NWRA WELL CONSTRUCTION WORKSHOP

Nevada Water Resources Association

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Safety Share

Halliburton Red Rules

Product Handling

- Safety Is The #1 Priority
- SDS provide valuable information regarding Product Safety, Potential Hazards, and Emergency Contact - have them available and consult them:
  - Safe Usage, Storage and Transportation
  - Personal Protective Equipment (PPE)
    - It is not enough to have PPE onsite, you must use PPE in order for it to be effective
    - Respiratory Safety –Your lungs are important
    - If there is any doubt, play it safe!!!

Basic Protection

- When mixing dry drilling additives and grouts in confined areas always wear breathing protection
- N95 respirators are designed to filter at least 95% of airborne particles 0.3 microns and larger

N95 Respirator

Basic Protection

- Protect your sight
- Eye protection is always appropriate

The Red Rules

- Know what is expected of you.
- Understand the job, the procedures, and the objectives.
- Make sure you have the correct equipment/tools and that you are confident they will work as expected.
- Confirm the job, procedures and objectives with the customer.
- Understand the customer's expectations.
- Know when and who to call for help, and have their phone number ready and available.
- *When in doubt ask.*

Drilling Fluids and Seals

What Is Our Goal

- Optimal Drilling Performance
- Maximize Sample Recovery
- Protect the Aquifers
- Optimize the well for long-term water production at highest acceptable volume
- Maximize Aquifer Potential

SUCCESS

Success begins before the first turn of the bit !!!

What is required for success?

- Pre-planning, Pre-planning, Pre-planning
- Obtain offset well information
  - Geologic information
  - Flow & pressure data
- Materials & Equipment
  - Pumps
  - Mixing equipment (adequate – mixers & pit volume)
  - Casing & Casing Accessories (cement basket, centralizers)
  - Drilling Fluid Additives & Barite?
  - It is better to be looking at it rather than looking for it

Pre-Planning

- Factors to Consider
  - Geology
  - Vadose Zone
  - Subsurface Environment
    - Formation Water Chemistry
    - Contaminants
  - Drilling Method
    - Mud Rotary, Air Rotary, Reverse Circulation, etc.
  - Well Construction
  - Local Codes and Regulations

Points to Ponder

- Know Where Producing Formations Occur
- Utilize Adequate Concentrations During Early Stages
- Combine Different Sizes & Shapes To Achieve “Matting Effect”
- Solids Control
- Monitor Drilling Fluid Properties

Use the correct tool for the job

Myths and Misconceptions

- I always drill with water, *until I have problems*
- Drilling fluid additives, especially polymers, *are too expensive to use*
- All bentonites, polymers, and other drilling fluid additives *their all the same*
- Bentonite *causes formation problems and damage*

What is a Drilling Fluid?

Fluid: defined as any substance that that tends to take the shape of its container, and has low resistance to flow.

Can be: Gas, Liquid

DRILLING FLUIDS

- There is no way you will ever drill with clear water.
- Water and cuttings = *mud*
- Water and additives = *drilling fluid*
- DRILLING FLUID makes your life easier
- **I GUARRANTEE IT !!!!!!**

Scale of the Situation

Do you want to drill your
with MUD, or with a

Drilling Fluid?

DRILLING FLUIDS

DESIGNED TO KEEP US OUT OF TROUBLE IN THE FIRST PLACE

DRILLING FLUIDS

PROBLEM SOLVING MEANS A YOU ARE IN TROUBLE

A PROBLEM EXIT AND IT CAN AND PROBABLY WILL BE EXPEN$IVE TO CURE

DRILLING FLUIDS

PROBLEM AVOIDANCE IS MUCH MORE

CO$T EFFECTIVE

Functions of a Drilling Fluid

- Protect the Borehole and Maintain Borehole Stability
- Control and Reduce Filtrate Invasion
- Remove and Transport Cuttings Away From the Bit
- Release Cuttings so they Settle at the Surface
- Suspend Cuttings When not Circulating
- Control Subsurface Pressures
- Insure Maximum Geologic Information/Sample Recovery
- Cool and Lubricate the Bit and Drill String
- Transmit Hydraulic Horsepower to the Bit
- Reduce Development Time
- Optimize Well Productivity

DRILLING FLUIDS

WATER BY ITSELF IS NOT AS USER-FRIENDLY AS WE NEED IT TO BE

DRILLING FLUIDS

ADDITIVES ARE NEEDED TO MAKE THE WATER

MORE

USER-FRIENDLY

Primary Drilling Fluid Additives

- Soda Ash
  - Calcium Removal
  - pH Control
- Extended Yield Sodium Bentonite
  - Mixes & Fully Hydrates in a Short Time
  - Filtercake Development
  - Produces a Low-Solids System

Bentonite ?

- Naturally occurring, swelling, sodium *montmorillonite* clay - named after a deposit in Montmorillon, France.
- ***Bentonite*** is named after a deposit found near Fort Benton, Wyoming.
- The term *bentonite* was originally defined as a clay produced by in situ alteration of volcanic ash to *montmorillonite*.
- *Bentonite* is now used for any clay whose physical properties are dominated by the presence of a *smectite*.

Bentonite - Uses

Abrasive wheels Anticorrosive Arc-welding Artificial stone Asphalt roads Auto polish Batteries Beauty clays Bleaching agents Blood albumin Briquets Bricklayers cement Building blocks Calcimines Cardboard Casein Cement tile Chicle Clarifying agent (wine, oil, vinegar) Clay brick Cleansing agents Concrete Cork Crayons Crude oil Dams Degreasing (hides, wool) De-inking agent Dentifrices Detergents Dikes Drilling Fluids Dry cells Dust preventive Dye fixatives Dynamite Electrical insulation Electrolyte solutions Enamels Face cream Facial clay packs Fertilizers Filtration Firebrick Fire clay Fire extinguishers Floor emulsions Foundry sand Fruit juices Fungicides Gelatinizing agent Germacides Glauconite Glazes Glue Golf green binder Graphite crucibles Grouts Gypsum Hair treatment Highways Horticultural sprays Indelible lead Insecticides Insulation blocks Insulation board Insulators Internal x-rays Irrigation ditches Kerosene Laquers Latex Laxatives Lead pencils Leather treatments Linoleum cement Lubricating Magnesia Magnesium Masonary cement Matches Mechanic's soap

Bentonite - Uses

Medicinal emulsions Metal polish Mining Mortar Nitro-starch explosives Oil paints Ointment Old-water paints Paints Paper Paperboard Paste Pastel colors Phonograph records Pipes Plaster Plaster board Plastic Poles printer's ink Porcelain Posts Pottery Putty Refining (fats, grease) Reservoir walls Roofing Roofing paper Rosin Rosin Preventative Rubber Rubber tire puncture preventative Rubbing stones Scouring soap Sealing Seed disinfectant Sewage treatment Sewer pipe Sheep & cattle dips Shoe polish Sizing (cotton, yarn) Sizing agent (cord) Slag cement Spark plugs Special soaps sticking agent (sprays) Stock feed Stove polish Stucco Tar varnishes Textile printing Thread cutting compound Valve grinding components Viscosifiers Wall board Wall sealing agent Water coagulant Water colors Waterproof concrete Waterproof paper Well drilling Wood dips Zeolite water softeners

Colony, Wyoming

Primary Drilling Fluid Additives

- Filtration Control Polymers-PAC's
  - Reduce Filtration Rate & Invasion
  - Improve Composition & Characteristics of Filtercake (Borehole Stability)
- Shale and Clay Stabilizers-PHPA's
  - Encapsulate Reactive Shales and Clays
  - Coat Exposed Formations

Primary Drilling Methods

- Conventional Mud Rotary
- Conventional Air Rotary
- Flooded Reverse Mud Rotary
  - Traditional Flooded Reverse
  - Dual-Tube Flooded Reverse
- Cable Tool

Conventional Mud Rotary Drilling Fluid Requirements

- Low Solids
- Adequate Viscosity to Assist Hole Cleaning
- Filtration Control
- Effective Clay & Shale Stabilization

Drilling Fluid Requirements Flooded Reverse Mud Rotary

- Low Solids
- Minimal Viscosity
  - Viscosity not required to assist in hole cleaning
  - Resultant viscosity will be whatever results in achieving the necessary drilling fluid properties
- Filtration Control
- Effective Clay & Shale Stabilization

Environmental Concerns

ANSI/NSF 60 Certification

The NSF Drinking Water Additives Program is responsible for the Certification of drinking water chemicals to ensure that these products do not contribute contaminants to drinking water that could cause adverse health effects.

Baroid has the most complete line of products certified in the industry.

NSF Globally

- NSF crosses all political boundaries and country regulations - it is an independent not for profit organization founded in 1988
- Assures the operator that compliance with environmental concerns are being met as closely as possible and that the groundwater is being protected

Drilling Fluid Components

- Water (91-99.9% by weight)
- Bentonite (3-6% by weight)
- Polymers
  - Clay Inhibitors (0-0.5% by weight)
  - Filtration Control Additives (0-0.5% by weight)
- Surfactants
  - Wetting Agents (0-2% by weight)
  - Foams (0-2% by weight)

Well Maintained Low-Solids Drilling Fluid

- **Faster Penetration Rates (Make More Hole Faster)**
- **Requires Fewer Horsepower to Pump (Fuel-Savings)**
- **Reduces Pump Repair (Less Down Time)**
- **Better Sample Recovery**
- **Less Damage to Producing Formations**
- **Reduced Development Time**
- **Less Time on the Job**

Critical Drilling Fluid Properties

- pH- 8.5 to 9.5 - Adjust with Soda Ash
- Hardness < 150 mg/l - Adjust with Soda Ash
- **Mud Weight < 9.0 ppg**
- Filtrate- 15 to 25 cc/30 min (API Test)
- Filter Cake </= 2/32nds
- Viscosity – as Low as Possible - Necessary to Clean the Hole. Test with Marsh Funnel
- Sand Content < 1 % by Volume

Monitoring Of Drilling Fluid Properties

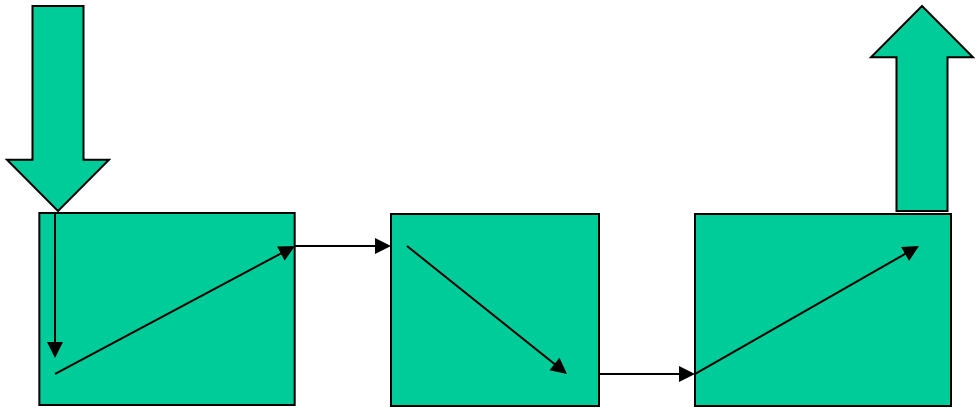
- Why Check Drilling Fluid Properties
- Achieve and Maintain Desireable Drilling Fluid Properties
- Monitor the Transfer from Desirable to Non-Desirable Solids
- What Properties Should We Check

Correct Pit Design

- Pit Volume - Twice the Final Hole Volume
- Pit Design Must Slow Fluid Velocity
- Facilitate Settling of Solids
- Diversions Must Sectionalize Pits and Redirect Flow to Break Gels
- Utilization of Baffles
- Adjust Depth of Suction

Correct Pit Design

Flow Line ***Suction***



Maintenance of Drilling Fluid Systems

- Drilling Fluid Design
- Product Selection
- Product Concentration & Addition
- Monitor Drilling Fluid Properties
- Monitor Penetration Rate
- Solids Control, Solids Control, Solids Control

Mechanical Solids Control

- **Preferred Method**
- **More Efficient**
- **Reduces Environmental Concerns (Site Mgmt.)**
- **Reduces Fluid Disposal Problems**
- **Reduces Drill Site Clean-Up Costs**

Common Problems

- Borehole Instability
- Water Activated Clays or Shales
  - Formation Swells and/or Becomes Sticky
  - Sloughing Shale
  - Formation Incorporates Into Drilling Fluid
- Borehole Erosion (Hole Enlargement)
- Poor Sample Evaluation
- Casing/Screen -Won't Go to Bottom
- Poor Production
  - Reduced Specific Capacity
- Extended Development Time
  - Excessive Filter Pack Thickness
    - Erosive factors create inefficient delivery of hydraulic energy
  - Stubborn Turbidity Levels
- Poor Annular Seal and Zonal Isolation

Effect of the Drilling Process

- **Drilling is a Disruptive Process**
- **Various types of formations are encountered - Reactive, Non-Reactive, Permeable and Semi-Permeable**
- **Water-Based Drilling Fluids are the Predominate Circulating Medium Used**
- **Design & Maintenance of the Drilling Fluid System is Critical to Borehole Stability**
- **Contaminants will be Encountered in the Sub-Surface**
- **The Single Largest Contaminant is the Solids Produced by the Drilling Process Itself**

Dealing with Contaminants

- Calcium: Soda Ash at 0.5-2.0 lb/100 gallons
- Chlorides: If high levels exist seek out new water source
- Chlorine: If high levels exist seek out new water source – Can be aerated so chlorine will be released to the atmosphere

Objectives of Well Sealing

- Seal the annular space by replacing native material with a product that meets or exceeds the sealing capability of the formation
  - Generally means a permeability of $1x10^{-7}$ cm/sec or less
  - $1x10^{-7}$ cm/sec is approximately 1 ¼ inches/year
- Maintain and protect water quality
  - Prevent surface contamination
  - Prevent commingling of aquifers
- Provide casing support
- Thermally couple a heat loop to the ground
- Comply with federal, state and local well construction codes
- **Because it's the right thing to do!**

Quality of Sealing Materials

- High quality bentonite produces higher quality seals
- Definition of high quality bentonite
  - High percentage of sodium montmorillonite
  - Results in greater liquid limits and increased expansion pressure
  - Determined from analysis of untreated bentonite
- High degree of confidence in seal

Why Use Bentonite For A Seal?

- Ability to hydrate and expand
  - Hydration of material results in expansion pressure when confined
- Low permeability of material, less than $1x10^{-7}$ cm/sec
- Increased slurry volume yield
- Produces a flexible seal
- No heat of hydration

Sealing Materials

- Sodium Bentonite
  - Pumpable Grouts
  - Chips
  - Pellets
- Calcium Bentonite
  - Pumpable Grouts
  - Chips
  - Pellets
- Cement
  - Portland Cement (ASTM Type I, API Class A)
  - Cement/Bentonite Mix
  - Specialty Cements

Design the Grouting Process

- Annular Space - 4” minimum
- Casing
  - Centralized
  - Casing in tension during grouting
- Tremie Pipe - 1” minimum
  - 1 ¼” - 1 ½” Optimum
- Pump with maximum volume & velocity
  - Displace from bottom up
  - Keep tremie submerged in grout column a minimum of 5-10 ft
  - Best to be pumping grout as the tremie line is extracted
- Effective grouting may require a combination of products

Quantity of Solids vs. Quality of Solids

- Do higher % solids insure a quality seal?
  - Define the type and quality of the solid
- Experience shows that the liquid limit and % sodium montmorillonite of the bentonite are good indicators of quality
- The resultant hydration, expansive properties and structural integrity makes seals of this nature superior to just monitoring % solids of the grout

Influence of Geology

- Sand/gravel
  - Borehole stability
  - Erosion
  - Problems getting casing/screen to depth
- Clay
  - Boot formation
  - Excessive mud weight development
  - Problems getting casing/screen to depth
- Rock
  - Effective hole cleaning
  - Penetration rate

The Vadose Zone

- The unsaturated zone between the ground surface and the water table
  - Changes seasonally
  - Varies with climate changes
- Sealing materials will desiccate and crack over time

Formation Water Chemistry

- Excessive chlorides & total hardness can have a negative impact on bentonite seal
  - Chlorides>1500 mg/l (Salt)
  - Total Hardness>500 mg/l (Ca^{++} & Mg^{++})
  - Cumulative influence
- Impact hydration and permeability

Water Preparation

- “You only get one chance to get it right”!!!
- Check properties of make-up water
- pH
  - Optimum Range 8.5 - 9.5
- Hardness (Calcium)
  - Optimum Range <100 mg/l (<6 grain/gal)
  - Treat water with Soda Ash if necessary (0.25 lb/100 gallons to treat 100 mg/l Ca++)
- Temperature Awareness
  - Low Temperature => Materials react slower
  - High Temperature => Materials react faster

Mixing Procedures

- Remember Objective
  - Place bentonite material into annular space in as near “un-yielded form” as possible
- Blend grout - “Do Not Shear or Over Mix”
- Prepare small batches to maintain accuracy, consistency and percentage of active solids in grout
- Mix grout only until suspension is achieved then pump material down hole

Effective Placement

- Bentonite grouts need to be placed in a manner that allows for “In-Situ Swelling” for optimum results
- Structure grouting procedure to allow for maximum volume and flow
- Place grout into annulus under turbulence and high velocity
  - This helps insure complete filling of the annular space volume and reduces potential of channeling
- In general, the larger the annular space the less problems during grout placement (2”)

Effective Placement (cont.)

- Know the annular volume to insure adequate amounts are utilized
- Active pumping of the grout should continue as the tremie pipe is extracted from the annular space or open hole to insure effective displacement
- The first indications of grout returning to surface is not an indication to stop pumping
- Observe the consistency of the return grout to the surface; should be of the same consistency of that being pumped

Grout Subsidence

- Definition – Reduction of grout column due to loss of slurry to formation after grouting operations are completed
- Causes
  - Geology: Rock Stratigraphy
  - Drilling Method and/or Technique
  - Induced Fracturing
  - Inadequate fluid system design and/or maintenance
  - Inability of bentonite to yield due to quality of make-up water
  - Not following manufacturer's recommended formulation
  - Incorrect Grout Selection

Counteracting Grout Subsidence

- Analyze geology and what was done during the drilling phase
- Solutions
  - Effective solids control
  - Monitor pump and/or compressor volumes
  - Effective design & maintenance of drilling fluid
  - Use of “LCM” in drilling fluid and/or grout
  - Effective use of stiff-foam or gel-foam systems
  - Pre-treatment of make-up water with soda ash
  - Grouting options
    - Inhibitive grouts vs. Dispersed grouts
    - Use of HOLEPLUG instead of pumpable grout
    - Combination of materials (pumpable grout & HOLEPLUG)

What Does This Mean???

- Pumpable grouts may not stand the test of time in the "***unsaturated zone***" regardless of solids content
  - Materials will desiccate and crack over time
- HOLEPLUG is the bentonite additive of choice for applications in vadose zone
  - HOLEPLUG is more resistant to the impact of the vadose zone
    - Surface area
    - Higher resistance to chemical attack than pumpable grouts
    - Resulting solids concentration
- Make the best recommendation based on this knowledge

HOLEPLUG®

- Best possible Bentonite Seal
- High percent solids
- Maximum structural integrity
- Less susceptible to contaminants or subsidence
- Best bentonite choice in vadose zone
- Requires adequate annular space and proper installation methods
- Recommended for above filter pack or to initiate casing seal
- Only seal that held in the Nebraska Grout Task Force results

Proper Application for Placement of HOLEPLUG®

- Know Local Regulations
  - Pour or Tremie – What is allowed?
- Pouring Operations Require Patience!!
  - Use ¼” square mesh screen to remove fines
  - Pour chip bentonite no faster than 2 minutes per 50-lb sack
  - Place an equivalent volume in a equivalent volume
  - Calculate amount of annular space or borehole that will be filled by one sack
  - Use a sounding line to confirm level of bentonite chips and insure bridging has not occurred

Cement

- Initially a true hydraulic fluid that transmits hydrostatic pressure
- Converts to a solid-set material with compressive strength
- Cement slurry densities range from 15.6 - 12.0 lb/gal
- Considerable amounts of heat are generated from the curing process – “Heat of Hydration”
- Thicker sections of cement evolve more heat
- Filtration control is minimal or non-existent

Cement (continued)

- Bentonite additions
  - For every 1% bentonite (bwoc) added an additional 0.65 gallons of water is required (Assumes dry blending)
  - Reduces slurry density and increase slurry volume
  - Reduces resistance of cement to chemical attacks from formation water
- Adequacy of annular seal is determined by hydraulic bonding
  - Hydraulic bonding of cement to formation is affected by the presence of thick filter cakes
  - Failure to remove drilling mud/filter cake is more detrimental to formation bonding than pipe bonding
- Effective cementing has several requirements

Cementing Requirements

- Effective Drilling Phase
  - Bore Hole Stability – Gauge Hole
  - Effective solids control during drilling operations
- Water Requirements
  - 5.2 - 6.0 gal/94 lb sack
- Adequate Mixing
  - High shear
  - Improves wetting of cement solids
  - Improves resultant reaction
- Filtration Control Additives for Cement Slurry
- Mud & Filter Cake Removal
  - Centralization of casing
  - Pumping Rate
  - Rotation/Reciprocation

How Do You Improve the Properties of Neat Cement?

- Use appropriate water requirement
- Reduce filtration rate
- Retard the set time
- This generally requires multiple products to achieve
- BARAD-381™

Treated Cements

Accelerated

- Higher heat for a shorter time
- Shorter set time
- Compressive strength (?)
- Accelerants can add to heat

Retarded

- Lower heat for a longer time
- Longer set time
- Compressive strength (?)
- Filtration control is better

Positive Displacement Pumps

- Grout slurry is moved by transporting a confined volume of fluid through the pump by some combination of moving parts it is defined as positive displacement.
- These pumps moves a set volume of fluid through the pump for each revolution of the driving shaft, making displacement of the pump a measure of its size or volume.

Positive Displacement Pumps

- Gear Pumps *Bowie*
- Piston Pumps
- Progressive Cavity *Moyno* Pumps
- Air-Diaphragm Pumps

Conclusions

- Pre-Treatment of Make-Up Water
- Correct Product Selection & Concentration
- Order of Addition
- Adequate Mixing Equipment
- Monitor and Maintain Drilling Fluid Properties

-Safe Handling & Usage of Additives-

if possible, keep dry and covered

-Yard Safety, housekeeping, trip and/or slip hazards.

Closing Thoughts

- Always remember “the fundamentals”
- Match the grout or sealing agent to the job
- Bentonite seals have limitations, don’t ask the material to do something it is not capable of
- The most common reason seals fail is due to improper placement
- Focus on quality

A Successful Seal Starts Before The First Turn of The Bit!!!

Questions

Success starts before the first turn of the bit!!

Points to Remember

- Plan your Drilling Program
- Monitor Drilling Fluid Properties Regularly
- Control Viscosity
- Monitor & Control Pump Pressures and Volumes While Drilling & Pumping Tubes
- Solids Control, Solids Control, Solids Control
- Higher Penetration Rates Increase The Need For Maintenance Of Drilling Fluids
- Use Right Products Correctly

We Make House Calls