THE BEST UNDER PRESSURE!

Compressible Fluids Training Course

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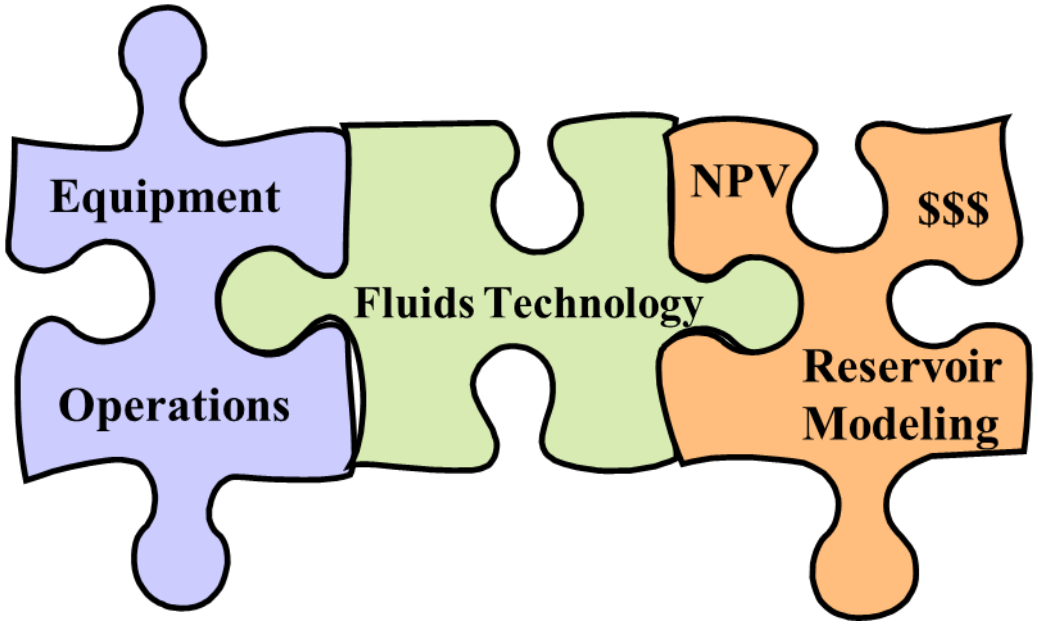
Fluids Complete the Puzzle



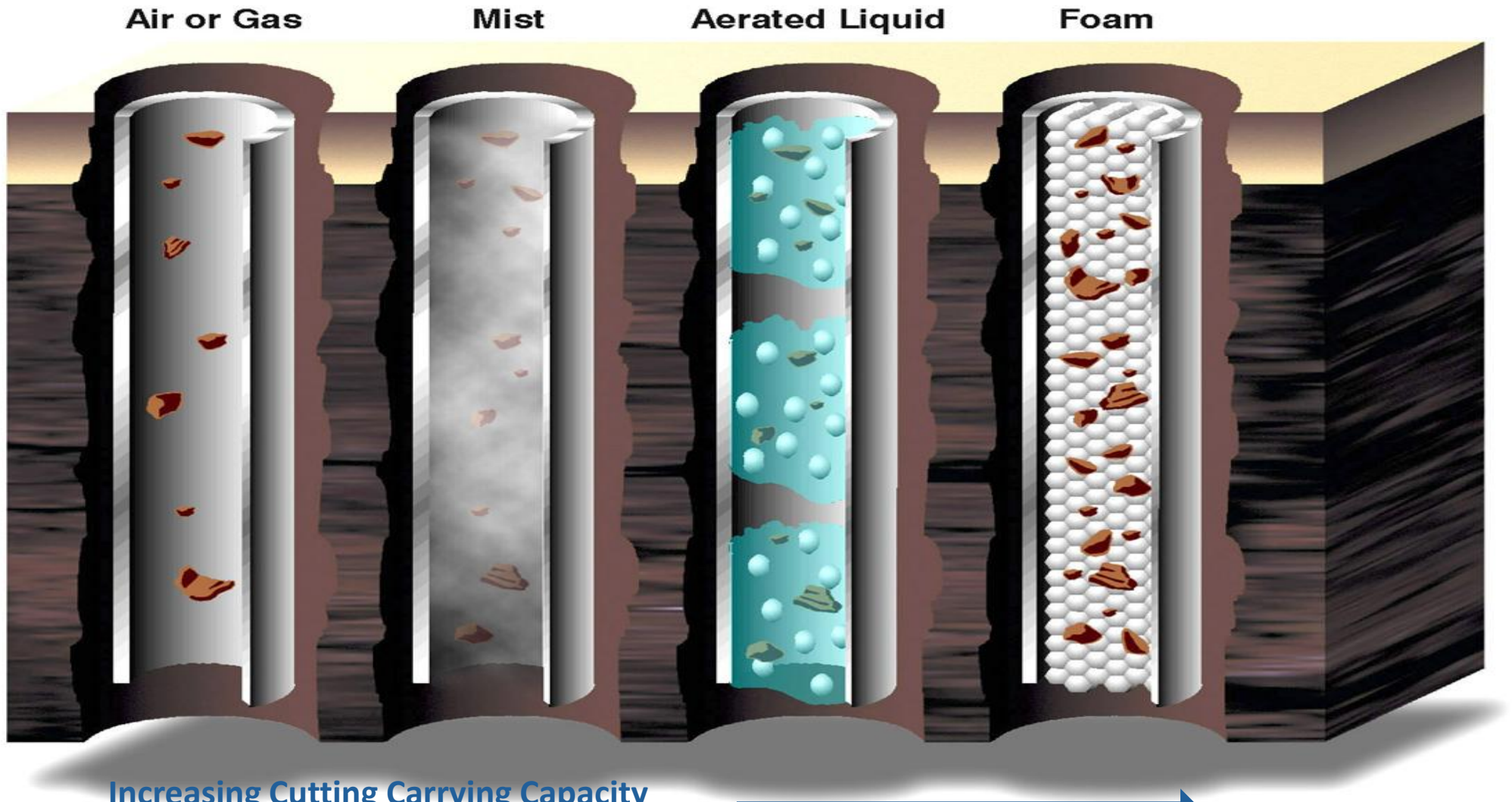
Purpose of Compressible Fluids

- **Removal of formation water when air drilling**
- **Removal of cuttings**
- **Drive and Cool Motors**
- **Lowering fluid density**
  - **Decreasing lost circulation - Economics**
  - **Decreasing Formation Damage – Production**
- **Increase ROP**
- **Increase Drill Bit Life**
- **Detection of Hydrocarbons**

Concept of Compressible Fluids

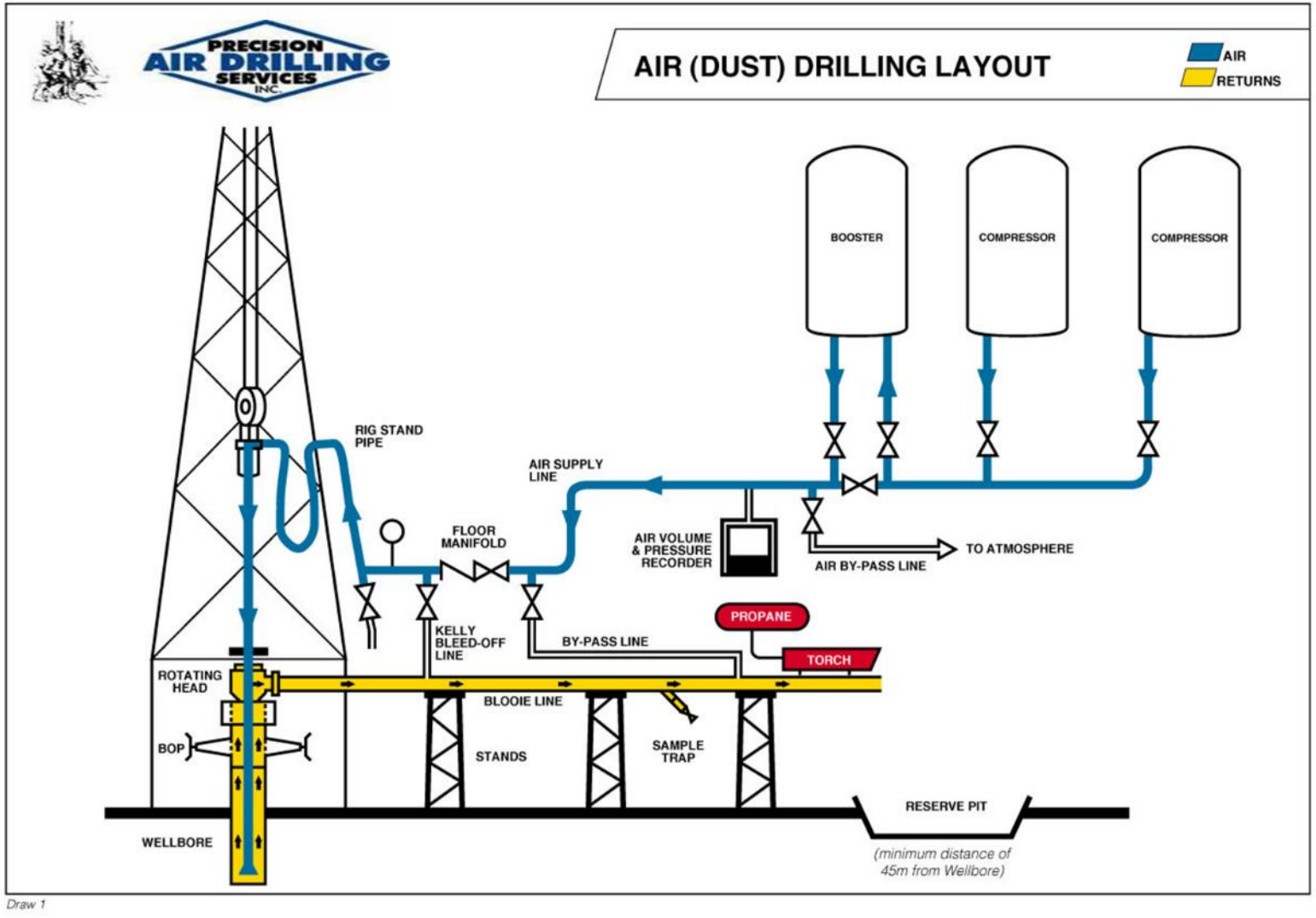
- **Foam**
  - **Defined as an emulsion between gas and a fluid**
- **The volume of the gas injected into the fluid characterizes or defines the Compressible fluid**
  - **Air Drilling – 100% gas**
  - **Mist Drilling Fluid – >96% gas / 4% fluid**
  - **Foam Drilling Fluid – 54-96% gas and 4-46% fluid**
  - **Two Phase or Aerated Fluid - <54% gas and >46% fluid**
- **Fluid Types**
  - **Water, brine, diesel, or crude**
- **Gas Types**
  - **Compressed Air, Nitrogen (Cryogenic or Membrane), Natural and Exhaust gas**

Compressible Fluid Classifications



Increasing Cutting Carrying Capacity
Decreasing Velocity Requirements

System Layouts



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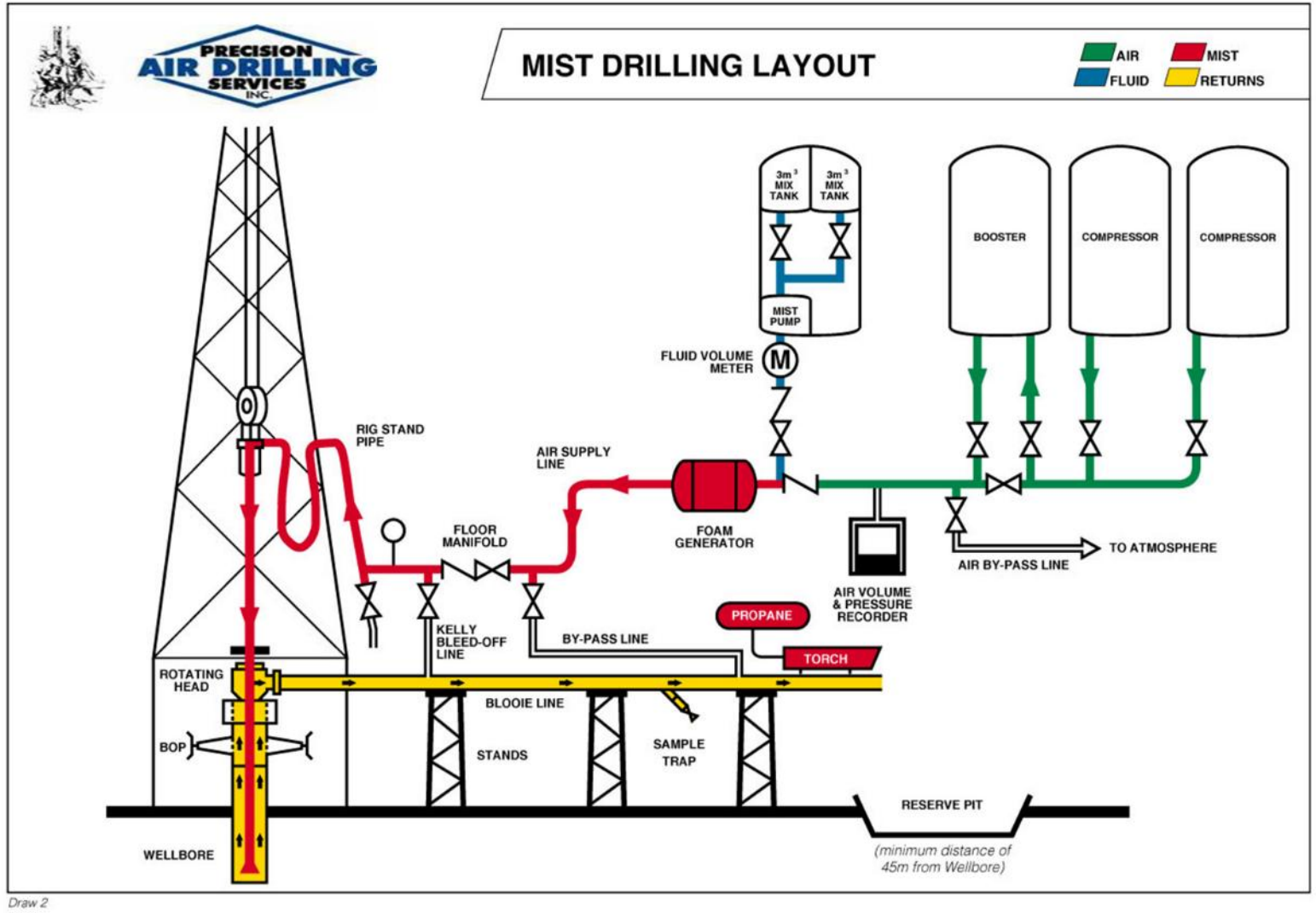

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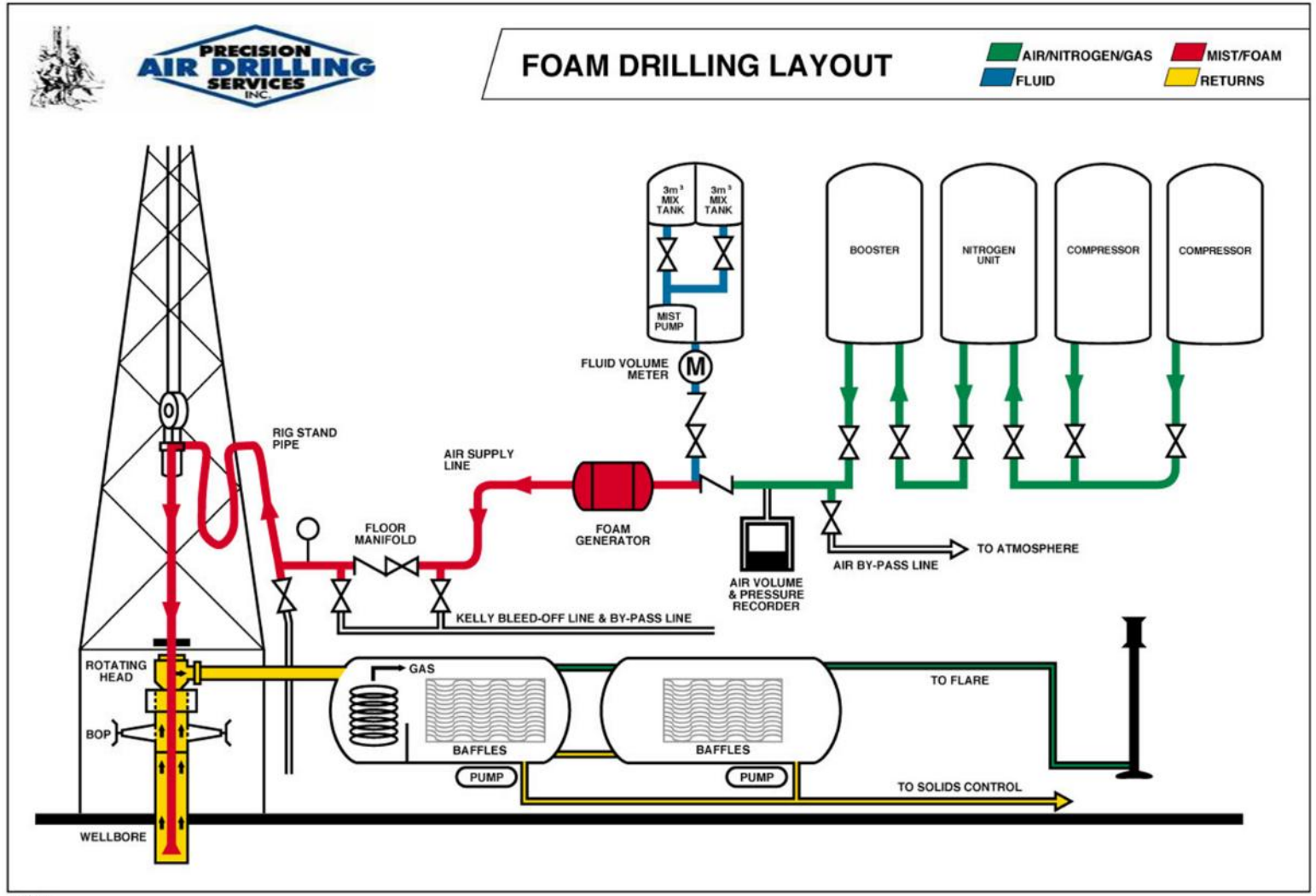

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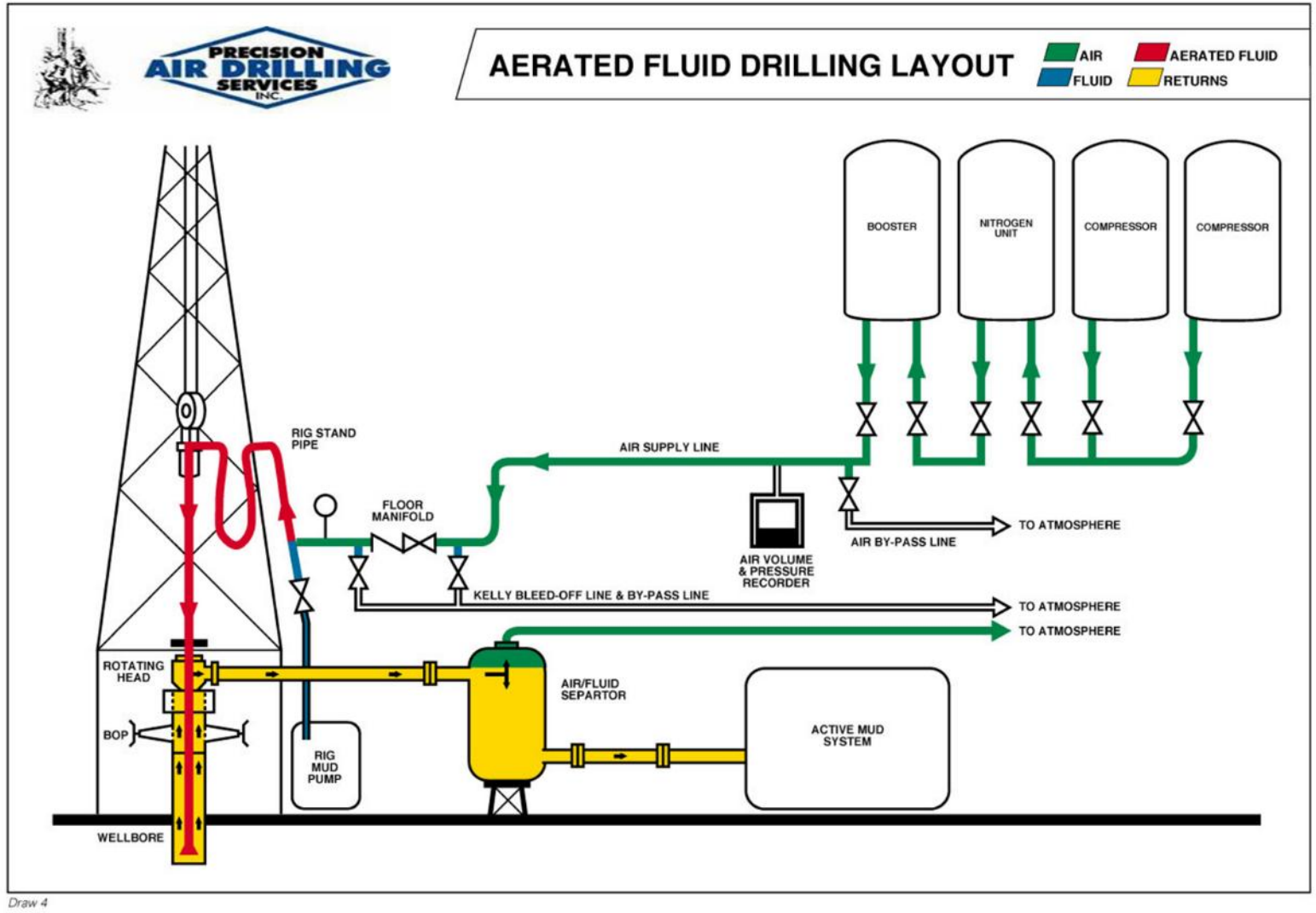


Mist Drilling Fluids

- **Typically used when encountering a fluid influx when air drilling**
  - **2 bbl/hr influx or when pressures indicate a change is required**
- **Drilling Surfactants and a corrosion inhibitor is injected**
  - **Surfactants coat the cuttings – preventing “mud ring” in annulus**
  - **Corrosion inhibitor for oxygenated system protects downhole tubulars and hardware**
- **A properly designed system can remove up to 500 bbls/hr of formation water**
- **During Mist Drilling Operations, it is not recommended that you attempt to drill without a surfactant**

Foamed Drilling Fluids

- **Typically used when large influx of fluid are possible, increased BHP are required or when annular flow rates are too low to transport cuttings**
- **As gas volume increases, hole cleaning increases in a foamed system. (Darley & Gray). Rheology + Velocity**
  - **85% - 96% gas to fluid ratio – "Foam Quality"**
- **Components (may, or may not) consist of;**
  - **Foamer**
  - **Corrosion Inhibitor**
  - **Shale Inhibitor**
  - **Viscosifier – "Stiff Foam"**
  - **Specialty Additives…….**
- **Foam Half Life (50% decay) is a critical measurement for evaluating cutting transport and suspension**

Properties of Foamed Drilling Fluids

- **Foam Height - Quality**
  - **Expansion of 100 mL of fluid mixed for 1 minute with a Hamilton Beach Mixer (max output)**
  - **Dependent on the volume of entrained gas**
- **Foam Half Life - Properties**
  - **Time it takes the foam to decay by 50% of the initial liquid volume**
  - **Distinguishing measurement of a foamed drilling fluid**
    - **Cutting transportation during extended connection time**
    - **Limited information on the relationship b/w ambient measurements and under downhole conditions**
  - **Function of the foamer type and base fluid viscosity**
- **Fluid viscosity, salinity, downhole temperature, downhole pressure all effect foam properties**

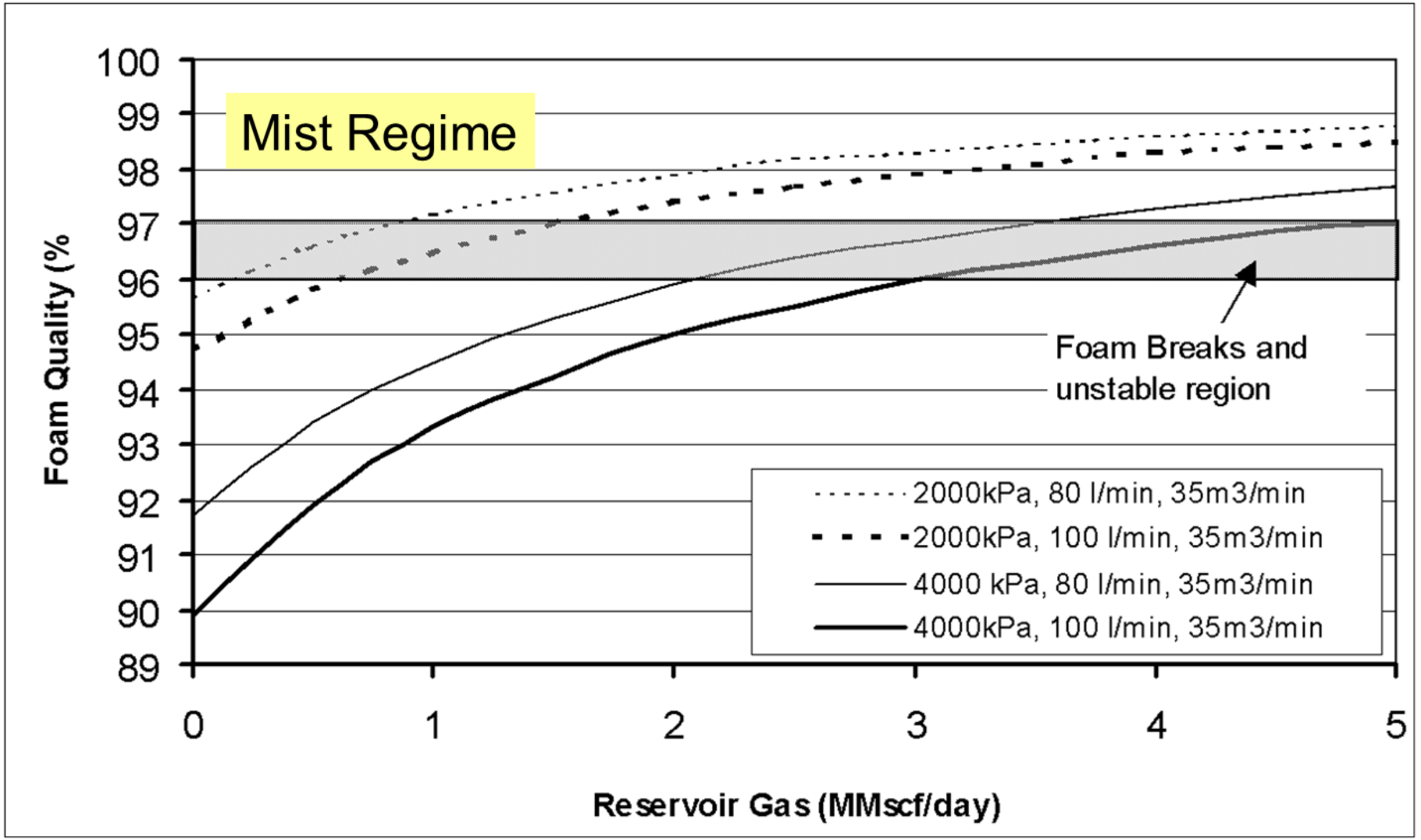
Foam in General

Foam texture is related to the size and distribution of the gas bubbles.

- Foam is composed of a liquid, surfactant, Gas and in some cases, a blend of polymers.
- Foam quality is a general term defining the ratio of gas to liquid volume. It does not define the properties of the foam.
  - i.e. 96% quality = 96% gas / 4% liquid
- How do you define foam quality????
- Foam used for Performance Drilling and Reservoir Drilling may be different.

Foam Quality

Foam quality has an optimal range and above 96% foam may have problems retaining a stable lattice structure



Foam Types

- **Foam**
- **Stiff Foam**
- **Stable Foam**
- **Styrofoam**

Mist Drilling Fluids

What type of foam is this?

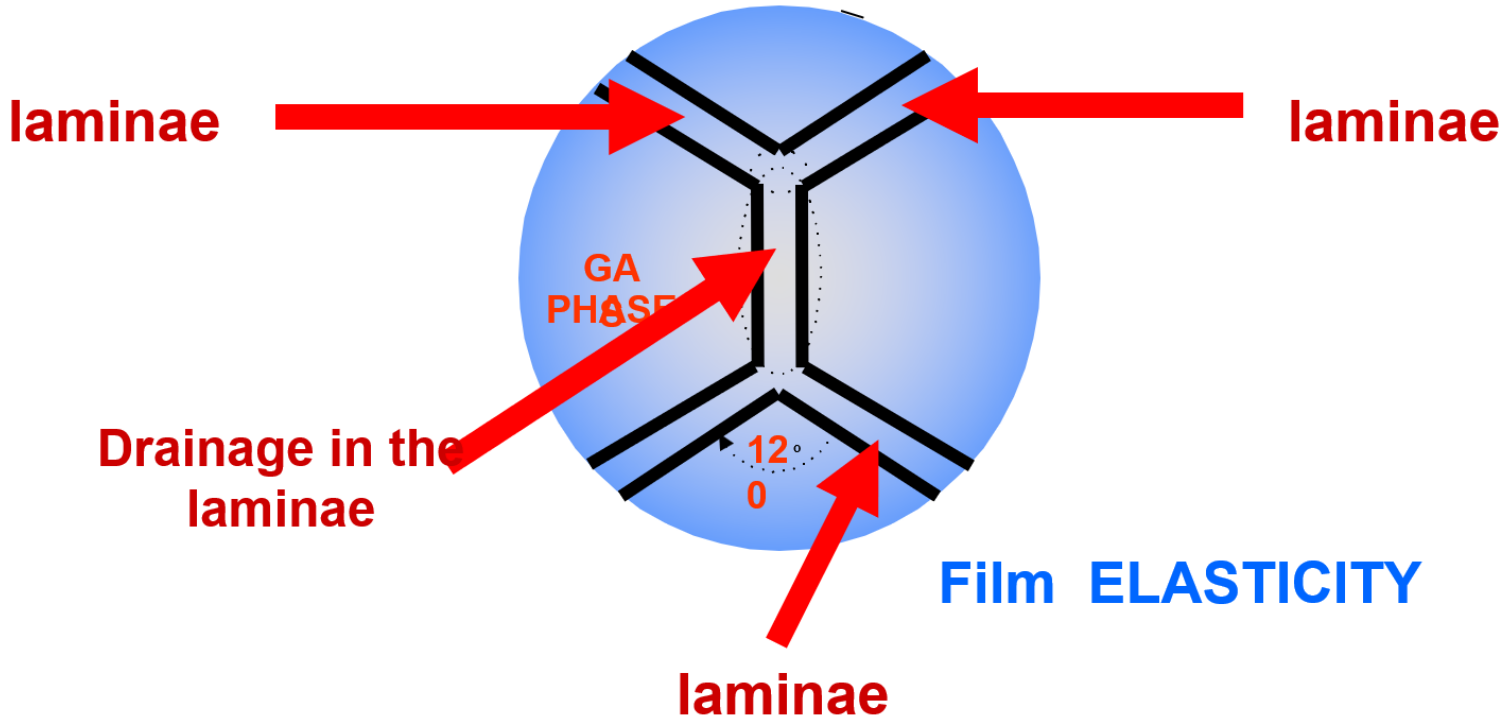
Stiff Foams

- **What is Stiff Foam?**
  - **Viscosified base fluids (polymer, gel, high surfactant concentrations, others)**
  - **Emulsions**
- **When do you use Stiff Foam?**
  - **Extended half life requirements**
  - **Torque/drag increases**
  - **Hole cleaning problems**
- **How does Stiff Foam work?**
  - **Increased viscosity reduces the water drainage**
  - **Decreased water drainage increases the foam ½ life**
- **When do you not use Stiff Foam?**

Chemistry of Foams

- **SOAP = Surfactant = Surface Tension Reducing Agent**
- **Surface Tension – the resistance of a fluid to changes in surface area.**
- **Surfactant – Surface active agent and a material that tends to orient itself to the interface of two immiscible liquids or a liquid and gas.**

What is Foam?

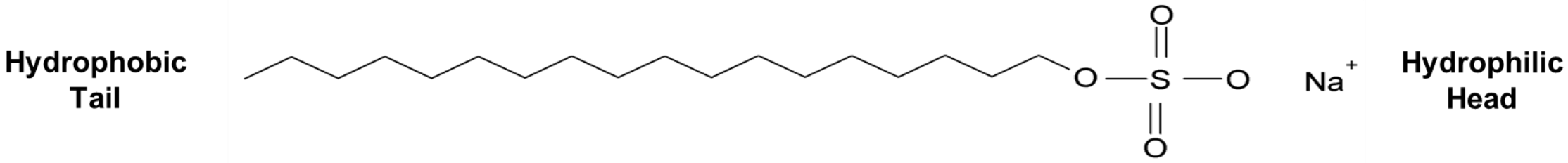


- Foam is an aggregation of bubbles separated by thin films of liquid.
- As liquid is drained from the laminae, the films become thinner until the foam collapses.

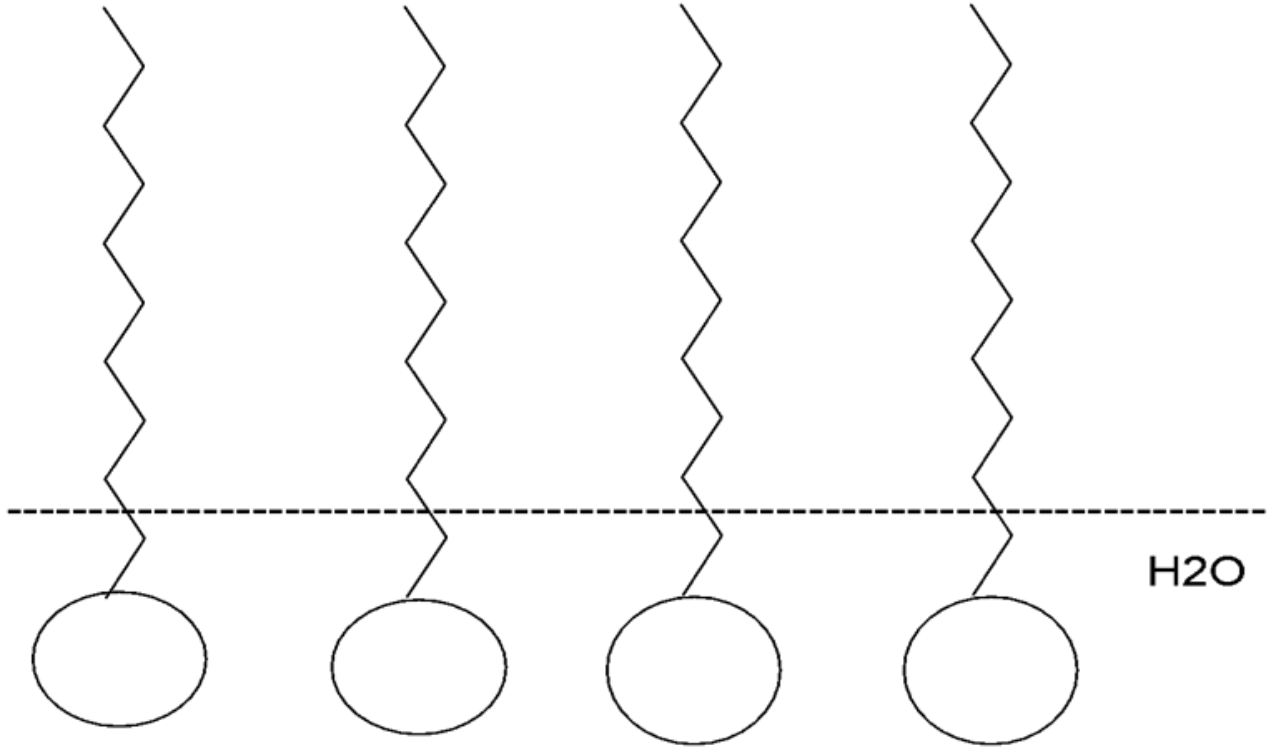
Surfactants

- **A surfactant is a long chain acid salt, which is comprised of two domains.**

- **It contains a hydrophilic head, the ionic carboxylate group that is soluble in water, and a hydrophobic tail, the long hydrocarbon portion that is repelled by water molecules and attracted to other hydrocarbon residues.**



Surfactants

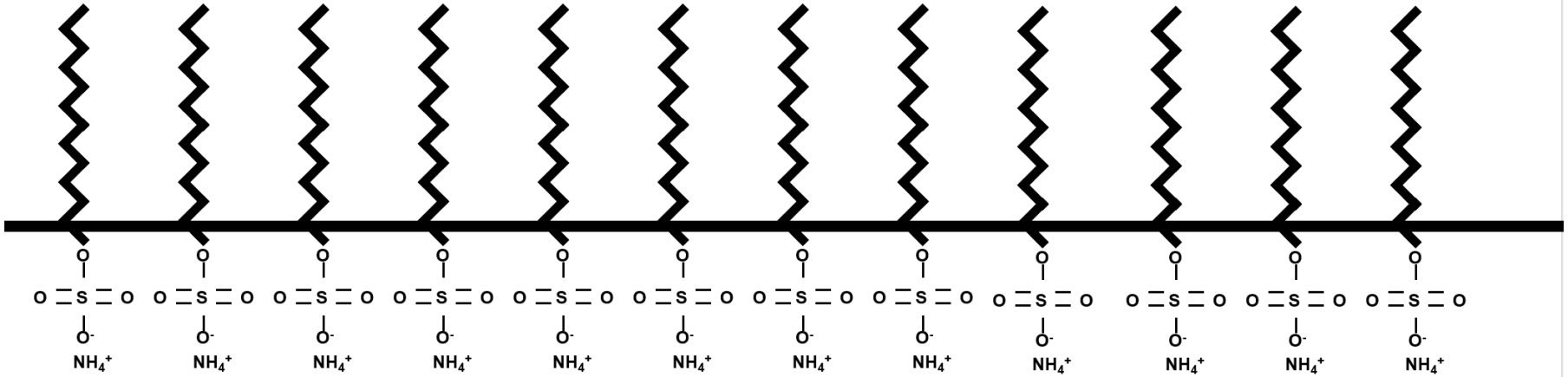


A surfactant reducing the surface tension of water

Surfactants

"Tail" "Head"

Gas Phase



Water

Benefits of Foam

- ✓Increased penetration rates
- ✓Completely acid soluble - biodegradable
- ✓Large hole drilling/less air requirements
- ✓Excellent cutting transportation – Rheology Driven
- ✓Not effected by the presence of evaporates such as anhydrite and salt.
- ✓EM-MWD systems are able to function effectively.
- ✓Down hole mud motors operate with minimum bearing wear.

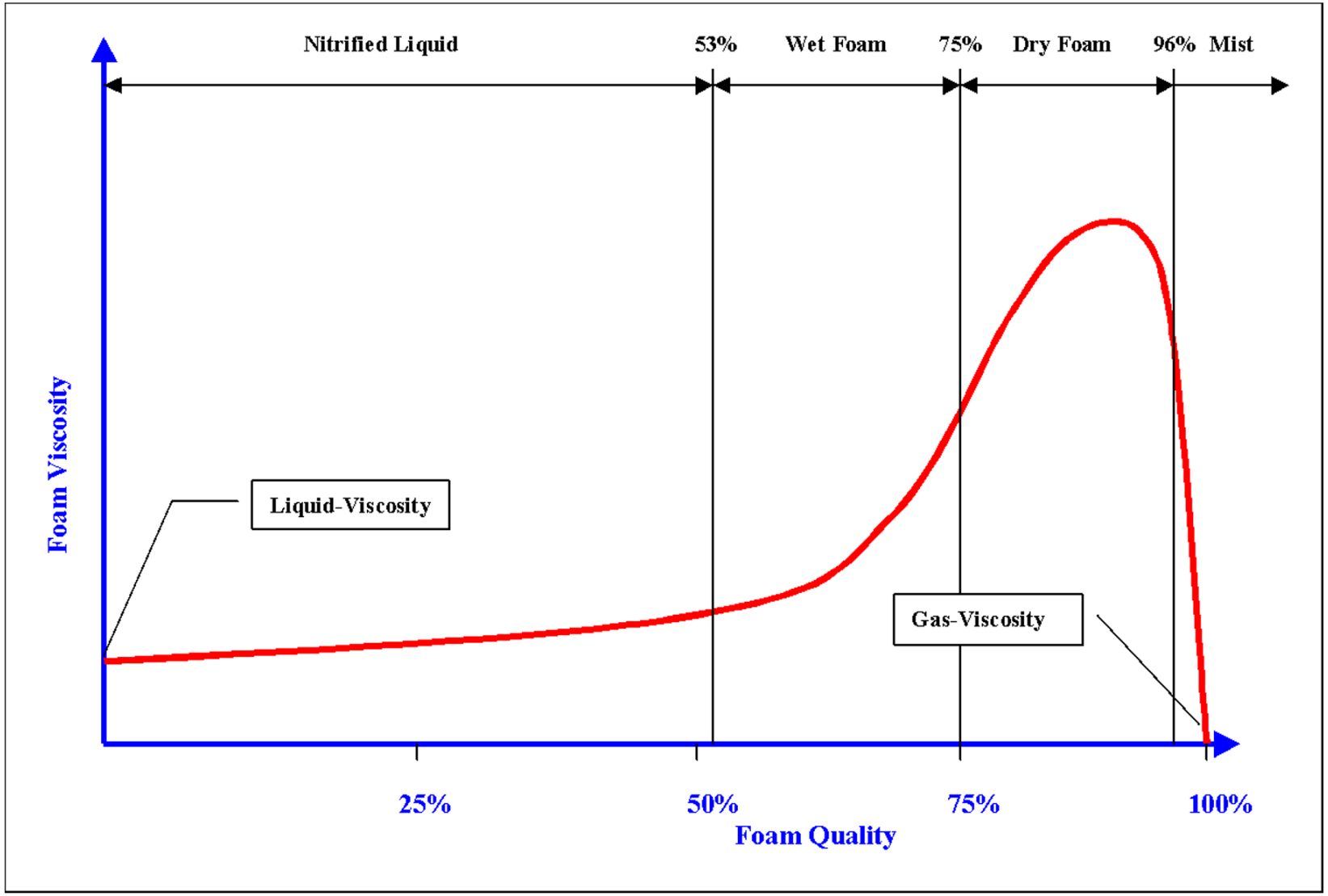
Benefits of Foam

- ✓Minimizes Formation Damage and Loss Circulation
- ✓Fluid Influxes are readily displaced
- ✓High viscosity properties downhole and at surface for solids removal
- ✓Applicable in Oil & Gas Reservoirs – less invasive / low FL
- ✓More stable UB circulation system than conventional 2-phase
- ✓Lower risk of borehole instability since reduced annular velocities
- ✓Provides a low UBD BHP drilling gradient at 0.09 psi/ft (2 kPa/m)

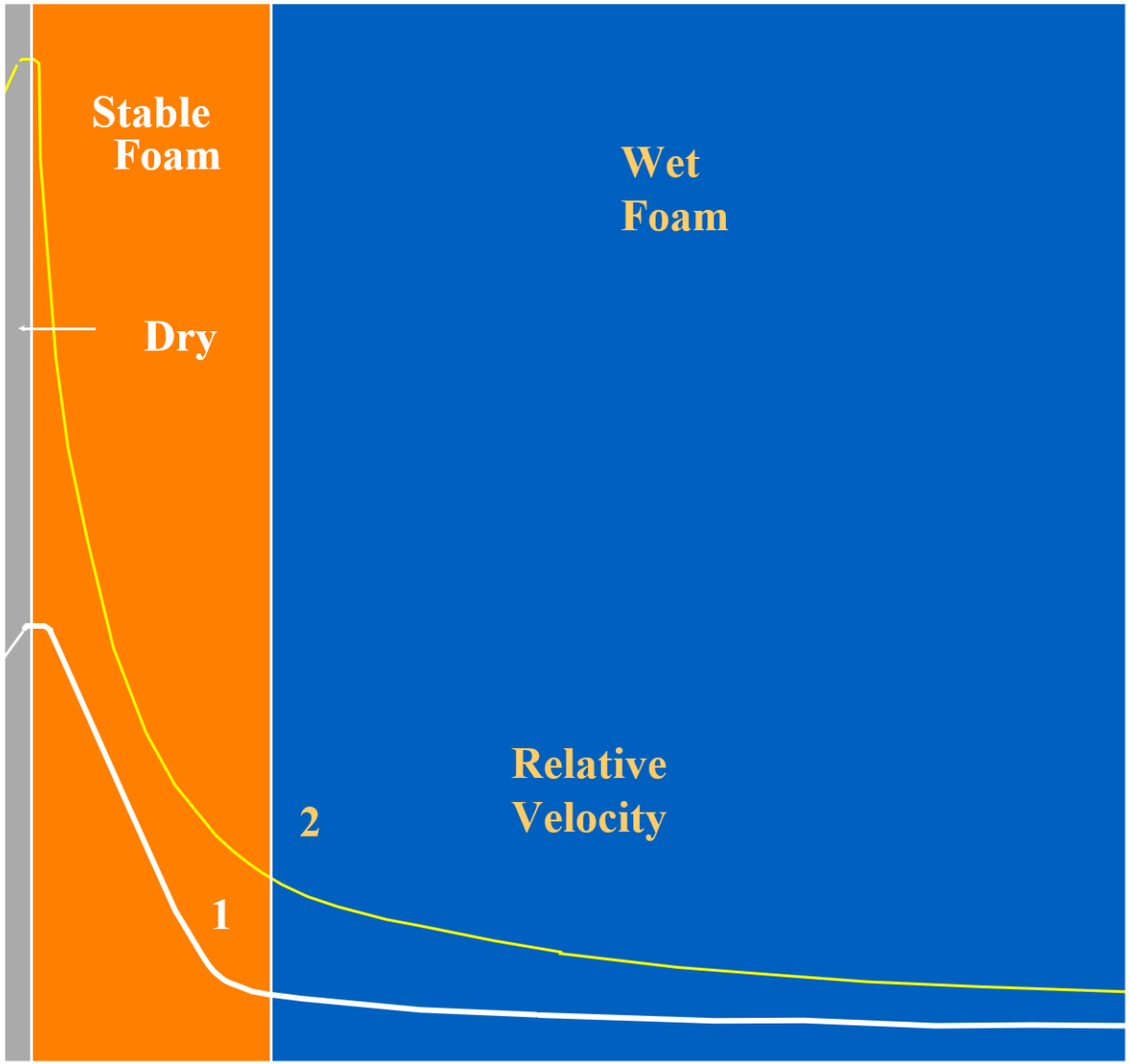
Criteria for Evaluating Foamers

- **Foaming Capability** – Foam Drilling
- **Surface Tension Increase** – Fog Drilling
- **Ionic Charge** – Compatibility with Additives
- **Salt Tolerance** – Compatibility with Brine Water
- **Hydrocarbon Tolerance** – Hydrocarbon Influxes
- **Temperature Limitations** –Deep High Temp. Wells
- **Costs** – Average approximately $7.00 - $10.00 per foot drilled

Viscosity vs Quality



Foam Lifting Capacity (Breyer et al, 1972)



Contaminants

Various contaminants can adversely affect foam.

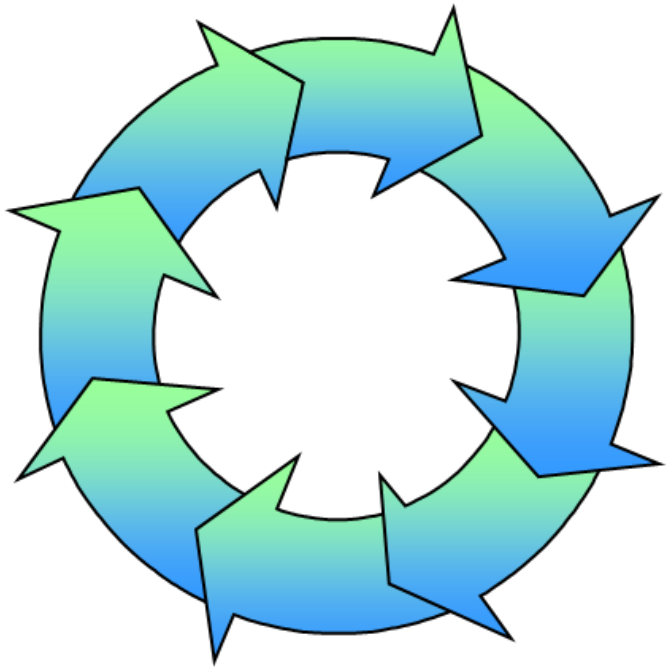
- **Drill Cuttings – Biggest potential problem**
  - **Reduce foaming capacity**
- **Hydrocarbon**
  - **Emulsions – Poor separation**
  - **Reduce foaming capacity**
- **Saltwater**
  - **Reduce foaming capacity**
  - **Increase corrosion**
- **Acid gases**
  - **Lower pH – reduce foaming capacity**
  - **Increase corrosion**

Foamers should be designed to address these issues

Non-Recycled Foam Drilling Fluid
1,200 scfm / 28 gpm

Recycling Foamed Drilling Fluids

- **Foam / De-foam and then Re-Foam / De-foam, etc... through many, many cycles**
- **Engineered foamed drilling fluid**
- **Reduces water consumption/fluid costs/disposal**
- **Environmental advantages**
- **Smaller overall footprint**
- **Provides substantial waste reduction**
- **Unique and sometimes patented processes**



Recycling Foamed Drilling Fluids

- **Utilizes a specialized foam technology**
- **Defoamer is typically added at the RCD or before the choke to reduce the foam in the Separator**
- **Optimize foamer/defoamer ratio**
  - **Typically, that ratio is 1:2**
- **Monitor foam in Separator**
  - **Typically, 4 ft of foam is ideal**
- **If defoamer concentration becomes high, a dump/dilute method should be implemented**

Two-Phase Systems

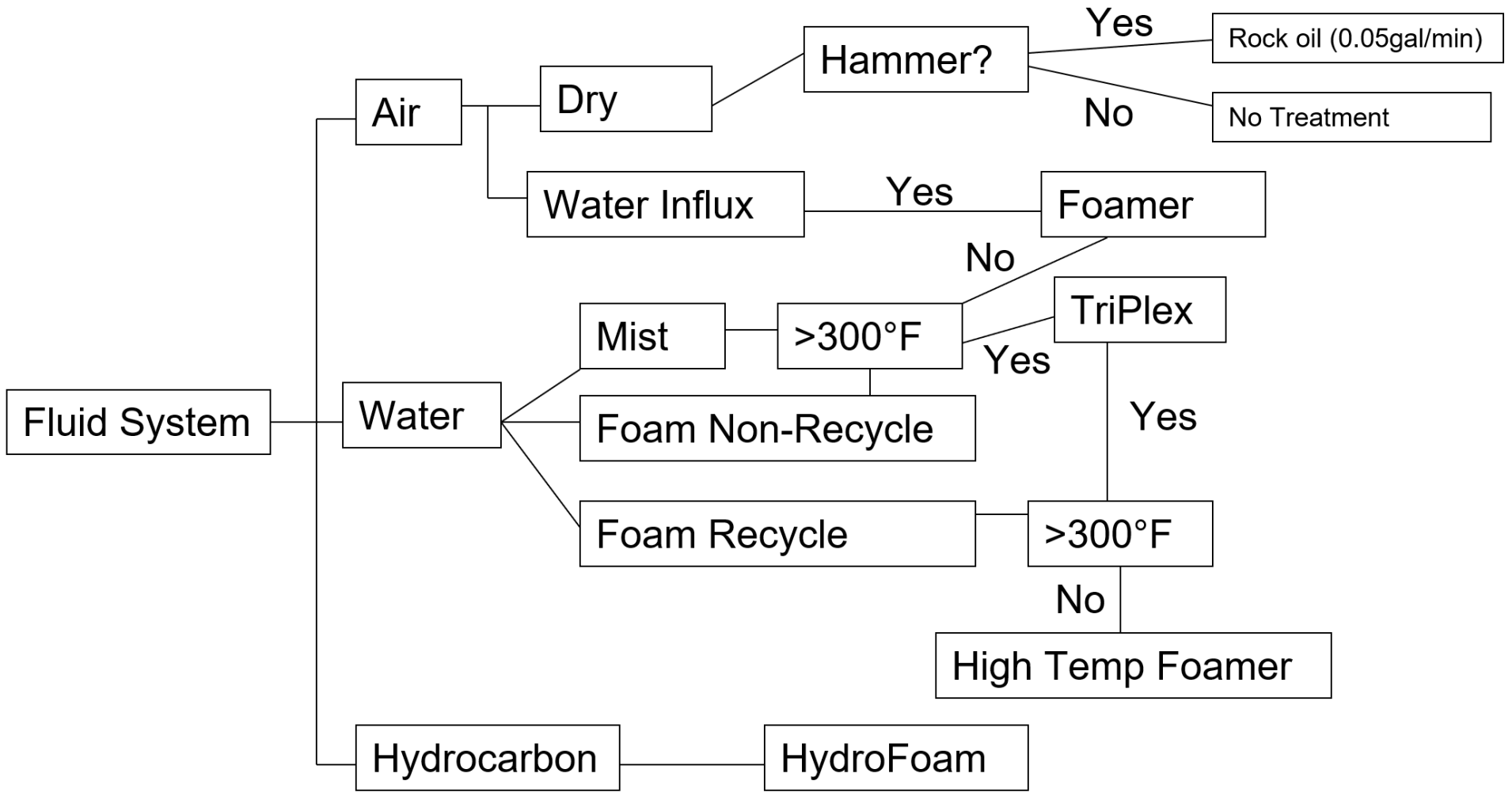
- **What is a Two-Phase System?**
  - **Commingled gas in a liquid held together only by velocity or turbulence**
  - **Typically does not incorporate a foamer**

- **When do you use Two-Phase System?**
  - **Geothermal drilling**
  - **Lost circulation – “aerated mud”**
  - **High temperature**
  - **Unstable formations**
  - **High BHP and high permeability formations**

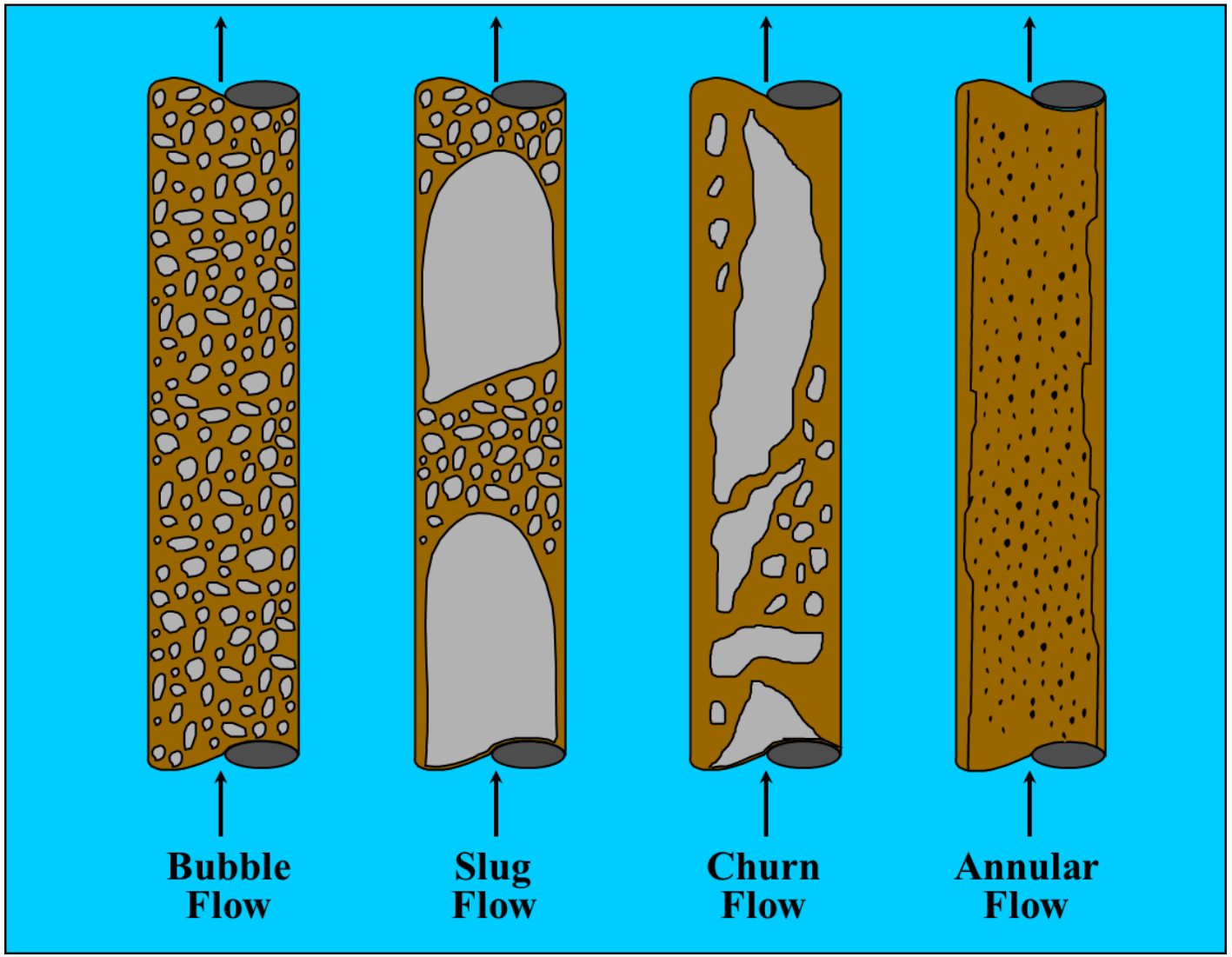
- **When do you not use a Two-Phase System?**
  - **Low BHP**
  - **Low permeability formations**

- **Requires viscosifying additive**
    - **<41 marsh funnel viscosity**

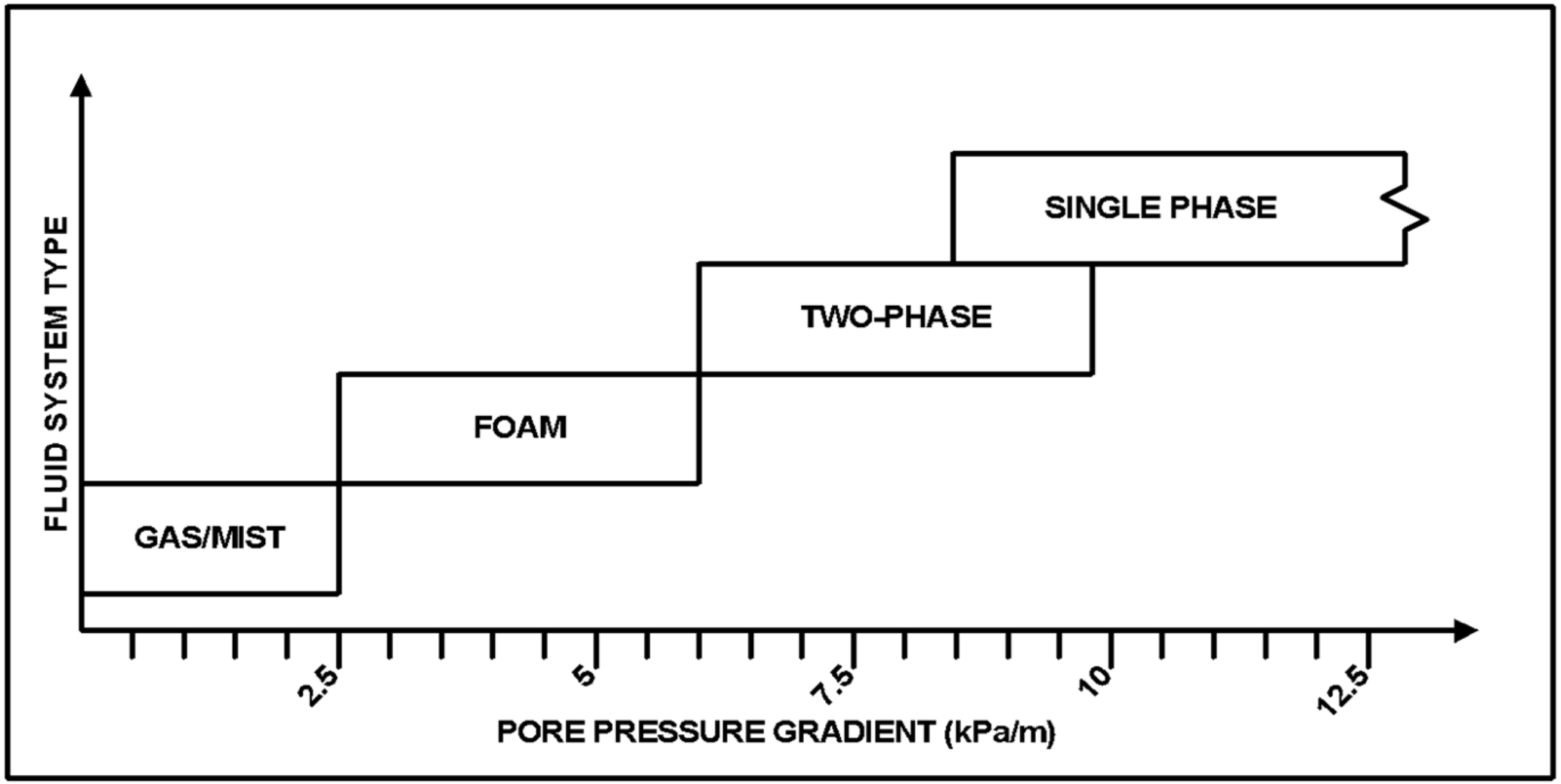
Fluid Product Line



Vertical Flow Regime Patterns
Two-Phase fluids (Williams, 1994)



Compressible Fluid Selection



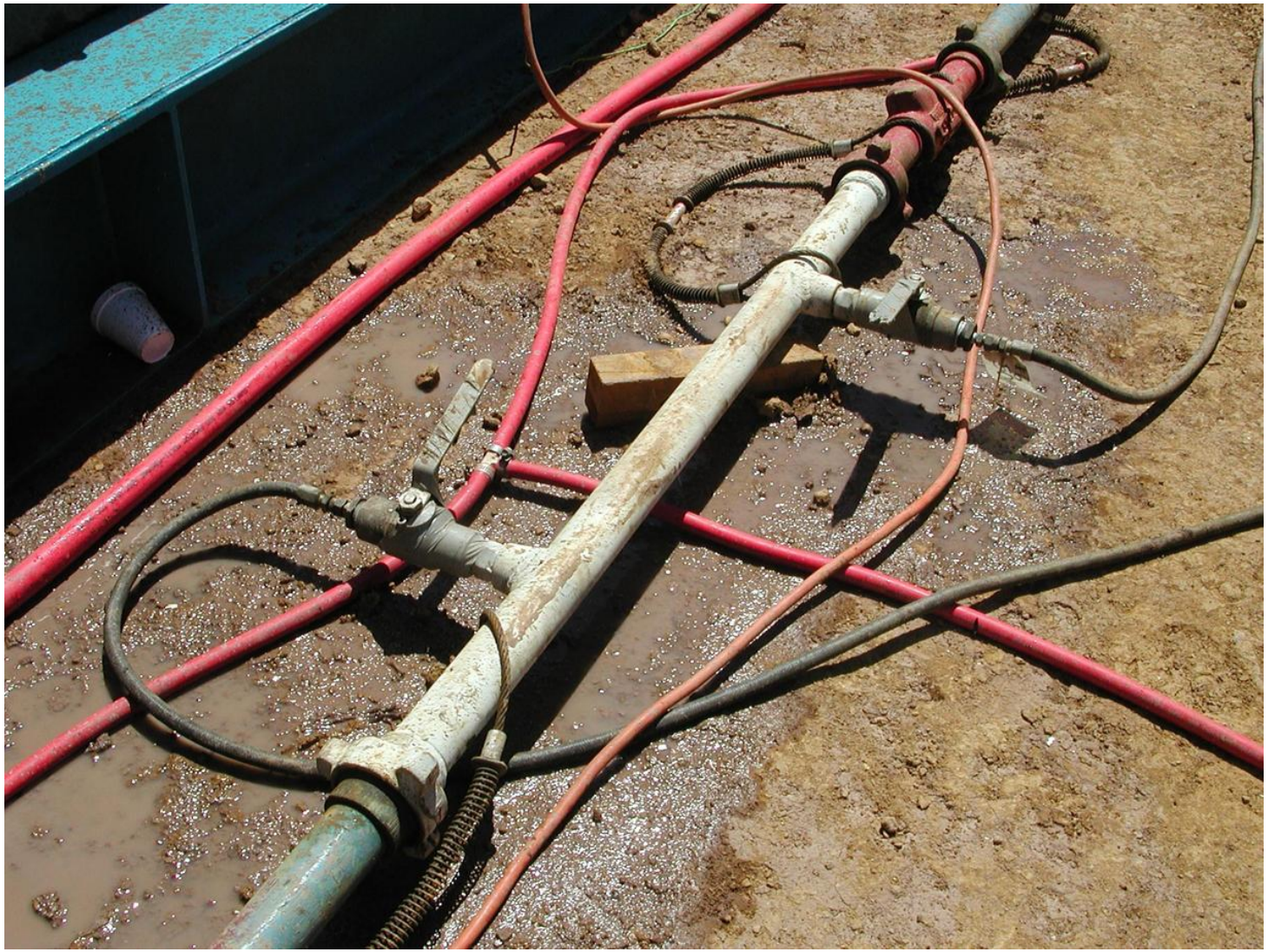
Foam Drilling Requirements

- **Sample points are a must**
- **Sample on the injection line downstream of all chemicals (including soap) injected**
- **Sample coming out of the well prior to injecting defoamer**
- **Take samples frequently and report results on the daily report**
- **Report all chemical usage daily**

Foam Drilling Requirements

- **Sample points are to be on the side of the injection line as the foam is not yet formed**
- **Use jets in the bit to be sure the foam gets well sheared**
- **Use polymers only when necessary**
- **Run circulating time test once a day**

Sampling Points



Foam Tests

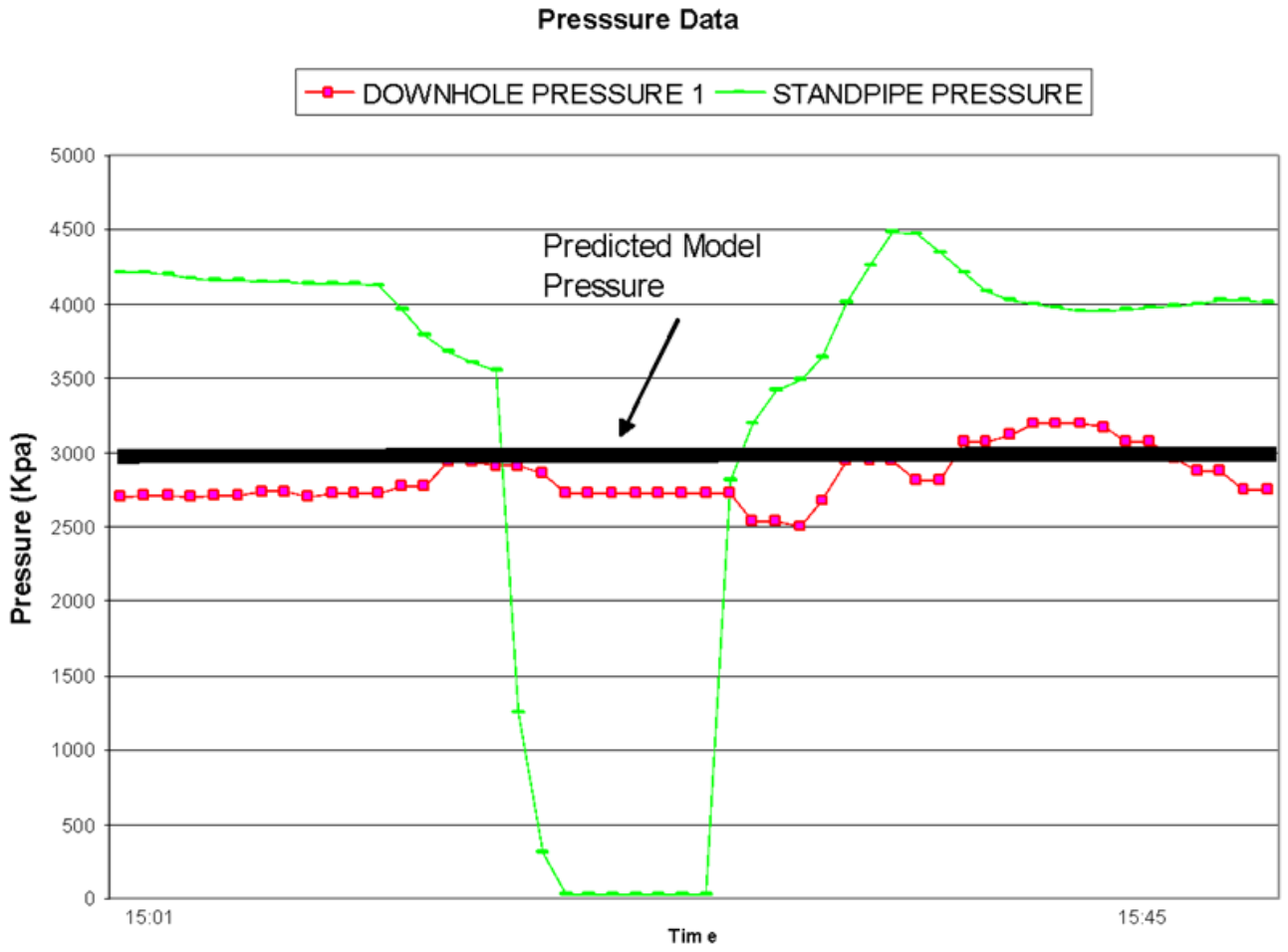
Two foam tests of different height and half life will give different friction pressure and carrying capacity results

Example In a given well condition:

- **Foam test #1 = 275 mm HT / 100 sec HL**
  - **SLIP = 116 ft/min**
- **Foam test #2 = 500 mm HT / 300 sec HL**
  - **SLIP = 61 ft/min**

Real Time Pressure Data

It is not always easy to match pressure data because the well bore is not always in a steady state condition.



Verifying the Model – Circulating time

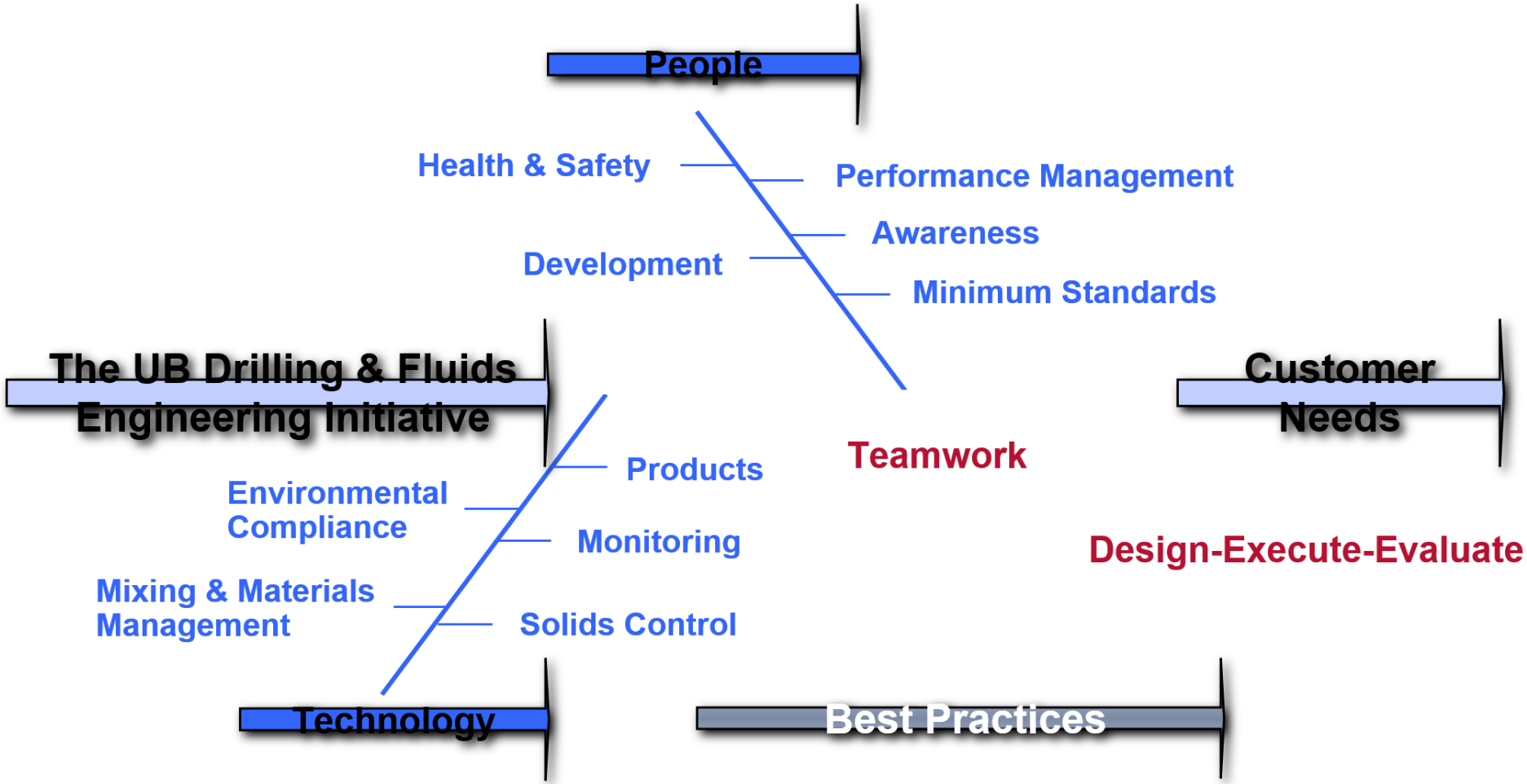
- **Circulating time tests are an excellent method to verify any model**

- **The following slides will explain the methods for running such tests:**

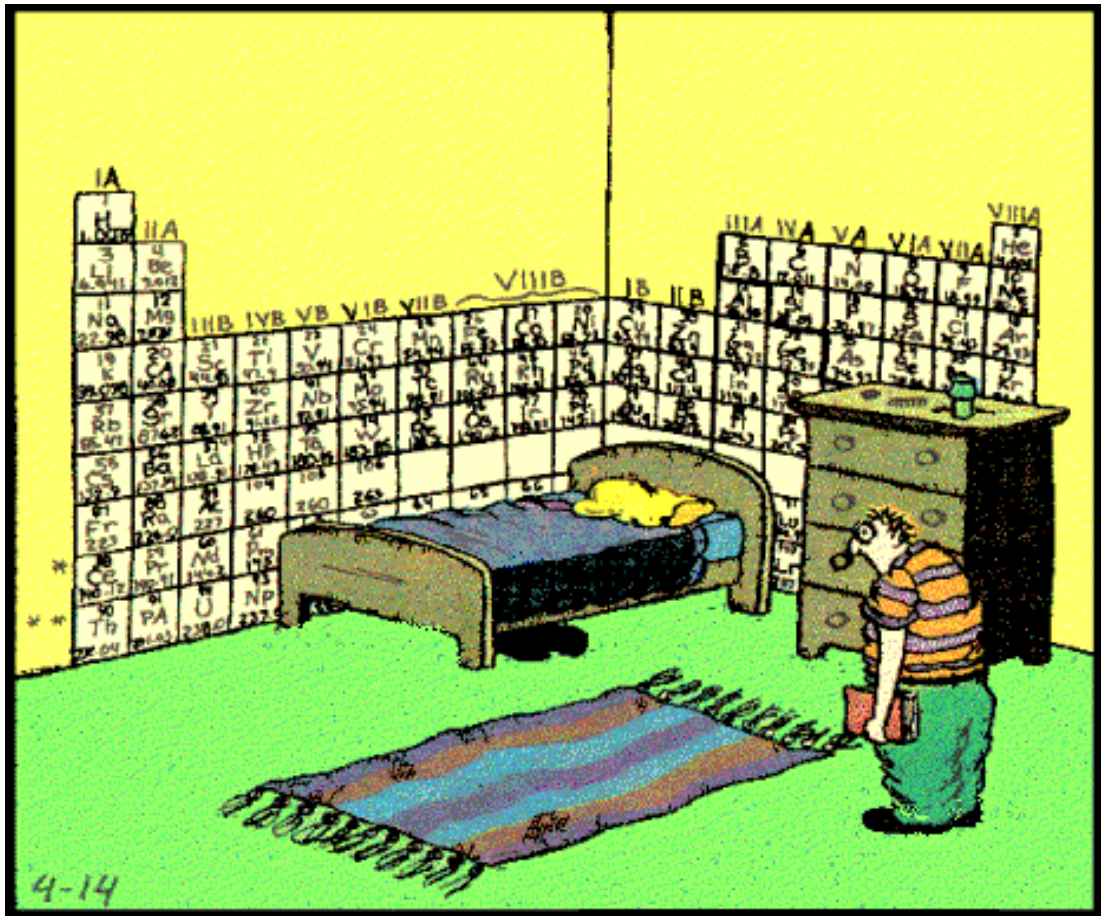
Slip Velocity

- **The cuttings slip velocity is a complex calculation depending on various factors.**
- **The factors always include size, shape and density of the cutting, density and type of circulating media.**
- **The factors can include viscosity for non turbulent systems and also wellbore deviation (above 15°)**

Objectives and Strategy



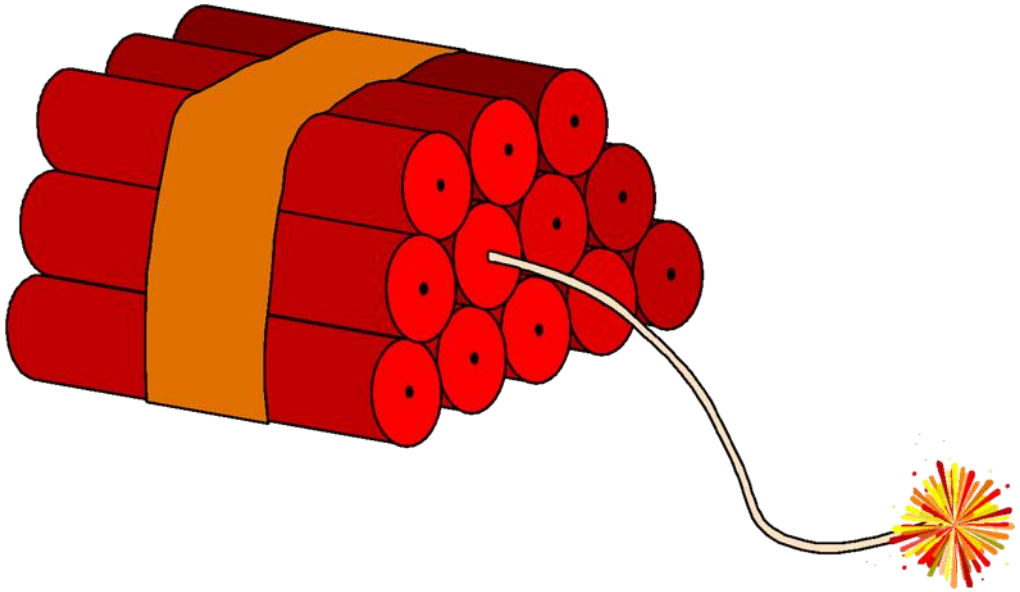
Periodic Table Wallpaper



Today, we will not discuss very much chemistry!

The Importance of Corrosion Issue Associated with Underbalanced Drilling

Corrosion is one of the most overlooked and potentially devastating problems with UBD. It is important that all potential corrosion mechanisms are dealt with in the pre-planning phase of any UBD well!!!



Corrosion Effects

Corrosion problems can cause severe UBD problems:

- **Wash outs in the drill string**
- **Twist offs**
- **Corrosion in the surface piping or mud pits that may result in large mud losses**
- **Premature retirement of separation vessels**

On-Site Equipment Setup

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