Rotary Vertical Drilling System (RVDS)
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The MICON-Drilling GmbH is member of the MICON Group, established in 1994, in Nienhagen, Germany. The privately owned company is specialized in design, manufacture, inspection and repair of drill string components, drill bits, sophisticated directional drilling systems and equipment. Main focus is technical service for drilling applications in the mining, tunneling, geothermal and HDD industries.

MICON manufactures drilling equipment for sales and for own purposes in two independent facilities on state-of-the-art CNC milling, turning and welding machines. Latest technology ensures a high degree of efficiency and quality.

An innovative engineering department and an established network with various German universities ensure the continuous development of designs and products. Conventional and unconventional approaches and implementation of German engineering allow a fast reaction time in designing specific equipment, improving existing equipment and developing new equipment.

Improving, existing and designing new equipment for the Raise Boring industries is core business and motivation for MICON. The well-known RVDS target drilling service for pilot hole drilling is one of our products which opens new fields of activities for the Raise Boring industries. In more than 300 projects around the world the MICON-Drilling has proven its reliability and accuracy. In average the RVDS pilot holes deflect less than 0.1% on the drilling distance - even under roughest conditions.
MICON Rotary Vertical Drilling System RVDS 7.3/4", 10", 12.7/8"
(system description and general information)

MICON Rotary Vertical Drilling System RVDS 7.3/4", 10" and 12.7/8"

The Rotary Vertical Drilling System RVDS is a pre-programmed self steering drilling device for drilling vertical holes. The RVDS consists of two modules which are integrated in the lower part of the BHA between the drill bit and the first string stabilizer. A read out unit consisting of a pressure transducer, an interface unit and a computer in the driller cabin complete the system. The data submitted from the RVDS with positive mud pulse technology are displayed in real time on the computer.

The RVDS consists of two modules. The lower module directly behind the drill bit carries the hydraulically activated steering ribs on a non-rotating sleeve and the electronics measuring and processing the actual deviation against the vertical axis of the borehole. The actual deviation against the vertical axis is measured in real time while drilling with 2-axis inclinometers and RVDS internally processed. Occurred deviations are corrected by the steering ribs pushing against the borehole wall and bringing the RVDS back to the vertical position in real time while drilling. The lower module is non-rotating.

The upper module of the RVDS is carrying the hydraulic tank as a reservoir for the hydraulically activated steering ribs, a turbine connected with clutches to an electric generator and to hydraulic pumps and the pulse unit transmitting the data to the surface. The turbine is activated by a defined flow of water or mud through the upper module. If too low or no water or mud flows through the turbine the RVDS is not activated. No electric power for measuring and data processing and no hydraulic pressure for the steering ribs are generated. Too high flows shut the RVDS off or damage it. The turbine is only spinning if water or mud is flushed in one direction through the system; a float valve closes against opposite directed flow. The generated voltage in standard configuration is within the range of 25-75 volts; the electric current is up to 2A, the RVDS internal hydraulic pressure is restricted to 100 bars.

In standard configuration the RVDS is only activated if an incompressible medium is flushed through the turbine; with no flow the RVDS is deactivated and no power is supplied or generated, the RVDS is not carrying batteries or accumulators.

The measured and processed data are transmitted from the RVDS to the surface (outside the borehole) by positive mud pulse technology. A conical piston is closing the flow through the RVDS partially and creating by this an increase of the pressure drop over the RVDS. The change in the pressure is measured by the pressure transducer which is installed in the pressure line between the pump and the drilling machine. A defined sequence of changes in the pressure is creating a signal which is measured by the pressure transducer, decoded by the interface unit located between pressure transducer and computer and the signal is displayed as a reading on the computer. The actual deviation against the vertical axis measured by the 2-axis inclinometers and the functional status of the RVDS are submitted in real time by the RVDS and displayed in real time on the computer. A full sequence of actual readings is displayed every 2 minutes but measured continuously.

The RVDS is pre-programmed and self-steering; only control of the proper function and steering is possible. The steering can be improved with changing the drilling parameters but a direct and active steering is not possible.

For drilling in hazardous areas the surface equipment (outside the borehole) for data display can be provided with ATEX certificates.
Schematic View, Standard Dimensions and Operational Parameters

MICON Rotary Vertical Drilling System (RVDS)

- Mud pulse valve for data transmission via positive mud pulse technology
- Hydraulic oil tank
- Generator and turbine unit carrying also internal electronic boards
- Non-rotating stabilizer carrying inclination sensors
- Steerable ribs hydraulically activated
- Mud flow
# RVDS Operation Parameters

<table>
<thead>
<tr>
<th>Borehole Diameter: 8.1/2” - 9”, Tool Type: 7.3/4”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Torque:</strong></td>
</tr>
<tr>
<td>European</td>
</tr>
<tr>
<td>Marke up torque Bit - Steerable Stab. Sub</td>
</tr>
<tr>
<td>Make up torque Stabilizer - Saver Sub</td>
</tr>
<tr>
<td>Make up torque Saver Sub - Drillstring</td>
</tr>
</tbody>
</table>

| **Flow Rate:** |  
| The Gen. voltage must be between 24 Volts and 80 Volts. This Voltage is generated by a mud flow of approximately: |
| Minimum | 750 l/min | 200 gpm |
| Maximum | 110 l/min | 290 gpm |

| Flow/Pressure for RVDS only (without drillbit and string): |  
| Min. Flow (750 l/min) | 10 bar | 150 psi |
| Max. Flow (1100 l/min) | 15 bar | 220 psi |
| Recommended Pump 80 kW (1100 l/min) | 35 bar | 510 psi |

| **Axial forces:** |  
| Max. WOB | 8 t | 17500 lbs |
| Max. Pull (if Bit is stuck) | 30 t | 66000 lbs |
| Max. Pull (if Steerable Stabilizer is stuck) | 10 t | 22000 lbs |

| **Rotation:** |  
| Operational RPM | 10 - 100 l/min | 10 - 100 l/min |
| Max. RPM | 110 l/min | 110 l/min |

| **Others:** |  
| Install filter in the drill string before circulating, always perform tool test before RiH, circulate 5 minutes each 200m during RiH or POOH, drill string must rotate without vibrations |
RVDS 7.3/4“ Body - 8.1/2“ Borehole Diameter
# RVDS Operation Parameters

<table>
<thead>
<tr>
<th>Borehole Diameter: 12.1/4&quot; - 13.3/4&quot;, Tool Type: 10&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque:</td>
</tr>
<tr>
<td>European</td>
</tr>
<tr>
<td>US</td>
</tr>
<tr>
<td>Marke up torque Bit - Steerable Stab. Sub</td>
</tr>
<tr>
<td>Make up torque Steerable Stab. - Pulser Sub</td>
</tr>
<tr>
<td>Make up torque Pulser Sub - Drillstring</td>
</tr>
<tr>
<td>Flow Rate:</td>
</tr>
<tr>
<td>The Gen. voltage must be between 24 Volts and 80 Volts. This Voltage is generated by a mud flow of approximately:</td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
<tr>
<td>Flow/Pressure for RVDS only (without drillbit and string):</td>
</tr>
<tr>
<td>Min. Flow (1000 l/min)</td>
</tr>
<tr>
<td>Max. Flow (1100 l/min)</td>
</tr>
<tr>
<td>Recommended Pump 80 kW (1100 l/min)</td>
</tr>
<tr>
<td>Axial forces:</td>
</tr>
<tr>
<td>Max. WOB</td>
</tr>
<tr>
<td>Max. Pull (if Bit is stuck)</td>
</tr>
<tr>
<td>Max. Pull (if Steeable Stabilizer is stuck)</td>
</tr>
<tr>
<td>Rotation:</td>
</tr>
<tr>
<td>Operational RPM</td>
</tr>
<tr>
<td>Max. RPM</td>
</tr>
<tr>
<td>Others</td>
</tr>
<tr>
<td>Install filter in the drill string before circulating. Always perform tool test before RiiH. Circulate 5 minutes each 200m during RiiH or POOH. Drill string must rotate without vibrations</td>
</tr>
</tbody>
</table>
RVDS 10” Body - 12.1/4”+13.3/4” Borehole Diameters

66-101148
8.1/4” DI22

203 [8.0’]

8.1/4” DI22

203 [8.0’]

254 [10.0’]

279 [11.0’]

349 [13.75’]

optional Ø 311 [12.25’]

6.5/8” API Reg.
063-806-611

241.3 [9.50’]
# RVDS Operation Parameters

**Borehole Diameter:** 15”/17.1/2” (1400 l/min Turbine), **Tool Type:** 12.7/8” (DI22)/(DI42)

<table>
<thead>
<tr>
<th>Torque:</th>
<th>European</th>
<th>US</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make up torque Bit - Steerable Stab. Sub</td>
<td>30 kNm</td>
<td>22 kft-lb</td>
</tr>
<tr>
<td>(DI42) Make up torque SS Sub. - Pulser Sub:</td>
<td>500 kNm</td>
<td>370 kft-lb</td>
</tr>
<tr>
<td>Make up torque Pulser Sub - String</td>
<td>500 kNm</td>
<td>370 kft-lb</td>
</tr>
<tr>
<td>(DI22) Make up torque SS Sub. - Pulser Sub:</td>
<td>250 kNm</td>
<td>180 kft-lb</td>
</tr>
<tr>
<td>Make up torque Pulser Sub - String</td>
<td>440 kNm</td>
<td>320 kft-lb</td>
</tr>
</tbody>
</table>

**Flow Rate:**
The Gen. voltage must be between 24 Volts and 80 Volts. This Voltage is generated by a mud flow of approximately:

- **Minimum** Flow | 1000 l/min | 265 gpm |
- **Maximum** Flow | 1600 l/min | 425 gpm |

**Flow/Pressure for RVDS only (without drillbit and string):**

- **Min. Flow (1000 l/min)** | 10 bar | 150 psi |
- **Max. Flow (1600 l/min)** | 25 bar | 360 psi |
- **Recommended Pump 100 kW (1500 l/min)** | 30 bar | 435 psi |

**Axial forces:**

- **Max. WOB** | 25 t | 55 klbs |
- **Max. Pull (if Bit is stuck)** | 100 t | 220 klbs |
- **Max. Pull (if Steerable Stabilizer is stuck)** | 10 t | 22 klbs |

**Rotation:**

- **Operational RPM** | 10 - 60 1/min | 10 - 60 1/min |
- **Max. RPM** | 70 1/min | 70 1/min |

**Others:**

- Install filter in the drill string before circulating, always perform tool test before RiiH, circulate 5 minutes each 200m during RiiH or POOH, drill string must rotate without vibrations.
RVDS 12.7/8” Body - 15”+17.1/2” Borehole Diameters
RVDS Lifetime Records

RVDS Record 2009, Canada

RVDS Record 2013, South Africa
Use of automatically controlled vertical drilling systems in drilling projects with the highest requirements on accuracy

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The surveying and development of deposits in the worldwide mining industry require the wider use of reliably operating automatically controlled directional drilling systems. The fields of application of these systems extend over the entire spectrum of drilling technology in the mining industry – from freezing boreholes via degasification boreholes to pilot boreholes for raise boring. Two completed projects, in which the function and handling of these systems defining the state of the art are explained, are described below.

Drilling of freezing boreholes with a diameter of 8 ½” to a final depth of 650 m in a specified target window of 0.3 m diameter for a shaft sinking project in Poland.

Drilling a pilot borehole with a diameter of 13 ¾” to a depth of 865 m in a specified target window of likewise 0.3 m diameter for a subsequent raised borehole in the Canadian gold mining industry.

Because of the increasing depths automatically controlled directional drilling systems are being used to an increasing extent in the surveying and development of deposits in the international mining industry. Two completed projects, in which the function and handling of these systems are explained, are described in the contribution.

The possible combinations of this system originally developed for specific applications with the different available drilling rods and rigs as well as the widely varying geology in the different areas of the mining industry with a uniform and reliable method of operation distinguish these automatically controlled systems from conventional directional drilling technology.

Construction and method of operation of the MICON-RVDS

In the drilling rod the so-called rotary vertical drilling system (RVDS) is installed immediately behind the roller bit. The MICON-RVDS consists of two 1.5 m long components (Figure 1). The lower component carries the control ribs as well as the electronic control and measuring system on a non-rotating sleeve. The power supply, data transmission and the hydraulic tank are incorporated in the upper component.

The actual inclination values are measured and adjusted continuously with the required values during drilling. If the measured values deviate from the required values – i.e. the tool moves from the vertical – the control ribs are activated and act against the build-up of deflection. The measured inclination values are converted into signals and are transferred from the lower to the upper component for transmission to the surface.

At the same time these measured values as well as other relevant data such as flushing floor, borehole temperature and control status in the RVDS are stored internally.

The incoming signals are transmitted by so-called positive pulse technology from the upper component to the surface. Furthermore, a turbine and hydraulic tank are incorporated in the upper component.
were drilled with the 7 ¾” x 8 ½” RVDS to depths of 430 m and 650 m.

Table 1. RVDS field results from 1993 to 2008 (153 projects).

<table>
<thead>
<tr>
<th>RVDS</th>
<th>Drilled distance by continent</th>
<th>Average deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 ¾” (8 ½” – 9 ⅞” holes)</td>
<td>18,739 m</td>
<td>Europe 0.05 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Asia –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Australia –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– Africa –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– North America –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>– South America –</td>
</tr>
<tr>
<td>Total</td>
<td>18,739 m</td>
<td>Worldwide 0.05 %</td>
</tr>
<tr>
<td>9 ⅞” (12 ¼” – 13 ¾” holes)</td>
<td>7,948 m</td>
<td>Europe 0.13 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asia 0.23 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Australia 0.08 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Africa 0.23 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North America 0.10 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South America –</td>
</tr>
<tr>
<td>Total</td>
<td>15,328 m</td>
<td>Worldwide 0.15 %</td>
</tr>
<tr>
<td>10” (12 ¼” – 13 ¾” holes)</td>
<td>1,290 m</td>
<td>Europe 0.04 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asia 0.04 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Australia 0.10 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Africa –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North America 0.08 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South America –</td>
</tr>
<tr>
<td>Total</td>
<td>3,802 m</td>
<td>Worldwide 0.06 %</td>
</tr>
<tr>
<td>12 ¼” (15” – 17 ½” holes)</td>
<td>3,056 m</td>
<td>Europe 0.05 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asia –</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Australia 0.07 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Africa 0.06 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>North America 0.21 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>South America 0.34 %</td>
</tr>
<tr>
<td>Total</td>
<td>15,591 m</td>
<td>Worldwide 0.10 %</td>
</tr>
<tr>
<td>Total all RVDS-Sizes</td>
<td>53,460 m</td>
<td>Worldwide 0.09 %</td>
</tr>
</tbody>
</table>

component. This turbine is driven by the flushing flow. An electrical generator and the hydraulic pumps are connected to the turbine. With the turbine running both the required electrical energy for the internal power supply as well as the hydraulic pressure for actuation of the control ribs are generated. The hydraulic oil for equalisation of small leakages is stored in the hydraulic tank.

Depending on the application the RVDS is supplied in individual components or fully assembled – usually in 1.5 m long components for use on raise bore machines or fully assembled in a length of 3 m for use on rotary drilling rigs. Different RVDS adapted to the borehole diameter are used.

The usual RVDS diameters are as follows:

- 7 ¾”
- 10” and 12 7/8”

with the suitable control ribs in the borehole diameter.

Common borehole diameters are as follows:

- 8 ½”
- 9 ½”
- 13 ¾”
- 15”
- 17 ½”

The systems are adapted for diameters deviating from the above.

### Fields of application

The RVDS are used almost exclusively in areas, in which the highest accuracy requirements have to be met with regard to the course of the borehole and target window.

The borehole diameter of 8 ½”, for example, is a common diameter for freezing boreholes. In this case a small target window has to be hit with the straightest possible course of the borehole from the start of drilling to the final depth.

The borehole diameters of 12 ¼”, 13 ¾” and 15” are customary diameters in raise boring. In this case the requirements are again the same as those for freezing boreholes, viz. the straightest possible course of the borehole from the start of drilling to final depth in a small target window. Regardless of the borehole diameter the accuracies achievable with the RVDS are in the per thousand range referred to the borehole length – on average accuracies of 0.25 m referred to 500 m borehole length have been achieved over the past 15 years (Table 1).

Other fields of application are gas storage boreholes and boreholes for supply pipes in the mining industry. The borehole diameters in these applications of 16” and 17 ½” respectively differ from the above-mentioned diameters.

### Use of RVDS in freezing boreholes in Lagoszow, Poland

It was necessary to stabilise the rock by freezing boreholes before sinking a winding shaft in Lagoszow, Poland (Figure 2). A total of 36 boreholes were drilled with the 7 ¾” x 8 ½” RVDS to depths of 430 m and 650 m.

The bottom hole assembly (BHA) for depths up to 430 m consisted of an IADC 1-1-7 or 1-1-8 roller bit, the 7 ¾” x 8 ½” RVDS, an undersize stabiliser behind the RVDS, 6 ½” heavy rods and 5” API drilling rod. Because of the harder rock
the deeper boreholes below 430 m to the final depth were drilled with an IADC 4-3-7 roller bit, but otherwise the same BHA. In addition three monitoring boreholes were drilled to depths of 650 and 850 m outside the actual freezing circle (Figure 3).

During the entire project boreholes were drilled in parallel with two rigs. On average a gross drilling rate of 3.6 m/h was achieved over the entire project period. The nett drilling rate was higher by a factor of 2 than the gross drilling rate. A total of 18,000 m freezing boreholes and 2,100 m monitoring boreholes were drilled.

All boreholes remained over their full length within a “target cylinder” with a diameter of 0.3 m – including the borehole diameter of 0.2 m (Figure 4).

**Use of RVDS in a pilot borehole for subsequent raise boring in Rouyn, Canada**

A 13 ¾” pilot borehole for the subsequent raising of a ventilation shaft in Rouyn, Canada, was drilled with the RVDS. The borehole was drilled to a final depth of 865 m in a target window of 0.3 m diameter. The BHA from the start of drilling to the final depth consisted of an IADC 5-1-7 roller bit, the 10” x 13 ¾” RVDS, a roller reamer behind the RVDS, three 12 ¼” x 10 ½” DI raise bore rods, an undersize stabiliser and subsequently 12 ¾” x 10 ½” DI raise bore rods, an undersize stabiliser and subsequently 12 ¾” x 10 ½” DI 22 raise bore rods (Figure 5).

No deviation (dogleg) was measurable over the total borehole length, i.e. the straight borehole could be used without restriction for the raising in the planned diameter of 4.5 m. The drilling rate of 1.5 m/h usual in raise boring was always achieved. When the worn bit was changed the RVDS was also changed. Two round trips over a drilling length of 865 m were required for this purpose (Figure 6).

**Prospects**

The following RVDS further developments are currently at the planning stage or are nearing completion. The development of a 3-D-tool, a system which can drill in any direction after suitable programming is being planned. Development of an RVDS for drilling by the airlift method will be completed in April/May 2009. Both the EM data transmission system and the bidirectional communication with the RVDS, which will permit “reprogramming” and communication during drilling, will be completed in May/June 2009.

It is foreseeable that automatically controlled systems will be more widely used in future. This is associated firstly with the fact that the increasing complexity of imminent projects requires new approaches to solutions and secondly that the mere availability of these systems now permits the planning and execution of specific projects, which had already been planned five years ago, but at the time were feasible only at high costs. Only completed raise boring in the mining industry to a final depth of more than 1,000 m from existing roadways and freezing boreholes with the highest requirements on the course of the borehole and target accuracy are mentioned here as examples.