INTRODUCTION

Air drilling methods are widely used in groundwater development, mineral exploration, geotechnical investigations, and construction drilling because of their speed, reduced formation damage, and ability to drill consolidated formations efficiently. Unlike conventional mud rotary systems that depend primarily on drilling fluids for cuttings transport and borehole stabilization, air drilling systems use compressed air either alone or in combination with water, polymers, foaming agents, or surfactants.

Several drilling system options exist when air is used as the drilling fluid:

- Air only (dry air)
- Air and a small volume of water (mist)
- Air, a small volume of water, and a small amount of surfactant
- Air-foam
- Stable foam-air and surfactant
- Stiff foam-air, surfactant, and high-molecular-weight polymer or bentonite.
- Aerated drilling fluid—water-based drilling fluid and air

Factors to consider when deciding which of these systems to use include the volume of water entering the borehole, the penetration rate, the volume of air available, the nature of the formations being drilled, and environmental conditions affecting the drilling process.

AIR MIST SYSTEM

Adding small amounts of water to air creates an air mist system, which helps to control dust and to break down any mud columns forming on the drill rods. To increase the wetting action of the injected water, small amounts of surfactants also can be added to the airstream.

Air-mist techniques can be used satisfactorily if only a small volume of influx water **(15 gpm (81.8 m^3/day) to 25 gpm (136 m^3/day))** enters the borehole from the aquifer; if this volume increases, however, then an air-foam system must replace the air-mist system as needed.

DRY AIR SYSTEM

Optimum drilling rates are achieved because the column of air puts minimum pressure at the bottom of the borehole. As the removal of the rock proceeds, the cuttings become progressively easier to chip off because the overlying weight of the rock is reduced. With this method, penetration rate is affected adversely by downhole pressure. Water well drillers ordinarily begin drilling using only dry air, but dust and influx water usually create the need to alter the dry-air system to air mist.

Air drilling is extremely effective in hard, stable formations such as igneous and metamorphic rocks, and tough, dense sedimentary rocks such as dolomite, where penetration rates often are exceptional. Air has the lowest density of any drilling fluid and therefore places minimum downward pressure on the formation being drilled, and cuttings chip off readily when using either a roller cone or a downhole air-hammer bit. Boreholes are kept clean by the high annular velocity, which ranges **from 3,000 f/min (915 m/min) to 7,000 ft/min (2,134 m/min)** for dry air.

In general, the lifting capacity of air is proportional to its density and to the square of its annular velocity. Thus, to maintain the required annular velocity, the drilling professional adjusts air volume and pressure at the surface to compensate for the weight of the cuttings and for increases in density with depth.

FOAM-AIR SYSTEM

“Foam drilling” is a process where a surfactant-water mixture is introduced into the air system for drilling. Ordinarily, foam is defined as a dispersion of air in water. In an air-foam drilling system, however, air is the continuous phase and water is the dispersed or discontinuous phase. Thus, drilling foam is created when water and surfactant are injected into an airstream. Surfactants include anionic soaps, alkyl polyoxethylene nonionic compounds, and cationic amine derivatives. All of these are available commercially, but it is important to ensure that the surfactant chosen is designed for use in drilling potable water wells.

The addition of a surfactant to an air-based drilling fluid in essence thickens the air, and has several advantages over the use of air alone, including:

- Higher solids-carrying capacity:
- Ability to lift large volumes of water;
- Reduced air-volume requirements:
- Reduced erosion of poorly consolidated formations;
- Effective dust suppression; and increased borehole stability.

The surfactant concentration commonly varies from 0.25% to 2% of the injected water, but significantly more can be required for deep, large-diameter boreholes having large quantities of influx water.

Foams reduce the uphole velocity requirements to **50 ft/min to 1,000 ft/min (15.2 m/min to 305 m/min),** which is considerably less than the rate required for drilling with air alone. Lower uphole velocities reduce the amount of air required. Lower air-volume requirements, in turn, also can reduce the pressures needed. As a result, the loss of air into the formation is minimized.

Air-foam drilling systems improve borehole cleaning by preventing cuttings from clumping and by helping lift water and debris to the surface through the use of surfactants, which reduce water surface tension and break the water mass into droplets that can be easily lifted up.

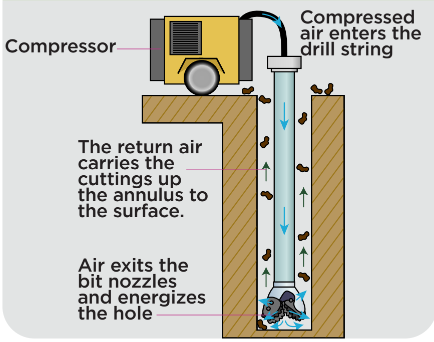
Low LVF Drilling Foam	High LVF Drilling Foam
	
Wet, Low-Volume foam	*Stable, high volume foam*

Performance can be further enhanced by adding polymers or bentonite to increase foam viscosity, stabilize borehole walls, and reduce friction, although bentonite should not be used with downhole air hammers. This is because the clay particles rapidly can cause the hammer to malfunction.

Because surfactants used in water wells must be biodegradable and nontoxic, foam management is also critical to prevent environmental release and control surface accumulation, especially in urban or windy conditions.

Foam drilling is used to air drill in consolidated formations in large diameter wells (12” and above).

Air Drilling - How it works



DOWN THE HOLE HAMMER SYSTEM

DTH drilling is a percussion drilling method where a pneumatic hammer operates directly behind the drill string at the bottom of the hole. Compressed air actuates the hammer while simultaneously removing drill cuttings.

The DTH hammer contains an internal piston that strikes the drill bit at high frequency.
Compressed air:

- Drives the hammer piston
- Removes cuttings
- Cools the hammer

The hammer action breaks the rock through percussion while rotation ensures even cutting.
The advantages of the DTH are that the system has very high penetration rates in hard rock, produces straight boreholes with excellent depth capability and reduced deviation.

However, the system also has limitations

- High air consumption
- Significant compressor fuel costs
- Noise and vibration
- Hammer wear in abrasive formations
- Reduced effectiveness in soft formations

Parameter	Rotary Air	Rotary Air with Mist	Foam	DTH Hammer	DTH Hammer with mist	DTH Hammer with foam
Primary Energy Mechanism	Rotary cutting	Rotary cutting with mist	Rotary cutting with foam	Percussion + rotation	Percussion + rotation	Percussion + rotation
Best Formation Type	Soft Rock	Soft Rock	Unstable/ fractured formations or large diameter holes	Hard competent rock	Hard competent rock	Hard competent rock / large diameter
Borehole Stability	Moderate	Moderate	Good	Good	Good	Good
Penetration Rate	Moderate to high	Moderate to high	Moderate	Very high	Very high	Very high
Dust Control	Poor	Good	Excellent	Poor	Good	Excellent
Water Requirement	Minimal	Low	Moderate	Minimal	Low	Moderate
Equipment Complexity	Moderate	Moderate	Moderate	High	High	High
Typical Cost	Moderate	Moderate	Higher	Higher	Higher	Higher
Hole Cleaning Efficiency	Good	Good	Excellent	Excellent	Excellent	Excellent

CONCLUSIONS

Air drilling technologies provide highly effective alternatives to conventional mud rotary drilling, particularly in hard rock and fractured formations. The selection of the appropriate air drilling variation should be based on formation characteristics, borehole stability, groundwater conditions, drilling depth, environmental considerations, and equipment availability.

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