# SUPPLEMENTARY MATERIAL

# ANTARCTIC SUBGLACIAL DRILLING RIG: PART II. IBED ICE AND BEDROCK ELECTROMECHANICAL DRILL

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**Table S1**. Main results of ice drilling tests

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Run** | **Drilling  fluid** | **Pump** | **Cutter type** | **Cutting load (N)** | **ROP (m h-1)** | **Penetration depth (mm)** | **Core catcher** | **Core length**  **(mm)** |
| 1 | Silicon oil | SPK4-11/11 | CSkB | <800 | 4.60 | 856 | + | 840 |
| 2 | Silicon oil | SPK4-11/11 | CSkB | <600 | 6.53 | 553 | + | 540 |
| 3 | Silicon oil | SPK4-11/11 | CSkB | <800 | 10.56 | 833 | + | 780 |
| 4 | Silicon oil | SPK4-11/11 | CSkB | <500 | 4.81 | 812 | + | 790 |
| 5 | Silicon oil | SPK4-11/11 | CSkB | <500 | 2.40 | 614 | + | 580 |
| 6 | Silicon oil | SPK4-11/11 | SC | <500 | 10.27 | 810 | + | 770 |
| 7 | Silicon oil | SPK4-11/11 | SC | <400 | 7.38 | 835 | + | 790 |
| 8 | Jet A-1 | SPK4-11/11 | SC | <400 | 7.50 | 835 | + | 795 |
| 9 | Jet A-1 | SPK4-11/11 | CStB | <400 | 6.67 | 839 | + | 835 |
| 10 | Jet A-1 | SPK4-11/11 | CStB | <800 | 4.02 | 708 | + | 700 |
| 11 | Jet A-1 | SPK4-11/11 | CStB | <800 | 2.70 | 775 | + | 745 |
| 12 | Jet A-1 | SPK4-11/11 | SC | <700 | 2.36 | 835 | + | 829 |
| 13 | Silicon oil | SPK4-11/11 | SC | <400 | 6.81 | 759 | + | 750 |
| 14 | Jet A-1 | SPK2-23/23 | SC | <500 | 7.95 | 855 | + | 810 |
| 15 | Jet A-1 | SPK2-23/23 | SC | <700 | 5.27 | 765 | + | 735 |
| 16 | Jet A-1 | SPK2-23/23 | SC | <400 | 6.69 | 861 | + | 830 |
| 17 | Jet A-1 | SPK2-23/23 | SC | <400 | 6.75 | 707 | + | 680 |
| 18 | Jet A-1 | SPK2-23/23 | SC | <300 | 4.37 | 560 | + | 550 |
| 19 | Jet A-1 | SPK2-23/23 | SC | <250 | 6.85 | 866 | + | 810 |
| 20 | Jet A-1 | SPK2-23/23 | SC | <250 | 6.76 | 853 | + | 800 |
| 21 | Jet A-1 | SPK2-23/23 | SC | <400 | 6.30 | 875 | + | 860 |
| 22 | Jet A-1 | SPK2-23/23 | SC | <400 | 6.80 | 858 | + | 845 |
| 23 | Jet A-1 | SPK2-23/23 | SC | <500 | 6.49 | 873 | + | 840 |
| 24 | Jet A-1 | SPK2-23/23 | SC | <400 | 6.91 | 864 | + | 830 |
| 25 | Exxsol D60 | SPK2-23/23 | SC | 800 | 5.26 | 2250 | + | 2187 |
| 26 | Exxsol D60 | SPK2-23/23 | SC | 800 | 7.60 | 2260 | + | 2221 |
| 27 | Exxsol D60 | SPK2-23/23 | SC | 800 | 8.75 | 2190 | + | 2159 |
| 28 | Exxsol D60 | SPK2-23/23 | SC | 900 | 7.42 | 2550 | + | 2521 |

\*CSkB – cutters with skewed blades; CStB – cutters with straight blades; SC – staggered cutters

**Table S2.** Main results of debris-containing ice drilling tests

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Run** | **Drill bit\*** | **Volume percentage of granite chips (%)** | **Average cutting load (N)** | **Average ROP  (m h-1)** | **Penetration depth (mm)** |
| 1 | A | 10 | 1010 | 4.0 | 284 |
| 2 | B | 10 | 524 | 4.0 | 510 |
| 3 | A | 30 | 1063 | 1.9 | 364 |
| 4 | B | 30 | 1237 | 4.7 | 184 |
| 5 | C | 10 | 1131 | 1.6 | 118 |
| 6 | A | 30 | 1085 | 2.6 | 382 |
| 7 | B | 30 | 1074 | 10.9 | 692 |
| 8 | B | 10 | 1017 | 6.7 | 390 |

\* A – drill bit equipped by flat cutters with rake angle 0°; B – drill bit equipped by flat cutters with rake angle -10°; C – drill bit equipped by waved cutters with rake angle 0°

**Table S3.** Main results of bedrock drilling

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Run** | **Drilling fluid** | **Pump** | **Core barrel** | **Drill bit ID/OD (mm)** | **Cutting load (N)** | **ROP  (m h-1)** | **Penetration (mm)** |
| 1 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | <2000 | 0.74 | 700 |
| 2 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | <2000 | 1.1 | 720 |
| 3 | Jet A-1 | SPK2-23/23 | Double-tube | 41/60 | 1000-2000 | 0.85 | 539 |
| 4 | Jet A-1 | SPK2-23/23 | Single-tube | 41/60 | <2000 | 1.3 | 662 |
| 5 | Jet A-1 | SPK2-23/23 | Double-tube | 41/60 | 1500-2000 | 0.92 | 459 |
| 6 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | <2000 | 0.9 | 523 |
| 7 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | 1400-1700 | 0.75 | 652 |
| 8 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | 1600-1800 | 0.7 | 612 |
| 9 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | 1400-1600 | 0.73 | 468 |
| 10 | Silicon oil | SPK4-11/11 | Double-tube | 41/60 | <1000 | 0.39 | 117 |
| 11 | Silicon oil | SPK4-11/11 | Double-tube | 41/60 | 800-1000 | 0.2 | 49 |
| 12 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 500-600 | 0.46 | 117 |
| 13 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 500-600 | 0.45 | 87 |
| 14 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | <2000 | 0.45 | 523 |
| 15 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 600-700 | 0.35 | 332 |
| 16 | Silicon oil | SPK4\_11-11 | Single-tube | 41/60 | 700-800 | 0.4 | 400 |
| 17 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 800-900 | 0.57 | 50 |
| 18 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 850-950 | 0.60 | 87 |
| 19 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 800-950 | 0.35 | 100 |
| 20 | Silicon oil | SPK4-11/11 | Single-tube | 41/60 | 850-900 | 0.65 | 210 |
| 21 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～800 | 0.86 | 500 |
| 22 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～850 | 1.1 | 550 |
| 23 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1000 | 0.8 | 400 |
| 24 | Jet-A1 | SPK4-11/11 | Single-tube | 41/60 | ～1000 | 0.85 | 350 |
| 25 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1000 | 0.86 | 402 |
| 26 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 0.88 | 398 |
| 27 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.0 | 374 |
| 28 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 0.93 | 311 |
| 29 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～800 | 1.0 | 210 |
| 30 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～900 | 1.0 | 200 |
| 31 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.0 | 450 |
| 32 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.1 | 650 |
| 33 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.0 | 400 |
| 34 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.1 | 540 |
| 35 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | ～1100 | 0.84 | 220 |
| 36 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.1 | 682 |
| 37 | Jet A-1 | SPK4-11/11 | Single-tube | 41/60 | ～1100 | 1.1 | 650 |
| 38 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | ～1200 | 0.86 | 383 |
| 39 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | ～1100 | 0.85 | 652 |
| 40 | Jet A-1 | SPK4-11/11 | Double-tube | 41/60 | ～1100 | 0.76 | 203 |
| 41 | Jet A-1 | SPK4-11/11 | Single-tube | 41/61 | -1200 | 0.74 | 250 |
| 42 | Jet A-1 | SPK4-11/11 | Single-tube | 41/61 | -1200 | 0.7 | 200 |
| 43 | Jet A-1 | SPK4-11/11 | Single-tube | 41/61 | -1200 | 0.5 | 260 |
| 44 | Jet A-1 | SPK4-11/11 | Single-tube | 41/61 | 1100-1200 | 1.0 | 650 |
| 45 | Jet A-1 | SPK4-11/11 | Double-tube | 34/62 | 1150-1250 | 1.0 | 670 |
| 46 | Jet A-1 | SPK4-11/11 | Double-tube | 34/62 | 1150-1250 | 0.8 | 300 |
| 47 | Jet A-1 | SPK4-11/11 | Double-tube | 34/61 | 1150-1250 | 1.0 | 700 |
| 48 | Jet A-1 | SPK4-11/11 | Double-tube | 34/61 | 1100-1300 | 0.9 | 670 |