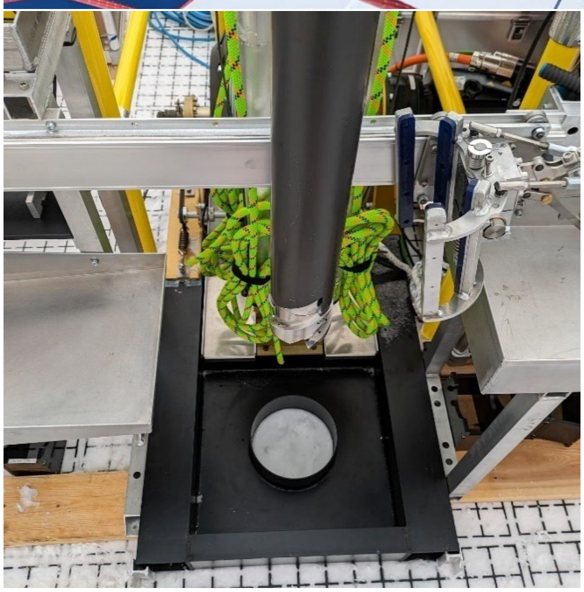
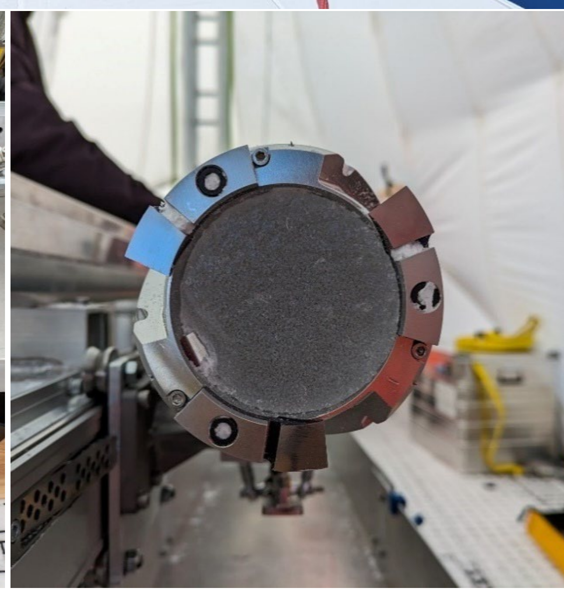
700 Drill: Operations and Maintenance Manual





NSF Ice Drilling Program
Space Science and Engineering Center
University of Wisconsin-Madison

1225 W. Dayton St.
Madison, WI 53706
icedrill.org

Ice Drilling Program

11/10/2025

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1 Safety Notices

The 700 Drill system includes a variety of hazards, some of which may be fatal. Only trained personnel should operate the 700 Drill system. Do not operate the system if it is damaged. Do not modify the system without direct guidance from the NSF Ice Drilling Program.

1.1 Shock

Voltages sufficient to deliver a fatal shock are present in this system:

600VDC – In the control box, sonde, drill cable, winch drum, and cabling between these.

208VAC – In the generator, SPIDER, control box, chip melter, and cabling between these.

120VAC – In the generator, SPIDER, control box, and cabling between these.

Electrical shock – Extreme care shall be taken when assembling, disassembling and servicing electrical equipment. Always disconnect power before servicing equipment. Proper lockout tagout procedures shall be followed and only qualified people should be working on electrical equipment.

Grounding – Because the drill sits upon a large thickness of ice, a common earth ground cannot be established. Workers shall ensure that all drilling equipment is bonded together to a common ground back to the generator(s).

1.2 Entanglement/Entrapment

The winch drum, drill cable, and sonde can move quickly! It is the responsibility of the lead driller to ensure that everyone, including visitors, has put away or secured any loose clothing, jewelry, or long hair that could become caught in the cable. All operators must read section *4.3.1 Unsafe Software Warning* and be aware of E-Stop button locations.

The sonde is heavy and often above head height. Use caution and warn others before raising or lowering it on the core processing line.

1.3 Sharp Edges

The cutters are extremely sharp! Never move the core barrel, either by hand or via the control software, when someone is working on the cutter head. Use verbal cues to warn others before moving the cutters or the sonde, when at the surface. Use the cutter head guard when extracting the core barrel to avoid injury.

1.4 Pinch Points

There are multiple pinch points on the 700 Drill system including when the sonde is moving, the rotating winch drum and use of the drill clamp.

The core tray can pinch fingers against the core barrel blocks. Always keep the full core tray in view when moving it.

Multiple pinch points are present when installing the hollow shaft and core barrel into the outer tube. Be aware of where your hands, and other helpers' hands, are when working with these parts.

1.5 Chemical Safety

Various fluids used for drilling, cleaning, or servicing the drill equipment present potential hazards to human and environmental health. Avoid unnecessary skin contact with drilling fluid. Wear safety glasses to avoid accidental eye contact. Do not open pressurized hoses or vessels without a containment plan. Take care when eating to avoid accidental ingestion.

1.6 Environmental Safety

This drill will be deployed to extremely cold climates. Operators shall wear outerwear suitable to protect themselves from the cold and should monitor their own and fellow workers' activities for exposure to cold.

The IDP Deployment Hazards Awareness Training, 8501-0017, describes known hazards encountered in the field and mitigations for each risk. All operators should be familiar with this training and may reach out to IDP personnel for more information. See section *2.2 IDP Contact Information*.

1.7 Personal Protective Equipment (PPE)

Personnel should wear appropriate PPE during drilling operations, including:

- Safety glasses
- Footwear – safety toe and liquid-proof
- Gloves – liquid-proof and cut-resistant
- Appropriate clothing – avoid loose clothing, jewelry, and loose long hair. Liquid-proof outerwear is recommended.
- Hard hats – required when working near suspended loads or when working below other personnel.

2 Introduction

The 700 Drill is a mid-range drill for use in remote areas such as mountain glaciers in the Arctic. The design prioritizes a low logistical footprint and does not require motorized support equipment for assembly of the drill system.

2.1 Key Specifications

Science:

- Nominal core dimensions.................1.0 m x 70 mm Ø
- Maximum core depth........................700 m
- Borehole diameter............................98 mm
- Drilling fluid....................................Isopar K or Estisol 140
- Maximum operating altitude ....3500 m

Operations:

- Shipping weights and cubes..............3000 kg, 460 cubic ft.
- Tent footprint dimensions ....9.3 m x 3.7 m
- Tower height....................................5.5 m usable
- Dry sonde mass ....54 kg
- Wind speed limits.............................20 kts (setup) or 60 kts (operations)
- Maximum tripping speed ....2 m/s (air) or 1 m/s (fluid)
- Minimum number of operators...........2 drillers and 1 core handler
- Nominal season schedule ....700 m in 35 drilling days
- Nominal fuel burn rate.......................1 gallon per hour

2.2 IDP Contact Information

Contact the following IDP personnel for technical support:

Title	Name	Email	Phone (SMS or call)
Field Support Manager	Kristina Slawny (acting)	kristina.slawny@wisc.edu	608-770-8625
Senior Drilling Engineer	Jay Johnson	jay.johnson@ssec.wisc.edu	608-333-4653

Parcels and/or equipment may be sent to the following addresses:

Mailing Address	Shipping Address
NSF Ice Drilling Program 1225 W. Dayton St Madison, WI 53706	NSF Ice Drilling Program 1 Marsh Ct, Suite 15 Madison, WI 53718

2.3 Terms and Abbreviations

AT Section – Anti-torque section, the uppermost section of the sonde.

ATA Case - A durable, protective shipping case designed to protect valuable, fragile, or sensitive equipment during transport, particularly by air. The name comes from the Air Transport Association (ATA).

Central Controller – The controller inside the control box, which mediates drilling operations.

Collet – The ring of small, sharp teeth that bite into and retain the core during core break. Used in soft firn instead of core dogs.

Core Dogs – The sharp teeth that bite into and retain the core during core break.

Cutter Pitch – The penetration per revolution of the cutter head, expressed in mm.

DNF – Do not freeze, a shipping designation that an item should be stored above freezing.

DOC – Depth of cut, per tooth.

DPS – Drill Power Supply

Dry Drilling – Drilling without fluid in the borehole.

Durabook – The semi-rugged laptop included with the system.

E-Stop – Emergency stop.

GFCI – Ground Fault Circuit Interrupter, a safety device designed to prevent electrocution by removing power when current into a device is not equal to current out (implying that some must have gone to ground, possibly through a person).

GUI – Graphical user interface.

IDP – Ice Drilling Program.

Kerf – The annular area cut away by the cutter head.

NSF – National Science Foundation.

QAS – Quality Assurance and Safety group.

Shoe Pitch – The maximum cutter pitch permitted by a given set of shoes, expressed in mm. Also used to name shoes, such that “2 mm shoes” refers to shoes with 2 mm pitch (not the thickness of the shoe).

SPIDER – The 208V/120V power distribution box, a purchased component.

SSEC – University of Wisconsin-Madison, Space Science & Engineering Center.

Stick-Slip – The pattern of cyclic sticking and slipping that may be observed in the sonde motion at low speeds inside the borehole, typically observed as a sawtooth pattern in the weight on bit.

UN3481 – A shipping code indicating the presence of a lithium-ion battery, typically for segregation on an air cargo flight.

Weight on Bit – The compressive force being applied to the cutter head as calculated from cable tension, payout, and fluid level, expressed in Newtons (N; 10 N is approximately equal to the weight of 1 kg). Becomes negative during core break. Any upward forces on the sonde (e.g. drag on the anti-torque blades) may increase the calculated weight on bit.

Wet Drilling – Drilling with fluid in the borehole.

WOB – See Weight on Bit.

2.4 Drill System Components

This section gives a brief overview of each of the major components of the 700 Drill System and provides some specifications for quick reference. For more detailed information, see Section 6 – Appendices.

2.4.1 Generator

The system ships with two Winco generators (P/N WL12000HE-04/A), Figure 1. One of the generators is used for drilling operations while the other acts as a spare. Each generator ships in its own ATA case. The case lid needs to be removed for operation, but the generator is secured to the case base. The case lid should be kept in place when the generator is not in use to limit blown snow ingress while the generator is not running. Alternatively, the fabric cover supplied with the generators can be used for this purpose.

High-level specifications of the generators are listed below.

- Voltage 120/208V 3-phase
- Starting Power (at sea level) .... 12 kW
- Running Power (at sea level)............... 10.8 kW
- 120V Receptacles .... (3) NEMA 5-20 20A (Duplex GFCI)
- 208V Receptacles .... (1) NEMA L21-30 30A
- Engine... Honda GX630
- Fuel .... Gasoline, 15-gallon tank
- Oil .... 0W-30 full synthetic, 1.8 L

2.4.1.1 High Altitude Operation

For best performance, the engine's carburetor needs specific jets installed based on the altitude of the drilling site. IDP personnel will install the proper jets as detailed below. Note, the generator's power rating will decrease 3.5% per each 300-meter increase in altitude above sea level.

- 0 m to 1500 m altitude .... Jet size #110, Honda P/N 99101-ZH8-1100
- 1500 m to 2250 m altitude .... Jet size #105, Honda P/N 99101-ZH8-1050
- 2250 m altitude and above................. Jet size #100, Honda P/N 99101-ZH8-1000

Figure 1. Image of one generator on its ATA case base.

2.4.2 Control Box

The control box is the electrical hub of the drill system; it converts operator inputs into winch motor and drill motor motion; it monitors the sonde-at-home and hard stop limit switches; it houses the drill's central controller; and it supervises the E-Stop system.

Major components inside the Control Box include a 30 Amp circuit breaker, 600V sonde power supply, winch motor drive, brake resistor, EMC filter, central controller, safety-rated relays for the E-Stop system, and a small electric heater to warm components as needed. Brief descriptions of the electrical connections on the control box are given in Figure 2.

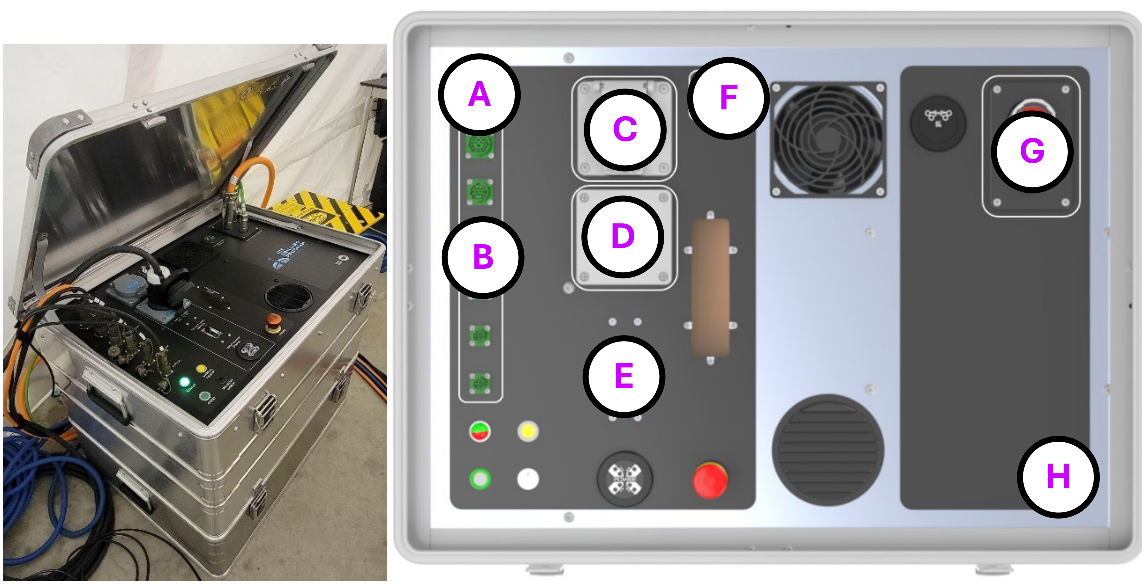


Figure 2. Top view of the control box. (A) USB-C port for auxiliary central controller connection, (B) low-voltage signal connections, (C) 208V 3-phase output to chip melter, (D) 208V 3-phase input, (E) 30A circuit breaker, (F) grounding lugs (G) DC winch power and resolver, (H) RJ45 for motor drive updates

2.4.3 Winch

The winch assembly consists of the winch base, cable drum, gearmotor, drill cable, slip ring, and cable keeper (which is also known as the snubber). There is no level-winding mechanism as the fleet angle to the crown sheave is small enough for the winch to self-level wind.

The winch base is an aluminum weldment with rivet nuts for winch, tower, and handrail mounting. There is a removeable drip tray that is installed under the winch drum, Figure 3.

The cable drum is a bolted assembly with a Lebus-groove core, Figure 3.

The gearmotor is a Stober PHQ832SFSS0220EZ803U, Figure 4. Its power rating is 8.36 kW and the gear box ratio is 22:1. The motor is equipped with a permanent magnet holding brake that engages automatically if supply voltage drops. The motor has two electrical connections: 1) power (orange cable) and 2) resolver (green cable).

The drill cable is TE Rochester 4-H-222D (P/N A240222). There are 750 meters of cable installed on the winch drum, Figure 4. The cable has two #22 AWG and two #24 AWG conductors. Its rated breaking strength is 22.7 kN (5,100 lbf) and its voltage rating is 600 VDC. The cable's termination is a PMI Evergrip, PN: 115-3C-L.

The slip ring is Rotary Systems SR 018 series, 30060-1806-000. It is located inside of the winch drum and is not accessible without significant disassembly of the winch. Connection to the slip ring occurs at the Amphenol connector on the opposite side of the winch drum from the gearmotor.

The cable keeper (or snubber) is a red polyurethane roller that keeps the drill cable from unwinding from its drum when the cable goes slack, which happens each time the sonde is laid down for core removal, Figure 3. The cable keeper is positioned to press against the outermost wrap of cable; this can be adjusted with the set screw stop near the assembly's spring. The handle can be used to temporarily release the cable keeper from the drum if needed.

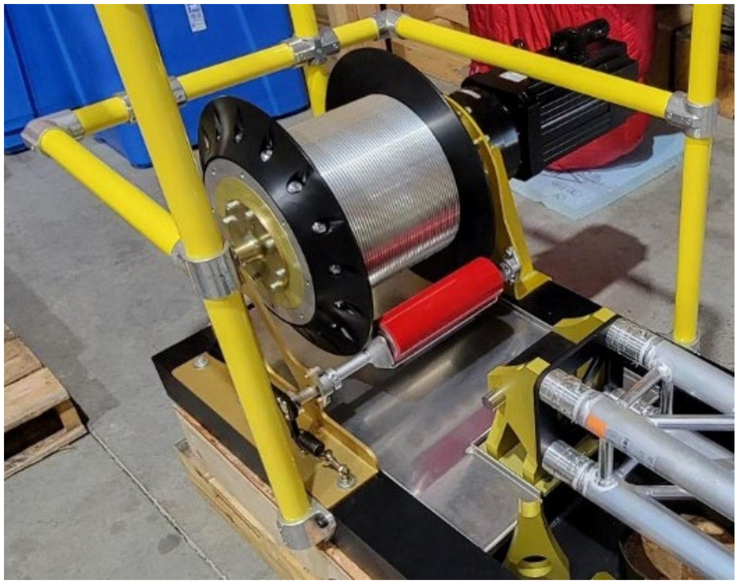


Figure 3. Image of winch assembly showing handrail, Lebus-groove core, removeable drip tray, and cable keeper

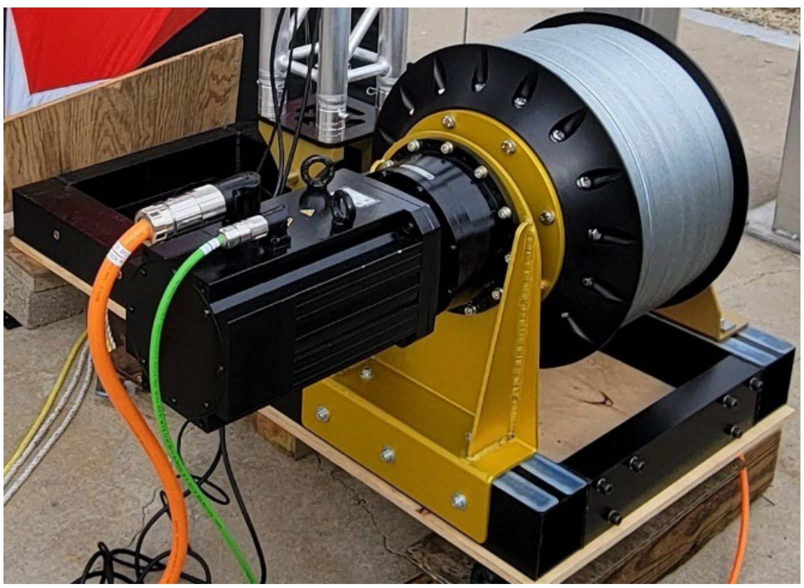


Figure 4. Image of winch assembly showing gearmotor, electrical connections, and cable-filled drum.

2.4.4 Tower

The tower is composed of three aluminum truss sections with the crown sheave assembly mounted on top, Figure 5. The tower is mounted to the winch base with a universal joint, which allows the tower to be leveled independently from the winch base. The tower is supported by four guy ropes that are anchored to the snow surface.

Removable yellow pillow blocks are used to lock the universal joint into a single axis of rotation for tower raising and lowering.

The roller guide arm extends outward from the upper section of truss. This arm prevents the cable from contacting the tent wall during drill lay down and houses the magnetic sonde-at-home switch.

The crown sheave is instrumented with an encoder that measures cable payout and a load pin that measures cable tension. There is a hard stop limit switch that, when actuated, cuts power to the winch to prevent the sonde from being pulled into the crown sheave.

Figure 5. Tower Assembly

2.4.5 Sonde

The sonde is the downhole component of the drill system. It attaches to the end of the drill cable and trips up and down the borehole each run to retrieve a 1-meter length of ice core. The sonde is made up of 3 sections: 1) the anti-torque section, 2) the motor section, and 3) the barrel set.

2.4.5.1 Anti-Torque Section

The purpose of the anti-torque (AT) section is to counteract the torque required to cut ice; without this section, the sonde will "slip" in the borehole and spin backwards while the cutter head remains stationary. This is referred to as "AT slip" and can also occur if the AT blades are not set properly. See Section *4.5.1 Anti-Torque Adjustment* for instructions on setting the anti-torque blades. Reference drawing *83890100_AT Section Assembly* for component details.

The AT section has three leaf spring blades that are offset such that the edge of the blade contacts the borehole wall. At the top of the AT section, there is a strain relief to protect the cable during drill lay down. The strain relief has a wire rope recovery loop that can be grabbed by fishing tools. The magnets for the sonde-at-home switch are housed in the red aluminum cuff on the strain relief. The drill cable termination connects to the sonde in the AT section. There is a slip ring and bearing assembly to allow the sonde to spin freely with respect to the cable.

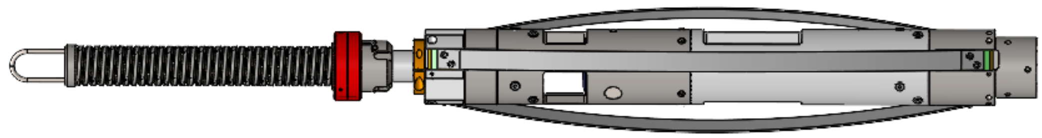


Figure 6. Anti-Torque section.

2.4.5.2 Motor Section

The motor section houses the drill motor and associated electronics inside of a pressure tight housing. It is located between the anti-torque and barrel set in the sonde assembly. The internal electronics package communicates with the surface control system and is controlled by the GUI. In addition to controlling the drill motor, the electronics monitor internal temperatures and pressure, borehole temperature and pressure, drill orientation and heading, and inclination. The internal motor with gear reducer rotates the hollow shaft, core barrel, and cutter head. The upper and lower bulkheads are removable for servicing the internal components. Reference drawing *83890125_Motor Section Assembly* for further details.

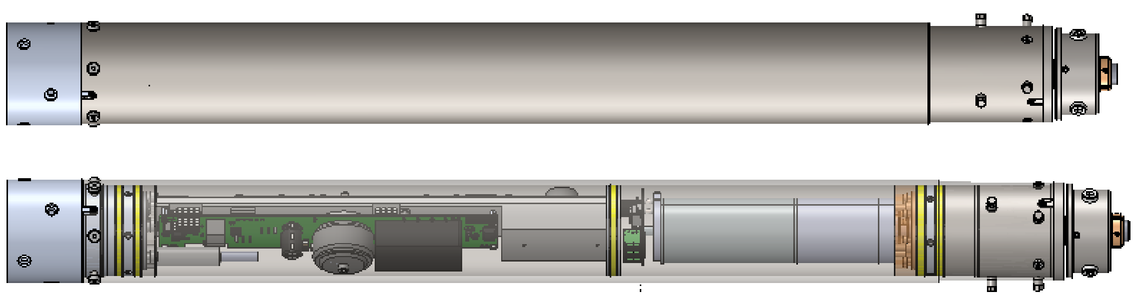


Figure 7. Motor section. The lower view has a transparent outer tube to show the internal components.

2.4.5.3 Barrel Set

The barrel set mounts to the lower end of the motor section and includes the outer tube, hollow shaft assembly, core barrel, and cutter head assembly. The outer tube, with internal grooves to aid with chip transport, houses the hollow shaft and core barrel. The hollow shaft connects to the rotating output of the motor section with three quick connect pins and connects to the core barrel on the other end with another set of three quick connect pins.

Ice cuttings are collected around the hollow shaft for return to the surface at the end of a drill run. The OD of the hollow shaft has a series of holes in it that are covered by a fine screen. During wet drilling, drill fluid is squeezed out of the ice chips and passes through the screen and up the center of the hollow shaft where it flows back around the drill. A single turn spiral, called a booster, can be mounted in various locations along the hollow shaft and is placed for best chip transport performance.

Also located on the hollow shaft, directly above the core barrel, is a butterfly check valve. This optional valve is helpful during wet drilling to help prevent cuttings from flushing out of the barrel while tripping the drill back to the surface.

Next in line is the core barrel with external plastic spirals. It has a capacity of up to a 1.1 m long core. The cutter head, which mounts to the end of the core barrel, cuts a 70 mm diameter core and creates a 98 mm diameter borehole. Reference drawings *83890170_Outer Tube Assembly, 83890146_Hollow Shaft Assembly, 83890162_Core Barrel Assembly, 83890165_Cutter Head Assembly, and 83890180_Collet Cutter Head Assembly* for further details.

Figure 8. Barrel Set components include the outer tube, hollow shaft assembly, core barrel, and cutter head assembly.

2.4.6 Sonde Support System

The sonde is supported at the surface by the drill clamp, which clamps around the end of the outer barrel and slides on a rail, and a sonde rest mounted in line with the rail. The drill clamp can normally move the full length of the rail, but may also be stopped before the end of the core processing line if the clamp stop (aka flip chip) is flipped out. Stopping the sonde in this position permits it to be serviced without needing to open the tent door.

2.4.7 Core Processing

The core processing line is an integrated part of the 700 Drill system that mounts to the winch base, Figure 9. It is designed for receiving and packing one-meter-long cores. Due to the length of the tent, the two-meter-long core receiving tray is on a slider. The tray is two meters long so that cores from two drill runs can be on the tray at the same time for logging.

The tray first slides towards the tower to make room for the core barrel when a core is being pushed out of the core barrel. Once the core barrel has been reassembled with the drill, the tray then slides over where the core barrel was to make room on the other end of the work area for packing the core from the previous run. Adjacent to the core processing line is workspace for the core handlers, which includes a worktable and room for one core box.

Figure 9. Views of the core processing area.

2.4.8 MAST Tent

For safe operation of the drill in most weather conditions, the MAST tent is supplied with the drill system, Figure 10. This same tent is also used with the IDP Blue Ice Drill and Foro 400 Drill systems. The tent is suspended from the tower while an internal frame and external ropes give the tent its shape. In good weather, the tent can be set up by as little as two people. The tent can be safely set up in winds up to 18 knots and can handle wind speeds up to 60 knots once properly set up.

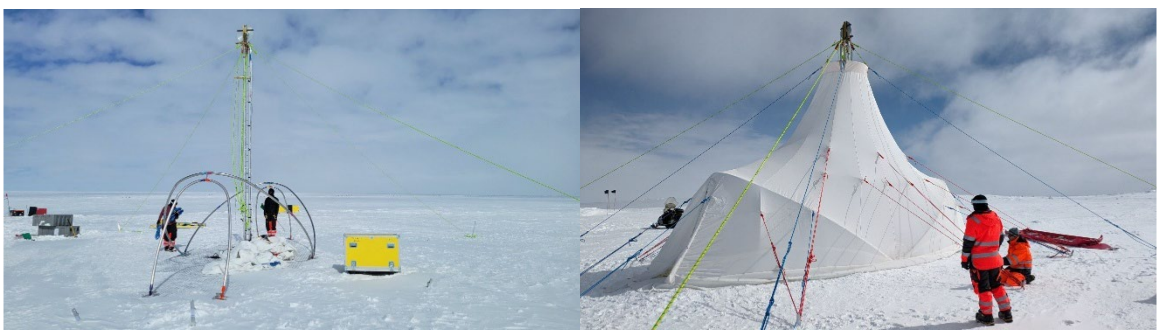


Figure 10. Erecting the MAST Tent (left) and the fully set up MAST Tent (right).

2.4.9 Geoblock Flooring

The tent flooring is made up of interlocking Geoblock panels, Figure 11. They provide grip and traction for walking on, as the snow surface alone would become dangerously slick in high traffic areas of the tent. The panels are 40” long x 20” wide x 1.2” tall and are made of HDPE. One panel has a square cutout; this panel goes under the winch base, and the cutout allows the sonde to pass through the Geoblock.

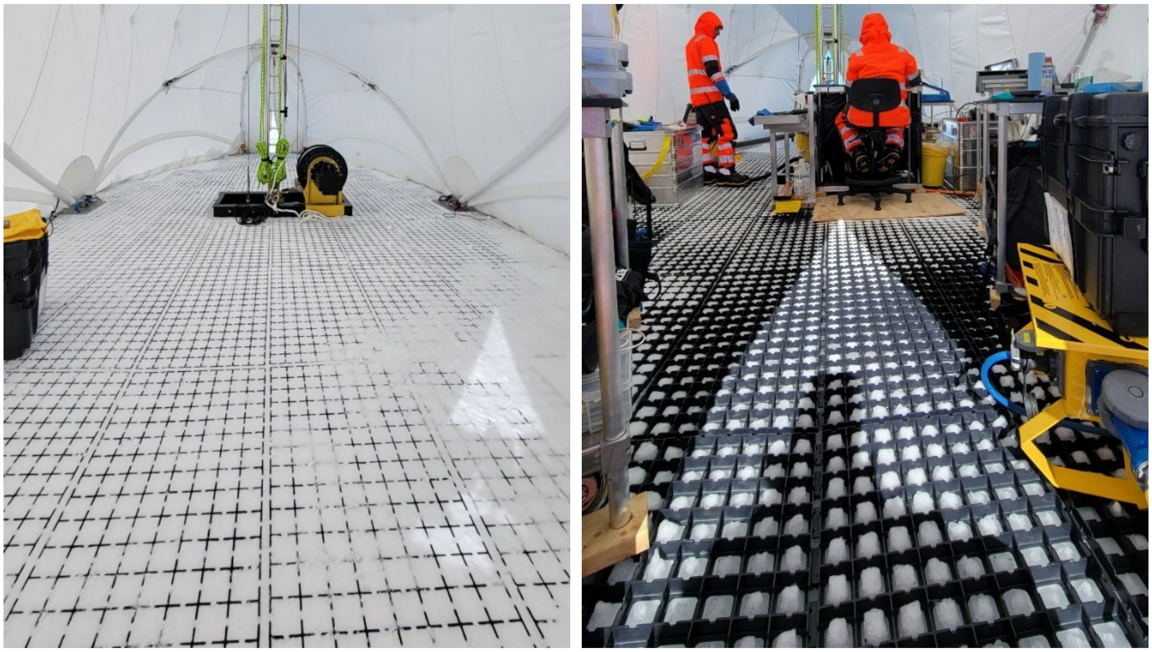


Figure 11. Geoblock panels used as flooring inside the drill tent.

2.4.10 SPIDER Power Distribution Box

The Hubbell SCTL0 SPIDER II Temporary Power Box receives a single 3Ø 208VAC power feed from the generator and splits it into one 3Ø 208VAC line for the control box and six 120VAC receptacles for smaller loads, Figure 12. All outputs have circuit breaker protection, and the 120 VAC loads also have GFCI protection. Note that this box has been modified to replace the 60A Pin and Sleeve connections with 30A versions.

General specifications of the SPIDER power distribution box are listed below.

- Rating: 60A, 3Ø 120/208VAC
- 6x Twist-Lock 20A, 125VAC receptacles, with overload and GFCI protection
- 1x Pin and Sleeve 30A, 3ØY 120/208VAC (inlet) receptacle
- 1x Pin and Sleeve 30A, 3ØY 120/208VAC (outlet) receptacle

Figure 12. SPIDER Power Distribution Box.

2.4.11 Drill Control Station

The drill system can be run from one of two interfaces, a touch screen console or rugged Durabook laptop, Figure 13. Only one interface can be in control at a time, but it gives the drillers an option for which one they prefer to use, and they also serve as a backup for each other. If using the laptop, connecting an external keyboard and mouse makes running the drill system much easier, however, the drill system can be operated from just the laptop keyboard. The Durabook is also used for logging drilling data.

Figure 13. Drill control console (left) and Durabook laptop (right).

2.4.12 Chip Melter

The chip melter is used to recover drilling fluid from the cuttings by warming the drilling fluid and ice mixture and separating the two fluids by density. The denser water sinks to the bottom, and the drilling fluid will rise to the top.

The chip melter consists of a 140-liter insulated polyethylene tank with a 1 kW 3Ø 208VAC electric heater, a sight glass for viewing the water level, and upper and lower valves for draining off the two fluids, Figure 14. Power for the heater is supplied from the control box and can be switched on/off automatically by the control system to manage load on the generator or manually on the drill control station.

The temperature of the fluid in the tank is controlled by a thermostat located inside the heater junction box. It is recommended to maintain the fluid temperature around 15°C to 20°C to minimize evaporation. The chip slurry is transported in 5-gallon buckets to the chip melter and carefully poured in the top.

Caution: Wind can cause the lid to close unexpectedly. Be sure to secure the lid open when working with the chip melter to prevent operator injury.

Figure 14. The chip melter has an upper and lower valve and sight glass on the front. When the transition between water and drilling fluid is visible between the valves in the sight glass, water can be drained from the lower valve and drilling fluid from the upper valve.

2.4.13 Fluid Chiller

The fluid chiller is an open-top 55-gallon barrel with a fluid circulation loop running through an external heat exchanger, Figure 15. Warm drilling fluid from the chip melter is transferred to the fluid chiller in 5-gallon buckets. The warm fluid is circulated through the heat exchanger until it cools below freezing. It can then be transferred to one of the empty fluid drums or added directly back to the borehole.

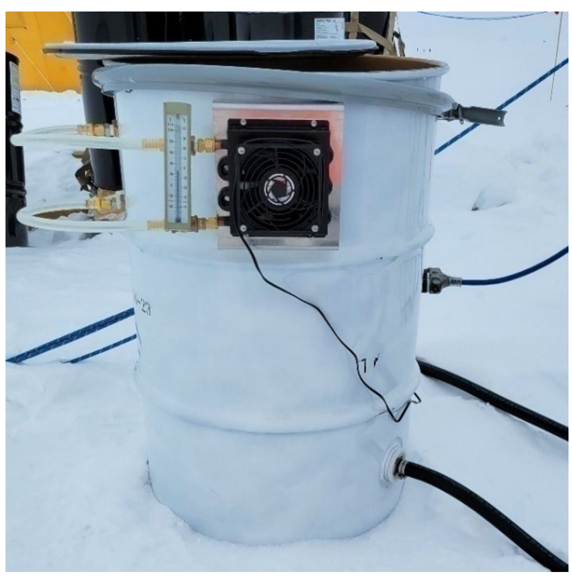


Figure 15. Fluid chiller drum with heat exchanger.

2.4.14 Vacuum

The Tiger-Vac 12.5-gallon explosion proof vacuum, model EXP1-15, has multiple uses with the drill system, Figure 16. Its primary functions are (1) removing drilling fluid from the ice cores using a crevice tool with end contoured to fit the core, (2) removing drilling fluid from the winch cable using a specially made cable cleaner attachment, and (3) cleaning chips and drilling fluid from the drip trays. The vacuum is mounted to a custom-built tilting frame so one person can empty the vacuum canister into a 5-gallon bucket. The vacuum runs on 120VAC and draws 9 Amps.

Figure 16. Industrial vacuum for picking up drilling fluid and ice cuttings.

2.4.15 Drum Pump

For transferring drilling fluid to the borehole or for other fluid transfer tasks, a Lutz brand explosion proof drum pump is included with the drill system, Figure 17. The pump runs on 120 VAC, draws 640 W, includes an on/off switch and variable speed dial, and has a maximum flow rate of 64 gallon/min.

Figure 17. Lutz drum pump being used to transfer fluid back into drums after the fluid was bailed from the borehole.

2.4.16 Layflat Hose

The 700 Drill was designed to not require a borehole casing to maximize drilling efficiency. Therefore, for sites with firn, drilling fluid must be introduced below the firn-ice transition to prevent fluid loss into the firn. Three sections of layflat hose totaling 100 m in length are stored in a Zarges case in the drill tent. When drilling fluid needs to be added to the borehole, the hose is deployed down the borehole and drilling fluid is added using the drum pump, Figure 18. The hose is then brought up by hand and coiled back into the Zarges case.

Figure 18. Yellow layflat fire hose is used to add drilling fluid to the borehole below the firn-ice transition.

2.5 Drill History

This section documents major changes made to the drill system between deployments to provide context for what could otherwise become confusing in pictures, CAD models, or procedures.

Date	Description of Change
Summer 2025	Redesigned the barrel clamp
Summer 2025	Added the tower lifting fixture
Summer 2025	GUI updates
Summer 2025	Changed drill motor/gearbox to increase maximum torque, with decrease in maximum speed (previously 150rpm)

3 Drill Site Setup Procedures

3.1 Shipping Boxes and Summary of Contents

Data in the table below is subject to change.
Refer to the packing list/proforma for the latest information.

Piece ID	Package Type	Description	Weight (lbs)	L (in)	W (in)	H (in)
700-01	ATA Case, Yellow	Winch	616	44	24	33
700-02	ATA Case, Yellow	Tower	491	82	30	27
700-03	ATA Case, Yellow	Tent frame	220	103	22	11
700-04	Hardigg	Tent fabric	396	48	35	39
700-05	ATA Case, Yellow	Generator 1	590	45	33	36
700-06	ATA Case, Yellow	Generator 2	590	45	33	36
700-07	ATA Case, Yellow	Core processing	233	76	27	15
700-08	ATA Case, Yellow	Core processing	241	122	14	11
700-09	ATA Case, Yellow	Anti-torques	103	39	11	9
700-10	ATA Case, Yellow	Sondes	172	114	11	8
700-11	ATA Case, Yellow	Motor sections	101	39	11	9
*700-12**	*ATA Case, Yellow*	*Spare cable drum*	-	-	-	-
700-13	Zarges	Spares	139	27	25	18
700-14	Zarges	Fluid Handling	141	31	23	24
700-15	Zarges	Power distribution	167	27	26	18
700-16	Zarges	Tools	132	27	25	18
700-17	Zarges	Control box **DNF**	172	31	23	24
700-18	Zarges	Electronics **DNF UN3481**	114	27	26	18
700-19	Zarges	Freezer **DNF**	106	31	23	24
700-20	Crate, wooden	Geoblock	640	48	48	54
700-21	Tool Case, black	Hand tools	46	25	17	14
700-22	Tool Case, black	Tools	64	23	15	18
700-23	Drum, white	Fluid Chiller	169	24	24	36
700-24	Tank, blue	Chip Melter Tank	112	18	30	37
700-25	Hardigg	Furniture **UN3481**	378	38	38	42
700-26	Hardigg, green	Tables	125	30	39	16

*Note that piece ID 700-12 is reserved for future use.

3.2 Site Requirements

Site selection should include locating a place that is fairly level, or can be leveled, for placement of the drill tent and drilling equipment contained within it. A dense snow layer of at least one meter thick is ideal for anchoring the winch and MAST tent. However, it is possible to set up the drill system on blue ice if ice screws or v-thread anchors are used in place of snow pickets. The tent should be positioned with the long axis in line with the prevailing wind direction. The generator should be placed downwind from the tent to minimize noise and exhaust in the work area. Figure 19 shows an example site layout. Structures and equipment are spaced out to minimize drifting and placed in a line perpendicular to the prevailing wind direction with the generator placed downwind.

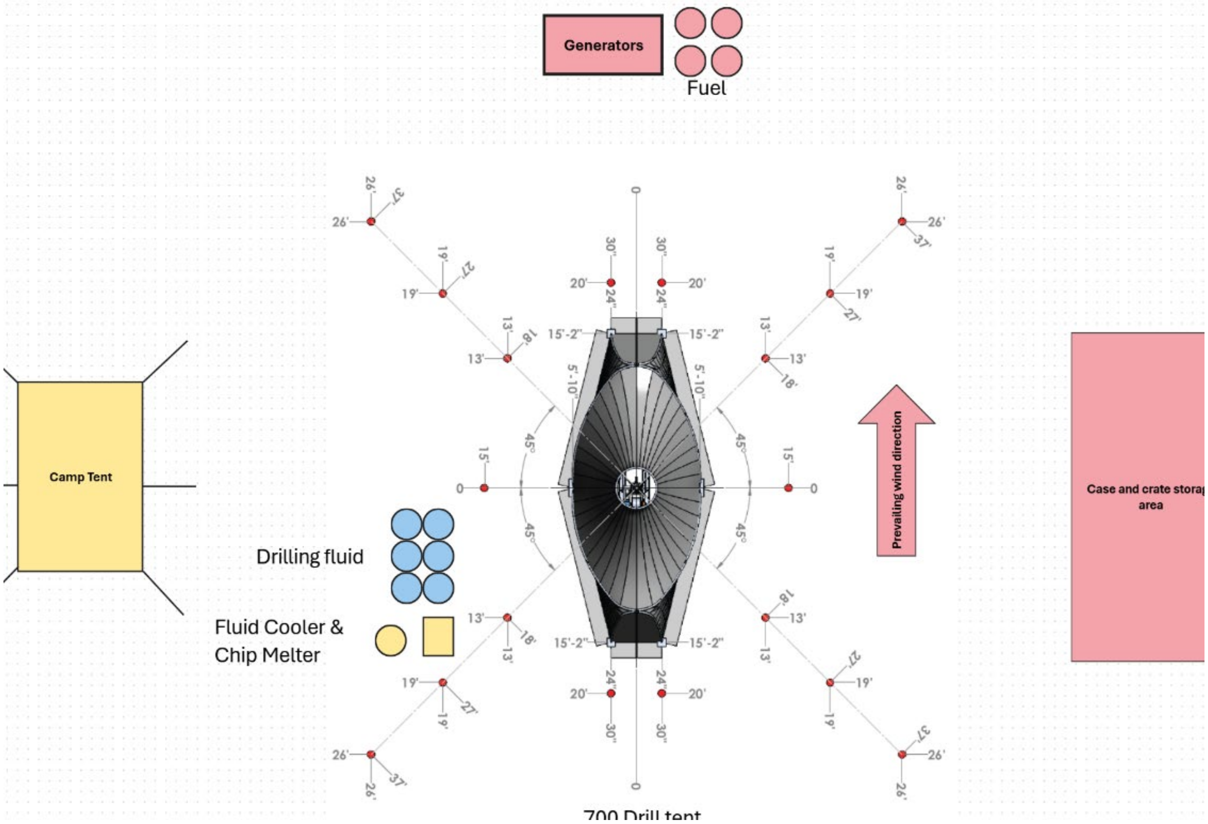


Figure 19. Example drill site layout.

3.3 Geoblock Flooring

The drill tent flooring is designed to provide an easy to maintain non-skid surface throughout the season. The floor consists of 48 Polyethylene GEOBLOCK 2 tiles, each measuring 20" x 40" x 1.2" thick. A 13.5" square hole is cut in one piece at the borehole location, which is marked with the red flag in Figure 20. Each piece is levelled and interlocked with its adjacent tiles to create a continuous surface, over which the tent is ultimately raised. The flooring is assembled in the pattern shown in Figure 20. Once the tiles have been laid, pack snow around the perimeter and fill them with snow to lock the tiles in place.

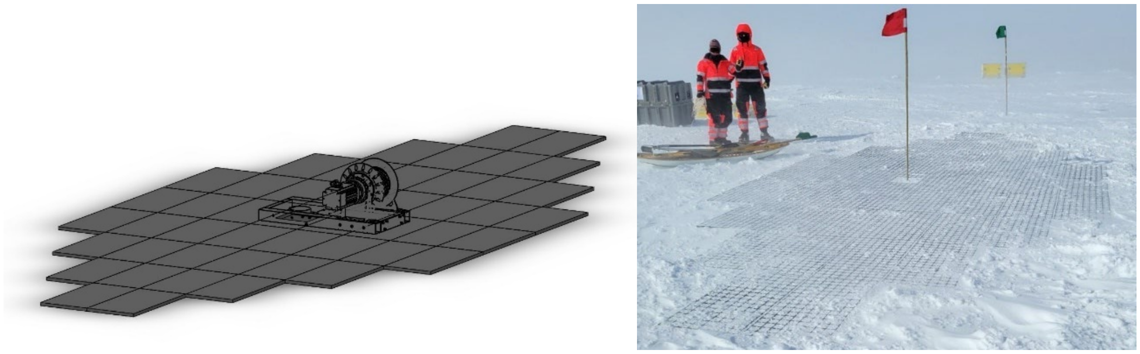


Figure 20. Layout of Geoblock flooring panels.

3.4 Winch Base Anchoring

The winch base is anchored into the firn through the GEOBLOCK with a 3-foot snow stake at six of the corners, Figure 21. The snow stakes can be driven through the GEOBLOCK without having to cut openings. If working on blue ice, secure the winch base in place using ratchet straps and ice screws or v-thread ice anchors. Once secured, the remainder of the winch is assembled onto the base, including the drum, motor, cable keeper, and guard rail. The tower base must be securely anchored before raising the tower to prevent it from sliding.

Figure 21. Anchoring the winch base with snow stakes.

3.5 Tower Setup and Take Down

3.5.1 Tower Assembly

Before beginning the assembly of the tower, drape the MAST tent fabric over the winch with the top hole centered on the tower pivot. See the tent setup procedure in the MAST Tent Assembly Instructions (8431-0002) for details. The tower is then assembled horizontally, including the tower sections, cable roller guide arm, crown sheave and cabling, Figure 22.

The tower is connected to the universal joint at the winch base, and the drill cable is routed through the crown sheave. The load pin and crown sheave cables are connected and secured to the side of the tower. The four ropes for anchoring the tower are connected to the pink eye bolts at the base of the crown sheave. One rope should be tied to each of the four pink colored eye bolts. The four red color progress capture pulleys, with ropes that attach to the tent top ring, must be attached to the two pink eye bolts offset from the centerline of the crown sheave assembly. Two capture pulleys are attached to each side of the tower using a triangle carabiner.

A climbing rope with belay device should also be secured to the top of the tower to allow for safe climbing if needed. Figure 23 shows how the tower guy lines and capture pulleys should be connected to the crown sheave assembly before raising the tower.

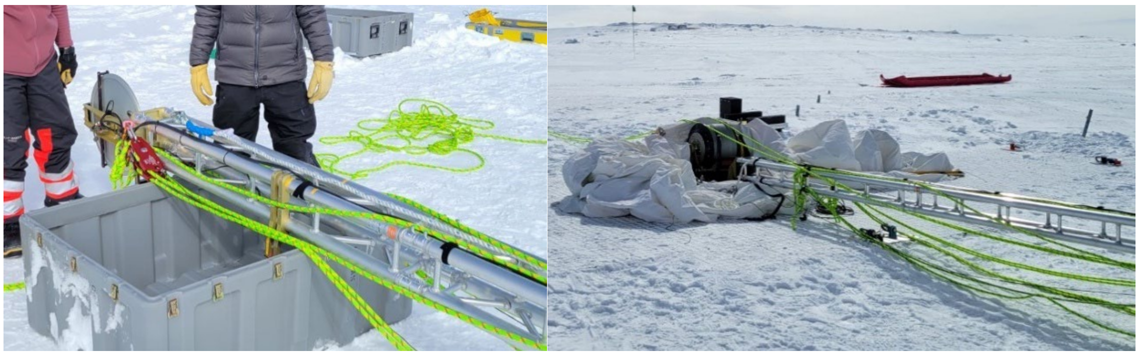


Figure 22. Tower assembly with cables and ropes in place and the tent fabric positioned around the winch.

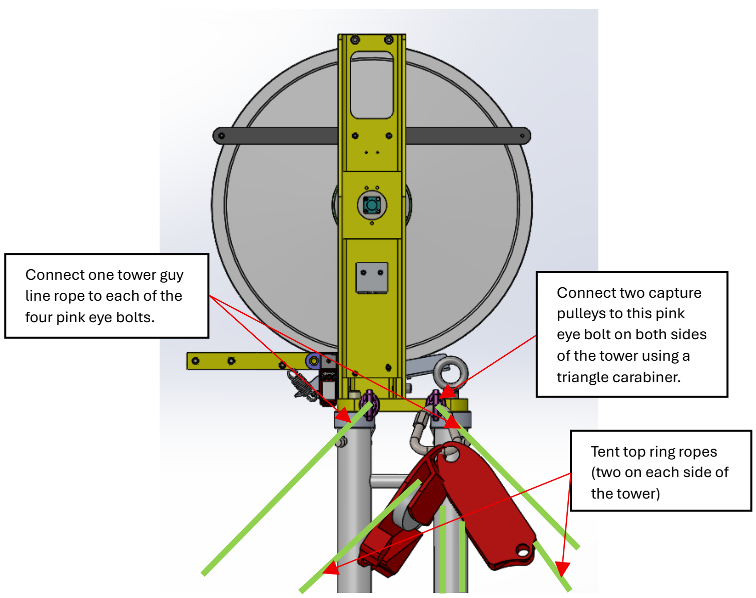


Figure 23. Connection points for the four tower guy ropes and four red capture pulleys for raising the tent.

3.5.2 Tower Raising and Lowering

Assemble the tower lifting frame to the legs with the supplied pins. Mount the two legs to the winch base, place the support leg on the winch drum, and secure the lifting frame to the winch base with a ratchet strap as shown in Figure 25. Next, install the chain hoist. Connect the hook on the chain hoist body to the ½” diameter pin on the tower lifting frame. Place the supplied 1” wide x 3’ long lifting strap at the first tower joint (2 m above the tower universal joint), as shown in Figure 24 and Figure 25, and attach it to the hook on the chain end of the chain hoist. Take up the slack in the lifting chain. The winch base is heavy enough that it will not tip, even without being anchored, when raising or lowering the tower.

Figure 24. Tower lifting strap placement.

Figure 25: Tower lifting components installed on the winch base and connected to the tower.

Four people are required to raise or lower the tower. One person to operate the chain hoist, two people to each man a guy rope to maintain side-to-side stability of the tower, and a fourth person to direct the operation and help with tying off ropes as needed. Before starting the raising/lowering process, all people involved with the procedure should talk through the procedure and understand what each of their roles are. Any bystanders not involved should stand well clear of the area.

Figure 26. Raising the tower using the tower lifting fixture and team of people.

3.5.2.1 Procedure: Tower Raising

1) Check all tower connections are properly assembled and secure.
2) Check the wiring to the crown sheave and the winch cable is properly connected, installed, and secured.
3) Check that the ropes attached to the top of the tower are properly installed and routed.
4) Verify the four stakes, or v-threads if on blue ice, that the tower ropes will be tied off to are in place and properly located.
5) Using the chain hoist, raise the tower a few inches off the ground. Stop and inspect the rigging, tower lifting frame, and tower to make sure everything is in order before continuing to raise the tower.

6) With rope handlers in place on either side of the tower and standing on the opposite side of the tower pivot from the person manning the chain hoist, raise the tower using the chain hoist. The rope handlers should keep light tension on their ropes to stabilize the side-to-side movement of the tower, being careful not to pull the tower in their direction. The director oversees the tower alignment and calls out to the people on the ropes to make adjustments as needed.
7) The tower will stop against the horizontal tube of the tower lifting frame if brought all the way vertically. However, it is recommended to stop raising with the chain hoist a little before reaching this point and pull the tower the final few degrees to vertical using the ropes. The person that was running the chain hoist can take one of the other two ropes, so three ropes are being used to stabilize the tower in a triangle pattern, and the director can guide the tower vertically either by eye or using a level held against the tower. Once it is close to plumb, tie off all four tower ropes using a trucker hitch. Final truing of the tower will need to be done once the sonde is hanging on the winch cable to align it with the borehole opening in the winch base.
8) Remove the chain hoist and tower lifting frame once the tower ropes are secure.

3.5.2.2 Procedure: Tower Lowering

1) Install the tower lifting fixture and chain hoist. Take up the slack in the chain.
2) Disassemble and lower the MAST Tent. See the MAST Tent Assembly Instructions (8431-0002) for tent disassembly instructions.
3) The two tower ropes on borehole side of the tower can stay tied off to their anchors.
4) The two ropes on the winch side of the tower each need to be firmly held but with light tension by a person as they are untied from their anchors. These two ropes will be used to stabilize the tower side-to-side as it is lowered.
5) Slowly start paying out the chain hoist. If the tower doesn't start tilting on its own, the person running the chain hoist can give it a push or the two people manning the ropes can give it a gentle pull.
6) Continue lowering the tower all the way to the ground with the chain hoist as the two people manning the ropes keep light tension on their ropes to stabilize the tower side to side as it is lowered.
7) A shipping case can be placed under the tower, as shown in Figure 25, to rest the tower on to keep the sheave out of the snow.
8) Remove and pack the chain hoist and tower lifting frame.

3.6 Tent Setup and Take Down

See the MAST Tent Assembly Instructions (8431-0002) for more information.

3.7 Core Processing Assembly

The core processing assembly ships mostly disassembled in two yellow cases, 700-07 and 700-08. Reference drawing *83890122_Core Processing Assembly* for assembly of this system. It consists of two major assemblies, the longer Core Barrel Table Assembly on the left and shorter Sonde Table Assembly on the right. Before beginning assembly, verify the ground under the core processing assembly is level and at the same height as the winch base.

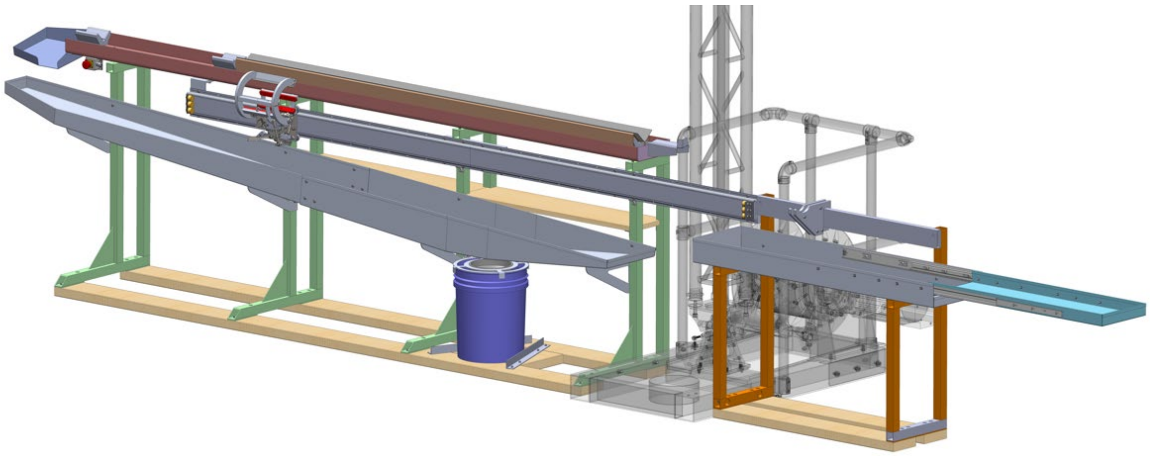


Figure 27. Core Processing Line assembly.

3.7.1 Procedure: Sonde Table Assembly

1) Reference drawing 83890370_Sonde Table Assembly
2) Place the two short 2x6 wood footers on the right side of the winch, as shown in Figure 27.
3) Mount the leg with the two slotted holes in the side of the base tube to the right side of the winch base.
4) Place the Sonde Support Assembly on the Sonde Support Tube and then mount the tube onto the two legs.
5) Mount the Extended Tray Assembly to the legs.
6) Screw the legs to the wooden footer.

3.7.2 Procedure: Core Barrel Table Assembly

7) Reference Drawing *83890379_Core Barrel Table Assembly*
8) Place the two long 2x6 wood footers on the left side of the winch, as shown in Figure 27.

9) Mount support leg D (the leg with the two slotted holes in the side of base tube) to the left side of the winch base.
10) Place the left most of the four legs, support leg A, on the footer and then mount the Processing Line channel to the two legs.
11) Install support legs B and C.
12) Install the three shelves.
13) Screw the legs to the footer, leaving them finger tight.
14) Install the sheet metal brackets for the drip tray.
15) Assemble the upper and lower tray halves together.
16) Mount the tray assembly to the legs and adjust the support brackets as needed so they each contact the tray and tighten the mounting screws.
17) Install the cutter head drip tray.

18) Mount the two bucket stops so the bucket is centered under the drip tray drain hole.
19) Install the drill clamp and rail assemblies per drawing *83890122_Core Processing Assembly*.

3.8 Furniture and Tent Layout

There are five 36" L x 20" W x 30" H tables and one 36" L x 15" W x 36" H table for the following locations.

36" x 20" x 30" tables

- Drill control station
- Two workbenches
- Core processing worktable
- Drillers' worktable

36" x 15" x 36" htable

- Drillers' worktable

The tables have removable legs and an adjustable lower shelf, and they easily break down and pack flat for shipping. Wooden boards with pocket holes for the table legs are also provided for using the tables on soft snow and the Geoblock flooring. Figure 28 shows the typical layout of the tables. However, they can be placed wherever they work best for a particular project.

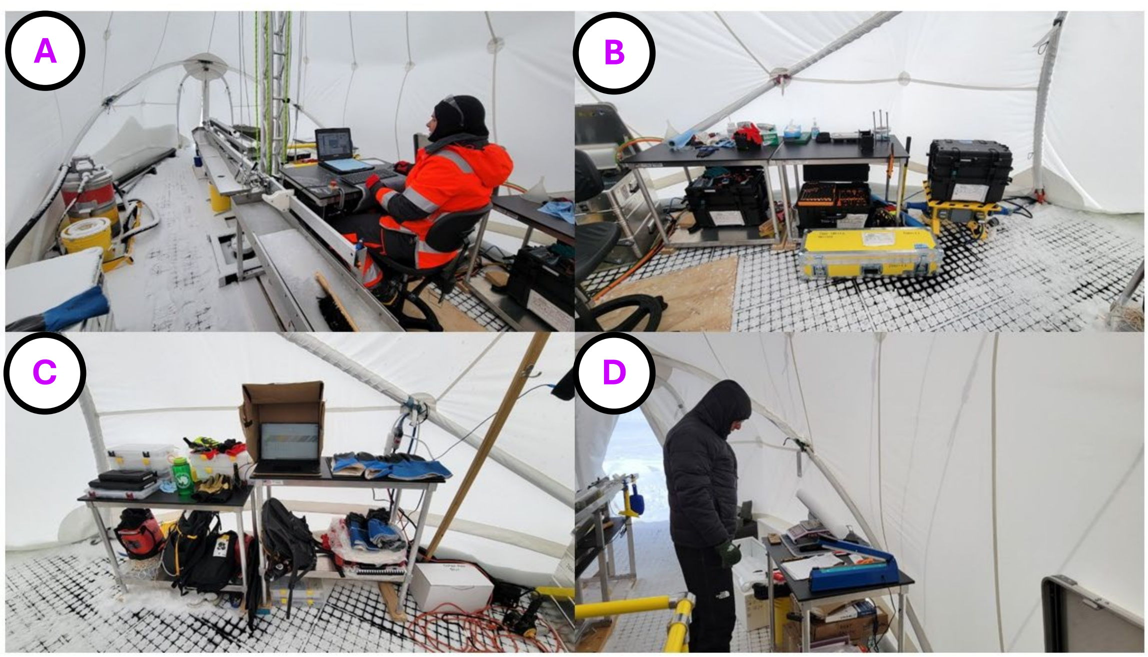


Figure 28. Table layout in the drill tent. (A) Drill Control Station. (B) Workbenches. (C) Drillers' worktables. (D) Core processing worktable.

The other major pieces of equipment inside the drill tent include the SPIDER Power Distribution box located to the right of the workbenches, fluid vacuum, and layflat hose Zarges case.

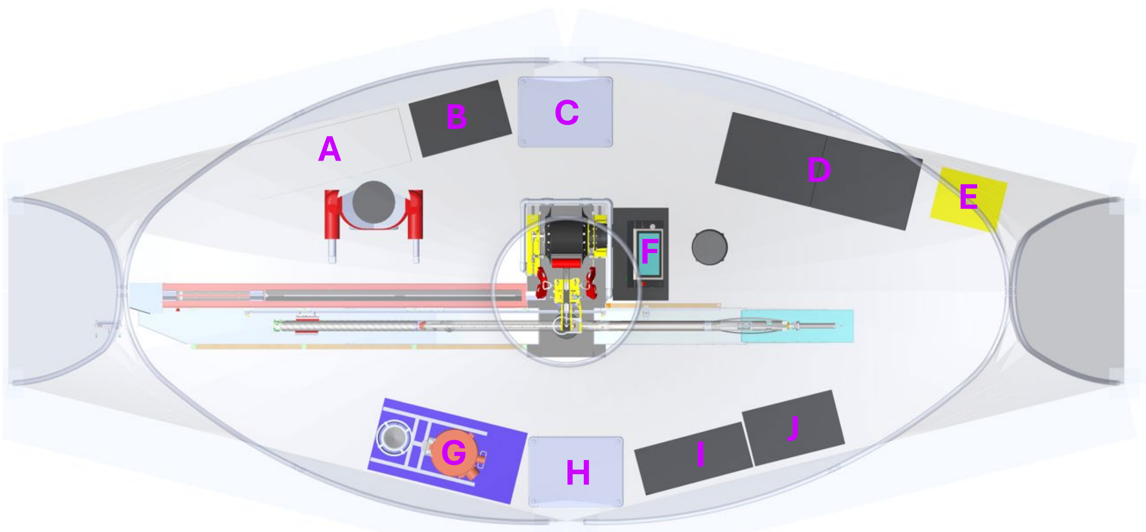


Figure 29. Drill tent equipment layout. (A) Core box. (B) Core Processing Worktable. (C) Control Box. (D)Workbenches. (E) SPIDER power distribution box. (F) Drill control station. (G) Fluid vacuum. (H) Layflat hose Zarges. (I & J) Drillers' worktables.

3.9 Cables

The cables within the drill tent are listed in the table below.

ID	Description	From	To	Color	Length
DRS1	208VAC	Generator	SPIDER	Black	100 ft
DRS2	208VAC	SPIDER	Control Box	Black	25 ft
	120VAC Triple Outlet	SPIDER	Fluid Chiller	Blue	50 ft
	120VAC Triple Outlet	SPIDER	Core Processing	Blue	50 ft
DRC2	600VDC Drill Power	Control Box	Winch Drum	Orange	16 ft
DRS3	Winch Power	Control Box	Winch Motor	Orange	16 ft
DRS5	Winch Feedback	Control Box	Winch Motor	Green	16 ft
HTR	208VAC	Control Box	Chip Melter	Black	70 ft
CON	E-Stop, Data	Control Box	Console	Black	16 ft
DRS6	Data	Control Box	Crown Sheave	Black	34 ft
DRS4	Data	Control Box	Load Pin	Black	34 ft
DRS8	E-Stop	Control Box	Core Processing	Black	32 ft
DRS7	Data	Control Box	Borehole Cover	Black	14 ft

ID	Description	From	To	Color	Length
EGC1	Ground	Control Box	Tent Frame	Green	10 ft
DRC1	600VDC	Winch Drum	Sonde	Steel	750 m

3.10 Sonde Assembly

The sonde ships disassembled into the following major components for ease of shipping.

- Anti-torque section
- Motor section
- Barrel set including the outer tube, hollow shaft, and core barrel
- Cutter head

Before beginning assembly, inspect each component for damage or corrosion from shipping. Clean the anti-torque blades, if needed, to remove the corrosion preventative. Sonde stands are provided to aid in drill assembly. They come in two varieties, one with the smaller curve to fit the anti-torque and motor sections and a second with a larger radius to fit the larger diameter barrel outer tube.

3.10.1 Procedure: Sonde Assembly

Reference drawing *83890288_Sonde Assembly* for the components needed for this assembly.

1) Place the anti-torque and motor section in line on sonde stands on the ground in front of the core processing line.
2) Connect the anti-torque electrical connector to the receptacle at the top of the motor section. Hand tighten the connector. **Note:** ensure the connector and receptacle are clean and dry internally before mating them.
3) Carefully mate the anti-torque and motor sections, being careful to feed the wires into the hole in the middle of the anti-torque so they don't get pinched. Align the mounting holes and install the six M5 shoulder screws. **Note:** apply a light coating of anti-seize to the threads and body of the shoulder screws before installing them.
4) Slide the cable strain relief assembly over the winch cable head.
5) Insert the cablehead into the top of the anti-torque. As the end of the cablehead comes through the bearing section, slide the threaded clamp collar over the end of the connector housing, item 1 in Figure 30. Align and seat the electrical connector with the mating receptacle on the slip ring.
6) Thread the clamp collar into place, tighten, and tighten the pinch bolt.
7) Tighten the pinch bolt on the slip ring clamp collar, item 2 in Figure 30.

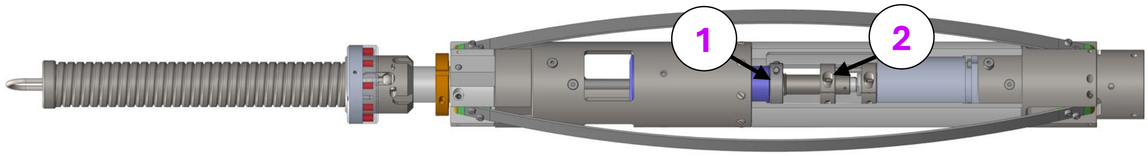


Figure 30. Anti-torque assembly. (1) Cablehead retaining nut. (2) Slip ring clamp collar.

8) Install the strain relief assembly onto the top of the anti-torque and tighten the locking set screw. **Note:** apply a light coating of anti-seize to the thread on the anti-torque before installing the strain relief.

9) Power up the motor section and test for proper operation.

10) Remove the hollow shaft and core barrel from the outer tube.

11) Place the outer tube on sonde stands and align it with the motor section.

12) Mate the outer tube with the motor section. Strap wrenches can be used to help rotate the outer tube as it is fitted to the motor section.

13) Install the 6 headless shoulder screws using a 7 mm wrench or socket. **Note:** apply a light coating of anti-seize to the threads and body of the shoulder screws before installing them.

14) Slide the hollow shaft assembly into the outer tube leaving the last few inches sticking out.

15) Install the core barrel on the hollow shaft and lock it into place by turning out the three lock pins.

16) Continue pushing the hollow shaft and core barrel assembly into the outer tube until the coupler at the top of the hollow shaft engages with the drive plate on the motor section. Turn out the three locking pins to secure the hollow shaft.

17) Set up the cutter head and install it onto the core barrel. See section *3.10.2 Cutter Heads* for details.

18) Note the drill configuration in the drill log (anti-torque A or B, motor section 1 or 2, outer tube A or B, hollow shaft A or B, Core barrel A or B, core dog head 1 or 2 or collet head C1 or C2).

3.10.2 Cutter Heads

The 700 Drill is supplied with two cutter head versions. One using core dogs for recovering the core and a second using a collet for recovering the core. The collet head works best in firn where core dogs typically cut grooves in the core. The core dog head works best in dense firn and ice. Reference drawings *83890165_Cutter Head Assembly* and

83890180_Collet Cutter Head Assembly. The cutter head assembly mounts to the core barrel with three screws and specialized bushings, as shown in Figure 32.

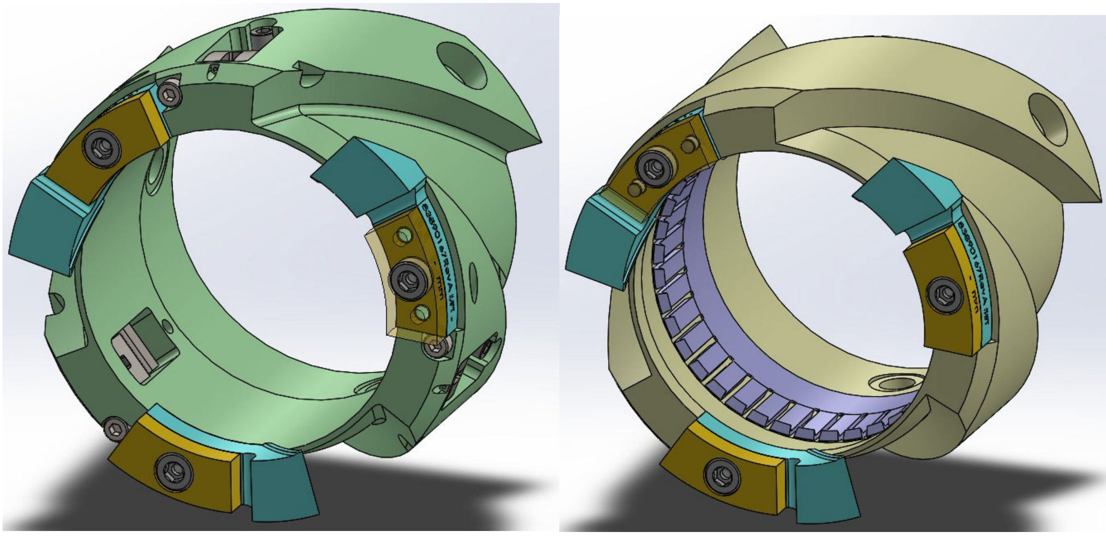


Figure 31. Core dog cutter head (left), Collet cutter head (right).

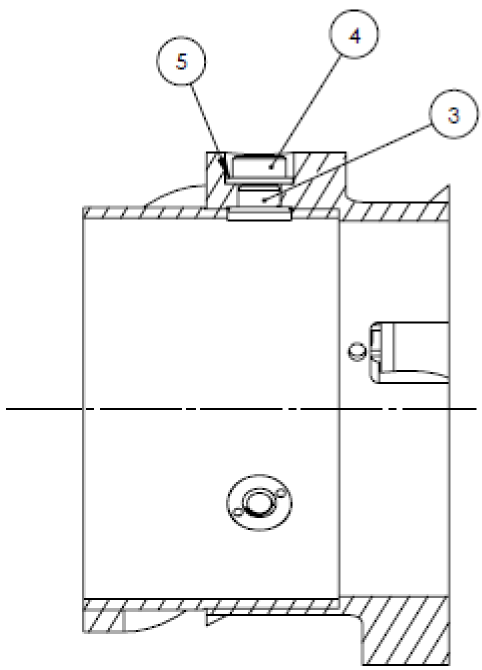


Figure 32. Section view of the cutter head showing one of the three head mounting screws. (3) Head Mounting Bushing, (4) M6 low head socket head cap screw, (5) Washer.

Two lengths of core dogs, long and short, are provided for the core dog head. The long core dogs work best in firn, while the short core dogs work best in ice. For sites with firn, start drilling with long core dogs. When cores come up sticking out of the core barrel, or the drill isn't recovering them at all, it is time to switch to the short core dogs. The core dogs are double-sprung, meaning a light-force torsion spring is used to hold the core dog retracted in the head and a stiff u-spring engages the core dog with the core so it will bite into the core when the drill is raised. The force of the u-spring can be adjusted by bending them to change how hard the core dog engages the core. The bend of the u-springs should be checked after every drill run while the cutter head is being cleaned. To change a core dog, loosen the pin retaining screw on the bottom of the head and then push out the core dog pivot pin using a small screwdriver or hex key, being careful not to lose the torsion spring.

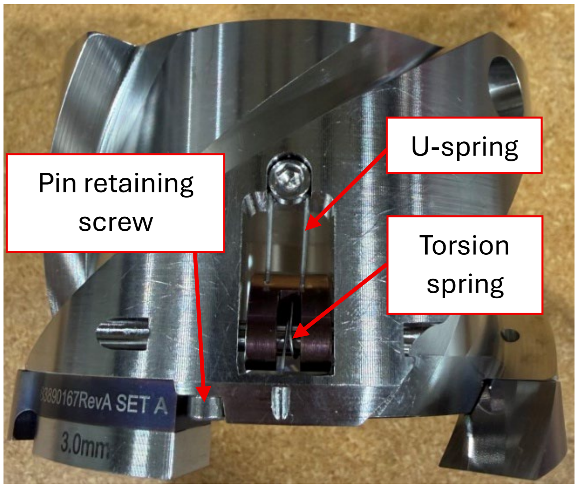


Figure 33. Cutter head with double sprung core dog.

See section *4.4.5.1 Cutter and Shoe Selection* for details on cutter head hardware not covered here.

3.10.2.1 Chip Transport

Cutting creates ice chips that are transported by the flights on the core barrel into the chip chamber, around the hollow shaft. They are ultimately recovered with the core, and processed as part of fluid handling; see section *4.4.6 Fluid Handling* for more information.

Poor chip transport can lead to poor penetration and is typically caused by a) the fine ice chips associated with shallow DOC, and/or b) high drill velocity when wet drilling. See section *4.7.2 Slow Cutting Speed* for more information.

4 Operating Procedures

Drilling requires the coordination of two operators. There is no strictly required division of tasks, but there are roughly two roles:

Driver – This operator sits at the console and operates the winch and drill motors.

Driller – This operator works the sonde when it is out of the borehole: guiding it during lowering or raising, disassembling the sonde to extract core, servicing the cutter head and hollow shaft, and reassembling the sonde for the next run.

These two roles are fluid and overlapping – the Driver frequently gets up to help the Driller, and the Driller frequently sits near the Driver to discuss or observe the drilling progress. The definition provided here serves mainly to avoid ambiguity in referring to the different operators in the following procedures.

4.1 Emergency Stop

When depressed, any Emergency Stop, or E-Stop, button will immediately stop operations, which cannot be resumed until it has been pulled back out to its normal operating position. When activated, the E-Stop prevents any motion of the winch and removes power from the drill cable and sonde, i.e. the 600VDC supply is shut down.

To resume operations after an E-Stop or power cycle, press the green Start button on the control box.

Press at least one of the E-Stop buttons when leaving the drill unattended, even for a short time, e.g. a break. There are three E-Stop buttons:

1. Control box

2. Core processing

3. Console

   a. If the console is not in use, the auxiliary E-Stop must be used.

4.2 Sonde Hard Stop

When raised, the sonde hard stop arm prevents any winch motion. This prevents the winch motor from damaging equipment or pulling down the tower, should the sonde or any other large object on the cable, e.g. a cable knot, be pulled into the crown sheave.

Operations may not be resumed until the sonde hard stop arm has been lowered. Use the Manual Payout button on the control box to pay cable out as necessary at a fixed speed of ~0.2m/s.

To resume operations following a hard stop or power cycle, press the Initialize Winch button.

4.3 Control System Overview

The 700 Drill has a semi-automated control system. The automated aspects of the control system are implemented in the central controller in the control box, sonde controller in the sonde, and the GUI in the console or Durabook.

4.3.1 Unsafe Software Warning

The 700 Drill does NOT have safe software. IDP engineers make every effort to find and address software issues, prioritizing those that may create unsafe situations. However, the control software and firmware developed by IDP may still contain serious software issues.

UNCONTROLLED WINCH OR CUTTER MOTION MAY OCCUR AT ANY TIME, unless the system is powered off or a hardware safety feature is triggered.

The hardware safety features of the 700 Drill are the E-Stops and Sonde Hard Stop. See sections *4.1 Emergency Stop* and *4.2 Sonde Hard Stop* for more details.

4.3.2 Automated Features

The central controller detects the following operation modes based on the payout and cable tension:

Mode	System State	Limits	Notes
Parking	The sonde is at the surface.	Winch speed is limited to 200rpm (~0.2m/s). The GUI requires constant interaction (e.g. press and hold) to move the winch and/or drill motor.	This mode is the default at power on, until prior system state information is loaded by the GUI.

Mode	System State	Limits	Notes
Tripping	The sonde is entirely below the surface.	Maximum winch speed is allowed.	This mode may only be entered: a) from parking, when the borehole cover is closed and the weight on bit is sufficiently low; or b) from cutting, when the operator has declared cutting to be complete.
Cutting	The sonde is near the cutting face.	Winch speed is limited to 200rpm (~0.2m/s).	This mode is entered any time the cutter is near the cutting face (including directly from Parking when the hole is shallow). This mode can **only** be left when the operator has declared cutting to be complete.

The central controller performs real time computation to support critical features. It does not store any data. Aside from managing the transitions between the operation modes described above, the central controller automatically performs the following tasks:

- Increments the drill run number when exiting parking mode after sonde service.
- Updates the hole depth once cutting is complete.
- Rotates the core barrel to align core North to sonde reference position once the core has been broken.

The central controller will also autonomously reduce winch speed in the following circumstances:

- Winch speed is reduced when the fluid transition is detected while tripping down hole.
- When tripping down, winch speed is reduced to zero just before the sonde reaches the bottom of the borehole.
- When tripping up, winch speed is reduced to zero just before the sonde reaches the surface.

Note that the system detects when the sonde is floating but does not automatically reduce winch speed – it only prevents further increase in winch speed.

The Driver must react when the sonde is floating to prevent irreparable damage to the cable.

4.3.3 Console Hardware Interface

The console is the primary user interface for controlling the drill system. It includes a touchscreen, an E-Stop, push-button knob, and other user interface elements shown below.

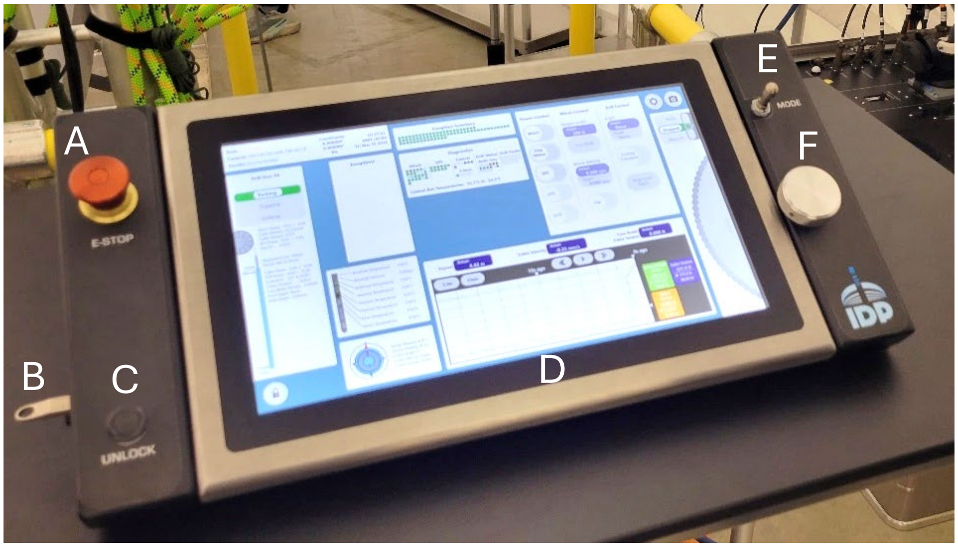


Figure 34. Console with labelled user interface elements. (A) E-Stop, (B) 2x USB-A receptacles for connection of a keyboard, mouse, or memory stick. (C) Unlock button. (D) Touch screen display. (E) Mode toggle switch. (F) Push button knob.

The console features a resistive touchscreen which, unlike typical capacitive touchscreens on a cell phone, functions by the physical deformation of the touch surface. It is unaffected by the stylus material but requires continuous pressure to detect the stylus and does not support multiple touch points, i.e. no pinch-to-zoom.

4.3.4 Graphical User Interface (GUI)

The GUI is designed to facilitate gloved use of the console's resistive touchscreen. The same software runs on the Durabook, which serves as a viewing terminal and backup console. The Durabook has a capacitive touchscreen, but this is disabled due to poor performance in the cold – a mouse and keyboard are provided for use with the Durabook or the console, as desired.

The touchscreen and knob are used to change control values associated with elements displayed in the GUI. The desired element is selected via the GUI by tapping or clicking. The value associated with a selected GUI element may be changed by turning and/or pressing the console knob. When using the Durabook, console knob interactions may be executed by using the mouse click/wheel with the cursor over the knob graphic or by using the hotkeys listed below. Similarly, when using the Durabook, the mode toggle switch may be moved by clicking on the desired position of the mode toggle graphic.

A complete list of GUI hotkeys is shown in the table below:

Key	Effect
Numbers, symbols, backspace	Edit value
Enter	Confirm edited value
Up/Down Arrow Keys	Rotate the knob
Console unlock button	Press the knob
Spacebar	Press the knob
Escape	Un-maximize GUI window

The GUI screen is divided into a static area on the left, and a dynamic area. The static area always displays the same information, providing a snapshot of the system's status. The dynamic area changes in response to user input and system state. At the right edge of the screen, graphical representations of the console hardware interface reflect interactions with the mode toggle switch and push button knob. The user may tap or click the following panes to access more detailed information and settings, which will hide the remainder of the dynamic area, this can be undone by repeating the tap or click:

Exceptions – Lists all the possible exceptions, and the status of each: nominal (green), triggered (red), or disabled (gray). Provides controls to override or adjust specific exception trigger/reset thresholds. Note that these settings are lost when power is cycled. Exceptions may trigger automated mitigations, such as disabling a subsystem. These are typically denoted by the terms ALARM, for conditions that may lead to equipment damage, or FAULT, for conditions suggesting a component failure.

Diagnostics – Lists detailed status information for all subsystems and guides interpretation with indicators that are positive (green), negative (red), or neutral (gray). Provides controls to reset various subsystems.

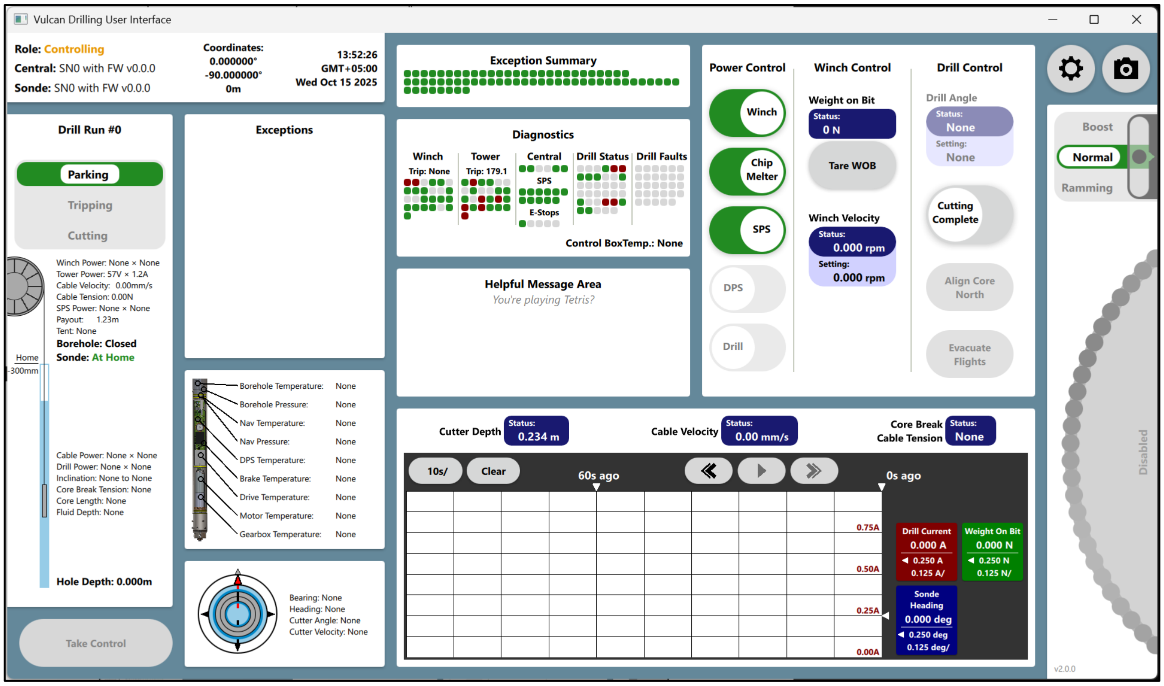
Graph – Provides controls to enable or disable graphing of up to 6 system variables from a wide selection. See appendix *6.3 List of Graph Variables*.

Settings – Provides controls to configure many system variables. See appendix *6.4 List of Settings*.

GUI elements that support different user interactions are styled differently. Elements that have flat sides display data, while those with rounded sides are buttons, i.e. the GUI or system state will change if they are pressed.

The GUI reacts to different operation modes by presenting the operator with controls relevant to each mode. Some GUI elements may appear in only one mode, while others may appear the same but have a different sensitivity, e.g. winch velocity can quickly reach 2000 rpm in tripping mode but can be adjusted by 0.1 rpm in cutting mode.

4.3.4.1 GUI: Parking Mode



In parking mode, the GUI requires continuous user engagement to sustain movement of either the winch or drill motor; this contrasts with the behavior in tripping and cutting modes, where the winch and/or drill motor can run without continuous engagement. For example, the winch velocity control is forced to zero unless the console knob or console unlock button is pressed and held. In parking mode, the winch can be stopped by simply letting go.

Parking mode includes the following features:

Tare WOB – Set the weight on bit to 0 N. Only enabled when the sonde is at home.

Winch Velocity – Set the winch velocity (limited to ±200 rpm). Press and hold the knob (or unlock button or spacebar) while turning the knob.

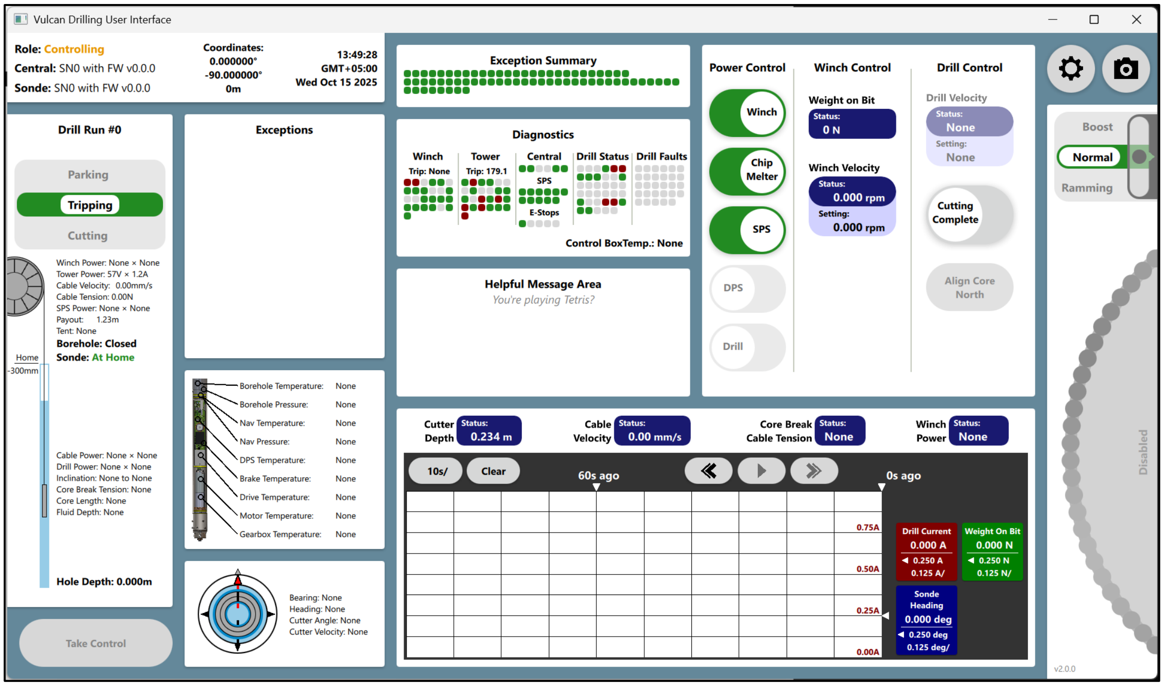
Drill Angle – Set the angle of the drill motor. Used to align the motor quick connects during sonde dis/assembly.

Cutting Complete – Force the system out of cutting mode and into parking or tripping mode, depending on hole depth.

Evacuate Flights – Press and hold to turn the drill motor in reverse at maximum speed.

Align Core North – Moves the core barrel such that the part of the core that faced North at core break is aligned with the reference mark on the exterior of the sonde. Note that this is also performed automatically after core break.

4.3.4.2 GUI: Tripping Mode



Tripping mode includes the following features:

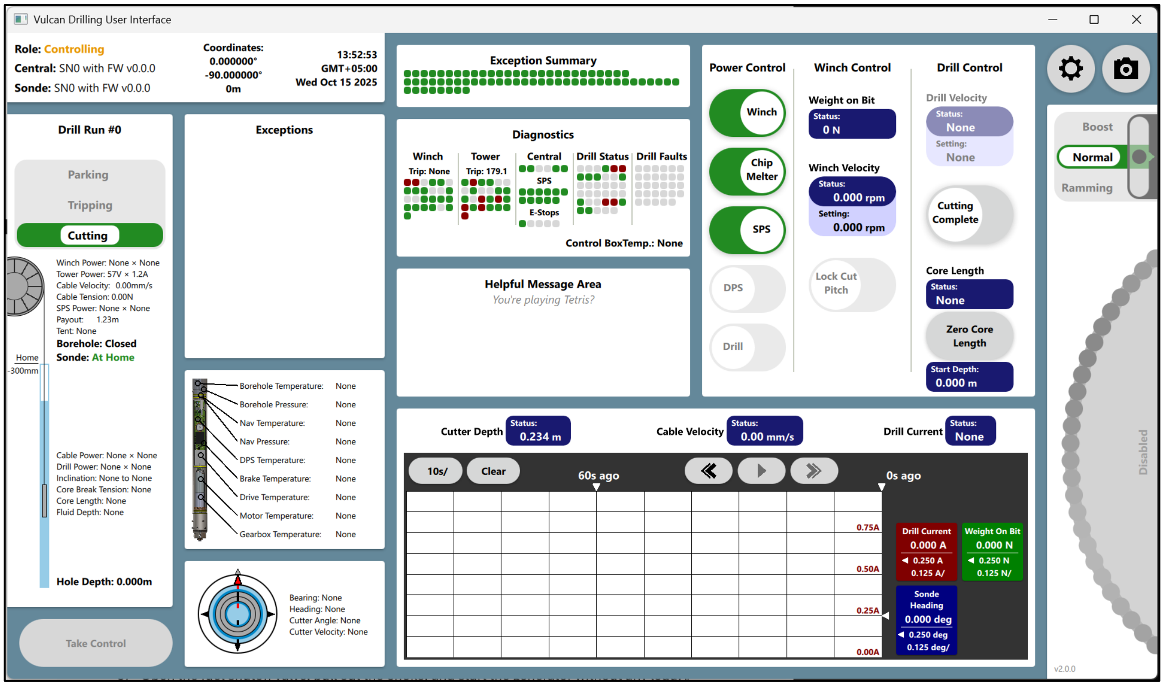
Winch Velocity – Set the winch velocity. Note that up/down direction is encoded as positive/negative values.

Drill Velocity – Set the drill motor velocity.
Note that turning the drill motor while tripping can open/close the hollow shaft valves, drastically affecting the speed at which the sonde will float.

Cutting Complete – Force the system out of cutting mode.

Align Core North – Moves the core barrel such that the part of the core that faced North at core break is aligned with the reference mark on the exterior of the sonde.

4.3.4.3 GUI: Cutting Mode



Cutting mode includes the following features:

Winch Velocity – Set the winch velocity.

Lock Cut Pitch – Link the drill velocity and winch velocity, such that the current cut pitch is maintained.

Drill Velocity – Set the drill motor velocity.

Cutting Complete – Force the system out of cutting mode.

Zero Core Length – Sets the coring start depth to the current cutter depth. Note that the core length start depth uses the prior hole depth as the default if this button is not pressed.

4.4 Daily Operations

4.4.1 Inspections

- Check the crown sheave and upper ropes for rime ice. Strike the tower and shake the ropes to get anything loose to fall before beginning work.
- Check the generator fuel and oil levels. Add fuel/oil as necessary before beginning work.
- Check that the core tray slides freely. Remove any ice as necessary before beginning work.

4.4.2 System Start and Stop Procedures

4.4.2.1 Procedure: System Start after Long Work Stoppage

1) Remove the generator cover (typically requires two people).
2) Check fuel and oil levels and add fuel/oil as necessary.

3) Open the fuel shutoff valve, pull out the choke, and start the generator without any load.
4) After a few seconds, push the choke in.
5) Plug in the power cable and switch the breaker on the generator to the ON position.
6) Move the power input switch on the control box to the ON position.
7) Press the RESET button on each of the 120V GFCIs in use on the SPIDER power distribution box.
8) Wait a few minutes for the console interface to boot up – no user interaction is required.
9) Boot up the Durabook and start the GUI application.
10) Press the Start and Initialize Winch buttons on the control box.

4.4.2.2 Procedure: System Stop for Short Work Stoppage

1) Stop the winch and drill motors, if moving.
2) Press any E-Stop.

4.4.2.3 Procedure: System Stop for Long Work Stoppage

1) Stop the winch and drill motors, if moving.
   a) The sonde is typically left in the hole if the drill is going to be parked for any length of time, such as for breaks or overnight.
2) Press and hold both the unlock button and knob button on the console for 10 seconds, until it shuts down. The strong spring on the knob button typically requires a palm press to ensure continuous actuation for the entire 10 seconds.
3) Close the GUI application on the Durabook and shut down the computer. Close the lid to prevent snow or ice from falling on the keyboard.
4) Move the power input switch on the control box to the OFF position.
5) Switch the breaker on the generator to the OFF position, turn off the generator, and close the fuel shutoff valve.
6) Unplug the power cable from the generator.
7) Place the cover over the generator (typically requires two people).
   a) Allow the generator exhaust pipe to cool a little before placing the lid, to avoid damage to the foam lining.

4.4.3 Sonde Service Procedures

Parking mode is used when the sonde is at the surface, and for all sonde service procedures.

4.4.3.1 Procedure: Laying Down the Sonde

This procedure assumes that a) the system has just entered parking mode while wet drilling with the sonde below the closed borehole cover, and b) the core will be extracted next. Adapt the steps as necessary to other scenarios.

The sonde moves quickly when it is near vertical. The Driver must use caution and communicate clearly with everyone in the drill tent. Take care if raising the sonde with missing components or in other configurations, e.g. with the chip bailer. Changes to the center of mass of the sonde may result in unexpected movements.

1) **Driver**: Pay in until the sonde reaches home.
   Driller:
   a) Remove the cable vacuum adapter from the cable and let the drill push open the borehole cover – if it is opened too soon it may trigger the Cable Knot Alarm exception.
   b) Use the vacuum to clean the sonde exterior as it rises, focusing on the anti-torque blade hinges and motor quick-connect windows.
   c) Close the borehole cover if it doesn't fall closed on its own.
   d) Wipe down the lower end of the outer barrel with a rag, then engage the outer barrel clamp.
   e) If the core is sticking out of the core barrel, tell the Driver as this can be relevant for estimating core lengths during cutting.
      i) If dry drilling, simply push the core up into the barrel.
      ii) If wet drilling, do NOT push the core up into the barrel, as it will cause fluid to spurt out of the motor quick connect windows. Pull the sonde around the end of the drip pan, then towards the core processing area until the protruding core clears the edge of the drip pan. While holding the sonde at an angle, bring it into line with the roller guide and engage the clamp.
2) **Driver**: Pay out slowly, just until the sonde has started to rest on the clamp.
   Driller: Gently pull the sonde/clamp towards the core processing area. Take care not to pull so much that the clamp release is triggered – just enough to ensure the sonde moves in that direction as the cable pays out.
3) **Driver**: Once the sonde is angled in the right direction, pay out more quickly until it is on the sonde rest. Guide it with one hand as necessary. Continue paying out a little extra cable.
   Driller:
   a) Walk the clamp down to the core processing area, slowing the sonde to prevent violent impacts. **Take care to avoid the cutters.** Do not place hands anywhere between the cutters and the drip pan while the sonde is moving. If the clamp slips the sonde will fall, cutters first, into the drip pan.
   b) After the sonde is on its rest, push the sonde towards the Driver until the flip chip is exposed. Flip the chip out, then pull the sonde until the clamp rests against the chip.

4.4.3.2 Procedure: Extracting the Core

This procedure assumes that the sonde is laying down, with the drill clamp resting against the flip chip. Adapt the steps as necessary to other scenarios.

1) **Driver**: After ensuring everyone's hands are clear of the sonde near the cutter head, move the drill motor such that one of the motor quick connects is visible in the windows. Keep moving them into view as the Driller disengages them.
   Driller: Use a 5mm hex driver to disengage the motor quick connects as they become visible in the windows.
2) **Driller**: Put the cutter guard on the cutter head and use the handle to pull the core barrel until the hollow shaft quick connects are exposed.

   a) If dry drilling, keep pulling until the entire hollow shaft has come free of the outer barrel. This must be done in one smooth motion, as allowing the packed chips around the hollow shaft to rest may result in them sticking to the outer barrel.
3) **Driller**: Disengage the hollow shaft quick connects. Gently separate the core barrel from the hollow shaft and set it on the core barrel blocks on the core processing line. Hold the core barrel in place while the core handler pushes the core out with the push stick.

4.4.3.3 Procedure: Servicing and Reassembling the Sonde

This procedure assumes the core has just been extracted. Adapt the steps as necessary to other scenarios.

While the driller is performing barrel assembly service, the driver typically makes use of a brush, pick, and ethanol rag to ensure that the AT blades are clean and can move freely.

Ethanol, applied directly or with a rag, may be used to efficiently remove ice buildup on the sonde. However, because ethanol melts insulating ice into conductive water, cleaning electrical components with ethanol may create a shock hazard. ***Avoid cleaning electrical connectors with ethanol; dry components thoroughly with a heat gun before mating connectors cleaned with ethanol.***

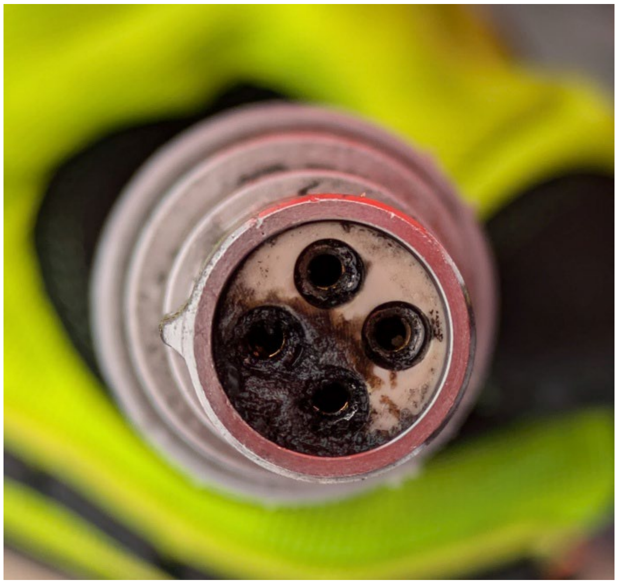


Figure 35. The aftermath of a 600V connection, shorted by ethanol/water mixture pushed onto the mating face by drilling fluid.

1) Extract the hollow shaft from the outer barrel and wipe it clean.
   a) If wet drilling, swap it out with a clean hollow shaft. Melt away any remaining ice from the dirty hollow shaft during the next drilling run.
2) Insert the hollow shaft into the outer barrel, leaving the hollow shaft quick connects exposed. Place the hollow shaft brace board on the hollow shaft, just above the quick connects. Push the core barrel back onto the hollow shaft and engage the quick connects.

3) Clean the core barrel flights:
   a) If dry drilling, simply brush the chips off.
   b) If wet drilling, wrap a rag around the flights near the top of the core barrel. While holding the rag against the flights, rotate the core barrel and hollow shaft together from the cutter head. Continue turning until the flights drive the rag and ice down past the cutter head. Note that this typically requires two operators.
4) Remove the hollow shaft brace board and slide the core barrel into the outer barrel until it is well supported.
5) Clean the cutters with a nylon brush or bamboo scraper to free them of adhered ice. Inspect them for damage and wear to the cutting edge.
   a) If necessary, replace the cutters with a sharp set.
6) Clean the shoes with a nylon brush or bamboo scraper to free them of adhered ice.
7) Clean the core dog windows with a brush or pick to free them of packed ice. If necessary, bend the U-springs so that the dogs will be engaged against the core. Do not bend them too far, lest the spring prevent the dog from moving back into its window.
8) Push the core barrel into the outer barrel until the hollow shaft is in contact with the motor quick connects. Rotate the core barrel as necessary to align the hollow shaft coupler to the locator pin on the motor section drive plate.
9) **Driver**: After ensuring everyone's hands are clear of the sonde near the cutter head, move the drill motor such that one of the motor quick connects is visible in the windows. Keep moving them into view as the Driller engages them.
   Driller: Use a 5mm hex driver to engage the motor quick connects as they become visible in the windows.

4.4.3.4 Procedure: Raising the Sonde

This procedure assumes that a) the sonde is laying down in the clamp and fully assembled for cutting core, and b) tripping down the borehole is next. Adapt the steps as necessary to other scenarios.

The sonde moves quickly when it is near vertical. The Driver must use caution and communicate clearly with everyone in the drill tent. Take care if raising the sonde with missing components or in other configurations (e.g. with the chip bailer). Changes to the sonde center of mass may result in unexpected movements.

1) **Driller**: Push the sonde towards the console until the flip chip is exposed. Flip the chip in and pull the drill towards the core processing area until it is in contact with the end stop.
2) **Driver**: Pay in until the sonde reaches home.
   Driller: Standing near the borehole, catch and slow the sonde as it reaches the vertical position. Do not hold it back as this will release the clamp. The clamp will automatically release once the sonde is entirely supported by the cable. Be ready to prevent the sonde from striking the wall of the drip pan if the clamp releases before the sonde is vertical.
   a) If the clamp has slipped during core extraction, the cutter head may scrape against the drip pan as the sonde tilts to vertical. Alert the Driver to stop before this happens. If necessary, lay the sonde down again and reposition the clamp.

3) **Driller**: Open the borehole cover.
4) **Driver**: Pay out until the system exits parking mode.
   Driller: Guide the sonde into the borehole. Straighten the strain relief once it is in reach. Close the borehole cover once the sonde is below it.

4.4.4 Tripping

Tripping mode is used to traverse the length of the borehole quickly. Tripping mode is also used to break the core. Because the drill will decelerate and stop automatically when leaving tripping mode, the Driver is encouraged to go at the maximum speed until tripping is complete.

Suggested tripping speeds are as follows:

Through Air – Pay in or out at the maximum winch speed: ±2000 rpm (~2 m/s).

Through Fluid, Tripping Down – Pay out at -1000 rpm.
See section *4.4.4.1 Floating the Sonde while Tripping*.

Through Fluid, Tripping Up – Pay in at 1250 rpm.

Note that large, sudden changes in winch velocity can surge the load on the generator and cause brownouts. See section *4.7.6.2 Brownouts*.

4.4.4.1 Floating the Sonde while Tripping

When tripping down in fluid, take care not to float the sonde. This occurs when the sonde reaches terminal velocity in the fluid. Changes to fluid flow around/through the sonde (e.g. by closing the hollow shaft valves) may drastically change the terminal velocity.

If the cable is paying out any faster than the sonde is falling, irreparable cable knots may occur.

If tripping with weight on bit above 400N and the system appears unresponsive to small changes in payout velocity, assume the sonde is floating. Immediately decrease payout velocity to take up slack until weight on bit becomes responsive again.

4.4.4.2 Procedure: Tripping Down

This procedure describes an efficient manner of traversing the borehole, but moving at slower speeds during any portion of tripping is also effective and may be preferred by users new to partially-automated drill systems.

1) Pay out at maximum winch speed while descending through air.
2) If wet drilling, the winch will decrease speed for the fluid transition, per the relevant settings. See appendix *6.4 List of Settings*.
3) After the fluid transition, the winch speed will return to the prior setting or -1000rpm, whichever is slower. Note that pay out speed in fluid is limited to -1250rpm.
4) The winch will automatically decelerate and stop whenever leaving tripping mode, permitting the user to trip at full speed until the system enters cutting mode just above the cutting face.

4.4.5 Cutting and Breaking Core

When cutting core, take care not to float the sonde. This occurs when the sonde is at the bottom of the borehole and is penetrating slower than the cable is paying out.

If a significant quantity of cable is paid out without the sonde able to move down, irreparable cable knots may occur. Due to the low speeds involved with cutting, this takes some time.

If cutting with weight on bit above 400N and the system appears unresponsive to small changes in payout velocity, assume the sonde is floating. Reduce or reverse payout velocity until weight on bit becomes responsive again. If the sonde has lost penetration, see section *4.7.2.2 Poor Penetration*.

4.4.5.1 Cutter and Shoe Selection

The shoes, which mount on the cutters, determine the cutter pitch, i.e. the penetration per revolution of the cutter head, and depth of cut (DOC). Deeper cuts lead to larger chips, which tend to flow more easily into the chip chamber. Deeper cuts also lead to higher stress on the core, which can degrade core quality. The goal is generally to maximize cutter pitch and depth of cut without compromising core quality.

The cutters determine only the sequence and width of cuts that sum to the full width of the kerf. The following cutters are provided with the drill:

Flat Cutters – Cut the full width of the kerf at every cutter tooth.
DOC is one third of the shoe pitch.

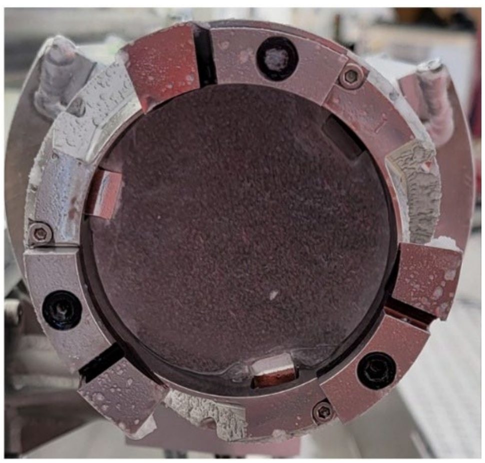


Figure 36. Flat Cutters

Step Cutters – Cut one third the width of the kerf at every cutter tooth.
DOC is equal to the shoe pitch.
Use the recommended step cutter sequence below.

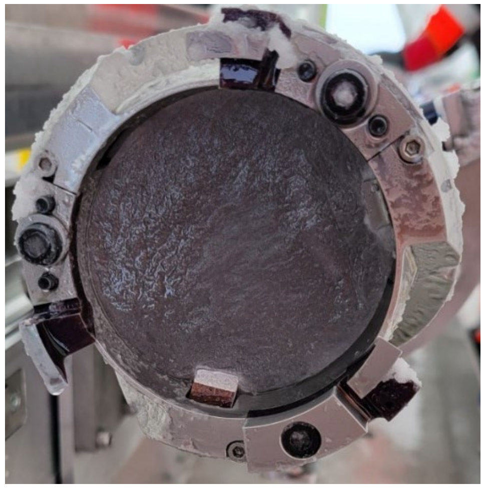


Figure 37. Recommended step cutter sequence. Viewing in the clockwise direction, the outer cutter should be followed by the middle cutter and then the inner cutter. Only one step cutter shoe is needed and should be placed on the inner cutter.

The shoes determine only the maximum cutter pitch. The actual cutter pitch depends on the winch velocity during cutting. Maintaining the cable payout slightly below the shoe pitch may be desirable to relieve the load on the cutter motor periodically: it is normal in this situation for the sonde (anti-torque blades) to stick to the borehole wall a little, cut free, and then slip into the cutting face, fully engaging the cutters and riding on the shoes. This phenomenon is called stick-slip, occurs any time the sonde is moving slowly in the borehole, and can be observed as a saw-tooth pattern in the weight on bit.

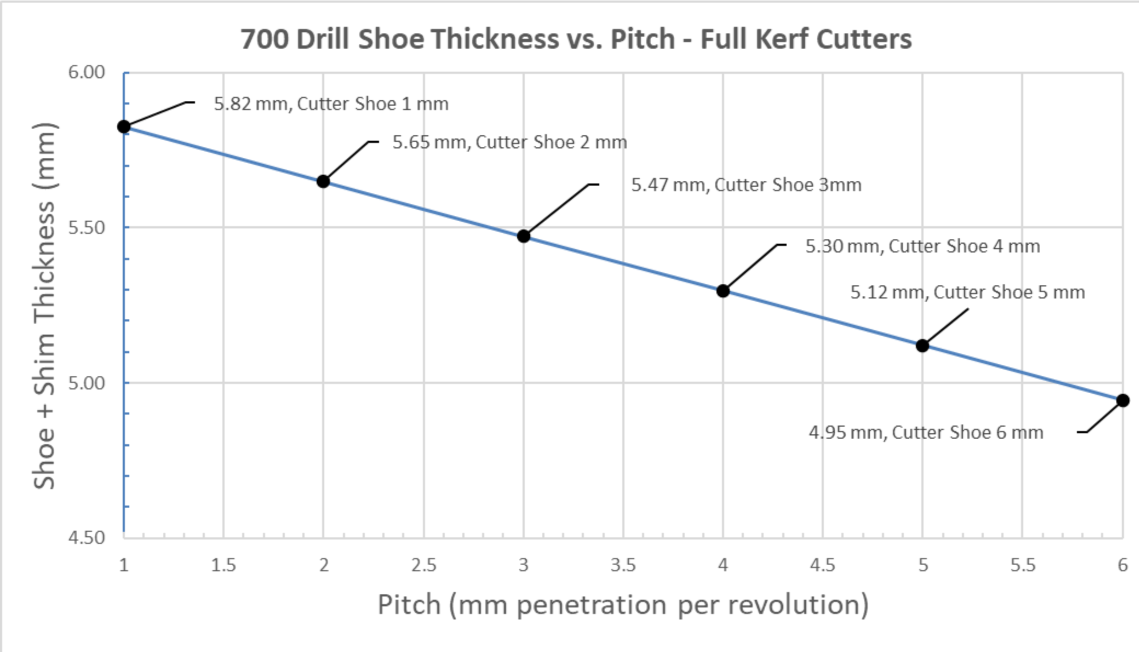
Because the shoes ride the ice shaped by the cutters, different cutters require different shoe geometry to achieve the same pitch. The following shoes are provided with the drill:

1 to 4 mm, Flat—For use with flat cutters.

1 to 3 mm, Step – For use with step cutters.

Nominal cutting parameters are as follows:

Drilling Type	Cutter Config.	Winch Velocity	Drill Velocity
Dry Drilling	3mm shoes Flat cutters 1mm DOC	-7.5 mm/s	150 rpm
Wet Drilling	2mm shoes Step cutters 2mm DOC	-2 mm/s	60 rpm



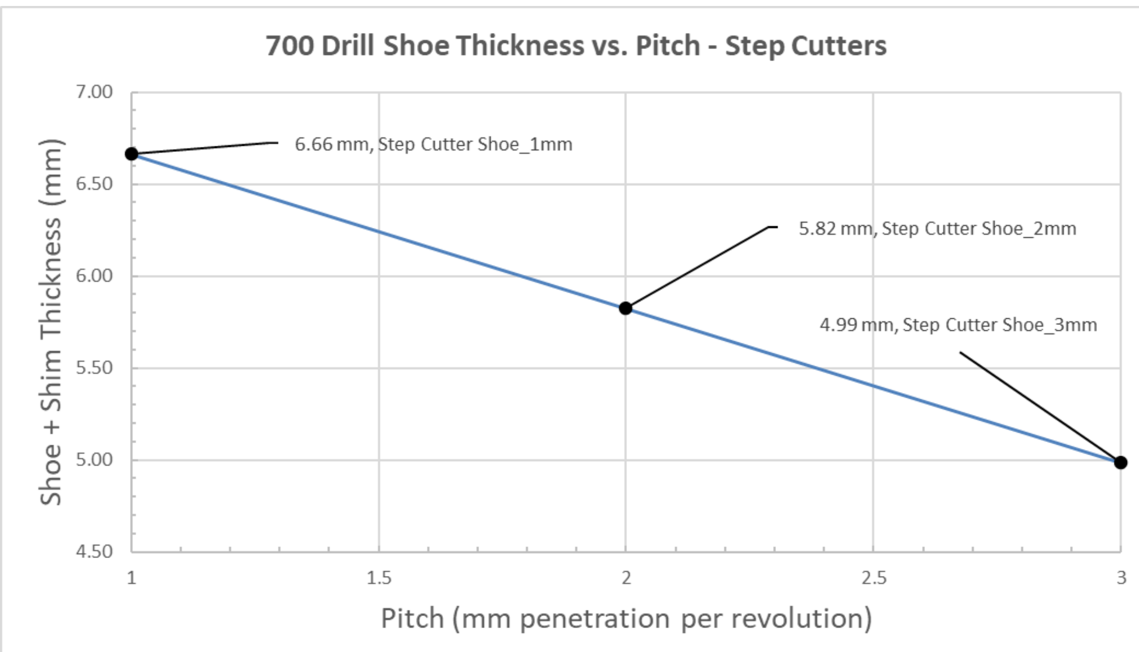


Figure 38. A guide to the relationship between shoe height and pitch for full kerf and step cutters.

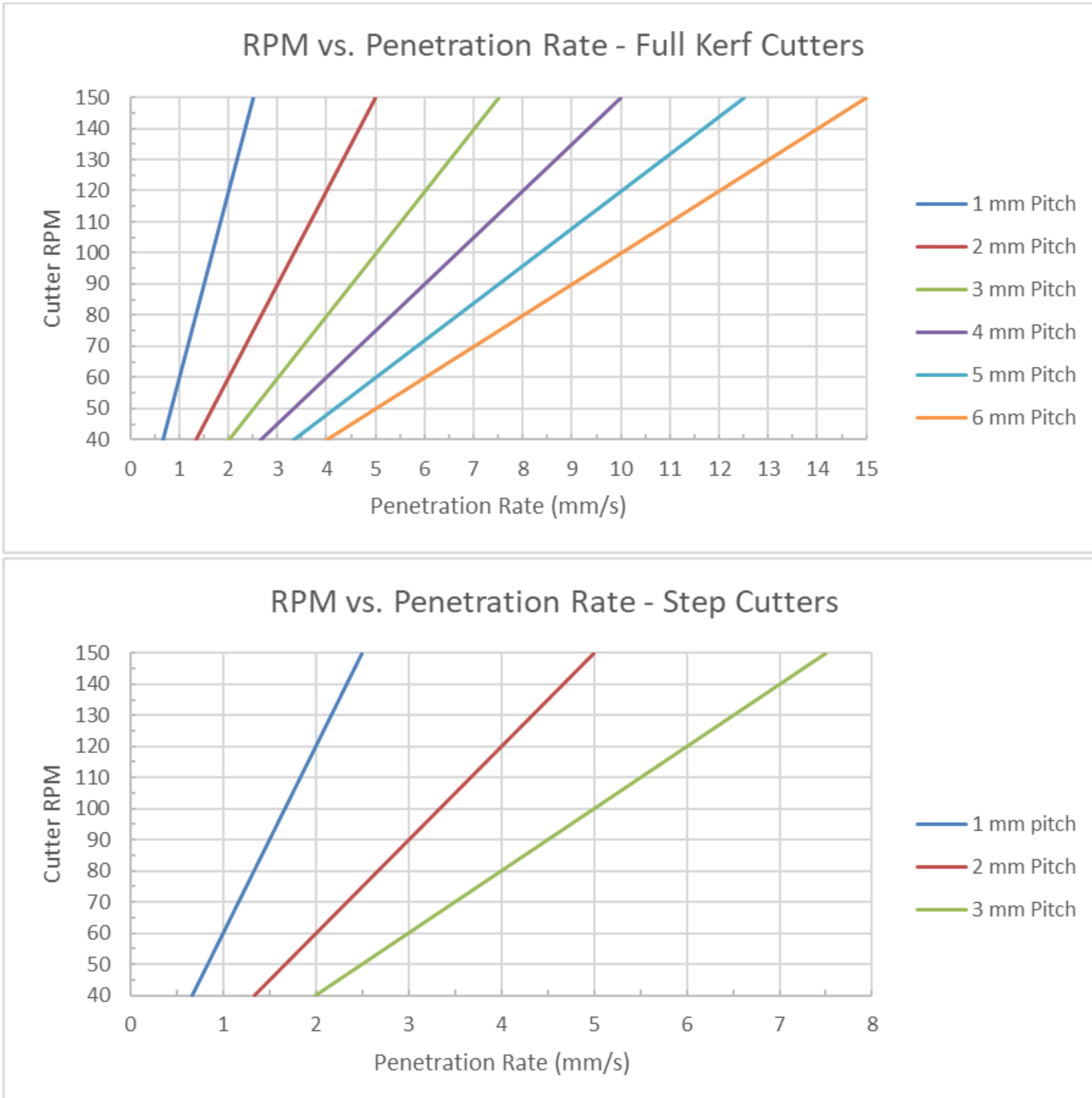


Figure 39. A guide to penetration rates as a function of shoe pitch and drill velocity for full kerf and step cutters.

4.4.5.2 Procedure: Cutting a core

This procedure assumes that the drill has been lowered to within 50 cm above the cutting face and the system is in cutting mode.

A keyboard is recommended to optimize cutting time, as it permits the user to type in a value for winch velocity before the new setpoint is desired and then hit the Enter key at a precise time. For example, this can permit movement at higher speeds to within shorter distances of the cutting face.

1) Set the drill velocity to the desired cutting speed. Enable the DPS and Drill toggles first if necessary.
   a) If dry drilling, default to the highest speed available.

   b) If wet drilling, default to 60 rpm.
2) Take note of the hole depth and plan to enter the cut about 5 cm above the hole bottom.
3) Set the winch velocity to the desired approach speed; default to -50 rpm.
4) Reduce the winch velocity to the desired cutting penetration rate about 5 cm above the hole bottom. Default to the nominal rate for the shoe and cutting speed combination. See *Figure 39* for details.
5) Drill current and weight on bit will rise when the drill has entered the cut. If this is notably above or below the prior hole depth, use the Zero Core Length button to set the correct reference point.
6) Once the drill has entered the cut, consider reducing the winch speed slightly, e.g. by 0.5 rpm. This allows the drill to periodically cut itself free, which appears as a sudden decrease in drill current, and can help reduce motor load associated with a tight chip pack at the cutter head or in the flights.
7) Continue cutting the core until the desired core length is achieved.
   a) Monitor the weight on bit. Reduce winch velocity if WOB is rising, as high WOB may cause excessive borehole inclination.
   b) Monitor the drill current. Excessive drill current may cause overheating in the sonde and/or anti-torque slip. High drill currents may be indicative of other issues, such as a damaged cutter tooth, that can compromise core quality.
   c) Use the Lock Cut Pitch button to keep a constant ratio between winch and cutter velocity, so that modifying one also modifies the other.
8) When the core is cut as desired, stop the winch by setting its velocity to zero, typically by pressing the knob or spacebar with the control selected.
9) Allow the drill to cut itself free. If this is not possible, e.g. due to a stalled drill motor, pay in cable at 1 rpm winch velocity until the weight on bit has decreased to a value under 50N.
10) Enable the Cutting Complete to exit cutting mode.

4.4.5.3 Procedure: Core Break and Tripping Up

This procedure assumes that the system is in cutting mode, the sonde is at the bottom of the hole with an unbroken core in the core barrel, and that there is drilling fluid in the borehole. Adapt the steps as necessary to other scenarios.

Cutting mode is used when approaching the cutting face and cutting the core. Core break is done in tripping mode, except for the initial runs when the sonde is at the surface during cutting. In this case, core break happens in parking mode – the sequence of steps remains the same, though speeds are reduced to those permitted in parking mode.

If core recovery is unsatisfactory, refer to section 3.10.2 Cutter Heads *for alternate core dog configurations.*

1) **Driver**: Enable the Cutting Complete toggle. The system is now in tripping mode and the winch and drill motors have stopped.
2) **Driver**: Enter a winch velocity of 500 rpm. The core is now broken. The core barrel rotates automatically to align core North with the sonde reference.
3) **Driver**: Enter a winch velocity of 1000 rpm.

4) **Driver**: Smoothly increase the winch velocity to 1250 rpm. Maintain this speed until the sonde has exited the fluid. This is not a sharp transition and is typically denoted by the winch power dropping below 4000 W.
   Driller: Connect the vacuum hose to the cable vacuum adapter. Turn the vacuum on.
5) **Driver**: Smoothly increase the winch velocity to 2000 rpm. Maintain this speed until the system enters parking mode.

4.4.6 Fluid Handling

Drilling fluid is added to the borehole to pressurize and lubricate the cutting face, thereby improving core quality and keeping the borehole from closing. At the surface, fluid and/or chip slurry accumulates in the drip pans and in the vacuum chamber. The Driller must periodically wipe down or vacuum out the drip pans, empty the bucket into which the drip pans drain, and empty the vacuum chamber.

If the recovered fluid is free of chips, it may be poured directly into the fluid chiller. Otherwise, it must first be put into the chip melter to melt all the chips. Drilling fluid does not mix with water and can be easily removed from the chip melter with a bucket or via the upper spigot of the chip melter. Water from melted chips is dumped back into the firn using the lower spigot of the chip melter. Drilling fluid from the chip melter must be put into the fluid chiller until its temperature has fallen below freezing.

4.4.6.1 Procedure: Adding Fluid to the Borehole

1) Remove the sonde from the borehole and lay it down. See section *4.4.3.1 Procedure: Laying Down the Sonde*.
2) Lower the entire 100 m layflat hose into the borehole, using leather gloves to control its descent. Ensure the rigid right-angle hose fitting is located over the edge of the borehole so the layflat hose is hanging straight in the borehole.
3) Use the Lutz pump to pump fluid down the borehole. Approximately 2 gallons are required to fill 1 meter of borehole.
4) Update the Fluid Depth setting in the GUI with the new estimated depth. **Failure to do so may result in tripping at high velocity through the fluid transition.**
5) Pull the layflat hose from the borehole and coil it in a figure-8 pattern in its case; this typically requires 2 people.
6) It is recommended to leave the end of the layflat hose hanging out of the case. This prevents it from causing knots by threading through any loops of hose inside the case.

4.4.7 Drill Log

The operators must capture a log of drill runs, either electronically (preferred) or on paper. This is used to take note of different drill hardware configurations, core quality, and drilling operations. It is an invaluable resource for discerning trends across drill runs. A digital template and blank paper drill logs are provided with the system.

The GUI application creates a log of drill run data for future reference, capturing all the graph variables every 200 ms. See section *6.3 List of Graph Variables* for more information.

4.5 Periodic Operations

4.5.1 Anti-Torque Adjustment

A good initial setting for the curve of the anti-torque blades is with X = 0.26" (6.6 mm), as shown in Figure 40. To adjust the curve of the blades, loosen the locking screw on the spanner nut (orange color in Figure 40) with a 5 mm hex. Then turn the spanner nut to increase or decrease the curve of the blades and then tighten the locking screw. Adjust distance X in 0.01" increments. If the anti-torque is slipping, reduce distance X. If the drill is stick slipping or will not penetrate, increase distance X.

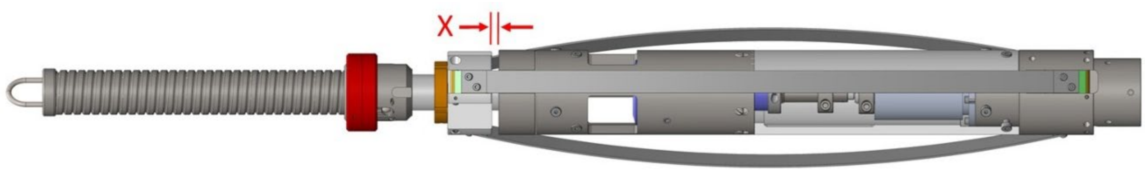


Figure 40. Position of the anti-torque blades is measured by distance "X".

4.5.2 Sharpening Cutters and Core Dogs

Field sharpening cutters and core dogs is a manual process that is completed using Atoma Diamond Plates. Four different grits are supplied, 140, 400, 600, and 1200 grits, along with a plate holder. 140 grit is the coarsest and 1200 grit is the finest.

Figure 41. Atoma Diamond Plates. From left to right, 140-grit, 400-grit, 600-grit, 1200-grit.

Cutters should be changed or resharpened whenever a change is noticed in how the drill is cutting, the cutting edge is dulling, or there is a chip on the cutting edge. The core dogs should also be changed or sharpened if they look dull or are not grabbing the core when using stiff springs. If the cutting edge is only slightly dull, you will likely be able to start with the 400-grit plate. If the cutter or core dog is very dull or there are chips, then you will want to start with the 140-grit plate. Each plate should be used in progression, working from coarse to fine grit and always ending with the 1200-grit plate. The only downside to starting with too fine of a grit is that it will take excessively long to sharpen the cutter. Once the edge has been restored, it should only take 10-20 passes per grit on each face before moving on to the next finer grit. Care must also be taken to keep the face you are working flat on the plate as it is moved back and forth so the cutting edge doesn't get rolled. This takes some practice to get a feel for it.

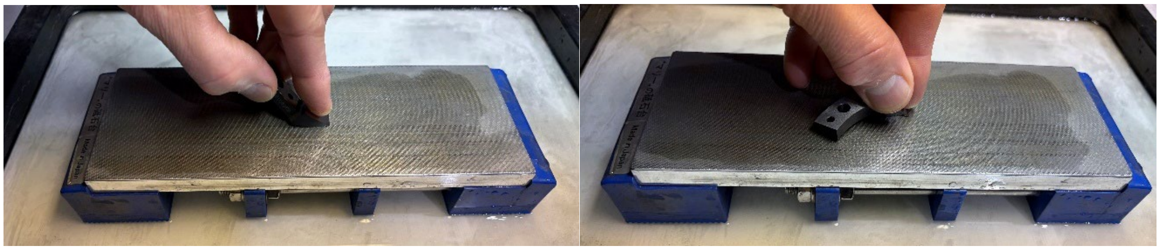


Figure 42. Sharpening the cutter rake face (left) and relief face (right).

4.5.2.1 Procedure: Sharpening Process

1) Place the desired plate in the blue holder.
2) Put water on the plate and spread it over the entire surface.
3) Lay the face you want to sharpen on one end of the plate. Position your hand on the cutter so that you can firmly hold it and keep the face flat on the plate.
4) With light pressure, slide the cutter from one end of the plate to the other and back again. If you feel you are unable to slide the cutter back and forth while keeping it flat on plate, it is ok to go one direction only, lifting the cutter off the plate at the end of the stroke and placing it back at the starting position.
5) Complete about 10 passes and then check the face to see if the cutting edge has been sharpened. If not, do another 10 passes and check again. Add water often to keep the plate wet and to wash away any cuttings. Do not move on to the next finer grit until the cutting edge has been fully sharpened.
6) Wipe the cutter off and switch to the next finer grit
7) Repeat steps 1 – 5 with each grit, ending with the 1200 grit plate.

Once done with the plates, wash them off along with the holder and allow them to dry before packing them up. Lightly oil the cutters to prevent them from rusting.

4.5.3 Chip Bailing

Chips that accumulate in the borehole may impede cutter penetration. A chip bailer is provided with the system to address this by passing a filter through the fluid in the borehole. It is mounted to the motor section in place of the outer barrel, hollow shaft, and core barrel.

All ice chips will fall to the bottom of the borehole when using an under-densified fluid, such as pure Isopar K. Neutral fluids, e.g. densified Isopar K or Estisol 140, nearer the density of ice may cause suspended chips to group together at various heights within the fluid column, differentiated by slight differences in ice density. Therefore, if using a neutral fluid, it may not always be necessary to bail the entire fluid column.

4.5.3.1 Procedure: Chip Bailer Assembly

The chip bailer mounts to the sonde in place of the barrel assembly, so the sonde must first be removed before installing the chip bailer. The chip bailer can be configured to bail chips while descending (down bailing) or ascending (up bailing) in the borehole. Chip bailing while down bailing is less risky since the tool collects cuttings as it is lowered. However, this can be slower since the descent speed will decrease as the bailer fills with chips. Up bailing can be potentially faster because the winch is used to pull the bailer through the fluid rather than gravity. However, if the bailing pass is started too deep, it is possible for chips to build up above the bailer and cause it to bind in the borehole. *Drawing 83890425_Chip Bailer Assembly* shows how to configure the bailer for both down and up bailing. Once the bailer has been configured for the desired bailing direction, mount it to the end of the motor section with the following steps.

1) Remove the valve assembly from the end of the bailer by threading in the M6 locking screw and then turning and pulling the bailer assembly.
2) Push the central tube assembly out the top of the bailer coupler to expose the first few inches of the central tube coupler.
3) Connect the central tube coupler to the drive output on the motor section by engaging the three quick lock pins.
4) Slide the outer tube onto the motor section and align the six attachment holes on the coupler with the holes in the motor section; install the six attachment pins, the same headless shoulder screws used to mount the outer tube.
5) Reinstall the valve assembly and back out the M6 locking screw.

4.5.3.2 Procedure: Bailing Chips from the Borehole – Down Bailing

1) **Driver**: Lower the bailer into the borehole until it reaches the fluid level.
   Driller: Guide the bailer into the borehole.
2) **Driver**: Turn on the drill motor, rotating in REVERSE at about 5 rpm. This closes the central tube valve, so all fluid is directed into the filter and rotates the internal brushes to wipe the screen and keep it from packing with chips right away.
3) **Driver**: Continue lowering the drill at about 0.3 m/s while keeping an eye on the Weight on Bit (WOB). As the bailer fills with chips, the WOB will increase so the winch will have to be progressively slowed to keep from overfeeding and floating the bailer. Once the bailer seems full or the descent speed becomes slower than you want to go, end the run.
4) **Driver**: Turn off the cutter motor
5) **Driver**: Return the bailer to the surface and park at home.
6) **Driller**: Close the hole cover, place a bucket under the bailer, and remove the bottom valve assembly by first turning in the M6 locking screw.
7) **Driver:** Rotate the drill motor FORWARD to empty the chips into the bucket.
8) **Driller:** Gently tap on the outside of the bailer tube as needed to help loosen the chips and get them to drop out.
9) **Driller:** Reinstall the valve assembly and back out the M6 locking screw.
10) Repeat steps 1 to 9 until the cuttings have been removed from the borehole. The start of each successive bailing run should be able to begin where the previous one ended.

4.5.3.3 Procedure: Bailing Chips from the Borehole – Up Bailing

1) **Driver:** Before lowering the bailer into the borehole, rotate the drill motor in the FORWARD direction to open the central tube valve.

2) **Driver**: Lower the bailer into the borehole and trip down to the desired starting depth.
   Driller: Guide the bailer into the borehole.
3) **Driver**: Turn on the drill motor, rotating in REVERSE at about 5 rpm. This will close the central tube valve and force all fluid into the filter area and rotate the internal brushes to wipe the screen and keep it from packing with chips right away.
4) **Driver**: Raise the drill at about 0.3 m/s while keeping an eye on the cable tension. As the bailer fills, the cable tension will increase. Once the bailer seems full, rotate the drill motor in the FORWARD direction one rotation to open the central tube valve. This will allow fluid to bypass the filter through the central tube.
5) **Driver**: Return the bailer to the surface and park at home.
6) **Driller**: Close the hole cover, place a bucket under the bailer, and remove the bottom valve assembly by first turning in the M6 locking screw.
6) **Driver:** Rotate the drill motor FORWARD to empty the chips into the bucket.
7) **Driller:** Gently tap on the outside of the bailer tube as needed to help loosen the chips and get them to drop out.
8) **Driller:** Reinstall the valve assembly and back out the M6 locking screw.
9) Repeat steps 1 to 8 until the cuttings have been removed from the borehole.

4.5.4 Fluid Bailing

A fluid bailer is provided with the system to remove the fluid from the borehole. It connects to the drill cable and replaces the entire sonde. It has a volume of ~5 gallons.

4.5.4.1 Fluid Bailer Assembly

The fluid bailer ships in two pieces and must be assembled before use by mounting the two tube sections together. Reference drawing *83890251_Fluid Bailer Assembly* for details. The fluid bailer connects directly to the winch cable termination, so the sonde must first be removed from the cable to mount the fluid bailer. Attach the fluid bailer to the winch cable by threading it onto the cablehead and then secure it from coming lose with the locking collar. Verify the check valve at the lower end of the tube moves freely.

4.5.4.2 Procedure: Bailing Fluid from the Borehole

1) **Driller**: Place an empty barrel near the borehole. Insert the Lutz pump and a length of 4x4 that reaches up to ~8” below the lip of the barrel.
2) **Driver**: Lower the bailer into the borehole until it is a few meters below the fluid surface.
   Driller: Guide the bailer into the borehole.
3) **Driver**: Raise the bailer out of the borehole, until it is at home.
4) **Driller**: Pull the bailer over the barrel.
5) **Driver**: Lower the bailer until the valve is pushed open by the 4x4.
   Driller: Hold the bailer until it is empty.
6) Repeat steps 2 to 5 until the borehole is empty.
7) When the barrel gets full, transfer the fluid into an empty drum the fluid came in using the Lutz pump.

8) Note that the last run may contain a dense chip slurry that does not flow through the open valve. To empty, disassemble the valve from the bailer over a bucket. Use caution, and keep your mouth closed, when doing so, as the fluid in the bailer will all fall out suddenly.

4.5.5 Freezing Glycol Pellets

One option for trying to free a stuck drill is to introduce frozen pellets made from a mixture of ethylene glycol and water to the borehole. The frozen pellets will sink through the fluid and down to the drill. As the pellets warm and melt, the glycol-water mixture will flow around the drill and melt the cuttings sticking the drill to free it. As the liquid glycol-water mixture melts the ice, it will dilute to a point where it will refreeze again. Therefore, the ratio of ethylene glycol and water is important and must be adjusted based on the borehole temperature at the drill depth to ensure it will be liquid at the borehole temperature and yet as concentrated as possible.

Using pure ethylene glycol and distilled or DI water is also important to ensure the mixture will freeze and melt at the correct temperatures. Figure 43 shows the characteristics of ethylene glycol-water mixtures at low temperatures. For example, at an ice temperature of -35°C, 80% to 85% glycol mixture would be ideal and remain liquid until about 50% dilution, where it will begin to refreeze again.

The freezer included with the drill system goes down to -80°C, which is cold enough to freeze an ethylene glycol-water mixture of 80% glycol or higher. Using the supplied silicone ice cube trays, make 3 to 4 liters of frozen pellets, which will likely be enough to free a stuck drill. See section *4.7.4 Stuck Drill* for the procedure of using glycol pellets to free a stuck drill.

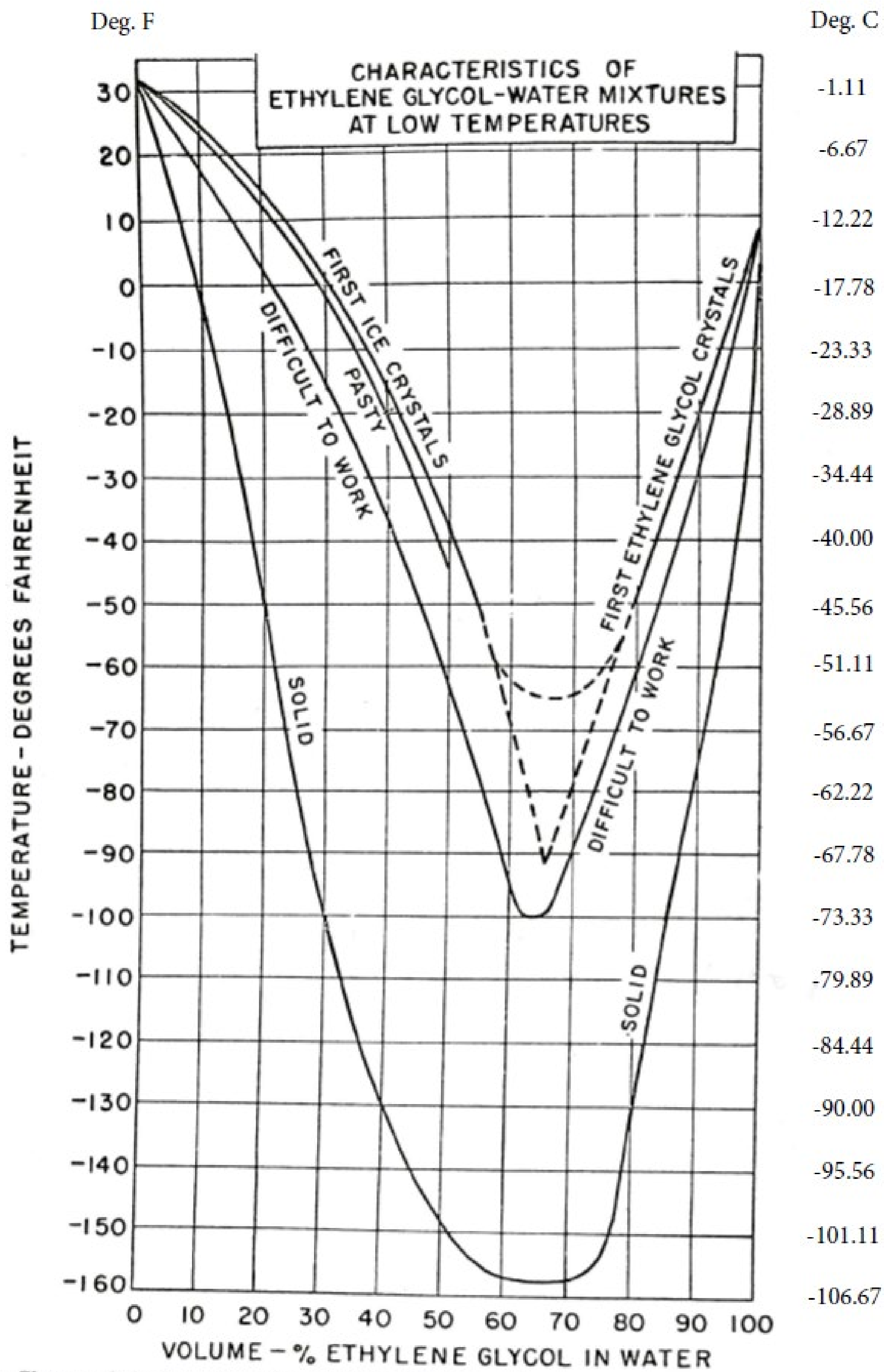


Figure 1. Characteristics of ethylene glycol-water mixtures at low temperatures.

Figure 43. Characteristics of ethylene glycol-water mixtures at low temperatures.

4.6 Weekly Maintenance

ITEM	ACTION
WINCH & TOWER	
Structural Components	Inspect for damage and wear. Check stability and leveling.
Fasteners	Check that all fasteners are tightened and pins are in place.
Crown Sheave	Inspect for ice build up in cable groove. Dribble ethanol on cable to clear build up as necessary.
Gearbox	Inspect for oil leaks.
CONTROL BOX & CONSOLE	
E-Stop Buttons	Verify all buttons stop operation.
Sonde Hard Stop	Verify actuation stops operation.
Power and Control Cables	Inspect for damage. Check that connections are tightened.
SONDE	
Structural Components	Inspect for damage and wear.
Fasteners	Check that all fasteners are tightened and pins are in place.
Drill Motor Transmission	Inspect for leaks.
Cable Bearing	Inspect for ice buildup.
FLUID & CHIP HANDLING	
Chip Melter	Inspect for damage and leaks. Verify thermostat setting.
Sock Filters	Replace if necessary.
Fluid Cooler	Inspect for leaks. Clear pump inlet filter. Determine if bottom of barrel is icing up. Verify fan spins freely.
Layflat Hose	Check that couplings are tight. Check that anchor is secure.
Interconnect Hoses	Inspect for damage and leaks.
CORE PROCESSING	
Structural Components	Inspect for damage and wear.
Fasteners	Check that all fasteners are tightened and pins are in place.
TENT	
Frame & Fabric	Inspect for damage and wear.
Ropes & Fabric	Check for proper tension.
Anchors	Check that stakes and anchors are secure.
GENERATORS	
General Condition	Inspect for damage and leaks. Check that covers are in place and all fasteners are tightened.
Maintenance Schedule	Perform maintenance as needed per manufacturer's maintenance schedule.
Power Cables	Inspect for damage. Check that connections are tightened.
DRILL SITE	
Toolboxes	Organize loose tools into their toolboxes.
Trip Hazards	Move cables, hoses, cases out of high traffic areas.
Slip Hazards	Scuff up areas of packed, slick snow.
Snow Drifts	Remove any significant snow drifting, especially around tent, generators, and chip melter/fluid storage area.

4.7 Troubleshooting

A wide variety of problems may arise while drilling. If the guidance provided here is insufficient to address an issue with the drill system or its performance, please reach out to IDP personnel by any means of communication available. See section *2.2 IDP Contact Information*.

4.7.1 Core Quality

Poor core quality may take different forms with different causes.

4.7.1.1 Axial Fractures

Spalling and axial fracturing of cores typically occur at core break, or in rare cases during tripping if the winch is stopped and started suddenly. Occasionally, a loose piece of core may fall out of the core barrel, causing issues with penetration on the next run (see section *4.7.2.3 Obstructed Cutting Face*).

To address axial fractures: Add drilling fluid to the borehole until the fluid level is around 100 m below the surface. The additional fluid increases the pressure holding the core together during cutting and core break. Note that raising the fluid level above this yields limited improvement and risks suffering increased fluid loss into the firn.

4.7.1.2 Radial Fractures

The stress imparted during cutting may cause the core to develop radial cracks. These cracks may range in depth from sub-mm to the full diameter of the core. In extreme cases, the entire core is reduced to a stack of wafers or pile of rubble.

To address radial fractures: Reduce the depth of cut as described in section *4.4.5 Cutting and Breaking Core* to reduce the force exerted on the ice during cutting, which reduces radial fractures, and creates finer chips. The fine chips associated with shallow DOC may cause issues with chip transport and/or poor penetration; see section *4.7.2 Slow Cutting Speed* for more information.

Note that severe spalls created during core break may sometimes go across the diameter of the core, appearing as radial fractures. Regardless of origin, adding drilling fluid to the borehole may help address radial fractures as well as axial fractures. See section *4.7.1.1 Axial Fractures* for more information.

4.7.1.3 Short Cores

Drill runs may end before cutting a complete core, typically due to poor chip transport and/or poor penetration. In some cases, the chip chamber or core barrel fills with chips before a complete core is cut; both phenomena are associated with a borehole that has been polluted by chips.

See sections *4.7.2.1 Poor Chip Transport* and *4.7.2.2 Poor Penetration* for more information.

4.7.2 Slow Cutting Speed

A variety of mechanisms may slow cutting progress by either causing the drill motor to stall or preventing any further penetration of the cutter into the ice. Not all of these are well-understood, and further experimentation may yield valuable results.

4.7.2.1 Poor Chip Transport

Ice chips that are not properly transported away from the cutting face can cause the drill motor current to rise until the motor stalls. This is typically associated with very fine chips, which tend to pack and sinter together in small gaps and spaces that larger chips pass over. Fine chips may become packed and sintered together in the flights and/or lower portion of the chip chamber, which reduces fluid flow through the sonde and further impedes transport. This can cause drill current to rise very sharply, similarly to the way it does at the end of a normal run when the chip chamber is full. If chip transport issues are suspected, take care when servicing the sonde to observe where chips are packed tightest, probing with a finger or small tool to determine hardness.

In some cases, fine chips can impede penetration by sintering inside the cutter head before transport up the flights has begun. This is typically associated with a borehole that has been polluted by fine loose chips, such as is the case after a challenging coring run that recovers no chips.

To address poor chip transport: Increase the depth of cut as described in section *4.4.5 Cutting and Breaking Core* to create larger chips, which have less surface area to sinter and don't fit in small gaps.

If chips are being packed in the flights or lower portion of the chip chamber, without filling the chip chamber, consider experimenting with the position/presence of the flapper valve and booster on the hollow shaft. Consult with IDP personnel for guidance. See section *2.2 IDP Contact Information* for more information.

If the borehole has been polluted, a single good run will typically capture enough chips to resolve the problem. If necessary, chips may be removed from the fluid column with the chip bailer. See section *4.5.3 Chip Bailing* for more information.

4.7.2.2 Poor Penetration

Poor penetration occurs when the sonde does not effectively cut into the ice despite a high weight on bit. This may simply be due to wear on the cutters. It may also be caused by any upward force on the sonde that relieves the force applied to the cutting face. This may be caused by an over-tightened anti-torque, accumulation of sintered ice chips between the core barrel and the core, a restricted fluid flow out of the core barrel, or some combination of these.

Some correlation seems to exist between the sonde being held stationary while the drill motor is turning and the creation of a ring or patch of sintered chips between the core and the core barrel, but the mechanism is poorly understood.

To address poor penetration: Replace dull cutters with a sharp set. Loosen the anti-torque blades, as described in section *4.5.1 Anti-Torque Adjustment*. Increase the depth of cut as described in section *4.4.5 Cutting and Breaking Core* to create larger chips, which have less surface area to sinter and don't fit in small gaps. Inspect and clean the hollow shaft to ensure unimpeded fluid flow out of the core barrel.

4.7.2.3 Obstructed Cutting Face

Large pieces of ice, such as a loose piece of core, can become wedged in the cutter head and prevent the cutters from contacting the cutting face. See section *4.7.1 Core Quality* for more information on how to avoid leaving such large pieces of ice in the borehole.

To address an obstructed cutting face: Ram the cutting face to break apart the wedged ice. If ramming fails to break apart the ice, it may wedge firmly enough into the cutter head that it can be removed from the borehole by raising the sonde.

1) Enable the Cutting Complete toggle to go into tripping mode.
2) Use the mode toggle switch to select Ramming mode.
3) Pay in a meter or two to provide a runway for the drill to accelerate to ramming speed.
4) Start the drill motor as normal for cutting.
5) Pay out at -1000 rpm (~1m/s) until the drill stops a little beyond the nominal hole depth.
6) If the drill motor current has risen to a level typically associated with engaged cutters, disable the Cutting Complete toggle to return to cutting mode.
   a) If the drill motor current remains low, repeat steps 3 and 5 as necessary.
   b) If after 5 ramming attempts the cutter is not engaged, return the drill to the surface for inspection.
7) Pay in slowly to return the high WOB to a normal level for cutting.
8) Continue cutting as normal.

4.7.3 Anti-Torque Slip

The anti-torque slip alarm comes on when the gyroscope on the sonde detects that the anti-torque has slipped on the borehole wall.

To address anti-torque slip: Tighten the anti-torque blades, as described in section *4.5.1 Anti-Torque Adjustment*.

4.7.4 Stuck Drill

If any part of the sonde, usually the cutter head, becomes frozen into the borehole, the winch may not be able to apply enough force to pull it out. Use the mode toggle switch to engage Boost mode while tripping to apply the maximum permissible winch current. Consult with IDP personnel for guidance on how to recover the sonde. A typical recovery plan has many fallback options, and care must be taken to ensure that initial recovery techniques do not compromise the efficacy of more desperate measures. See section *2.2 IDP Contact Information*.

To address a stuck drill: Add frozen glycol pellets to the borehole to melt ice around the drill.

1) Prepare about 4 l of frozen glycol pellets, as described in section *4.5.5 Freezing Glycol Pellets*.
2) Apply about 5000 N of cable tension.
3) Add all the frozen glycol at once.
4) Check the drill every 2 to 3 hours. The cable tension should decrease to about 1000 N when the drill is free.
5) If the drill is still stuck 18 hours after the addition of the glycol, take additional measures in consultation with IDP personnel.
   a) It is recommended that the glycol be added in the morning to avoid the necessity of checking the drill through the night.

4.7.5 Severed Cable

Regardless of where the drill cable is severed, the sonde may still be recovered. If it has been severed at the sonde, the sonde may be lifted via the recovery loop at the top of the sonde. If it has been severed above the sonde, the sonde may be lifted by the loose end of the cable.

To address a severed cable: Mount the sonde recovery tool to the end of the severed cable. Lower it down the hole until the teeth snag the loose cable or the recovery loop on the sonde. Pay in to raise the sonde. If necessary, use the slide hammer on the recovery tool to hammer the sonde free. If the slide hammer is insufficient, see section *4.7.4 Stuck Drill* for more information.

4.7.6 Poor Generator Performance

The generator uses high altitude carburetor jets sized for system operation at high altitude but may still struggle to perform in extreme polar conditions. Blowing snow impedes air flow into the engine, significantly reducing available power. Ice and snow accumulation may cause control mechanisms in the generator to misbehave. If one generator is struggling to perform, change over to the other. Consider erecting a windscreen around the generator and keep it free of drifting snow.

See generator manual listed in section *5.3 References* for more information.

4.7.6.1 Ground Fault Circuit Interrupter (GFCI)

The generator does not provide GFCI protection on the 208 V connection.

The only GFCIs in the system are on the 120 V outlets on the generator and SPIDER, and on the chip melter outlet in the control box.

4.7.6.2 Brownouts

Large, sudden changes in winch velocity can surge the load on the generator and cause brownouts. This depends on the operating conditions of the generator and the load applied by the winch, which is typically greatest when increasing winch velocity after exiting the fluid while tripping up. To limit the load on the generator, increase winch velocity gradually, especially at speeds above 1000 rpm.

4.7.7 Chip Melter GFCI

The control box includes a GFCI on the power going to the chip melter. This may be tripped by events that generate significant electrical noise within the control box, such as triggering an E-Stop, which suddenly removes power from the power circuitry of the winch motor drive. When tripped, a power fault exception will occur. To reset it, open the small hatch on the upper left side of the control box and reset the GFCI switch by moving it to the ON (up) position. Close and latch the door when done resetting the switch to prevent blowing snow or drilling fluid from entering the control box.

4.7.8 Software Bugs

IDP personnel are available to respond to software issues with remote technical support; see section *2.2 IDP Contact Information*. Technical support will be more successful if encountered issues are documented thoroughly. Use the GUI screenshot function by pressing the camera button in the upper right corner and take concurrent notes.

Sometimes unexpected software behavior is due to unusual circumstances. Check the GUI exceptions and diagnostics panes for possible causes.

Generally, resetting software is an effective strategy for recovering from a bug. This may be done with a “soft” reset (hardware remains powered) or with a “hard” reset (power is cycled). When attempting to recover from a bug, execute applicable subsystem resets in order of increasing impact.

GUI features associated with subsystem resets are listed below in order of increasing impact:

Description	Reset Type	Scope
Power Control > Winch (Cycle toggle)	Soft	Winch Drive
Diagnostics > Reset Winch Drive	Soft	Winch Drive Faults
Diagnostics > Reset Drill Drive	Soft	Drill Drive Faults
Power Control > DPS (Cycle toggle)	Soft (DPS) Hard (Drill Drive)	DPS and Drill Drive
Power Control > SPS (Cycle toggle)	Soft (SPS) Hard (Sonde)	SPS and Sonde
Power Control > Drill (Cycle toggle)	Soft	Drill Drive
Settings > Pg 4 > [Module] Enable (Cycle toggle)	Soft	Selected module
Diagnostics > Soft Reset Central	Soft (Central) Hard (Sonde)	Central Controller
Diagnostics > Soft Reset Sonde	Soft	Sonde
Cycle system power. See section *4.4.2 System Start and Stop Procedures*.	Hard	Entire system

5 About This Manual

5.1 Purpose

This document describes the operations and maintenance of the 700 Drill system.

5.2 Scope

This document applies to the operations and maintenance of the 700 Drill system including all major field-deployable sub-systems.

5.3 References

- 1008-0014: SSEC Project Safety Plan
- 8501-0017: IDP Deployment Hazards Awareness Training
- 8389-0002: 700 Drill Science Requirements
- 8389-0003: 700 Drill Engineering Requirements
- 8389-0004: 700 Drill Failure Mode and Effects Analysis – Table
- 8389-0005: 700 Drill Failure Mode and Effects Analysis – Summary
- 8431-0002: Mast Anchored, Suspended and Tensioned Tent – Assembly Manual
- Generator Manuals:
    - Located in *IDP - Documents\Ice Drill Equipment\700 Drill\Design\Prime Power\Generator*
        - Winco WL12000HE-04-A Engine Owner's Manual
        - Winco WL12000HE-04-A Engine Parts List
        - Winco WL12000HE-04-A Engine Service Manual
        - Winco WL12000HE-04-A Generator Manual
        - Winco WL12000HE-04-A Genset Manual
        - Winco Load Balancing Whitepaper

5.4 Responsibilities

IDP Engineering is responsible for the generation and maintenance of this document.

SSEC QAS is responsible for ensuring that this document is created, reviewed, approved, maintained and changed per applicable SSEC processes.

Project personnel are responsible for understanding this document.

5.5 Records

None.

6 Appendices

6.1 List Of Documents on USB Dongle

- Portable development environment, including:
  - Source code, compilers, and programming/deployment dependencies for GUI, console controller, central controller, and sonde controller
  - Installers for all configuration software
- Mechanical drawing package.
- Electrical drawing package.
- Datasheets for nearly all electrical components.

6.2 List of Graph Variables

- Borehole Pressure
- Borehole Temperature
- Cable Current
- Cable Tension
- Cable Velocity
- Cable Voltage
- Cutter Position
- DPS Output Current
- DPS Output Voltage
- DPS Temperature
- Drill Angle
- Drill Brake Temperature
- Drill Current
- Drill Drive Temperature
- Drill Gearbox Temperature
- Drill Motor Temperature
- Drill Velocity
- Drill Voltage
- Heater Temperature
- Nav Temperature
- Payout
- Sonde Axial Rotation
- Sonde Bearing
- Sonde Heading
- Sonde Inclination
- Sonde Internal Pressure
- SPS Current
- SPS Voltage
- Tent Temperature

- Weight On Bit
- Winch Current
- Winch Power
- Winch Torque
- Winch Velocity
- Winch Voltage
- Tower Velocity
- Tower Current
- Tower Power
- Tower Torque
- Tower Voltage
- Drill Velocity Setting
- Winch Velocity Setting

6.3 List of Settings

- Drill Run Id
- SPS Voltage Setting
- SPS Current Setting
- Coordinates
- Cutter Home Position
- Initial Payout
- Hole Depth
- Cutting Transition Offset
- Tripping Transition Depth
- Fluid Depth
- Fluid Transition Ramp
- Fluid Transition Winch Speed
- Fluid Transition Offset
- Fluid Density
- Sonde Length
- Sonde Mass
- Sonde Volume Per Meter
- Winch Velocity Limits
- Winch Current Limits
- Fluid Sensing Integrated WOB Delta Threshold
- Fluid Sensing Winch Velocity Error Limit
- Core Break Cable Tension Delta
- Fluid Sensing Integrated WOB Delta Time Constant
- Fluid Sensing Winch Velocity Error Time Constant
- Core Break Detection Window
- Fluid Sensing WOB Baseline Time Constant
- Enable Supervisor

- Calibrate Sonde Orientation
- Drill Angle Setting
- Drill Velocity Setting
- Controller Code Module Verbosity and Reset

6.4 Pre-Ship Maintenance Checklist

The following items should be completed prior to each shipment.

ITEM	ACTION
WINCH & TOWER	
Winch Frame & Base	Inspect components for damage.
Fasteners	Inspect for missing hardware and check for tightness. Re-torque hardware with torque specs as necessary.
Tower	Inspect for damage. Ensure tower sections fit together, fit the winch base, and fit the crown sheave. Confirm there is an adequate quantity of truss connectors, pins, and cotter pins.
Crown Sheave	Inspect for damage. Check that sheave spins freely. Check that sonde hard stop moves freely.
Encoder	Verify proper operation and calibration.
Load Pin	Verify proper operation and calibration.
Roller Guide	Inspect for damage. Verify operation of sonde at home switch.
Cable Keeper	Inspect for damage. Set position to clamp cable on winch. Verify roller rotates smoothly.
Hole Cover	Inspect for damage. Verify switch actuation when opened.
Winch Cable	Inspect cable and termination for damage. Check cable conductor continuity and resistance thru slip ring.
Winch Motor	Verify motor rotates in both directions at various speeds. Verify brake engages when power is lost. Check tightening torques of screw connections between gearbox and motor.
Gearbox	Inspect for oil leaks. Verify operation is smooth and quiet. Check shaft seal rings for external damage and leaks every 6 months/3000 hours. Check tightening torques of screw connections between gearbox and spool/winch frame.
CONTROL BOX & CONSOLE	
Internal Connections	Check that all wire terminations are tight.
Displays, Buttons, and Lights	Inspect for damage. Verify function.
Interconnect Cables	Inspect for damage. Check strain reliefs are tight.
DRILL MOTOR & ANTI-TORQUE SECTIONS	
Drill Motor	Verify rotation in both directions at various speeds.
Transmission	Inspect for leaks. If found, replace seals and check fluid level. Verify operation is smooth and quiet.
Core Barrel Quick Locks	Inspect for damage. Verify function.
Anti-Torque	Inspect for damage. Verify function.
Anti-Torque Blades	Inspect and sharpen as needed.
Fasteners	Inspect for missing hardware and check for tightness.
CORE BARRELS & CUTTER HEADS	

Core Barrels	Inspect for damage. Check fit with outer barrel, motor sections, and cutter heads. Verify flight screws are tight.
Outer Barrels	Inspect for damage. Check fit with motor sections.
Cutter Heads	Inspect for damage. Check fit with mating parts.
Cutters	Inspect for sharpness. Polish if necessary. Ensure proper quantity & types are included for the project.
Shoes	Ensure proper quantity & pitches are included for the project.
Core Dogs	Inspect for sharpness. Ensure proper quantity & lengths are included for the project.
Core Dog Springs	Ensure proper quantities are included for the project.
Collets	Inspect for damage. Check fit with collet cutter head.
Fasteners	Ensure small parts kit has adequate spares. Restock if necessary.
FLUID & CHIP HANDLING	
Chip melter	Inspect for damage. Check for leaks. Verify thermostat setting.
Chip bailer	Inspect for damage. Fit check the assembly.
Fluid bailer	Inspect for damage. Fit check the assembly.
Vacuum	Inspect for damage. Inspect hose. Verify operation.
Fluid cooler	Inspect for damage. Check for leaks. Verify pump and fan operation.
Layflat Hose	Inspect for damage. Ensure proper length is included for the project.
Miscellaneous Equipment	Check that adequate quantities of buckets, scoops, squeegies, filters, and hoses are included.
CORE PROCESSING	
Drill Clamp	Inspect for damage. Verify clamp and release function.
Linear Rails	Inspect for damage. Verify slides move smoothly.
TENT	
Tent Frame & Foot Plates	Inspect for damage.
Ropes	Ensure proper quantity and lengths are provided.
Stakes	Ensure proper quantity and types are provided for the project site conditions.
Progress Capture Pulleys	Inspect for damage. Verify release mechanism operation.
GENERATORS	
General Condition	Inspect for damage and leaks. Check that covers are in place and all fasteners are tightened.
Fuel Jets	Install proper jets for altitude at the field site.
Engine Oil	Change every 6 months/100 hours.
Engine Oil Filter	Replace every 200 hours.
Air Filter	Clean every 6 months/100 hours. Replace every 2 years/500 hours.
Spark Plugs	Check & adjust every 6 months/100 hours. Replace every year/300 hours.
Idle Speed	Check & adjust every year/300 hours.
Valve Clearance	Check & adjust every year/300 hours.
Combustion Chamber	Clean after every 1000 hours.
Fuel Filter	Replace every year/300 hours.
Fuel Tube	Check every 2 years
Operation	Verify engine runs and generator produces voltage.

TOOLS & SPARE PARTS	
Fishing Tools	Inspect for damage and sharpness. Check that all fasteners are tightened.
Toolboxes	Inspect contents for damage. Restock as necessary.
Geoblock Flooring	Inspect for damage.
Tables & Stools	Inspect for damage.
Spare Electrical Components	Ensure spares are included.
Spare Mechanical Components	Ensure spares are included.
SIP Equipment	Check that required equipment has been requested in the SIP.