Foro 400 DRILL

Operations and Maintenance Manual

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U.S. Ice Drilling Program
University of Wisconsin-Madison Space Science & Engineering Center

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1.0 PURPOSE

This manual outlines the proper assembly and operation of the Foro 400 Drill System, including integration with the MAST tent.

2.0 SCOPE

This document applies to all personnel working with the Foro 400 Drill system.

3.0 REFERENCES

- 1008-0014 SSEC Safety Plan
- 83150152 Slide Hammer Assembly
- LCI-90i Operations Manual
- 8315-0011 Foro 400 LCI-90i Quick Setup Guide
- 8431-0002 Mast Anchored, Suspended and Tensioned (MAST) Tent assembly manual

4.0 DEFINITIONS

- IDP – Ice Drilling Program
- PPE – Personal Protective Equipment
- QAS – Quality Assurance and Safety group
- SSEC – University of Wisconsin-Space Science & Engineering Center

5.0 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.

6.0 RECORDS

- Pre-season preventive maintenance checks.
- Weekly preventive maintenance checks.
- Drill logs.

7.0 SAFETY NOTICE

The SSEC Project Safety Plan, 1008-0014, describes in detail the processes used to define, evaluate, mitigate, report, and communicate potential and real safety concerns for equipment and field projects. This section highlights key safety concerns for the Foro 400 Drill system and is not meant to replace the SSEC Project Safety Plan. Only trained personnel should operate the Foro 400 Drill. All drillers or those operating or assisting with operations of the Foro 400 Drill must read and understand the following safety precautions prior to operating this device.

Personal Protective Equipment (PPE)

- PPE – Workers shall wear appropriate hand, eye, and ear protection during all drill operations and setup.

Mechanical Safety

- Cutters – The cutters on the drill head can be extremely sharp. Operators shall use care whenever handling cutter assemblies or cutter blades and should wear protective gloves whenever possible.
- Pinch Points – There are several areas on the drill where a finger, hand, arm, or clothing could be pinched, specifically, around the moving parts of the winch and winch cable. Operators should identify all pinch points prior to operation and should be mindful of all such points during operation and setup.
- Suspended Loads – Users shall never stand under suspended loads. Injury may result from a load that is moving, rotating, falling or unbalanced.
- Eye Protection – Standard operations of the Foro 400 Drill do not require eye protection be worn by operators; however, eye protection shall be available onsite in the event of non-standard operations such as those using chemicals to free a stuck drill.
- Burn Hazard – The muffler and exhaust of the generator can be extremely hot. Avoid contact with either component. If service is required, allow time for the generator to cool before servicing.
- Cold Hazard – Metal components and fuel may be extremely cold. Always wear appropriate gloves when handling.
- Slippery Surfaces – The snow may become icy and slippery in high traffic areas. Roughen up walk areas as needed to prevent slips and falls. Always use caution whenever walking around the drill operations area.

Electrical Safety

- Voltage – Extreme care shall be taken when assembling, disassembling and servicing electrical equipment. Equipment must be disconnected from the power source before servicing.
- Electrical equipment should only be serviced by personnel trained in electrical safety.

Chemical Safety

- Use fluid resistant gloves and eye protection whenever handling fuel or chemicals.
- Use care and observe all safety warnings when handling chemicals.
- Combustibles – This system uses combustible fuel for the generator and may be supplied with ethanol for freeing a stuck drill. Take care to properly store all combustibles away from all major heat sources.
- Secondary Containment – Fuels and other fluids should be stored in secondary containment to prevent spills and unplanned release. Secondary containment devices must be requested from the logistics provider.
- Drilling Fluid Hazard – If used, note any potential for combustion or potentially present health hazards. Proper PPE must be worn when handling and using drilling fluids.

Fire Safety

- No Smoking Areas – The following areas are non-smoking areas: Within any drilling and generator facilities, near chemical storage areas, near fuel storage areas, etc.

Environmental Safety

- Cold Exposure – This drill will be deployed to extremely cold climates. Workers shall wear outerwear suitable to protect themselves from the cold and monitor their own and fellow workers' activities for exposure to cold.
- Noise Hazard – Noise levels during operation of the drill are not expected to be of actionable levels.

8.0 System Overview

The Foro 400 Drill is an electromechanical ice coring drill that produces a 98 mm diameter core and creates a 126 mm diameter borehole. Core length is nominally 1-meter long, however core length will vary depending on the density of the snow/ice. Cores can be retrieved from depths down to approximately 400 meters. The drill sonde is based on the Danish Hans Tausen Drill, which has been used successfully for several decades, and the IDP Foro 1650 Drill. It is particularly useful on projects requiring continuous core from the surface, larger core than produced by the IDP Badger-Eclipse Drill, and/or the ability to deploy/retrieve downhole instruments with the drill winch. The drill can be transported by light fixed or rotary-wing aircraft. An overview of the drill system specifications is shown in Table 1.

Table 1. Foro 400 Drill system specifications.

Systems in Inventory	1
Max. Practical Depth	400 m
Hole Diameter	126 mm (4.96 inches)
Core Diameter	98 mm (3.86 inches)
Core Length	1 m
IDP Driller Required?	Yes; 1 required, 2 preferred
Drill Fluid Required?	No
Power Requirements/Source	240 V, 5 kW generator
Estimated Drilling Time	100 m – 30 hours 150 m – 50 hours 200 m – 75 hours
Time to move (breakdown and setup)	6 hours
Helicopter Transportable?	Yes
Light Aircraft Transportable?	Yes
Trench Required?	No
Shipping Weight With Tools and Spares	1800 lbs.
Shipping Volume With Tools and Spares	76 cubic feet

The goal of this manual is to provide a practical reference for the deployment and operation of the Foro 400 Drill. There are three main phases of any drilling operation: pre-deployment preparation, field operation, and return of the equipment from the field for maintenance and repairs. Understanding the relationship between the phases is essential for successful field operation. This manual is intended to provide the user with information on how best to execute each phase.

9.0 PRE-DEPLOYMENT PREPARATIONS

As the drill is prepared for shipment to the field, the condition and function of each component should be inspected. The Foro 400 Drill has six major component groups:

- Drill Tower
- Drill Sled and Drill Winch
- Drill Motor Sections, Anti-Torque Sections, and Barrels
- Drill Heads and Cutters
- Control Boxes
- Tools and Spare Parts

The pre-season checklist, located in Appendix A (section 15.0), will facilitate the pre-deployment inspection and ensure the proper components are packed and shipped. This checklist should be completed each time the drill system is sent out for a project.

9.1 Drill Tower

9.1.1 Required drill tower components:

- Crown sheave assembly
- 4x 1.5-meter truss sections
- Truss hardware, including:
    - 12x truss connectors
    - 32x tapered pins
    - 32x cotter pins
- 4x tower guy lines
- 22x one-meter-long snow stakes:
    - 4x for tower guy lines
    - 4x for anchoring winch base
    - 14x for tent guy lines

The tower assembly process described below is for setting up the Foro 400 Drill for use inside the Mast Anchored, Suspended and Tensioned (MAST) tent. If not using the tent, only 8 snow stakes are needed.

- Unpack tower assembly crate F4-2.
- Position, level, and anchor the winch sled at the drill site taking into consideration prevailing wind direction.
- Install the two tower rotation lock blocks and tilt the tower base away from the winch drum (Figure 9-1). The rotation lock blocks keep the tower from tilting side-to-side while it is being raised and lowered.

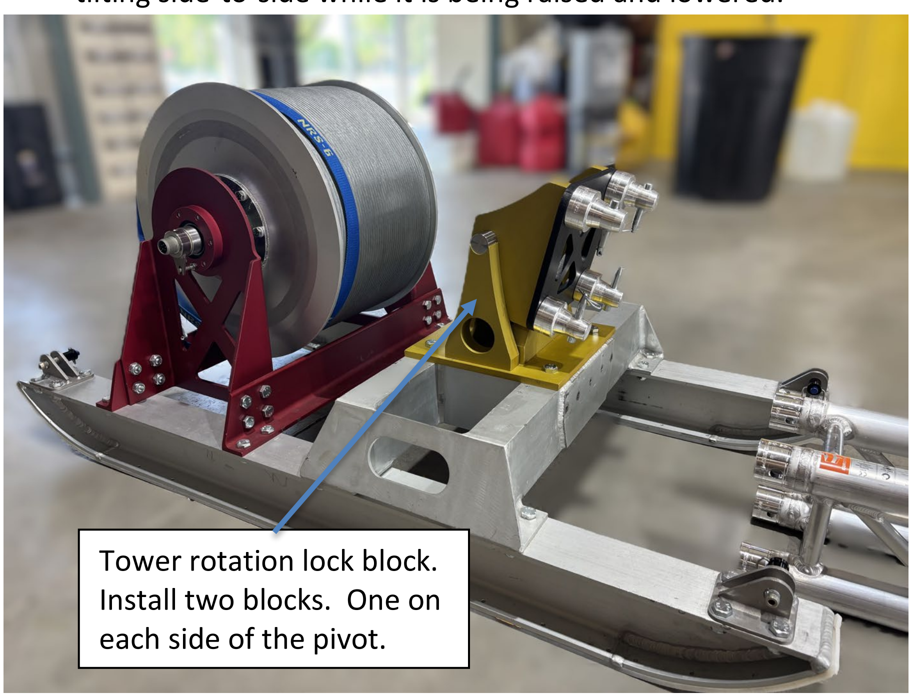

Figure 9-1: Winch sled tower base with rotation lock blocks in place.

- Assemble the 4 truss sections and attach them to the tower base (Figure 9-2 and Figure 9-3). Use a soft-faced hammer to gently tap the tapered pins into place and secure with the cotter pins.

Figure 9-2: Truss sections prepared for assembly.

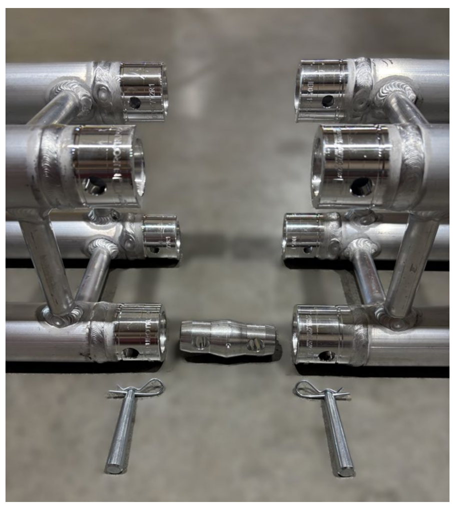

Figure 9-3: Hardware for assembling the truss sections.

- Attach the crown sheave to the top truss section. Rest the tower on a box or foam blocks to make attaching the crown sheave and required cabling easier (Figure 9-4 and Figure 9-5).

Figure 9-4: Tower resting on case for crown sheave attachment.

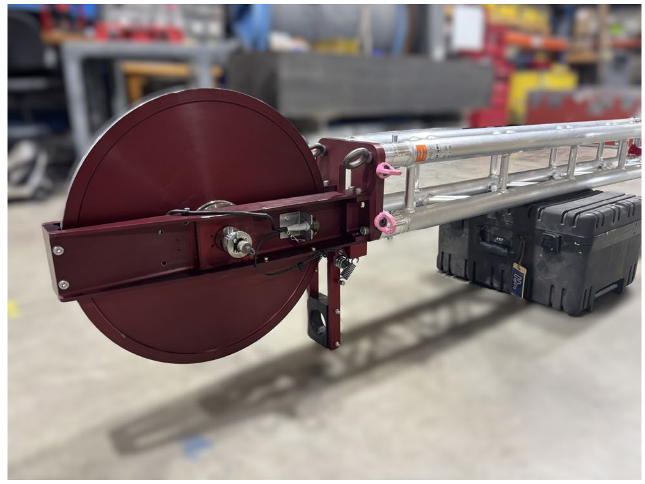

Figure 9-5: Crown sheave assembled to top tower section.

- Attach the load pin, encoder, and sonde hard limit switch connectors and route the cables neatly along the tower.
- Attach four guy lines at the crown sheave base. These lines will be anchored using snow stakes (or V-thread anchors on blue ice) outside of the tent. The tent top ring guy ropes will further stabilize the tower in high winds.
- If the MAST Tent is to be used, attach the four load-capturing pulleys with hoisting ropes and release lines to the swivel eyes on the crown sheave base. Make sure the pulleys and ropes are oriented properly to hoist the tent top ring. Secure all ropes/lines so that they cannot accidentally pull through the pulleys during the set-up process.

9.2 Drill Sled and Drill Winch

The winch is mounted on a sled for ease of maneuvering by hand or by snow machine with the included tow bar. The winch sled weighs 276 lbs. The body and lid of the winch sled case can be removed for easier access to contents and so the sled doesn't have to be lifted out of the case. (Figure 9-6).

The winch motor straps to the base of the winch shipping case for transport. It connects to the winch gear reducer with four bolts (Figure 9-7).

Note: Figure 9-6 to Figure 9-8 show an old version of the tower. It has been updated to the truss tower shown in Figure 9-1 to Figure 9-5.

Figure 9-6: Winch sled in its shipping case.

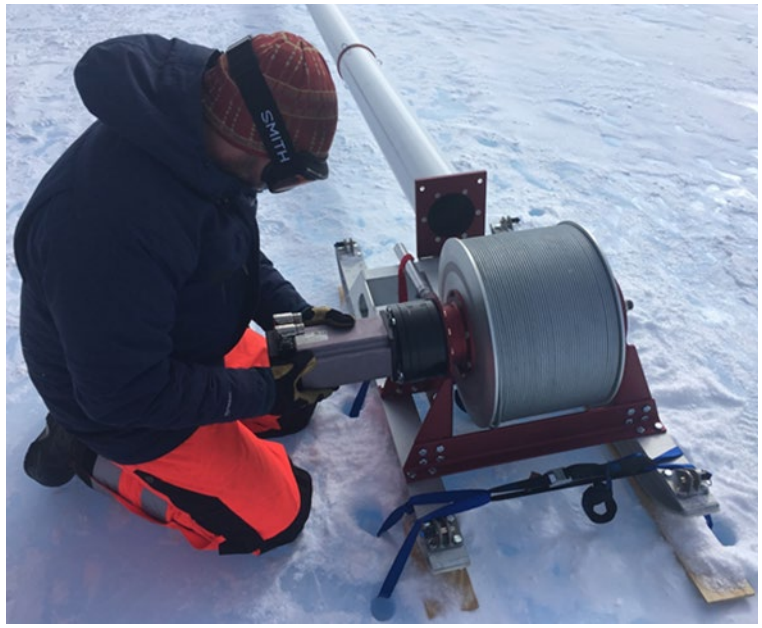

Figure 9-7: Attaching winch motor.

A slip ring comes mounted inside the winch drum on the opposite side of the gear box. The slip ring provides the electrical connection between the control box and the wires in the winch cable while allowing the winch drum to rotate (Figure 9-8).

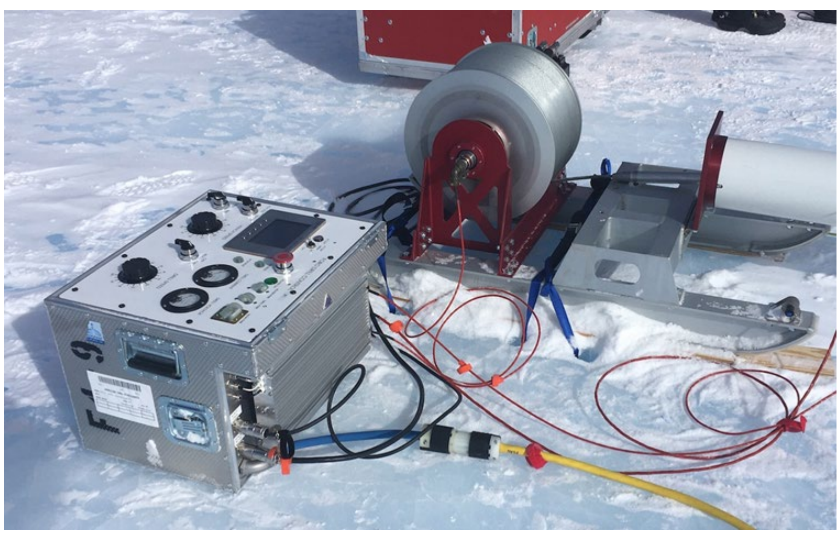

Figure 9-8: Control box and winch, showing the electrical slip-ring connection.

9.3 Drill Motor Section, Anti-Torque Section, and Drill Barrels

The Foro 400 Drill system comes with duplicates for each sonde component: motor section, anti-torque section, and barrel sets. Assemble the drill by following the steps outlined below.

- Align the motor and anti-torque sections on a case(s). Plug the electrical cable into the Anti-Torque (AT) slip-ring and the top of the motor section. Coil the extra wire and secure it to the AT struts with a Velcro strap. Connect the motor section and anti-torque section with six socket cap screws (Figure 9-9).
- Attach the cable head to the anti-torque section by threading the plugs and wires through the center bore of the cable bearing assembly (Figure 9-10). Align the flat on the EverGrip termination with the key inside the cable bearing housing. Remove the set screw from the cable bearing housing and use the provided metal rod (or Allen key) to rotationally lock the cable bearing shaft. Thread-on the EverGrip termination retaining nut and tighten (Figure 9-11), then replace the set screw. The drill cable wiring attaches inside the clamshell housing. Carefully coil any extra wire and secure the torsion covers with the hose clamps (Figure 9-12).
- Attach the outer barrel to the motor section with the six hex-cap spacer screws (Figure 9-13).
- Once the drill is hanging from the tower, attach the core barrel to the motor drive plate with the three quick lock pins (Figure 9-14).

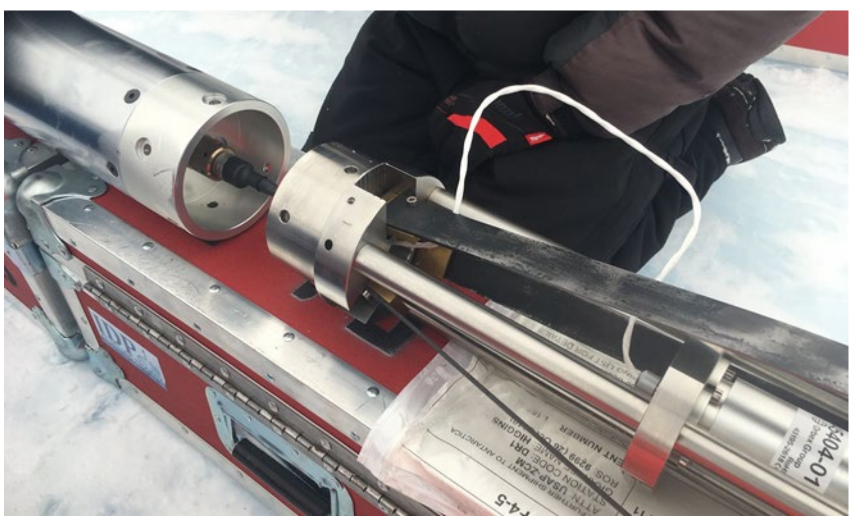

Figure 9-9: Motor section to anti-torque section connection.

Figure 9-10: Attaching the drill cable termination to the AT section.

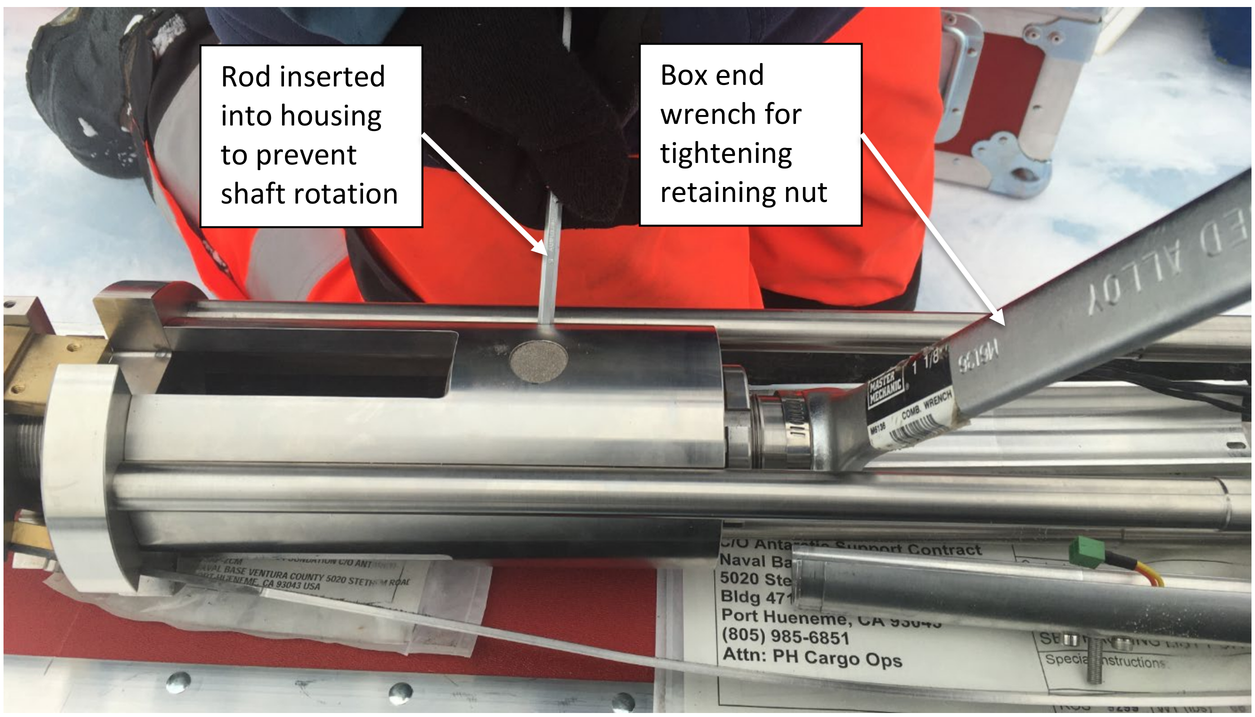

Figure 9-11: Tightening the EverGrip retaining nut with a wrench. A rod inserted through an opening in the side of the cable bearing housing prevents rotation of the cable bearing shaft while the nut is being tightened.

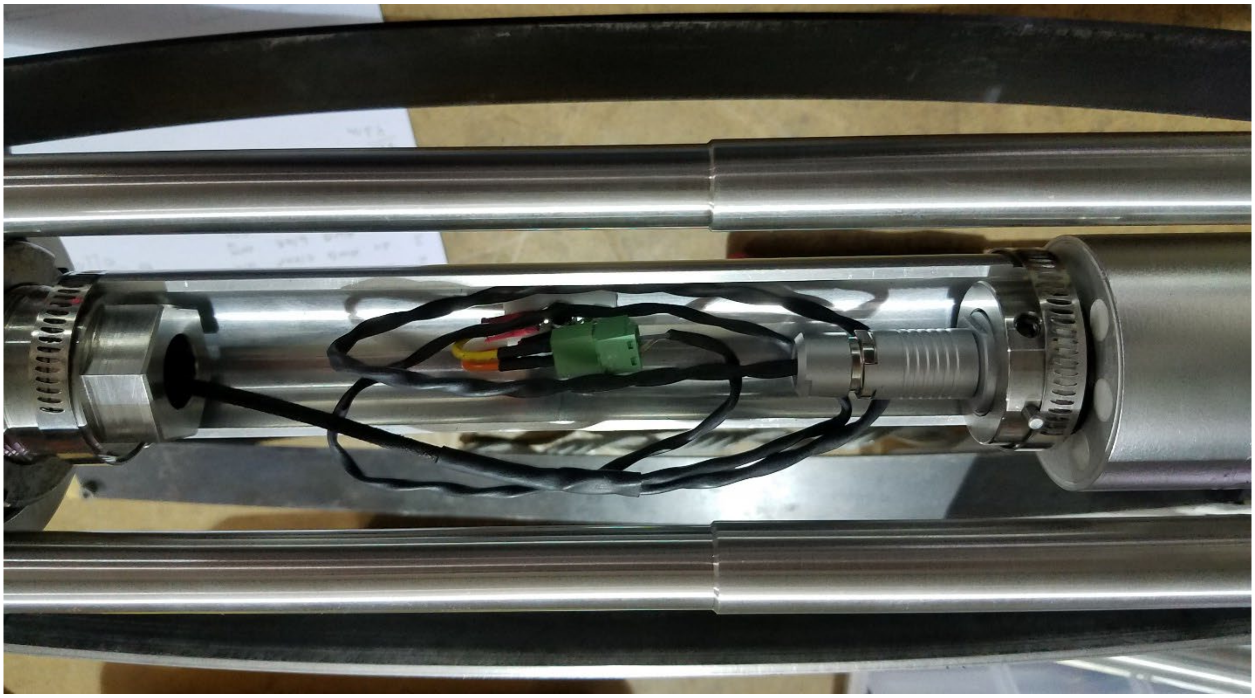

Figure 9-12: The cable assembly inside the torsion cover clamshell.

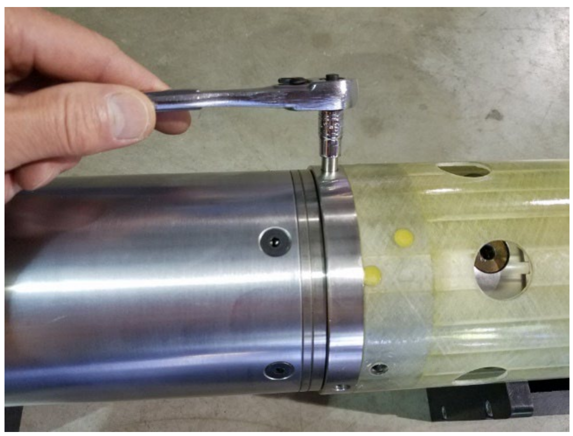

Figure 9-13: Motor section to outer barrel connection.

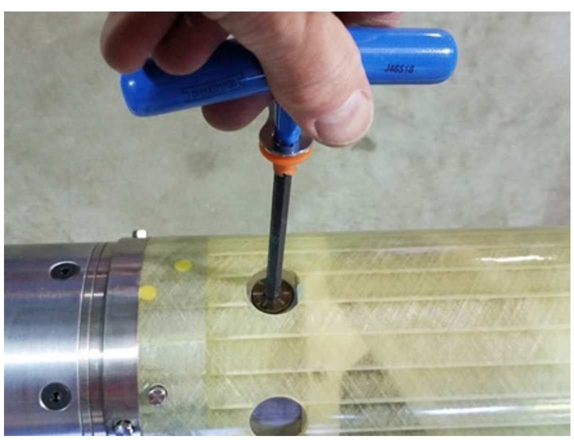

Figure 9-14: Core barrel to motor drive plate connection with locking pins.

The anti-torque section consists of three spring steel blades. The bow shape of the blades is adjusted as a unit by tightening or loosening the single spanner nut at the top end of the anti-torque section (Figure 9-15). This nut tightens against the recovery loop plate and acts as a stopper for the sliding block to which the blades are attached to limit the straightening of the blades when inside the borehole. Use spanner wrenches or a flathead screwdriver and a rubber mallet to secure the nut at the desired position. Measure the length of exposed threaded area while the drill is free hanging on the tower as a frame of reference for future blade adjustments.

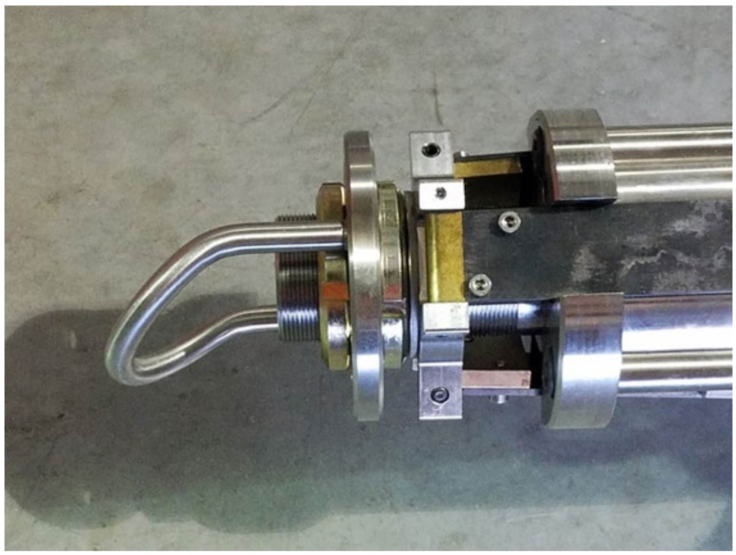

Figure 9-15: Anti-torque adjustment nut tightened against the recovery loop plate.

If the blades are set too loose, the anti-torque will slip, causing the blades to locally enlarge the diameter of the borehole. During a rapid slip of the anti-torque, the small spring on the torsion clamshell cover in the anti-torque section contacts one of the three vertical housing rods triggering an alarm in the control box. One may also notice the cable whipping back and forth and a loss of cutter penetration. The drill motor should immediately be turned off if this happens and the drill should be returned to the surface. Adjust the blades out until they effectively engage the borehole wall again. It is safer to spread them too much at once than in smaller increments. The priority is to stop the spin that damages the borehole wall. More precise adjustments can follow once the drill is below the spin area. If the blades are too tight, the drill will stick-slip while drilling and not penetrate smoothly. In this case, the blades should be brought in a little bit at a time until the drill penetrates smoothly.

The bottom of the motor section includes a magnetic-release slide-hammer mechanism to impart an impact force during core break. The slide-hammer can be set to various release forces (by adding or removing magnets) and slide lengths (by adding or removing spacers). The slide-hammer can also be locked to prevent movement. See drawing #83150152 for assembly details.

The core barrel connects to the motor section drive adapter with three locking pins. When engaged, the pins extend outwards into the corresponding holes on the core barrel collar. The core barrel has plastic spirals attached to the barrels' outside surface. Cut chips are transported upwards via the spirals and fall inside the core barrel through the openings, or windows, at the top. A core-chip separator is used to isolate the chips in the upper part of the barrel from the core in the lower part of the barrel. The core-chip separator is a plastic cup which is hung by parachute cord and a steel button that seats in a small hole near the top of the barrel. The core-chip separator should be initially set to about 1 meter above the cutters when the cord is stretched and adjusted as needed to maximize the length of core that can be drilled.

Three different types of outer barrels are supplied: fiberglass, aluminum with sawtooth grooves, and aluminum with square grooves. The first two types use the same core barrel while the third type uses a core barrel with a larger flight diameter. The square-groove aluminum barrel tends to work well in firn but performance diminishes as the ice densifies.

9.4 Drill Head and Cutters

The Foro 400 Drill uses core dog style cutter heads (Figure 9-16). The spring-loaded core dogs initiate the core break at the end of coring when the drill is raised. When drilling, the core causes the core dogs to hinge back into their windows in the cutter head. Core dogs come in two lengths: short and long. Generally, long dogs work best in firn and short dogs work best in dense ice. However, the long dogs of the Foro 400 proved preferable in the dense, blue ice at Allan Hills Antarctica. The Foro 400 short dogs produced deeper spalling, more surface scoring, and were more difficult to clean during dry drilling than the long dogs.

Pressure exerted by the core dogs on the core can be adjusted by hand by changing the bend on the legs of the U-spring, which is mounted at the top of the core dog window. The spring provides the initial pressure required to engage the core dog with the ice core.

Figure 9-16: Cutter head with long core dogs, step cutters, and 2.0 mm shoes.

The core dogs are secured in the drill head window with a pin and a cap screw. The coil spring is also retained with the same pin and functions to hold the core dog in the retracted position against the U-spring. One leg of the spring is located in a hole inside the slot of the core dog and the other in the hole at the bottom of the window in the head. The legs of the springs should be trimmed so they don't stick out where they could injure the operator.

The cutters are supplied in matched sets of three. They must be kept in matched sets, meaning if one cutter needs to be changed all three must be changed. Failure to do this can lead to penetration issues or uneven cutting. The cutters come in two styles: full kerf and step. Both styles of cutters drill a 98 mm (3.86") diameter core and 126 mm (4.96") diameter borehole. Each cutter has three holes, two for the locating pins and one for the securing screw. When assembling the drill head, the cutters mount first followed by the penetration shoes. Step cutters should be installed so that the middle cutter leads the inner cutter so that chips have space to move away from the core (Figure 9-17).

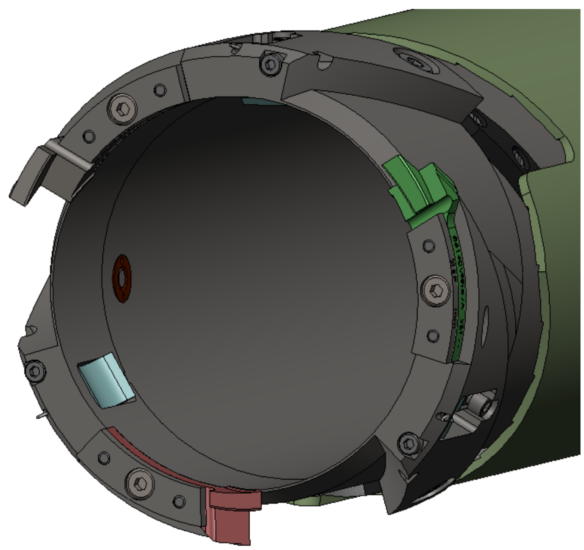

Figure 9-17: The middle step cutter (green) leads the inner cutter (red) so that chips have space to move away from the core.

The penetration shoe angle limits the depth of cut. The aggressiveness of the cutting action influences the core quality. A finer penetration rate will generally provide better core quality; however, it comes at the expense of slower drilling rates and smaller sized chips. Larger chips transport up the barrel spirals better and cause fewer penetration issues and less packing at the drill head.

Full kerf cutters and step cutters require different shoes and mounting screws. Full kerf shoes have a recessed pocket for the mounting cap screw, whereas a flathead screw is countersunk into the step shoes. Confirm the flathead screw mounting the cutter and shoe is flush with the surface of the shoe. If they stick proud of the shoe face, they will affect drill penetration.

There are five sets of full kerf shoes creating a depth of cut range between 1 mm and 5 mm. There are four sets of step cutter shoes ranging between 1 mm and 4 mm. A depth of cut of 5 mm in firn and 3 mm in ice is a good starting point

Shims are included for fine tuning the depth of cut and core quality. Shims seat between the cutters and the shoes. Care must be taken when changing shoes/shims that all faces are free of ice and rime in order to achieve desired shoe height. Figure 9-18 and Figure 9-19 show the relationship of shoe height vs pitch (vertical distance the drill will progress in one revolution).

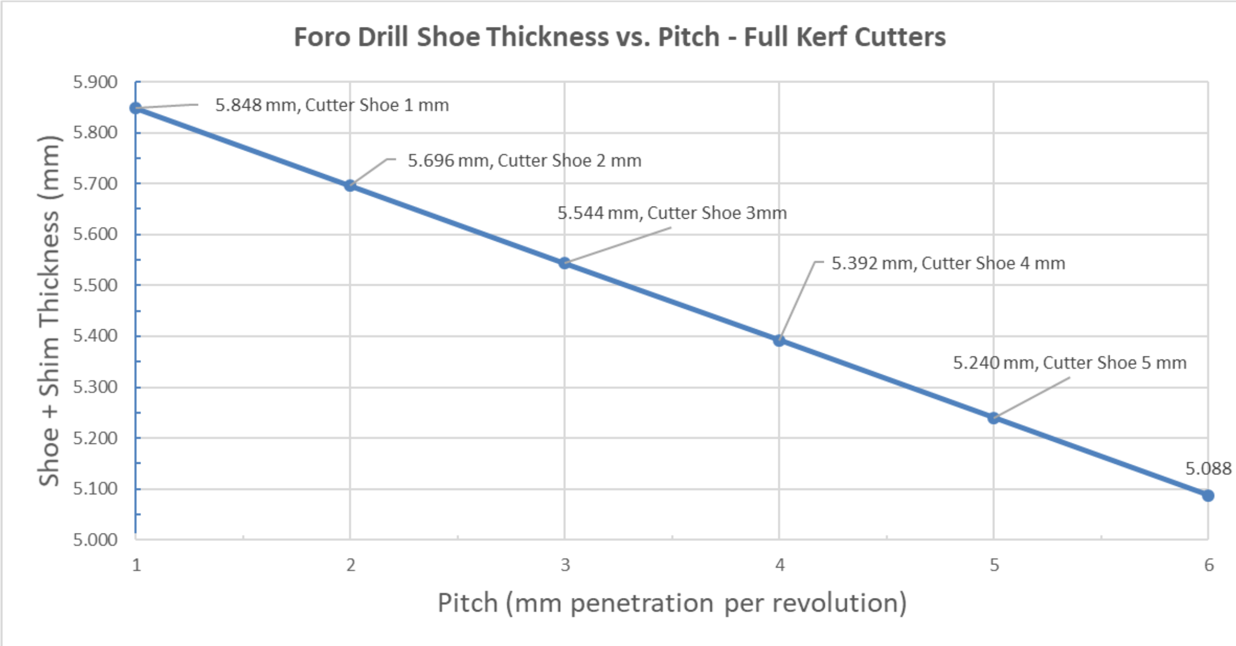

Figure 9-18: Full Kerf Cutters Shoe Thickness vs. Pitch

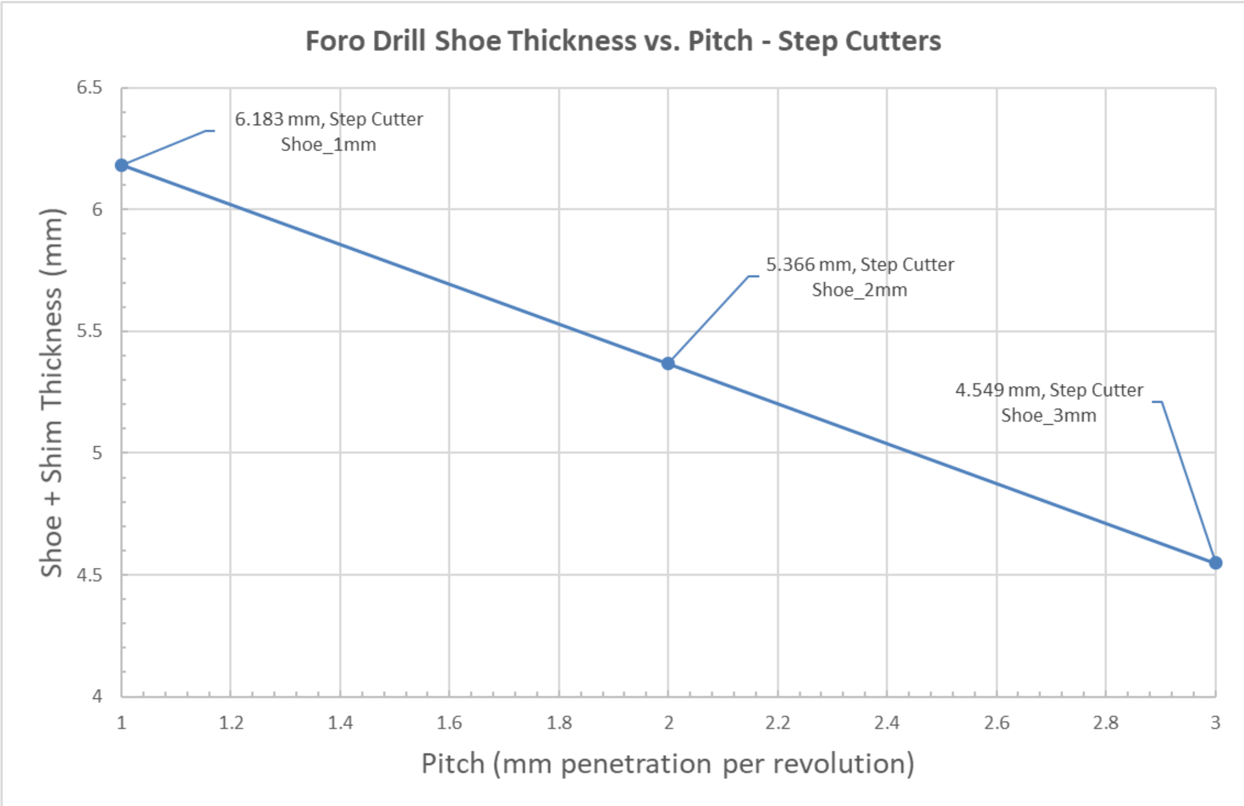

Figure 9-19: Step Cutters Shoe Thickness vs. Pitch.

9.5 Control Box

The Foro 400 Drill system comes with two identical control boxes. The control box enables the operator to control the winch and the drill (Figure 9-20). An LCI-90i display allows the operator to monitor drilling depth, cable tension, weight on bit (WOB) during coring, and length of core. Five buttons at the base of the display are used to navigate screens and settings within the LCI-90i. See the LCI-90i operations manual for details on how to navigate the functions of this display and the Foro 400 LCI-90i Quick Setup Guide, 8315-0011, for the default display settings.

Two buttons to the right of the display (DIFF RESET and WOB RESET) are useful during coring. Both buttons should be pressed at the start of coring. DIFF RESET provides a separate depth readout for tracking core length. WOB RESET provides a separate tension readout for ease of seeing weight on bit (applied downward pressure) trends over the coring run.

At the top of the control box from left to right are the following controls and indicators:

- Anti-torque slip sensor light and siren switch. The light only comes on when the siren is switched off.
- Emergency stop button. This button only disables the winch and drill motor drives. However, power will remain on to the heater and LCI-90i display. Cycle main control box power to reset the winch drive after the E-stop has been pressed.
- Control box internal heater indicator light and on/off switch. The thermostat is set to 45 degrees F. The heater fan runs continuously.
- Drill power on/off switch.
- Main power on/off switch.

Below the power switches are two analog meters which display drill current and drill voltage output during coring.

NOTE: The drill current meter will not read when the drill motor is running in reverse.

Winch motor controls are at the bottom left of the control box and drill motor controls are at the bottom right. Winch controls include a large dial for controlling winch speed, a directional switch (PAY OUT/OFF/PAY IN), and a speed control switch for tripping speed versus drilling speed (DRILL/TRIP). Drill motor controls include a large dial for controlling cutter head rpm and a directional switch (REV/OFF/FWD).

Figure 9-20: Control box face plate.

Figure 9-21 shows the cable connection points on the back of the control box. On the left side are the winch motor feedback cable, the winch motor power cable, and the main power cord. The main power cord brings 240V into the control box from the generator. An 80 ft. extension cord is included with the drill system. The Foro 400 Drill is normally powered by a 5-kW generator through the 120/240 V outlet.

On the right side of the back of the control box, there are 3 cable connections including: load pin, tower encoder, and cutter motor. The load pin and encoder cables run the length of the tower to their corresponding connections on the crown sheave. Care should be taken to secure these cables along the tower in a way that they do not interfere with the drill as it passes the tower. The cutter motor cable connects to the winch slip ring. Also, there is a hard limit switch reset button in the event that the hard limit switch on the crown sheave is triggered by driving the drill too high on the tower.

NOTE: If the sonde is run up into the sonde hard limit switch, the winch will not run in either direction. To reset the winch drive, the power must be cycled while depressing the Tower Limit Override button on the back of the control box above the Amphenol connectors. The button can be released once the drive powers up. The winch will now only run in the payout direction until the sonde hard limit switch is no longer engaged.

The load pin and the encoder are mounted on the crown sheave assembly (Figure 9-22). The encoder operates via a proximity sensor counting revolutions of the sheave. The load pin is integral to the axle of the sheave wheel.

NOTE: The control box has built-in current limiters. The winch motor current limit has been set to 15.9 Amps and the peak current limit is set to 31.8 Amps. The drill motor current limit has been set to 3.25 Amps. As the output current climbs past 3 Amps, the voltage will start dropping below 250 volts and the motor will begin to stall.

Figure 9-21: Control box cable connections.

Figure 9-22: Crown sheave assembly showing load pin and cable, encoder cable, and hard limit switch.

Figure 9-23: Control box setup with the drill system and core processing station on left.

9.6 Tools and Spare Parts

Toolboxes are provided with each drill and are an integral part of the drill system. A basic tool kit is included with each drill system; however, individual drillers often supplement the kits with additional or preferred tools that can be supplied by IDP upon request.

In addition to the tool kit provided with the drill is a selection of spare parts. These spare parts have either been identified as mission critical or at an elevated risk of failure due to use or environmental conditions in which the system is being used.

10.0 SHIPPING

It is rare for the drill shipment to go directly to a drilling site, and there is usually at least one stop in between. The equipment often transfers through multiple shippers and on several forms of transportation, such as truck, boat, and aircraft before reaching its final destination. The possibility for cargo to be damaged or lost increases every time it is handled. It is essential that the received content is verified against the packing list, before the final leg of a shipment to the actual field site. One should also look for potential damage incurred during shipping. Identifying any missing or damaged cargo as soon as possible will provide more time to resolve the issue and help minimize any impact to the field project. To minimize the chance of cargo getting lost, each piece of cargo should have its own shipping label, even for multiple items banded onto a single pallet. Contents of pallets often get rearranged during shipping and this is when unmarked boxes tend to get lost.

11.0 DRILL SITE

Once a drill site is selected, it should be properly marked with flags. The integrity of the snow surface should also be protected. The generator should be placed as far from the drilling site as possible and downwind, primarily to protect the snow surface from contamination and also to improve working conditions by limiting noise. The generator should be protected from drifting snow or intensive cold. Some generators come in protective boxes, allowing only certain sections to be exposed. If a protective box is not available, a cardboard box can serve as a simple shelter. Raising the generator on top of a spare crate will help to keep out the snow blowing. Follow general rules for handling hazardous materials and set up a proper refueling station to limit possible fuel spills.

Figure 11-1: General site setup.

The prevailing wind direction should be taken into consideration when orienting the drill and selecting a location for the generator. Sastrugi are usually a good indication of the prevailing wind direction.

If a tent is not available, wind breaks will improve efficiency and comfort of the worksite and provide protection to sensitive equipment. They can be as simple as a wall made of snow blocks or tarps setup with bamboo flags. IDP also has an inventory of commercially made wind breaks that can be deployed with the drill system.

12.0 ON-SITE SETUP AND PREPARATIONS FOR DRILLING

Aside from the winch case, none of the Foro 400 Drill components are excessively heavy, but proper warmup and stretching should be done first before any lifting or dragging of the equipment.

Move the winch sled into position, orienting the sled so the winch drum will be upwind from the borehole. Two people can drag the sled with relative ease; however, if a snowmobile is available, it should be used for this operation to reduce the risk of injury. The sled should be anchored in place with aluminum snow stakes on all four sides (V-thread anchors when on ice).

It is critical to level the winch sled side-to-side and to a lesser extent front to back. If the sled is not level side-to-side the top sheave will not be aligned with the midpoint of the winch drum. This will cause the winch cable to not level wind properly and to stack at one flange. This can quickly lead to the cable jumping off the winch drum, which can damage or break the cable.

The winch motor installs by aligning the keyed motor shaft with the keyed bore of the gearbox and securing the motor flange with 4 socket-cap screws.

In section 9.1, tower assembly is described in detail. Once the tower is assembled, place the control box on the slip ring side of the winch and connect all cables as described in section 9.5. Start the generator and turn on the heater power switch on the control box. The green indicator light will stay on (indicating the heater is running) until the control box is sufficiently warm. Once the control box is warm, turn on the main power switch which will energize the winch controls. Ensure the winch speed control dial is at zero, the directional switch is set to PAY OUT, and the speed switch is set to TRIP. The winch will always start in DRILL speed when the control box is first powered up regardless of switch direction. Toggle the switch between DRILL and TRIP to achieve TRIP speed.

Prior to operating the control box, clearly communicate with other team members to ensure that all involved knows your intended actions and are clear of the area of moving drill parts, such as the drill and winch, both of which can cause injury when moving.

Before turning on power to the control box, always verify the position of the directional switches are set to OFF and the motor control dials are turned to ZERO.

Pay out enough winch cable to run it over the crown sheave and back to the sled, fit the cable to the groove on the sheave, and temporarily strap the cable head end to the tower while raising the tower. The tower is ready to be raised when all cables are in place and the three guy lines are attached and uncoiled. If using the MAST tent, the pulley system for raising the tent and the tent body will need to be in position before raising the tower. See 8431-0002 MAST Tent assembly manual for tent assembly procedures.

With one person or preferably two, walk the tower up while two others pull it up with the upper guy lines (Figure 12-1). Tower raising should always involve all available field team members for efficiency and safety. As the tower nears vertical, it is important to have a person man the guy line opposite those being used to raise the tower. This is to prevent the tower from being pulled past vertical, and possibly tipping over, as it is brought to vertical.

Figure 12-1: Raising the drill tower with drill tent body and rigging. Note: the old tube tower is shown in this picture.

Once the tower is vertical, tie off each line to the snow stake using a trucker hitch. The lines should be guyed out so the angle between them and the snow surface is in the 15°-30° range. The snow stakes should be driven into the snow at about a 30° angle, with the top angled away from the tower. This angle will keep the stakes from pulling out when the ropes are tensioned. The angle of the snow stake may need to be adjusted depending on the rope angle and surface conditions. If the snow is very soft, the stakes should be used to put in dead-man anchors (Figure 12-2). V-thread anchors and/or ice screws should be used in blue ice areas.

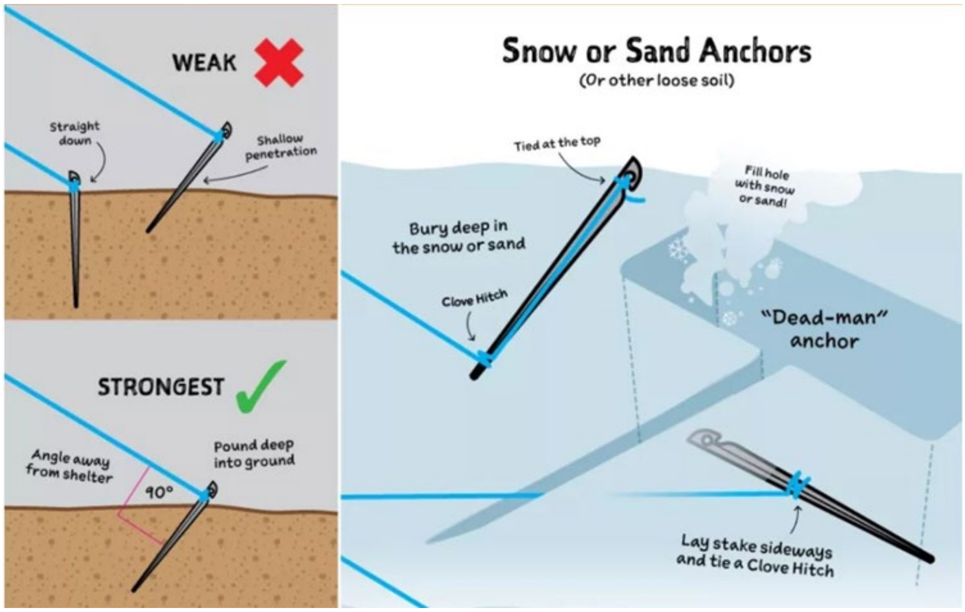

Figure 12-2: Proper placement of snow stakes and dead-man anchors.

Final adjustment of the tower will be performed when the drill is attached and hanging on the winch cable, as it will serve as a plumb bob.

Once the tower is secured, remove the two tower rotation lock blocks. The drill can now be assembled and connected to the cable head, as described in section 9.3. It is easiest to assemble the drill in a horizontal position on top of barrel cases. Plastic cradles are provided for holding drill sections. Once the anti-torque and motor sections are connected to the drill cable and before attaching the outer barrel, verify the proper function of drill motor controls. Turn on the drill power switch, select either direction (FWD/REV), and slowly turn the drill motor speed dial clockwise until the motor drive plate spins. Ensure the speed dial is at zero after both directions have been tested.

It is now possible to raise the drill string and insert the core barrel.

The drill should be placed in front of the winch and in line with the winch sled (where the drill tower was laying before being raised) and not off to the side. The winch cable must be kept aligned with the tower as the drill string is raised. If the cable is pulled to the side of the crown sheave, it can jump off the sheave and damage the cable.

Attach the cable guide to protect the winch cable from being kinked at the top of the anti-torque section while the drill is being raised (Figure 12-3). The driller helper guides the drill string, as the driller slowly raises it with the winch. The helper should lift the end of the outer barrel, so it will not drag in the snow as the drill string is raised. Once the drill is vertical, remove the cable guide.

Next, place the core barrel upright on the snow surface and lower the drill string over it.

NOTE: When lowering the outer barrel over the core barrel, it is very important for the helper to keep their hands away from pinch points where the barrels are sliding together (Figure 12-4).

Figure 12-3: Cable guide used while raising drill string onto tower.

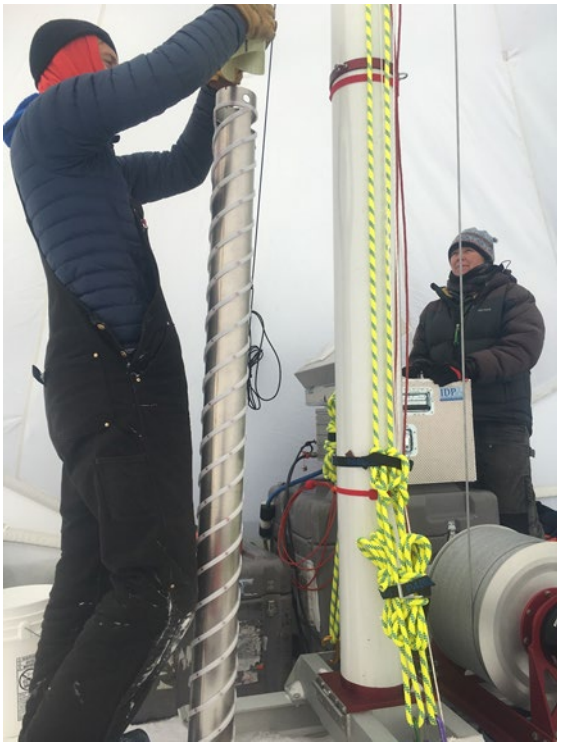

Figure 12-4: Lowering drill string over core barrel.

Once the outer barrel has been lowered over the core barrel, engage the lock pins with a hex wrench through the openings in the outer barrel to secure the core barrel to the drive adapter. The lock pins are flush with the drive adapter when disengaged and protrude into the holes on the core barrel when engaged. If the pin holes are not visible in the opening of the outer barrel, slowly rotate the drill motor until they come into view. To facilitate the locking and unlocking of the pins, a shallow hole can be drilled in front of the main borehole just deep enough so the top of the core barrel can be comfortably reached when it is placed in the shallow hole. Figure 12-5 shows the location of the hole in reference to the winch sled location. Place a piece of foam at the bottom of the pit to provide a resting surface for the drill head.

Figure 12-5: Shallow hole drilled in front of the main borehole to facilitate barrel disassembly.

With the pins engaged, the driller next drives the winch in reverse to raise the drill until the cutter head is just above the snow surface. If this is the first time raising the drill, check how the drill is hanging in relation to the tower. It should be in line with the tower side-to-side and centered in the opening in the drill sled. Adjust the tower guy lines as needed to align the drill.

While the drill is hanging on the tower, this is also a good time to run the drill motor to check for barrel clearance by listening for unusual friction noises. The driller helper will need to manually stabilize the drill string by holding the outer barrel while staying clear of the rotating cutter head.

For safety, it is always best to run the drill head in reverse when out of the borehole.

BEFORE THE START OF DRILLING, it is useful to STEP BACK and verify that all equipment is set up properly and the site is neat and organized for safe and productive operation. All excess cabling and ropes should be bundled out of the way of normal operations. All tools used for assembly should be put away, so they don't get lost in the snow. Any tools that will be routinely used during drilling, such as for manipulating pins or cleaning the cutter head, should be secured to the winch sled or tower with a lanyard so they don't accidentally fall into the borehole.

Safe footing around the drill site is important. Some drill sites are extremely soft, while some can be solid ice. Areas where drilling personnel are working should be arranged to ensure safe and efficient operation. For example, plywood can be placed over soft snow, or crampon-type boot attachments can be used when the surface is slippery. Areas that become icy should be roughed up with a shovel, so they don't become a slip hazard.

Synchronization of the driller and drilling helper(s) is important both for productivity and safety. Proper explanation of all drilling tasks among the team members is essential. It is important that everyone understands each step and how it fits into the drilling sequence.

Drill run times generally decrease as personnel get more familiar with their tasks and get into a rhythm. This will happen naturally, as people learn the equipment and tasks and get comfortable working as a team. This process should not be rushed. Everyone learns and works at different rates and that should be respected.

13.0 DRILLING SEQUENCE

13.1 Drill Run Operations - Reference Guide

1. Start a new drill run in the logbook.
2. Remove the borehole cover.
3. Ensure the drill motor controls are set to zero speed and OFF. Turn winch switches to PAY OUT and TRIP. Lower the drill to the snow surface and zero the depth and tension displays.
4. Lower the drill until it is positioned about 10-15 cm above the bottom of the borehole.
5. Switch the winch to DRILL mode, the drill directional switch to FWD, and turn the drill speed dial. A setting of 100% on the knob provides a good cutter speed of approximately 60 rpm. Turn the winch speed dial to an appropriate speed for your cutting pitch.
6. When the drill starts cutting, zero the DIFF and WOB.
7. Drill the appropriate core length. Stop the winch motor, then stop the drill motor. Turn the drill directional switch to OFF.
8. Record the bottom depth and core length in the logbook.
9. Turn the winch control switches to TRIP and PAY IN. Slowly turn the winch speed dial until the core breaks and tension releases. Increase winch speed after the core break occurs.
10. Raise the drill string to clear the hole. Install the borehole cover.

11. Put a 5-gallon bucket underneath the drill and run the cutter in reverse to clear any chips in the flights. Stop cutter rotation when lock-pins are visible in the outer barrel windows. Remove the chip bucket.
12. Switch to PAY OUT and lower the drill to the shallow hole and unlock the pins securing the core barrel. Switch to PAY IN and lift the drill string up over the core barrel. It is recommended to store the drill down the borehole during surface operations to keep it cold and dry. Switch to PAY OUT, remove the hole cover, lower the drill, then set the winch controls to zero and OFF before assisting with floor operations.
13. Move the core barrel to the core processing area. Pull out the core-chip separator to remove the cuttings and push the core out of the core barrel onto the core tray. Reinstall the core-chip separator.
14. Reassemble the core barrel with the drill string. Switch to PAY IN and raise the drill out of the borehole, install the hole cover, then switch to PAY OUT to lower the drill over the core barrel. Engage the three lock pins.
15. Switch to PAY IN and raise the drill for cutter head cleaning at about head height.
16. Clean the cutters, shoes, and core dogs. Make sure they are free of built-up ice and that the core dogs spring freely.

13.2 Expanded Details for the Drill Run Operations

Reference Guide in section 13.1

Details for Reference Guide step 1.

Detailed records should be kept of each drill run in a logbook. Information recorded about the drill setup and details of each run is very useful during a project for monitoring drill performance as well as historically for keeping a record of drill performance and ice conditions at a particular site. A drill log is included in Appendix A (section 15.0).

Details for Reference Guide step 2.

The borehole cover prevents objects from falling down the borehole, mainly tools and snow or ice chips. **It takes very little time to cover the borehole, but it takes a lot of time to retrieve objects that fall down the borehole.** It is usually the driller helper's task to cover the hole, but everyone present at the site should keep this in mind. **WHEN THE DRILL IS OUT OF THE BOREHOLE, THE HOLE COVER SHOULD BE IN PLACE.**

Details for Reference Guide steps 3 & 4.

Winch speed is displayed on the LCI-90i (Figure 13-1) and is a useful reference, especially during coring. The maximum winch speed at 100% on the dial reaches approximately 1 m/s depending upon depth. Take a moment to carefully and slowly practice driving the winch while the drill is on the tower to see the relationship between the speed dial and corresponding drill travel.

The driller helper should steady the barrel as the drill string descends, and the drill head reaches the top of the borehole. Once stationary, this is a good time to note the free hanging weight of the drill (~620 N) and zero the tension.

There are two depth readouts on the LCI-90i display: the larger readout indicates total depth; the DIFF readout can be used to show the length of core drilled during the run. Zero the total depth, with the cutters at the snow surface at the top of the borehole, by depressing the right silver button at the bottom of the LCI-90i screen twice quickly. Zeroing the depth is not necessary for every run, but the driller should double check it and zero it if necessary. Note that if there is a large discrepancy between the depth readout and the zero point (top of borehole) when zeroed, the bottom of the borehole will reflect that discrepancy and seem to come either too late or too early on the next run.

Figure 13-1: LCI-90i screen on the faceplate of the Foro Drill Control.

When starting a new borehole, the driller helper should guide the barrel until the anti-torque blades are able to engage the ice. When guiding the barrel, one should keep it as vertical as possible, so as not to affect the borehole inclination.

When adjusting the anti-torque blade bow, one should consider the softness of the firn. There are many places, especially in Antarctica, where drilling the first 10 meters is very difficult, mainly due to the size of the ice crystals (Figure 13-2). Initially, the anti-torque blades may need to be set wider to avoid a drill spin in these firn conditions. Bring the anti-torque blades back in as the firn density increases.

Figure 13-2: Large crystals of the firn ice core.

Details for Reference Guide steps 5, 6 & 7.

Selecting an appropriate cutting pitch is usually an iterative process. Pitch is determined by your cutter head configuration, specifically the shoes you are using. Factors to consider are the density of the ice or firn you are drilling and core quality. Section 9.4 discusses cutting pitch and shoe selection in depth.

Zero the DIFF readout, by depressing the DIFF RESET button to the right of the LCI-90i screen, when cutting action starts at the bottom of the borehole. Generally, there is an increase in cutter amperage seen on the drill current meter when the cutters engage the ice. This bump in amperage can be subtle (+ 0.1 to 0.2 A) and may be hard to see at shallow depths. The driller helper may be able to detect the start of cutting by feeling for pulsing through the drill cable. When in doubt, zero the DIFF at the depth corresponding to the end of the previous drill run. You can always zero the DIFF again if the actual start of coring is detected later.

Zero the WOB readout, by depressing the WOB RESET button, at the same time as you zero the DIFF.

The load cell displays (tension and WOB) provide the driller with feedback pertaining to the cutting action. When the drill is hanging above the cutting surface, the relative tension display value is high (WOB is low), since the weight of the drill string is not being supported by the ice surface. When cutting starts, the tension value will decrease (WOB will increase), since part of the weight of the drill string is now being supported by the ice surface. **Understanding how to interpret changes of the load cell values is essential.**

Each drill run sequence will have a unique set of load cell values, corresponding to:

1. Drill hanging above the cutting surface.
2. Drill starting the cut.
3. Drill in a steady cutting state.

Winch speed may need to be adjusted over the coring run to maintain efficient and consistent penetration. Since the cutting action is relatively fast, changes of the load cell values will also happen fast, and oscillation of the tension/WOB values between high and low will occur throughout the run. Winch speed can be synchronized with the changes in load cell values to maximize coring efficiency.

A typical drilling sequence can be described as follows; when the tension increases (WOB decreases; corresponding to less weight of the drill resting on the borehole bottom), the driller slowly increases the feed rate until the tension/WOB stabilizes; alternatively, the driller slows or stops lowering the drill when the tension decreases (WOB increases; corresponding to more of the drill weight being supported by the borehole bottom). This slowing/stopping of payout should allow the drill to use up any slack in the cable and the drill will eventually cut itself free until all drill weight is off the borehole bottom (tension increases, WOB decreases).

Weight will increase as the drill goes deeper, due to the additional weight of the cable. The load cell values displayed at 10 meters depth will be different than those at 100 meters. What is most important are the relative changes between the high and low values during each run. The objective is to keep the high-low oscillation consistent from run to run, which translates to **repeatable** and **consistent penetration** from run to run.

NOTE: If too much of the weight of the drill is supported by the borehole bottom (low tension/high WOB) over numerous coring runs, the borehole inclination may start to increase. It is best to maintain as low of WOB (high tension) as possible while still achieving efficient cutting.

A decrease in tension (increase in WOB) may signify dull cutters, changing ice conditions, and/or poor penetration. It has been seen in highly stressed blue ice that a period of decreased tension during coring typically corresponds with a section of poor core quality within an ice core (Figure 13-3).

Figure 13-3: Rubble section in middle of core corresponding to low tension while coring.

When the core is retrieved, observation of the core surface often shows delicate grooving left by the cutters. The maximum depth of cut is controlled by the pitch of the shoes, but the groove markings can provide some feedback to the actual penetration as a result of winch speeds. If penetration was steady through the drill run, spacing of the core markings should be uniform (Figure 13-4).

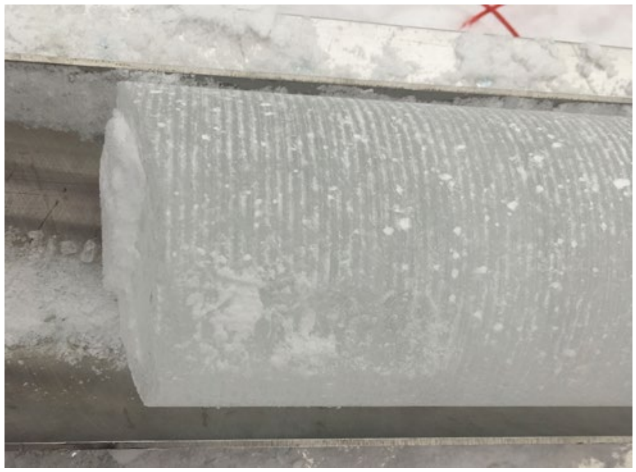

Figure 13-4: Grooves on the surface of an ice core in dense ice.

There are no set rules regarding how fast the drill should be run. However, the two main objectives are to drill good quality cores and to create proper size chips. If the chips are flaky and uniform, the rotation speed and penetration rate is correct. If there are a lot of very fine chips, often called flour, being generated, the rotation speed could be too fast, the cutters may be dull, or the penetration rate is too slow. Evaluation of the chips provides important feedback to the effectiveness of the cutting action. If the chip size is correct, they will move easily up the core barrel flights and the bottom of the borehole will remain clean. If the chips are not removed efficiently from around the cutter head, they will negatively impact core quality and drill penetration.

The core length is limited by the volume of chips being generated and collected in the core barrel. Firn cores are generally longer than ice cores. Typical firn cores can be over 100 cm long, whereas core length in dense ice will be about 80 to 100 cm. The core quality is more important than the core length and should be the primary concern. In dense ice, the chips will be approximately 1.8 times the volume of the cored ice.

Drillers should monitor the amperage of the drill motor. If the drill current spikes rapidly, immediately stop the winch and the drill motor and return to the surface. A rapid spike in current signifies either a full core barrel, a packed cutter head, or an iced up outer barrel. All three conditions significantly affect chip transport, thus hindering free barrel rotation and resulting in a high drill current.

When the drill motor is first turned on while free hanging above borehole bottom, the drill current will read approximately 0.6-0.8 Amps (slightly higher if the drill motor is cold or the outer barrel is icing up). If a significant increase in amperage is noticed prematurely during dry drilling (to a value of 1.5 Amps or greater), it is likely that there is an icing issue. Stop drilling, return to the surface, and address the issue.

NOTE: Amperage values are for blue ice conditions.

Details for Reference Guide step 9.

Slowly increase the winch speed until the core dogs make the core break. Continue to increase the winch speed and raise the drill string to the surface. The maximum safe ascent speed will depend on operator experience and borehole depth. The main determining factors are safety, smooth drill ascent, cable spooling evenly on the winch, and the operators' comfort with the situation. Ascending at 100% on the winch speed dial is acceptable if within the operator's comfort level. Close attention should be paid to tension, depth, and cable spooling during the trip up. When the drill begins to come out of the borehole, and while it is being raised up the tower, it is recommended to decrease speed to 0.15 m/s.

Details for Reference Guide step 10.

With the possibility of different core breaks each run, it is important to check and see if the core is sticking out of the drill every time it is brought to the surface. If the core is sticking out below the cutters, one must manually push it back into the barrel, so the core is not damaged when the barrel is set down in the shallow hole.

With a proper core break, the entire drilled core is retrieved from the borehole, and it is not sticking out beyond the cutters. Comparing the DIFF value to the actual core length retrieved indicates how effective the core break was and if the drill was allowed to cut free (full weight of the drill is hanging on the cable) at the end of coring.

If the core dogs are not functioning properly, the driller can change the length of the core dogs, adjust the spring tension, or sharpen the leading edge of the core dogs. If the core dogs are sliding and leaving grooves in a firn core, the core dogs are probably too short. If the longest core dogs are being used, the engagement should improve in a few runs as the firn density increases. While drilling ice, if the core dogs have been engaging well and then start sliding before engaging, leaving the core sticking out of the barrel, then check that the dogs are sharp, switch to shorter core dogs, or try increasing the spring tension. Generally, as the density of the ice increases you will need to switch to shorter core dogs. However, with the Foro Drill, long dogs were preferable in blue ice as explained in section 9.4.

Occasionally, the core will protrude beyond the cutters due to a bottom break. A bottom break occurs at the cutting face rather than at the core dogs, leaving a few centimeters of core hanging below the cutters. One may see a flange of ice from under the cutting surface attached to the core signaling a bottom break. A bottom break is the sign of a clean borehole free from residual core and chips (Figure 13-5).

Figure 13-5: Bottom core break.

Details for Reference Guide step 11.

If the outer barrel grooves are iced up (Figure 13-6), or the core barrel is packed full, running the drill in reverse to clear chips may be difficult to impossible. Tapping up and down the outer barrel with a rubber mallet may help free the barrels. If the barrels become difficult to separate, it may be necessary to winch them apart with choker cords wrapped around the cutter head and attached to the winch sled (Figure 13-7). Place a thick piece of foam on top of the hole cover as a landing pad for the core barrel. Pay in with the winch to raise the outer barrel. Once the barrels are apart and the core has been unloaded, swap the iced outer barrel with a clean spare.

Figure 13-6: Iced-up grooves in outer barrel.

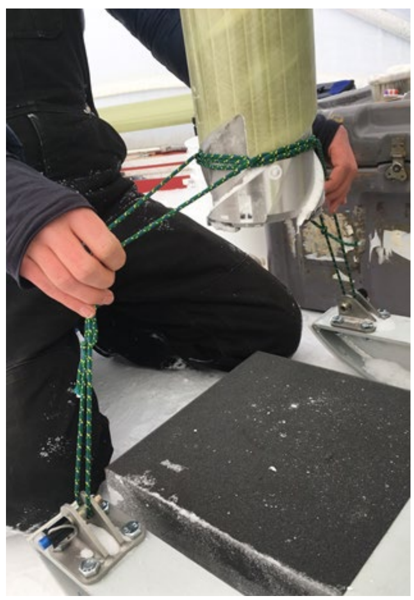

Figure 13-7: Winching apart stuck barrels with thick foam covering borehole to protect cutters.

Iced outer barrels can be cleaned by thawing in the sun, with a heat gun, or by sublimation. Once completely clean and dry, the barrel will need to be cooled before the next coring run. The easiest way to cool the barrel is with it attached to the drill and suspended in the borehole for several minutes.

Details for Reference Guide step 12.

If the drill is raised too high on the tower, the hard limit switch by the crown sheave will be triggered, stopping all winch motion. To clear the winch drive, cycle power to the control box while depressing the button on the back of the control box. The button can be released once the drive powers up. The winch will only function in the payout direction until the drill is off the hard limit switch.

Solar radiation can warm the drill barrel and cause ice chips between the core and outer barrels to melt. Liquid water will freeze after returning the drill to the borehole and can cause the drill to freeze up. It is important to keep the drill cold and dry. In warm temperatures or on calm sunny days, surface operations will have to be made as efficient as possible. Drill components and core trays should be kept out of direct sunlight.

When storing the drill down hole during surface operations, the drill helper will need to move the hole cover out of the way (under the winch is easiest), tilt the core barrel away from the tower, and guide the drill into the borehole.

Details for Reference Guide step 13.

Once the core barrel has been removed from the drill, the cuttings and core can be pushed out. Grab the button and cord for the core-chip separator and pull it out to remove the cuttings. If the core-chip separator is difficult to pull, have another person push on the ice core to break the suction. Rest the top end of the core barrel on the edge of the core tray, insert the core pusher into the cutter head and push the core out onto the core tray. The core pusher should be carefully positioned on the center of the core to avoid any damage to the cutters or core dogs when pushing out the core (Figure 13-8).

Replace the core-chip separator in the core barrel before reinstalling the core barrel in the drill.

Figure 13-8: Core processing station.

Details for Reference Guide step 14.

Move the core barrel from the core processing station to the shallow hole. Now is a good time to clean the flights and collar if necessary and to double check the core-chip separator is in place.

The position of the locking pins should be carefully verified each time they are engaged to make sure they are protruding through the core barrel holes.

Details for Reference Guide Step 15.

Take care when cleaning the cutter head. Cutters and core dogs should be kept very sharp. Always clean cutters and dogs with a plastic toothbrush or piece of bamboo in a downward direction toward the tip of the blade to not dull them. A dental pick may be useful in removing built-up ice from around the core dogs. Now is a good time to take note of any wear on the cutters and change them if necessary. Ensure the hole cover is in place during cutter head cleaning and maintenance.

14.0 Returning Equipment from the Field

Packing of the drill should be a mirror operation to deployment. Drill components taken from specific storage boxes should be returned to the same location. Following that procedure makes packing of the drill components easier and ensures proper packing for shipping.

When packing equipment in the field, clean as much snow off as possible. Where possible, dry the drill components and tools. Accumulated moisture will corrode and damage components and tools during shipping. Document any damage, lost components, or repairs that should be made when the equipment is returned from the field.

15.0 Appendix A

- Weekly Checklist
- Pre-Season Checklist
- Drill Log Template

Foro 400 Drill Preventive Maintenance Checklist				
WEEKLY CHECKS	**WEEK OF: __________**			
ITEM	**ACTION**	**DATE**	**INITIALS**	**COMMENTS**
SLED BASE AND TOWER				
Sled base/winch frame	Inspect for damage and check for settling (level)			
Sled base/winch frame	Inspect for missing hardware and check for tightness			
Sled base/winch frame	Check that it is level			
Tower/crown sheaveInspect for damage/proper operation**WINCH**				
Winch cable	Inspect for damage			
Motor brake	Verify functionality			
CONTROL BOX & DISPLAY				
Control & Display	Inspect for functionality			
Cables	Inspect for damage			
Encoder	Inspect for functionality			
Load Pin	Inspect for functionality			
Sonde Hard Limit Switch	Inspect for functionality			
DRILL MOTOR & ANTI-TORQUE SECTION				
Drill motor	Inspect for functionality/damage/oil leaks			
Anti-torque	Inspect for functionality/damage			
Hardware	Verify all hardware is in place and tight			
BARRELS				
Inner & outer barrel	Inspect for damage			
Inner barrel locking pins	Inspect for functionality			
CUTTER HEAD				
Fasteners	Inspect for damage and tightness			
DRILL TENT				
Fabric and frame	Inspect for damage and wear			
Ropes and rigging	Inspect for damage and wear			
Ropes and fabric	Check for proper tensioning			
Anchors	Verify anchor points are sound and not coming loose			
NOTES:				

Foro 400 Drill Preventive Maintenance Checklist				
PRE-SEASON CHECKS (to be performed before the drill system is shipped from IDP)				
Field Project:				
ITEM	**ACTION**	**DATE**	**INITIAL**	**COMMENTS**
Sled Base and Tower				
Sled/winch frame & hitch	Inspect components for damage			
Tower	Inspect for damage and proper fit of tower sections			
Crown sheave	Inspect for damage and proper operation			
Fasteners	Inspect for missing hardware and check for tightness			
WINCH				
Winch cable	Inspect cable and cable termination for damage			
Gearbox	Check for smooth/quiet operation			
Winch motor	Verify motor & brake are functioning properly			
Cable continuity	Check cable conductor continuity and resistance			
CONTROL BOX & DISPLAY				
Control & Display	Inspect for damage/functionality			
Internal connections	Check that all wire terminations are tight			
Cables	Inspect for damage & strain reliefs are tight			
Encoder	Verify proper operation and calibration			
Load pin	Verify proper operation and calibration			
DRILL MOTOR & ANTI-TORQUE SECTIONS				
Drill motor	Inspect for functionality			
Transmission	Replace seals and check fluid level if leaking			
Core barrel quick locks	Inspect for damage/functionality			
Anti-torque	Inspect for damage/functionality			
Anti-torque springs	Inspect and sharpen as needed			
Fasteners	Inspect for missing hardware and check for tightness			
CORE BARRELS				
Inner & outer barrel	Inspect for damage/wear			
Fit check	Verify proper fit with motor section and cutter heads			
		OVER →		

ITEM	ACTION	DATE	INITIALS	COMMENTS
CUTTER HEADS				
Heads	Inspect for damage and verify fit with mating parts			
Fasteners	Inspect for damage and verify proper quantity			
Springs	Inspect for damage and verify proper quantity			
CUTTERS & SHOES				
Cutters	Inspect for damage and sharpness			
Quantity - Cutters & Shoes	Verify proper quantity & types are included for the project			
CORE DOGS				
Core dogs	Inspect for damage and sharpness			
Quantity	Verify proper quantity & lengths are included for the project			
SPARE PARTS				
Fasteners	Verify spares are included			
Winch motor	Verify spare is included			
Winch gearbox	Verify spare is included			
Transmission oil (MTR sect)	Verify spare is included			
EverGrip termination	Verify spare is included			
Load pin	Verify spare is included			
Anti-torque springs	Verify spares are included			
Drill motor and AT sects	Verify spares are included			
Core barrel assembly	Verify spare is included			
NOTES:				

Drill Log

Project:	Control Box:	Motor/AT Section:
Location:	Barrel Set:	AT Setting:
Date:	Head:	Drill RPM/Volts:
Drillers:	Core Dogs:	Generator:
Drill Configuration:	Cutters:	
Initial Setup:	Shoes:	

Changes [-]	**Date**	**Time**	**Run #**	**Start Depth [m]**	**End Depth [m]**	**Drilled [cm]**	**Recovered [cm]**	**Core Quality [pcs]**	**Drill ROP [mm/s]**	**Drill Current [Amps]**	**Core Break [N]**	**Comments**

Changes [-]	Date	Time	Run #	Start Depth [m]	End Depth [m]	Drilled [cm]	Recovered [cm]	Core Quality [pcs]	Drill ROP [mm/s]	Drill Current [Amps]	Core Break [N]	Comments