ARZESH AFARIN

MINING & MINERAL INDUSTRIES CO.

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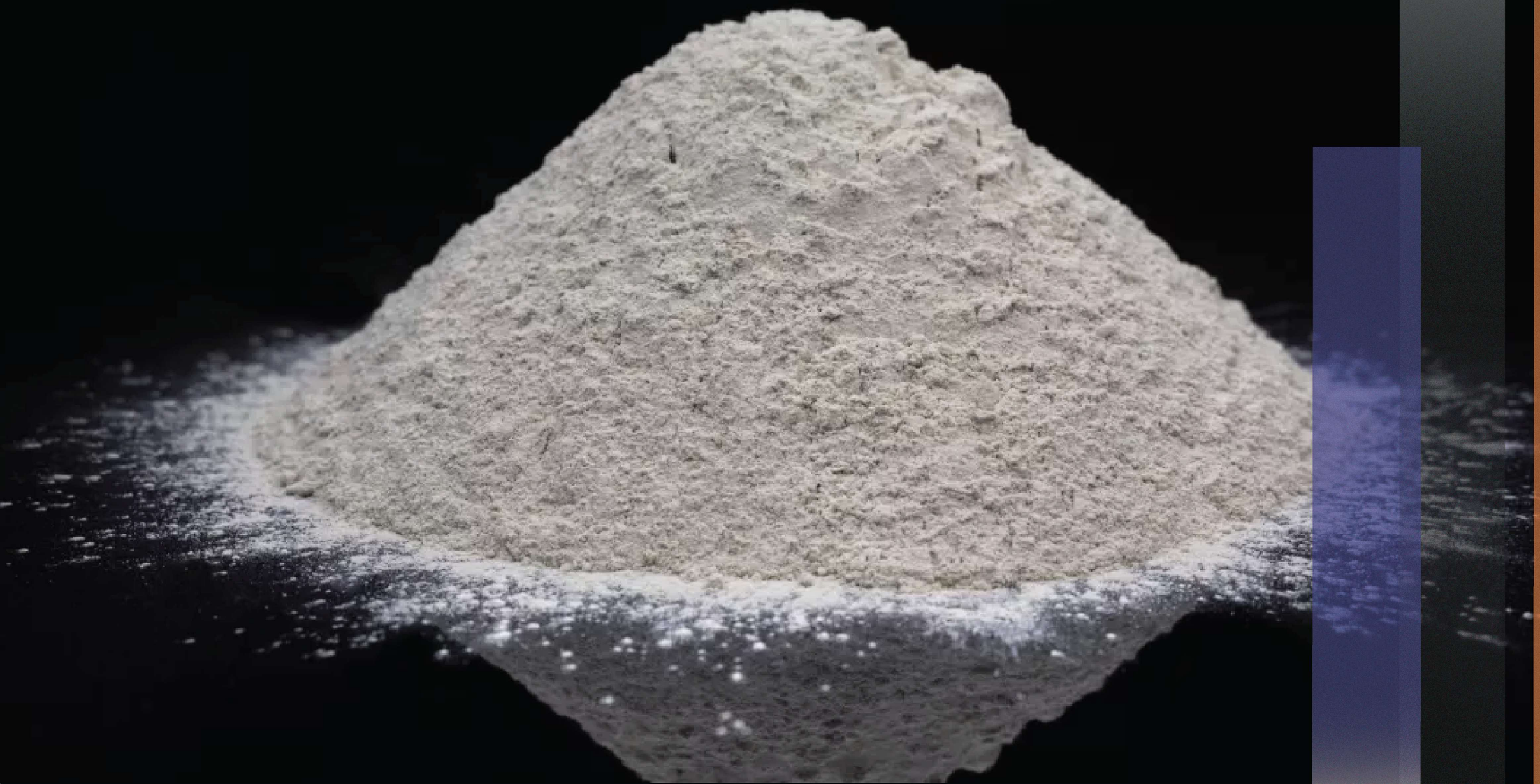

Drilling Bentonite

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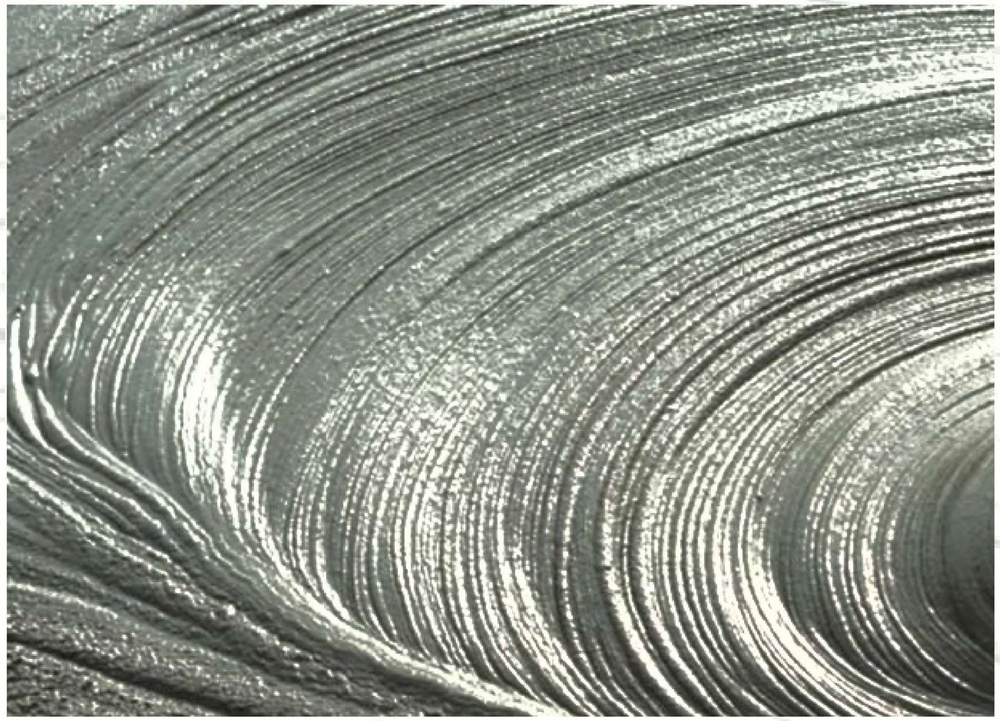

Functions of drilling mud

1- The drilling mud system plays a crucial role in drilling operations and can be likened to the circulatory system in the human body because drilling cannot be performed without this fluid. At the onset of rotary drilling, the primary function of drilling muds was to transport drill cuttings from the bottom of the well to the surface. However, with the development of this industry, drilling muds also evolved, moving beyond their initial form, and their roles have become more numerous and complex. Today, a good drilling mud must be able to perform at least ten functions simultaneously, which are as follows:

1. Cleaning the bottom of the well and transporting drill cuttings to the surface.
2. Cooling the drill bit and drilling pipes.
3. Lubricating the drill bit and drilling pipes.
4. Coating the well walls and preventing their collapse.
5. Controlling underground pressures.
6. Suspending cuttings and weighting materials when pumps are off.
7. Discharging sand and drill cuttings onto the shale shaker.
8. Bearing part of the weight of the drill pipes, drill collars, and casing pipes.
9. Minimizing damage to adjacent formations and providing maximum information about them.
10. Transmitting the hydraulic power of the pumps to the drill bit.

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1-1- Cleaning the bottom of the well from drill cuttings is still considered one of the most important functions of drilling muds. When mud exits the drill bit jets, due to its intense eruption, it cleans the bottom of the well and the edges of the bit. This not only extends the bit's lifespan but also increases the speed and efficiency of drilling. As the mud rises through the annulus, it carries the drill cuttings with it and transports them from the bottom of the well to the surface. While moving towards the surface,

the cuttings are also influenced by gravity, which continuously causes them to fall back into the well. If the mud's ascent speed in the annulus is greater than the cuttings' fall speed, it can be expected that the cuttings will reach the surface.

The fall speed of cuttings and solid particles depends on their geometric shape and specific weight, as well as the viscosity, molecular cohesion, weight, and speed of the mud in the annulus. The ability of the mud to keep the bottom of the well clean and transport the cuttings to the surface depends on several factors, the most important of which are the mud's speed in the annulus, weight, and viscosity.

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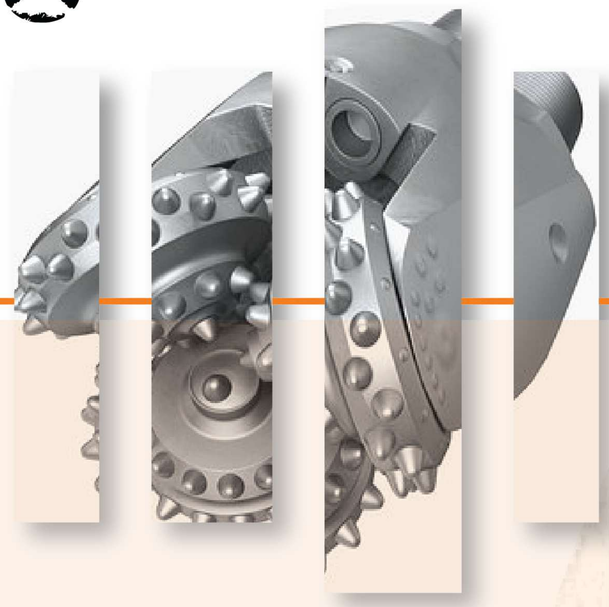
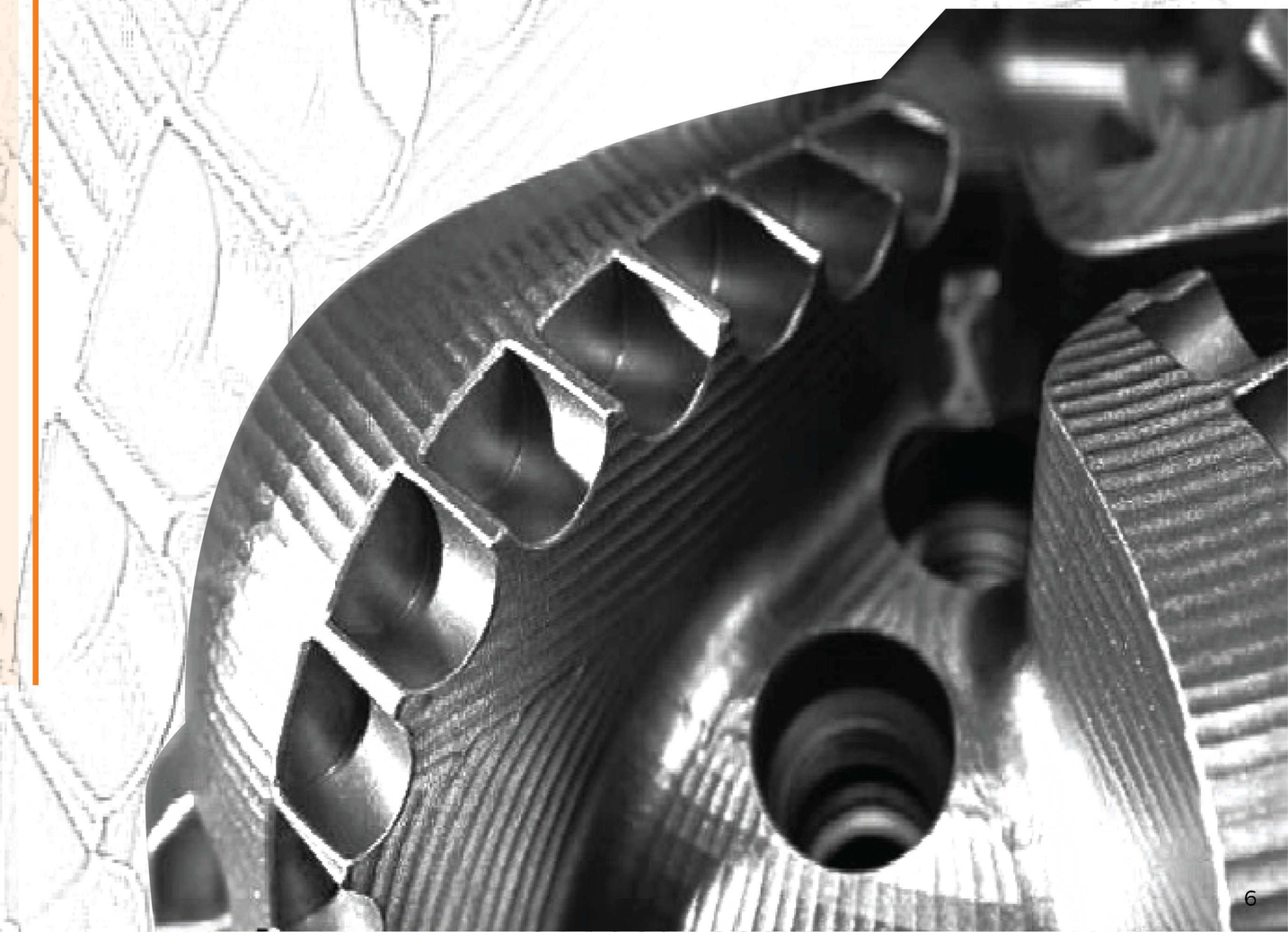


1-2- Cooling the drill and drilling pipes

At the bit and in parts of the well where the drill pipes are in contact with formations (or casing pipes), extreme heat is produced due to friction. If this heat is not rapidly transferred, the bit will burn and the drill pipes will wear through at their contact points with the formations. Since formations cannot conduct and transfer such heat away from the bit and drill pipes, the mud takes on this task. As the mud circulates in the well, it absorbs the heat produced at friction points into its liquid phase (water) and releases it into the air when it reaches the surface, cooling down and preparing to return into the well.

1-3- Lubricating the drill and drilling pipes

Drilling mud also somewhat lubricates the bit and drill pipes in the well. Clay, used in most water-based drilling muds, acts as a lubricant in addition to its other functions. Adding oil or other lubricating substances to the mud increases its lubricity, reducing torque on the bit and drill pipes, extending the bit's lifespan, and reducing the pressure on mud pumps. However, if the weight on the bit is excessively high, even the best oil-impregnated mud cannot prevent bearing erosion and failure. In such cases, using extreme pressure lubricants can be effective in resolving the issue.



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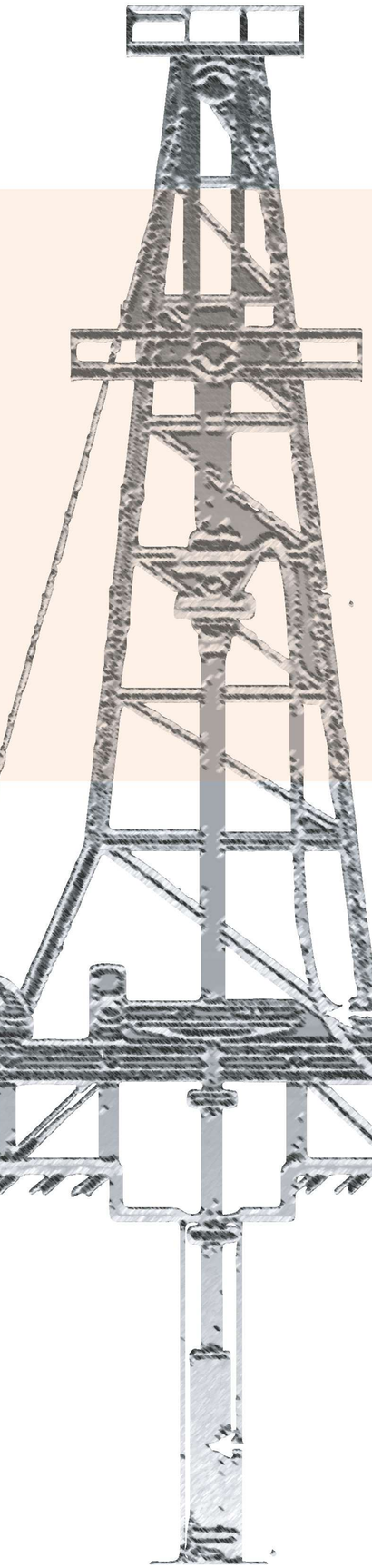
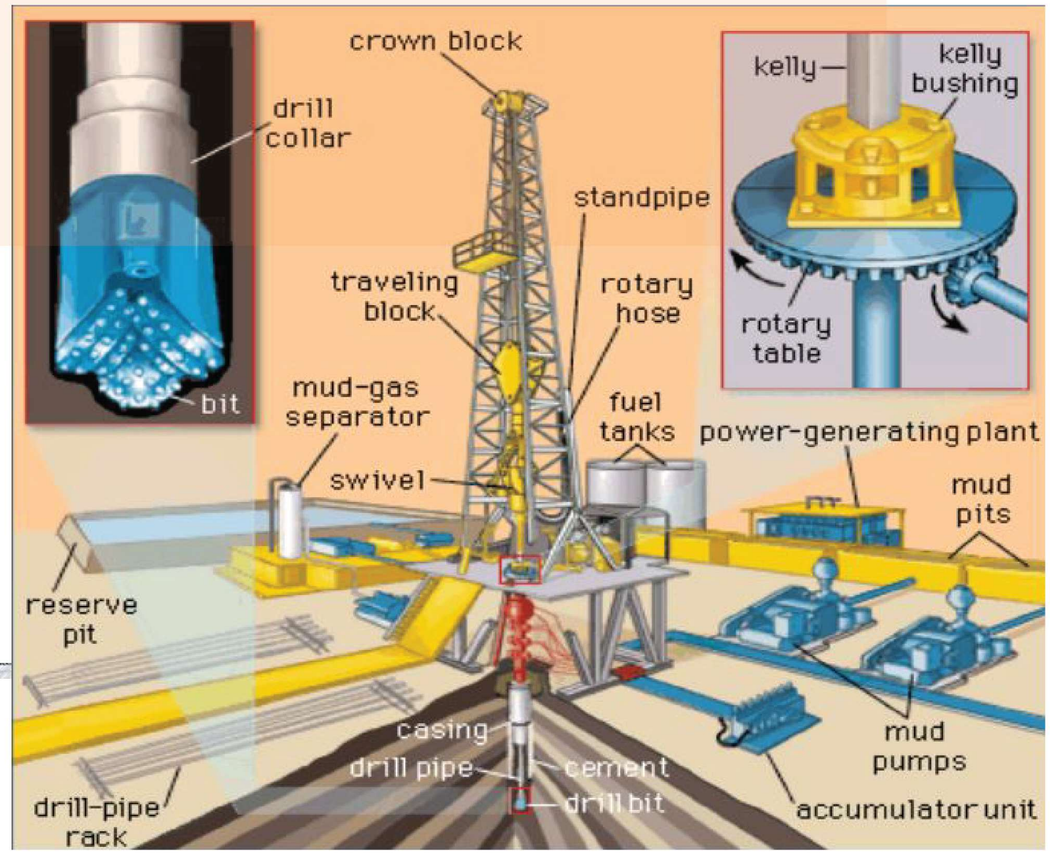
1-4- Lining the wall of the well and preventing it from falling

A good drilling mud must be able to coat the well walls, even if they have a loose and incoherent texture, with a thin, impermeable layer to prevent mud and filtrate loss into formations and to help stabilize and consolidate the well wall rocks, preventing their collapse into the well.



Adding bentonite and chemically treating the mud to create a uniform environment of solid particles and avoid flocculation enhances the colloidal properties of the mud and its ability to form an impermeable coating on the well walls. Sometimes, the mud must be treated with fluid loss control agents (like starch) to improve the quality of the coating and reduce mud filtrate loss.



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1-5- control of underground pressures

During drilling, formations containing water, oil, or gas under very high pressure may be encountered. Controlling these subsurface pressures is the responsibility of the drilling mud. One of the physical properties of mud is creating hydrostatic pressure in the well. This pressure depends on the mud weight and well depth. By appropriately adjusting the mud weight with weighting materials, the hydrostatic pressure can be equalized with formation pressure for control. The difference between mud pressure and formation pressure is known as differential pressure. If this differential pressure is positive, meaning hydrostatic pressure exceeds formation pressure, there is a risk of fracturing the well walls and losing mud into the formations. If the differential pressure is negative, meaning hydrostatic pressure is less than formation pressure, there is a risk of well flow and potential blowout. Note: The normal pressure gradient is 0.465 psi/ft of depth, equivalent to the pressure of a column of formation water one foot high.

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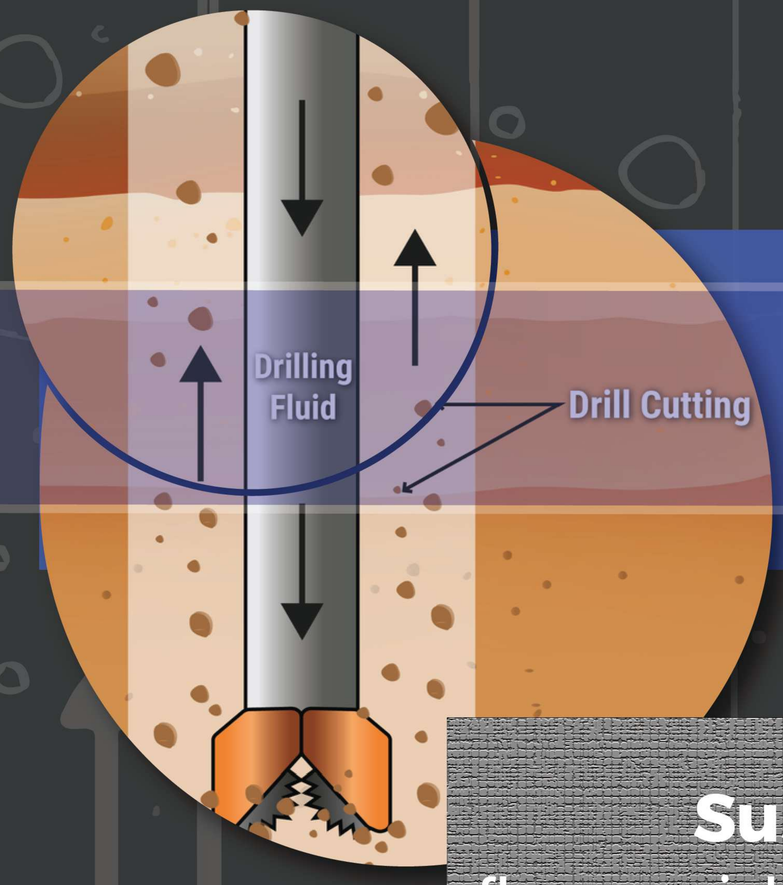

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1-6- Keeping the logs and mud weighting materials suspended when the pumps are turned off.

operations for various reasons. The duration of this stop can range from a few minutes to several hours (or even days). During this time, cuttings and solid particles in the mud can settle in the well, burying the bit and a large portion of the drill pipes, making further drilling impossible or at least very difficult. However, if the mud has sufficient weight, viscosity, molecular cohesion, and gel strength, it can be expected to keep the cuttings and other solid particles suspended during the entire period of inactivity, locking each particle in place until circulation resumes, preventing their sedimentation.

Suspending
flower weight increasing material

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Vibrating Screens

1-7- Clearance of sand and drilling logs on vibrating screens

A good drilling mud should allow easy separation of drill cuttings and sands when poured onto shale shakers, preventing their return into the well. Sand content on shale shakers is crucial because sand is highly abrasive, and if not removed from the mud and re-entering the pumps, it can cause rapid and severe wear of their parts and connections. The sand content in the mud should always be measured, especially when drilling sandy formations, and should never exceed two percent.

1-8- Bearing part of the weight of drilling pipes and wall pipes

As drilling depth increases, the weight of drill pipes and casing pipes to be lowered into the well increases, putting more pressure on their supporting devices on the rig. Since the pipes will inevitably be in the mud, they will experience buoyancy, reducing their weight by the volume of mud displaced (Archimedes' principle). This weight reduction, borne by the mud, benefits the hoisting equipment holding the pipes on the rig. Naturally, the heavier the mud, the lighter the pipes become, or in other words, their apparent weight decreases.

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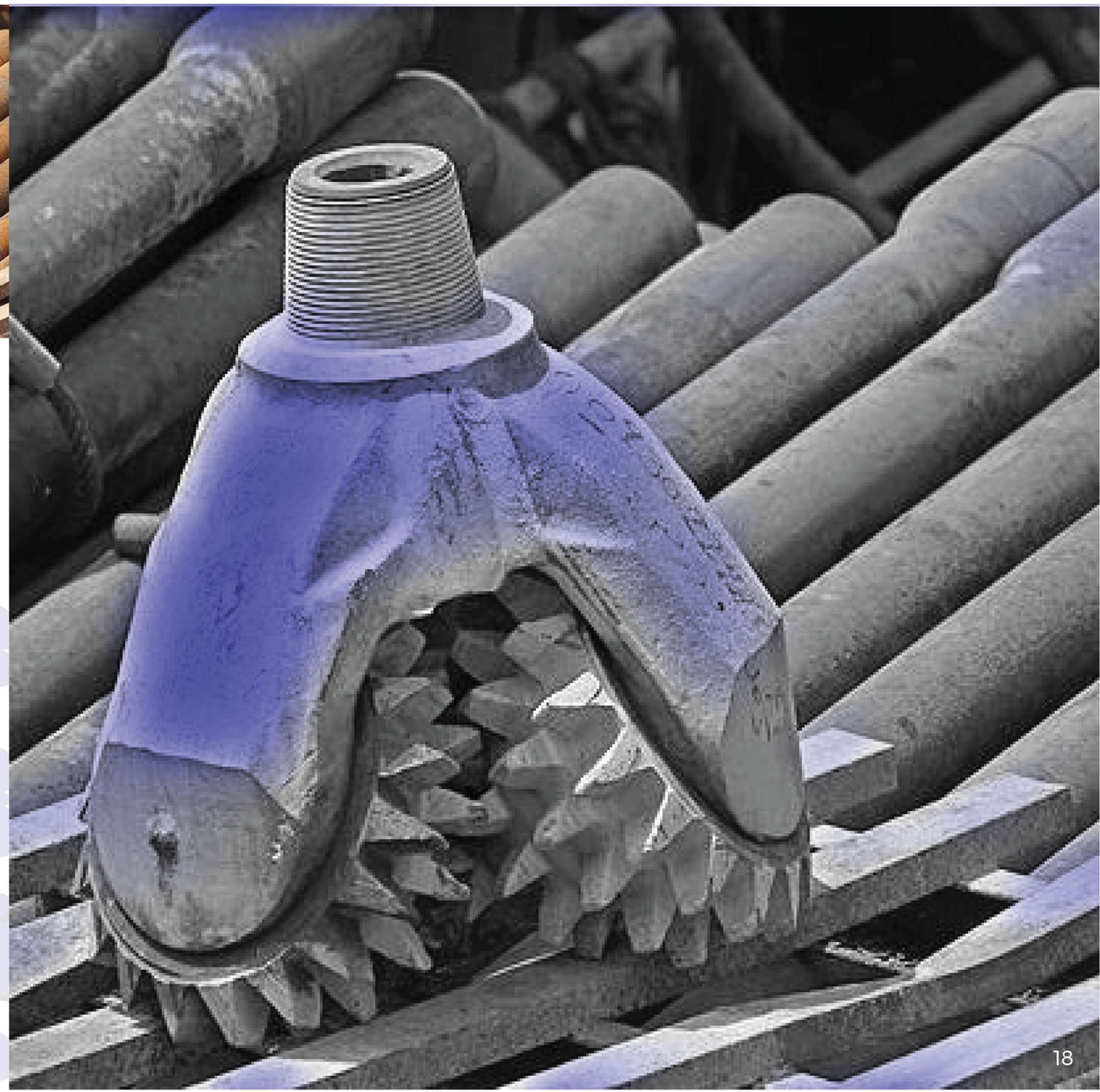
1-9- Minimizing the damage to the formations near the well and providing maximum information about them.

To protect formations, maintaining all drilling mud properties at an optimal level is essential, but sometimes these properties must be sacrificed to obtain sufficient information about the drilled formation. For example, salt, though it destabilizes the mud and increases its filtrate loss, must be added to the mud to control its resistivity for accurate results from electric logs. Similarly, adding oil to the mud, though it improves well efficiency and production rate, must be avoided if it disrupts geological operations



1-10- Transmission of hydraulic power of pumps to the drill

Drilling mud is a continuous medium that transfers power generated by pumps to the drill bit while losing some of this power as heat along its path (ineffective power). Therefore, not all the power generated by the pumps reaches the drill bit; only a part of it, known as effective power, reaches the bit for cleaning the well bottom. During drilling mud planning, sufficient attention must be paid to its hydraulics, meaning the mud circulation speed, its physical properties, and the type and percentage of suspended solid particles must be considered to minimize heat loss and maximize effective power for well bottom cleaning.

Drilling mud applications maintain high quality when its properties are regularly controlled by standard tests. Properties such as weight, viscosity, gel strength, fluid loss, abrasive agent content (like sand), pH, etc., are indicators of mud efficiency. In addition to these properties, various chemical tests are performed on the mud and its filtrate to control properties and determine mud loss amounts. These tests include pH, alkalinity, lime content, salt content, hardness, etc., which will be discussed in future chapters.

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2- Properties of drilling mud and how to measure them

In this section, we will discuss some of the properties of drilling mud that affect its performance and how to measure them. These properties are:

1. Specific Gravity
2. Mud Viscosity

2-1- Specific Gravity of Drilling Mud

The specific gravity of drilling mud is particularly important in drilling because it creates hydrostatic pressure at depth, which can prevent problems caused by the hydrostatic pressure of the layers. In the drilling industry, the specific gravity of mud is usually specified in pounds per gallon. Due to the ease of converting gallons to barrels, the barrel is often used as the volume unit for mud tanks (with drilling mud tanks ranging from 300 to 700 barrels).

2-2- Viscosity

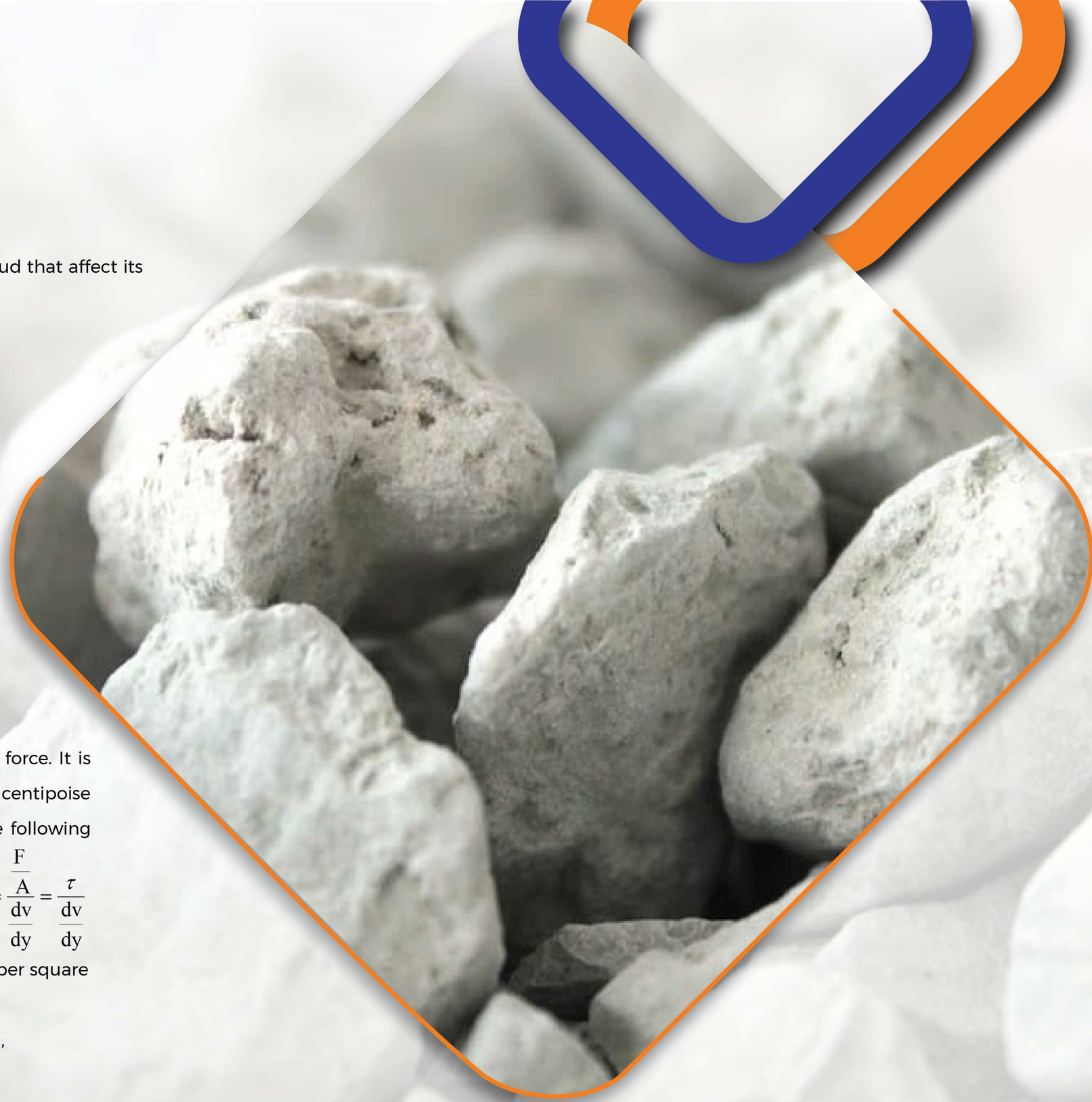
Viscosity is the resistance a fluid shows to flow under an applied force. It is represented by the symbol uuu and is typically measured in centipoise (one-hundredth of a poise). The viscosity is determined using the following relation:

$$u = \frac{\frac{F}{A}}{\frac{dv}{dy}} = \frac{\tau}{\frac{dv}{dy}}$$

In this equation:

- τ is the shear stress causing the fluid to flow (measured in dynes per square centimeter in the CGS system),
- dv is the change in velocity (measured in centimeters per second),
- y is the height or thickness of the fluid (measured in centimeters).

Therefore, the unit of viscosity in the CGS system is dyne-second per square centimeter, or poise. The viscosity of water at room temperature (25°C) and atmospheric pressure is one centipoise.



2-3- Plastic Viscosity

Plastic viscosity is part of the resistance to flow due to mechanical friction. This friction can arise from: a) The collision of solid particles with each other, b) The collision of solid particles with the liquid that surrounds them, c) Friction caused by the movement of fluid layers over one another.

2-4- Yield Point

Another component of the resistance to flow in drilling mud is the yield point. In fluids that are plastic or follow Bingham's law, the yield point is the point where the fluid starts to flow after a certain amount of pressure is applied.

2-5- Gel Strength

Gel strength indicates the thixotropic property of the mud, which is the measure of the inter-molecular attraction force under static conditions. When the yield point decreases, gel strength usually also decreases. However, a lower yield point does not necessarily mean the gel strength must be zero.

2-6- Bingham Plastic Model

The Bingham plastic model is often used to demonstrate the rheological properties of drilling muds. The mathematical equation for this model is:

$$S.S = S.S\Big|_{SR=\cdot} + PV \times S.R \qquad S.S\Big|_{SR=\cdot} = Y_p$$

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When using a Fann viscometer, SR is proportional to rpm (revolutions per minute) and SS is proportional to the dial reading. The equation then becomes:

$$\theta = Y_P + PV\frac{\omega}{300}$$

This equation shows that the dial reading θ\thetaθ is a function of the rotational speed ω\omegaω (where PV and τy\tau_yτy are the parameters of the equation). To obtain the values of these parameters, measure θ\thetaθ for different values of ω\omegaω, then solve for the coefficients using the resulting equations.

$$\omega_1 = 600pm \longrightarrow \theta = \theta_{600}$$

$$\omega_2 = 300pm \longrightarrow \theta = \theta_{300}$$

$$\omega_{600} = Y_P + PV\frac{300}{600}$$

$$\omega_{300} = Y_P + PV\frac{300}{300}$$

From solving the equations we will have:

$$PV = \theta_{600} - \theta_{300}$$

$$Y_P = \theta_{300} - PV$$

Apparent Viscosity (AV): Apparent viscosity is defined as the viscosity of a non-Newtonian fluid at an SR equivalent to 600 rpm. If the dial reading at 600 rpm is θ600\theta_{600}θ600, the apparent viscosity is calculated as:

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2-7- Filtration Rate

Filtration rate or the wall-building properties of the mud are determined using a filter press. The test measures the rate at which the liquid phase of the drilling mud passes through a standard filter paper under specific conditions of pressure, temperature, and time, as well as the thickness of the cake left on the filter paper due to filtration. Filtration of drilling muds is usually measured under two different conditions:

1 -1- API Standard Filtration

which takes place in the conditions of 100 psi and room temperature and within 30 minutes in some cases 7.5 minutes.

2 -2. High-Temperature, High-Pressure Filtration

Conducted at 500 psi for 30 minutes.

It should be noted that the equipment used for obtaining data for each sample is calibrated, and the error due to the experiment is very minimal and negligible.

3- Classification of drilling mud

Drilling Muds are Divided into Two Categories: Water-Based and Oil-Based

3-1- Oil-Based Drilling Mud: Oil-based drilling mud consists of petroleum hydrocarbons as the main component, along with other materials like clays or colloidal asphalts. By adding emulsifiers, polymers, and other additives, including weighting agents, the desired viscosity for drilling can be achieved.

Fresh Water Muds	pH from 9.5-7, bentonite mud, phosphate mud, natural mud (red mud, lignite mud, lignosulfonate mud)
Inhibited Muds	Water-based drilling mud that prevents the hydration of clays (lime mud, chalk mud, sea water mud, saturated salt water mud)
Flowers with a low percentage of solids	They contain %6-3 of solids, they mostly contain an organic polymer
Emulsions	Oil in water or water in oil (reversed phase, with more than %5 water)
Oil base flowers	Less than %5 water, a mixture of diesel fuel and asphalt

Oil-based drilling mud can be categorized into two main types: wet and dry drilling mud. Wet oil-based drilling mud generally has lower viscosity, higher density, and lower cost compared to dry oil-based drilling mud. It can be derived from mineral oil, synthetic oil, or vegetable oil. Mineral oil is extracted from crude oil and typically has lower cost, higher density, and greater magnetic properties compared to other oils. Synthetic oil is produced through chemical processes, while vegetable oil is obtained from plant seeds such as rapeseed, soybean, and corn. The choice of oil-based mud in drilling depends on the conditions, properties of the mud, and environmental standards in drilling.

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The solid materials in oil-based mud can be either natural or synthetic. Natural solids are typically composed of soil, rocks, and mineral deposits, while synthetic solids are usually made of polymers, metals, and nanoparticles.

Applications of Oil-Based Drilling Mud: Oil-based drilling mud is produced from a mixture of oil and other chemical compounds. This type of mud is used in situations where water-based drilling mud is not feasible or desirable. Some applications of oil-based drilling mud include:

- Increasing lubrication and reducing friction between the drill and the wellbore.
- Preventing swelling and fracturing of water-sensitive shales and rocks.
- Enhancing thermal tolerance and reducing corrosion of the drill and drilling equipment.
- Transporting and removing drilling cuttings.
- Controlling high and low pressures in the well.

Oil-based mud is prepared from oils such as diesel, motor oil, synthetic oil, and vegetable oil. Additionally, various additives like emulsifiers, viscosifiers, pH regulators, pressure reducers, bactericides, and corrosion inhibitors are added. Oil-based drilling mud has several advantages and disadvantages compared to water-based drilling mud, which are as follows:

Advantages

• Reducing drilling time and increasing drilling efficiency.

• Preventing damage to the drill and drilling equipment.

• Reducing the likelihood of the drill getting stuck in the well.

• Lowering the risk of blowouts and gas leaks.

• Improving the accuracy and quality of logging data.

Disadvantages

• High cost of preparation and replacement of drilling mud.

• Environmental and health issues arising from the disposal of drilling mud.

• Requirement for special equipment and devices to maintain and control mud properties.

• Chemical and physical issues due to the interaction of drilling mud with reservoir fluids.

• Legal restrictions and permits related to the use of oil-based drilling mud.

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Additives for Oil-Based Drilling Mud

Additives for oil-based drilling mud are chemical compounds added to the oil mud in drilling to impart desirable properties and eliminate undesirable ones. Oil-based mud additives in drilling can be divided into several general categories, which include:

Viscosifiers

Viscosifiers are chemical compounds that increase the viscosity of the drilling mud, thereby enhancing its performance in drilling operations. Some benefits of viscosifiers include:

•Enhancing the transport of drilling cuttings and reducing the risk of sedimentation.

•Improving wellbore stability and preventing the drilling tools from getting stuck.

•Better control of well pressure and prevention of mud leakage.

•Heat transfer and preventing the settling of drilling mud.

Some well-known viscosifiers used in oil-based mud include:

•Organic polymers like xanthan gum, cellulose, and polyacrylamide.

•Inorganic polymers like bentonite, attapulgite, and sepiolite.

•Natural materials like wheat flour, starch, and gelatin.

3-2- Water-Based Drilling Mud

Common additives include viscosifiers, fluid loss control agents, weighting agents, lubricants, emulsifiers, corrosion inhibitors, salts, and pH control agents.

3-2-1- Sea Water Mud

This type of water-based mud is designed for offshore drilling. Sea water has a low salt content, around %4-3 sodium chloride, but due to the presence of magnesium and calcium ions, it has high hardness. This hardness can be removed by adding sodium hydroxide and disodium carbonate to precipitate these ions.

Additives used for sea water mud include:

Bentonite Clay
Ligno sulfonate
Lignite
CMC
Custic Soda

3-2-1-1- Seawater drilling mud additives

3-2-1-2- Additives for Reducing Fluid Flow Rate

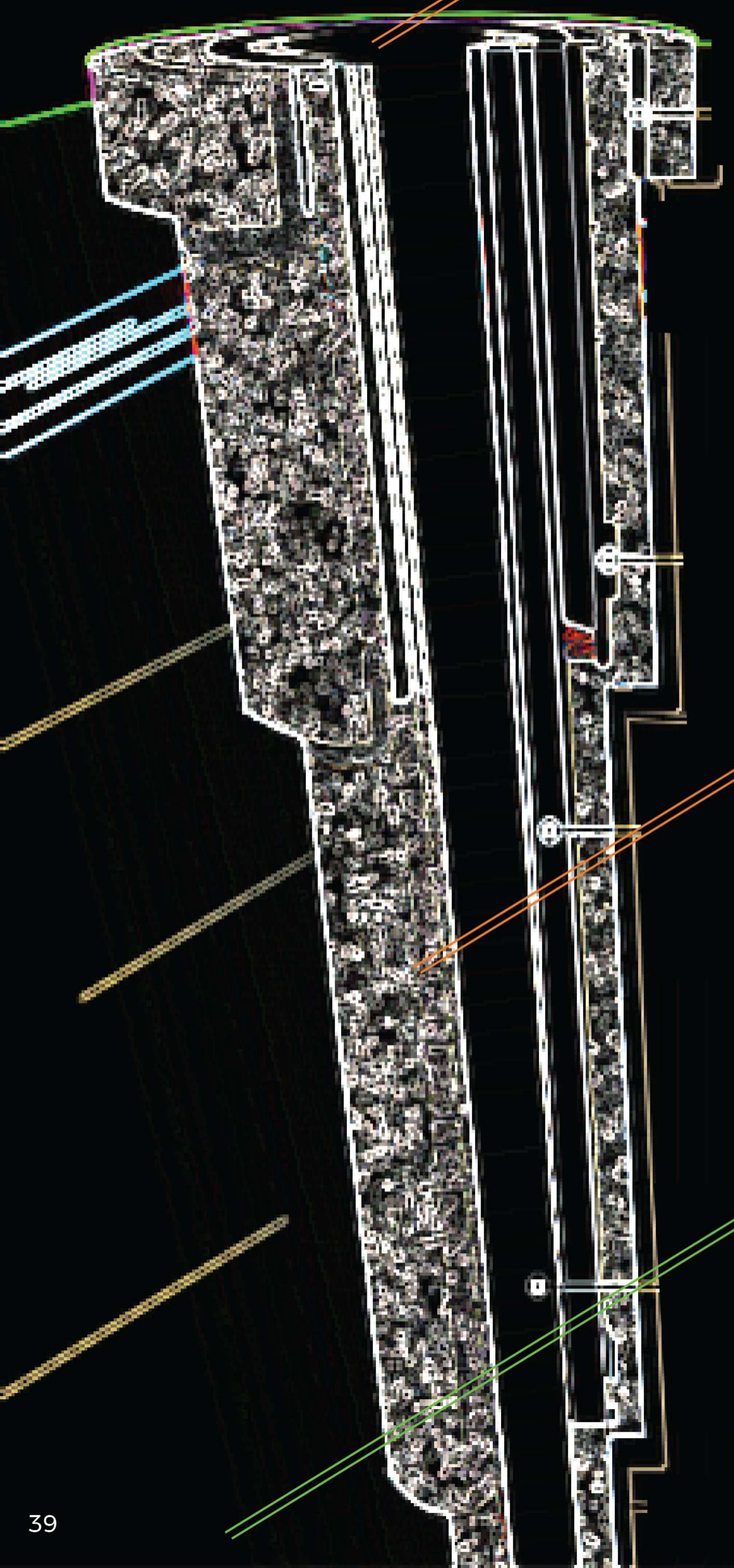
Reducing the fluid flow rate occurs when the fluid comes into contact with a porous environment. This issue pertains to fracturing fluids and cement slurries. The extent of fluid flow reduction depends on the porosity and permeability of the drilling environment. Fluid flow reduction additives are divided into several categories:

(Note: The categories for the fluid flow reduction additives were not provided in the original text. Additional information might be required to complete this section.)

Mineral additives

Bentonite
Sodium Metasilicate
Bridging agents include calcium carbonate, suspension salts or oil-soluble resins

Typical well design and cementing



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4- Well Cementing

Cementing wells, especially deep ones like exploratory, oil, gas, and water wells, is performed for various reasons without exception. The casing pipe requires cementing to prevent the drilling mud from flowing out of the well. Additionally, to prevent fresh groundwater layers near the surface from entering the well, the space between the outer wall of the surface casing pipe and the well needs cementing. The outer wall of the intermediate casing pipe is cemented to reduce the impact of abnormal formation pressures and weak zones such as shale and clay. Finally, the final casing pipe is cemented to prevent formation fluids from entering the well and to prevent the bottom of the well from becoming bogged down. Cementing the casing pipes also increases the durability of the pipes and prevents them from wearing out due to fluids present in the formations, which are typically found in the lower layers of the earth, especially in sedimentary rocks.

The primary composition of the cements used in well cementing is similar to industrial cements (such as construction cement) but with some differences in composition. These differences are mainly aimed at enhancing the pumpability of well cements. Therefore, and for other reasons, additional materials are mixed into the cements used in the drilling industry. The type and amount of materials in well cements should create the following properties:

1. The slurry cement should be pumpable to a certain depth in the well.
2. It should quickly develop sufficient strength upon placement in the well.
3. Over the long term, it should form such a cohesive and strong bond to prevent mechanical failure.
4. The chemical composition should be such that formation fluids do not affect it.
5. The cement should be durable over time, resisting decomposition and degradation.
6. The cement must be impermeable to prevent formation fluids from infiltrating it.

4-1- Bentonite Cements and the Capabilities of Bentonite Types from Arzesh Afarin Company

Bentonite Cements and the Capabilities of Bentonite Types from Arzesh Afarin Company

Common slurry cements used in drilling wells, with specific gravities ranging between 14 to 16 pounds per gallon, have a potential for water loss. When water loss occurs, the initial strength of the cement develops very quickly and excessively. Such cement, if placed behind the casing pipes, can cause fractures in the formations, especially in weak formations, particularly when a large amount of cement is used. The water loss characteristic in permeable formations leaves a thick layer of cement on the formations. Excessive water loss into the formations can lead to water entering formations with fluid potential, which can cause the clay in the formations to react with the water, leading to swelling and blocking some pores and reducing the permeability of the formations. In such a situation, some bentonite is added to the slurry cement mixture to increase the consistency of the slurry cement. The recommended amount of bentonite in the cement mixture is up to %25 by weight, which is referred to as bentonite cement. According to the API definition, water loss occurs when the rate of water loss reaches 1000 cubic centimeters per minute. However, practical experience has shown that adding %25 bentonite reduces water loss to 100 cubic centimeters per minute. The micronized bentonite products from Arzesh Afarin Company, with minimal water loss, controlling viscosity and swelling, perform best in drilling cement. Besides having suitable rheological properties, due to the natural origin of the product, it exhibits very high stability over the usage period of the well compared to activated bentonites.

5- Types of Drilling Methods and the Role of Bentonite Grades from Arzesh Afarin Mining and Mineral Industries Co.

5-1. Manual Drilling System

In this system, drilling is carried out using human power without the use of mechanical energy.

5-2. Percussion Drilling System

Percussion or cable drilling was first used by the Chinese for drilling water wells. The drilling equipment consisted of a hard steel bit with a sharp edge attached to the end of a metal cable, which was lowered and raised by a crane to bore through the ground. Essentially, this method of well drilling is similar to using a crowbar to dig a hole and removing the soil with a bucket. In 1859, Colonel Drake used this method to drill the first oil well in the United States and the world in Pennsylvania. The primary advantage of using cable drilling is its low cost for shallow wells.

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The overall benefits of this method include:

• Low cost of rig transportation and relocation.

• Short setup time and consequently low cost of rig erection.

• High drilling speed in shallow wells, especially in hard formations compared to rotary drilling methods.

• Generally, rotary drilling systems are designed for wells with a diameter greater than four inches. Therefore, for wells with smaller diameters and depths, the percussion method is preferred.

• Simple construction and ease of repair and maintenance of its components.

However, there are significant drawbacks to this method, including:

• The most significant limitation is the drilling speed and well depth. For deep wells, the high time and cost make this method economically unfeasible. The deepest well drilled using this method reached 11,145 feet, which incurred a high cost.

• Inability to manage potential well blowouts due to the absence of drilling fluid.

• Lack of wellbore stability in loose formations due to the absence of drilling fluid.

• Frequent cable breaks, resulting in high time and cost.

Given these disadvantages and the inability to drill deep wells with this method, as well as the discovery of hydrocarbon reservoirs at greater depths, this method has become obsolete and was replaced by the rotary drilling method.

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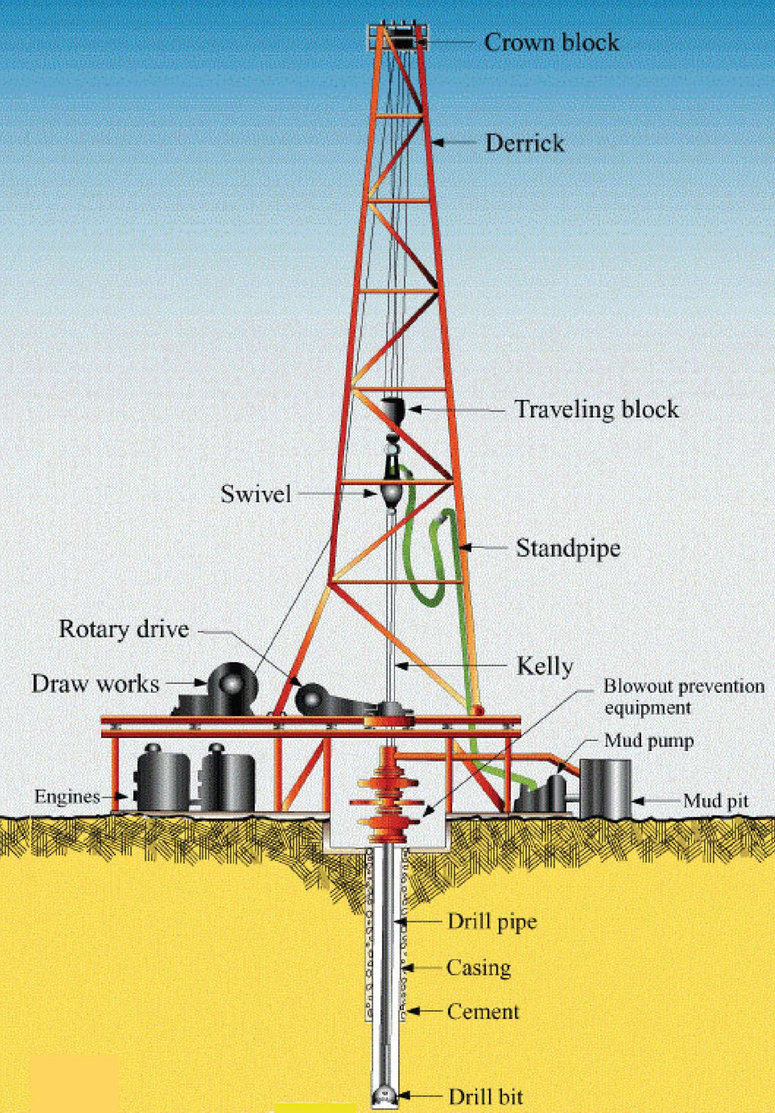

Percussion-Rotary Drilling System (HTD - Hole The Down)

In this method, drilling is achieved through the simultaneous application of impact and rotation to the drill bit using a drilling hammer and compressed air. In HTD, the piston or drilling hammer, which delivers the impact, is placed immediately after the bit and goes down the well with it. Since there is no intermediary between the drilling hammer and the bit, there is no energy loss through the drill pipe. This allows the machine to drill deeper and wider wells. Compressed air from the compressor, along with some foam and oil, enters the hammer, moving the piston inside, which then delivers continuous and efficient impacts to the bit. Additionally, the injected air and foam pass through the hammer and the bit neck to the bottom, pushing the cuttings upward.

This method is used for wells with diameters between 4 to 9 inches. The required air pressure typically ranges between 100 to 250 psi, and the air speed for removing cuttings is about 4,000 feet per minute (1,200 meters per minute). The weight on the bit needed for this system usually depends on the bit diameter and rotation speed. Drill pipes have a longer lifespan in HTD drilling because the only energy they transmit is the weight on the bit, not the impact energy. Noise levels are also lower as the impact source is inside the well. Challenges arise in wells with cavities or shale where bit sticking may occur, causing the loss of the hammer. This method can be used in almost all geological formations except loose and collapsing grounds. The minimum well diameter that can be drilled with HTD is usually 4 inches.

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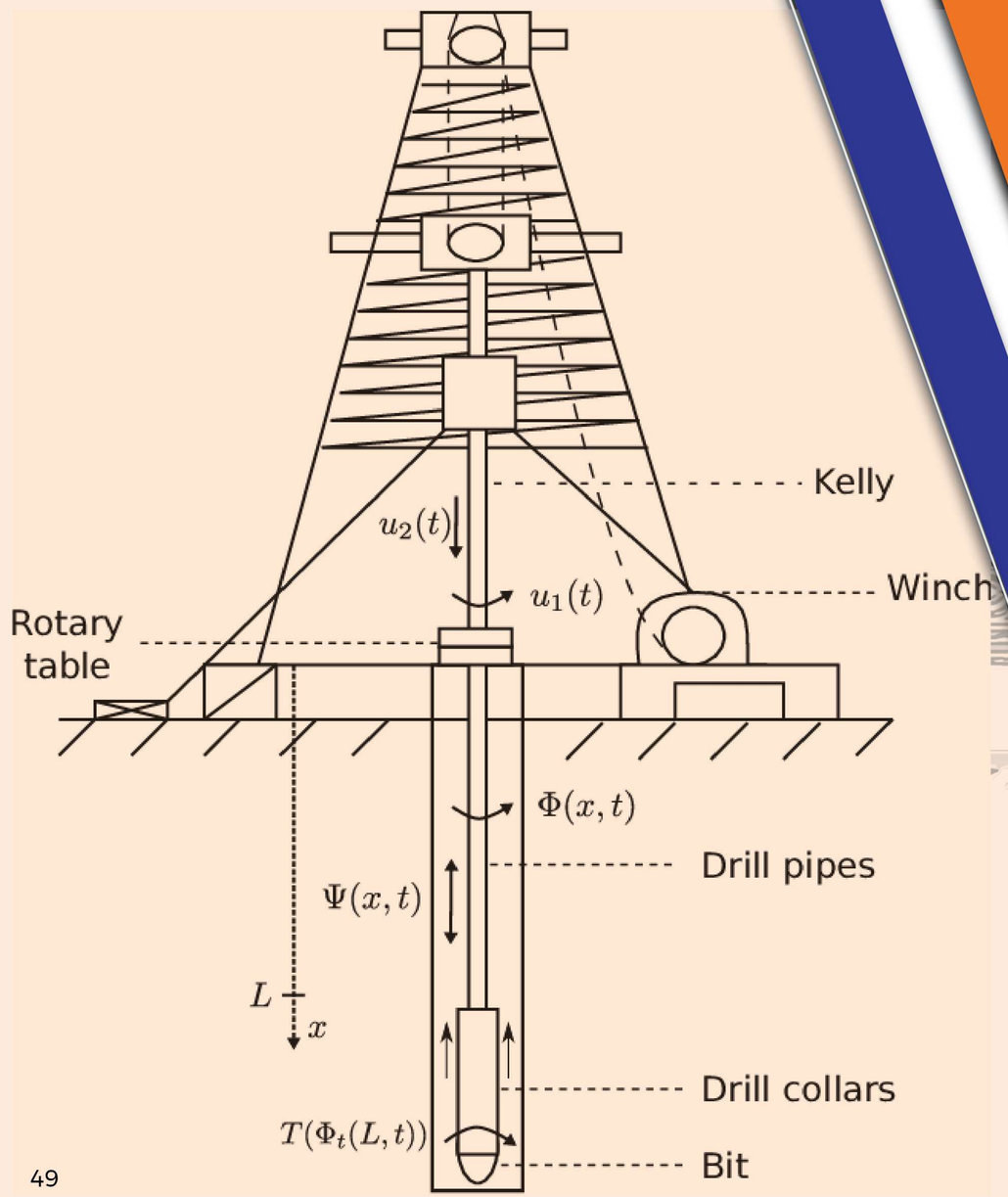

Rotary Drilling System

In 1890, the first rotary drilling rig was introduced. In this method, drilling fluid continuously circulates to bring the cuttings to the surface. The first well drilled using rotary drilling reached oil in Texas in 1901 at a depth of 1,020 feet. Today, rotary drilling is the standard method for drilling oil and gas wells. In this system, the bit is connected to the drill pipe, and penetration into the rock and well drilling is achieved through bit rotation and downward force applied using heavy and thick pipes known as drill collars, placed above the bit. Power is typically provided by steam, diesel, gas, or electricity, and the crushed particles at the bottom are brought to the surface by circulating air, water, or drilling mud. The drilling cuttings are separated from the drilling fluid at the surface. In rotary drilling, bentonite is added to the drilling fluid as a viscosifier and to transport the cuttings and line the well walls. Depending on the depth, pressure, and formation type, various grades of drilling-grade bentonite from Arzesh Afarin Company are used in vertical rotary drilling.

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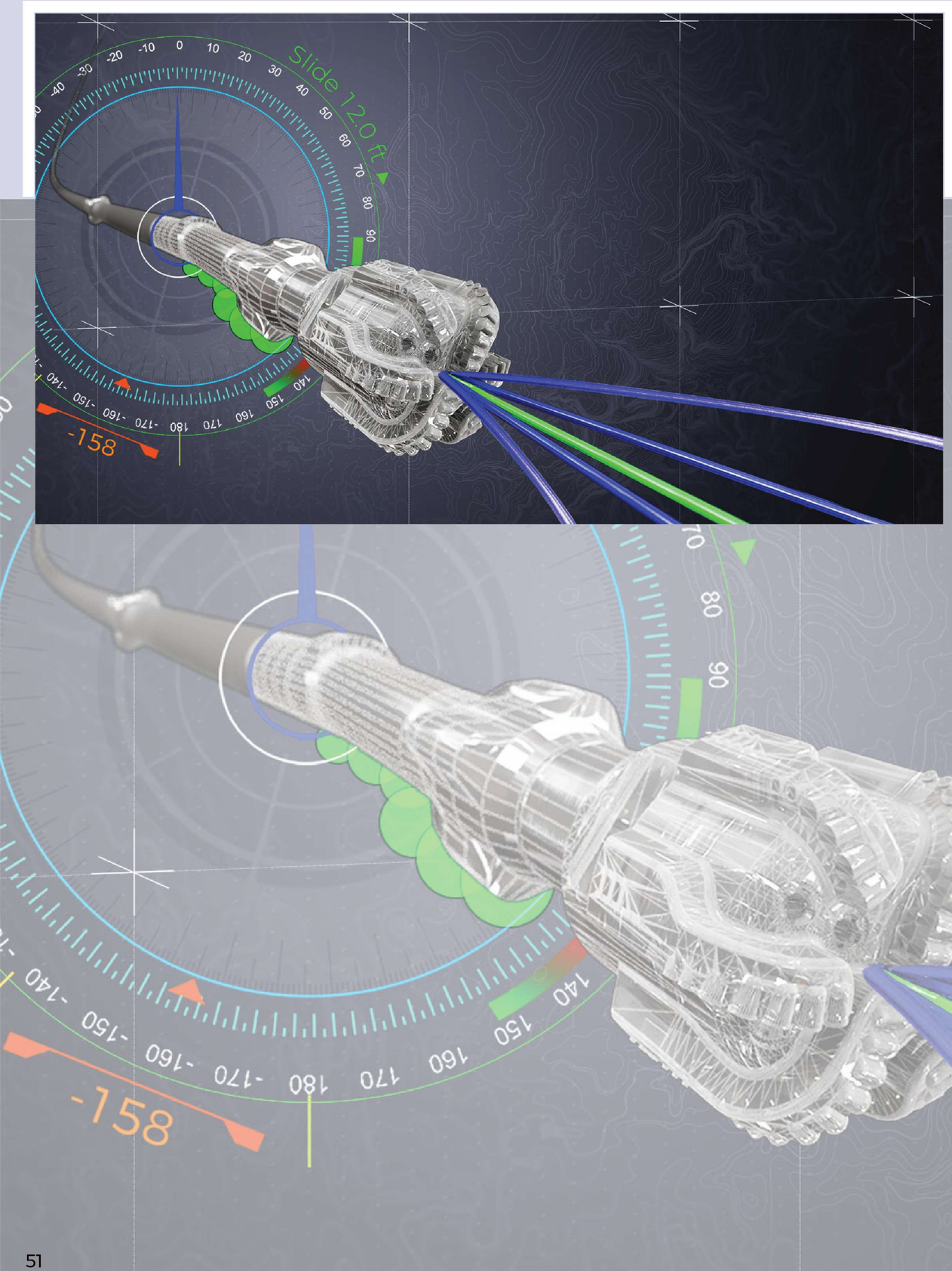

5-4- Directional Drilling

Directional drilling is a type of drilling where the well path is deviated from the vertical according to a pre-designed plan to reach the target area. This method is also known as slant, inclined, or guided drilling. It is used when the target is laterally offset from the starting point on the surface. Given the high costs of oil and gas production, directional drilling has become a necessity. The primary feature of this method is enabling producers to tap into reservoirs that would not be economically viable by any other method. Advances in mud motors and sophisticated positioning devices have significantly contributed to the development of this industry. These advanced devices, which guide the motors, provide accurate positioning data, crucial for successful directional drilling.

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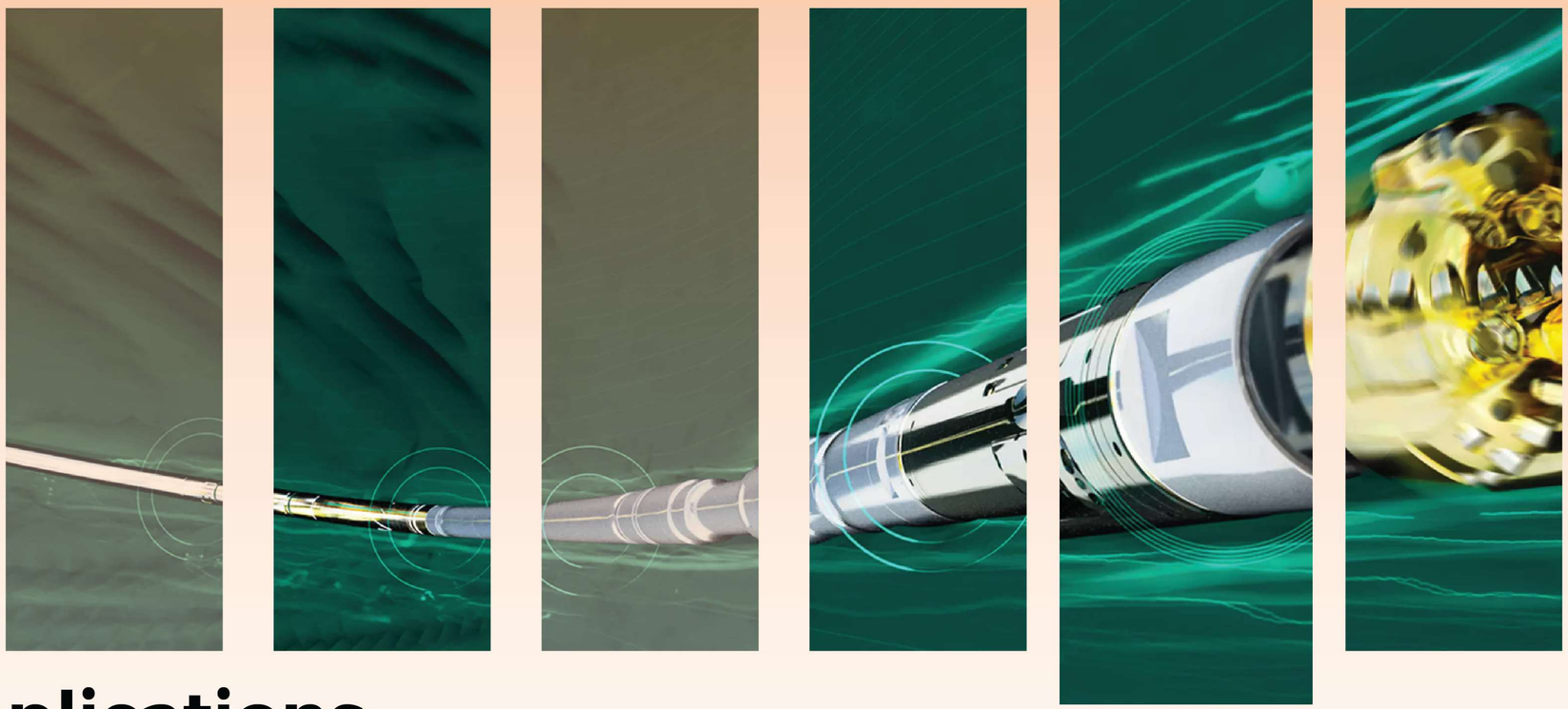
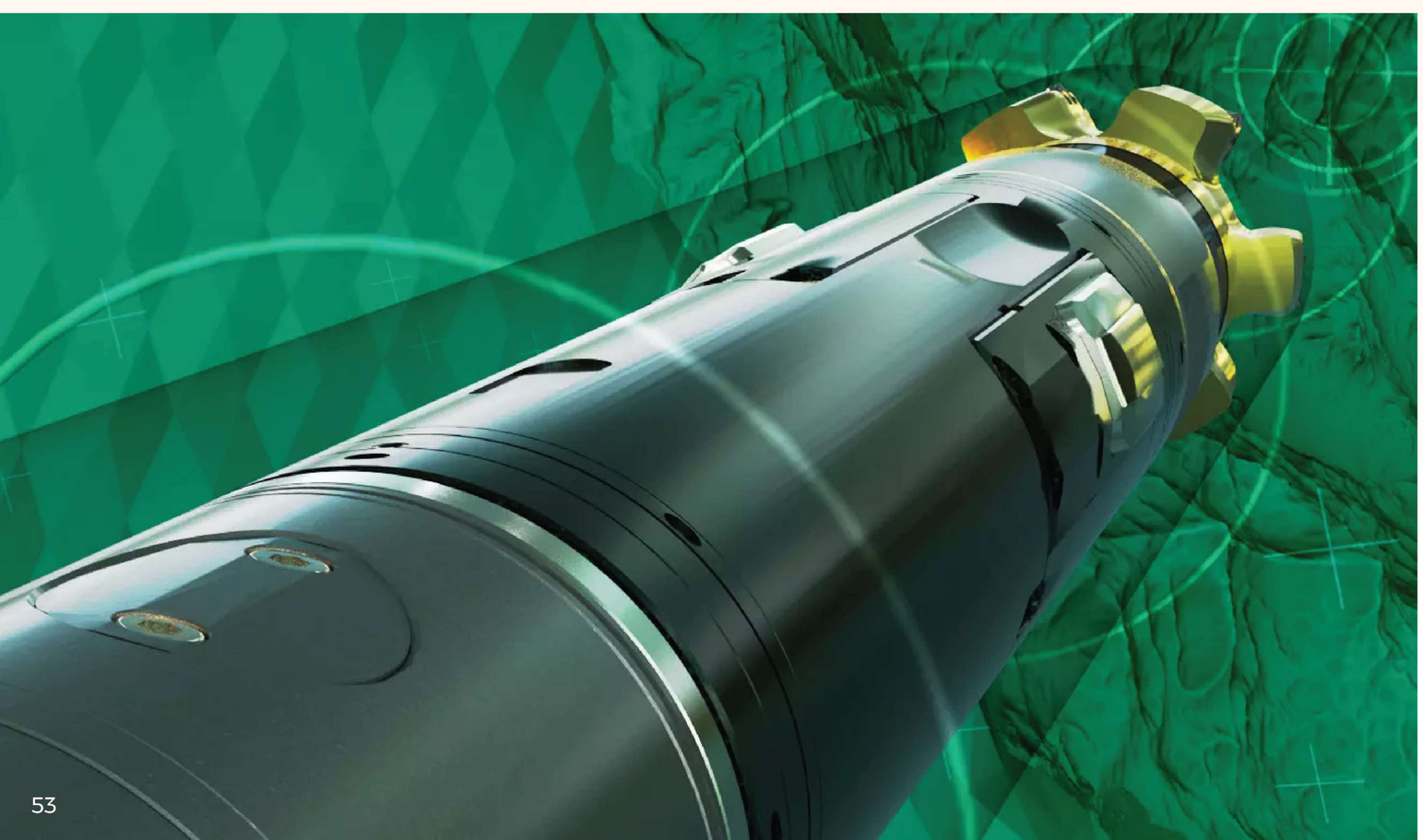


Deviation drilling applications:



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Applications of Directional Drilling:

· **Deviation from the Initial Path:** The initial method for directional drilling was to bypass or avoid in-well obstructions. Nowadays, slight deviations are common, especially when unexpected geological structures are encountered. If vertical wells deviate from their path, they can also be considered as directional drilling.

· **Correcting Entry Depth into the Reservoir:** This is particularly relevant in fields with significant formation dips, where initial seismic interpretations might lead to incorrect depth predictions. Directional drilling allows for adjustments, ensuring entry into the oil-bearing section rather than water zones.

· **Accessing Inaccessible Locations:** Some reservoirs are located beneath urban areas, mountains, or other inaccessible places. Directional drilling allows access from a distance, avoiding the need to disturb these sensitive areas.

· **Salt Dome Drilling:** Sometimes, oil reservoirs are found beneath hard salt domes. Drilling through these formations is challenging, and directional drilling provides an alternative by starting the well outside the salt dome.

· **Faults:** Vertical wells sometimes encounter faults which cause deviations. Directional wells can avoid faults, reducing risks of geological disturbances.

In directional drilling, due to the reduced influence of gravity, higher viscosity and lower density drilling fluids are needed to ensure proper cuttings removal. High-yield bentonite grades from Arzesh Afarin Company, designed to consider pressure and angle calculations, are ideal for horizontal drilling, increasing viscosity while maintaining low density.

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6. Bentonite Products from Arzesh Afarin Mining and Mineral Industries Co.

The high-yield grades 1 to 3 from Arzesh Afarin are used as viscosity agents in water-based and oil-based drilling fluids.

High Yield Grade 1 contains the mineral Bidellite as its main phase. This mineral increases the positive charge in the aluminosilicate networks, enhancing the absorption and retention of sodium cations between the layers. As a result, the increased cation capacity leads to more extensive bonding and a greater expansion of the aluminosilicate layers, thereby enhances viscosity to approximately 70 Pa at a shear stress of 600 RPM. Additionally, due to stronger bonds in the aluminosilicate network, water loss is minimized.

As mentioned, in directional drilling systems where the influence of compressive forces is minimal, a high-viscosity agent without added weight is required. Therefore, bentonite must have maximum viscosity, and high-yield grades can be effectively used as the primary component of the drilling fluid.

Regarding wellbore wall coverage, which is a crucial function of the fluid, bentonite with high water absorption and swelling capacity performs well as an expansion agent. It ensures the sealing of the wellbore walls and reinforces the walls in less cohesive layers, preventing collapse. Additionally, on the basis of calculating the formation fluid pressures and balancing them with drilling fluid pressure, it prevents formation fluids from leaking into the well.

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Under formation pressure, the membrane formed by the drilling fluid must be able to retain the fluid phase between the aluminosilicate networks. This is crucial because fluid intrusion into formation pores can lead to wellbore failure. According to API Standard 13A, the volume of fluid loss is measured under specific conditions using a filter press, with a maximum acceptable volume of 16 ml. Bentonite grades from Arzesh Afarin exhibit fluid loss of less than 16 ml, as presented in the tables.

Moreover, Arzesh Afarin's bentonite products, with swelling indices between 15 and 30 and fluid loss below 16 ml, effectively perform sealing and protection of the wellbore.

Thus, in drilling operations where other clays such as Attapulgite and Sepiolite are used as primary materials, Arzesh Afarin's bentonite products with lower swelling indices can be used as a smoothing control agent.

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6-1- Bentonite grades of Arzesh Afarin Company

Chemical Analysis (OCMA)

SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	SO_3	LOI
60.7	14.34	3.26	4.04	0.56	0.66	0.02	0.8	0.08	2.56	0.07	12.1

Physical Analysis (OCMA)

Parameters	unit	Result
Viscometer dial reading at 600 rpm	r/min	43
Viscometer dial reading at 300rpm	r/min	37
Plastic viscosity (PV) = R600-R300	CP	6
Yield point (YP) = R300-PV	$\frac{lb}{100ft^2}$	31
YP/PV Ratio	$\frac{lb/100ft^2}{cp}$	5.16
Fluid Loss	ml	13.50
Moisture Content	%	8.5
Residue > 75micrometers	wt. %	2.5

Chemical Analysis (High Yield 1)

SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	SO_3	LOI
62.98	14.72	1.93	5.11	0.25	0.71	0.02	0.98	0.12	3.37	0.02	9.67

Physical Analysis (High Yield 1)

Parameters	unit	Result
Viscometer dial reading at 600 rpm	r/min	60-70
Viscometer dial reading at 300rpm	r/min	55-65
Plastic viscosity (PV) = R600-R300	CP	6-10
Yield point (YP) = R300-PV	$\frac{lb}{100ft^2}$	20-30
YP/PV Ratio	$\frac{lb/100ft^2}{cp}$	6-10
Fluid Loss	ml	15.10
Moisture Content	%	9
Water Absorption porous plate Method	wt. %	580-650
Distribution 325 mesh	wt. %	max 2.5

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Chemical Analysis (High Yield 2)

SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	SO_3	LOI
50.51	16.15	1.72	3.8	0.82	0.78	0.03	1.99	0.08	5.54	0.01	18

Physical Analysis (High Yield 2)

Parameters	unit	Result
Viscometer dial reading at 600 rpm	r/min	50-60
Viscometer dial reading at 300rpm	r/min	45-55
Plastic viscosity (PV) = R600-R300	CP	6-10
Yield point (YP) = R300-PV	$\frac{lb}{100ft^2}$	43
YP/PV Ratio	$\frac{lb/100ft^2}{CP}$	6-10
Fluid Loss	ml	15.10
Moisture Content	%	9
Water Absorption porous plate Method	wt. %	580-650
Distribution 325 mesh	wt. %	max 2.5

Chemical Analysis (High Yield 3)

SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	SO_3	LOI
60.02	11.49	1.5	3.73	0.14	0.55	0.03	0.81	0.06	3.73	0.01	16

Physical Analysis (High Yield 3)

Parameters	unit	Result
Viscometer dial reading at 600 rpm	r/min	40-50
Viscometer dial reading at 300rpm	r/min	35-45
Plastic viscosity (PV) = R600-R300	CP	6-10
Yield point (YP) = R300-PV	$\frac{lb}{100ft^2}$	20-30
YP/PV Ratio	$\frac{lb/100ft^2}{CP}$	6-10
Fluid Loss	ml	15.10
Moisture Content	%	9
Water Absorption porous plate Method	wt. %	580-650
Distribution 325 mesh	wt. %	max 2.5

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Chemical Analysis (API)

SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	SO_3	LOI
60.7	14.3	3.26	4.04	0.56	0.66	0.02	0.8	0.08	2.56	0.07	12.1

Physical Analysis (API)

Parameters	unit	Result
Viscometer dial reading at 600 rpm	r/min	Min 30
Viscometer dial reading at 300rpm	r/min	Min 25
Plastic viscosity (PV) = R600-R300	CP	9
Yield point (YP) = R300-PV	$\frac{lb}{100ft^2}$	27
YP/PV Ratio	$\frac{lb/100ft^2}{CP}$	3.00
Fluid Loss	ml	14
Moisture Content	%	8.5
Residue > 75micrometers	wt. %	2.5

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