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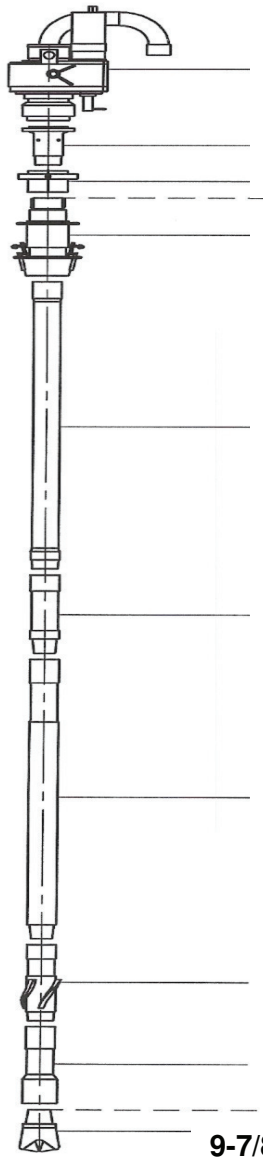
Case Study: Direct Circulation Drilling

A Typical Drill-String for Direct Circulation Drilling:



Power Swivel

Adapter Sub with Pin PSG 146

Sliding Sleeve for PSG 146

Pulling Device for PSG 146 with box PSG 146 -SL

Chucks for Make-up and Break-Out Device

Drill Pipe 146x8 mm, ID = 127 mm, with box/pin PSG 146

Clamping Device Inserts for Ø 146 mm

Cross-Over box PSG 146-SL / pin 4-1/2“ IF

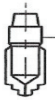
Drill Collar Ø 6-1/4“, with box/pin 4-1/2“ IF

Stabilizer Ø 9-3/8“, with box/pin 4-1/2“ IF

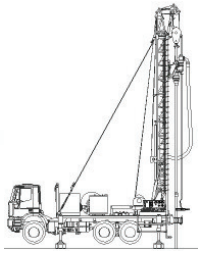
Bit Sub box 4-1/2“ IF / box 4-1/2“ Reg.

9-7/8“ Tricone Bit

Stepped Drag-Bit



Winged Drag-Bit



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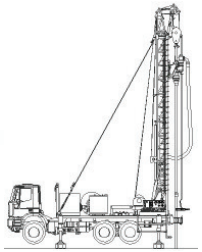
Case Study: Direct Circulation Drilling

Borehole Ø [inch]	Borehole Ø [mm]	Drill Pipe Ø [mm]	Pump Flow Rates [l/min] 450	700	1400	2000	3000	optimal Annular Rising Velocity (0,7 - 1,0 m/s)
			Mud Annular Rising Velocity [m/s]					
4¾	120,6	83	1,25	1,94	(3,88)	---	---	0,75 - 1,5
5⅝	142,9	83	0,71	1,10	2,20	(3,14)	(4,71)	
6¼	158,7	83	(0,53)	0,82	1,63	(2,32)	(3,48)	
		108	0,71	1,10	2,20	(3,14)	(4,71)	
7⅝	193,7	83	(0,32)	(0,49)	0,97	1,39	2,08	0,67 - 0,92
		108	(0,37)	(0,58)	1,15	1,65	2,47	
		146	(0,59)	0,92	1,84	2,62	(3,93)	
8¾	222,3	83	(0,23)	(0,35)	0,70	1,00	1,50	0,65 - 0,90
		108	(0,26)	(0,40)	0,79	1,13	1,69	
		146	(0,34)	(0,53)	1,06	1,51	2,27	
9⅝	244,5	83	(0,18)	(0,28)	0,57	0,81	1,21	0,56 - 0,75
		108	(0,20)	(0,31)	0,62	0,89	1,33	
		146	(0,25)	(0,39)	0,78	1,11	1,66	
11	279,4	83	(0,14)	(0,21)	(0,42)	0,60	0,90	0,50 - 0,65
		108	(0,15)	(0,23)	0,45	0,64	0,96	
		146	(0,17)	(0,27)	0,53	0,75	1,13	
12¼	311,2	83	(0,11)	(0,17)	(0,33)	0,48	0,71	0,45 - 0,60
		108	(0,12)	(0,18)	(0,35)	0,50	0,75	
		146	(0,13)	(0,20)	0,40	0,57	0,85	
		244	(0,26)	0,40	0,80	1,14	1,71	
13¾	350,0	108	---	(0,14)	(0,27)	0,39	0,58	0,40 - 0,55
		146	---	(0,15)	(0,30)	0,42	0,63	
		244	---	(0,24)	0,48	0,68	1,02	
14¾	374,6	108	---	(0,12)	(0,23)	(0,33)	0,50	0,37 - 0,48
		146	---	(0,13)	(0,25)	0,36	0,54	
		244	---	(0,19)	0,37	0,53	0,79	
17½	444,5	108	---	---	(0,16)	(0,23)	0,35	0,34 - 0,43
		146	---	---	(0,17)	(0,24)	0,37	
		244	---	(0,11)	(0,22)	0,31	0,47	
20	508,0	108	---	---	(0,12)	(0,18)	(0,26)	Air-Lift
		146	---	---	(0,13)	(0,18)	(0,27)	
		244	---	---	(0,15)	(0,22)	0,32	
Pressure losses [bar] per 100 m in respective Drill Pipes:		83	1,10	2,60	5,80	10,00	---	
		108	0,20	0,40	1,70	3,20	5,00	
		146	0,04	1,10	0,20	0,30	0,50	
		244						

Annular Mud Velocities Using Direct Circulation Drilling in relation to Borehole Ø and the Respective Drill String Employed



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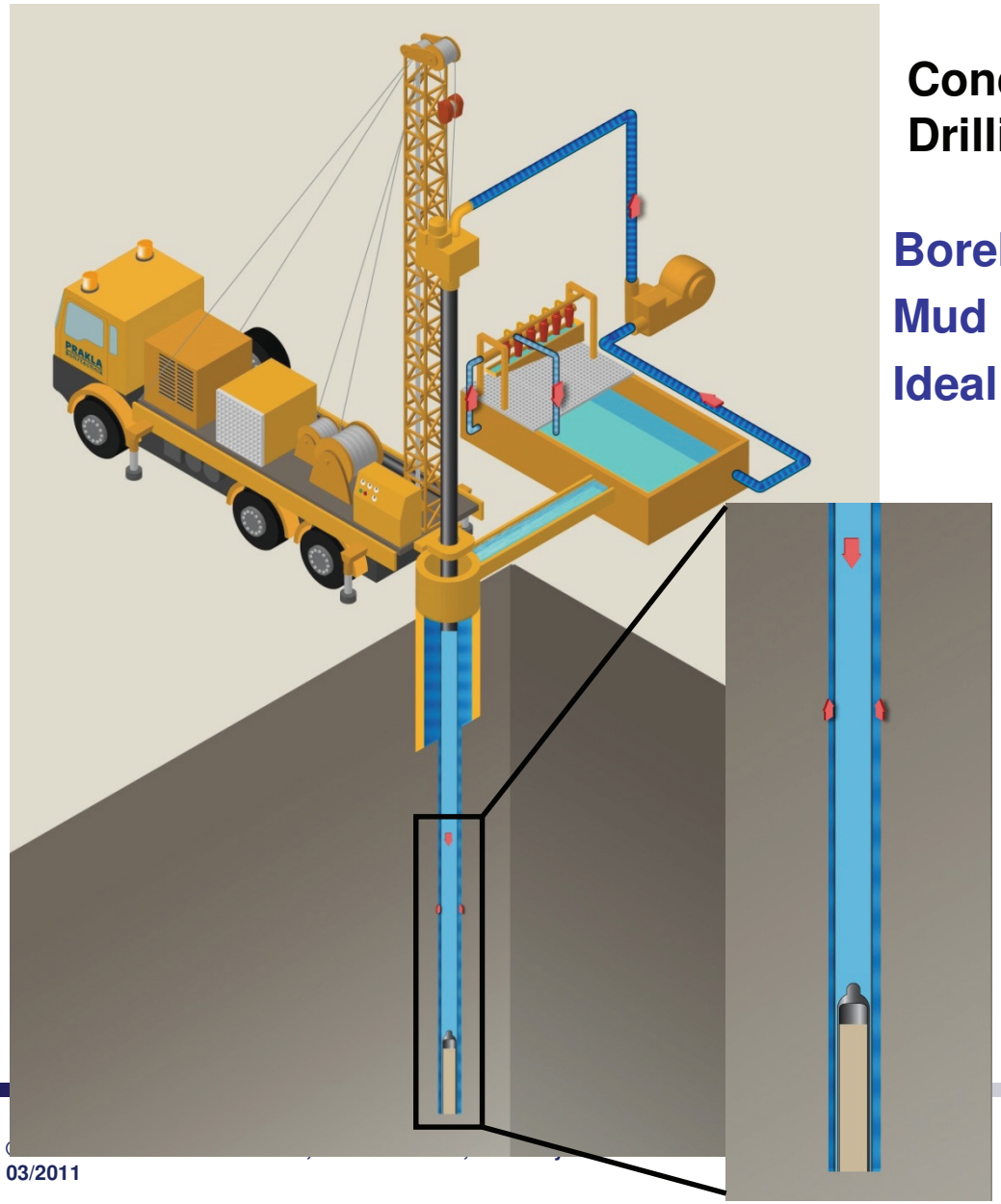
Case Study: Core Drilling



Concept of a Borehole for Core Drilling in Direct Circulation:

Borehole Diameter: 60 - 175 mm

Mud rising velocities in Annulus:

Ideal: 0,8 - 1 m/sec

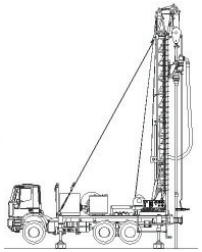
Applications:

- Geotechnical Investigations, Exploration

(Piston Mud Pump:

High Pressure rating

lesser Flowrates)



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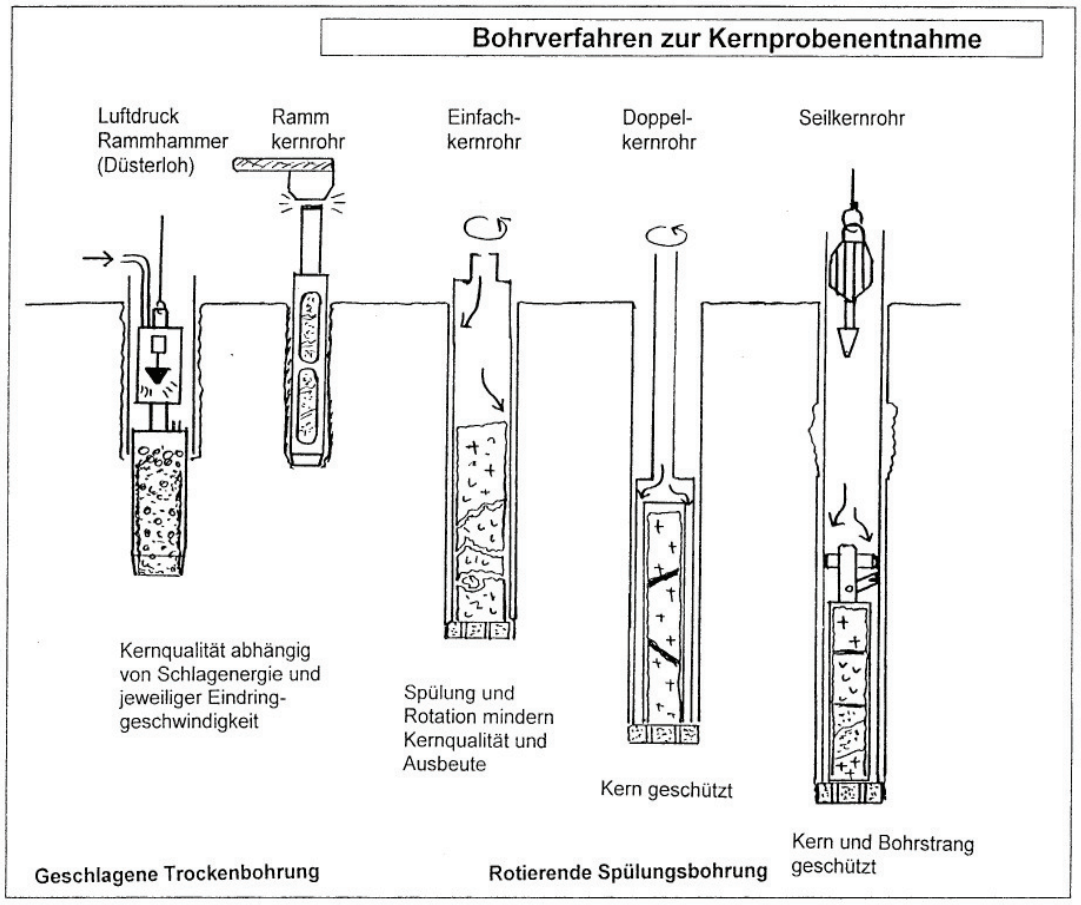
Case Study: Core Drilling

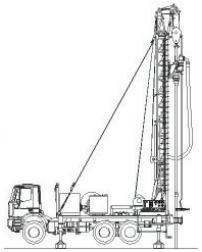
Power Swivel Requirements:

- Rotational Speeds: 240 – 350 rpm
- Core diameters >= 85 mm
- Piston Mud Pump Pressure Ratings



Technically deployable

- **Single Core Barrel**
- **Double Core Barrel**
- **Wireline Core Barrel**



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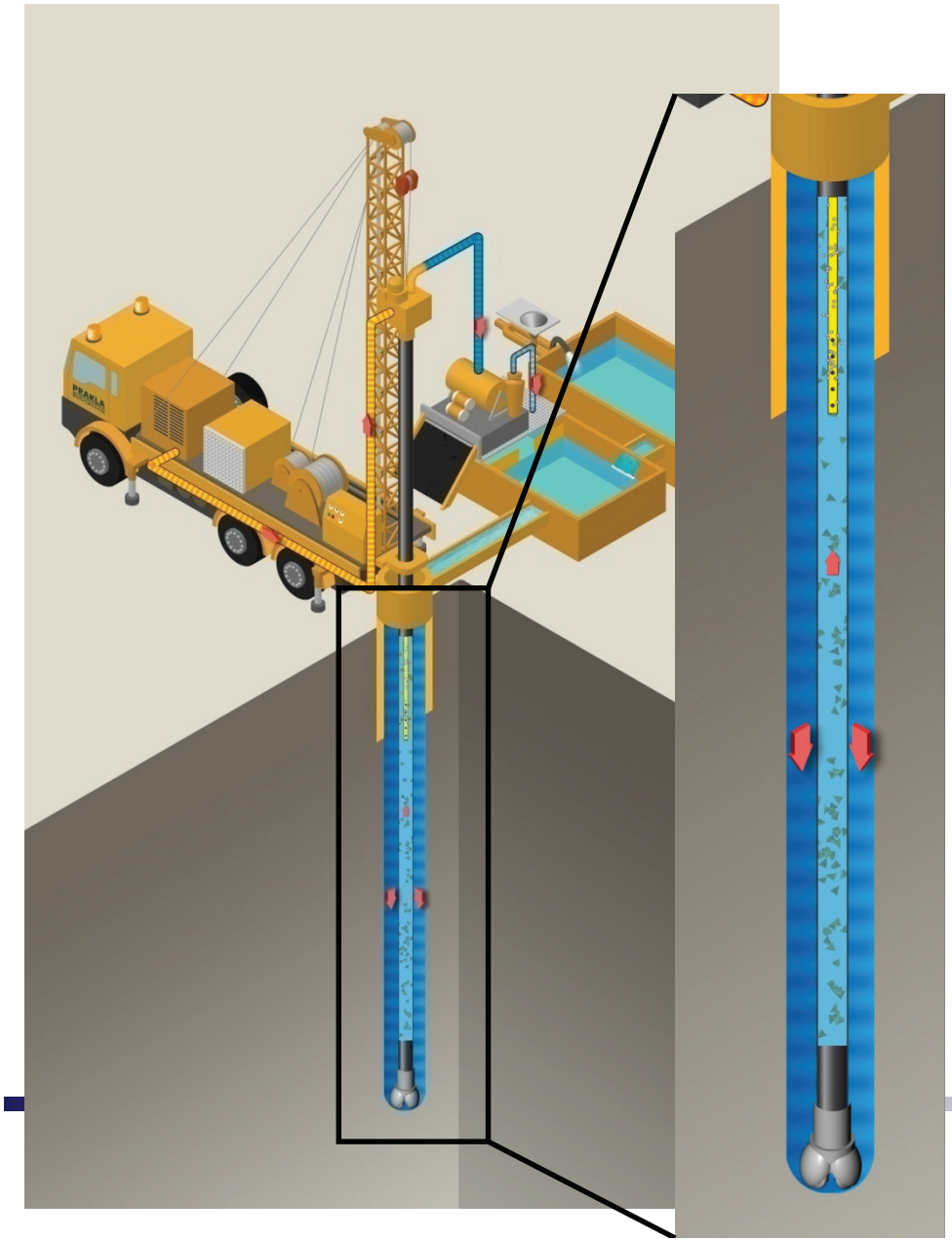
Case Study: RC Air-Lift Drilling



Concept of a borehole being drilled using Reverse Circulation Air-lift Drilling:

Drilling Diameter: 300 – 1 200 mm

Mud Rising Velocities inside Drill Pipe:

Ideal: 3 - 4 m/sec

Mud Sinking Velocities in Annulus:

approx. 20 m/min

Application:

- **In wells with larger drilling diameters (Ø >300 mm)**
- **In sensitive geology (loose, unconsolidated rock)**
- **In depths from ca. 30 m, depending on hydrostatic constellation > 1 000 m**

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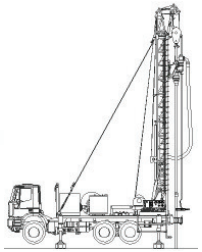
Case Study: RC Air-Lift Drilling

Borehole Ø [inch]	Borehole Ø [mm]	Drill Pipe Ø [mm]	Pump Flow Rates [l/min] 450	700	1400	2000	3000	optimal Annular Rising Velocity (0,7 - 1,0 m/s)
			Mud Annular Rising Velocity [m/s]					
4¾	120,6	83	1,25	1,94	(3,88)	---	---	0,75 - 1,5
5⅝	142,9	83	0,71	1,10	2,20	(3,14)	(4,71)	
6¼	158,7	83	(0,53)	0,82	1,63	(2,32)	(3,48)	
		108	0,71	1,10	2,20	(3,14)	(4,71)	
7⅝	193,7	83	(0,32)	(0,49)	0,97	1,39	2,08	0,67 - 0,92
		108	(0,37)	(0,58)	1,15	1,65	2,47	
		146	(0,59)	0,92	1,84	2,62	(3,93)	
8¾	222,3	83	(0,23)	(0,35)	0,70	1,00	1,50	0,65 - 0,90
		108	(0,26)	(0,40)	0,79	1,13	1,69	
		146	(0,34)	(0,53)	1,06	1,51	2,27	
9⅝	244,5	83	(0,18)	(0,28)	0,57	0,81	1,21	0,56 - 0,75
		108	(0,20)	(0,31)	0,62	0,89	1,33	
		146	(0,25)	(0,39)	0,78	1,11	1,66	
11	279,4	83	(0,14)	(0,21)	(0,42)	0,60	0,90	0,50 - 0,65
		108	(0,15)	(0,23)	0,45	0,64	0,96	
		146	(0,17)	(0,27)	0,53	0,75	1,13	
12¼	311,2	83	(0,11)	(0,17)	(0,33)	0,48	0,71	0,45 - 0,60
		108	(0,12)	(0,18)	(0,35)	0,50	0,75	
		146	(0,13)	(0,20)	0,40	0,57	0,85	
		244	(0,26)	0,40	0,80	1,14	1,71	
13¾	350,0	108	---	(0,14)	(0,27)	0,39	0,58	0,40 - 0,55
		146	---	(0,15)	(0,30)	0,42	0,63	
		244	---	(0,24)	0,48	0,68	1,02	
14¾	374,6	108	---	(0,12)	(0,23)	(0,33)	0,50	0,37 - 0,48
		146	---	(0,13)	(0,25)	0,36	0,54	
		244	---	(0,19)	0,37	0,53	0,79	
17½	444,5	108	---	---	(0,16)	(0,23)	0,35	0,34 - 0,43
		146	---	---	(0,17)	(0,24)	0,37	
		244	---	(0,11)	(0,22)	0,31	0,47	
20	508,0	108	---	---	(0,12)	(0,18)	(0,26)	Air-Lift
		146	---	---	(0,13)	(0,18)	(0,27)	
		244	---	---	(0,15)	(0,22)	0,32	
Pressure losses [bar] per 100 m in respective Drill Pipes:		83	1,10	2,60	5,80	10,00	---	
		108	0,20	0,40	1,70	3,20	5,00	
		146	0,04	1,10	0,20	0,30	0,50	
		244						

Annular Mud Velocities Using Direct Circulation Drilling in relation to Borehole Ø and the Respective Drill String Employed



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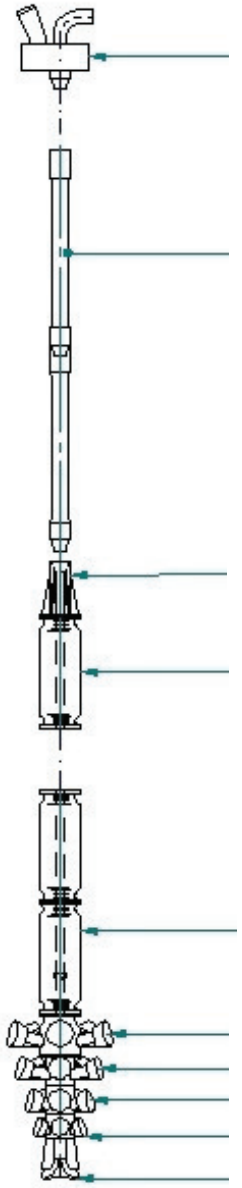
Case Study: RC Air-Lift Drilling

2 Typical Drill Strings for Air-Lift Drilling:



Power Swivel with
Adapter Sub and
Air-Side Entry for
pin DWG 200

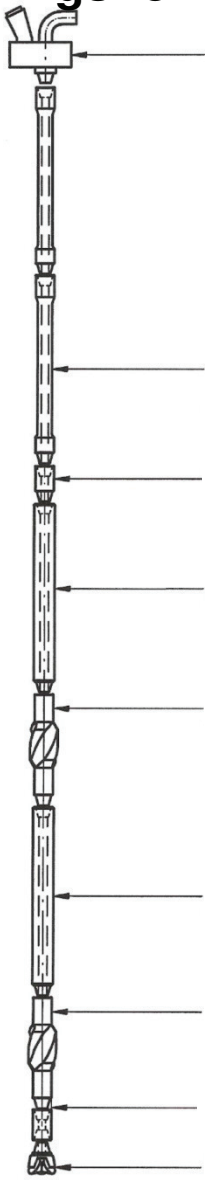
Double Walled Drill Pipe
200x168 mm (OD – ID)
With box/pin DWG 200

Cross-Over Sub box DWG 200
to Flange 520 mm OD for DC

Double Walled Drill Collar Ø 520 mm,
With Flange 520 mm OD
ID: 150 mm
Weight: 2000 kg, Length 1500 mm

Double Walled Drill Collar Ø 520 mm,
With Flange and Air-Outlet Valve

4. Reamer Bit Ø 1270 mm
3. Reamer Bit Ø 1050 mm
2. Reamer Bit Ø 820 mm
1. Reamer Bit Ø 620 mm
Pilot Tricone Bit Ø 415 mm



Power Swivel with
Adapter Sub and
Sliding Sleeve for
pin PSG 178

Drill Pipe 178x10 mm,
ID: 155 mm,
With box/pin PSG 178

Cross-Over Sub box PSG 178
on pin 5-1/2“ IF

Drill Collar Ø 9-1/2“, ID = 110 mm,
With box/pin 5-1/2“ IF

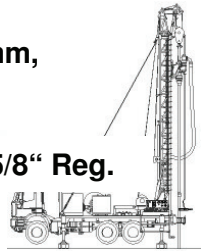
Stabilizer Ø 17-3/8“, ID = 110 mm,
With box/pin 5-1/2“ IF

Drill Collar Ø 9-1/2“, ID = 110 mm,
With box/pin 5-1/2“ IF

Stabiliszer Ø 17-3/8“, ID = 110 mm,
With box/pin 5-1/2“ IF

Bit-Sub box 5-1/2“ IF on box 7-5/8“ Reg.

17-1/2“ Tricone Roller Bit



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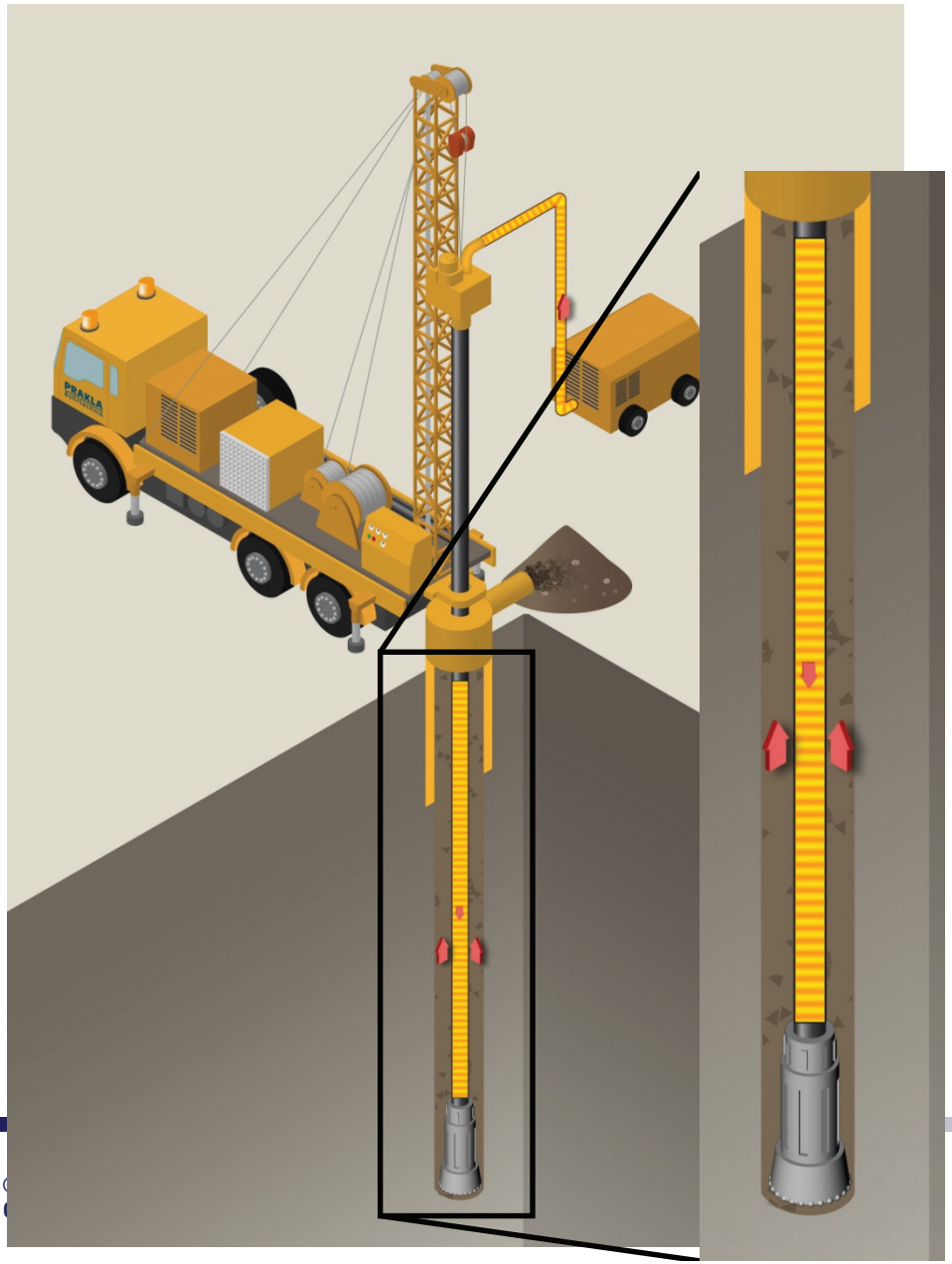
Case Study: DTH Hammer Drilling



Concept of a borehole being drilled using DTH Hammer Drilling:

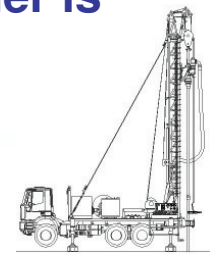
Drilling Diameter: 100 – 800 mm

Air Rising Velocities in Annulus:

Ideal: ca. 25 - 30 m/sec!

Application:

- **In wells with any drilling diameter (Ø >100 mm)**
- **In competent geology (hard rock!)**
- **In depths down to ca. 800 m, depending on hydrostatic borehole conditions.**
- **RC-Drilling with DTH Hammer is also possible**



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Case Study: DTH Hammer Drilling

Borehole Ø		Annulus 6A	Hammer Type Mission	Drill Pipe Diameter [mm]					
				83 Ø	108 Ø	146 Ø	178 Ø	244 Ø	267 Ø
				Tool Joint OD [mm]					
[inch]	[mm]	[cm²]	[-]	96 Ø	120 Ø	158 Ø	194 Ø	268 Ø	
6	152,4	1.) 770 2.) 545	SD-6	12,8	9,1	---	—	—	
6⅛	155,6	1.) 816 2.) 591	SD-6	13,6	9,9	---	—	—	
6½	165,1	1.) 960 2.) 736 3.) 280	SD-6	16,0	12,3	4,7	—	—	
7	177,8	1.) 1165 2.) 940 3.) 485	SD-6	19,6	15,7	8,1	—	—	
7⅝	193,5	2.) 1215 3.) 760	SD-8	---	20,3	12,7	—	—	
8	203,2	2.) 1396 3.) 941	SD-6 SD-8	---	23,3	15,7	—	—	
8⅝	219,0	2.) 1710 3.) 1256	SD-6 SD-8	---	28,6	21,0	—	—	
8¾	222,3	2.) 1779 3.) 1324 4.) 836	SD-8	---	29,7	22,1	14,0	—	
8⅞	225,4	2.) 1845 3.) 1390 4.) 902	SD-8	---	30,8	23,2	15,1	—	
10	254,0	2.) 2256 3.) 2096 4.) 1547	SD-6 SD-8	---	37,7	34,0	25,8	—	—
10⅝	270,0	2.) 2886 3.) 2431	SD-8	---	48,2	40,6	32,4	—	—
11⅞	301,6	4.) 2793 5.) 1481	SD-10	---	---	---	46,6	24,7	—
12	304,8	4.) 2885 5.) 1572	SD-8		---	---	48,2	26,3	—
12¼	311,6	4.) 3082 5.) 1770	SD-10			---	51,5	29,6	—
13	330,2	4.) 3645 5.) 2332	SD-12			---	60,9	38,9	—
14	355,6	4.) - 5.) 3153	SD-12			---	—	52,6	—
15	381,0	4.) - 5.) 4035	SD-12				—	67,4	—
17½	444,5	4.) - 5.) 6505 5.) 5951	SD-12				—	108,6	99,4

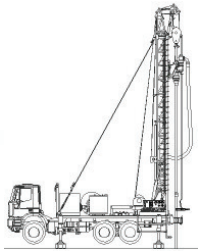
Air Consumption [m³/min]

Air Volume stream required to have respective rising velocities using DTH-Hammer Drilling in relation to Borehole Ø and the respective Drill String employed:

Whereby:

$Q = v*6A$

[l/min = m/s*m²]



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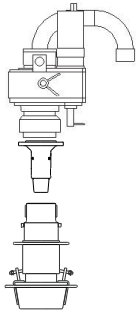
Case Study: DTH Hammer Drilling



Power Swivel

Adapter Sub with Pin PSG 146

Sliding Sleeve for PSG 146

Pulling Device
for PSG 146 with
box PSG 146 5-1/2“ IF

Drill Pipe 146x10 mm, ID = 125 mm, with
box/pin 5-1/2“ IF

Cross-Over box 5-1/2“ IF (DP)
to pin 5-1/2“ IF (DC)

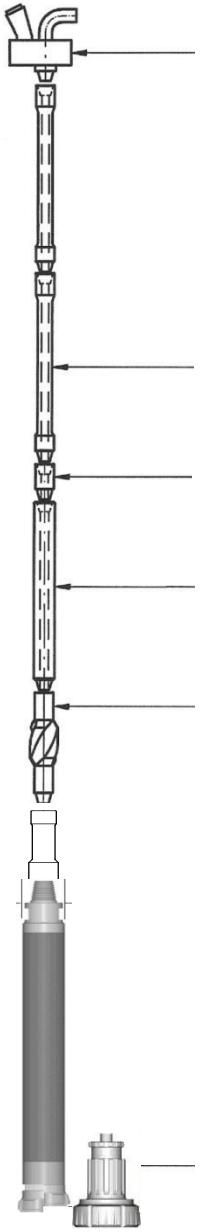
Shockabsorber, with box/pin 5-1/2“ IF

Drill Collar Ø 9-1/2“, with box/pin 5-1/2“ IF

Bit Sub box 4-1/2“ IF / box 4-1/2“ Reg.

12“ DTH Hammer Body

13“ Button Bit



Power Swivel with
Adapter Sub and
Sliding Sleeve for
pin PSG 178

Drill Pipe 178x10 mm,
ID: 155 mm,
With box/pin PSG 178

Cross-Over Sub box PSG 178
on pin 5-1/2“ IF with Shockabsorber

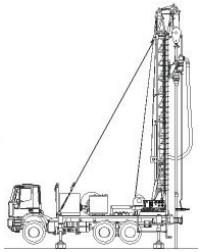
Drill Collar Ø 9-1/2“, ID = 110 mm,
With box/pin 5-1/2“ IF

Stabilizer Ø 17-3/8“, ID = 110 mm,
With box/pin 5-1/2“ IF

Bit-Sub box 5-1/2“ IF on box 7-5/8“ Reg.

DTH Hammer Body 12“
with pin 7-5/8“ API Reg.

17-1/2“ Button Bit



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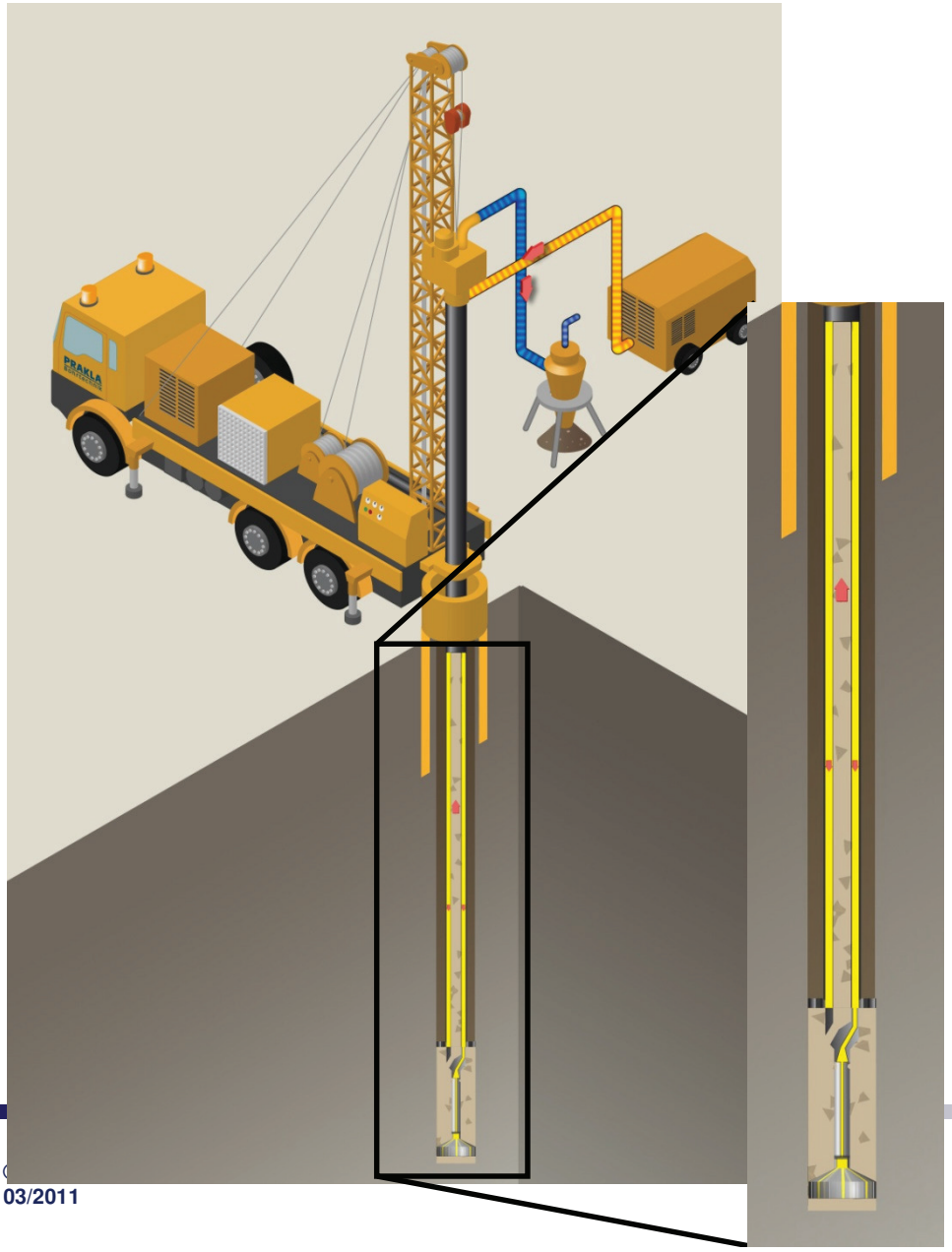
Case Study: RC DTH Hammer



Concept of a borehole being drilled using RC DTH Hammer Drilling:

Drilling Diameter: 300 – 800 mm

Air Rising Velocities in Central Pipe:

Ideal: ca. 25 - 30 m/sec or faster!

Application:

- **In wells with any drilling diameter (Ø >300 mm)**
- **In competent geology (hard rock!)**
- **In depths down to ca. 600 m**
- **Depending on hydrostatic borehole conditions: in combination with Booster!**