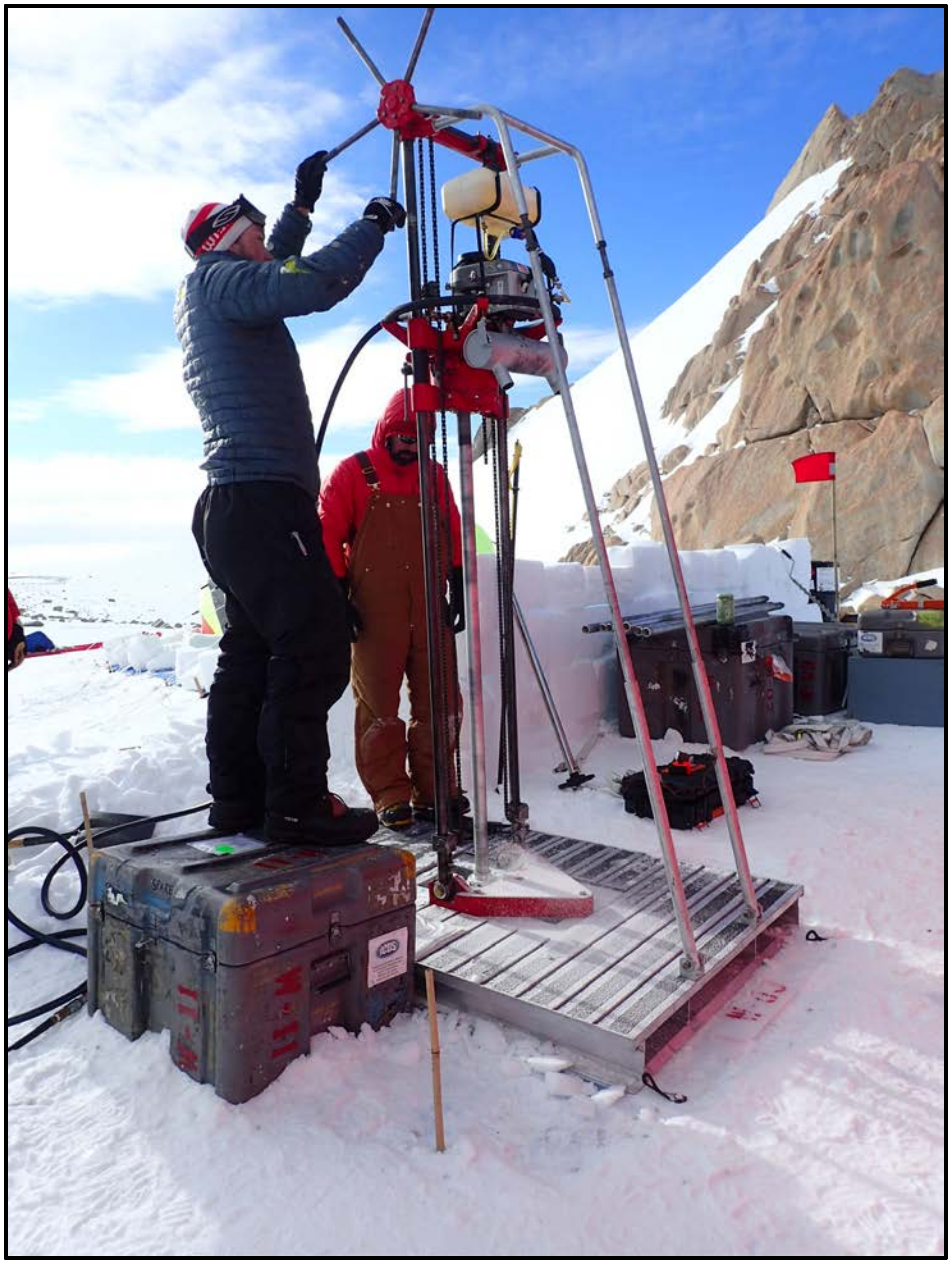

WINKIE DRILL

Operations and Maintenance Manual

October 29, 2019

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

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1.0 PURPOSE

1.1 This document outlines proper set up and operation of the Winkie Drill.

2.0 SCOPE

2.1 This document applies to all personnel working with the Winkie Drill.

3.0 REFERENCES

3.1 8323-0014 ASIG Auger and Packer Test Report

3.2 8393-0017 Winkie WI Field Test Report

3.3 8393-0018 Electric Motor Test Report

3.4 8393-0019 Equipment Packing List

3.5 8512-0006 Operations and Maintenance Manual (Eclipse)

4.0 DEFINITIONS

4.1 ASC – Antarctic Support Contractor; the logistics support provider for the United States Antarctic Program (USAP)

4.2 ASIG – Agile Sub-Ice Geological Drill; an ice and rock coring drill system developed by IDP with depth capability to 700m

4.3 BLDC – Brushless Direct Current

4.4 IDP – U.S. Ice Drilling Program, formerly IDDO

4.5 PDC - Polycrystalline Diamond Compact (bit material)

4.6 PFS – Polar Field Services; the logistics support provider for the United States Arctic program.

4.7 PI – Principal Investigator

4.8 QAS – Quality Assurance and Safety group

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

4.10 WD – Winkie Drill

4.11 WDS – Winkie Drill System

5.0 RESPONSIBILITIES

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

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

5.3 Project personnel are responsible for understanding this manual for safe set up and operation of the Winkie Drill.

6.0 RECORDS

6.1 None.

7.0 SAFETY

7.1 The Winkie Drill is an agile drill capable of drilling 33.5mm and 71.7mm diameter cores in blue ice, rock, or a mixture of both. Only trained personnel should operate the Winkie Drill. All Winkie Drill personnel should read and understand the following safety precautions.

7.2 Personal Protective Equipment (PPE)

7.2.1 PPE – Workers shall wear appropriate hand, eye, and ear protection during the entire drill operations – drilling, handling fluids, rod tripping, etc.

7.3 Mechanical Safety

7.3.1 Pinch Points – There are several areas on the drill where a finger, hand, arm or clothing could be pinched. Operators should identify all pinch points prior to operation and should be mindful of all such points during operation.

7.3.2 Rotating Components – Drill rods, core barrels, and bits may be rotating and exposed to the operator on the surface. Keep hands, limbs, loose clothing, and hair away from any rotating components during drill operations. Always ensure the transmission is in neutral when handling drill rods attached to the rig.

7.3.3 Eye Protection – Operation of the Winkie Drill requires eye protection be worn by operators at all times. This includes during both dry and wet drilling.

7.3.4 Burn Hazard – The exhaust and engine of the generator can become extremely hot. Avoid contact with hot generator components. If service is required, allow time for the components to cool.

7.3.5 Cold Hazard – Drill rods, core barrels, bits, and drilling fluid may be extremely cold after being in the borehole. Always wear appropriate gloves when handling.

7.3.6 Slippery Surfaces – Rig footing and surrounding ice may become slippery when wet with drilling fluid. Use caution whenever walking on the rig footing or around the drill operations area.

7.3.7 Overhead Masses – Drill rods, hoist ring, and tripod components are above head level. Be mindful of hazards and always work as a team when using the winch to lift drill rods. Ensure composite toe boots are worn when suspended masses are present.

7.4 Electrical Safety

7.4.1 Voltage – Extreme care shall be taken when assembling, disassembling and servicing electrical equipment. Always disconnect power before servicing equipment.

7.4.2 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.

7.5 Chemical Safety

7.5.1 PPE - Use fluid resistant gloves and eye protection whenever handling drilling fluid.

7.5.2 Other Chemicals - Use care and observe all safety warnings when handling Ethanol and/or other chemicals.

7.6 Environmental Safety

7.6.1 Cold – 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.

8.0 INTRODUCTION

8.1 The Winkie Drill System (WDS) is an agile, lightweight, portable commercially-available rock coring system, designed by Fred Wink and sold by Parts Head Quarters Inc. IDP has modified the WDS for subglacial rock and ice/rock interface coring, as well as drilling and coring access holes through ice. The WDS uses a blushless DC motor with a two-speed gear reducer and Unipress hand feed system. Using standard AW34 drill rod (for 33.53 mm diameter rock and ice core), the system has a depth capability of 120 meters. The system has also been adapted to collect 71.7mm cores at up to 12m with an Atlas Copco 86T2 core barrel system and custom drill rods. The drill uses traditional forced fluid circulation during coring, as is common in rock coring applications. The drill can be configured with casing and packer, allowing the drill to be operated in areas of blue ice, snow, or firn. Operation of the WDS results in minimal environmental impact, and the system will operate from sea-level to high altitudes. Variable drilling speeds, using a two-speed transmission (100 rpm to 1666 rpm), allow the WDS to operate efficiently and allows the operators to adjust operational parameters to the type of formation being drilled and core diameter. Aluminum or thin-wall steel drill rods reduce the overall system weight. The Unipress frame enables the driller to exert a steady feed pressure with minimal physical exertion. The drill can be easily and quickly assembled and disassembled in the field for shipping.

9.0 WINKIE DRILL SYSTEM AND SUB-SYSTEMS

The main components, Fig. 1, of the WDS include:

- Drill rig
- Tripod with capstan winch
- Downhole tooling – augers, drill rods, and core barrel assemblies
- Circulation system, including casing and packers, and drilling fluid
- Tooling and spares
- Environmental protection – wind screen
- Transportation equipment

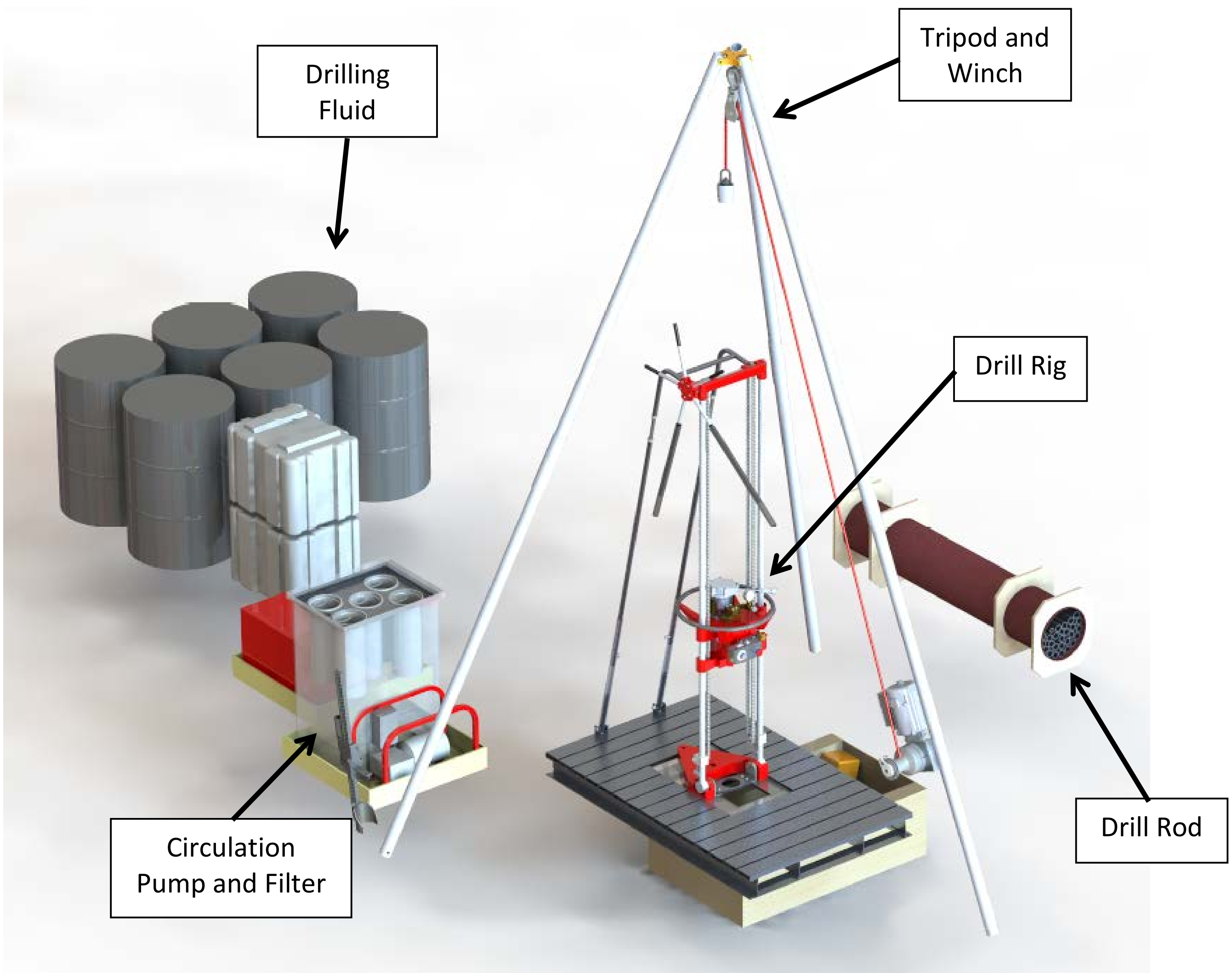

Fig. 1. Layout of the drill rig and major components.

9.1 Drill Rig

The WDS drill rig is comprised of the components that support and generate the power to drive the downhole tooling. The sub-systems that make up the drill rig include the footing, Unipress frame with hand wheel, and power-head.

9.1.1 Rig Footing

The force generated by the weight of the rig, drill rod and the force of core breaks, must be spread across a large surface to ensure the drill does not sink into the firn. For this purpose, a modified aluminum pallet with an UHMWPE base has been added to the system. This footing must then be anchored to the firn or ice to anti-torque the drill as well as hold the rig down when feed pressure is applied. Methods for securing the footing will be discussed in Section 10.2.1.

9.1.2 Unipress Frame

The Unipress is the frame to support the power-head. It consists of the base, rod guide assembly, slide rails, hand wheel, tilting legs, chain, and chain tensioning system (Fig. 2). As a whole, the role of the Unipress is to anti-torque the powerhead while providing linear travel as the drill string progresses.

The base is rigidly attached to the rig footing with three hex head bolts. The slide rails and rod guide assembly are mounted to the base. The base is also used as a rigid structure to support the auxiliary core break jack (discussed in Section 11.1.10).

The purpose of the rod guide bearing is to support the drill rod. Should the borehole become oversized, the rod guide will suppress rod whip near the surface. See Section 11.1.7 for further explanation of rod whip. The bearing surface is a plain bearing that does not need to be lubricated. The guide bearing assembly and rig base can be seen in Fig. 3.

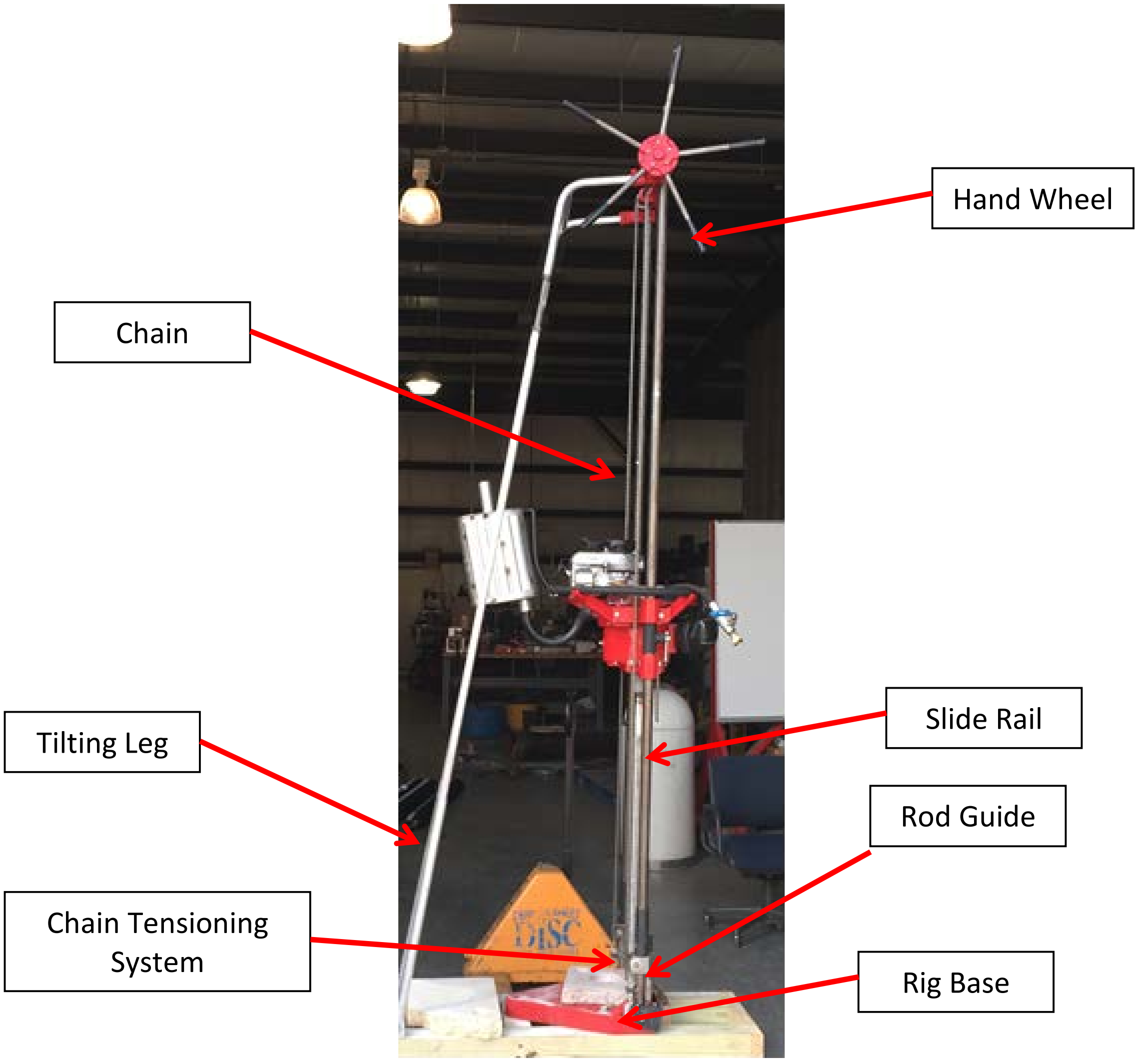

Fig. 2. The assembled Unipress frame.

Fig. 3. Unipress base and rod guide assembly. NOTE: 3/4-10 hex bolts have been extended and jam nut must be used to prevent loosening from vibration.

The assembled drill rig requires two slide rails to guide the power-head assembly. The purpose of the rails is to anti-torque the power-head during drill operations and allow the power-head to travel vertically as the drill string progresses. One slide rail is marked with 0.1 m increments for approximate depth tracking.

At the top of the slide rails is the hand wheel assembly. The hand wheel is the mechanism used by the drill operator to guide the power-head along the slide rails during drilling. The hand wheel is the primary input of the drill operator, and is one of few paths through which the operator receives feedback from the drill on downhole conditions. The rig system includes two hand wheel extensions to make operation from the ground easier. The extensions also reduce the effort required to apply feed pressure and reduce operator fatigue.

Force is transferred from the hand wheel to the power-head by two roller chains. At the base of the slide rails is the mechanism to tension the chain. There is also adjustment at the power-head to equalize chain tension between the two chains. See Section 10.2.2.5 for the chain installation and tensioning procedure.

9.1.3 Power-Head Assembly

The Winkie Drill power-head consists of a brushless DC (BLDC) electric motor with integrated drive, planetary gear reducer (optional), motor controller, transmission, and water swivel, Fig. 4.

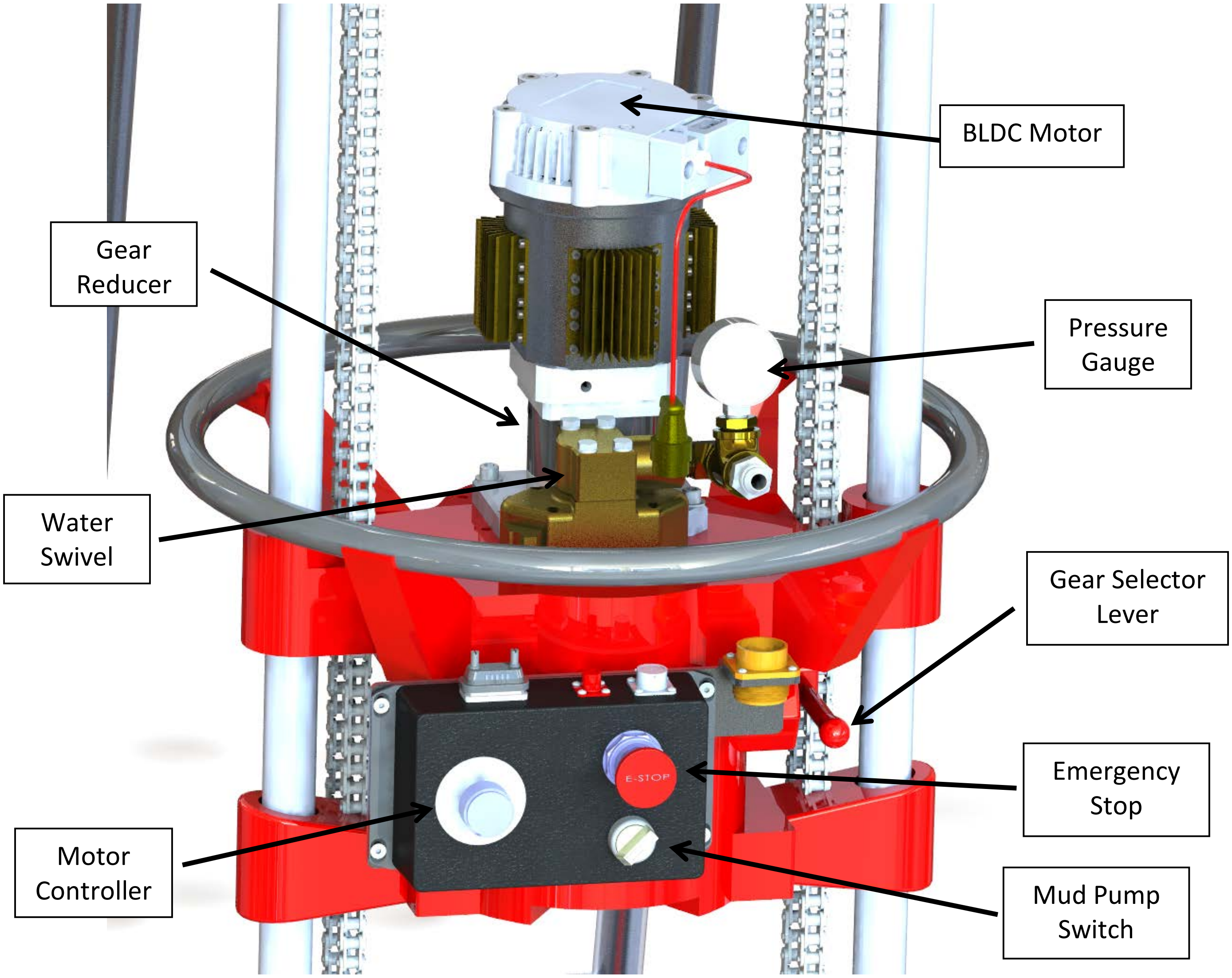

Fig. 4. Winkie power-head components.

The torque for drilling is generated by an Evo3 BLDC motor. The required drive electronics are integrated into the top of the motor. The assembly is rated to IP54 (splashing water). The user interface with the motor is accomplished with a push-button E-stop and potentiometer knob mounted on the front of the power-head.

When drilling with the 86T2 core barrel assembly, high torque and low speed is desirable. The 3:1 planetary gear reducer should be added between the motor housing and transmission when using the 86T2 core barrel. Note that a different mount plate is needed to adapt the gear reducer to the transmission, PN 83930084.

The two-speed transmission contains the gear selector and water swivel. The transmission is lubricated by an oil bath of 75W-90 gear oil. The purpose of the water swivel is to allow drilling fluid to be pumped into the rotating drill string under pressure. Circulating drilling fluid through the drill rods and down to the bit is required to flush away cuttings and cool the bit.

9.2 Augers

When an access hole through clean ice is desired (without collecting core samples) the quickest option is to use a string of augers. The primary advantage of the augers is the ability to drill without drilling fluid. Without drilling fluid, the process is quick and clean. The augers are modified Kovacs Enterprise ice augers. Each auger section is 1 m in length and 5 cm in diameter so only the AW34 core barrel assembly can be passed through the access hole for future samples. The bit uses replaceable carbide inserts, Fig. 17.

9.3 Wet Drilling Downhole Tooling and Circulation System

Wet drilling refers to the drill configuration that uses pumped fluid to transport ice and rock particles to the surface. Wet drilling must be done anytime core samples are collected. This is done for two reasons. First, the fluid is needed to remove particles from the borehole. There are no flights or chip storage areas in the drill string so the cuttings must be pumped to the surface, suspended in the fluid. Second, the fluid keeps the bit cold when rock coring is occurring. Without fluid, the bits could burn into the rock, wrecking the bit or sticking the drill string.

9.3.1 Downhole Tooling

The WDS can be configured to collect two different core sizes with minor modification. A 33.5 mm core will be collected with AW34 downhole components and a 71.7 mm core will be collected with the use of a 86T2 components. For both the AW34 configuration and the 86T2 configuration, the downhole tooling includes drill rods, core barrel assembly, and coring bit. These three components, together, transfer the power from the drive-head into crushing the rock or cutting the ice and collecting a core.

9.3.1.1 Drill Rod:

Drill rods act as a rigid connection between the power-head and core barrel assembly. The WDS has two sets of drill rods, one for AW34 coring projects and one for 86T2 coring projects. The AW34 rods are 5 feet long each (1.524m). The body of the rod is made from aluminum with box threads on each end. There is a steel coupler to join them together. Each rod section with coupler weighs 7.5 lbs (3.4kg). The 86T2 drill rod is assembled with one pin thread and one box thread and is made of steel (4140 coupler, 1020 mid-body). The assembled length is 4.92 ft (1.50m) and weighs 17.0 lbs (7.7kg).

9.3.1.2 Core Barrel:

The core barrel is a narrow kerf, double tube system. At the top of the assembly is the bearing section. The bearing sections allow the inner barrel to be stationary and support the core while the outer barrel rotates the bit at its base. Slid onto the bottom of the inner barrel is the core lifter and lifter shoe. The lifter is a tapered collet that allows the core to slide into the barrel but then holds the core when the drill string is lifted. Fig. 5 shows an exploded view of the AW34 core barrel. A detailed parts list of the core barrel can be obtained from IDP, see Section 14.1.

9.3.1.3 Bits:

Three bit types are included with the WDS, Fig. 6, each intended for optimum performance in different media. The AmSet bit (Fig. 6a) is effective when drilling through ice, dirty ice, or ice with suspended pebbles. However, it dulls quickly when drilling hard sediment samples (such as granite). The PDC bit (Fig. 6b) also cuts ice, dirty ice, and suspended pebbles well. The PDC bit has greater ability to core hard formations but still is not designed for that application. The 86T2 PDC bit cuts well at 100 rpm. For hard rock formations, an impregnated bit (Fig. 6c) is the most effective option. Impregnated bits also come in different series to match the formation being drilled. Typical series to be included with the drill are #6 through #14. Series #6 should be used in soft rock formations and series #14 should be used in the hardest rock formations. Impregnated bits should be rotated much faster than either the AmSet or PDC pits. Typical AW34 speeds are around 1500 rpm and 86T2 speeds are around 700 rpm.

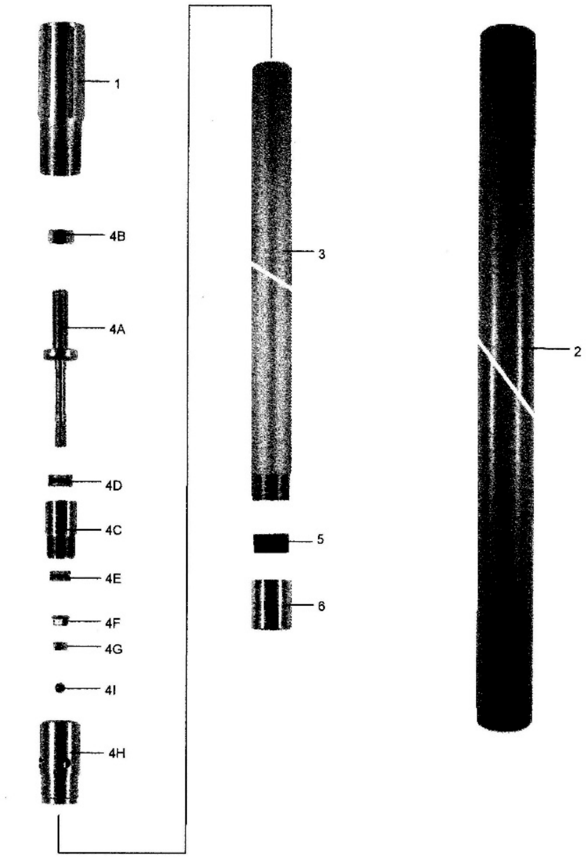

Fig. 5. The core barrel components seen in an exploded view from the American Diamond Tool catalogue.

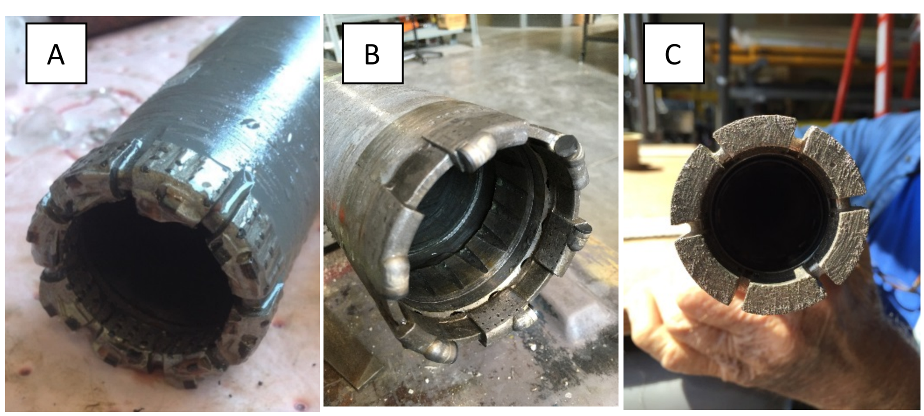

Fig. 6. (A) Amset bit – best suited for cutting solid ice, dirty ice, and suspended pebbles
(B) PDC bit – effectively cuts ice, dirty ice, suspended pebbles, and soft rock formations
(C) Impregnated bit – cannot core any type of ice; varying series for formation properties

9.3.2 Circulation System

Drill fluid is used to flush ice and rock particles away from the face of the bit and transport them to the surface. Isopar K is used as the drill fluid. The Isopar K must be recovered, filtered, and reused when it returns to the surface. There are four main components to the fluid circulation system: drilling fluid, mud pump, pit pump, and filtration tank. The system layout can be seen in Fig. 7.

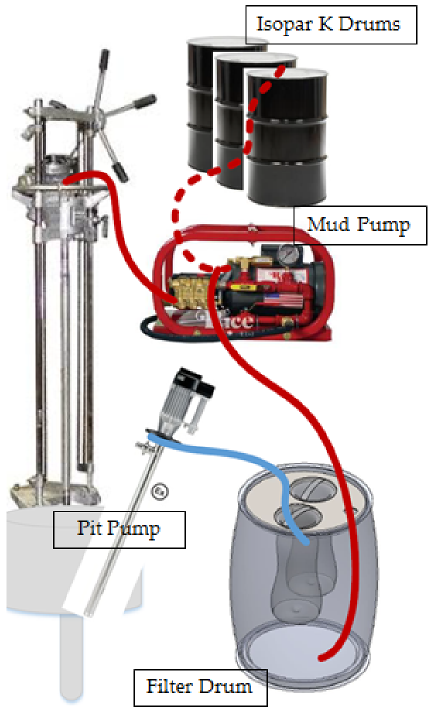

Fig. 7. Wet drilling fluid circulation schematic.

9.3.2.1 Drill Fluid

To keep the bit temperature below freezing, it is critical that a liquid is used as a circulation media rather than air. Isopar K has been chosen as the best candidate based on density, viscosity, and thermal mass as well as safety to personnel and the environment. A list of all job related chemicals and associated hazards can be found in Section 14.2, Table 4. Printed copies of all chemical Safety Data Sheets (SDS) are provided with the drilling equipment.

9.3.2.2 Mud Pump

The role of the mud pump is to pump clean fluid from either the Isopar K drums or the filter tank down the drill rod, across the bit, and back up the annulus around the drill rod (carrying ice and rock chips). The pump speed is variable to optimize drilling parameters. The characterization of flow output can be seen in Table 1. There is also an adjustable blow-by valve that can be set from 0-300 psi. Testing conducted for IDP for the ASIG Drill System predicts that ice fracturing will occur at a fluid pressure near 200 psi so the blow-by valve should not be set above 200 psi.

Table 1. Mud Pump output flow characterized as a function of the VFD dial position.

Dial Position [-]	Flow Rate [gpm]
2	0.42
4	1.15
6	1.76
8	2.40
10	3.00

9.3.2.3 Sump Pit and Pit Pump

When the Isopar K returns to the surface, it is collected in a sump pit below and to the side the rig footing. For this system, it is essential that crack free ice is present up to the surface so that the drilling fluid can be contained without additional equipment. After the drilling fluid pools in the sump pit, it is pumped into the filter drum via a Lutz drum pump. The pump operates with a centripetal vane that can handle both the rock and ice particles that may be suspended in the fluid.

9.3.2.4 Filtration Drum

After the Isopar K has cooled the bit and transported chips back to the surface, it cannot be discarded into the Antarctic environment. Instead, it is pumped into a gravity forced filtration system (Fig. 7). The fluid is pumped into 100 micron filter socks. As the sock fills with fluid or is plugged, the flow is transferred to another sock as the first is cleaned. The drum can hold as much as 30 gallons of fluid and is translucent so the fluid level can be monitored easily.

9.3.2.5 Casing

Casing is required whenever wet drilling is conducted in snow, firn, fractured ice, or any other scenario where drill fluid could be lost along the return path around the outside of the drill rod. The casing lines the access hole, sealing the drill fluid from escaping into the surrounding environment.

The casing used for AW drill rod is a thin wall steel BTW drill rod. The ID is 1.909”, nearly perfectly matching the drilled borehole diameter. The rods weight 3.50 lbs/ft.

Casing sections are lowered into the borehole using the same technique as tripping rods with the tripod, hoist ring, Kwik Klamp, and tube wrenches. Depending on the access borehole diameter, centralizers are needed to support the casing from buckling, Fig. 8(A). Centralizers should be installed at intervals not greater than 5 m. The centralizers can be installed with a set screw in the body of the centralizer or with an aluminum ring above and below the centralizer to allow for free rotation of the casing string. This is needed for the use of the burn-in casing shoe described below.

Fig. 8. (A) Centralizer installed with aluminum collars for free rotation. (B) Freeze-in casing shoe with polished steel casing nose piece.

When the casing is used, the sump pit box assembly must be used to collect the fluid returning to the surface. The sump pit box is PN 83930148.

9.3.2.6 Casing Packers

There are several solutions available for sealing the bottom of the casing to the access borehole wall; an inflatable packer, burn-in impregnated shoe, and freeze-in polypropylene shoe.

9.3.2.6.1 Inflatable packer

The inflatable packer has been used by several drill systems and numerous drilling projects to seal casing. Because it has been tested by these systems, it is the most promising solution and should be considered the primary tactic. The concept is quite simple, there is a bladder that surrounds a tube in the access hole. When air is added to inflate the bladder it applies a pressure on the borehole wall, sealing fluid below the packer.

The packer procured for the WDS is made by QSP Packers, LLC. The packer has a 2.00-inch ID, 24.50-inch element length and weighs 30 pounds. The bladder material is wrapped in Neoprene for drill fluid compatibility. Inflation is done via a ¼ inch nylon hose that runs to the surface where it is connected to the high pressure, MAX PowerLite air compressor. The compressor will store air at 500 psi, however, the packer should not be inflated beyond 200 psi. Field tests and deployments with the ASIG drill system suggest 150 psi is an effective pressure for sealing without increasing the risk of ice fracture. The inflation procedure is as follows:

- Run the compressor, filling the tanks to 500 psi. Screw out the high pressure regulator to keep pressure below 200 psi through the after treatment. Let the compressor cool. The highly compressed air will be warm and at dew point. Letting the air cool to ambient will condense out as must water as possible.
- Connect the ¼" nylon air hose to the packer with the compression fitting. Secure a second nylon hose to the casing just above the packer, this line is used to inject ethanol if the packer becomes stuck. Trip the packer to the bottom of the access hole, adding centralizers as needed and securing the nylon lines with electrical tape. The packer must be placed in firn with density of 0.87 g/cm^3 or greater.
- Attach the quick connect fitting to the compressor. Use the compressor regulator to increase the pressure up to 150psi. Monitor the pressure as drilling operations continue.

9.3.2.6.2 Burn-In Casing Shoe

If it is determined that an inflatable packer will not effectively seal the access hole a burn-in casing shoe can be explored as on option. The inflatable packer may not work because the firn did not reach a sufficient density or there are known voids in the ice or interface below the packer. The burn-in shoe is an impregnated bit with no waterways that threads directly onto the end of the casing string. The bit can cut, melt, or grind its way into the rock formation at the bottom of the borehole. It is intended to be used into bedrock but could be effective in any media it can generate enough heat to melt an annulus. The bit can then be froze in place or removed for the polypropylene freeze-in shoe.

9.3.2.6.3 Freeze-in Shoe

The freeze-in casing shoe is a polypropylene tube with o-ring that slips onto the end of the steel casing string, Fig. 8(B). When water is added to the bottom of borehole, submerging the bottom of the shoe, the water freezes to the shoe forming a water-tight seal. The water is added in a bulk amount using the fluid bailer. One full bailer deployment fills the borehole with 2 feet of water (sufficient to seal to the casing shoe). Depending on ice temperature, the water could take up to several days to completely refreeze. When the water is frozen the ice filing the tube is drilled or cored and sampling continues past the now sealed casing.

9.4 Tripod and Winch

The purpose of the tripod is to quickly trip the drill string into and out of the borehole with limited fatigue to the operator. The winch is a self-tailing capstan winch with two speeds and foot switch. Supplied with the winch is 40m of static nylon rope. The rope can be attached to either the hoist ring adapter or ball-type rod puller depending on the drill rod being used and configuration.

The tripod is also used in conjunction with the fluid bailer sub adapter to recover fluid from the borehole when the drilling is complete, Fig. 9.

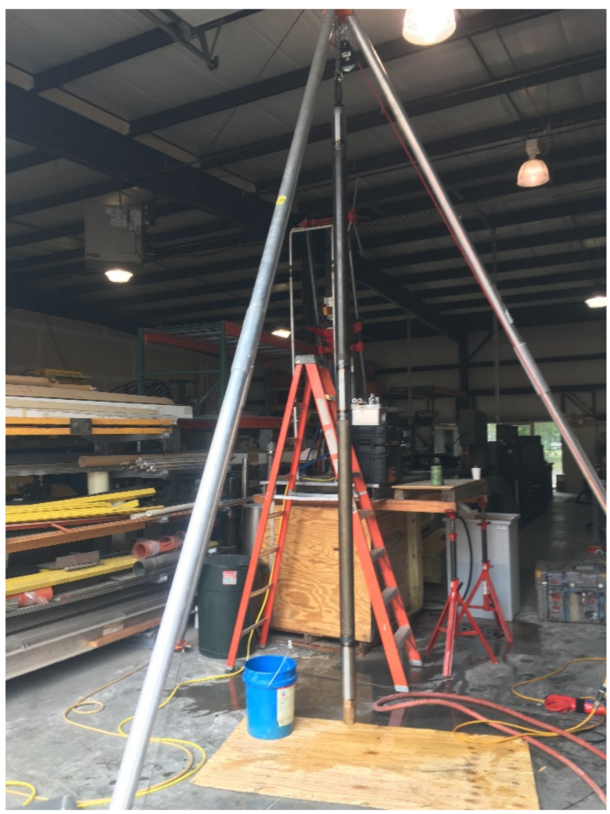

Fig. 9. Tripod with suspended drill rod and bailer sub adapter.

9.5 Tools and Spares

Supplied with the WDS is a complete set of hand tools and spares for the drill system. A list of spare parts and packed locations can be found in the packing lists for each field deployment.

9.6 Protection from the Elements

Structures for environmental protection will be evaluated and provided based on specific drill sites. Options for protection include windscreens and tents.

9.7 Transportation Equipment

To provide efficient field operations, the rig must be transported between drill sites easily and in as little time as possible. However, each drill site has unique limitations so transportation will be evaluated for specific drill projects. In general, Siglin sleds are an effective means to transport the WDS short distances while in the field. In addition, no individual piece packed for shipping weighs more than 250 lbs (113.4 kg).

10.0 SITE SETUP

10.1 Site Preparation

If the drill site has solid ice up to the surface and is frozen to the bedrock interface the drill rig can be set up immediately. The surface should also be relatively flat. However, if the drill site selected is snow, firn, or has known voids before reaching bedrock, an access hole must be drilled and casing added and sealed.

Depending on weather conditions, setting up the windscreen may be a beneficial first step. The windscreen can be used to block the wind or shade the drill and fluid circulation system on warm days. The posts for the windscreen can be inserted into holes drilled with the supplied ships auger. The guy lines can be anchored using either the supplied ice screws or with a v-thread anchor, Fig. 10.

Fig. 10. V-thread anchor © George McEwan Collection

10.1.1 Blue Ice Drill Site

Begin the process of preparing the ice by using the electric chainsaw provided by the logistics provider to cut a sump pit into the ice that is approximately 16” on all sides. Once again, this sump pit needs to be cut into solid ice so that drilling fluid is not lost into cracks during wet drilling operations. If small cracks are present, it may be possible to seal the sump walls with the supplied heat gun. It will be beneficial to have the bottom of the sump pit inclined up slightly toward the borehole to avoid having rock and ice chips re-enter the borehole. One corner should also be cut or drilled lower as the pick-up area for the pit pump. This will make it possible to pick-up the maximum amount of fluid for recirculation. See Fig. 11 for an example of the ideal sump pit.

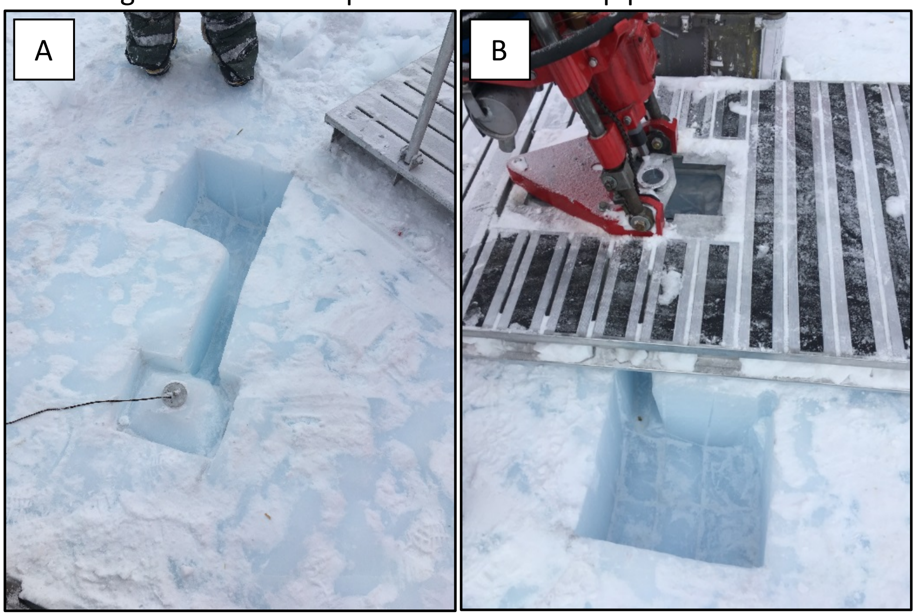

Fig. 11. (A) Sump Pit, Uncovered – using a chainsaw or handsaw, cut the sump pit that directs all fluid and drill chips away from the borehole.
(B) Sump Pit, Covered – when the rig footing is centered over the borehole, the sump pit should be accessible with the pit pump.

10.1.2 Snow or Firn Drill Site

When there is not solid ice at the drill site an access hole must be drilled and cased to seal the drill fluid from running into the porous firn. The preferred method for drilling an access hole is to use the IDP Eclipse drill. This allows density measurements to be made, ensuring the packer is placed at a depth with minimum density of 0.87 g/cm^3. The operator’s manual for the eclipse drill can be found in document #8512-0006. Drilling with the Eclipse drill should continue until either the bedrock is reached or density measurements reveal a density sufficient for setting the packer.

When the access hole is complete, assemble and place the packer as described in section 9.3.2.6.1. The sump pit in the ice is replaced by a welded polyester tank clamped to the casing with a shaft collar. The fluid is diverted into the tank with a piece of layflat tubing and hose clamp. The tank has a fitting for draining into the filter tank or the sump pump can be used to pump the fluid from the sump.

In the event that an inflatable packer will not seal, consider using either the burn-in or freeze-in casing shoe described above.

10.2 Drill Rig Assembly

After the ice surface is prepared and wind protection is in place, the rig can be assembled. Start by anchoring the footing. Then build the drill rig up from the footing. Finally connect the circulation system components with containment.

10.2.1 Anchor system

Follow these steps to create your anchor system.

- Locate Footing

  Begin by placing the rig footing over the sump pit. Locate the footing so that drill rod bearing is directly above the desired location of the borehole.

- Locating Ice Screws

  Use four ice screws mounted through the UHMW plastic sheet in the footing to secure the footing to the glacier.

- Hold-Down Anchor

  Using either four ice screws or four v-thread anchors and webbing, slings, or ratchet straps, create a rigging system to hold the footing from lifting (this could happen if high feed pressure is applied).

  When the “anchor system" is referenced throughout this document, the above three steps describe the construction. The anchors consist of four ice screws, four v-threads or ice screws, and webbing or cargo straps.

10.2.2 Drill Rig

10.2.2.1 Now that the footing is secured to the ice, the rig can safely be assembled to the footing without risk of shifting.

10.2.2.2 Locate the rig base and attach it to the footing sub-frame using the supplied fasteners. NOTE: Use medium strength thread locker.

10.2.2.3 Locate the power-head (including the power-head brake assembly) and slide rails. Have an assistant hold the power-head in the proper position while the depth-marked slide rail is assembled through the power-head guides and threaded into the pin connection on the rig base. Assemble the power-head brake and footpad and hold in the proper position while the second slide rail is assembled. Allow the rails to tilt forward and rest on the rig base (they should be approximately 45° from vertical). NOTE: The depth-marked slide rail and power-head brake can be assembled on either side of the rig, but be conscious of their location for easy operation. NOTE: Use thread compound on slide rail connections.

10.2.2.4 Assemble the upper pin connection, threaded rod, slide rail extensions, and hand wheel housing to the top of the slide rails. NOTE: Ensure the hand wheel housing is orientated with the chain sprocket facing rearward. NOTE: Use medium strength thread locker on slide rail extension nuts and use thread compound on slide rail pin connection.

10.2.2.5 Route the chains through the sprockets and join using the included master links (Fig. 12). Tension and equalize the chain as needed. NOTE: Be careful to keep the power-head resting on the base of the rig throughout this process to prevent damage to the slide rails or base.

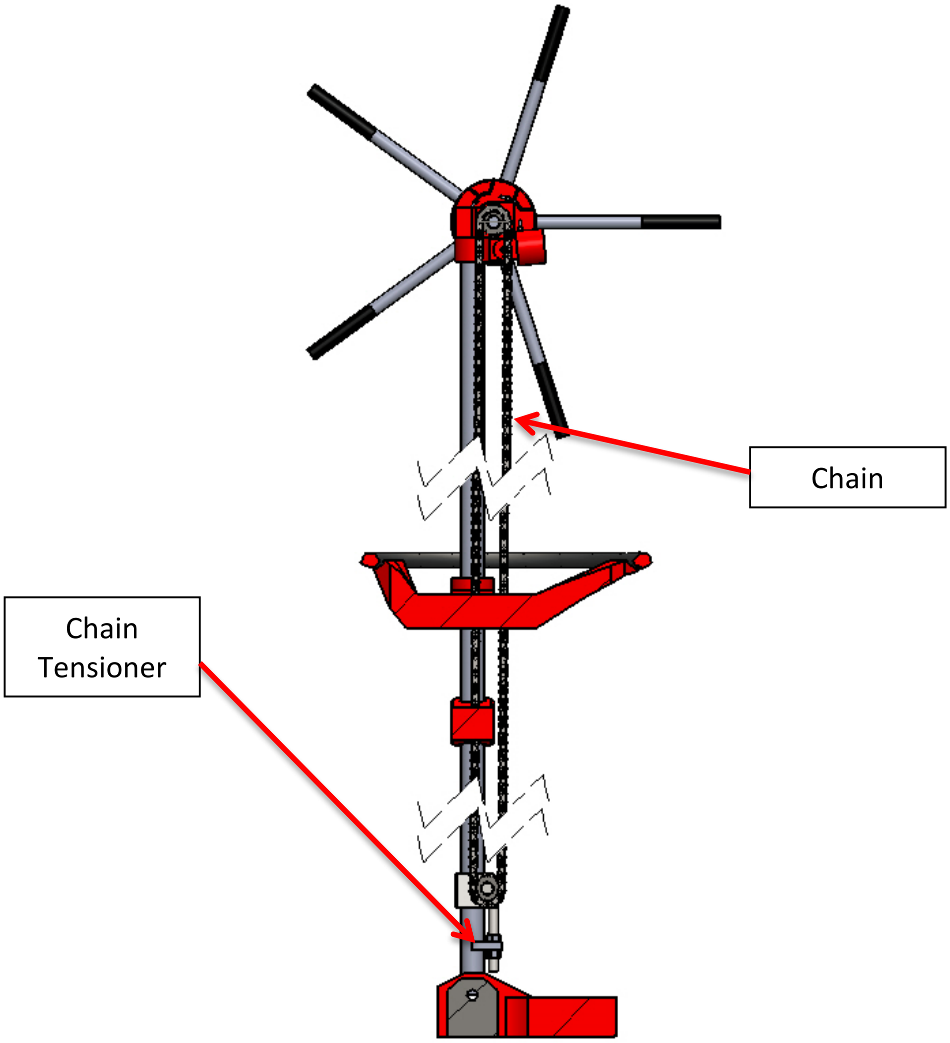

Fig. 12. Section view of chain path and location of tensioner.

10.2.2.6 Assemble the tilting legs to the footing and at the top of the slide rails. Using an assistant, tilt the rig into a vertical position while guiding the upper legs into the lower legs. Verify both locking pins are active when the rig is vertical. NOTE: Use medium strength thread locker on all threaded connections and setscrews.

10.2.2.7 Connect the power cable to the drill and run the extension cord to the generator.

10.2.2.8 Check the lubricant level in the transmission. Add lubricant as needed.

10.2.3 Circulation System

See Fig. 7 for the correct hose connection pattern. All hoses have identical specifications; however, one hose assembly only has one JIC fitting. This hose must be used for either the pick-up into the mud pump or the output from the pit pump.

Use proper containment berms supplied by the logistics provider (e.g. ASC, PFS) for the drilling fluid drums, filtration drum, fuel cans, and generator.

10.3 Tripod and Capstan Winch

The tripod should be assembled with at least two people. Begin by laying out the P-cord and carabiner harness with the carabiners in the approximate location of each foot of the tripod. Next, run the nylon rope through the pulley and ensure there is sufficient rope length on either side of the pulley to reach the ground. Assemble two of the tripod legs, and clip the feet into the harness. Have one person lift the third leg of the tripod while the other person slips the lower leg into the top section. Clip the final carabiner to the foot of the third leg. Position the tripod to that the pulley at the peak is centered over the borehole. Ensure the p-cord harness is tight between all the feet. Attach the winch to the tripod leg with supplied hex bolts.

11.0 STANDARD DRILLING OPERATIONS

11.1 Coring Procedure

11.1.1 Configure the drill for the core size to be collected.

Table 2. Drill components that are specific to the core size.

	AW34	**86T2**
Drive Shaft Adaptor	N/A	Drawing# 83930110
Rod Bearing	Drawing# 83930010	Drawing# 83930129
Rod Clamp	Kwik Klamp or Ball Puller	Kwik Klamp II
Planetary Gear Reducer	Drawing# 83930081	Drawing# 83930089
Tube Wrench	1.75 inch	3.25 inch

11.1.2 Assemble the core barrel

Use thread compound on all threaded connections. Ensure the core lifter is free to slide in the lifter shoe. Use the appropriate bit; see 9.3.1.3 for bit selection guide. If the impregnated bit is selected, ensure it is properly dressed before each run to expose new diamonds to the cutting face, Fig. 14. The spacing between the core lifter and the bit, referred to as bit gap, should be in the range of 1/16 inch to 1/8 inch (AW34 core barrel only). For the AW34 core barrel, grease the bearing section before each run. Install an ice reamer above the bearing section.

11.1.3 Installing the core barrel

Feed the drill rod through the rod guide with the cutter down (Fig. 13a). Do this by removing the plastic guide bearing and slipping it over the drill rod above the ice bit. Rotate the rod to a vertical position and connect to the drive output of the power-head (Fig. 13b). It is best practice to have the transmission in neutral and spin the output shaft onto the rod rather than rotate the drill string. Use thread compound and tighten the connection with tube wrenches.

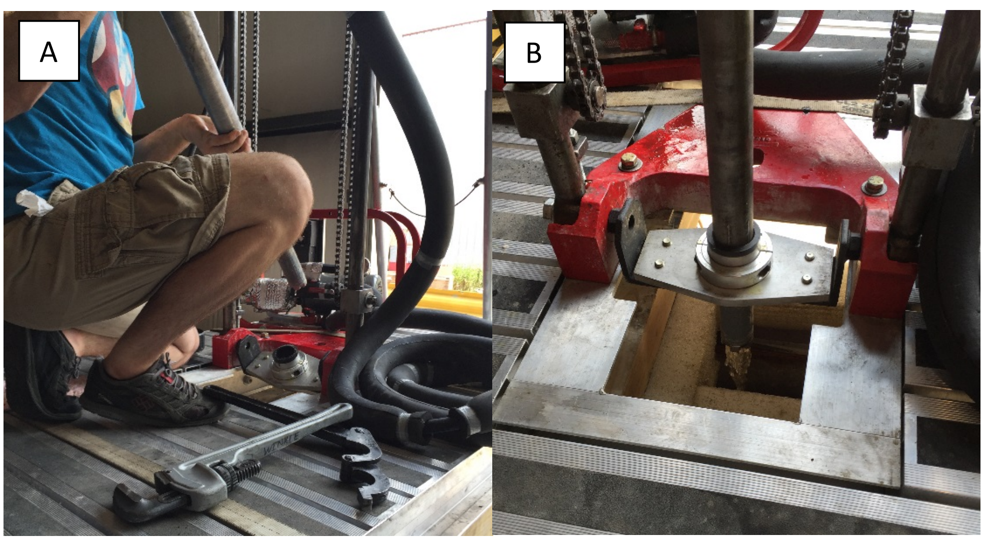

Fig. 13: The first drill rod must be placed into the guide bearing. (A) The guide bearing rotates to facilitate assembly. (B) Assembled drill rod in vertical drilling position.

11.1.4 Start the generator

11.1.5 Adjust the mud pump flow

Start the mud pump. Adjust the mud pump flow rate to match the bit being used. The impregnated bits need 2-3 gpm while the PDC/AmSet bits can be run as low as 1 gpm.

11.1.6 Drill string rotation

Place the transmission in gear, turn on the power supply, disengage the E-stop, and turn the potentiometer to begin drill string rotation. Note the location of the power-head on the graduated slide rail when the bit contacts the ice.

11.1.7 Starting the borehole

The first several inches of coring should be done in low gear and at low speed to prevent the drill rod from vibrating before the bit face and reamer is fully engaged. Once the full ice bit is engaged in the ice, speed can be increased. If the drill rod starts to "whip", change the drill speed. Rod whip is caused by the drill rod reaching a resonance frequency and can usually be alleviated by altering the rotational speed or feed pressure.

11.1.8 Feed pressure

The amount of feed pressure required will vary based on the bit and sample composition. In general, the higher the feed pressure the faster the rate of penetration. However, feed pressure is limited by the power of the motor, strength of the anchors, and heat generated by the bit.

11.1.8.1 If the power-head motor begins to stall, reduce feed pressure.

11.1.8.2 If the rig and footing lift or shift, reduce feed pressure. At the end of the coring run, apply more anchors or tighten the existing system.

11.1.8.3 Always monitor the fluid pressure gauges. There is one at the input of the water swivel, Fig. 4, and one on the manifold of the mud pump. If the pressure ever approaches 200 psi or if visually the fluid flow stops from around the drill rod annulus, reduce feed pressure and lift the bit off the bottom of the hole. Keep the fluid flowing and rod rotating to prevent sediment from settling on the bit and sticking the drill string. NOTE: The core lifter will be engaged on the core when the drill bit is raised from the bottom. If the barrel is lifted too far, the lifter shoe will contact the back of the bit and fault the motor or break the core.

11.1.9 Completing the core run

Continue to apply feed pressure until either the power-head reaches the bottom of the slide rails or the core fills the core barrel. If the power-head reaches the bottom of its stroke before collecting a full core, a drill rod can be added to the drill string. Continue to rotate the drill string and circulate fluid until the fluid coming to the surface is clean. This flushes any chips that are in the annulus to the surface so they do not settle on the core barrel and possibly stick the string. After the annulus is clear, stop drill rotation and fluid circulation. Break the drill rod joint between the top drill rod and the power-head. Crank the power-head to the top of the Unipress while the drill string sits at the bottom of the hole. Add a drill rod between the drill string and power head. Be sure to apply thread compound to all connections and tighten the joints with tube wrenches. Restart fluid circulation. Restart drill rotation. Apply feed pressure. Continue drilling until the complete core is collected.

Fig. 14. A bastard file is used to dress the bit; disrupt the surface of the bit to promote matrix wear and expose new diamonds at the beginning of each run.

11.1.10 Break the core

This can be achieved by any of three methods below:

11.1.10.1 Use the Unipress for the core break; lift the drill string with the necessary force to break the core by rotating the hand wheel.

11.1.10.2 Use the provided Hi-Lift jack to generate the required pull-back force for the core break; disconnect the power-head from the drill string and tilt the Unipress away from the drill string.

- AW34 - Slip the rod-puller over the drill string and place the jack between the bearing guide base and rod-puller.

- Screw the hoist ring adapter onto the top of the drill string and place the jaw of the jack through the hoist, Fig. 15.

11.1.10.3 While pressure is applied to the drill string using the jack, use a hammer and rod sleeve to gently tap the drill rod until the core breaks; the hammer is meant to induce a vibration and the resulting impulse will assist in breaking the core.

Fig. 15. Hi-lift jack positioned to break a rock core with the 86T2 coring barrel assembly.

11.1.11 Trip drill string out of the borehole

Trip rods out of the hole using the tripod with capstan winch and Kwik Klamp (II) or ball-type rod puller. Using the winch to lift and lower the drill string has inherent risks due to moving of overhead mass, keep all non-essential personal clear during the rod tripping procedure. After the core is broken, remove the jack and allow the drill string to sit on the bottom of the hole. Connect the lifting hoist adapter to the drill string and the winch rope to the hoist ring. Making sure to handle only the output side of the rope from the winch, lift the drill string until a drill rod joint is sufficiently above the rod bearing for the Kwik Klamp to fully grip the lower drill rod. With the clamp in place, use tube wrenches to break the joint above the Kwik Klamp. Have one person hold and direct the drill rod while another lowers the rope from the capstan winch. Remove the lifting hoist from the drill rod and attach to the drill rod now held by the Kwik Klamp in the borehole. Take up slack with the winch until the Kwik Klamp is no longer holding the weight of the drill string. Remove the Kwik Klamp. Repeat this process until the entire drill string has been brought to the surface.

11.1.12 Extract the core

The method for extracting core from the AW34 core barrel and 86T2 core barrel differ slightly.

11.1.12.1 AW34 – Separate the outer barrel from the bearing section using appropriate tube wrenches. Remove the inner core barrel from the bearing section using the appropriate tube wrench. Push the core through the inner barrel, Fig. 16, (into and up through the core lifter) onto a tray for logging.

11.1.12.2 86T2 – Remove the bit from the core barrel. Slide the core through the lifter and into the inner tube. Slide the core lifter shoe off the inner tube. Tilt the core barrel, the core will slide out. If the core does not slide out of the inner barrel, remove the outer and inner core barrel and use a rod to push the core out of the core barrel.

Fig. 16. Removing the rock core.

11.1.13 Trip rods down

Begin tripping rods down the borehole by assembling the lifting hoist adapter to the top of the core barrel assembly. Attach the capstan rope to the lifting hoist. Using two people, carefully lift the assembly with the winch and lower it into the borehole until the Kwik Klamp can clamp onto the bearing section while resting on the drill base. Secure the Kwik Klamp. Unscrew the hoist adapter. Add a drill rod to the drill string and attach the hoist adapter with rope to the top. Take up slack in the system and remove the Kwik Klamp. Use the hoist to lower the string until the Kwik Klamp can once again be secured just below the box thread of the drill rod. Repeat this procedure until the drill string is at the bottom of the borehole

11.1.14 Collect a downhole core

Repeat the coring procedure described in 11.1.9. Follow by tripping the rods out and recovering the core. Repeat until the final borehole depth is reached.

11.1.15 Fluid Recovery

When coring operations are complete, recover fluid from the borehole to be filtered and used in future boreholes. Assemble the fluid bailer assembly to a drill rod, Fig. 17. Assemble the lifting hoist to the top of the same drill rod. Use the tripod to lower the assembly into the borehole. Lower the assembly until the drill rod is either submerged in fluid or the drill rod reaches the bottom of the borehole. Use the hoist to lift the assembly from the borehole. The drill rod will be full of fluid. To drain the fluid, simply lower it into a 5 gallon bucket. There is a pin at the bottom of the bailer assembly that is depressed when it rests on the bottom of a bucket. This pin, when depressed, releases the contained fluid. Dump the fluid through the filter socks and into the fluid tank. Repeat this process until no more fluid is recovered from the borehole.

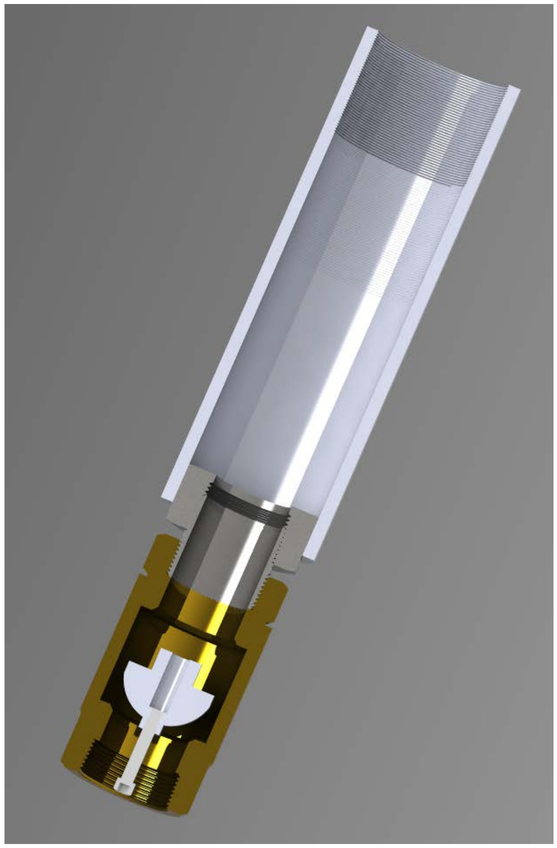

Fig. 17. Fluid bailer assembly section view.

11.2 Ice Augering Procedure

For projects that require quick access through clean ice, augers are an efficient means to create an access hole to the bedrock below. Note, the current augers are only compatible with the AW34 core barrel and should not be used deeper than 30m.

11.2.1 Rig adapters

The augers use a pushbutton style connector so an adapter is required to attach the first auger to the drive head. Install the adapter to the power-head using thread compound and tighten with tube wrenches.

11.2.2 Auger drill head and cutters

The auger cutter head is designed by Kovacs Enterprise and features a replaceable carbide cutter. Ensure the cutter is sharp and hardware is tight before installing on the auger string. To attach to the drill, simply depress the pushbutton and slide into an auger section until the button lines up with the hole in the shaft.

Fig. 18. Auger cutter head. Note the outside edge of the cutters are dulled from contact with bedrock.

11.2.3 Drilling parameters and speed

The augers are used only with the power-head in the AW34 configuration (no planetary gear reducer). The augers will cut well at a wide range of speeds but if the string rotates too quickly it could cause the borehole to become enlarged and result in less effective chip transport. Therefore, it is best to run the augers at a slow speed while advancing the borehole (low gear). Once the final hole depth is reached, the auger string should be increased (high gear) to remove as many chips as possible. Spin the augers only as long as chips continue to be transported to the surface. Continuing to spin the augers could result in excess heat added to the system and chip melting and refreezing.

11.2.4 Adding auger sections

Adding augers is similar to adding a drill rod during core drilling. Simply disconnect the auger from the power-head and allow the auger string to rest on the bottom of the borehole. Lift the power-head and add another section to the top of string.

11.2.5 Reaching bedrock

When bedrock or other large pebbles are reached it will be obvious to the drill operator; penetration will stop and, usually, the drill string will shake violently. Contact with bedrock will damage the carbide cutters, Fig. 18, but they are easily replaceable. Quickly lift the auger sting so the auger head is no longer in contact with the bedrock. Increase the rotational speed to clear all possible chips to the surface.

11.2.6 Pulling the auger string

Removing the auger string is also similar to pulling the drill rod string. However, specialty jaws need to be installed on the Kwik Klamp, Fig. 19, and the AW adapter used to drive the auger string needs to be coupled with the lifting hoist to enable the winch to be attached to the auger string. More than one auger may be removed at a time.

Fig. 19. Specialized Kwik Klamp jaws for use with Kovacs Enterprises augers.

12.0 Site Pack-Up and Transportation

Drill transportation options are largely dependent on the drill site surface conditions and distance between drill sites.

For short distances over smooth ice or snow, it is only necessary to remove the anchors holding the rig footing to the glacier and slide the drill onto a Siglin sled. Allow the power-head to rest on the rig base so the rig has the lowest possible center of gravity.

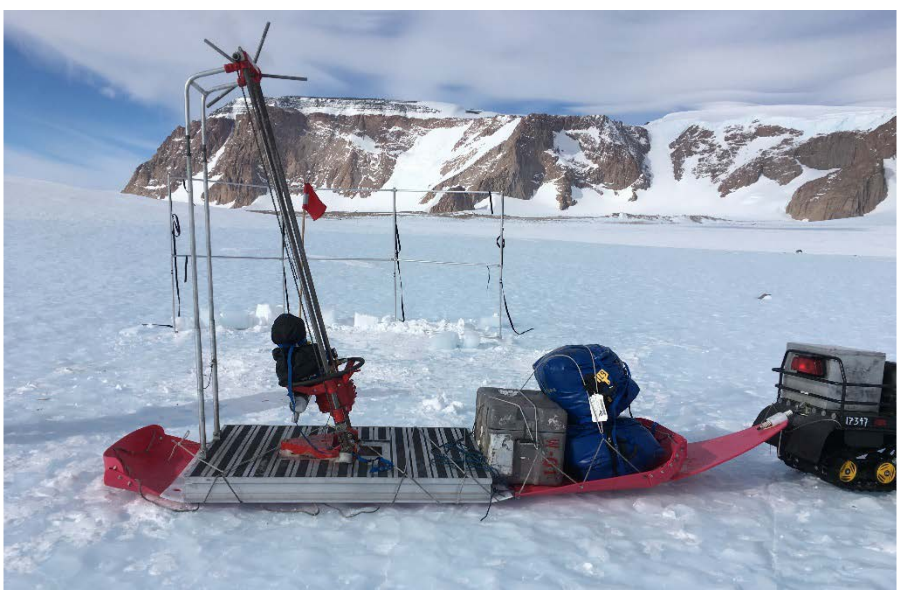

Fig. 20. The WD strapped to a Siglin sled and ready for transportation to a new drill site.

For projects in terrain that does not permit the use of snow machines and Siglin sleds, the drill may need to be disassembled further. This will depend on means of transportation to be used.

13.0 Troubleshooting

Table 3. Issues that may arise and solutions that can be implemented in the field.

Issue	Possible Cause	Fix
Power-Head		
Motor does not function	E-Stop engaged	Pull out E-Stop button on the motor controller, turn potentiometer knob to 0
Motor does not function	Circuit breaker tripped	Check cables and connectors between the generator, power supply, and motor; reset breaker
Motor does not function	Power supply over-temperature fault	Check status light on the back of the power supply; allow the system to cool
Motor does not function	BLDC motor fault	Cycle power to the motor; plug in laptop and read codes; monitor motor during drill runs with laptop
Drill string does not rotate	Transmission in neutral	Select high or low gear
Drill string does not rotate	Broken jaw coupler	Inspect couplers, replace broken components; measure for alignment
Drill string does not rotate	Downhole tooling has become frozen	Use the auxiliary jack to pull on rods while tapping on the rod sleeve with a hammer; use glycol to melt ice around drill rod
Power-head does not move with hand wheel	Broken chain	Remove broken links, splice in new chain section using master links
Cannot move power-head/drill string	Frozen	Use the auxiliary jack to pull on rods while tapping on the rod sleeve with a hammer; use glycol to melt ice around drill rod
Drilling fluid leaks at water swivel	Worn seal	Replace water swivel seal, polish drive shaft
Circulation System		
Mud pump does not function	Circuit breaker or GFCI	Add auxiliary in-line GFCI and filter; inspect cables and connectors; reset breaker
Pit pump does not pick up fluid	Plugged inlet	Clear the intake port of chips; use bucket to manually remove fluid from sump pit
Fluid leak	Damaged hose	Replace damaged connector; remove damaged section of hose and splice together
Fluid pressure too high	Incorrect bit gap	Adjust the bearing shaft length of the core barrel assembly to proper bit gap tolerance
Down-Hole Tooling		
Core lifter slips	Undersized core	New bit and/or bend the core lifter to decrease diameter and/or cut and bend small tabs at the top of the lifter to engage with the core
Fluid does not circulate	Plugged bit	Clear plug, increase drill fluid flow rate
Bit does not penetrate	Dull or damaged bit	Replace bit
Excessive rod vibration (rod whip)	Oversized Borehole	Use rod bearing section, modify rod rotational speed

14.0 APPENDIX A: REFERENCE DRAWINGS AND SAFETY DATA SHEETS

14.1 Reference Drawings

Drawings referenced within this document may be obtained from IDP, if desired. They are not included in this manual in order to ensure users obtain the most up-to-date drawings upon request.

14.2 Safety Data Sheets

Safety data sheets for all chemicals used with the drill system may be obtained through IDP and will be deployed with the drill each season. Table 3 below outlines hazards for each chemical

Table 4. Job related chemicals and associated hazards.

Chemical	**Hazard**
Unleaded Gasoline	Extremely Flammable, Eye Irritant, Toxic
Isopar K (Drilling fluid)	Flammable, Aspiration Toxicant
Ethanol	Flammable
Propylene Glycol	No Special Hazards
Motor Oil, Gear Lube	No Special Hazards
Penetrating Oil	Flammable, Toxic, Skin Irritant
Loctite Thread Locker	Eye and Skin Irritant

15.0 APPENDIX B: ITEMS TO REQUEST FROM THE LOGISTICS PROVIDER

Table 5. Items required for the WDS that are not supplied by IDP. Items should be requested of the logistics provider. Additional items may be requested for specific site or project requirements

Qty. Requested	Description
*	Drum Isopar K (qty is project specific)
*	Gasoline (qty is project specific)
*	Snow machine
*	Wide Siglin sled 10' x 42"
2	5 kW generator
2	Propylene Glycol, gal
1	Spill kit (large, for punctured drums)
1	Spill kit (medium, for fuel transfer)
1	Containment berm (4'x6')
2	Containment berm (3'x3')
1	Shovel, square short handle
1	Shovel, grain scoop
1	Electric chainsaw (16" bar)
1	Ice chisel
4	Extension cord 25', 120 VAC
1	Extension cord 25’, 230 VAC
1	“Hurdy Gurdy” fuel pump
1	Bung wrench
1	4 lb. sledge hammer
1	Graduated jerry can with flex spout and funnel
1	Survey tape
1	Drum Funnel
2	5 gallon bucket

*qty is project specific

16.0 APPENDIX C: PREVENTIVE MAINTENANCE CHECKLISTS

Winkie Drill Preventive Maintenance Checklist			
SEASONAL CHECKS (to be performed at the start of each drill season)			
ITEM	**ACTION**	**DATE**	**INITIALS**
FRAME			
Inspect Unipress for cracks or damage	Base, hand wheel housing, slide rods free of cracks, bends, or excessive wear		
CIRCULATION SYSTEM			
Hose	Inspect for damage including cracks or damage at fittings		
MOTOR			
Jaw Couplers	Inspect for signs of damage or excessive deformation of the polymer insert		
TRANSMISSION			
Change Oil	Replace gear lube, inspect oil for excessive metal particles		
ELECTRICAL			
Electrical cables	Inspect cables, plugs, and grommets for damage or exposed conductors		
TRIPOD/WINCH			
Rope	Inspect for damage to jacket or core		
Tripod	Inspect for damage, cracks, or bends		

Winkie Drill Preventive Maintenance Checklist			
SITE CHECKS (to be performed prior to the start of each borehole)			
ITEM	**ACTION**	**DATE**	**INITIALS**
FRAME			
Loose Hardware	Visually inspect for any loose hardware that may have vibrated loose during operation		
Anchors	Examine anchors and ice integrity		
Slide Rails	Grease slide rails		
Hand Wheel	Apply grease to hand wheel shaft via four grease fittings		
Rod Bearing	Inspect guide bearing for excessive wear; replace as needed		
POWER-HEAD			
Water Swivel Seal	Monitor during drilling for excessive leakage		
Output Shaft Seal	Check for excessive oil leakage		
Cables	Inspect cables and connectors for damage or loose connections		
TRANSMISSION			
Check Oil	Check oil level of the transmission		
GENERATOR			
Cables	Inspect cables and connectors for damage or loose connections		
Fuel	Check fuel and oil levels; fill as needed		