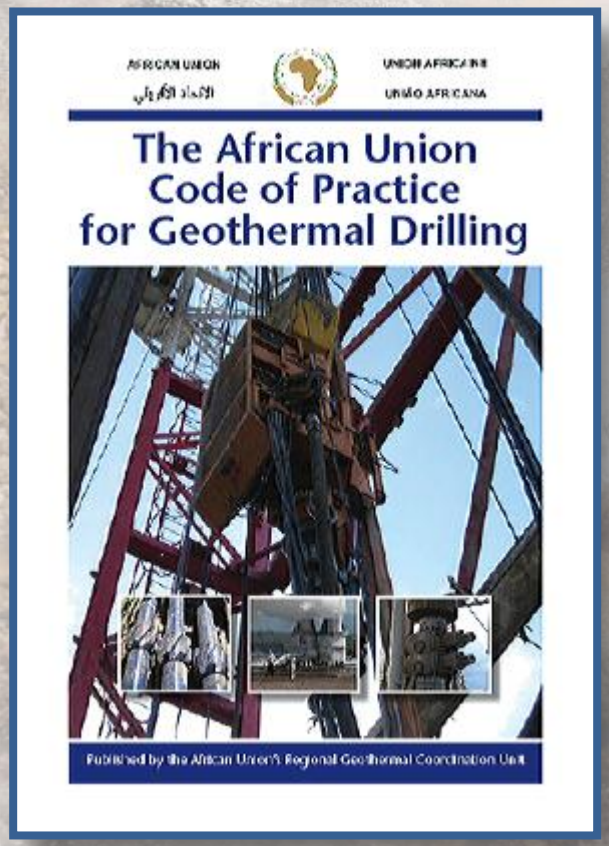

Welcome



The African Union Code of Practice for Geothermal Drilling

African Union

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

June 13-14, 2018
Addis Ababa, Ethiopia

Sam Abraham

Geothermal Engineer and Consultant

Contents

Sharing and Learning from Best Practices,
Improving your operations Saving Cost, Better Efficiency,
Fewer Accidents, Higher Well Outputs

Introduction

Significant Growth in East African Geothermal Development

- Increased Risks in Drilling, Environmental, Social, Health & Safety when undertaking deep exploration and reservoir conformation.

Introduction

Significant Growth in East African Geothermal Development

- Increased Risks in Drilling, Environmental, Social, Health & Safety when undertaking deep exploration and reservoir conformation.

Risks – Blowouts, H_2S (hydrogen sulfide), Personnel Injuries

Introduction

Significant Growth in East African Geothermal Development

- Increased Risks in Drilling, Environmental, Social, Health & Safety when undertaking deep exploration and reservoir conformation.

Risks – Blowouts, H_2S (hydrogen sulfide), Personnel Injuries

Code as a guidance document ensures sound drilling practices, capture of vital data during drilling, logging and testing of the wells.

Introduction

Significant Growth in East African Geothermal Development

- Increased Risks in Drilling, Environmental, Social, Health & Safety when undertaking deep exploration and reservoir conformation.

Risks – Blowouts, H_2S (hydrogen sulfide), Personnel Injuries

Code as a guidance document ensures sound drilling practices, capture of vital data during drilling, logging and testing of the wells.

Part of legal and regulatory framework made up of rules and regulations for natural resources, environment and occupational Health & Safety in compliance with country's regulations.

Introduction

Significant Growth in East African Geothermal Development

- Increased Risks in Drilling, Environmental, Social, Health & Safety when undertaking deep exploration and reservoir conformation.

Risks – Blowouts, H_2S (hydrogen sulfide), Personnel Injuries

Code as a guidance document ensures sound drilling practices, capture of vital data during drilling, logging and testing of the wells.

Part of legal and regulatory framework made up of rules and regulations for natural resources, environment and occupational Health & Safety in compliance with country's regulations.

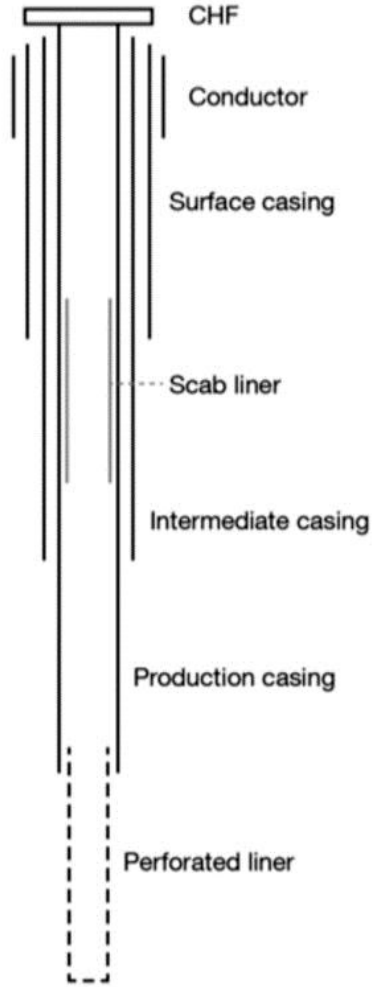
Geothermal Industry Best practices, Improvements and Record Keeping

Well Design

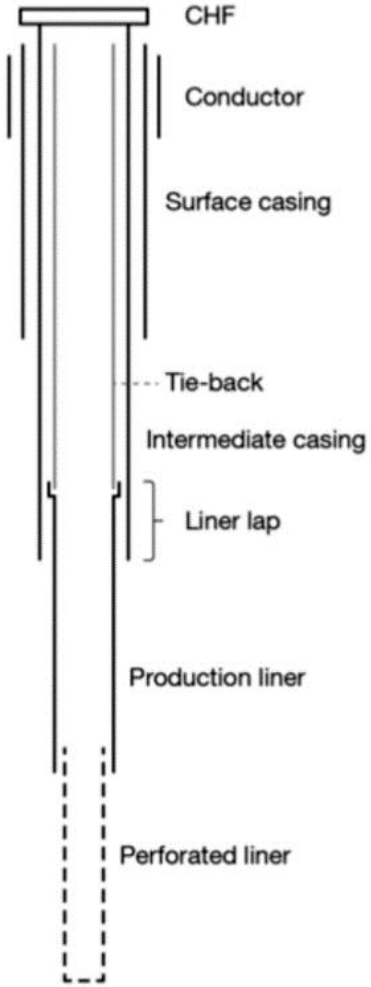
- Design Considerations
- Drilling Program Preparation
- Casing Strings
- Well Head Attachment

Rule of Thumb:

1/3 of the new open hole section should be have been cased and cemented



(a) Completion with production casing used as anchor casing



(b) Completion with an intermediate casing used as anchor casing

Well Design

Assessment of Subsurface Conditions

Brown Field

- Lithology stratigraphic markers
- Rock Alteration, Unstable Formations, Fracture Pressures – Leak Off Test (LOT) and Formation Integrity Test (FIT)

Well Design

Assessment of Subsurface Conditions

Brown Field

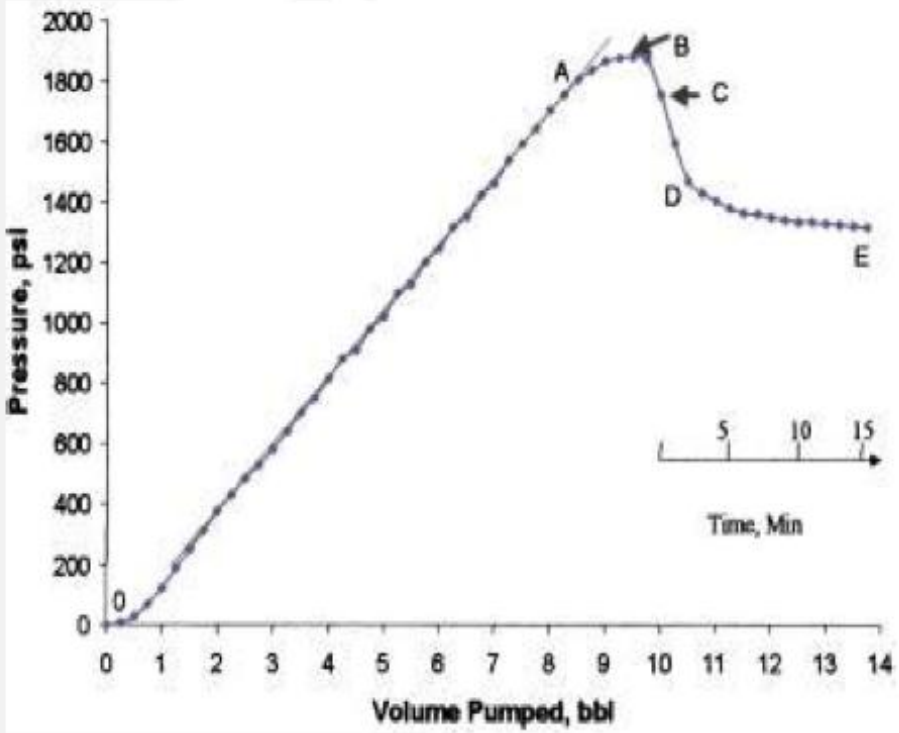
- Lithology stratigraphic markers

Rock Alteration, Unstable Formations,
Fracture Pressures – Leak Off Test (LOT) and
Formation Integrity Test (FIT)

Green Field

- Hydrostatic values of cold water
- Artesian Conditions
- Saturation Conditions of Column of Boiling Water

Hydrostatic pressure and boiling point of water at that depth



LOT pressure = 1600 psi; Casing shoe True Vertical Depth (TVD) = 4000 ft; Mud weight = 9.2 ppg
LOT in equivalent mud weight (ppg) = 1600 psi ÷ 0.052 ÷ 4000 ft + 9.2 ppg = 16.9 ppg

Required FIT (ppg) = 14.5, Current mud weight (ppg) = 9.2 Shoe depth TVD (ft) = 4000 TVD Pressure required for FIT = (14.5-9.2) x 0.052 x 4000 = 1102 psi

Maximum Design Pressure for each section shall be for the corresponding hole section

Injection Condition – max continuous Inj Press

Steam Condition – 100%

Pressure Containment

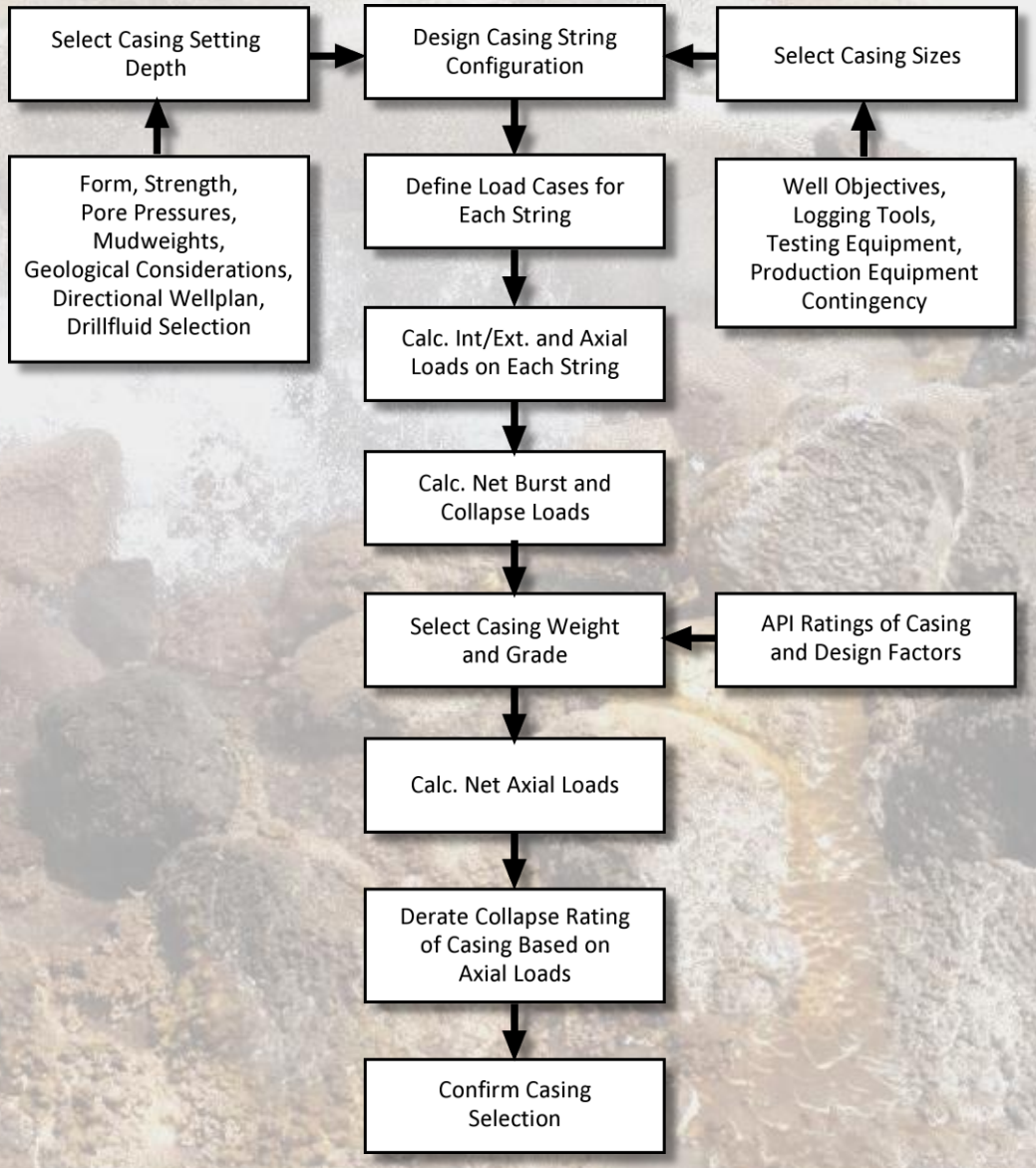
- Effective Pressure Containment – to prod C (Casing) Shoe
- Objective of Pressure Containment – no blowout
- Estimation of Fracture Pressure using Eaton Formula

– Maximum Allowable Surface Pressure (MAASP) = Formation Break Down Pressure - Head of mud in use or

– MAASP = Equivalent Mud Weight (E.M.W) - MW_{MUD}) x 0.052 x Shoe Depth (TVD), where E.M.W = Equivalent mud weight at which formation breaks at shoe, MW_{MUD} = Mud Weight

The casing design process involves three distinct operations:

1. The selection of the casing sizes and setting depths;
2. The definition of the operational scenarios which will result in burst, collapse and axial loads; and
3. The calculation of the magnitude of these loads and selection of an appropriate weight and grade of casing.



Prepared by: Tan Nguyen,
University of New Mexico

Casing Setting Depths

- Competent formation, case out loss zones
- Reservoir isolation, corrosion protection
- Setting casing shallow to save cost ????? correlation

Casing Setting Depths

- Competent formation, case out loss zones
- Reservoir isolation, corrosion protection
- Setting casing shallow to save cost ????? correlation

Casing Diameters

- Drilling tools for next section, desired Prod / Inj capacity fishing tools diameter, acceptable flow velocities cementing annulus space, American Petroleum Institute (API) Spec 5CT or 5L

Casing Setting Depths

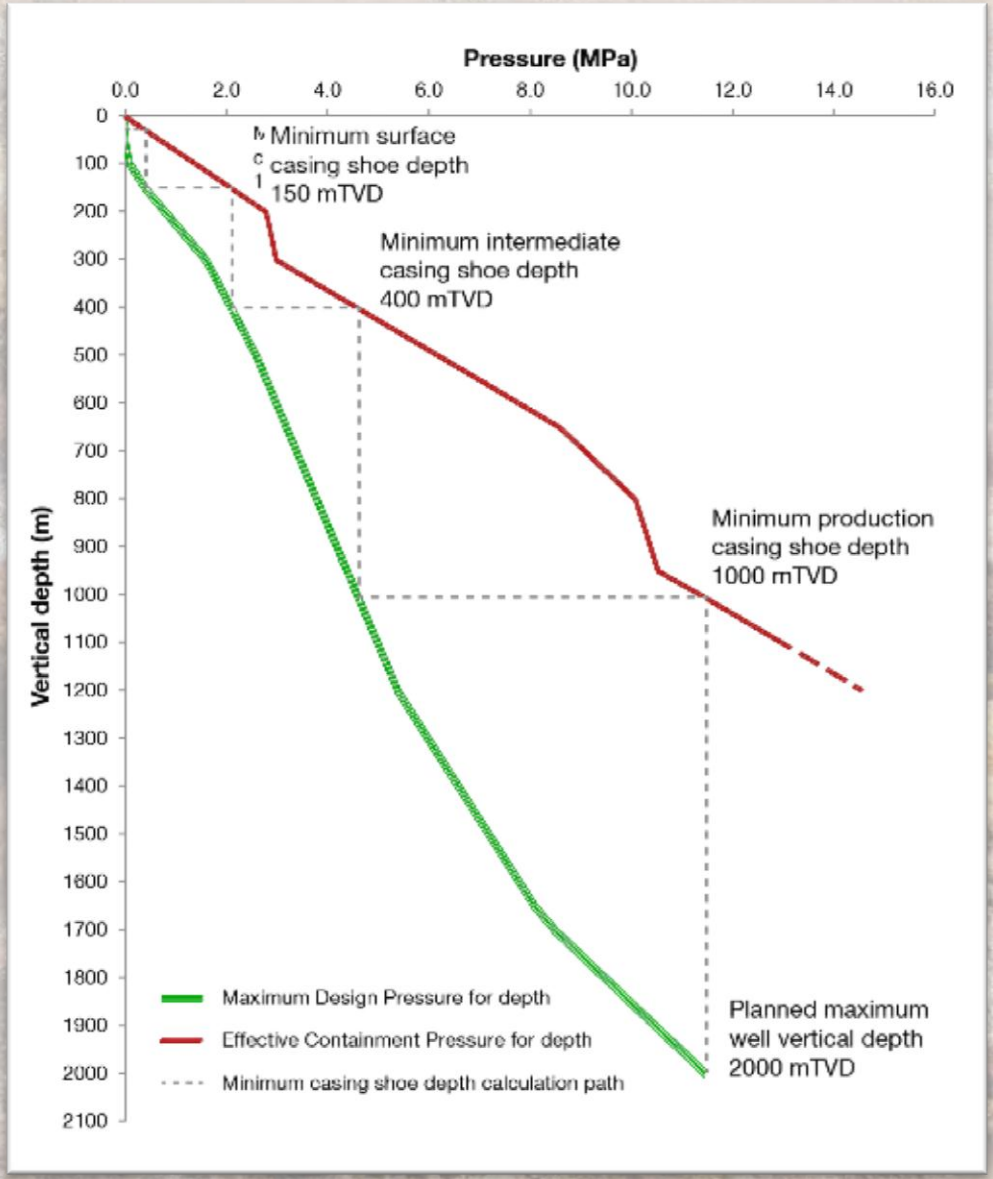
- Competent formation, case out loss zones
- Reservoir isolation, corrosion protection
- Setting casing shallow to save cost ????? correlation

Casing Diameters

- Drilling tools for next section, desired Prod / Inj capacity fishing tools diameter, acceptable flow velocities cementing annulus space, American Petroleum Institute (API) Spec 5CT or 5L

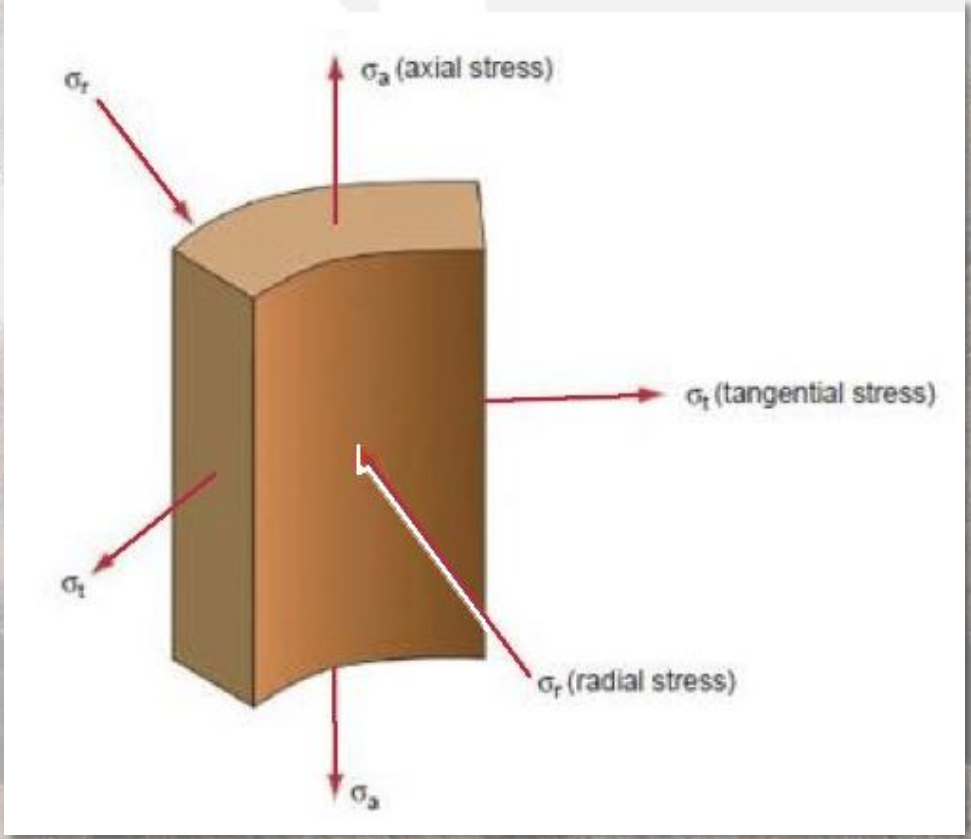
Casing Materials and Properties

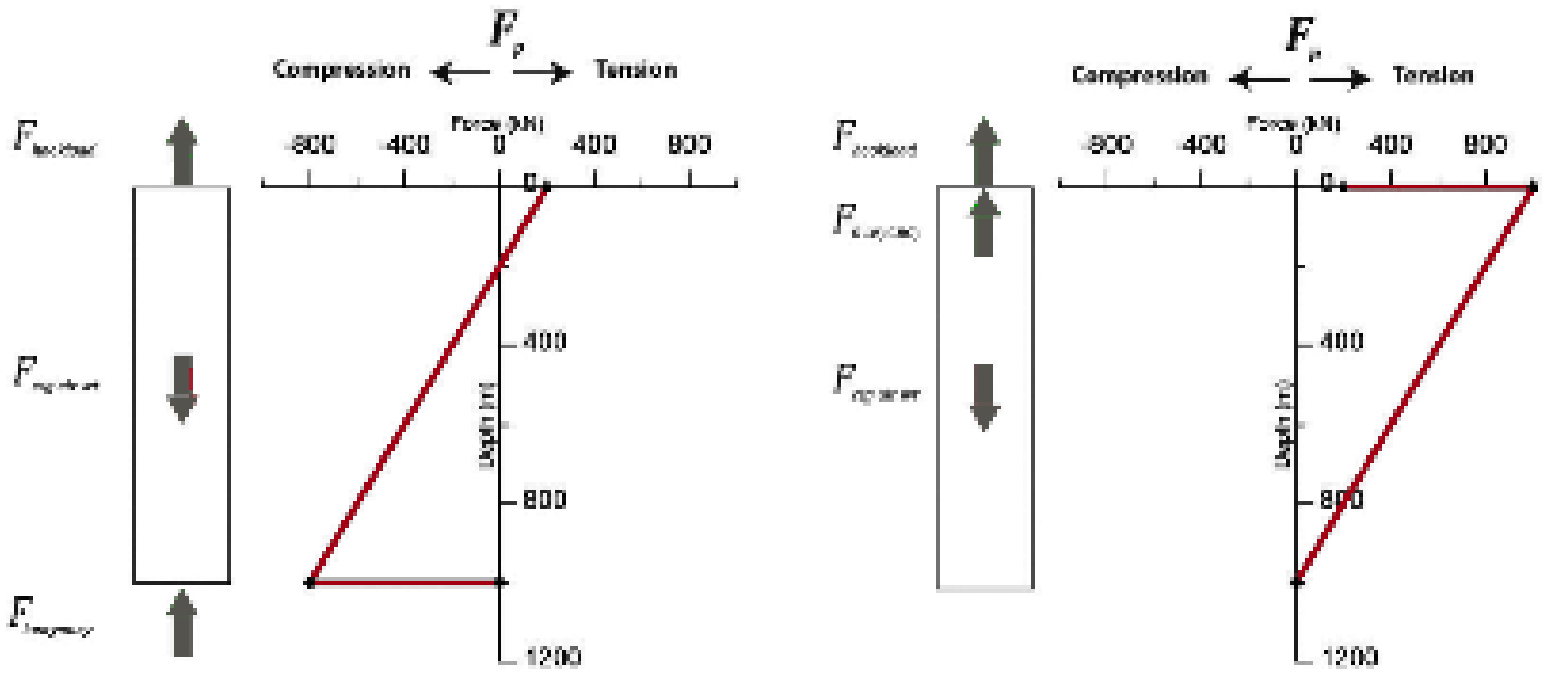
- Sulphide stress corrosion, expected high temperature,
- Axial strength, Internal yield and collapse resistance


Pressure (MPa)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Vertical depth (m)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
Minimum surface casing shoe depth 150 mTVD
Minimum intermediate casing shoe depth 400 mTVD
Minimum production casing shoe depth 1000 mTVD
Planned maximum well vertical depth 2000 mTVD
Maximum Design Pressure for depth
Effective Containment Pressure for depth
Minimum casing shoe depth calculation path

Casing Stress – Combined Stress Effects

- Assessing axial loading before and during cementing process.
- Axial loading after cementing.
- Axial loading in uncemented liners.





(a) Buoyancy force applied at bottom of casing

(b) Buoyancy force applied at surface

Minimum Design Factors

Hoop stress – Internal Yield and Collapse Reduction in cross sectional area due to corrosion or wear.

Design Factors

- **Triaxial**
- **Axial** – Tensile Forces during casing job, Fluid Lifting force, thermal Load, Helical buckling due to self weight and thermal load on uncemented casing.
- **Hoop** – Internal Pressure, Well Head Pressure (WHP) due to steam when shut in and WHP when wellhead is fixed to casing, External pressure collapse during cementing and during production.

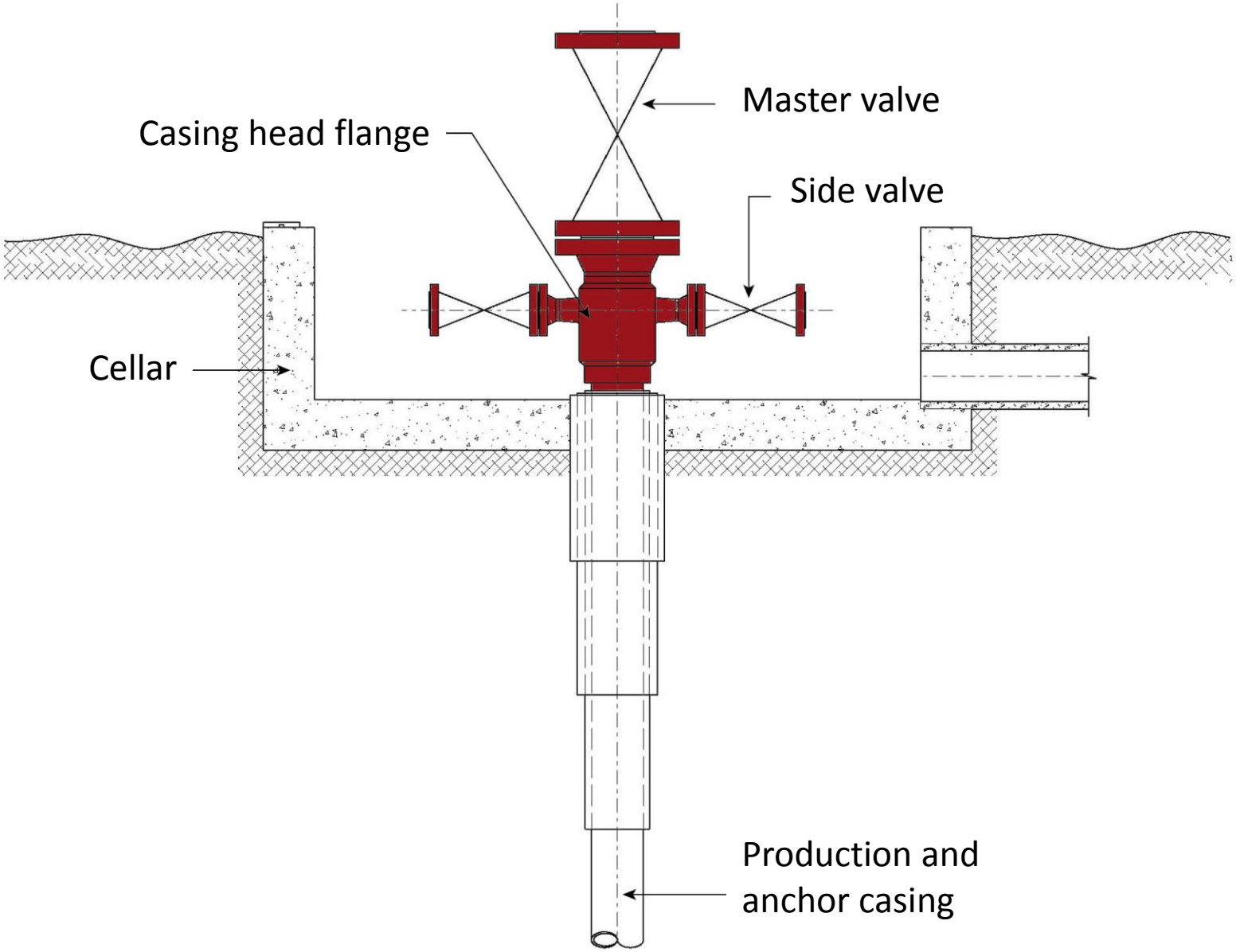
Combination strings

Permanent Well Heads

Outer Flanges of Master Valve and Primary Side Valves directly exposed to the well fluids

Bottom of the Casing Head Flange (CHF) attaching Well head to casing, and any spools in between (if used)

Designed for Pressure and Temperatures service API Specs 6A or 6D, materials withstand chemical attacks


Master valve
Casing head flange
Side valve
Cellar
Production and
anchor casing

Permanent Well Heads

(Continued)

Design Factors

Corrosive Environments, Rise and Fall of Well heads, orientation of well head to sump, attachment of surface pipework. Raised face flanges.

Well Head Flanges – rating above American National Standards Institute (ANSI) 400 using ring jointed flanges, prefer not using studded connections on permanent well heads.

Threaded CHF connection to anchor casing, avoid thread lock.

Permanent Well Heads

(Continued)

CHF welding – Appropriate materials and welders qualified in the specific procedure. All welds inspected and tested.

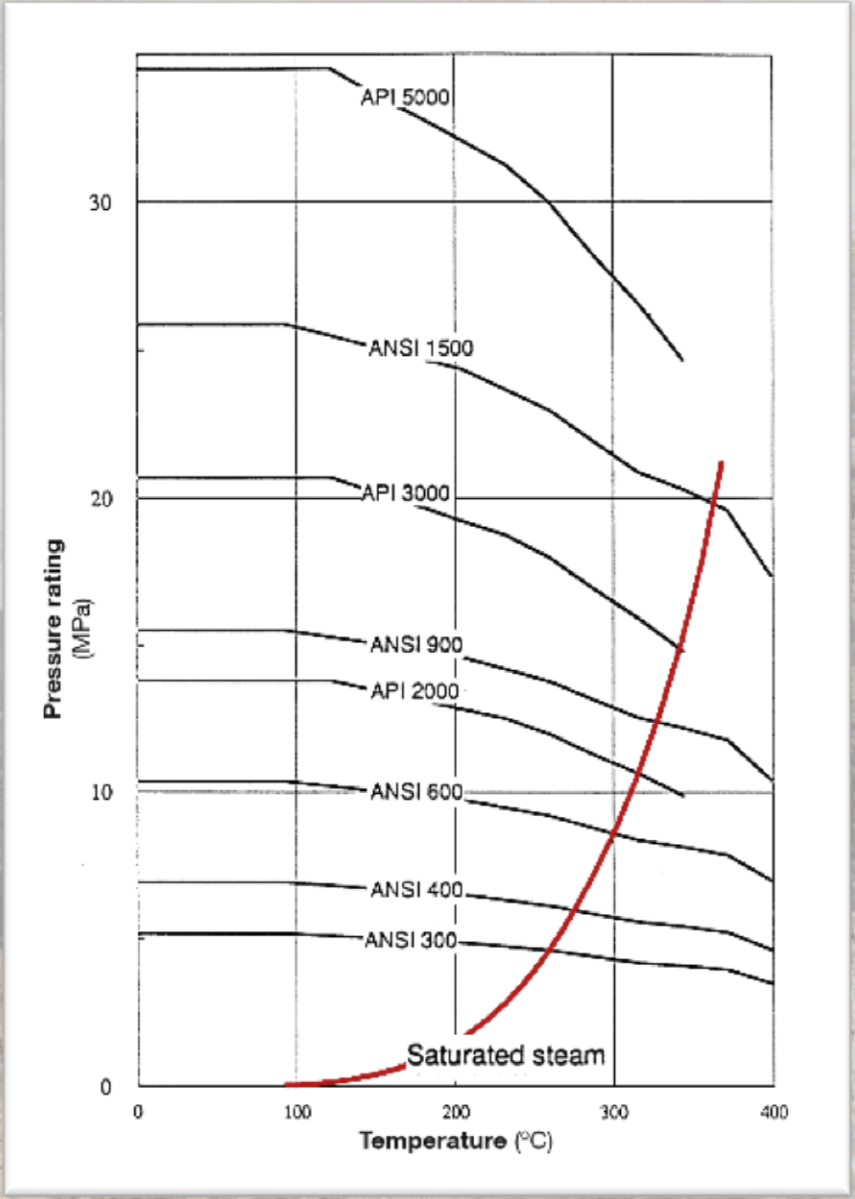
API/ANSI Bolted Flanges compatibility – similar dimensions, but check for different steel grades and pressure ratings.

Entire Well Head – Clear Bore Diameter at least 3 mm larger than any tool.

Permanent Well Heads

(Continued)

Figure shows working pressure derating due to temperature for flanges and valves API 6A and ANSI B16.5.



Permanent Well Heads

(Continued)

Valve sealing to be metal to metal seal, fluid and particulate materials that may erode the exposed gate valves, elastomers rated for ambient conditions.

Master Valve gate position indicated externally, allow for repacking of sealing, prevent trapping of fluids inside valve cavity, mechanical pressure relief valves or burst disks to prevent overpressure.

Permanent Hang Down Casing or tubing string through master valve, consideration for primary well isolation design and procedures.

Review and Modification of Well Design During Drilling

- Downhole fluids conditions such as temperature, pressure or gas may create greater pressures than initially designed.
- Downhole formation conditions like faults or weak formation may show less containment pressure than initially designed.
- Casing setting depths are materially changed from the depths used for well design.

Review and Modification of Well Design During Drilling

(Continued)

WELL DESIGN RECORDS

shall indicate design inputs and assumptions, steps followed, safety factors and well head design engineering and these records to be maintained (hard copy and digital).

Well Sites

Well Site Access

- Roads, bridges, culverts for continuous access.
- Load capacity, road grades, alignment & drainage.

Well Site Selection

- Appraisal of soil bearing capacity.
- Shallow geotechnical and thermal activity conditions.
- Sufficient open surroundings for gas dispersion.

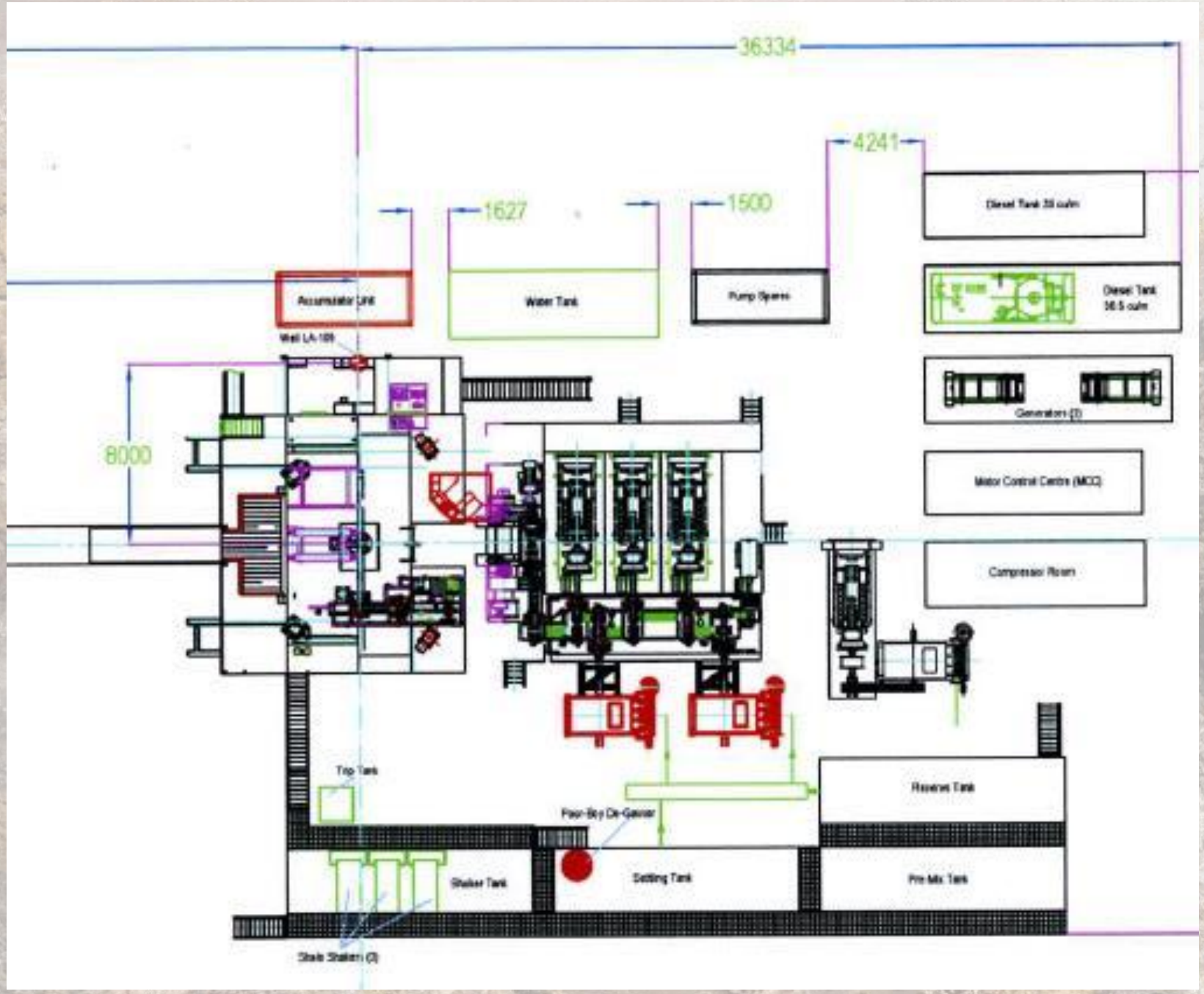
Well Sites

Site Design Considerations

- Support all the loads by drilling equipment.
- Control run off and contain drilling fluids.
- Review Geotechnical assessment and remedy.
- Consolidation grouting, if needed.
- Site finished grading within rig equipment.
- Original equipment manufacturer (OEM) tolerances.

Well Sites

- Geotechnical Investigation shall be carried out during site construction.
- Manage and treat run-off within drilling site during drilling operations.
- Well sites and associated works to comply with applicable environmental permits and consents of the country and the Occupational Health and Safety Administration (OSHA).
- Compaction requirements – rig footprint area.


36334
4241
1627
1500
8000
Accumulator Unit
Water Tank
Pump Spares
Diesel Tank 38 cu/m
Diesel Tank 36.5 cu/m
Generators (3)
Motor Control Centre (MCC)
Compressor Room
Trip Tank
Reserve Tank
Shaker Tank
Settling Tank
Pre-Mix Tank

Well Sites

Cellar

- Collection sump for drilling fluids returns, cementing returns, accommodate the drilling well head and local drainage collection.
- Should be ventilated, shall have good load bearing, have controlled access if deeper than 1 meter, easy exit means.
- Permanent datum line on the cellar for reference point.
- At least 250 mm inside diameter (ID) drainage pipe, grade of 1 to 40.

Well Sites

Drainage and Waste Disposal Consent

- Compliance with local environmental permits.
- Waste sumps for cuttings and liquids during drilling and cementing.
- Solids and liquid isolation, top level below cellar floor level.
- Prevent erosion of walls.
- Holding capacity of 5 times total solid volume of well; hole volumes (2 times in-situ volume) and formations to be drilled.
- Cuttings removed at shakers and solid removal.
- Avoid run off to cellar after well completion.

Well Sites

Multi Well Sites

- Well head and cellar locations to allow for installation and operation of drilling rig over a well without endangering another well.
- Means of exits provided between each well in the cellar.

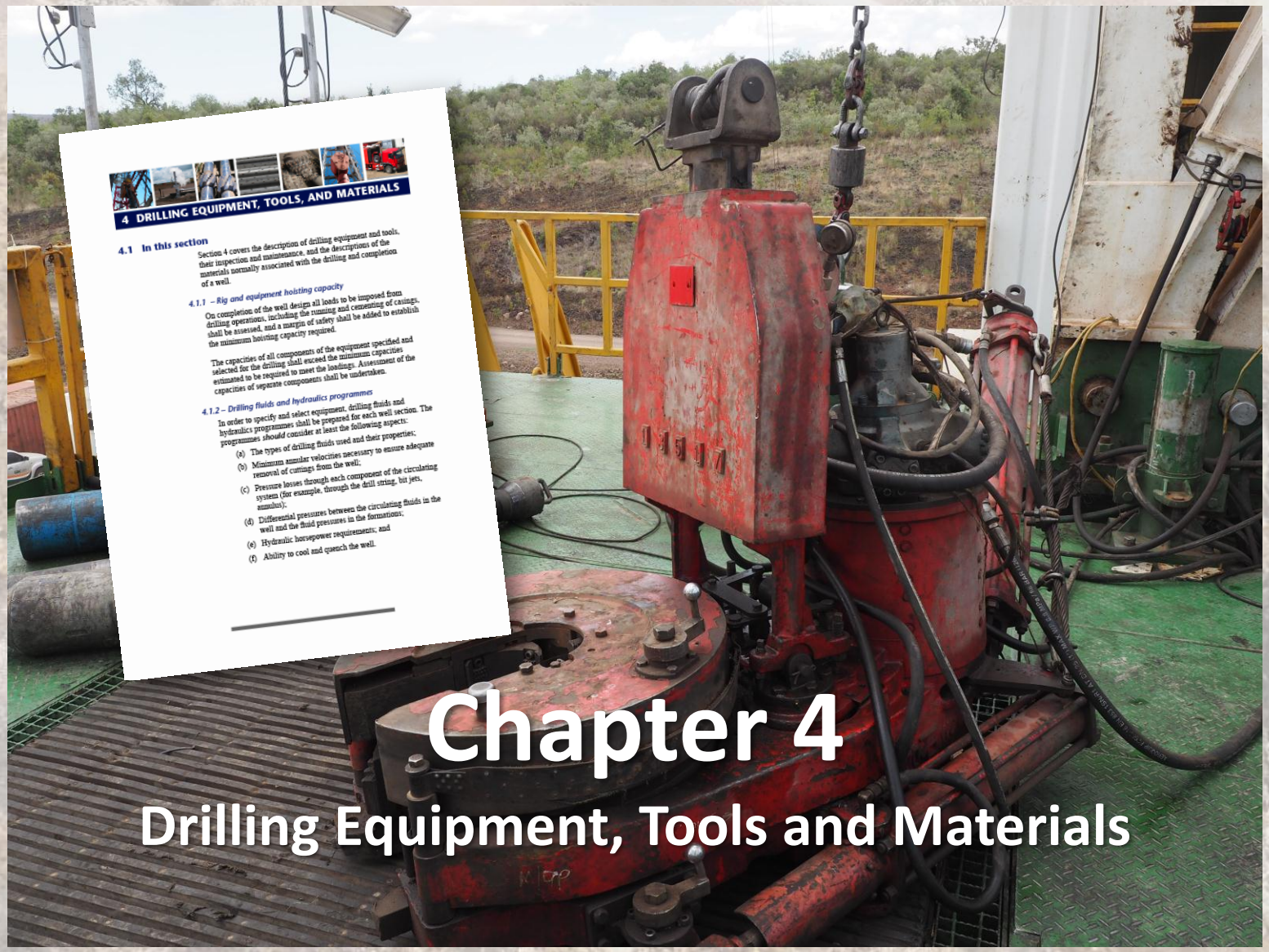
Well Site Records (as built)

- Well location, cellar, underground pipework, drilled cuttings location, areas of cut and fill or grouting, sump location.

Well Sites

Site Security and Signage

- *Authorized Personnel Only* allowed access to site during drilling operation.
- **Signing in and out of location – Safety.**
- Personal Protective Equipment (PPE) Usage, Waste Sumps, Hazardous Gases and Hazards signage to be posted.
- Permanent signage on well head or cellar with well identification name or number and name and contact details of the owner.
- **Signage not only posted, BUT to be implemented.**



4 DRILLING EQUIPMENT, TOOLS, AND MATERIALS

4.1 In this section

Section 4 covers the description of drilling equipment and tools, their inspection and maintenance, and the descriptions of the materials normally associated with the drilling and completion of a well.

4.1.1 – Rig and equipment hoisting capacity

On completion of the well design all loads to be imposed from drilling operations, including the running and cementing of casings, shall be assessed, and a margin of safety shall be added to establish the minimum hoisting capacity required.

The capacities of all components of the equipment specified and selected for the drilling shall exceed the minimum capacities estimated to be required to meet the loadings. Assessment of the capacities of separate components shall be undertaken.

4.1.2 – Drilling fluids and hydraulics programmes

In order to specify and select equipment, drilling fluids and hydraulics programmes shall be prepared for each well section. The programmes *should* consider at least the following aspects:

(a) The types of drilling fluids used and their properties;
(b) Minimum annular velocities necessary to ensure adequate removal of cuttings from the well;
(c) Pressure losses through each component of the circulating system (for example, through the drill string, bit jets, annulus);
(d) Differential pressures between the circulating fluids in the well and the fluid pressures in the formations;
(e) Hydraulic horsepower requirements; and
(f) Ability to cool and quench the well.

Chapter 4

Drilling Equipment, Tools and Materials

Chapter 4
Drilling Equipment, Tools and Materials

Maximum Hoisting load capacity – running and cementing of deepest casing and safety margin.

Drilling Equipment, Tools and Materials

Drilling Fluids and Hydraulics Programs

- Type of fluids, minimum annular velocities for cutting removal from well.
- Pressure losses through circulating system.
- Hydraulic horsepower requirements.
- Cooling and quenching the well.

Equipment

- Suitability of equipment – national or API standards.
- Mast and substructure designed as per API Spec 4F full mast setback capacity, excess of drawworks input power.
- Inspected periodically fatigue, corrosion or damage.
- All welding to have pre- and post-heat treatment, safe working load reduced.
- Traveling block – API spec 8A, inspection and preventive maintenance (PM) – RP 8B.
- Drilling line – API spec 9A, inspection and PM – RP 9B.
- Visual Inspection and Ton Mile calculations.
- Safety Device to prevent T-Block hitting the crown block.

Ton Mile Calculation

Round-trip ton-mile

Mud Weight	10	ppg
Measured depth (D)	5500	ft
Drillpipe weight	13.3	lb/ft
drill collar weight	85	lb/ft
drill collar length	120	ft
HWDP weight	49	lb/ft
HWDP length	450	ft
BHA weight in air	8300	lb
Length of BHA	94	ft
Block weight (Wb)	95000	lb
Average length of one stand (Lp)	94	ft
Buoyancy factor	0.847	
Buoyed weight of drill pipe (Wp)	11.27	lb/ft
Buoyed weight of BHA (drill collar + heavy weight drill pipe + BHA) in mud minus the buoyed weight of the same length of drill pipe (Wc)	26,876.24	lb
Round-trip ton-mile (RT TM)	**258.75**	**Ton mile**

Equipment
(Continued)

- Rotary equipment to be maintained as per API 7K and 8C.
- With dynamic capacity in excess of maximum hookloads.
- Top drive equipment to be maintained as per API RP7G
- Rig Engines and Drives – API Spec 7F.
- Drive train arranged that mud pump can operate even while tripping in and out of the hole.
- Generator capacity adequate to supply entire electrical load required by rig and associated equipment during drilling.

Equipment
(Continued)

- Standby generator capacity to run prime movers, air compressors, lighting and blowout preventer (BOP) accumulator pump.
- Air compressors – adequate flow rate and pressures, and adequate capacity to provide air supply to all equipment together.
- Back up air supply for rig air, purging system and workshop.

Equipment
(Continued)

Rig Engines and Drives – API Spec 7F

- Drive train arranged that mud pump can operate even while tripping in and out of the hole.
- Generator capacity adequate to supply entire electrical load required by rig and associated equipment during drilling.
- Standby generator capacity to run prime movers, air compressors, lighting and BOP accumulator pump.
- Air compressors – adequate flow rate and pressures, and adequate capacity to provide air supply to all equipment together.
- Back up air supply for rig air, purging system and workshop.

Cementing Equipment

Cement, Mixing facilities, slurry pumps, head, storage and transfer for water and additives, testing facilities

- Sized to pump the largest single cementing operation for the well.
- Cement storage restocking in timely manner.
- Storage facilities to keep away from weather and pressurized silos for bulk storage with working gauges.
- Parameter recording sensors to be in working condition, calibrated and data storage.

Cementing Equipment
(Continued)

- Capacity to mix and pump slurries at required rates including holding tank with stirrers.
- Water supply with backup on site storage.
- Dedicated mixing and pumping systems preferred, with safety links.
- Piping manifold to allow rapid transfer from pumping downhole to down the annulus and cleaned after every pump job.
- Quality control of cement slurry – mud balance, collecting cement samples and chart recording (analog and digital).

Cementing Equipment
(Continued)

Drilling Fluids Systems

- Mud tanks
- Pump suction and discharge pumping
- Mud mixing and circulating
- Air compressors discharge piping
- Fluid mixing and distribution manifold
- Standpipe, rotary hose
- Flow lines, blooie line, separators
- Shale shakers, mud cleaners
- Mud cooler, other equipment
- Gas detection systems

Drilling Fluids Systems
(Continued)

High pressure lines to consider erosion, corrosion and wear

- Blooie line to have valves to the well head. Separators shall be designed for erosion from aerated returns.
- Mud cooling system to keep mud going to the pumps below 60°C
- Positive displacement mud pumps, redundant pump capacity for well control, capable of pumping fluids at higher temperature (not over 85°C).

Drilling Fluids Systems
(Continued)

- Pressure Gauges – installed, calibrated, maintained and recording the parameters

- Drilling Fluids parameters measured regularly
  - Mud Weight (MW)
  - Viscosity
  - Plastic Viscosity (PV)
  - Yield Point (YP)
  - Gel Strength
  - Solids
  - Temperature of mud going IN and OUT of the well

Drilling Well Heads

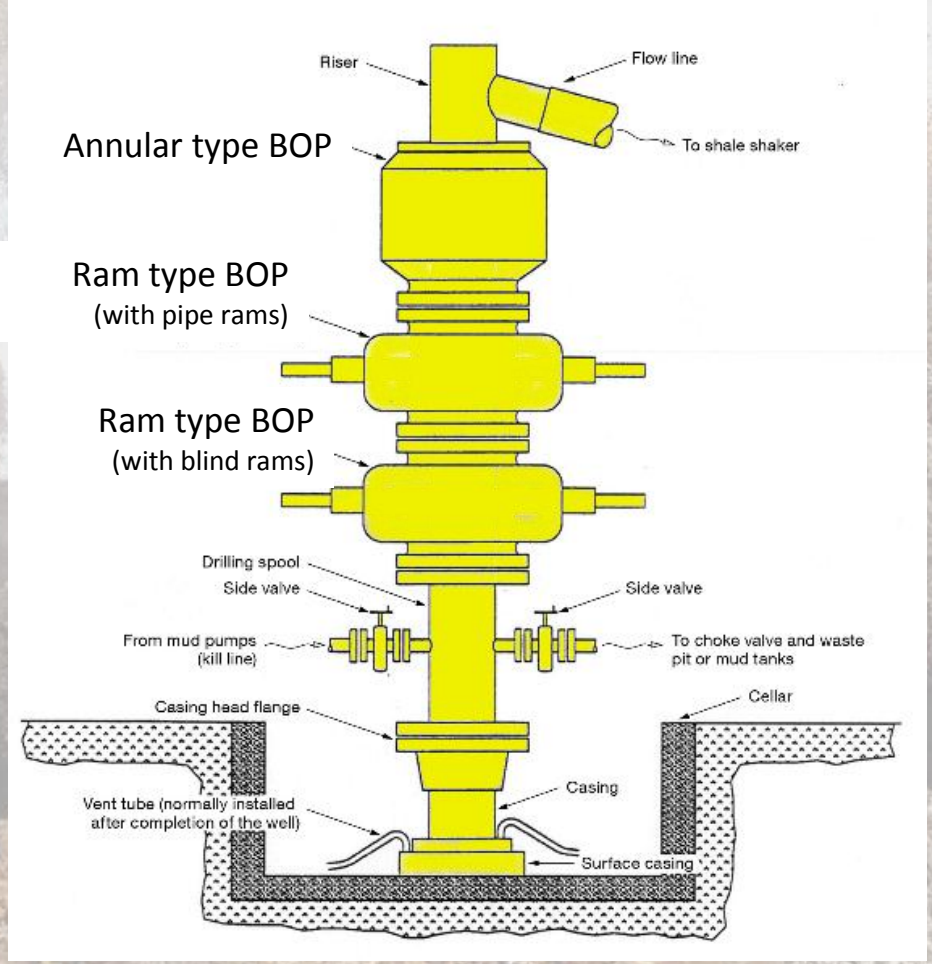
- All well heads capable of containing well or drilling operation pressures and pressure rated for Maximum Design Pressure.
- **Valves and flanges to comply with API Spec 6A and Spec 6D.**
- **Drilling spools shall conform to API Spec 16A and Spec 6A.**
- All drill through equipment shall conform to API Spec 16A.
- Well head made up of: Valves, BOPs, Flanges or clamped bolts, Spools, Tees and Crosses, Banjo Box, Rotating Head.
- **DO NOT USE FABRICATED EQUIPMENT – WHICH ARE UNCERTIFIED AND UNINSPECTED.**

Aerated Drilling Fluids Systems

- High pressure lines on surface with pressure relief valves of adequate flow capacity.
- Non Return Valves in the air lines to prevent fluids from entering the lines for rig pumps, the drill string or the well.
- NRV in drill string to be in the upper section to minimize vented fluids, and should have high temperature seats and seals.
- **All flexible air lines to be clamp chained / wire rope safety links across all end connection for safety if the lines fail.**
- Bypass lines for any excess air and blow down from string
- Rotating head with proper seals on the BOP stack to divert return fluids in a controlled manner.
- All discharge pipework to have a pressure rating sufficient to withstand maximum dynamic well head pressure.

Blowout Preventers and Accumulators

- All hydraulically operated BOP equipment shall conform to API STD 53, selected and installed.
- Gate Type BOP could be complete shut off or blind, pipe, variable and shear rams.
- Annular BOP and Rotating Head.
- Wireline BOP.



Blowout Preventers and Accumulators

(Continued)

- **BOP installed on the well shall be inspected, maintained and function tested in accordance with API STD 53, with test pressures not less than max service conditions predicted (Pressure test records to be maintained).**

- **BOP system operation possible from two independent locations, near driller's console and accumulator location.**

Blowout Preventers and Accumulators

(Continued)

- Elastomers chosen to withstand high temperature and quality of geothermal fluids likely to be encountered.
- Rotating head BOPs shall use high temp materials when using aerated drilling fluids.
- Temperature rating of seals documented, drilling conditions maintained below the temperature ratings.
- Pumping units on the accumulators shall be powered by minimum of two independent power sources (API STD 53).
- Accumulator volumetric capacity shall be sized to allow for shutting and keeping shut the annular plus single closure of either pipe or blind rams.

Gas Detection

- **Gas detector system** – two sensors to detect H_2S and CO_2, shall be on site and functioning at all times, and have audible and visual alarms, maintained as per manufacturer's OEM manual.

- **These detectors installed, tested, calibrated and routine calibration checks – this can lead to a FALSE SENSE OF SECURITY and LEAD TO A FATALITY.**

- **Gas hazard abatement plan** shall be prepared and all rig crew and support personnel shall be familiar with its operation.

Gas Detection
(Continued)

- Gas hazard escape equipment shall be provided at appropriate location in proper working condition and available for use at all times.
- All rig personnel shall be trained and competent in the use of Emergency Life Support and self contained breathing apparatus.
- Self contained breathing apparatus on the rig floor for the appropriate number of personnel required to shut the well in and secure it, including the monkey board for the derrick man. Air supply cascade systems can provide air supply for breathing when in well control situations.

Rig Instrumentation

- Total Weight on Hook indicator
- Mud Tank Volumes and gain/loss indicators
- Standpipe pressure gauge
- Pump Speed indicators
- Rotary speed indicator
- Rotary Torque indicator
- Rate of Penetration and Hook Height indicator
- Mud flow out indicator
- Drilling Fluid Density indicator
- Make Up Torque indicator
- Well head pressure indicator
- Gas Monitoring indicators
- Sampling Intervals Alarms – Lag Time Calculations

Rig Instrumentation

- Recorders which record any or all parameters (both analog and digital like geolograph and Pason recording systems).

- **All the instrumentation to be installed, tested, and calibrated before spudding the well and maintained in working condition with routine checks including recalibration as per OEM standards during drilling operations.**

Storage Facilities

- Storage facilities for hazardous substances shall protect them from adverse effects of local environment and also ensure they do not endanger the rig personnel.
- Fuel storage tanks shall be designed and located to minimize potential hazards including spills and comply with local regulations, including containment bays to reduce spill contamination.
- Safety measures like eye wash station and shower stations to be in the proximity of the storage facilities as needed to take care of personnel during spills.
- **Provision and use of proper Personal Protective Equipment.**

Tools

- Drill Pipe manufactured and tested to API Spec 5DP.
- Resist sulphide stress cracking, remain within strength capacity, if internally coated should have high temperature coating.
- Drill collars and other subs as per API Specs 7-1.
- Connection selection according to API RP 7G Drill string and casing tubulars shall be stored according to API RP 5C1.
- Pipe Racks with dunnage straps for proper storage.
- Reamers, stabilizers and hole openers to have same connection as the drill collars on which they will be run to reduce crossovers.
- Near bit tools have box connection – API Spec 7-2.

Drilling Bits

- Bits threaded to API Spec 7-2, selected based on anticipated drilling conditions.
- Tricones, Polycrystalline Diamond Carbine (PDC) and hybrid bits.
- Abrasive formations – additional protection against shirt tail and loss of gauge.
- Seals should be designed for higher temperature.
- Provision for expansion of bearing lubricants at higher temperatures.

Do we need labels for this?

CUTTING STRUCTURE				B	G	REMARKS	
INNER ROWS	OUTER ROWS	DULL CHAR.	LOCATION	BRNG/ SEALS	GAUGE 1/16"	OTHER CHAR.	REASON PULLED

Drilling Bits
(Continued)

- Checking bit gauge and bit condition prior to running in and recording the dull bit conditions (8 characters) after bit is pulled out.

- Hours on bottom, and total Krevsto be recorded daily. Bit breaking at the start of drilling and monitor rotary torque towards end of bit life. Pictures of dull bits.

Pipe Handling & Fishing Tools

- Hoisting tools shall be inspected and maintained as per API Spec RP 8B.
- Other handling tools like tongs, lifting subs inspected and maintained in a safe and functional condition.
- Fishing tools to have high temperature elastomers and use high temperature oil if they are hydraulic.
- If explosives are to be used downhole, all the parts should be selected for the anticipated downhole conditions.

Pipe Handling & Fishing Tools

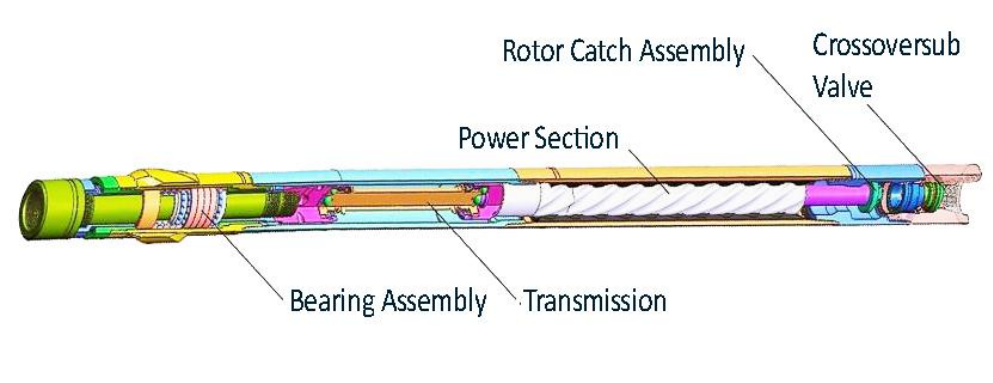
(Continued)

- **Measuring OUTSIDE and INSIDE diameters of tools and fish neck of every tool going in the hole and maintaining the records. Check to have a fishing tool for every tubular that goes below the rotary table, and have fishing tools on standby always at the rig site during drilling operations.**

- **FISH GROWS ROOTS**

Directional Drilling and Downhole Measurement Tools

- Directional drilling tools which provide data while drilling to be rated for appropriate temperature and protection to last long in the hole including high temperature stator.
- Before running the directional drilling tools, including the tubulars in the well, check for the maintenance and service documentation from the provider.



Consumables

- Casings and accessories.
- Casing conform to API Spec 5CT or 5L.
- Centralisers shall be complete with stop rings.
- Accessories threaded to adjacent casing have the same steel grade or materials selection criteria.
- If not threaded, the crossover connection – 1 joint long.
- Slotted casings – casing slots machined, or
- Slotted, check the ID reduction.
- **TRACEABILITY – Certificates.**

Consumables
(Continued)

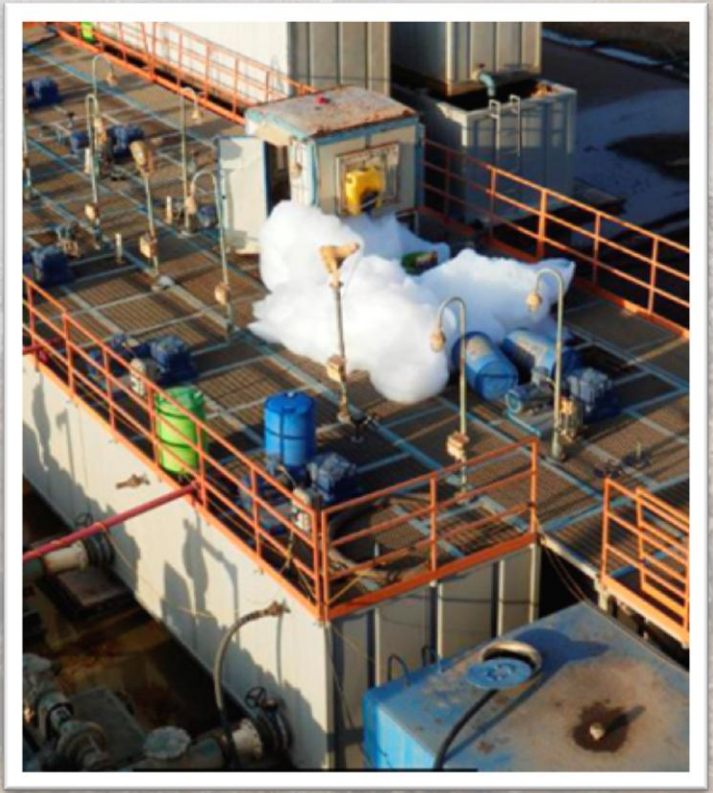
Cement and additives

- Quality that has predictable properties when mixing, pumping and predicted service conditions, long term exposure to geothermal fluids and high temperatures.
- **Mixing cement from different manufacturers X**
- Water quality to undergo lab tests for slurry characteristics of flowing, thickening and strength – for nitrate, pH, chloride, sulphate and silica which affects hydration.
- Retarders and accelerators shall be selected after considering minimum and maximum likely circulating temperature, certified by manufacturer and tested in a lab for expected temperatures.

Consumables
(Continued)

Drilling fluid materials

- Water based – bentonite, polymers and additives, to the deepest cemented casing or liner.
- Aerated fluids, no bentonite in production section
- Loss Circulation Material (LCM) – size to not affect pump valves, downhole tools, stable at high temperature.



Consumables

(Continued)

Drilling fluid materials (continued)

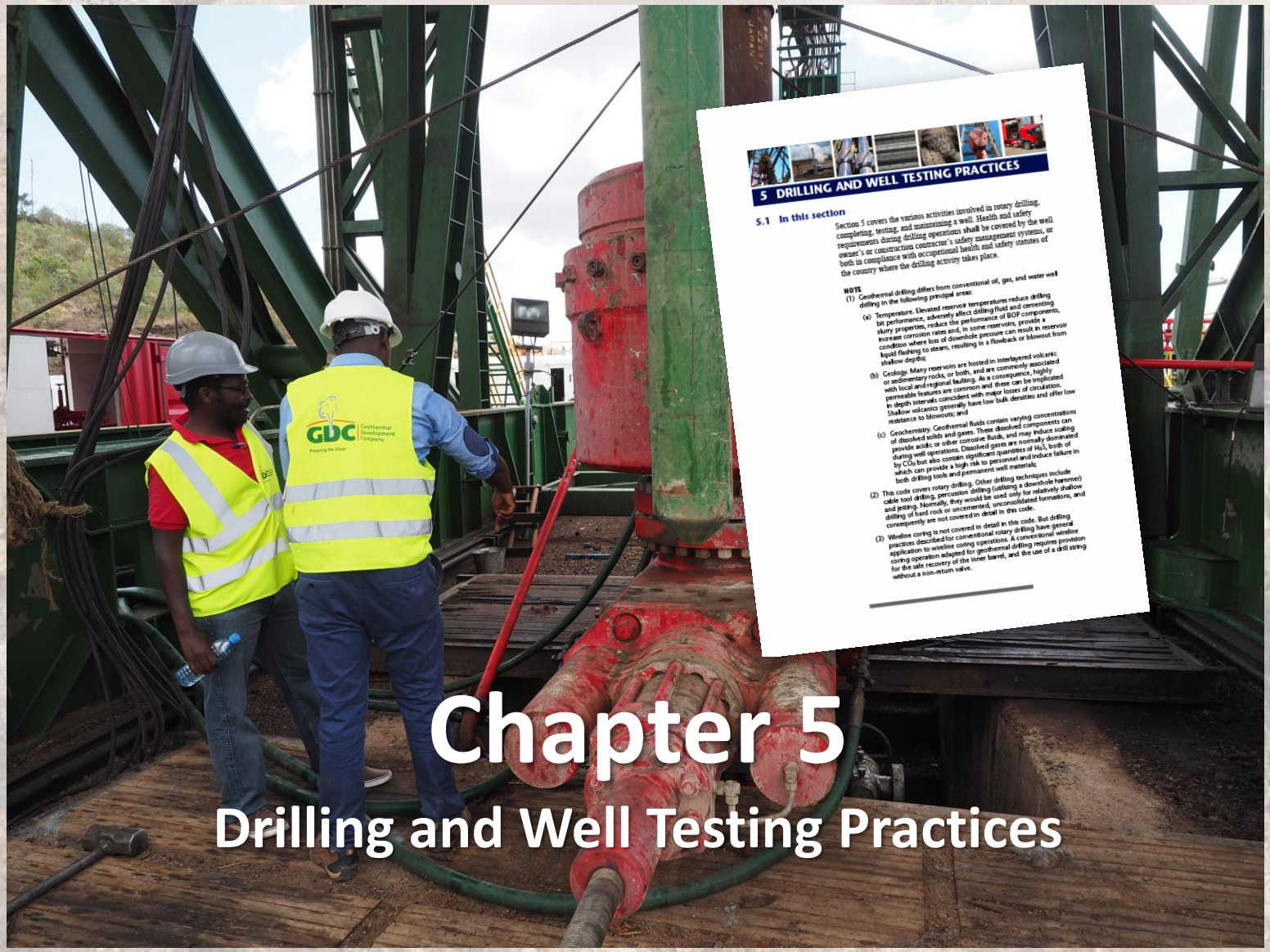
- Water based – bentonite, polymers and additives, to the deepest cemented casing or liner.
- Aerated fluids, no bentonite in production section
- Loss Circulation Material (LCM) – size to not affect pump valves, downhole tools, stable at high temperature.

Consumables
(Continued)

Cement Plugs

- For combating loss circulation zones.
- For sidetracking in open hole.
- As completion plugs.
- Pumping spacers with LCM to seal partial loss zones.
- Balanced cementing plugs.


These 5 tools
come with no
spare parts!
See that yours
last a lifetime!



Chapter 5

Drilling and Well Testing Practices

5 DRILLING AND WELL TESTING PRACTICES

5.1 In this section

Section 5 covers the various activities involved in rotary drilling, completing, testing, and maintaining a well. Health and safety requirements during drilling operations shall be covered by the well owner's or construction contractor's safety management systems, or both in compliance with occupational health and safety statutes of the country where the drilling activity takes place.

NOTE

(1) Geothermal drilling differs from conventional oil, gas, and water well drilling in the following principal areas:

(a) Temperature. Elevated reservoir temperatures reduce drilling bit performance, adversely affect drilling fluid and cementing slurry properties, reduce the performance of BOP components, increase corrosion rates and, in some reservoirs, provide a condition where loss of downhole pressure can result in reservoir liquid flashing to steam, resulting in a flowback or blowout from shallow depths;

(b) Geology. Many reservoirs are hosted in interlayered volcanic or sedimentary rocks, or both, and are commonly associated with local and regional faulting. As a consequence, highly permeable features are common and these can be implicated in depth intervals coincident with major losses of circulation. Shallow volcanics generally have low bulk densities and offer low resistance to blowouts; and

(c) Geochemistry. Geothermal fluids contain varying concentrations of dissolved solids and gases. These dissolved components can provide acidic or other corrosive fluids, and may induce scaling during well operations. Dissolved gases are normally dominated by CO_2 but also contain significant quantities of H_2S, both of which can provide a high risk to personnel and induce failure in both drilling tools and permanent well materials.

(2) This code covers rotary drilling. Other drilling techniques include cable tool drilling, percussion drilling (utilising a downhole hammer) and jetting. Normally, they would be used only for relatively shallow drilling of hard rock or uncemented, unconsolidated formations, and consequently are not covered in detail in this code.

(3) Wireline coring is not covered in detail in this code. But drilling practices described for conventional rotary drilling have general application to wireline coring operations. A conventional wireline coring operation adapted for geothermal drilling requires provision for the safe recovery of the inner barrel, and the use of a drill string without a non-return valve.

Drilling and Well Testing Practices

- Activities in rotary drilling, completing, testing and maintaining a well.
- Health and safety requirements shall be covered by well owners or contractors safety management systems and in compliance OHSA statues of the country.

Chapter 5 – Drilling and Well Testing Practices

- Differences in Geothermal drilling
  - Elevated reservoir temperatures – bit, cement, BOP, corrosion, liquid flashing to steam, blowouts.
  - Interlayered volcanic or sedimentary rocks –highly permeable, low bulk densities.
  - Geothermal fluids with dissolved solids and gases – acidic or corrosive fluids, H_2S and CO_2, high risk to personnel and equipment materials.

Drilling Fluids

- At least one person directly in control of the operational rig shall have a valid well control certificate (2 years).
- Drilling fluid properties to be measured and controlled are:
  - density
  - viscosity
  - get strength
  - water loss, and
  - solids content.
- Monitoring of drilling fluids volumes, flow rate, temperatures and contents of returns – early Well Kick warnings and losses.
- Drilling fluids circulated to lift cuttings, hole cleaning and cooling.

Drilling Fluids
(Continued)

- Drilling fluids circulated to lift cuttings, hole cleaning and cooling.
- Return fluids shall be cooled before pumping back to maintain fluid properties, avoid boiling and avoid equipment damage.
- When using water for drilling, consideration should be given to pumping high viscosities sweeps to help in hole cleaning.
- Ensure adequate supply of water when drilling **blind**, or stop drilling until water storage is built up.

Drilling String Practice

- Design, selection and use of drill string components as per API RP 7G.
- New drill string connections should be broken in Thread lubricants for high temperature should be used for rotary shouldered connections, **casing threads X** – API RP 5 A3.
- Calibrated torque gauge to be used to ensure that correct make-up torque is applied to drill string connections.

Drilling String Practice
(Continued)

- Drill string component inspections at regular intervals for wear, corrosion, cracking, pitting based on previous drilling and storage.
- Tripping speeds to be restricted to avoid surge and swab pressures Should have non return valve at lower end of drill string.

- Cooling downhole tools while tripping in by circulating through the drill string to avoid damage and formation damage.

Well Control

- A drilling well head with BOPs shall be installed for all phases of drilling after **first** casing string is cemented.
- Drilling wellhead attached to deepest cemented casing that extends back to surface except when shallower casing satisfies design requirements for predicted service conditions.
- BOP shall have provision to completely **SHUT OFF** the well with or without drilling tubulars in the hole, together with kill and choke line below shut off point.

Well Control
(Continued)

- Minimum Drilling well head requirements:
  - Valve or Ram type BOP with shut off rams.
  - Annular type BOP with kill and choke lines lower part of lower.
  - BOP or drilling spool between BOP and casing head.

- Master valves installation – avoid damage by tools, have primary isolation of well bore, using a sleeve or flange with smaller ID.

Testing and Inspection of BOPs

- When drilling underbalanced with positive annulus pressure a rotating BOP and diverter shall be included in the well head.
- Drilling well heads shall be pressure tested assembly and prior to drilling out cement from casing.
- BOPs shall be regularly inspected, function tested and maintained in accordance with API STD 53.
- **BOP drills – regularly to familiarize the crew with well control.**

Drill Practices to Avoid Well Influx

Avoid flow back or well discharge by these practices:

- Filling the drilling before re-establishing circulation.
- Maintaining trip speeds to avoid surge and swab.
- Filling hole with fluid when pulling out drilling string.
- Cooling drilling fluids on surface.
- Pumping at adequate rate to cool the well.
- Avoid pumping fluid with foam down the well.
- Adequate fluid density maintained over reservoir pressures.
- Hole filled with fluid with sufficient density.
- Controlled rate of penetration to allow hole cleaning.
- Pumping water down the annulus when drilling blind and monitoring the pump on the annulus.
- Breaking circulation in stages while tripping in the hole.

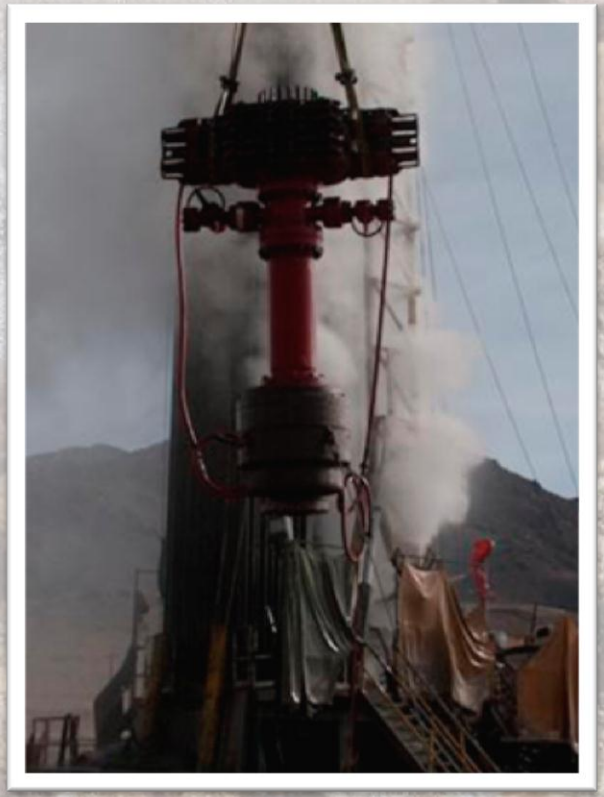
Well Control by Monitoring

Drilling parameters to be monitored to maintain well control:

- Changes in the total volume of drilling fluids.
- Signs of formation gas in the drilling fluid returns.
- Increase in temperature and flow rate of returns.
- Drilling break or increase in rate of penetration (ROP)
- Loss of circulation.
- Pumping at adequate rate to cool the well.
- Loss of drill string weight while drilling.
- Contamination of drilling fluids by reduction in density or chemical properties.
- Change in stand pipe pressure due to deeper loss of returns.

Well Control by Monitoring
(Continued)

Well control procedures shall be implemented at the first sign of a flowback or possible flowback – ready to pump cold water down the well.



Managing Hazardous Gases

When hazardous gases are detected in the fluid returns:

- Take all safety actions are taken to ensure that personnel are not a risk.
- Pick up off bottom, continue rotation, increase pump rate.
- If needed close the BOP and well circulated back to the pits through the choke lines.

Managing Hazardous Gases

(Continued)

- The sensors recording the gas parameters should be working and working properly with **alarms** set for gas levels.
- The working breathing apparatus and escape pack breathing apparatus to be available in working and fully charged condition.
- List of personnel on location to assist in accounting for crew when assembling at muster point.

Running Casing

- Casing shall be handled and stored as per API RP 5CI.
- Avoid physical or welding damage to casing and connections.
- Lower thread protectors (pin end) should not be removed until in the mast, except when cleaning and inspecting threads.

Running Casing
(Continued)

- Prior to running threaded casing thread protectors should be removed, threads cleaned and visually lubricated.
- Casing to be drifted on the racks as per API Spec 5CT.
- Damaged casing to be rejected, marked and replaced.
- Casing joints to be measured, recorded and reconciled in the final casing tally.
- Different casing grades, weights or connections shall be positively identified.
- Centralisers with stop rings and not placed over couplings.

Running Casing
(Continued)

- Casing preparations prior to starting running casing include:
  - All casing handling equipment and accessories
  - All cementing materials
  - All cementing accessories
  - Measuring devices
- Shall be on the ground and fully operational.
- Thread locking lubricants shall be formulated to perform well at the anticipated elevated temperatures.
- If welding is unavoidable, qualified welders to be used.

Running Casing
(Continued)

- Prior to running casing hole should be free of ledges, dog legs and thick wall mud cakes, have additional rat hole.
- Circulate the hole prior to running casing to remove any cuttings and reduce gel strength and fluid loss (wiper trip?).

Running Casing
(Continued)

- Proprietary connections shall be torqued as per manufacturer's recommended procedure and type of thread lubricant used.
- Thread dope for casing shall be as per API RP 5A3.
- A backup tong and make up tong to be used to make up casing connections, do not use locked rotary table.
- Casing running speeds controlled to avoid excessive surge.

Running Casing
(Continued)

- Casing running speed to be reduced before inserting slips to prevent shock loading.
- While running casing, circulate the hole using circulating head to cool the well while reciprocating the casing to avoid differential sticking.
- Prior to cementing after running casing circulate the hole to cool the well.

Cementing Casing

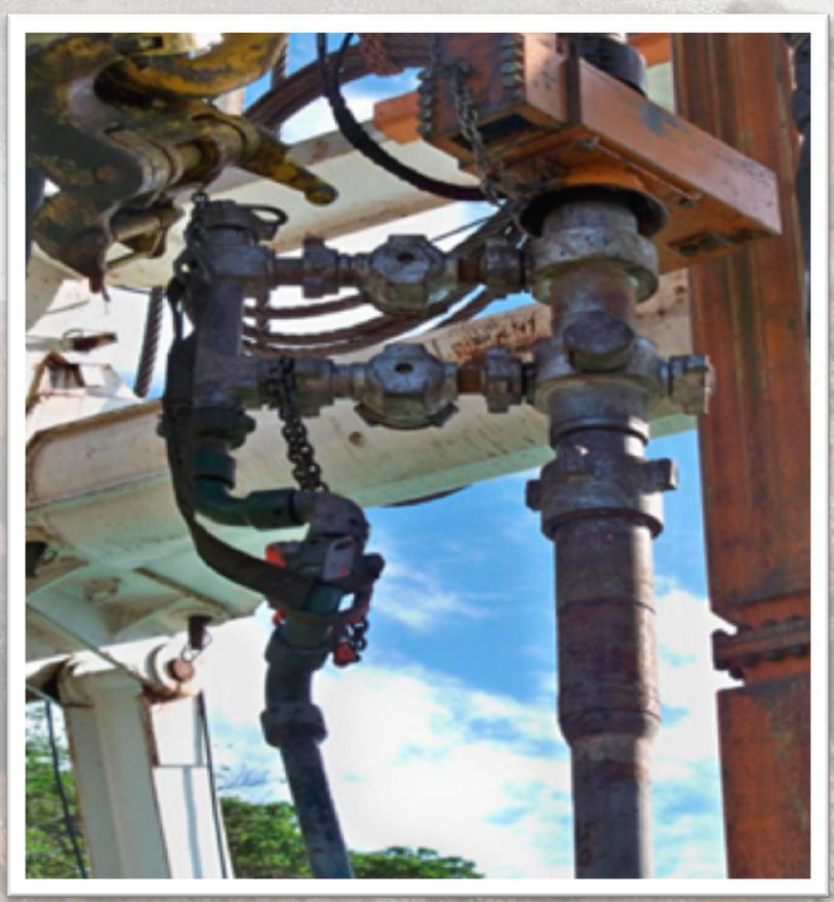
- Cementing program
  - Designed to ensure entire length of annulus is filled with a good quality cement, no water entrapped in the casing to casing annulus.
- Slurry volume allowance for:
  - Displacement of contaminated slurries.
  - Overgauge hole.
  - Losses to the formation.

Cementing Casing
(Continued)

- Cement spacers prior to pumping cement for removal of mud and mud cake and reduce contamination of cement.
- Water or dense mud spacers, chemical flushes to seal loss zones and mud removal and scavenging cement slurry.

Cementing Casing
(Continued)

- Cement delivery pipework shall be installed so that pumping of cement can commence immediately after cement is displaced from inside casing (top plug), to avoid periods when cement slurry not in motion.



Cementing Casing
(Continued)

- Mixtures used for cementing shall be monitored and measured throughout the job to ensure the actual concentrations are maintained as close to design values.
- The cement returns to be monitored continually to check if the sub standard cement is in the casing to casing annulus, then flush the annulus to the shoe with water and may even break down the formation (watch collapse pressure and internal yield of casings and delivery lines).
- Back fill the casing to casing annulus if primary cement does not reach the surface, avoid trapping water.

Cementing Casing
(Continued)

- While pumping cement pressure applied to be limited to prevent casing damage over entire casing length.
- Pressure test drilling wellhead and casing prior to drilling out cement based on max anticipated service conditions and be held for five minutes and any leaks to be fixed.
- Squeezed (shutter) the casing shoe with cement if needed.
- The cellar shall be cleared of cement slurry before the cement sets, use sugar as a retarder.

Questions and Break

Lost Circulation

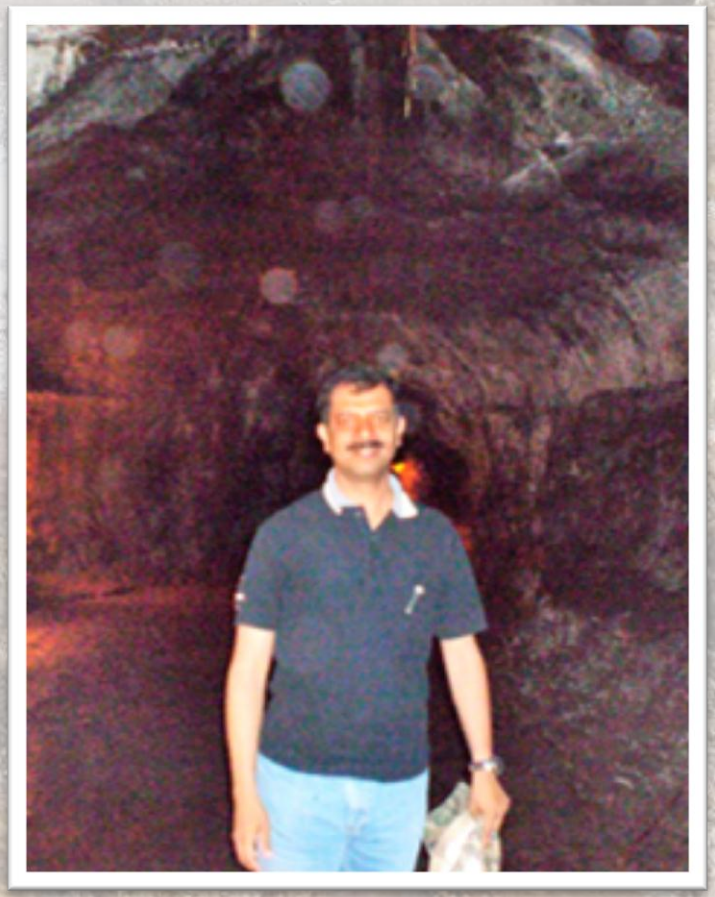
In order to reduce likelihood of inducing circulation losses:

- Use drilling fluids with density causing pressure marginally over the reservoir fluid pressures.
- Controlled tripping speed to avoid surge and surge pressures.
- Avoid excessive wall cake build up.

Lost Circulation
(Continued)

When drilling the deepest cement casing, try to seal all the loss zones.

- Partial losses sealed with mud or LCM.
- Drill to the bottom of loss zone prior to treatment.
- Chemical sealing additives.



Lost Circulation
(Continued)

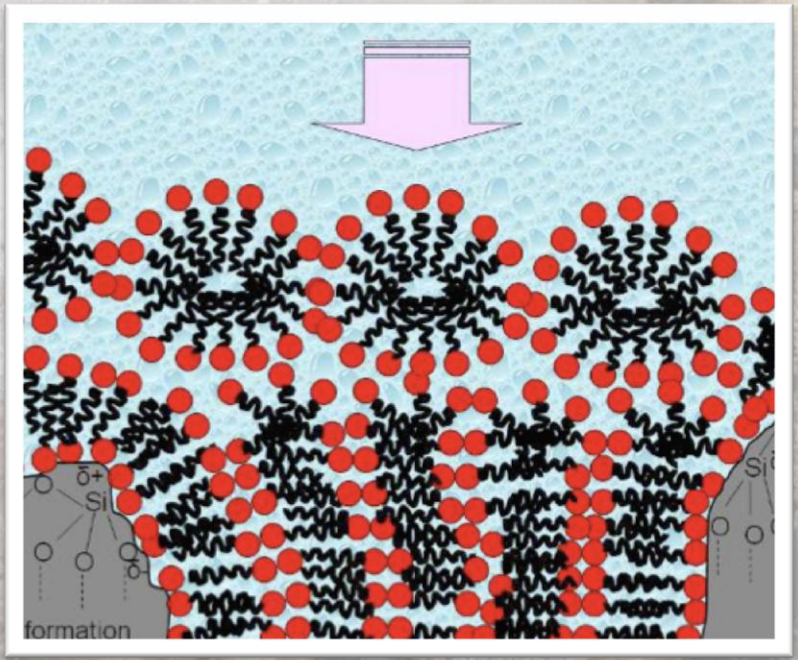
In order to reduce likelihood of inducing circulation losses:

- Use drilling fluids with density causing pressure marginally over the reservoir fluid pressures.
- Controlled tripping speed to avoid surge and surge pressures.
- Avoid excessive wall cake build up.

Lost Circulation
(Continued)

When drilling the deepest cement casing, try to seal all the loss zones.

- Partial losses sealed with mud or LCM.
- Drill to the bottom of loss zone prior to treatment.
- Chemical sealing additives.



Directional Drilling

- Selection of directional drilling equipment shall have consideration for additional capacity to overcome drag in the inclined hole.
- Kickoff point at least 50 meters below previous casing shoe.
- Drill string design should consider limitations of API RP 7G, not to be exceeded for hole geometry and drilling.
- Avoiding the rotation of hard banded tool joints when inside the casing where there is a change in hole angle.

Directional Drilling

(Continued)

- Pump liquid down annulus when total loss circulation (TLC) or use high temperature rubber protectors.
- When well is completed run a casing caliper to access the casing for any damage.
- Surveys across the complete wellbore to determine well track which will help in anti collision on multi well site.

Fishing

- All tubulars and tools run in the well bore shall be measured: Lengths, OD, ID, Fish necks and serial numbers.
- Fishing tools shall have a max OD not larger than the min drift diameter of the smallest casing in the well.
- No tools with large OD or fish neck to be run in hole which will make fishing them difficult.

Fishing
(Continued)

- Allowance in depth calculations for thermal expansion and contraction of the fish and the fishing string.
- The operating limits of the drill-stem as per API RP 7G.
- Explosives for fishing – consideration of operational temperature limitations.

Well Completions

- Inner cemented casing shall be logged to provide baseline record for casing condition and monitoring.
- Prior to running perforated liner ream the hole.
- Clean the well bore after reached **TD**, and strap out of the hole.
- Assess the well condition prior to running in the perforated liner, and make provision for well control as needed.
- Have adequate water supply for well quenching.

Well Completions

(Continued)

- Check for how long the well will stay quenched.
- Blank ends at the top of casing joint for well control.
- Blank liner on rig floor (end seal) for rapid installation If the time is not adequate, drop liner in the well.
- Internal tapered guide on top of slotted liner for easy entry of wireline and drilling tools
- The ID of the slotted liner to be clean of debris if manually slotted.

Installation of Permanent Wellhead

- Removal and installation of permanent well head shall be undertaken with the well in a fully controlled condition.
- Either keep the well dead by pumping water into the well, or setting a retrievable packer or drillable bridge plug inside the inner cemented casing.
- All permanent well head components shall be pressure tested prior to installation on the well.
- A protection system be installed if possible to prevent surface water entering the casing annuli and allows any gas migrating up to be vented away.
- Cellar cleaned and drains cleaned to prevent water accumulation in the cellar.

Installation of Permanent Wellhead

(Continued)

- After completing the well and prior to allowing the well to heat, a fixed point on the well head shall be measured and recorded with reference to a datum point on the cellar.

Installation of Permanent Wellhead

(Continued)

- Rig shall be released after the well has been completed in a safe condition and well head equipment shall be secured against operation by unauthorized personnel.
- The range of conditions under which a well can be safely operated shall be specified and documented, and later reviewed to reflect any changes in reservoir conditions.

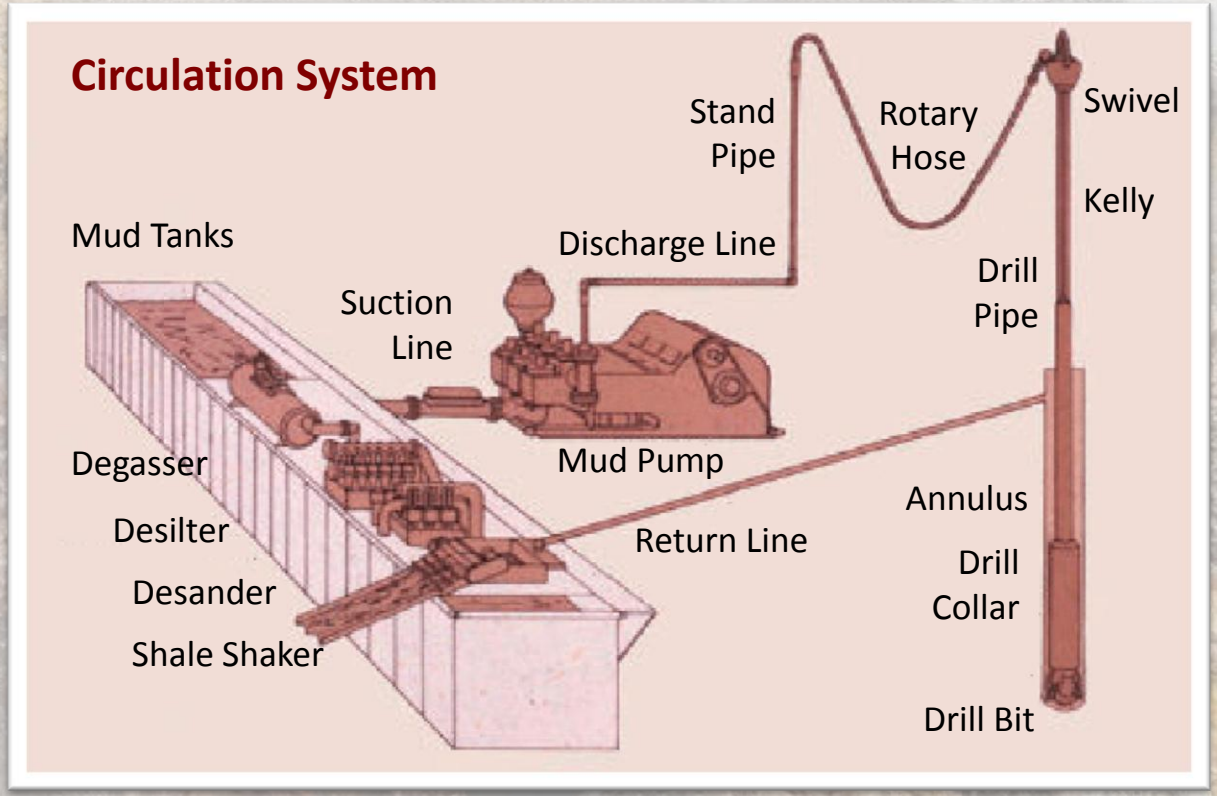
Well Logging and Testing

- Downhole conditions shall be assessed by running downhole logs and tests, while drilling, on well completion and periodically during the life of the well.
- Allowing or inducing the well to flow.
- Downhole pressure – temperature – spinner surveys.
- Pressure measurements at depth of primary permeability for well injectivity and reservoir permeability, skin effect.
- Formation integrity of leak off tests.

Well Logging and Testing
(Continued)

- Geophysical logs to map hydrothermal alteration and fracture encountered in the well bore.
- Fluid sampling at surface or downhole.
- Sampling of drilling cuttings – lag time calculations for correct sampling and correction factors when using aerated fluids.
- Cutting cores while drilling.

How to Calculate Theoretical Lay Time



© University of Texas at Austin

The are 3 steps:

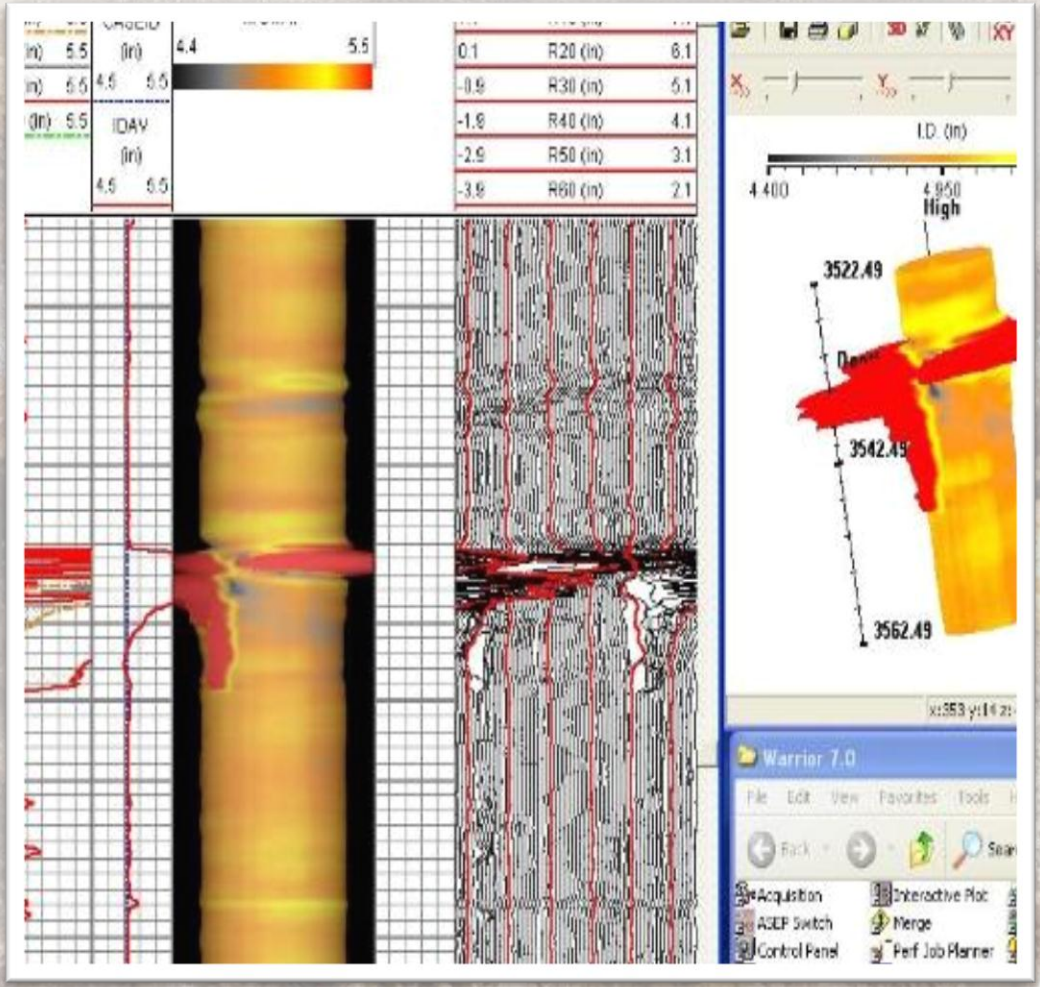
1. Calculate pump output
2. Calculate annular volume at certain depth of hole
3. Calculate the theoretical lag time

Well Logging and Testing
(Continued)

- Running downhole logs to assess cement placement.
- Down hole cameras.
- Dummy wireline runs.
- Mechanical calipers.
- Downhole retrieval of casing scale.
- Downhole videos or lead impression blockage.
- Downhole and well head conditions anticipated during logging and testing activities.
- Planned duration of the activities.
- Any changes that could happen downhole.

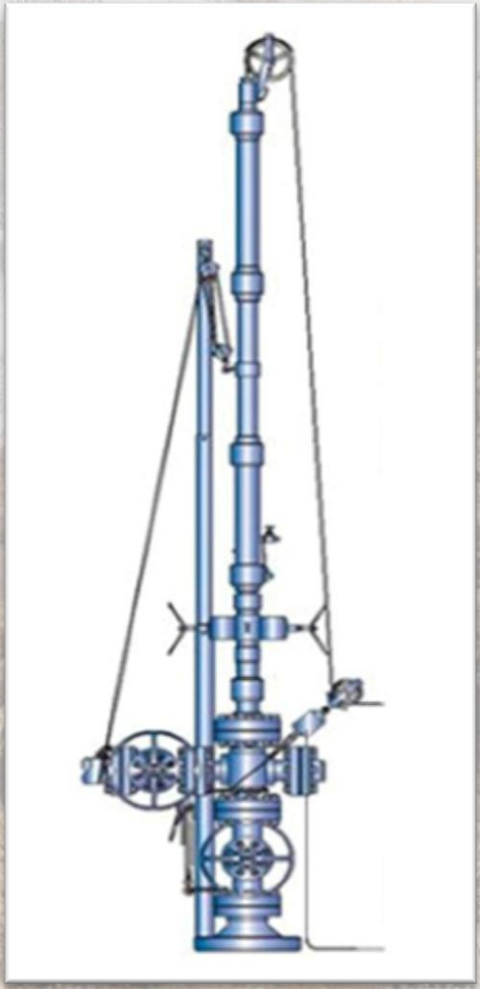
Well Logging and Testing

(Continued)



Well Logging and Testing
(Continued)

- Wireline BOP or lubricator.
- Discharging of an uncased hole can cause hole collapse due to reduction in downhole pressures.
- Pressure measurements taken with drilling mud in the well may not give true formation fluid pressures.



Well Logging and Testing
(Continued)

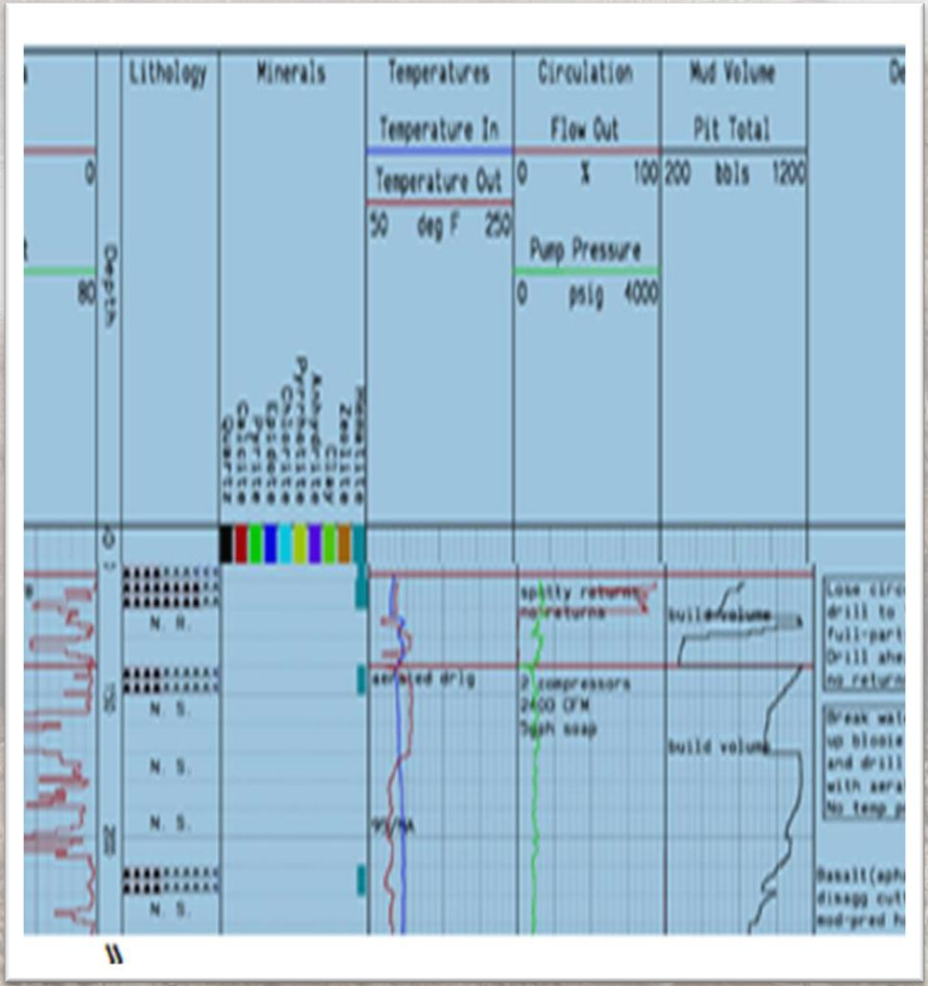
- Cooling of the hole from the drilling process could affect the temperature measurements.
- Fluid samples taken from a well during drilling may be contaminated with drilling fluids.
- All tools should be fishable.

Well Logging and Testing
(Continued)

- Thermal effects should be considered while selecting and running equipment.
- Wireline log data should be validated through comparable down and up logs across the same interval.
- Depth calibration against well construction records with provision for wireline stretch and expansion.

Drilling Records

- **Quality data acquisition** and retention of data and other information gathered during drilling including drilling parameters, cuttings logs and well logs.



Drilling Records
(Continued)

- Shall be permanently maintained and stored by well owner, and appropriate Government ministry or agency responsible for granting drilling licenses and maintaining geological data.

Drilling Records
(Continued)

Purpose of drilling records:

- Subsequent monitoring of well condition.
- For any well workover, intervention or abandonment.
- As offset data for planning of subsequent wells.
- Assist directional drillers to avoid collision by later wells and ensure well tracks within legal boundaries.
- Reservoir engineering and understand the geology.

Drilling Records: Wells
(Continued)

- Well design and Drilling Program.
- Design modifications.
- Daily drilling activity records (detailed).
- Hole measurements and casing string depths.
- Casing specifications.
- Cementing reports.

Contents

Drilling Records: Wells

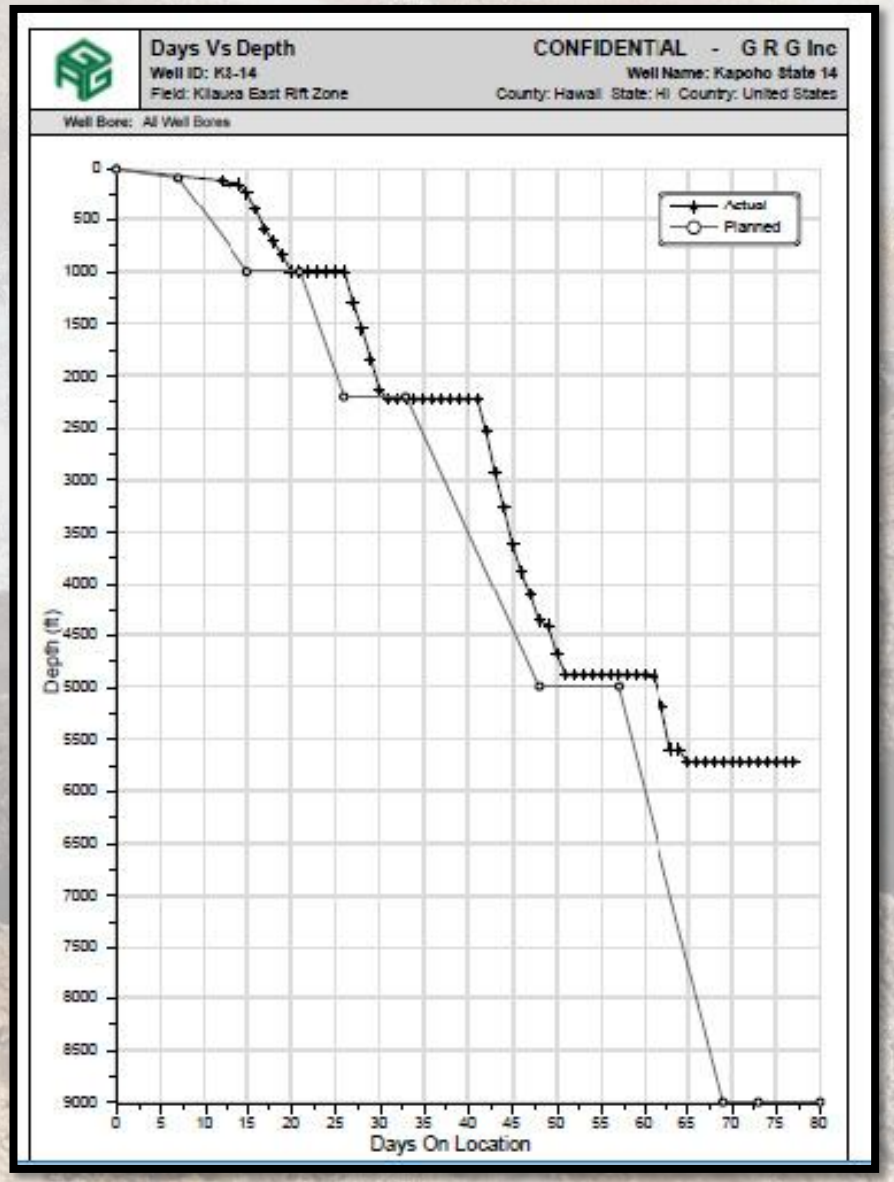
(Continued)

- Wellhead assembly (as built pictures).
- Downhole directional survey and pressure temperature surveys.
- Time Analysis and Cost Details.
- Unrecovered fish details.
- Wellhead location coordinates and datum level.
- Loss Circulation zones.
- Drilling Bits records.
- Detailed Master Log – Cores and cuttings.

Drilling Records: Daily

(Continued)

- Daily drilling activity records *(INFOSTAT Rimbase – IADC Drilling Report)*



Drilling Records: Daily

(Continued)

- Tool and drill string diameters.
- Drilling bit details.
- Drilling depth consumables – drilling fluids.
- Casing and cementing reports (if applicable).
- Detailed daily activity report.
- Changes in drilling conditions.
- Pressures.
- Drilling parameters.
- Daily cost and time breakdown.
- Safety tracker and personnel on board (POB) numbers.

6 WELL OPERATION AND MAINTENANCE

6.1 In this section

Section 6 covers the techniques and procedures to be adopted throughout the life of a well, following well completion. This includes operations pertaining to monitoring, inspecting, and repairing the well and wellhead components, and the discharging of the well. It does not include abandonment (see Section 7 starting on page 123).

6.2 Maintaining well integrity

Each well that has not been abandoned shall be operated and maintained to meet the objectives of this code, and be in general accordance with Section 2.

Any known deviation from the requirements of Section 2 (starting on page 11) shall require specific engineering assessment and an appropriate ongoing management plan.

When a potential defect is identified, additional monitoring or remedial work required to maintain the well condition shall be planned and carried out as soon as practicable, depending on the nature and the assessed risk resulting from that defect. Monitoring shall continue, at an appropriate frequency to allow for timely identification of any change in well condition, until the defect is remedied.

6.3 Well monitoring

6.3.1 – Well Monitoring Plan

A Well Monitoring Plan shall be established and maintained for both the downhole and surface components of all wells, taking into account:

(a) The subsurface conditions;

(b) The well operating range specified in accordance with 5.13.3 (see page 106);

(c) Well history;

(d) Changes observed in other wells in the field;

Chapter 6

Well Operations and Maintenance

Well Operation and Maintenance

- Procedure to be adopted during the life of a well.

- Maintaining well integrity
  - Operated and maintained as per the code and and any changes need engineering assessment.
  - When a potential defect is identified, additional monitoring and remedial work shall be undertaken ASAP (as soon as possible) depending on the nature and assessed risk.

Well Operation and Maintenance
(Continued)

- Well Monitoring – specify monitoring frequency.
  - Plan shall be established for both the downhole and surface components of all wells based on:
    - Subsurface conditions
    - Well history
    - Operating range
    - Changes in nearby wells
    - Ground subsidence
    - Well configuration
    - Equipment availability

Well Operation and Maintenance

(Continued)

Multiple Well Monitoring cover multiple wells or reservoir:

- Scope of work shall included any well or wells excluded.
- Copies of plan to appropriate agencies.
- Processes to be put in place to record any variations and take necessary action.

Well Operation and Maintenance

(Continued)

Identification of defects and Impairments:

- External or near surface leakages or corrosion of casing.
- Corrosion leakage of wellhead equipment.
- Broken or perforated casing and failed casing connections.
- Leaks in casing and buckled casing.
- Collapsed or corroded casing.
- Annular flow outside the casing.
- Chemical deposition or scale.

Observation of Change

Plan shall observe the following type of changes:

- Changes is discharged fluid chemistry, enthalpy, pressures or flow rates of production wells.
- Changes in surface manifestations of geothermal flow, new hot areas on or near the well site.
- Any indications of fluid entering into a cemented casing annulus at surface or deterioration of cement.
- Any changes in flow from the casing annuli.
- Loss of pressure measured at a side valve when the well otherwise known to be under pressure.

Wellhead Inspection Record

Documented Annual Inspection

- Wellhead pressure.
- Well Status (shut in, bleed, production, injection).
- Operating condition of well head valves.
- Leakage from valve gate or stem seals.
- Condition of protective paint coatings.
- Condition of anchor casing.
- Condition of the site and cellar drainage.
- Changes in vertical position of wellhead and position of CHF measured relative to the cellar datum.

Wellhead Maintenance

- Wellhead free of corrosion.
- Protective painted cleaned before fresh coat.
- Severe external corrosion of anchor casing is seen, casings outside shall removed to check casing and replaced after the remedial work is done.
- Anchor casing shall be replaced if pressure rating is compromised for the particular well.
- Or corrosion removed and casing painted.
- Casing annulus protection system should be maintained.
- No leakages across flanges, tappings, fittings, glands, valves and similar equipment and in sound operating conditions.

Risk Assessment

- Risk assessment for each well based on well monitoring and inspections, which should be documented.
- Any remedial works identified by the inspection program shall be completed as soon as practical.
- Especially when the potential deterioration could cause a risk to personnel safety and environmental damage.

Wells in Operation

- Master valve shall remain operational and capable of being closed at all times.
- Master valve nor side valves not to be used as flow control valves except in emergency situation.
- Master valve not to closed on a flowing well.
- Minimize the rapid change of temperature of well casings, cement sheath and wellhead. Controlled heating and cooling to mitigate this risk. Put the production well on bleed, increasing bleed rate or injecting hot fluid in the well are some measures.

Wells in Operation

(Continued)

- Bleeding of well should be done upstream of master valve through side valve, pipework should be anchored.
- Bleeding lines terminated at some distance away from the wellhead to avoid corrosion and accumulation of hazardous gases within low lying areas like the cellar.
- Designed in a way to avoid health or environmental hazard or noise nuisance.
- Any flow from the well shall be controlled by a valve, orifice plate, applies to low flow rates or high discharge rates.

Workovers

Operations conducted on completed well using drilling rig or similar equipment to achieve:

- Repair or replacement of a wellhead component.
- Repair or replacement of damaged casing.
- Removal of scale deposits from the well.
- Installation or removal of non cemented liner from the well.
- Any other work inside the well needed to modify the existing conditions in the well.

Workovers

(Continued)

More operations conducted:

- Workover operations shall comply with Section 5 needs and hazardous gases monitoring and managing.
- Prepare a well workover program including well control methods.
- Preferable to set a retrievable packer in the well than quenching the well, ***End of Well Workover report***.

Quenching

- When quenching the well with cold water gradually cool the well in a controlled manner.
- Initial flow rates to be controlled at low level at first and then gradually increased until well is off pressure.
- Sequence of 25 liters/minute for the first hour increase in 25 liters/minute increments every 30 minutes.
- During quenching control the non condensable gases by venting in order to control wellhead pressure.
- Any gas pressure that builds up in the well should be reduced slowly by bleeding prior to well quenching.

Wellhead Removal and Replacement

- Replacement of wellhead components may be undertaken using a retrievable packer set inside sound casing.
- Snub the packer, set it and take an upward pull to ensure packer is set.
- Otherwise, well is quenched and kept in the quenched condition for **twice** the estimated maintenance time required.

Wellhead Removal and Replacement

(Continued)

- Ensure adequate and secure water supply to keep well in the quenched condition.
- Any welding that is performed shall be in accordance with the welding procedures (pre- and post-heat).
- Cutting and removal of parts to avoid damage to other casing sections, if the wellhead height is changed – new height.

Downhole Works

- A drilling wellhead including BOPs shall be installed in any well that has potential to discharge during the downhole works.

Downhole Works

(Continued)

- A new casing or scab liner across damaged or failed casing, shall be cemented over its full length. The well bore below scab liner should be isolated from any other operations using a drillable plug or packer set in the casing.
- When drilling scale in a permeable well, fluid returns and pump pressures should be continually monitored as bit can be plugged or drill string can get stuck.

Suspended Wells

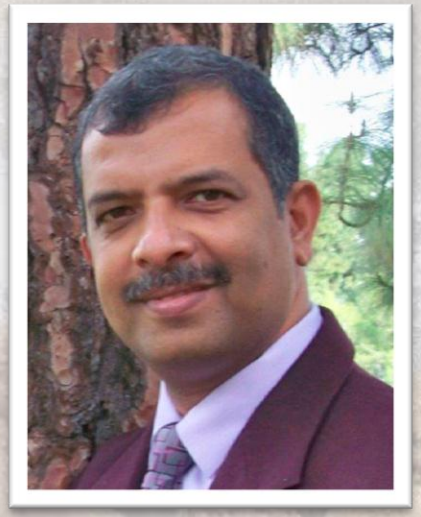
- Cement plugs shall be placed (not less than 100 meters) of continuous cement inside production casing.
- Cement plug placed on bridge plug near production casing shoe above 10 meters of the liner.
- Minimize dilution of cement slurries by well fluids
- Cement should withstand ambient fluids and temperatures.

Suspended Wells

(Continued)

- Casing above the sound cement should be filled to surface with drilling fluid (bentonite).
- Pressure test cement plug to a sufficient test pressure to provide sufficient integrity for duration of well suspension.
- Wellhead can be removed except the CHF.
- End of Well Workover report shall be prepared.

Questions



Thank You!

Sam Abraham, M.Sc.

Sam Abraham

Geothermal Engineer and Consultant

Email: *abrahamsamsamuel@yahoo.com*
Skype: samasrig

79843 Castille Drive
La Quinta, California 92253 – USA

Cell USA: +1 442 666 4367

Cell Kenya: +254 711 749 337
Cell Ethiopia: +251 937 931 375

Thank you to our sponsors

African Union

BGR Bundesanstalt für Geowissenschaften und Rohstoffe