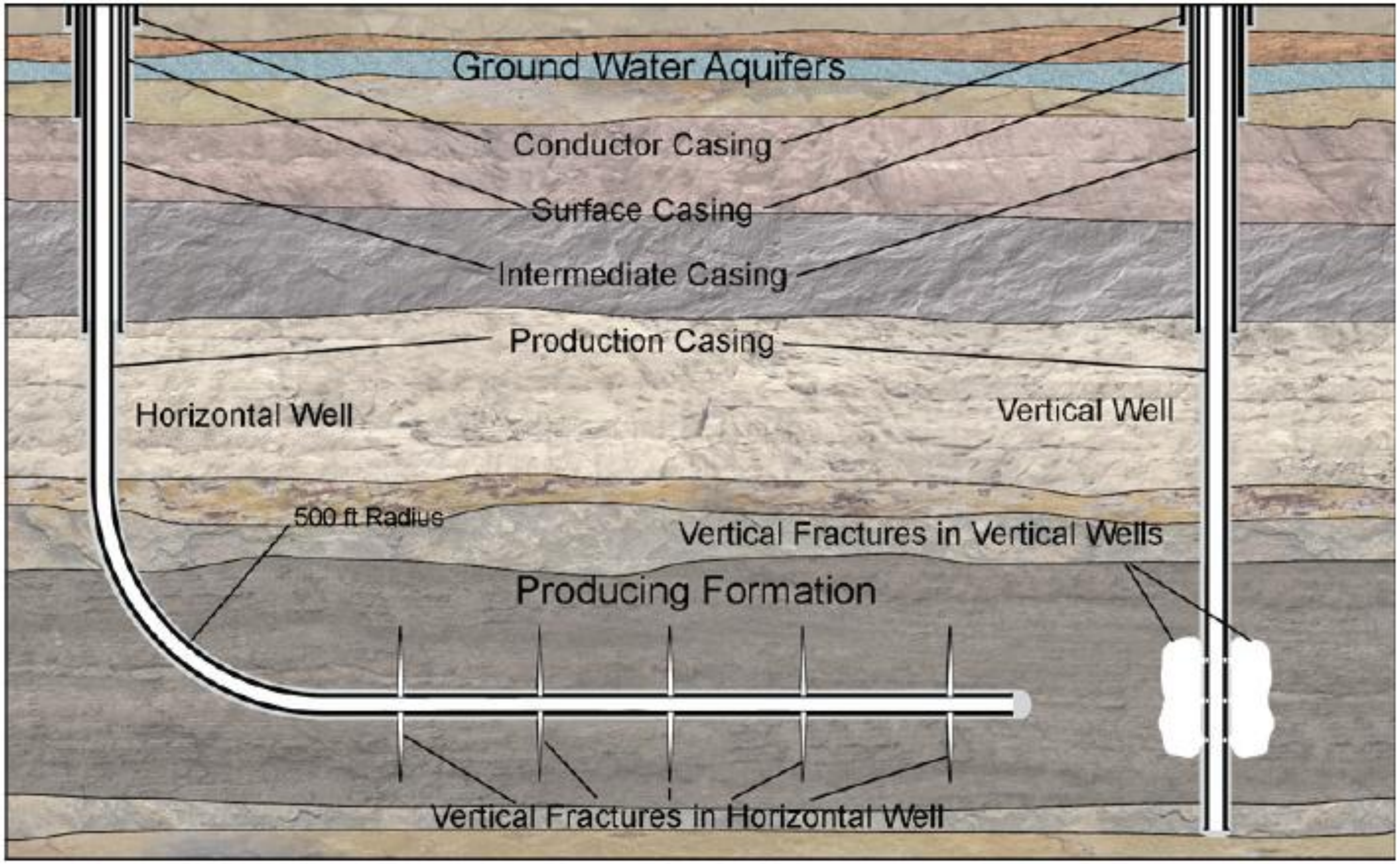


Figure 3—Example of a Horizontal and Vertical Well

Courtesy API 2009

Casing Setting and Design

- NORSOK 2004 lists factors to consider in casing design

  - Casing must be designed to withstand tensile, burst and collapse loads

  - Use safety factors (wear and tear) for casing deterioration

  - Axial and bending forces and shock load

  - Casing design should also consider buckling, piston and thermal effects

Function of Cements and Cement Components

- Restrict fluid movement between permeable zones within well
- Provide mechanical support for casing string
- Protect casing from corrosion from formation waters
- Support wellbore walls (in conjunction with casing) to prevent collapse

CEMENT COMPONENTS

- Main components are C3S and C2S

- C3S – shows faster rate of hydration; responsible for overall strength characteristics and for early strength

- C2S – a slow-reacting component; shows gradual increase in cement strength.

Properties of Cement Slurry

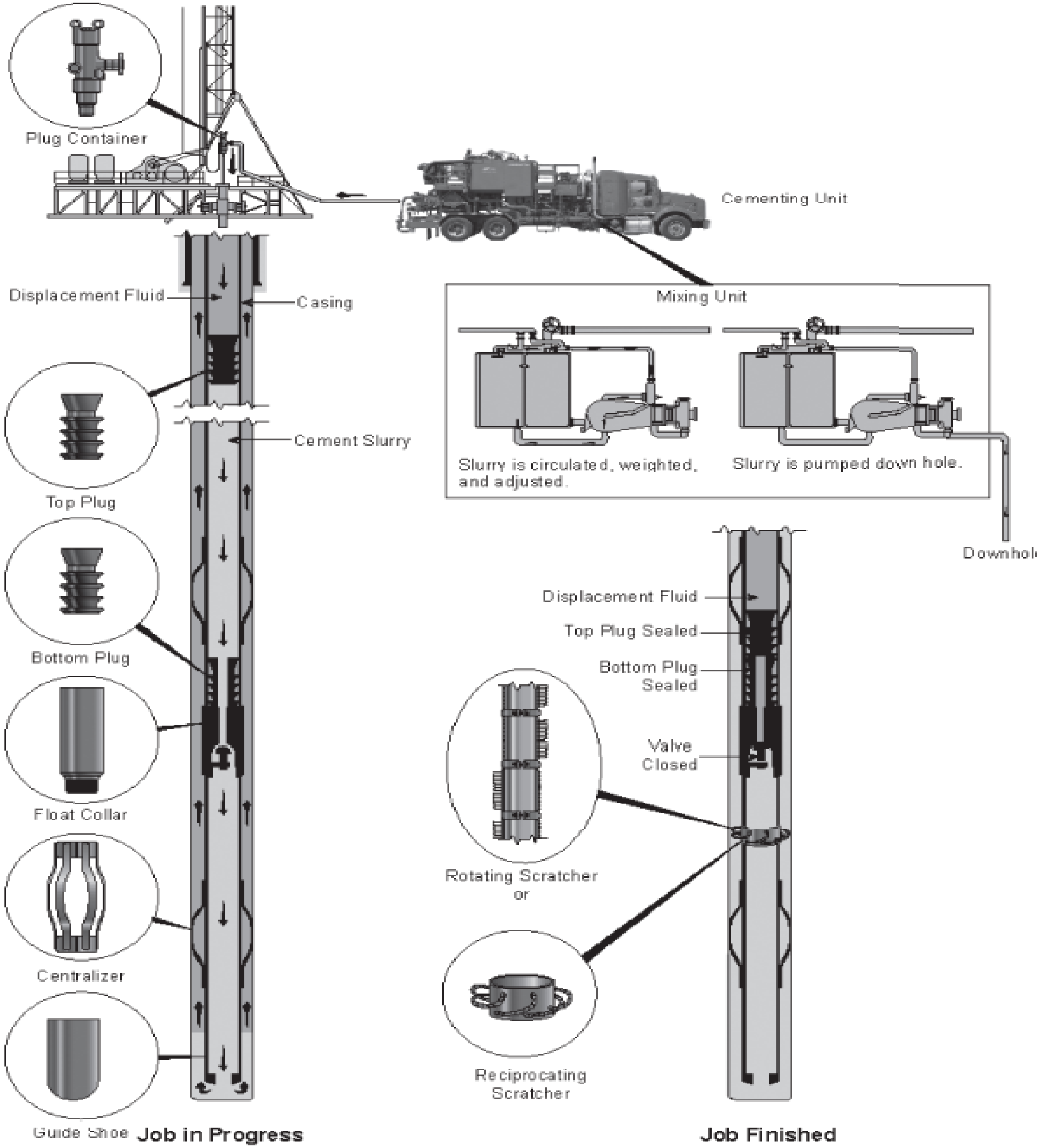
- *Thickening time* is equivalent to time required to keep the cement pumpable. It is critical that the thickening time exceed the actual cementing job to avoid cementing: surface pipes; cementing head; DP or inside of casing.

- Density-reducing additives result in a set cement of lower strength that can be obtained from a neat slurry. Examples: bentonite, diatomaceous earth, gilsonite and pozzolan
- Density-raising additives have the opposite effect. Examples: barite, ilmenite and hematite

  - *Compressive strength* widely used as an index for quantifying cement strength. Cement with compressive strength of 500 psi is adequate for most cementing operations. Determined in lab prior to running casing string.

Cementing operation

- Open bottom wiper plug and direct slurry through top valve
- Slurry pushes bottom plug down casing until plug seats on the Float Collar
- Continued pumping ruptures diaphragm in plug and allows cement to pass through and be placed around casing.
- After pumping complete volume, stop pumping and place top wiper plug in cementing head.
- Pump drilling mud through the top valve, pushing the top wiper plug down the casing.
- When top plug seats on the bottom plug, well is shut in and slurry allowed to set.



Courtesy API 2009

Figure 2—Cementing the Casing

Methods of Cementing

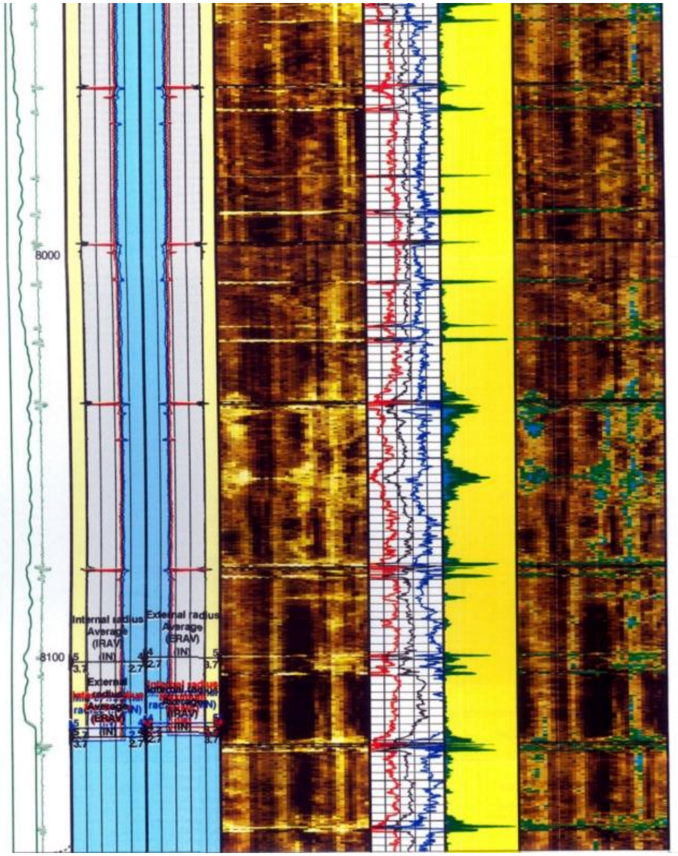
- Single-stage cementing used for conductor pipe and surface casing. All tools are easily drillable
- Multi-stage (2-stage or 3-stage) cementing used for cementing long strings:
  - Reduces total pumping pressure
  - Reduces total hydrostatic pressure on weak formations (prevent fracturing)
  - Allows entire length to be cemented
  - Ensures effective cementing around shoe of previous casing

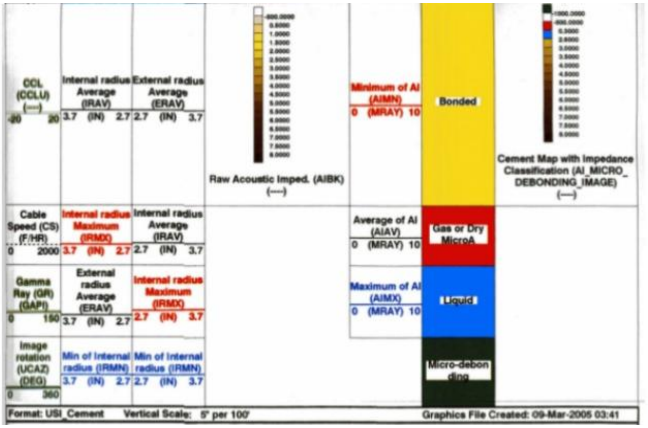
Cement Evaluation

- Two classes of sonic logging tools: (1) sonic (CBL/VDL) or SBT and (2) ultrasonic (USIT/CAST-V)
- Acoustic cement bond logs do not measure hydraulic seal but instead measure loss of acoustic energy as it propagates through casing. This loss of energy is related to the fraction of casing perimeter covered by cement
- The Ultrasonic Imaging Tool (USIT) is a continuously rotating pulse-echo type tool with nearly 100% coverage of the casing wall. The transducer ("sensor") rotates, emitting and receiving signals reflected back from the casing wall. Preferable to run CBL with it for overall well integrity picture
- The Segmented Bond Tool (SBT) measures the quality of cement effectiveness, vertically and laterally around the circumference of the casing. The SBT measures 6 segments around the pipe and uses high frequency steered transducers mounted on 6 pads. Each of 6 motorized arms positions a transducer and receiver against the casing wall. SBT is usually run with VDL

Table 3 shows acoustic properties of various materials

Table 3 Acoustic Properties of Materials (Smolen, 1996)			
Material	**Density**	**Acoustic Velocity**	**Acoustic Impedance**
	(kg/m^3)	(m/sec)	(MRayl)
Air	1.3-130	330	0.0004-0.04
Water	1000	1500	1.5
Drilling fluids	1000-2000	1300-1800	1.5-3.0
Cement slurries	1000-2000	1800-1500	1.8-3.0
Cement (Litefill)	1400	2200-2600	3.1-3.6
Cement (Class G)	1900	2700-3700	5.0-7.0
Limestone	2700	5500	17
Steel	7800	5900	46





Example USIT Log run on injection well

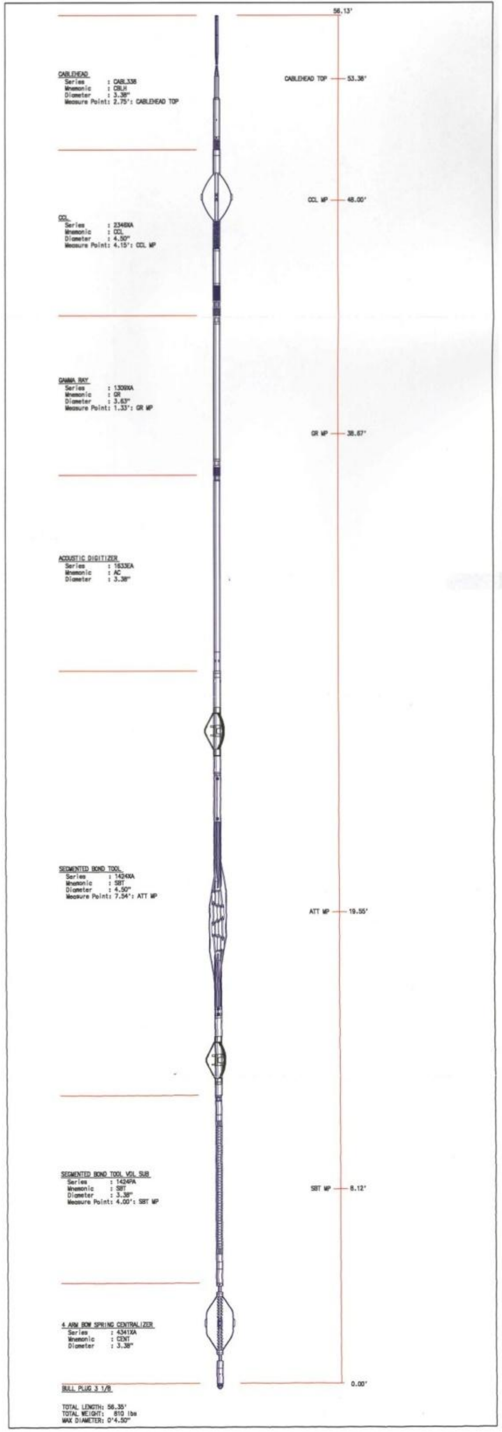


Figure 13: Typical SBT/VDL tool configuration (Smolen, 1996)

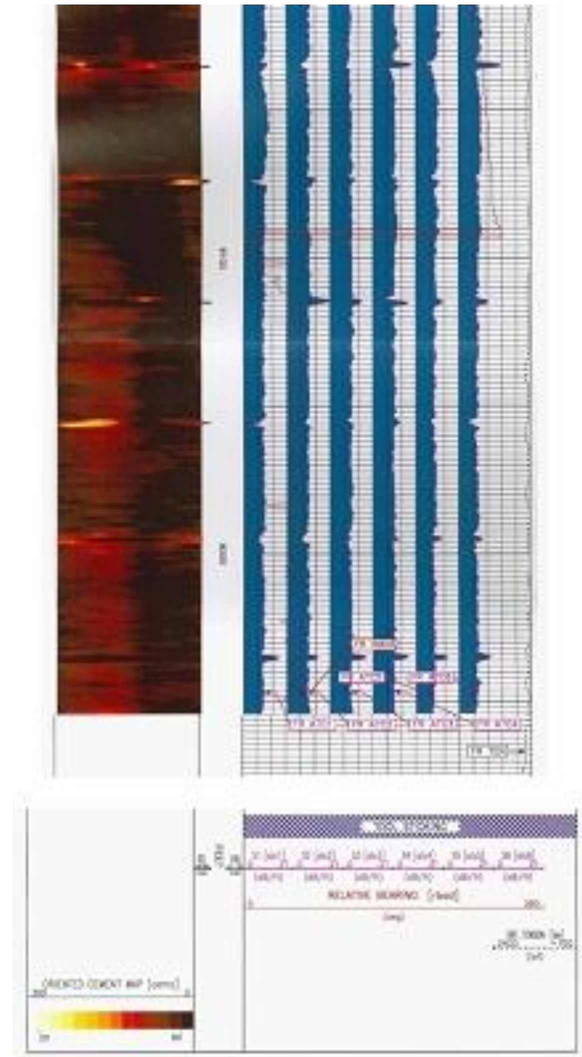


Figure 14: An example SBT log.

Factors affecting CBL/USIT tool performance

- *Microannulus* is a very small (annular gap) between casing and cement sheath and can result in misinterpretation of CBL/VDL. Generally, pressure up casing to 1000 to 1500 psi to close the gap (if cement job was good). Ultrasonic tools less affected than CBL/VDL and SBT (pads) in the presence of liquid in the gap with opposite effect in the presence of gas.
- *Eccentralization* a potential concern in deviated/horizontal wells due to absence of cement on the low side and small distance between casing and formation face.
- *Logging Tool Centralization* is mandatory for USIT and CBL/VDL tools. The SBT pads with articulated arms are unaffected, although the CBL/VDL part may be affected.
- *Fast Formations* – acoustic signals from some formations reach the receiver ahead of pipe signal. Fast formations affect the CBL/VDLs/SBT logs but do not affect USIT interpretation.
- *Lightweight Cement* – lack of contrast in acoustic properties between lightweight (used in weak formations) and regular cement slurry.
- *Cement Setting Time* – important for CBL interpretation. If run too early before cement is set, may indicate poor bonding and an unnecessary squeeze operation. Use UCA to determine WOC time and when to log.

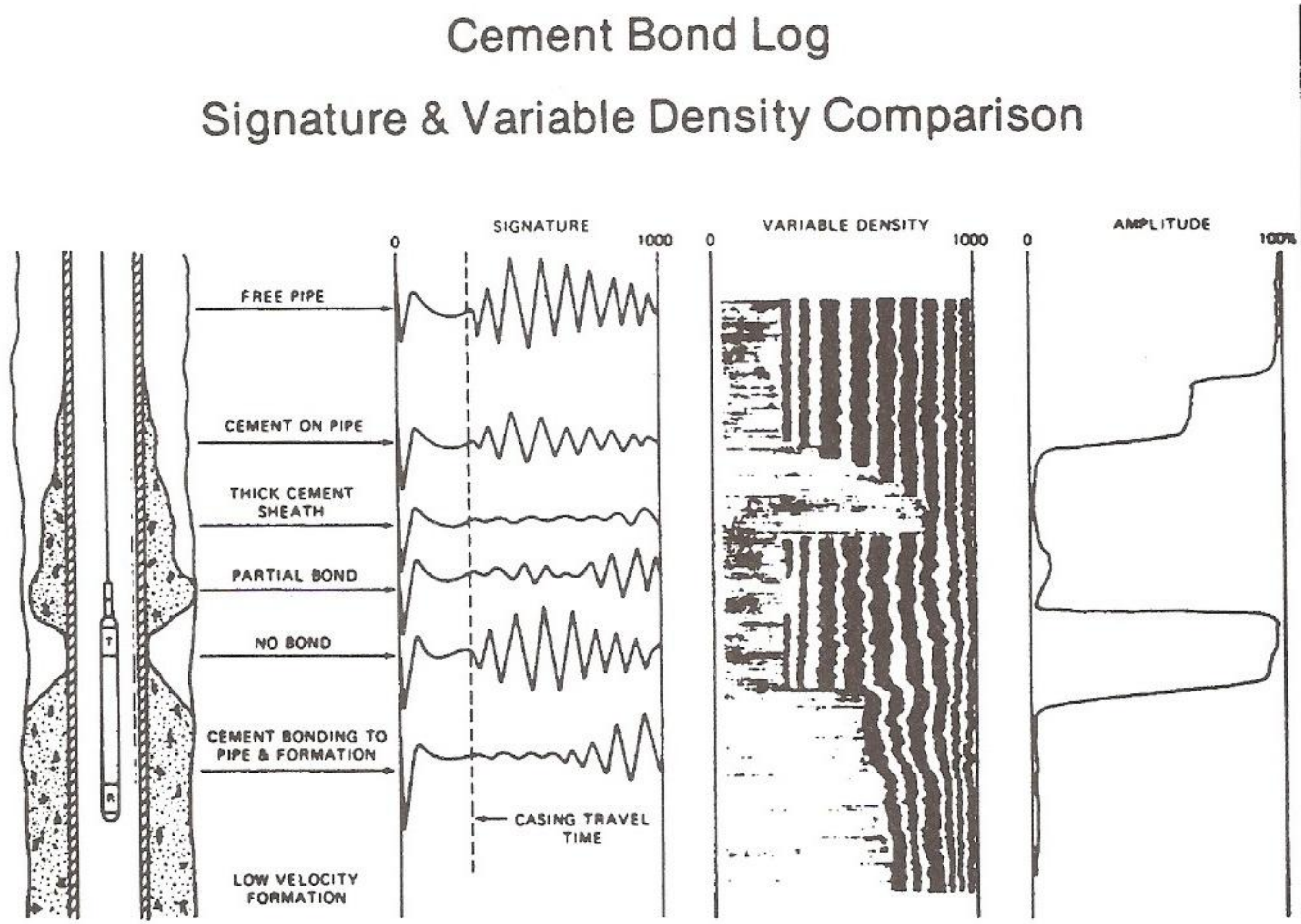


Figure 17: Comparison of wavetrain, VDL, and amplitude for a variety of cement conditions (Courtesy Western Atlas, Ref. 2)

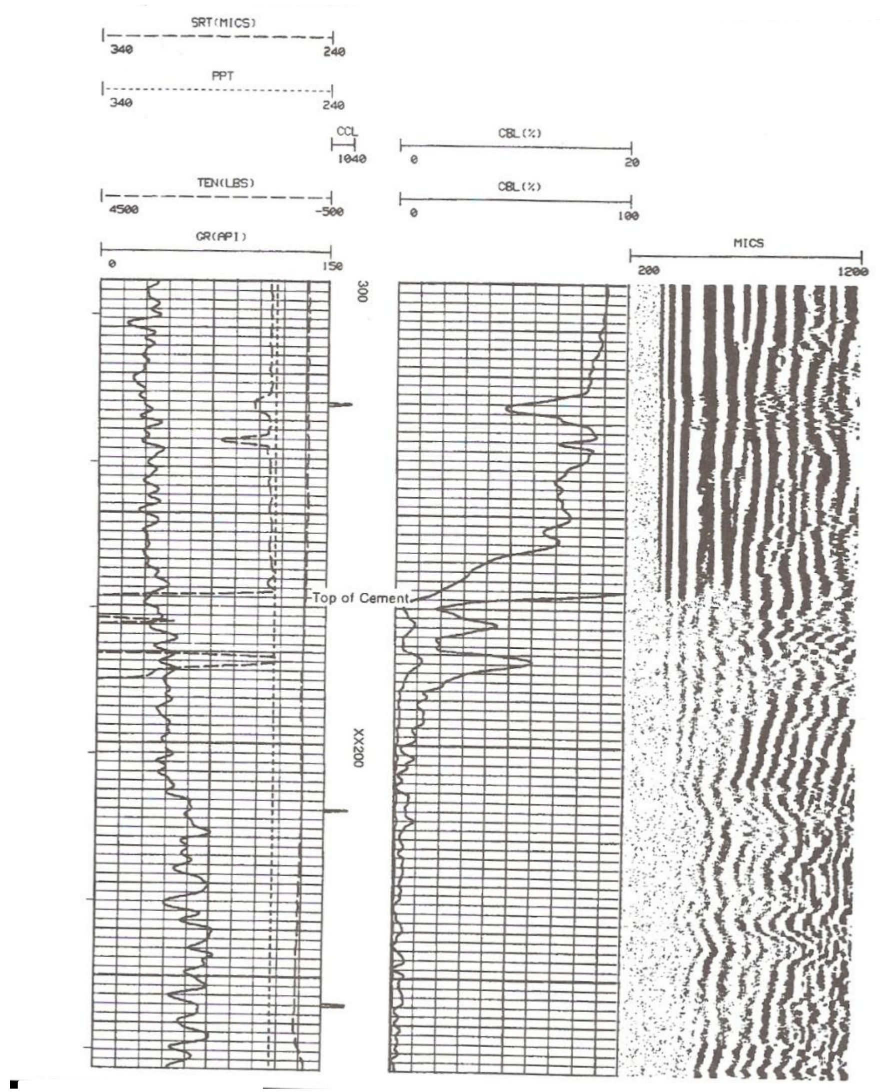


Figure 18: Bond log showing cement top (Courtesy Western Atlas)

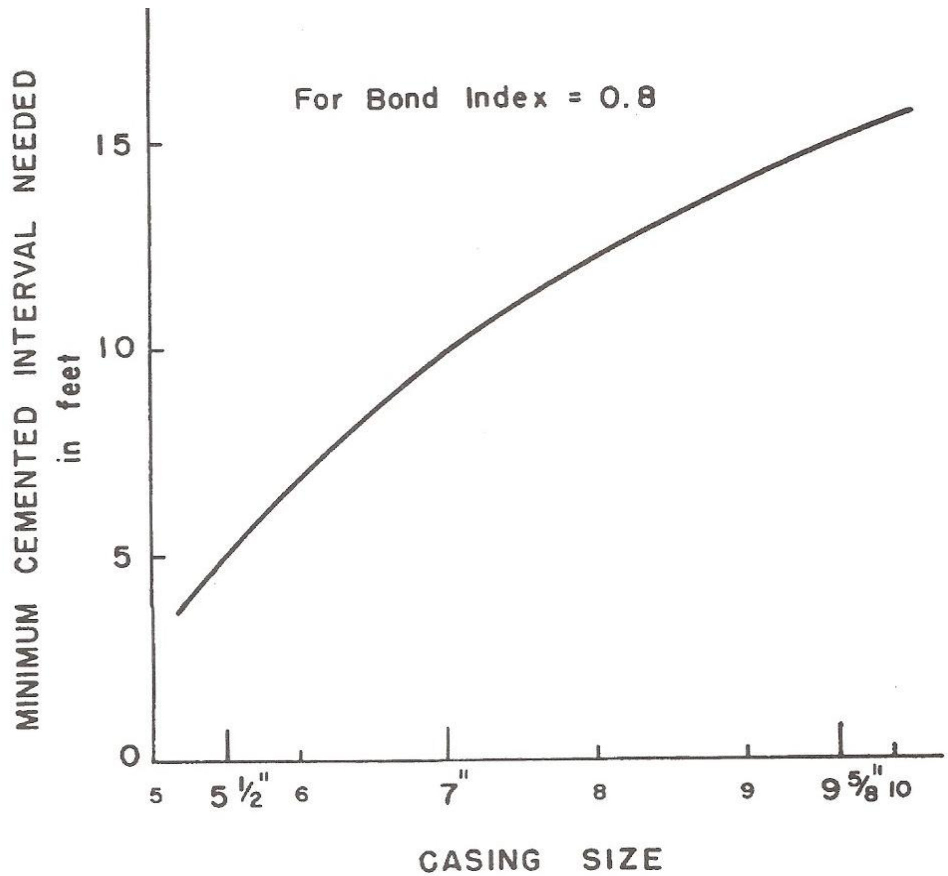


Figure 19: Interval required for isolation with bond index = 0.8
(Courtesy SPWLA)

Major problems with obtaining a good cement job in horizontal wells

- Hole cleaning and drilling-fluid displacement
- Centralization of pipe
- Optimizing cement slurry designs, and
- Evaluation with acoustic tools

Zonal Isolation and Casing Shoe Integrity

▪ Placement of cement completely around the casing and at the proper height (cement top) above the casing shoe is critical in achieving zone isolation and integrity

▪ Pressure tests to verify isolation at casing shoe include Formation Integrity Tests (FIT) (also called LOT – leakoff test) and Casing Integrity Tests (CIT). Pressure up inside the casing until pressure at shoe exceeds the maximum hydrostatic pressure expected at that point during subsequent drilling operations. Failure at shoe is usually due to contamination (from either original drilling mud or from displacement fluid) and is a result of poor cementing techniques rather than poor quality cements

Thank You

Questions?