

Bentonite as Material for Plugging and Abandoning Wells

Brad Brinkerhoff

Frank Micheli

Jeremy Meyers

Patrick Amole

Group Objectives

- Make plugs for the bentonite lab group and for future field trials
- Improve the design of the plug press
- Develop an argument for the Wyoming Oil and Gas Conservation Commission (WOGCC)
- Draft a rule change proposal for WOGCC
- Present the information in a hearing to the WOGCC

What is plugging and abandoning?

- Life of the well has reached the economic limit
- Production string removed
- Sections of gravel and cement are pumped down the well to seal off production zones
- Well head is removed and well is abandoned

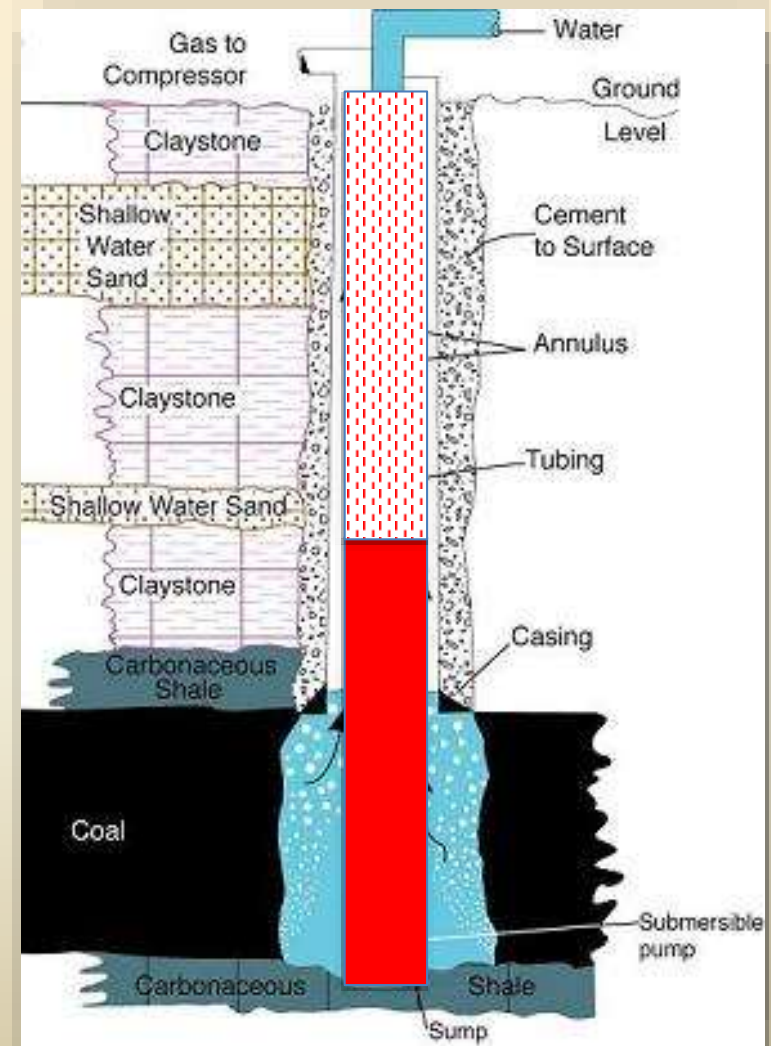


Figure. Typical CBM well

Plug Manufacturing

- Granulated bentonite compressed into bullet shape
- Custom design plug press



Figure. Raw bentonite



Figure. Plug press



Figure. Compressed bullet

New Press Design

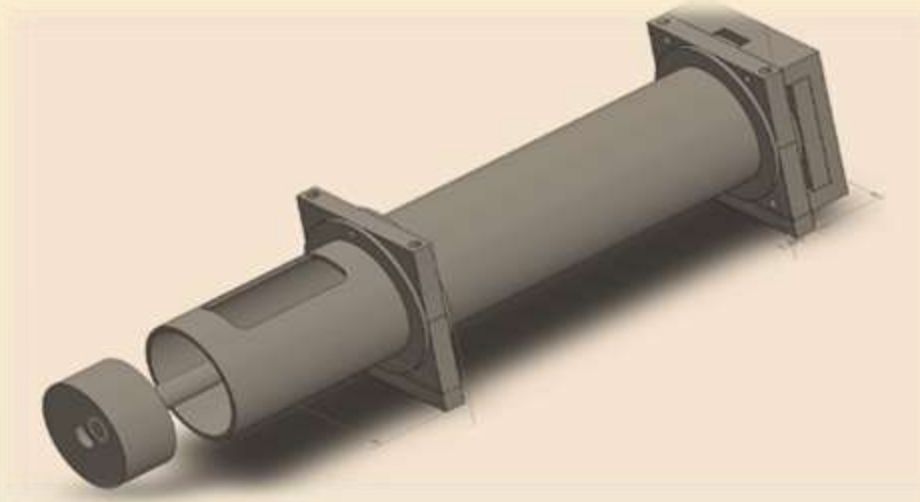


Figure. 3-D model of newly designed press assembly

- Modifications
- Design Process
- Assembly
- Materials
- Part Fabrication
- Success

Modifications

- Same form factor for both 3.5" and 5.5" molds
 - Multiple plug sizes needed
 - Only one hydraulic cylinder
- Shorter Chamber
 - Saves time, hydraulic arm has shorter travel distance
 - Allows cup and center rod to be easily removed and exchanged

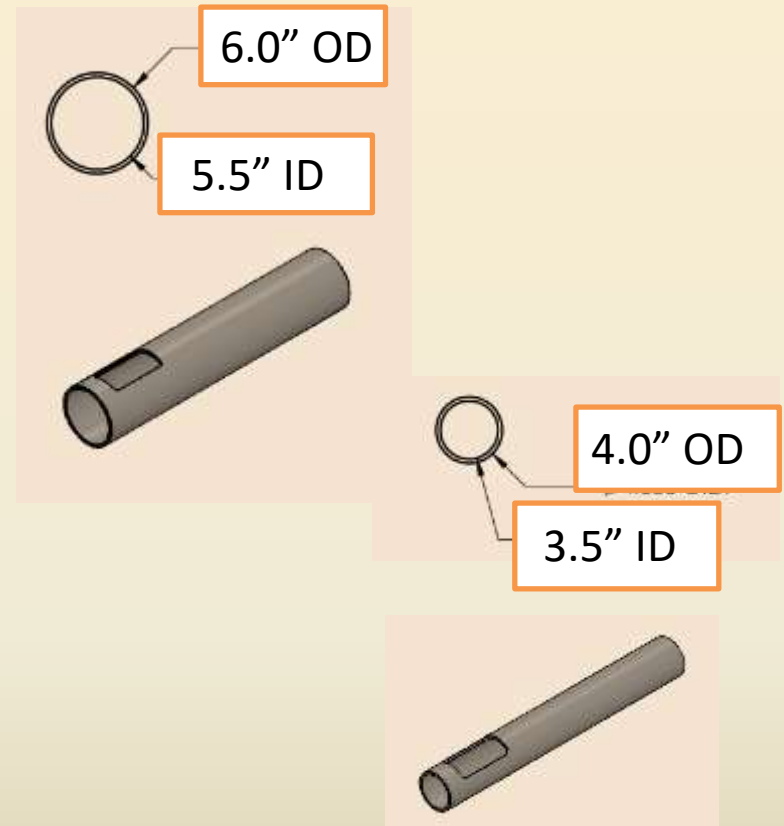
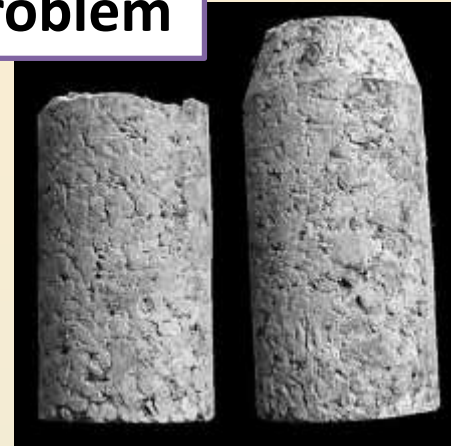


Figure. Newly designed 5.5" I.D. (top) and 3.5" I.D. (bottom) compaction chambers

Modifications

- Hopper/Funnel Loader
 - Prevents wasted bentonite
 - Saves time, easier to load
- PVC cup liner
 - Prevents post compaction breakage

Problem



Solution

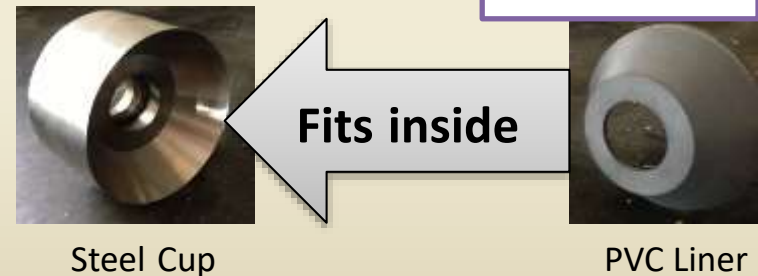


Figure. Bullet missing tapered end (top)
PVC liner fits inside stainless steel
compaction cup (bottom)

Materials

- Drawn-Over-Mandrel Tubing (DOM Tubing)
- Aluminum
- PVC
- Carbon Steel
- Stainless Steel



Figure. Drawn-over-mandrel tubing used to make the compaction chambers

Design Process

- Digital Models with SolidWorks
 - Parts
 - Assemblies
- Design Approval
 - Dr. Robert Erikson
 - Evaluated logic
- Fully dimensioned drawings
 - Section View
 - Hidden lines cannot have dimensions

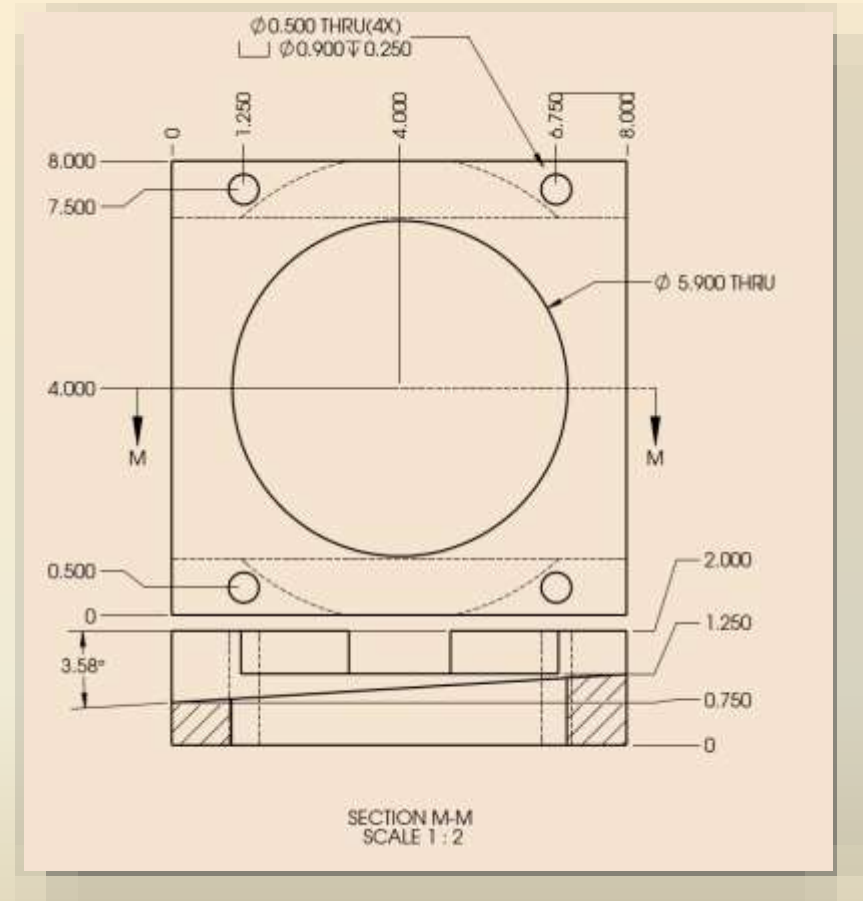


Figure. SolidWorks drawing of fully dimensioned wedge holder submitted to shop technicians

Part Fabrication

- Water Jet Cutter
 - Garnet (abrasive)
 - Used when possible to save time
 - Lacks precision
- CNC Lathe and Mill
 - Used for more complicated parts
 - Very Precise



Figure. Shop technician machining compaction cup on CNC Lathe

Assembly

- Align Parts
 - New parts mounted on I-beam platform
 - Press crudely operated to test alignments and clearances
- Weld Parts
 - Welded in place to avoid measurement mistakes



Figure. Technician welding support rings to 4" compaction chamber

Assembly

- Secure Parts
 - Tighten all bolts
 - Tighten Cup and Center Rod
 - Insert wedge
- Test Run
 - Carefully compress one 5.5" and one 3.5" plug
 - Ensure integrity of all components and press as a whole



Figure. Newly assembled press is mounted, secured and ready to compact bentonite bullets

Success of New Design

- Reliable method of producing bentonite bullets
- Capable of manufacturing a variety of plug sizes
- Better equipped for both lab and field tests
- Will help produce conclusive evidence that bentonite is a suitable abandonment material

WOGCC Presentation

Bentonite Plugging

- Wyoming's need
- Effective plugging material
- Better than cement
- Economics – cheaper than cement

Wyoming's Needs

- Currently 14,392 idle CBM wells
 - 622 are currently orphaned
 - Responsibility of the WOGCC to plug
- The state currently estimates the plugging cost to be \$10 per foot
 - Average well depth is 1000 – 2000 feet
 - Total cost to exceed \$6.2 million

Bentonite is Effective

- Currently legal in several states including New Mexico, Oklahoma, and California
- Used to plug water wells and seismic holes for years
- Gas wells plugged in California, Oklahoma, Texas, New Mexico and Australia
 - Over 5,000 wells
 - Deepest gas well plugged was 7,500 feet
- CBM wells have low pressure and temperature, shallower depths

Benefits Over Cement

- Ability to “heal” itself if fractured or disturbed
 - After re-healing bentonite plug is stronger than the original
- Immune to:
 - Seismic events
 - Deformations of the casing
 - Salt intrusions
 - Other possible fractures or imperfections
- Prevent gas channeling

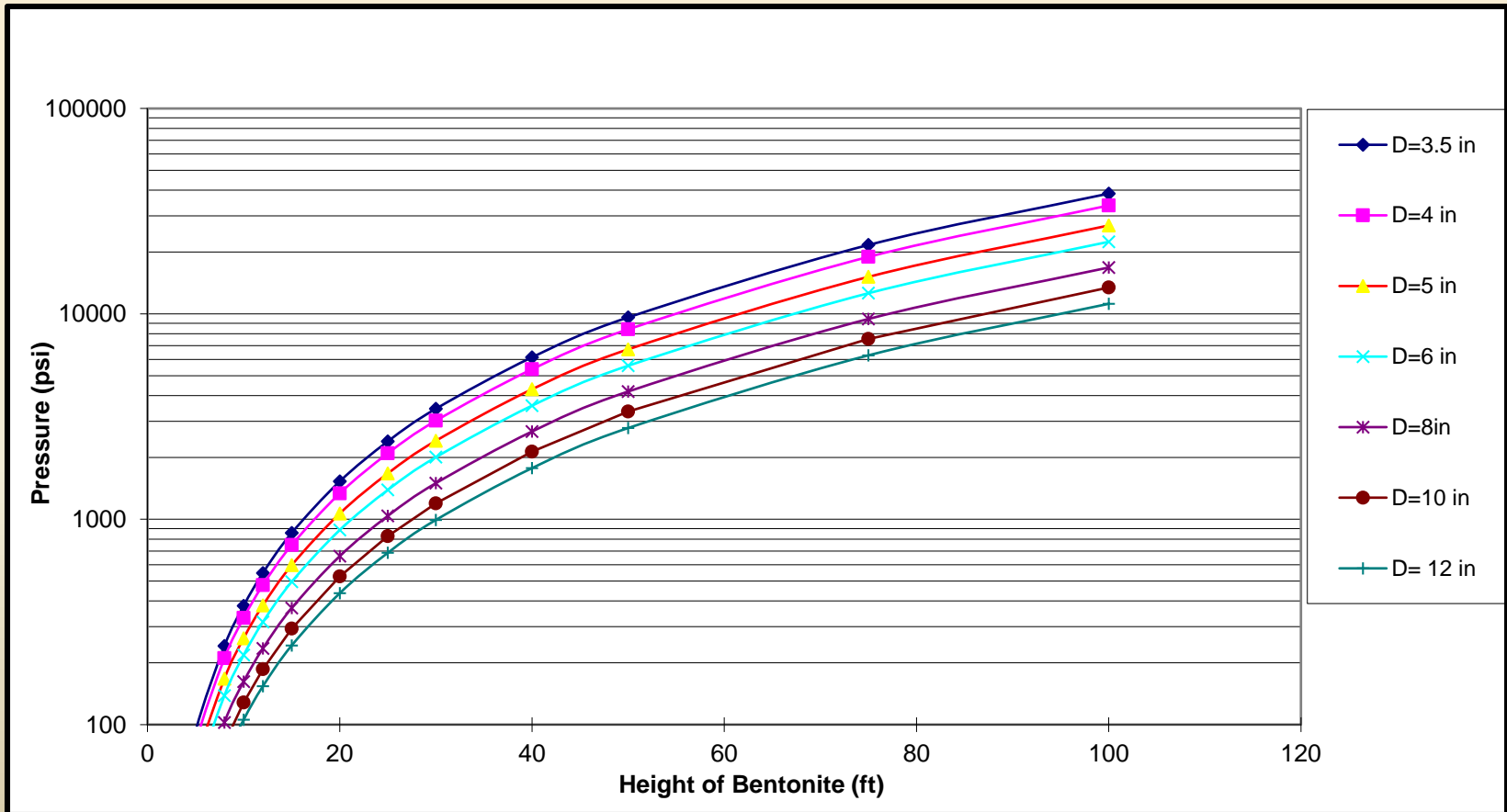
Pressure Difference Equation

Dr. Towler's equation calculates the pressure difference based on the friction factor between bentonite and steel casing

$$\Delta P = K_b \rho_w \left(\frac{4L_w H}{D} + \frac{2\gamma_b H^2}{D} \right) + \rho_w [L_w + \gamma_b H]$$

Pressure Difference Chart

- Equation used to build a plot of Pressure Difference Verses Height of Bentonite



Economics

- Bentonite plugging:
 - Cuts cost
 - Reduces overall time when compared to cement plugging
- Estimated to be $\frac{1}{2}$ the cost of cement plugging
 - Twice as many wells can be plugged

Economics

Gas Well - located in Barrow Island Field in Western Australia

Cement cost	Per well	
	Time (hrs)	Cost (\$)
MIRU, Well Control	12	2500
Bridge Plug	6	2500
Deep Cement Plug	6	7500
Shallow Cement Plug	6	7500
Waiting on Cement	6	2500
Surface Casing Cement	6	5000
Well Head Removal	6	2500
Contingency	6	2500
Supervision		2500
GRAND TOTAL	54	35000

Bentonite Cost	Per well	
	Time (hrs)	Cost (\$)
MIRU, Well Control	12	2500
Bridge Plug	6	2500
Bentonite Plugs	4	1000
Bentonite Retainer	1	1000
Bentonite Plugs	4	1000
Surface Casing Cement	6	2500
Well Head Removal	6	2500
Contingency	4	1000
Supervision		2500
GRAND TOTAL	43	16500

- Wyoming has 622 orphaned wells
 - Cement Plugging Cost: \$6.2 million
 - Bentonite Plugging Cost: \$3.1 million

State and Businesses

- Cheaper bonding prices
 - Companies can purchase more wells
 - Companies can afford to plug wells
- State saves money
 - Less tax payer money used
 - Less liability of newly orphaned wells
 - Companies can afford bonding prices

Proposed Rule Change

Chapter 3 Section 18:

- (iv) Powder River Basin Coalbed Methane Wells.
 - (B) Bentonite may be used in lieu of cement for Coalbed Methane wells with production casing. If bentonite is used, the Operator must provide adequate information on Form 4 to demonstrate that all of the necessary zones were adequately plugged.
 - (D) The bentonite plugs and/or mechanical bridge plugs shall be topped with a one hundred foot (100') cement or bentonite plug, and one hundred foot (100') cement or bentonite plugs will also be set every seven hundred fifty feet (750') along with a one hundred foot (100') cement or bentonite plug at the surface.
- Form 4 in Chapter 3, Section 17(a) still applies.

Health

- Bentonite has little health related problems
 - Basically mud
 - Will not contaminate a fresh water source
 - No short or long-term human health effects
- Fewer emissions from large equipment
 - Less equipment running time

Safety

Field Safety

- Less large equipment
- Fewer hours required to plug wells
 - Fewer injuries
- Safely isolate formation from water
- Easy clean up

SOP

- High pressure bentonite press
- MSDS- eye and skin irritant

Results

- Strategy to gain credibility before going to the WOGCC
 - Industry and political support
- Developed connections with Luca Technologies
 - After a great start complications came up
- Initiated new contacts
 - Ryan Lance of state lands
 - Anadarko and WPX

Conclusion

- Refined plug manufacturing process
- Complete redesign of plug press – completely modular design
- Complications with regulation change
- Bureaucracy encountered every step of the way