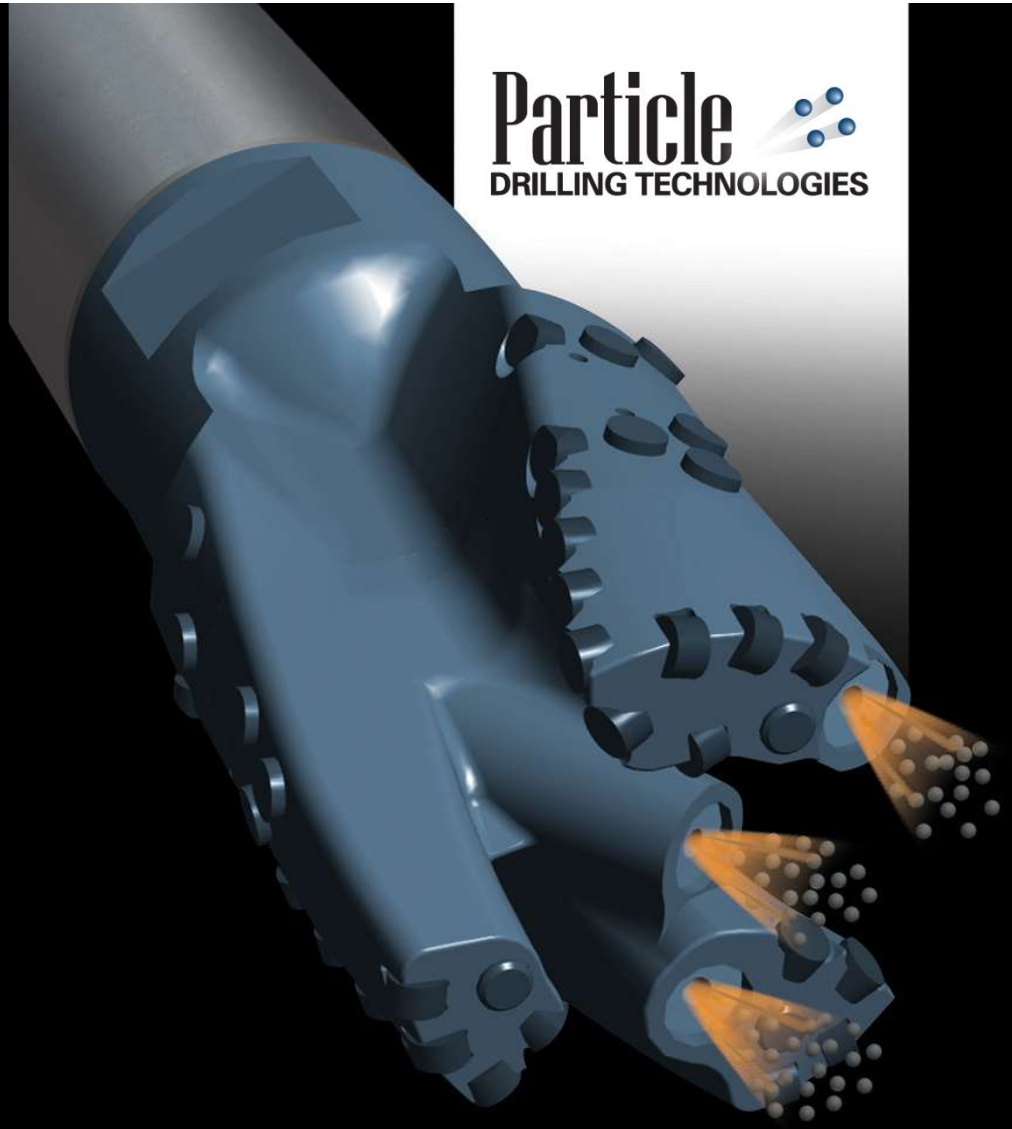


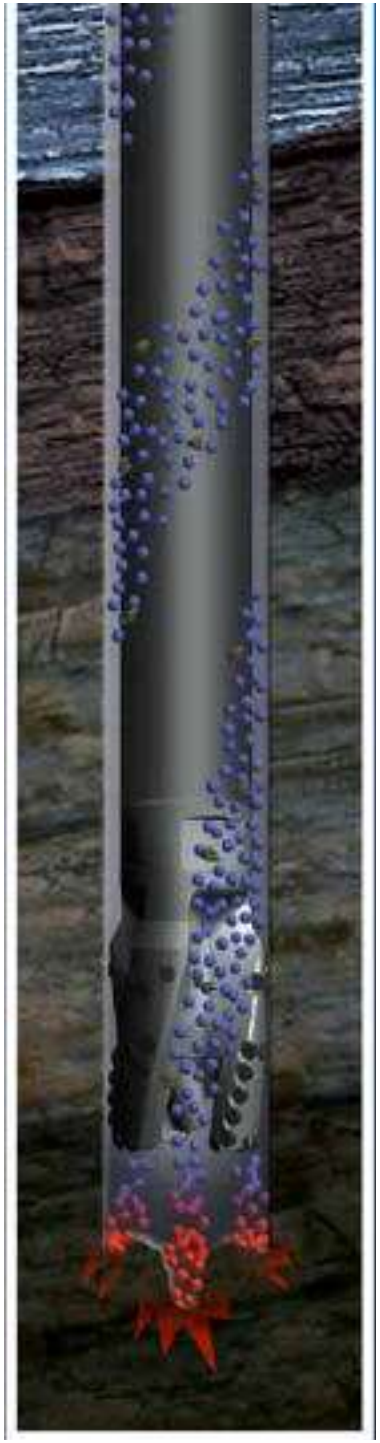
Particle Impact Drilling

Particle
DRILLING TECHNOLOGIES

The Particle Impact Drilling system blasts away hard rock ahead of the bit with hardened steel particles which are accelerated through specially designed nozzles.

Drilling tests in Sierra White Granite show the rock is removed three to six inches ahead of the bit.

Zero weight on bit is required to achieve these results.



Particle DRILLING TECHNOLOGIES

Particle Impact Drilling: The Science

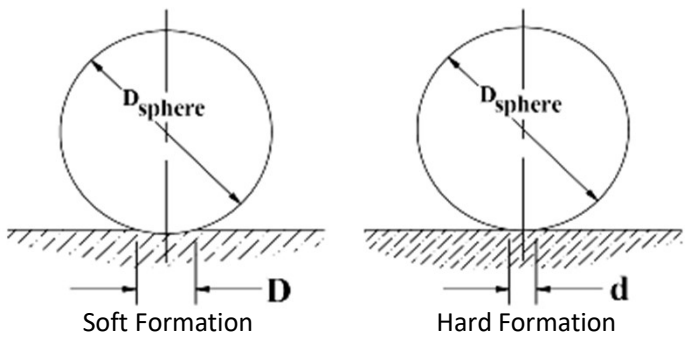
The Particle Impact Drilling (PID) System:

- MV^2 - Mass Times Velocity Squared
- Removes hard rock by <u>blasting</u> it away with hardened steel particles entrained in the drilling fluid
  - Steel particles accelerate through the PID bit nozzles
    - Impacting the hard rock ~12 Million times per minute at 500 ft/sec nozzle velocity
  - The volume of steel particles required is relatively small at only 2-3% of total fluid volume

Particle DRILLING TECHNOLOGIES

Particle Impact Drilling: Why It Works

- **Particle impact force acts over the area of contact between the shot and the rock as shown below. This area is quite small because hard rock does not deform readily nor does the steel shot. As an example; assume the contact area based on a contact radius of 0.010" thereby yielding a contact area of 0.00008 square inches. A force of only 65 pounds is required to generate a 830,000 psi contact stress**



- **Contact Area is a function of diameter squared: d^2**

$$AD >> Ad \qquad \frac{\pi D^2}{4} >> \frac{\pi d^2}{4}$$

- **Fracture propagation easier in harder material (higher comp strength = lower strain to failure)**
- **Contact stress is much greater in higher strength materials**
- **Smaller contact area and higher force due to a reduced time of contact**

Particle
DRILLING TECHNOLOGIES

PID Bits

Each bit diameter goes through rigorous testing to establish the optimum nozzle pattern for removing 100% of the formation in each hole size.

Particle DRILLING TECHNOLOGIES

Test Bits

8-1/2” Bit Diameter

- Delivery System for Steel Particles
- Nozzles and Nozzle Protectors on Face
- No Formation Cutting Structures (PDC’s)
- Used for drilling test patterns to assure full bottom hole coverage of impacting particles
- Two-piece body design allows for multiple nozzle angle configuration changes with short turn-around time between tests

Particle DRILLING TECHNOLOGIES

Test Bits

- **Several unique nozzle types for particle impact pattern testing**
  - **Straight**
  - **Various Angled Bore Nozzles**
  - **Straight Off-Center**
- **Test nozzles have grooves around the diameter**
- **Clocking pins allow for rotation to change the impingement location**

Allows for thousands of potential nozzle configurations in a single test apparatus

6” Diameter External Nozzle View

6” Diameter Internal Nozzle View

Particle
DRILLING TECHNOLOGIES

Nozzle Alignment

Multiple tests are run with varied nozzle configurations until drilling tests show that 100% of the formation is being removed by the steel particles.

Based on hole size, the bit can now be manufactured with a definitive nozzle placement that assures all rock is being removed and hole diameter is being cut to gauge or just over gauge.

Sierra White Granite 30,000 psi

No weight on bit is run during drilling

Particle
DRILLING TECHNOLOGIES

Field Utilization

Each new bit size developed goes through this nozzle alignment process to insure full bottom hole coverage.

The bit is manufactured around the final nozzle alignment and the complete system is ready for field mobilization.

In addition to the bit, there are two primary units that make up the Particle Impact Drilling system

- **Particle Injection Unit**
- **Particle Processing Unit**

Particle
DRILLING TECHNOLOGIES

Fully Automated With Independent Power Generation Unit

Particle
DRILLING TECHNOLOGIES

Particle Injection Unit

Self-contained "Plug and Play" design allows for rig up in a matter of hours

Redundancy on primary components for added reliability

Particle DRILLING TECHNOLOGIES

Particle Injection Unit

Out to standpipe with particle entrained fluid

In from mud pumps with drilling fluid

A three valve manifold is located between the mud pumps and standpipe so that the system can be isolated from the rig circulating system. One line into the particle injection unit and one line out.

Particle DRILLING TECHNOLOGIES

Three Valve Manifold

In From Mud Pumps

In To Injection Unit

Out To Standpipe

Particle Entrained Fluid Out

Particle Injection Unit can be easily isolated from drilling rig in a matter of minutes.

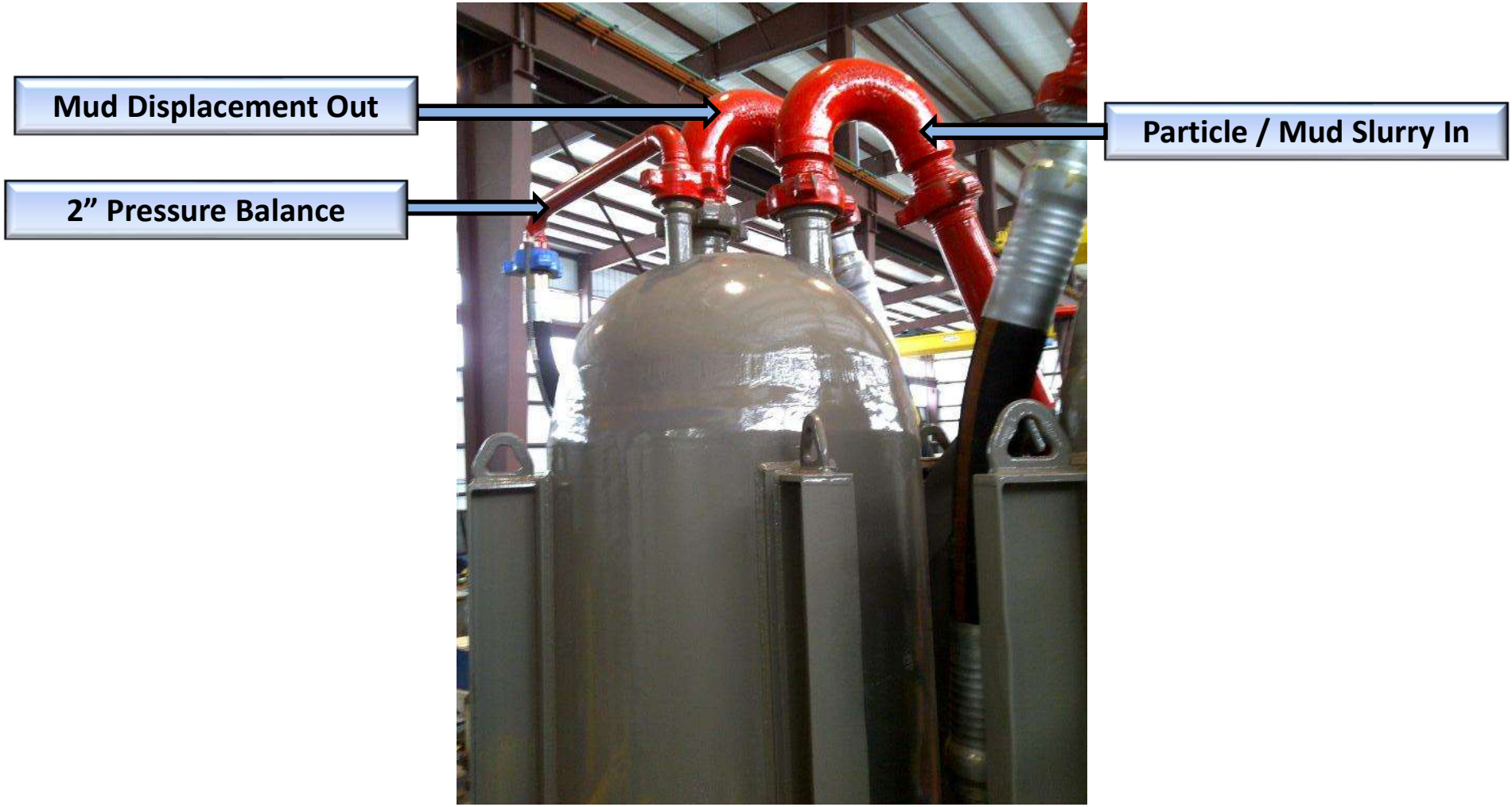
Particle DRILLING TECHNOLOGIES

Particle Injection Unit

- 2” Manifolds include
  - Pressure Transducers
  - Pressure relief valves
  - Pressure Balance Lines
- 4” Manifold Includes
  - Pressure Gauge
  - Pressure transducer

Particle DRILLING TECHNOLOGIES

Particle Injection Unit



Particle Vessel Plumbing

Particle DRILLING TECHNOLOGIES

Particle Injection Unit

Hydro-dynamic Rotary Seal

A two stage, 3 seal system is used to seal the Extruder shaft. Between the first 2 sealing elements, stand pipe pressure plus 200 psi is present. Half of that pressure is applied to the second stage. This insures a small lubricant flow across the sealing elements and prevents contamination with drilling fluid.

Particle DRILLING TECHNOLOGIES

Particle Injection Unit

The Extruder loads a precisely controlled volume of particles into the drilling fluid

Particle DRILLING TECHNOLOGIES

Particle Injection Unit

Extruder Valve Manifold

5” Manifold includes

- 4” Mud line in
- 4-1/16” ID skirted gate valve below each extruder
- 4” Mud Line to Standpipe
- Mud line Manifold 3 valves and 2 Tee’s

Particle
DRILLING TECHNOLOGIES

Particle Processing Unit

- 96,000 lb. drum capacity (keeps shot agitated)
- Load Pin Rollers front and rear
- Integral Motive Pumps
- Particle Hopper (not shown)
- Tandem Triple Deck Shakers
- Collapsible Cat Walks
- Control Panel Integral

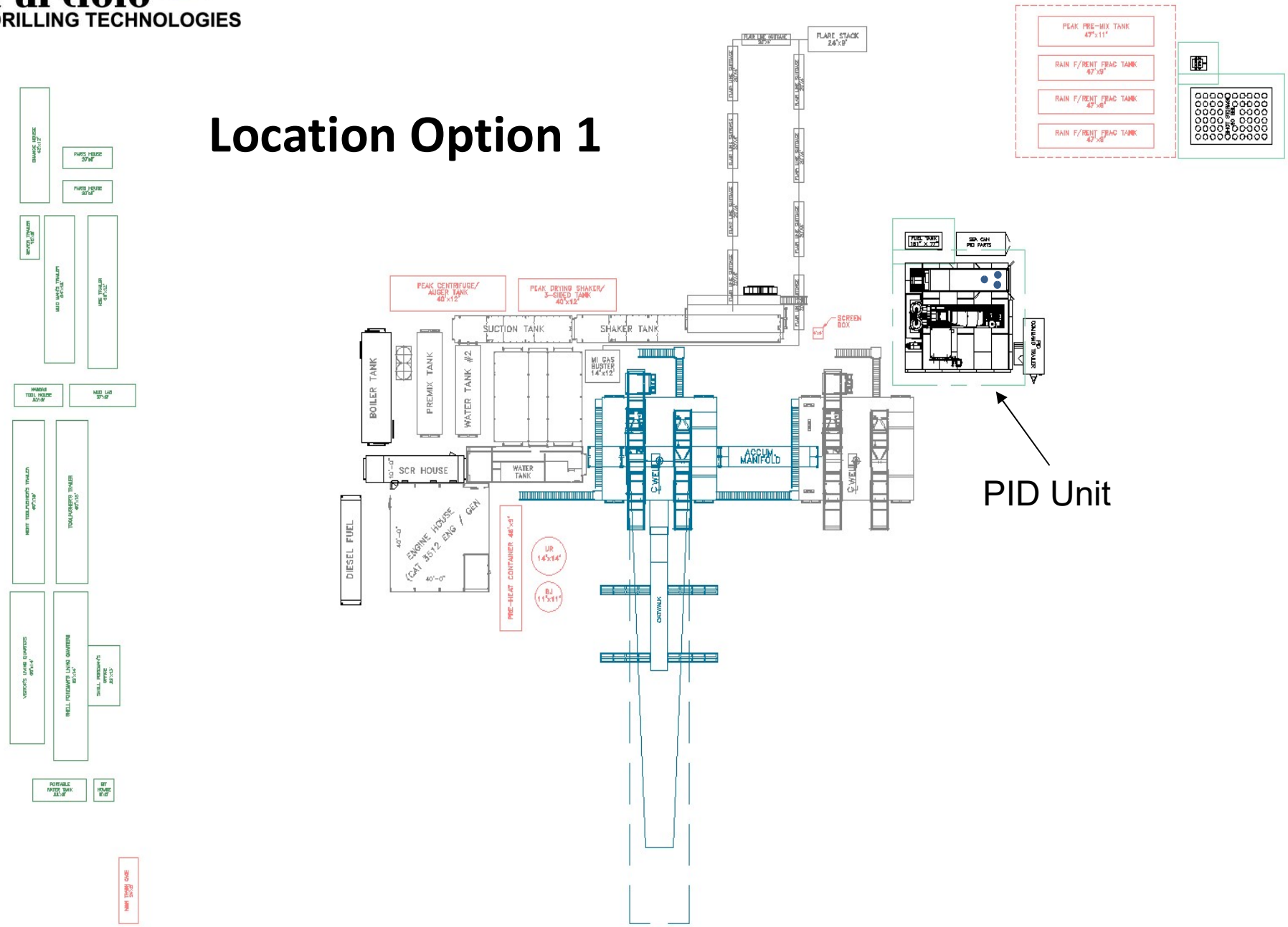
Particle DRILLING TECHNOLOGIES

Particle Processing Unit

The particle processing unit is tied into the particle extractor. A small amount of mud along with the steel particles are received at the unit where the particles are separated from the remaining cuttings with two triple deck shakers. They are then processed and stored for re-circulation into the system.

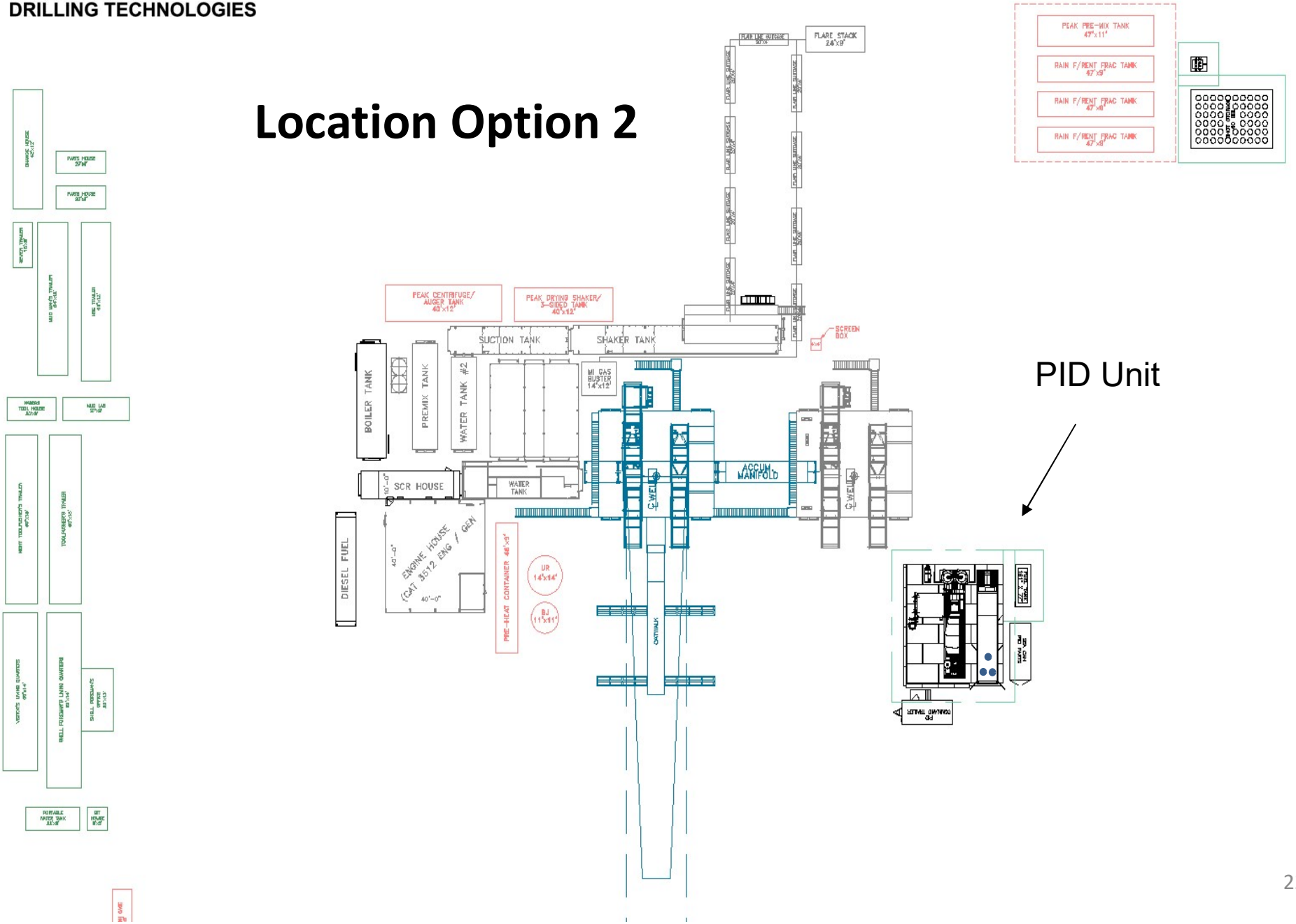
Particle
DRILLING TECHNOLOGIES

Location Option 1



Particle
DRILLING TECHNOLOGIES

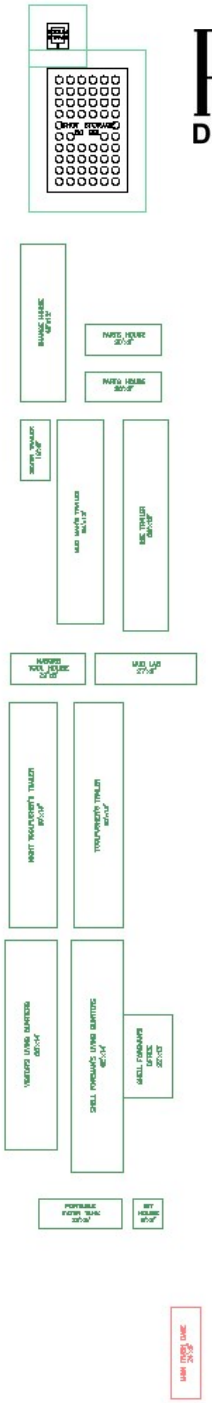
Location Option 2

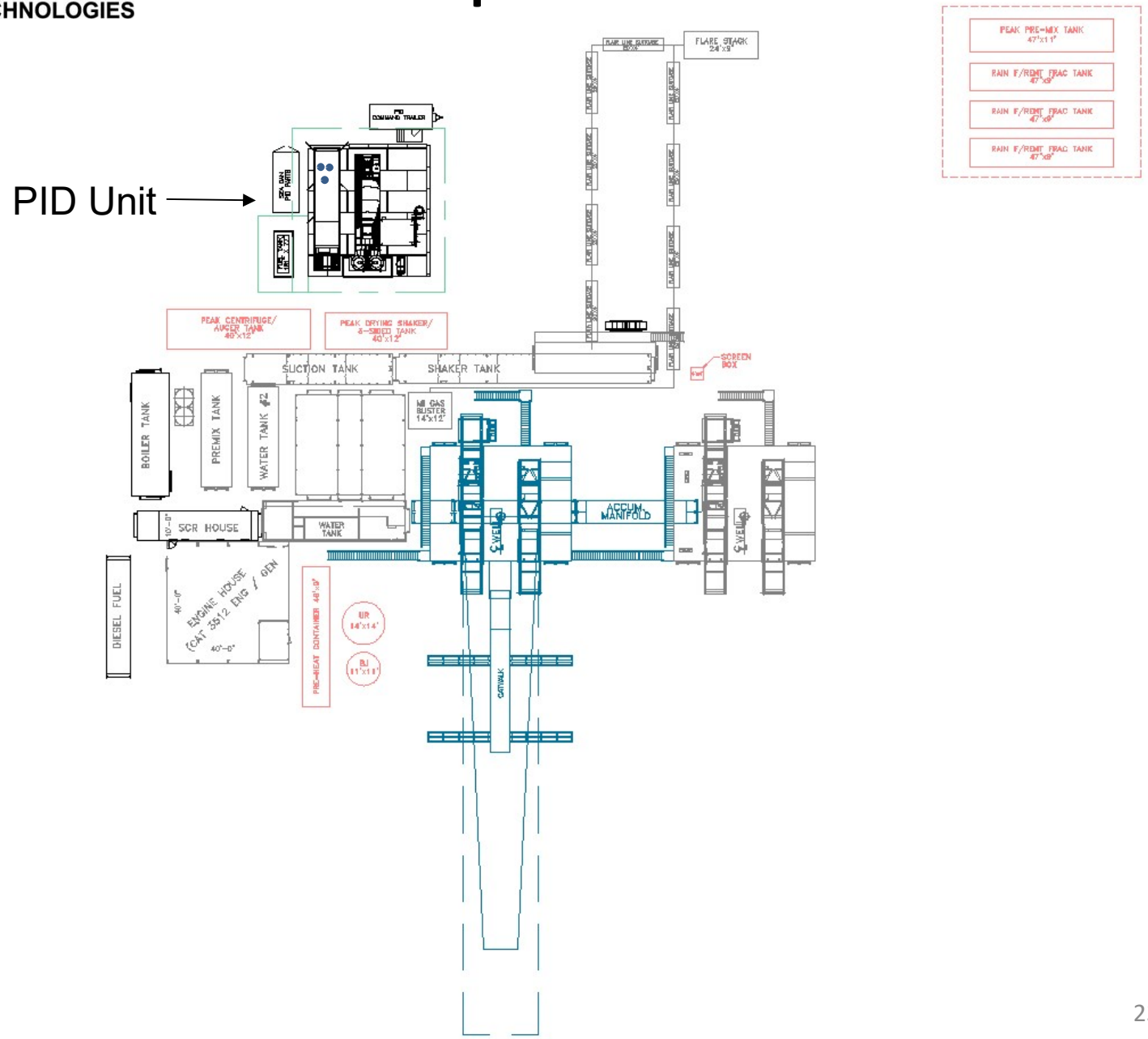


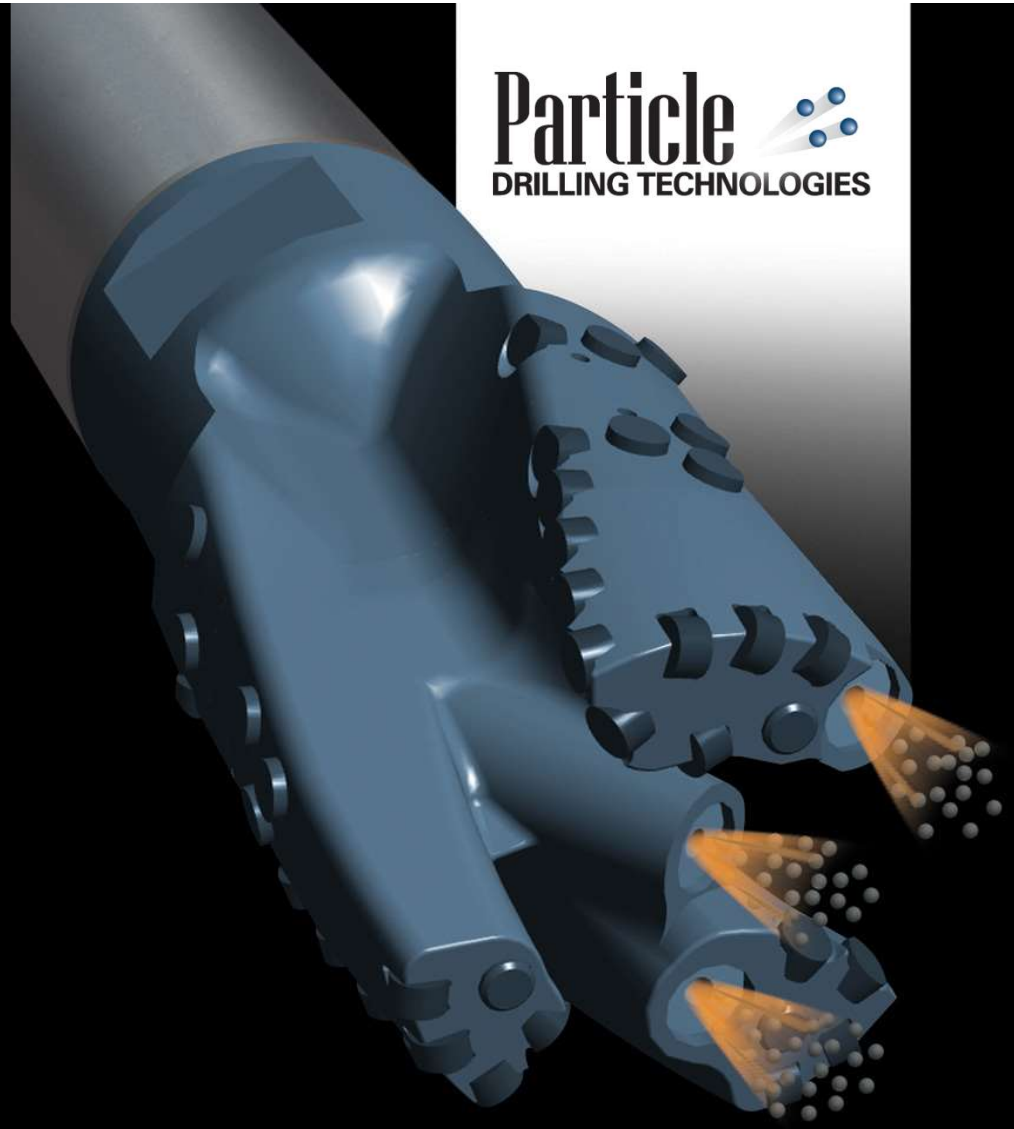
PID Unit

Particle DRILLING TECHNOLOGIES

Location Option 3







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