HALLIBURTON

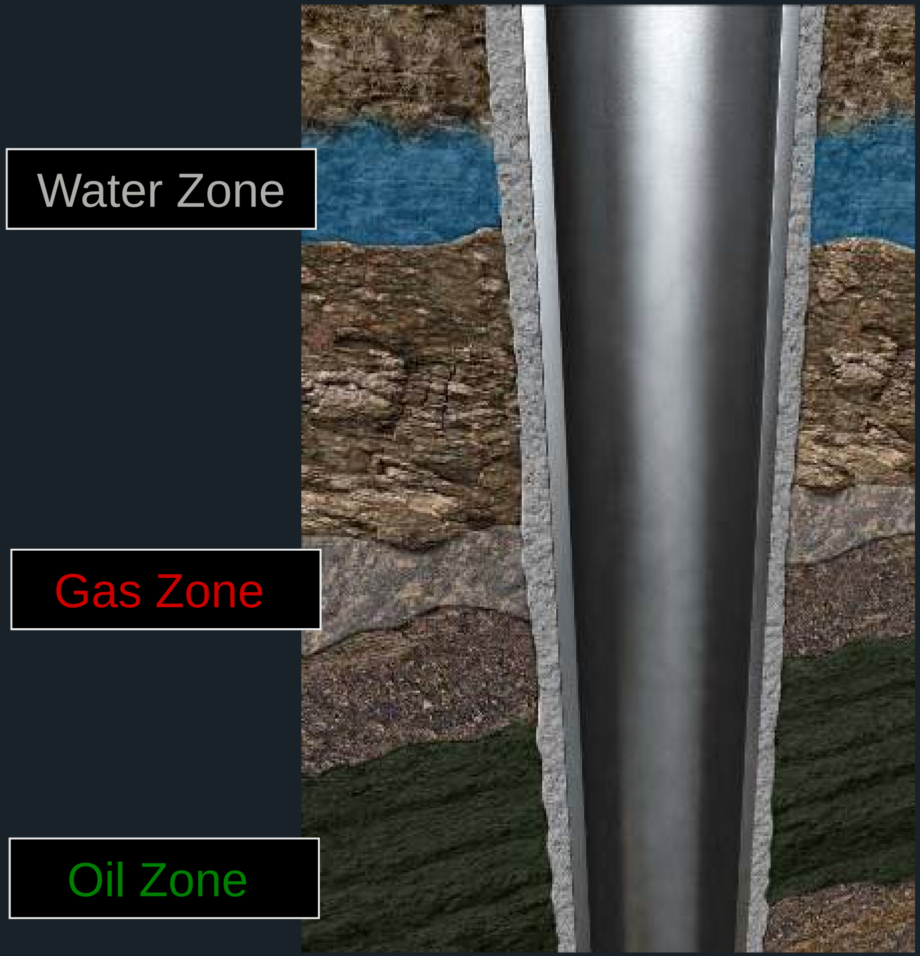
Well Cementing

Gary Funkhouser and Lewis Norman

Why do we cement wells

- Principle Functions of primary cementing
  - Restrict fluid movement between formations
  - Bond and support the casing

- Additional uses of cement
  - Protect the casing from corrosion
  - Prevent blowouts
  - Protect the casing from shock loads in drilling operations
  - Sealing off loss circulation or thief zones



Oil well cementing highlights

1883 – Hardison/Stewart - Pico, CA

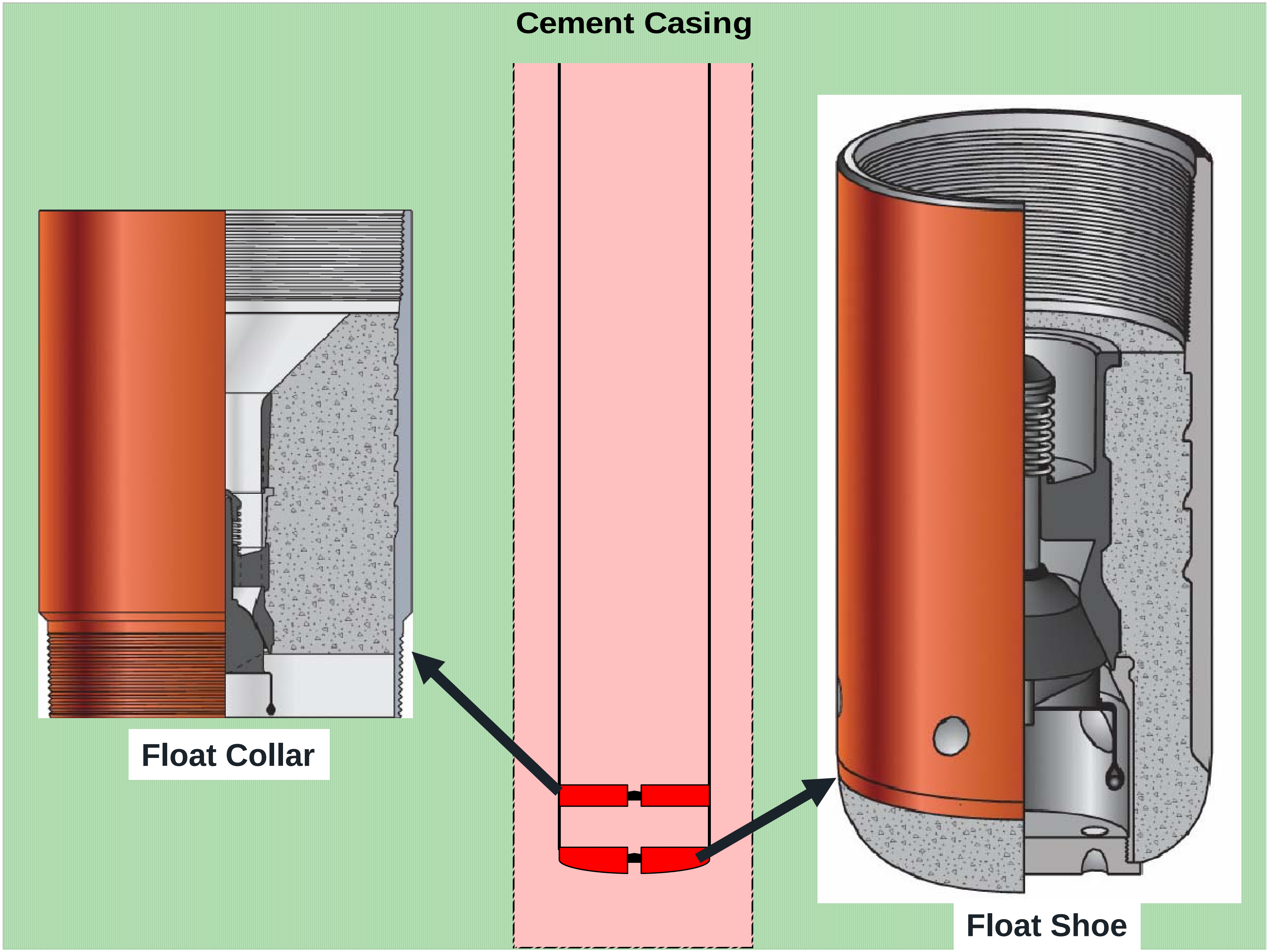
1903 – Steel casing cemented - Lompoc Field, CA

1910 – 2-plug cementing method – A.A. Perkins

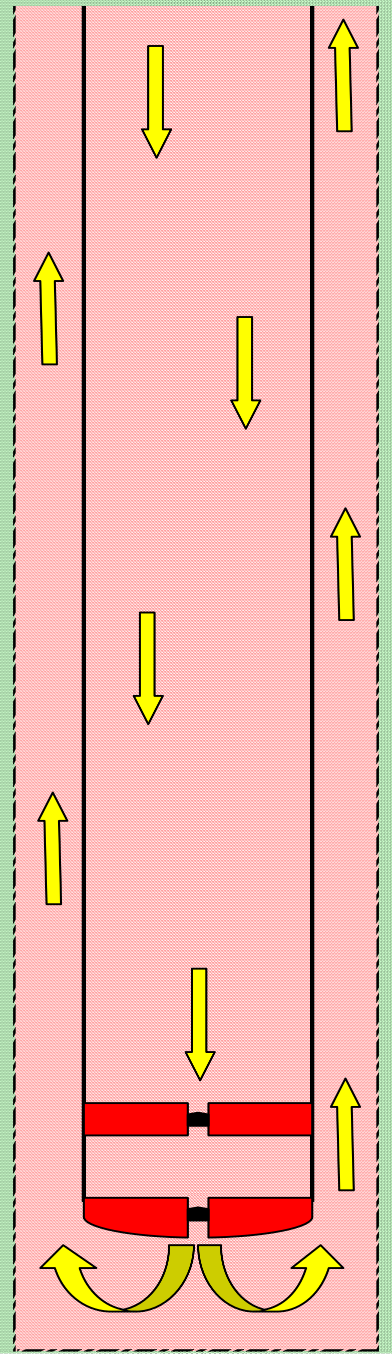
1919 – Erle P. Halliburton – Burkburnett, TX

1921 – Erle P. Halliburton patents Jet Mixer

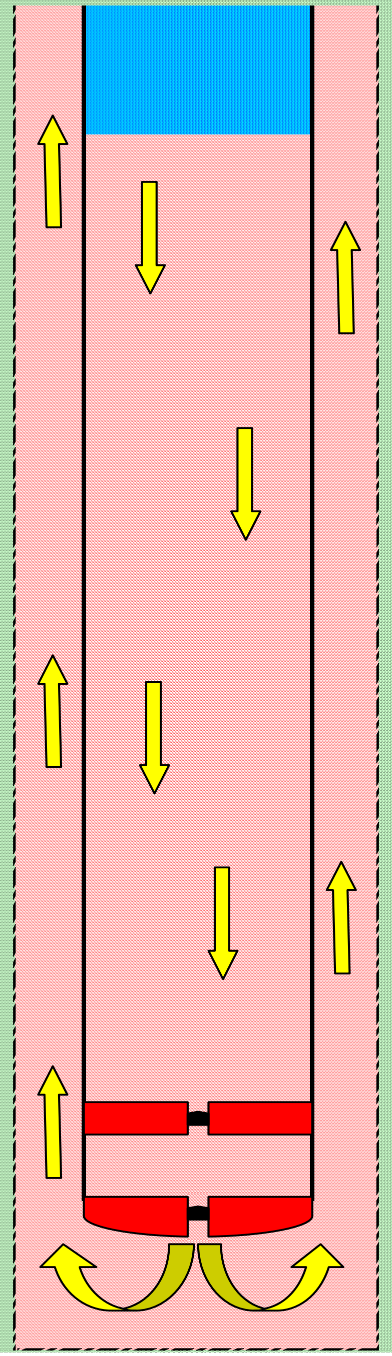
1940 – Halliburton introduces bulk cement


Cement Casing
Float Collar
Float Shoe

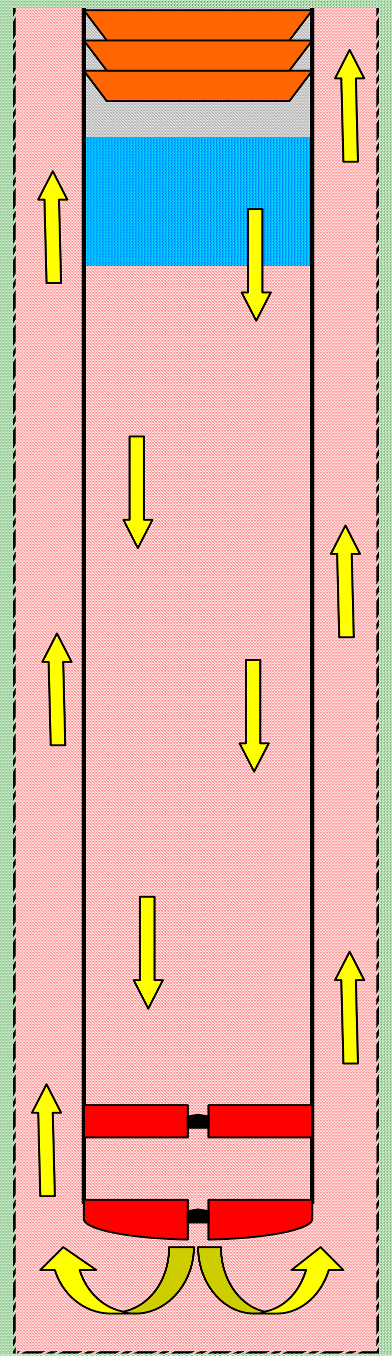
Circulating to condition mud



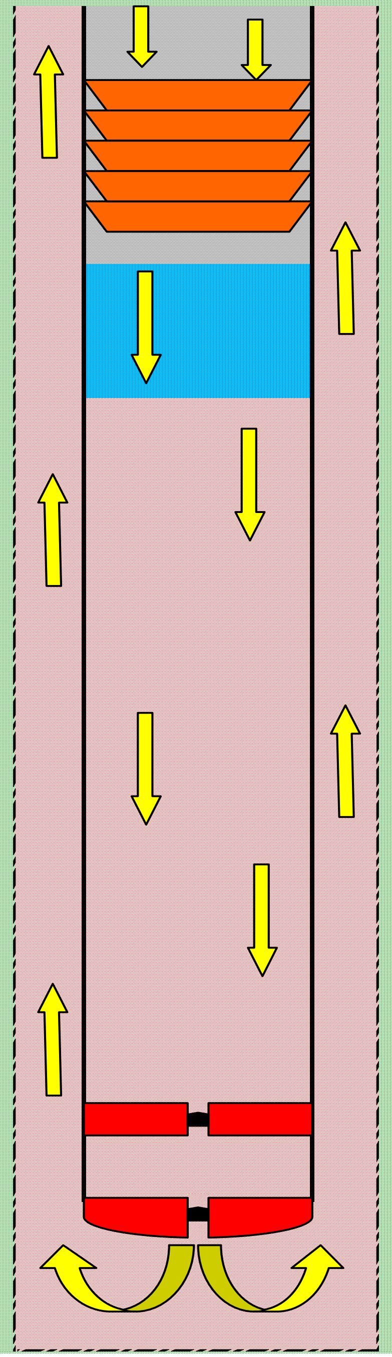
Pumping Spacer Ahead



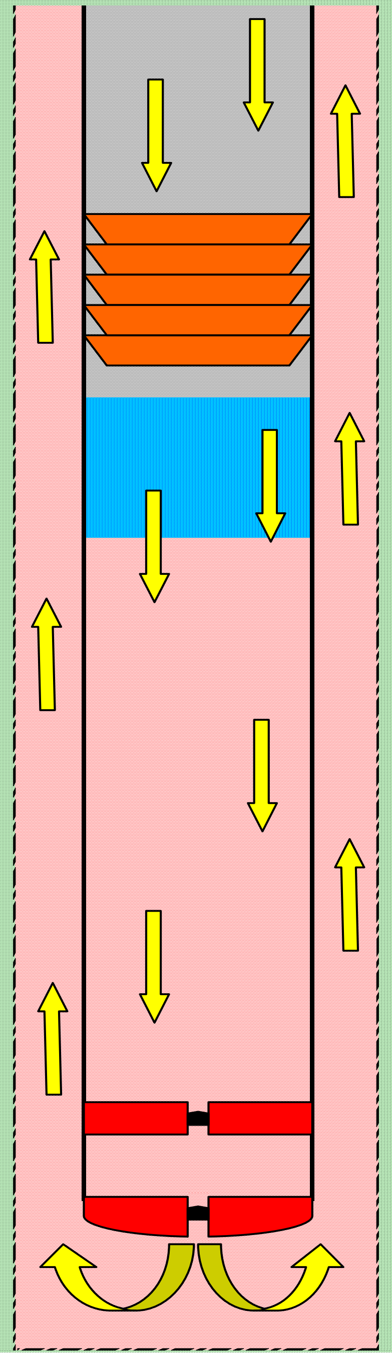
Pumping Lead Cement & drop bottom plug



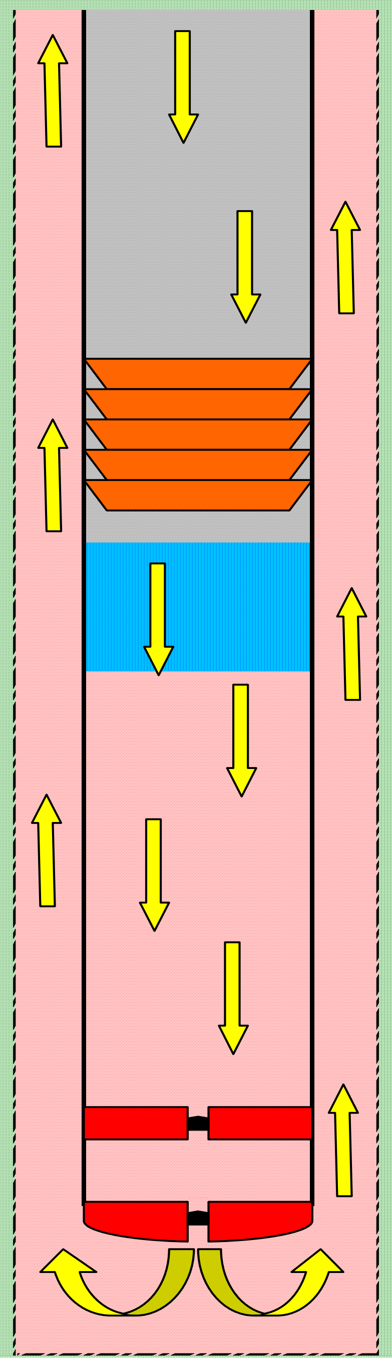
Pumping Lead Cement



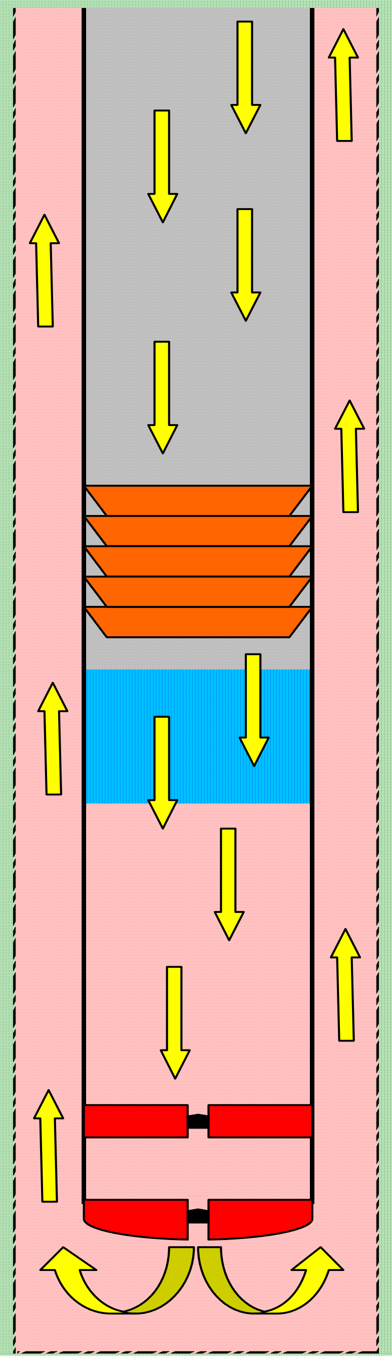
Pumping Lead Cement



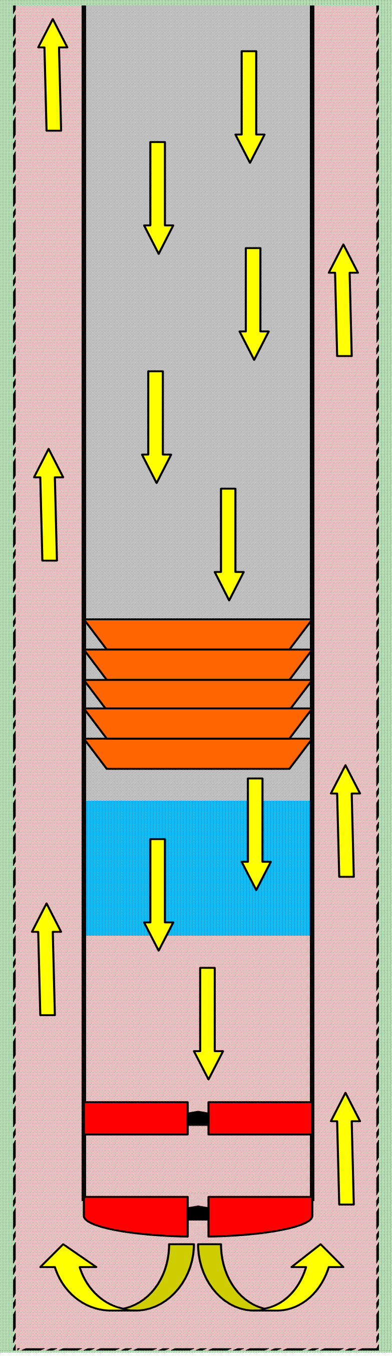
Pumping Lead Cement



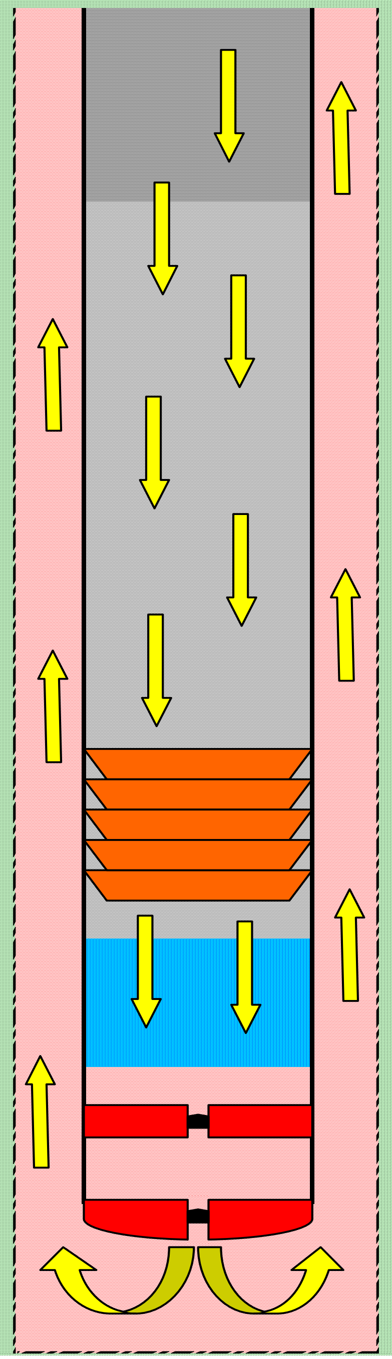
Pumping Lead Cement



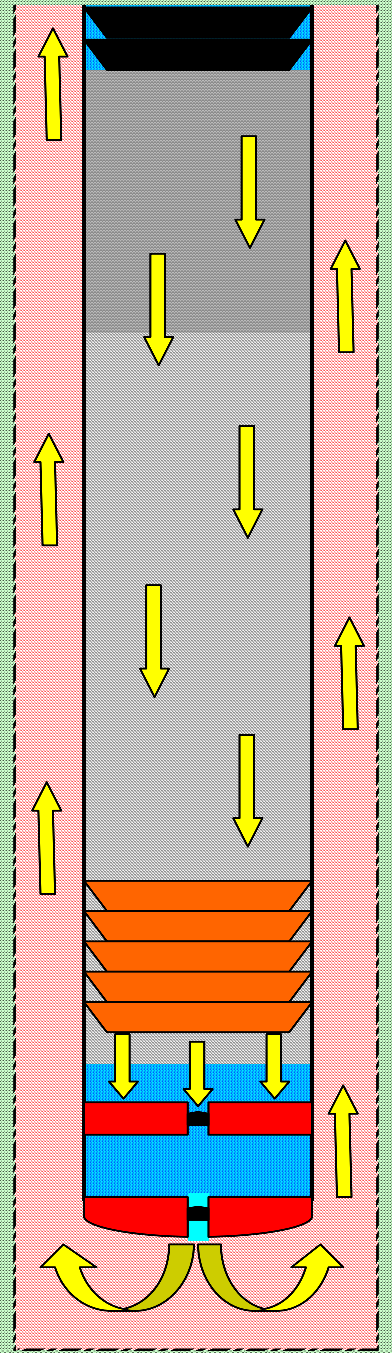
Pumping Lead Cement



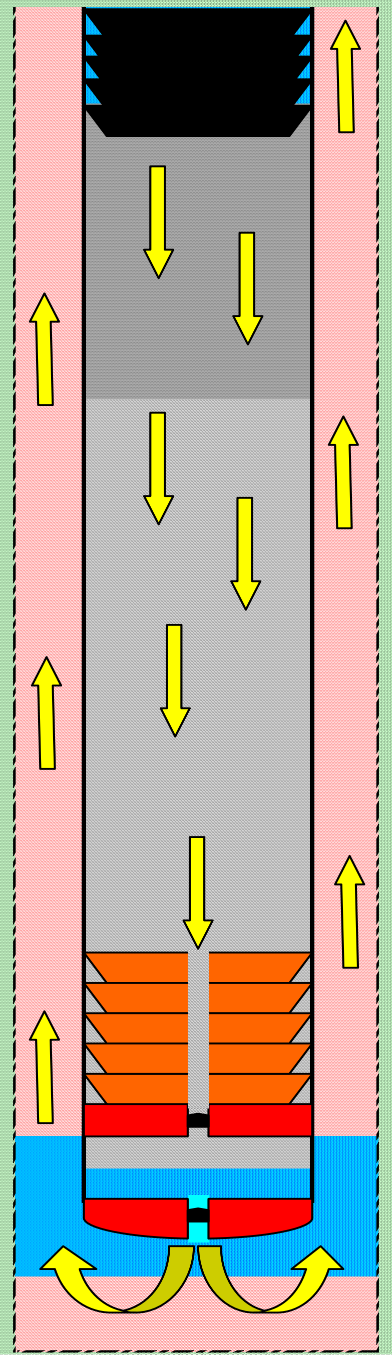
Pumping Tail Cement



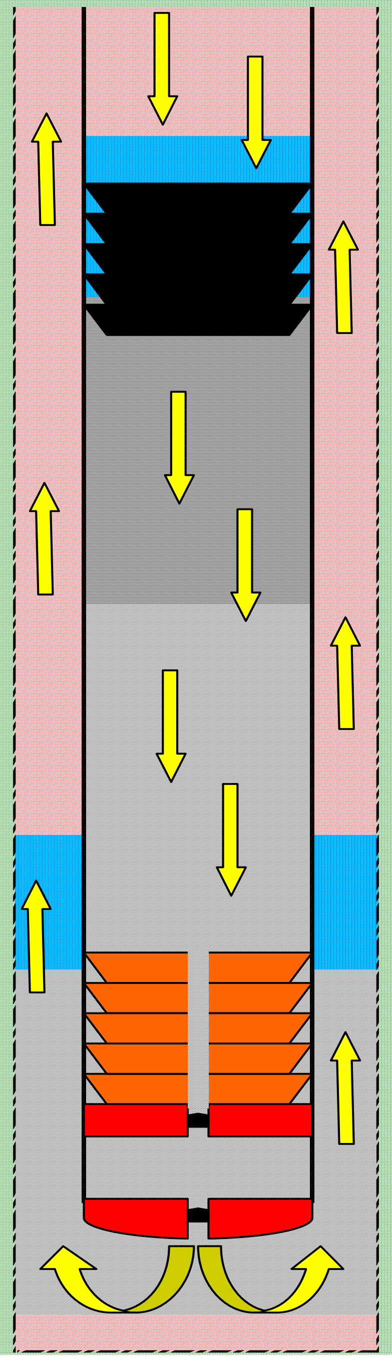
Drop Top Plug & Start Displacing with Spacer



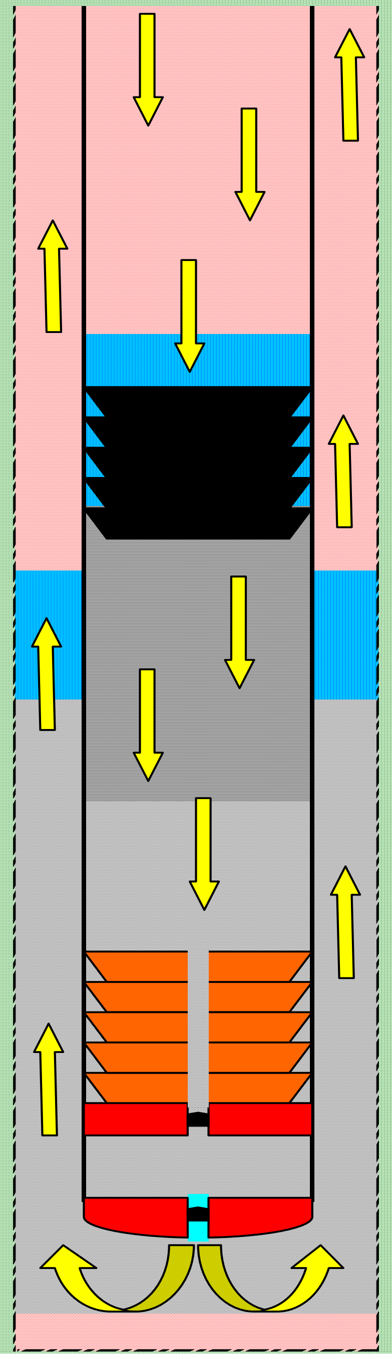
Displacing



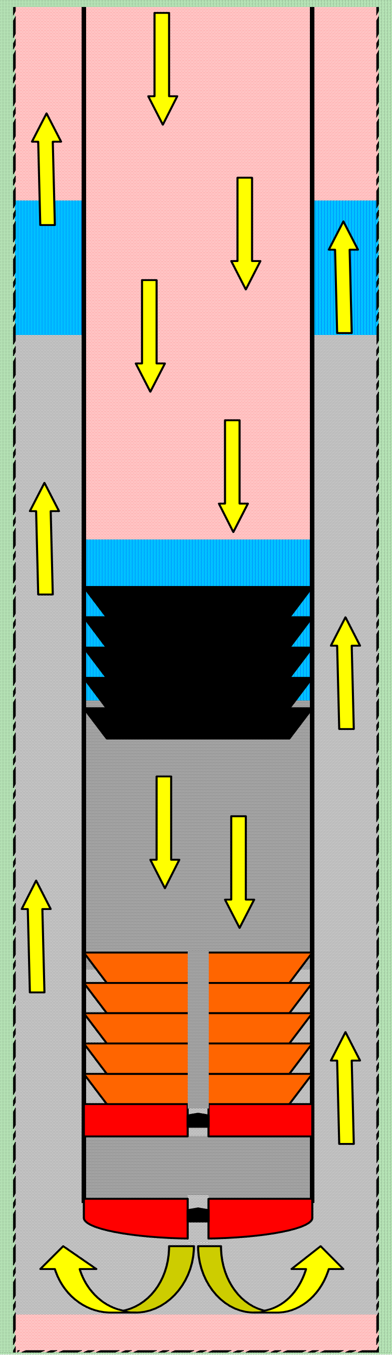
Displacing



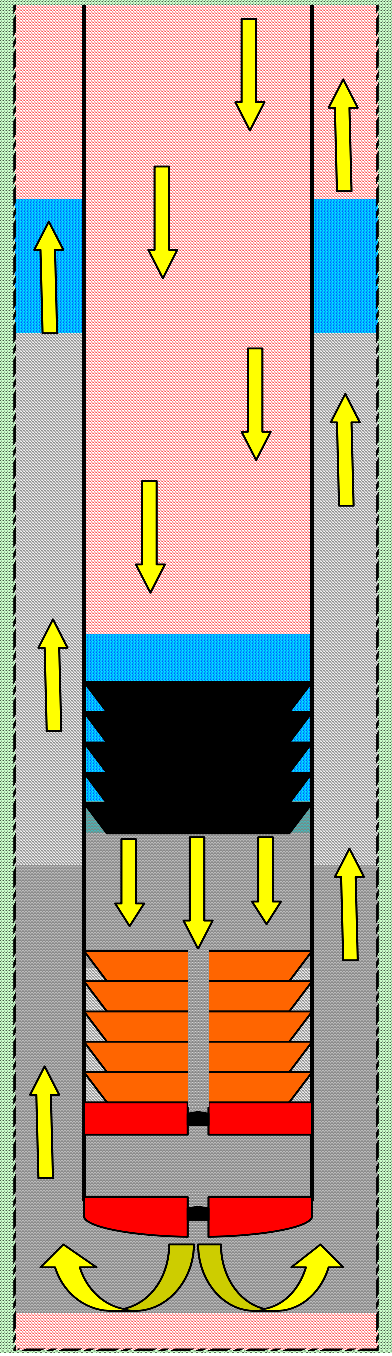
Displacing



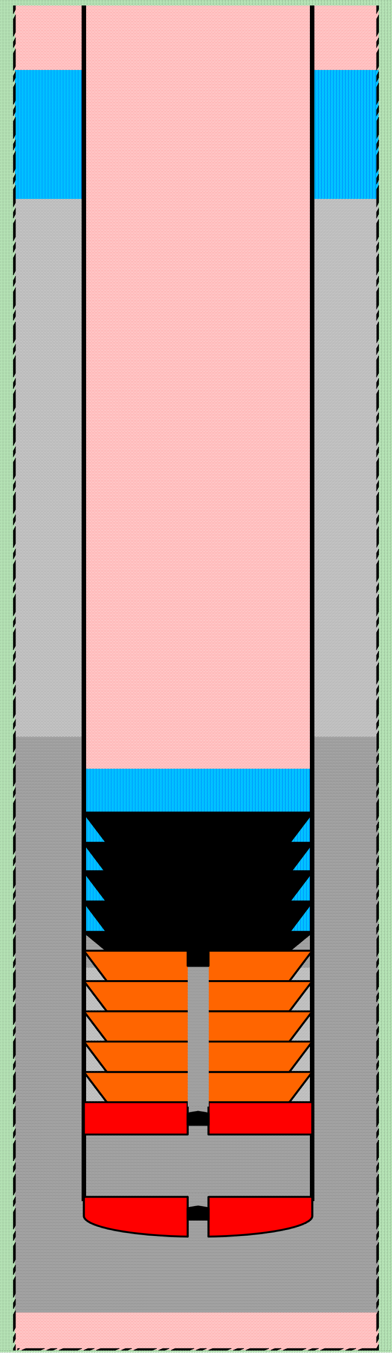
Displacing



Displacing



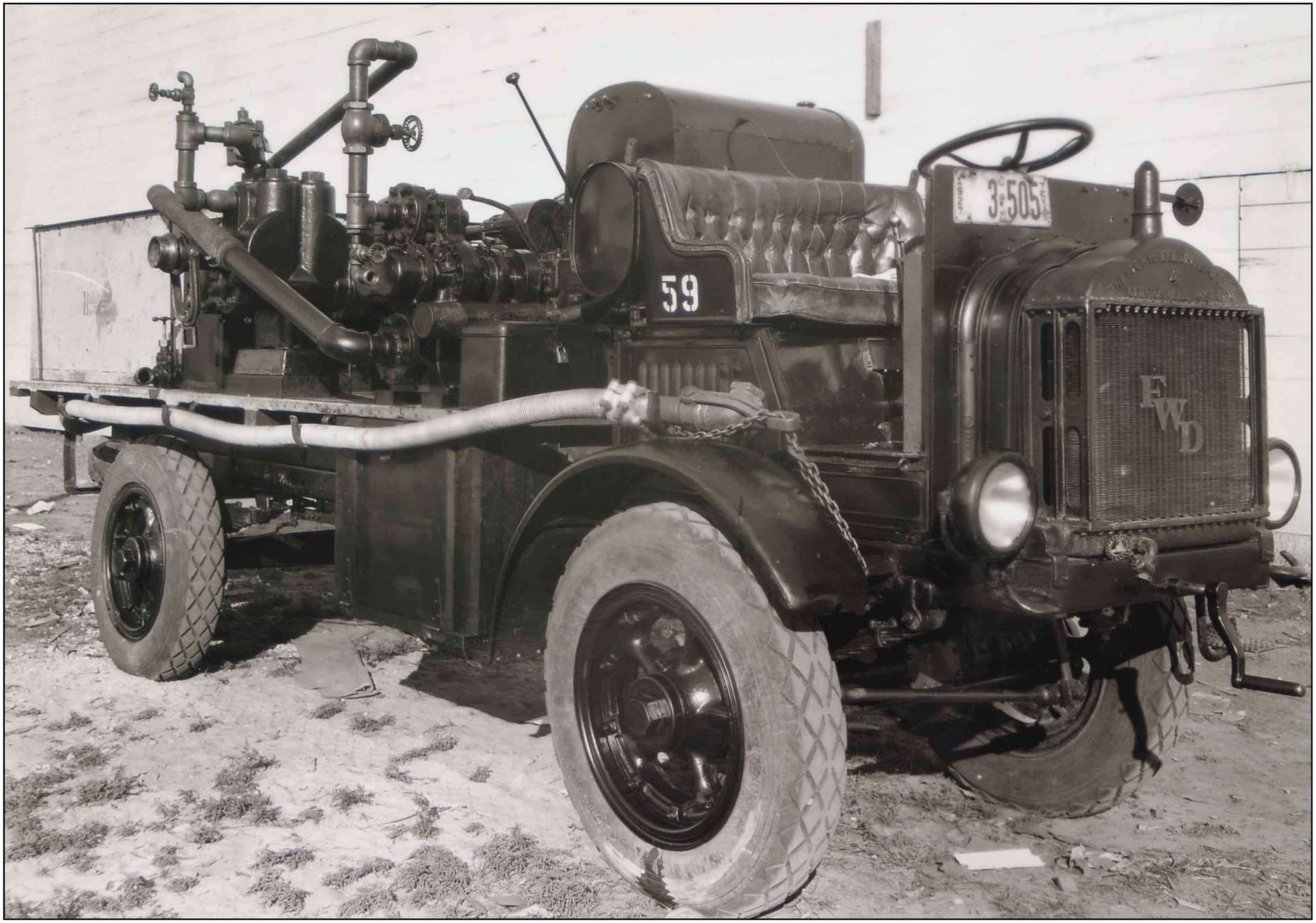
Plug Down



Job complete

Cementing Equipment Evolution - 1920

Cementing Equipment Evolution - 1930



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Cementing Equipment Evolution - 1940

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Cementing Equipment Evolution - 1950

Cementing Equipment Evolution - 1978

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Cementing Equipment Evolution - 2000

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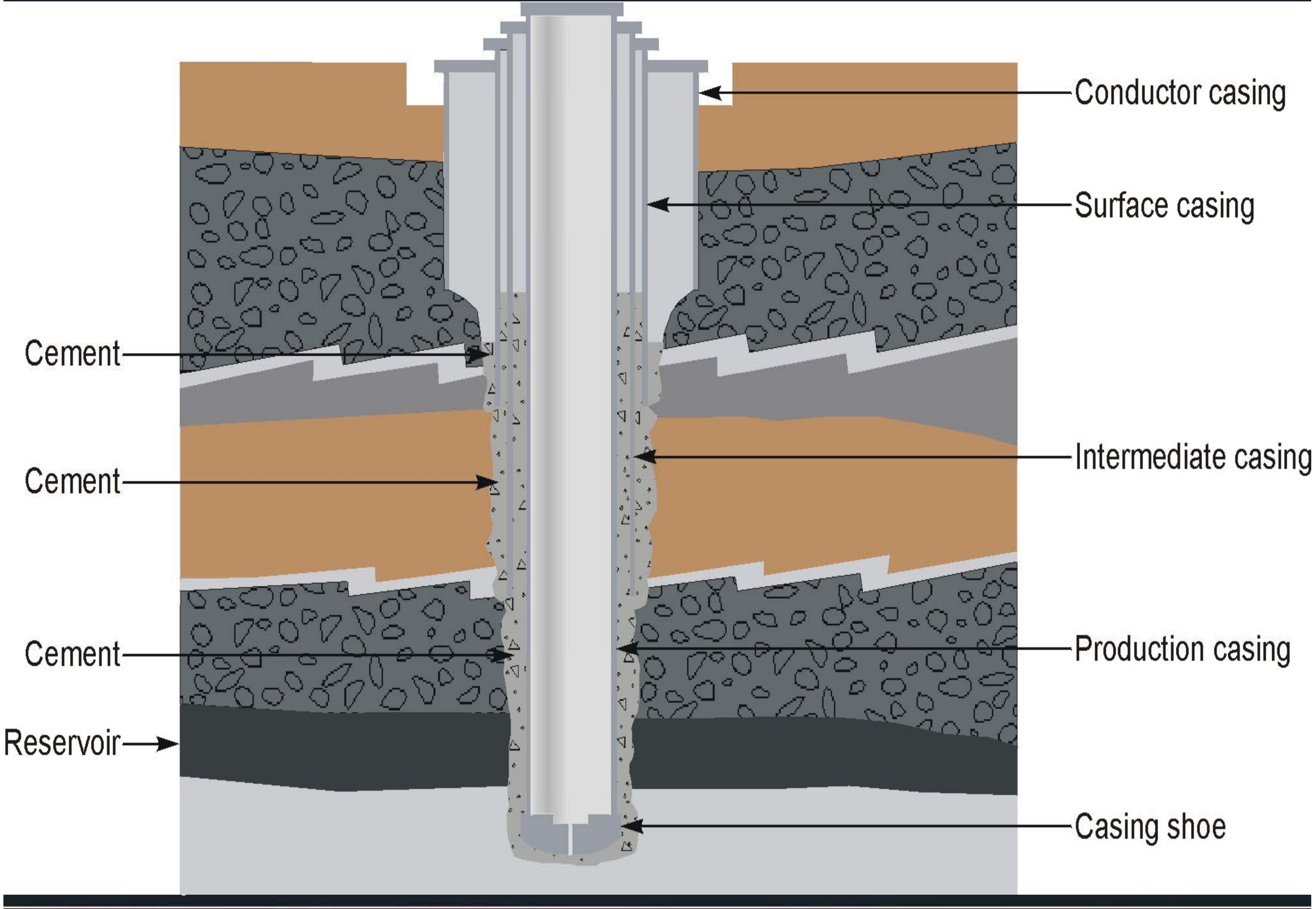
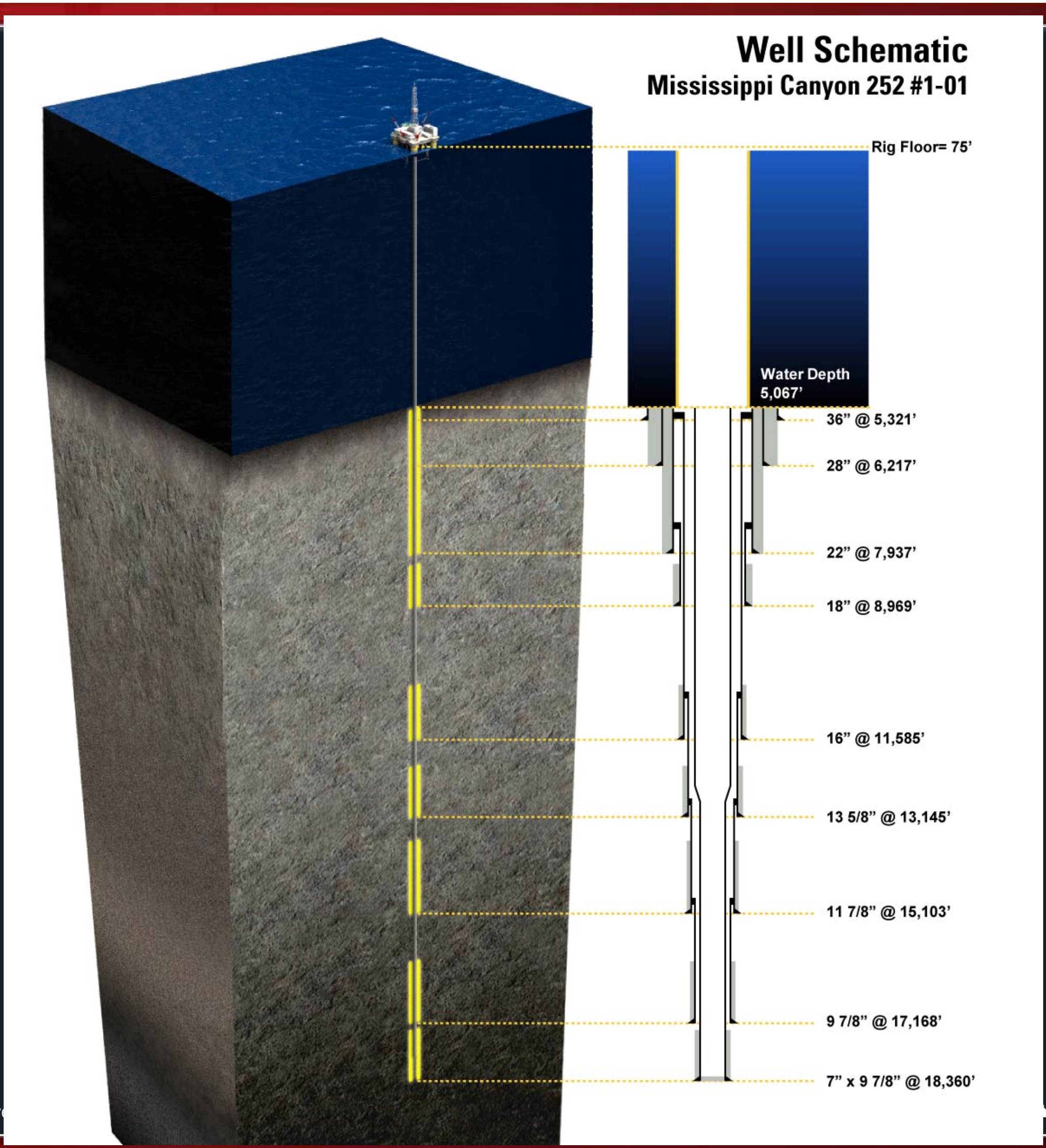
HALLIBURTON
FLECS
PASSENGER SIDE ENGINE
DRIVER SIDE ENGINE
AUXILIARY ENGINE
2 psi
2 psi
0.0 bbls
-0.34 ppg
8.22 ppg
458 gpm
EVENTS
Menu
ENTER
NEXT
PREV
BKSP
CTRL
ESC
F1
F2
F3
F4
F5
F6
F7
F8
STOP ENGINE
HT400
CHECK ENGINE
E-KILL
75% VERIFY OVERSPEED
IGNITION
POWER
IDLE
FULL
THROTTLE
TRANSMISSION TEMP
FLECS POWER
SYSTEM POWER
INSTRUMENT BATTERY
MASTER WATER
CEMENT VALVE
WATER VALVE
CONTROL PANEL WARNING LAMP TEST
BLOCK HEATERS
LIGHTS
HYDRAULIC CHARGE PRESSURE
START/AGITATOR SYSTEM
HYDRAULIC OIL TEMP
ADC SYSTEM PRESSURE
AIR PRESSURE
WARNING HYDRAULIC OIL TEMP
ENGAGE FULL
OFF
4X4 MIX PUMP SPEED
HYDRAULIC SYSTEM PRESSURE
HORN


Conductor casing
Surface casing
Cement
Cement
Intermediate casing
Cement
Production casing
Reservoir
Casing shoe



HALLIBURTON

Light Weight

Accelerators

Fluid Loss

Loss Circulation

Gas Migration

Cement Additives

Defoamers

Retarders

Specific Materials for
Optimum Cement Performance

Expansion

Heavy Weight

Dispersants

HALLIBURTON

Retarders

- Sodium and calcium lignosulfonates
- Oligosaccharides
- Tartaric acid
- AMPS copolymers
- Aminotri(methylphosphonic acid)

Fluid-Loss Control Additives

Prevent leak-off of water into rock

Maintain key characteristics cement slurries

(thickening time, rheology, and strength development)

Avoid build-up of cement filter cake

- Cellulose derivatives
- Synthetic polymers
- Latex

Weighting Agents

Maintain well control with increased hydrostatic pressure
(up to 21 lb/gal, occasionally higher)

- Hematite (Fe_2O_3)
  - Up to 100 lb/sk
- Hausmannite (Mn_3O_4)
  - Up to 100 lb/sk
- Ilmenite (iron-titanium oxide)
- Barite ($BaSO_4$)
  - Up to 135 lb/sk
- Sand
  - Often used in conjunction with other weighting agents

Supplementary Cementing Materials in the Oilfield

- Fly ash (50:50 fly ash:cement typical)
- Silica fume (15% bwoc typical, 28% max)
  - Low density slurry (>11 lb/gal) with little free water
- Silica flour (35-40% bwoc typical, 70%+ max)
  - Prevent strength retrogression >230 °F
- Pumice (up to 150% bwoc)
- Cement kiln dust
- Blast furnace slag
- Zeolite
- Metakaolin

Lab Testing

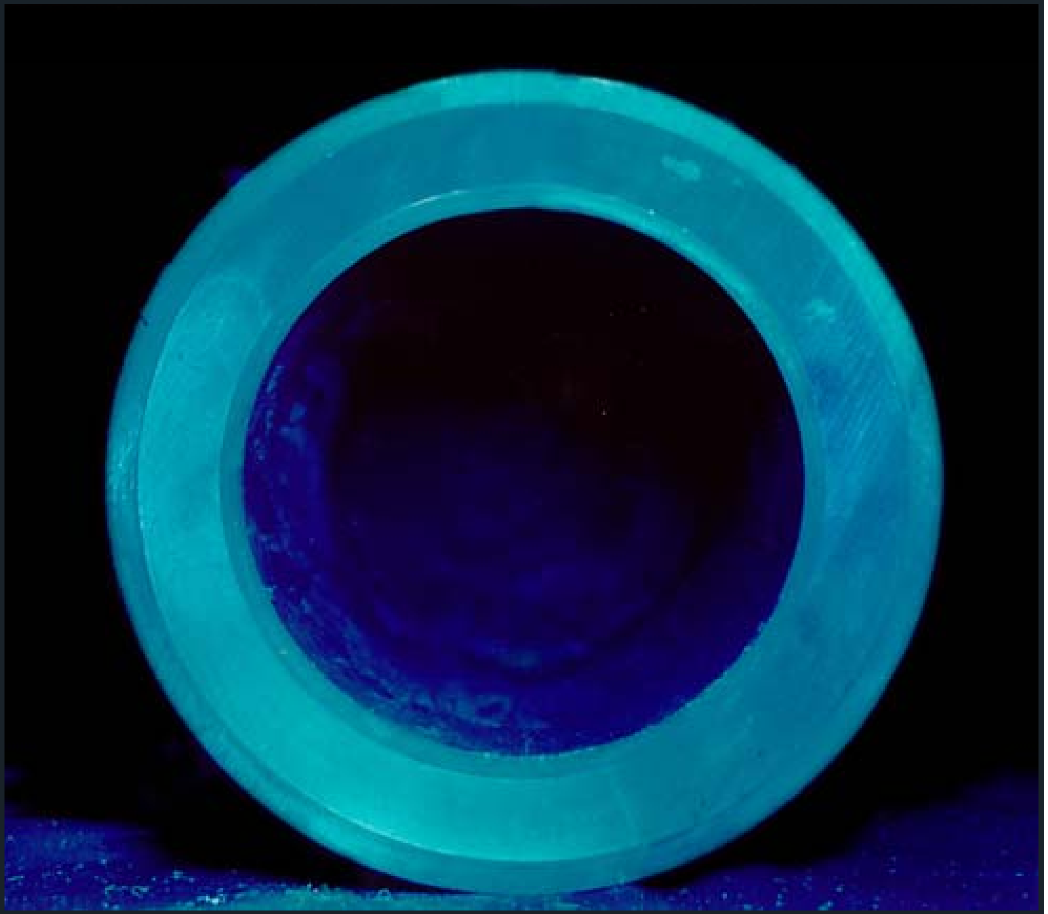
- Compressive Strength, Fluid Loss, Thickening Time, Gel Strength
  - Up to 600 °F and 40,000 psi

Conventional Cement

- Cement is brittle
- Radial cracks formed
- Longitudinal communication occurred
- Cement bond failed creating a microannulus

Foam Cement

- No radial cracks
- Only slight debonding
- Foamed cement deformed and absorbed the expansive energy without failure due to its elastic nature



Historical facts regarding EOR well cementing

- More than 35 years of EOR experiences
- More than 15,000 CO_2 EOR well in USA (9000 producing + 6000 injectors)
- Portland based formulations have been used in all the above wells
- Various 3rd party studies of CO_2-EOR operation in the USA have not detected any evidence of CO_2 leak in the drinking water

Source article: Summary of CO_2 EOR injection well Technology - API report 2008

HALF "GREEN" CEMENTING UNIT

HALLIBURTON

Equipment

1919
First jobs

1921
Jet Mixer

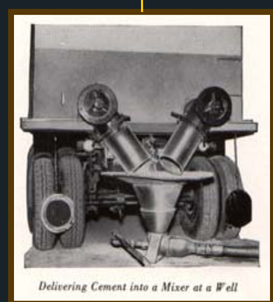
1932
Float/Guide Equipment

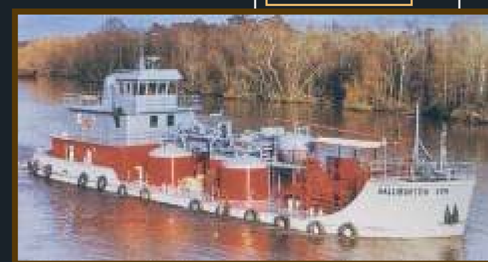
1947
Marine Department

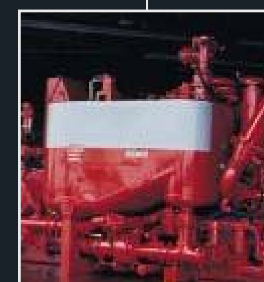
1957
HT-400™ Pump

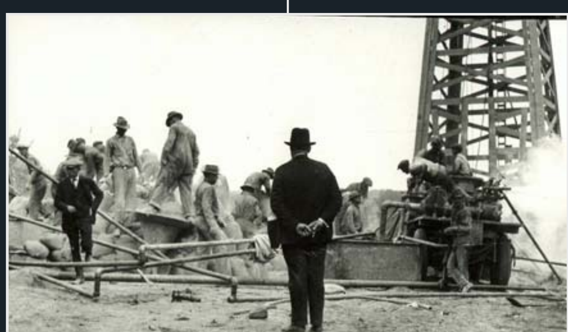
1971
Recirculating Mixer

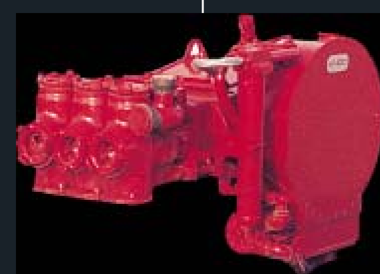
1991
Automatic Density Control







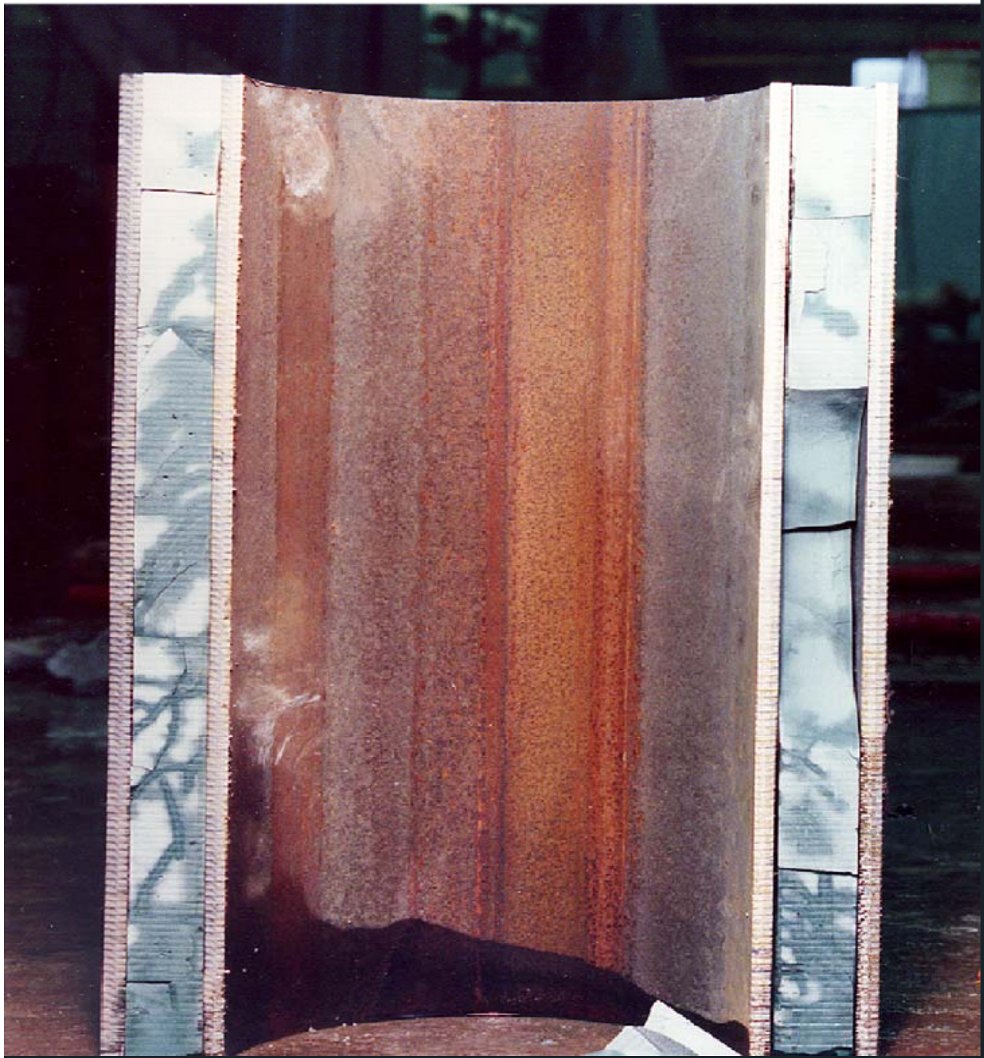




NABORS
797
HALLIBURTON
ELITE
HALLIBURTON

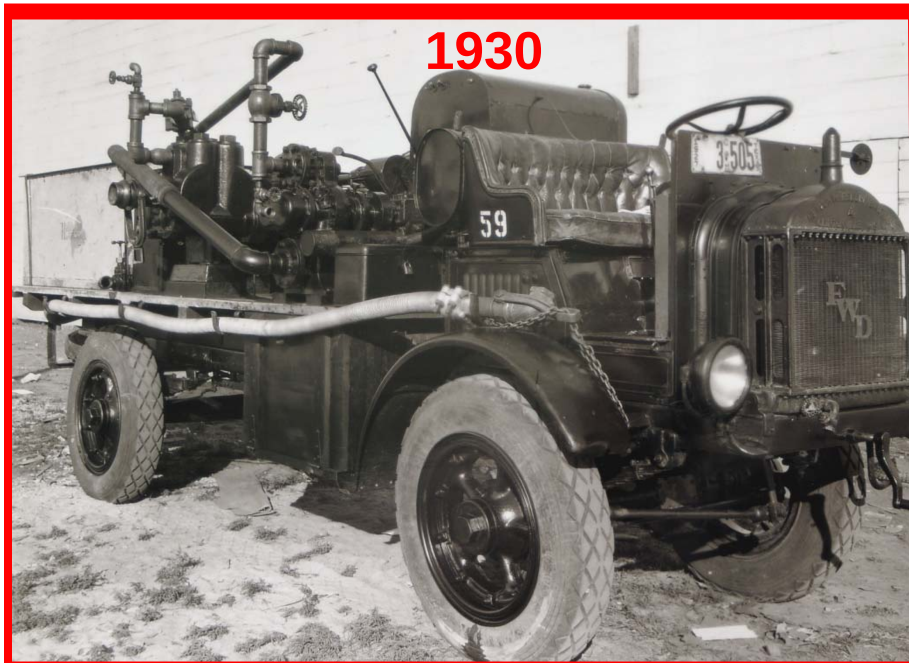
Large Scale Stress Testing

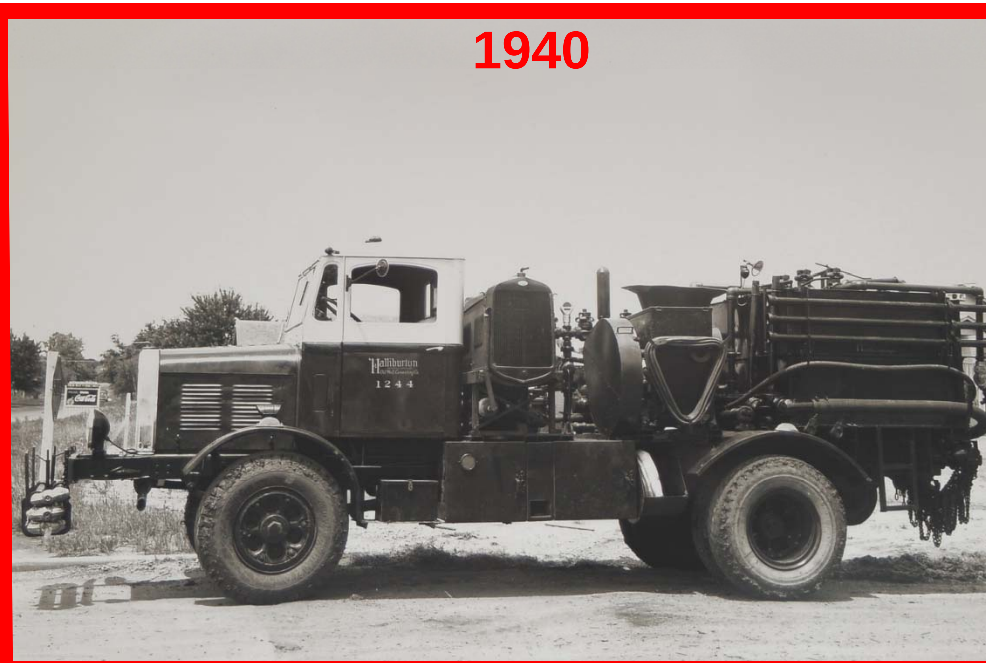
Conventional Cement

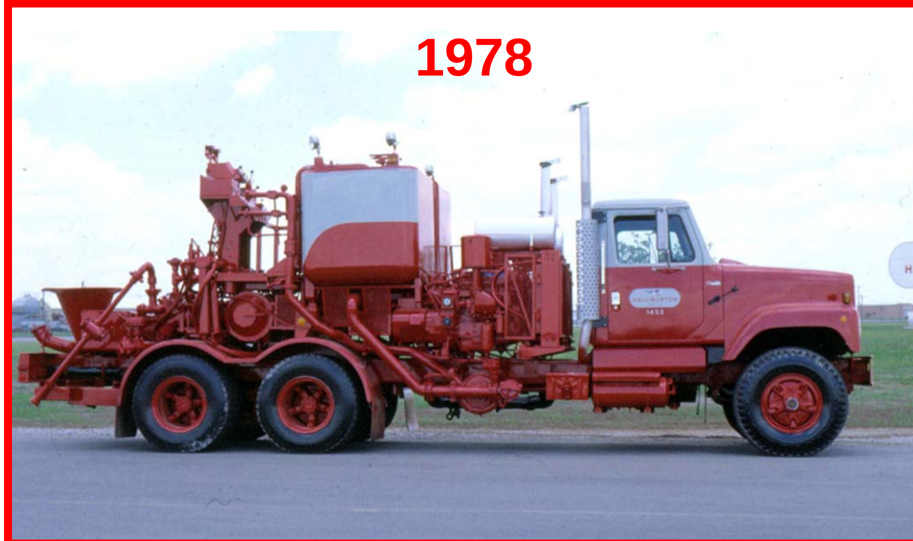


- 5 1/2” pipe cemented inside 7 5/8” casing
- Inner pipe pressured in stages until cement failure was indicated at 4500 psi

Cementing Equipment Evolution







HALLIBURTON


HALLIBURTON
ELITE