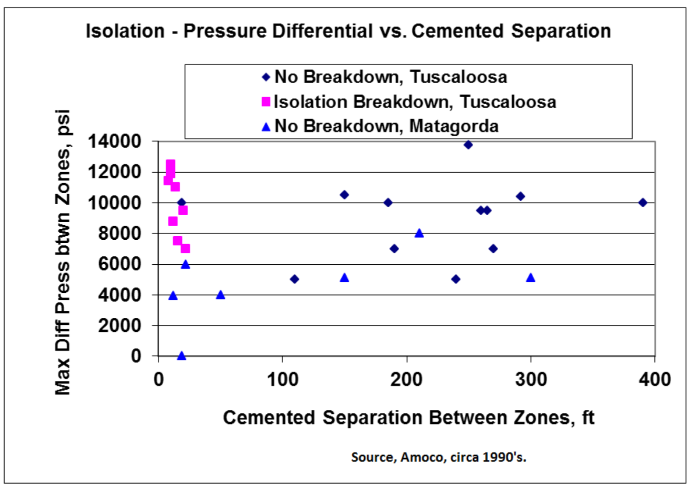
Basics of Wells – Cementing: How Effective is Cement in Creating Barriers?

During drilling, each section of a well is cased (a length of pipe is place to cover the well from surface to the bottom of a section) and liquid cement is pumped down the pipe and forced up the annulus between the outside of the pipe and the drilled hole wall. Within hours of placement, the cement sets or hardens into a stone-like seal between the pipe and the rock. Near the surface, where the wellbore penetrates a fresh water zone, the cement must pass a pressure test showing that it has sealed the annulus against leaks from the next phase of drilling. If the cement in a section of the well fails to pass testing requirements, the zone seal must be repaired and the pressure test passed before drilling of the next section can commence. Steel casing provides burst, collapse and tension strength and the cement provides the seal that isolates fluids and pressures. Cement on the outside of the casing string may come to the surface or to a lower level, depending on local regulations, requirements of the completion and the threat level of an isolation failure in the overall design. The isolation provided by cement and pipe depends on the quality of the cement, the pipe-to-cement bond and the cement-to-rock bond.

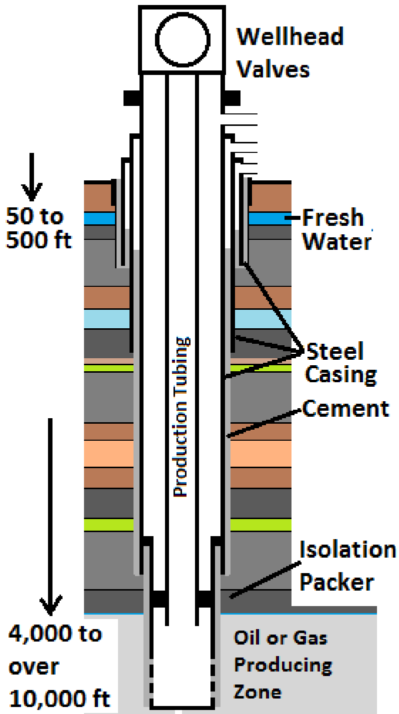
The vertical thickness of cement required in the annulus to form a seal to protect the environment and the well is surprisingly small. Field tests of high pressure gas wells, which are often the most difficult to effectively isolate, shows only 25 to 50 feet of high quality cement is needed to isolate zones that have over 6,000 psi differential pressure. Common practice in the industry is to use a cement sheath that comes completely to the surface for casing that covers groundwater sources, but deeper pipe and cement pairs may use a design for a partial open annulus that allows for improved monitoring and even possible repair if a leak is detected.



Cement does not need to be perfect over every foot of the cemented area, but at least part of the cement column must form a durable, dense and permanent seal sufficient to prevent fluids from moving behind the pipe. As a safety factor, Industry commonly uses from 200 to 600 ft of cement in overlap sections between pipe strings and above zones of widely different strength or pressure.

A US government study of subsurface water-injection operations in the Bakken area of North Dakota showed that the maximum quantifiable risk that water from water injection wells would reach an underground source of drinking water was seven chances in 1 million well-years where casing and cement adequately covered the drinking-water aquifers. Where surface casings and cement do not cover the USDW's, the probability is six chances in one-thousand well years (Michle, 1991). The 1000-to-1 improvement is a testimony to the efficiency of the cement seal in a well.

The question of how much cement to use in a well is often misunderstood. Regular cements, when mixed properly with water, have a slurry density of about 16 lb./gal., depending on cement type. This density translates into a vertical pressure application of roughly 0.83 psi for every vertical foot of cement slurry. When friction pressure from pumping is added, a full column of liquid cement may fracture formations along the drilled hole, damaging the rock and ruining the cement isolation attempt. For this reason, lower density cement or open annular spaces are often part of a deeper well design.



Cement Bond Logs (CBL), are often proposed as a need for every well, but these tools, while useful in early cement design or to help find problems, can give false readings, will miss small channels completely and are often difficult to run in a repeatable manner. A false reading by a CBL may cause a cement repair attempt where none is needed and repair operations may weaken the casing and leave a potential leak path where none existed before. For well rework and suspected changes in well integrity, other leak detection methods such as noise logs and borax logs offer more accurate determination of leaks than can be produced with a CBL. With the exception of a pressure test, requiring cement evaluation on every cement job appears to be a questionable decision, with possible detrimental structural consequences.

Best indicators of quality cement job are pumping records showing:

- steady density mixing,
- displacement pressures and returns within expectations, and
- drilling mud displacement by cement in line with expectations of time and volume.

An experienced operator can often predict cement quality from these records alone.

There are several critical and other important steps prior-to, during and after a cement job. The table has these items in rough order.

Factor	Reason	Casing String Target
Pressures within operation limits	Cement density & equivalent circulating density must be less than fracture gradient for exposed zones.	All strings
Casing centralization	Hold casing off borehole wall. Solid body centralizers preferred. 70% standoff is customary.	All strings
Wellbore & annulus cleaning	Mud thinning, filter cake removal & dispersal, separation of mud from cement.	All strings
Pump Chart Monitoring	Keep cement density, pressure, returns within job design.	All strings
Two plug system	Separation of mud/cement/flush – no contamination	Where isolation is critical
Gas migration prevention	Prevents gas channels in the cement.	Any casing string across a gas charged formation.
Pipe Movement	Important, but difficult to achieve in horizontal well	Vertical, near surface pipe
Float shoe & collar	Insures strong uncontaminated cement around the bottom of the well.	All strings where isolation is critical.
Pressure Test	Important for construction info. Critical for isolation.	Vertical casing isolation across fresh water zones.

Disclosure: George E. King is a Texas Registered Professional Engineer with over 44 years oilfield experience. His technical background includes fracturing, workovers, chemicals, acidizing, well integrity and horizontal wells.