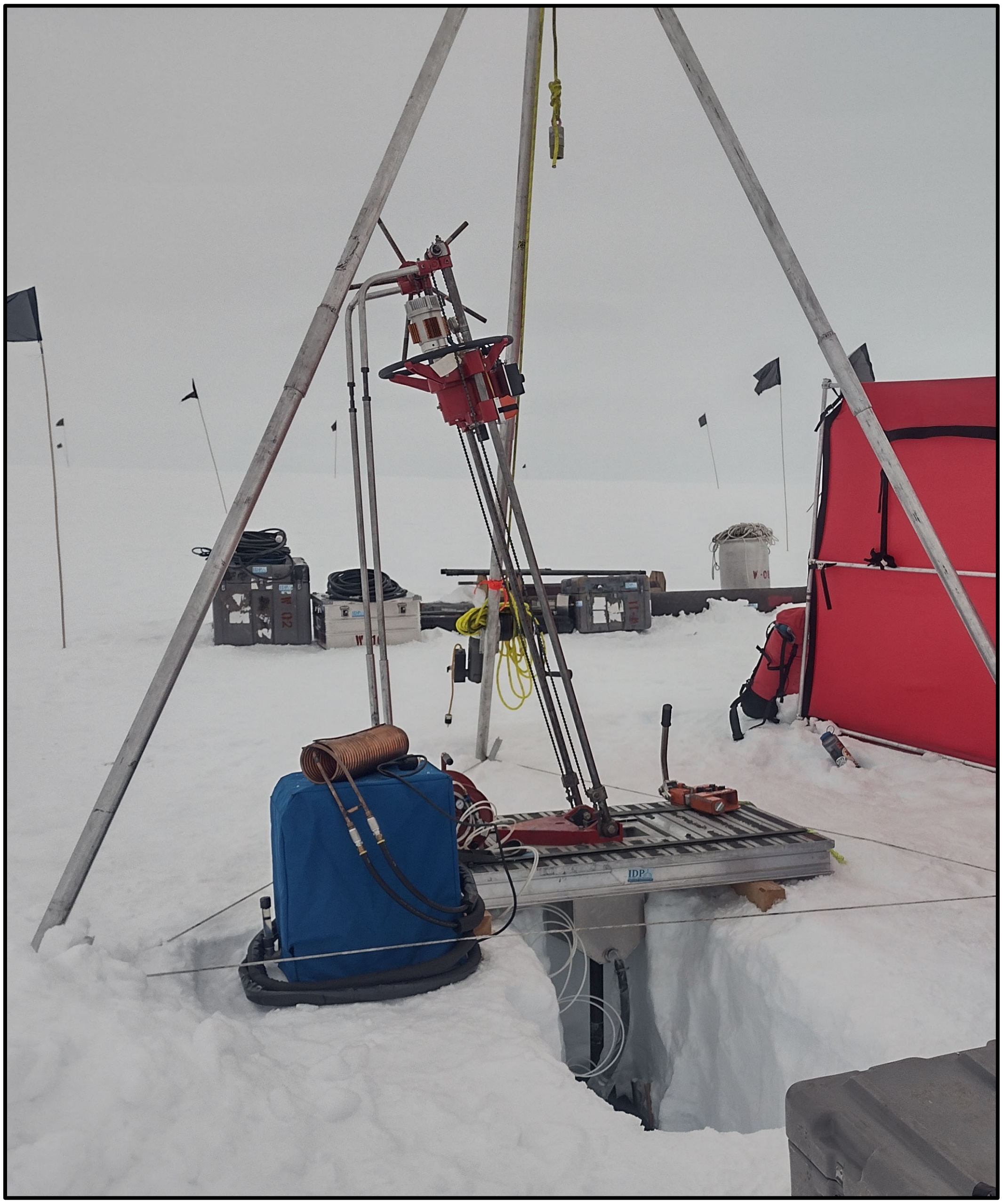

WINKIE DRILL

Operations and Maintenance Manual

March 14, 2024

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 the 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 8393-0021 Ice Bit Test Report

3.6 8393-0024 HYDAC_EDS300 Pressure Switch Manual

3.7 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 to 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 PHQ Global. 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 brushless 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 71.7 mm cores at up to 12 m 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 (50 rpm to 1000 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, SUB-SYSTEMS AND SETUP

The main components, Figure 1, of the WDS include:

- Drill rig
- Tripod with electric capstan winch
- Downhole tooling – casing, augers, drill rod, and core barrel assemblies
- Circulation system – casing, packer, mud pump, fluid chiller, insulated filtration tank, and drilling fluid
- Tooling and spares
- Environmental protection – Axion inflatable tent or windscreen
- Transportation equipment

This section will provide detail on each WDS component including sequential instructions on the setup of the WDS.

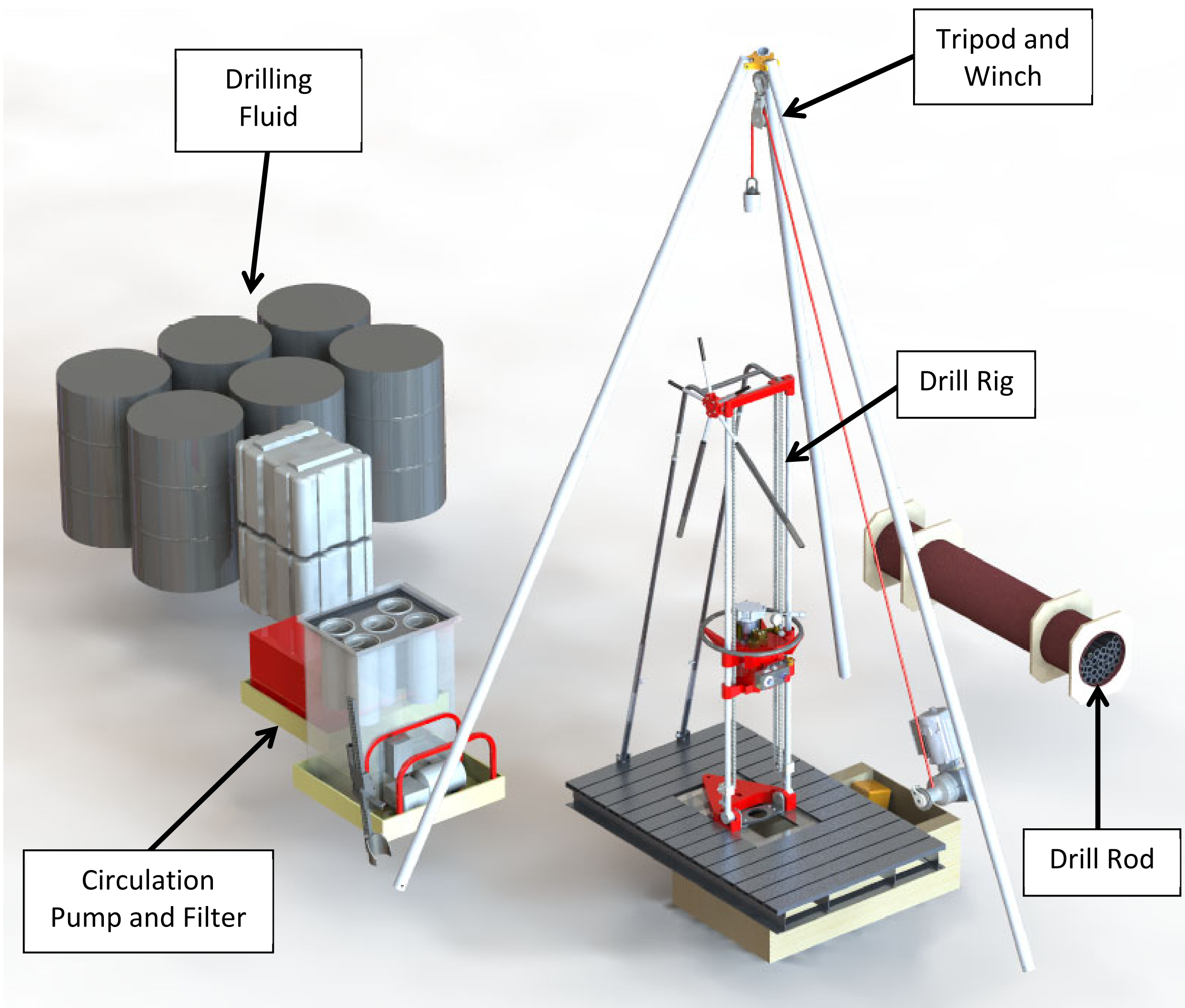

Figure 1: Layout of the drill rig and major components.

9.1 Site Preparation

9.1.1 Blue Ice Drill Site

Working on blue ice can simplify drill assembly significantly. When working on blue ice, it is important the selected site is relatively flat since wearing traction devices at the drill site is dangerous and not recommended due to the presence of electrical cabling and high-pressure fluid hoses. If the drill site has solid ice up to the surface and is frozen to the bedrock interface, the drill system can be set up immediately without drilling an access hole. If surface cracking in the blue ice is present, the SIPRE drill powered by the Winkie powerhead can be used to drill a shallow access hole to set the packer in competent ice. However, if the drill site selected is snow, firn, or has known voids before reaching bedrock, an access hole must be drilled, casing added and sealed.

Depending on weather conditions, setting up the windscreen or axion drill tent 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 a kovacs auger. The guy lines can be anchored using either the supplied ice screws or with a v-thread anchor, Figure 2, or with pickets (for snow/firn sites). The windscreen frame is color-coded to facilitate assembly. Assemble the frame first, then the anchors and finally the fabric covering.

Figure 2: V-thread anchor

Once the windscreen is set up, 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 operation. 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 Figure 3 for an example of the ideal sump pit.

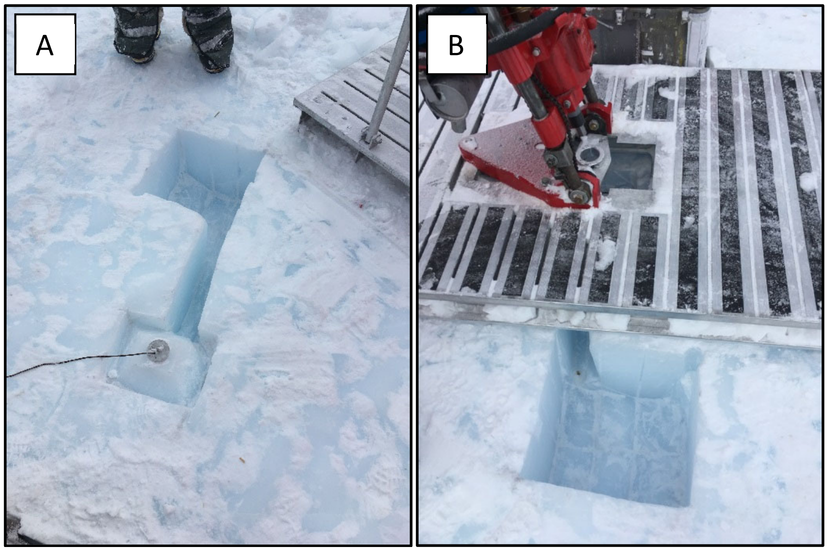

Figure 3: (A) Sump Pit, Uncovered – using a chainsaw or handsaw, cut the sump pit that directs all fluid and drill chips away from the borehole. (B) Sump Pit, Covered – when the rig footing is centered over the borehole, the sump pit should be accessible with the pit pump.

9.1.2 Snow or Firn Drill Site

When there is not surface blue 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 installed 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. For shallow holes less than 40 m, drilling with the Eclipse drill should continue as long as possible, ideally until the bedrock is reached or drill penetration stalls. For deeper holes, Eclipse drilling should continue until 80 m which is the maximum allowable casing depth. After setting the packer system, access hole drilling can then continue up to a depth of 120 m using the full-face ice bit. At a minimum, the access hole must reach a depth where ice dense enough (0.87 g/cm^3) to form a seal with the inflated packer.

In a firn site, the sump pit in the ice is not needed and is replaced by an aluminum tank mounted at the top of the casing, below the rig base, Figure 4.

Similar to blue ice sites, it is recommended to set up the windscreen before proceeding.

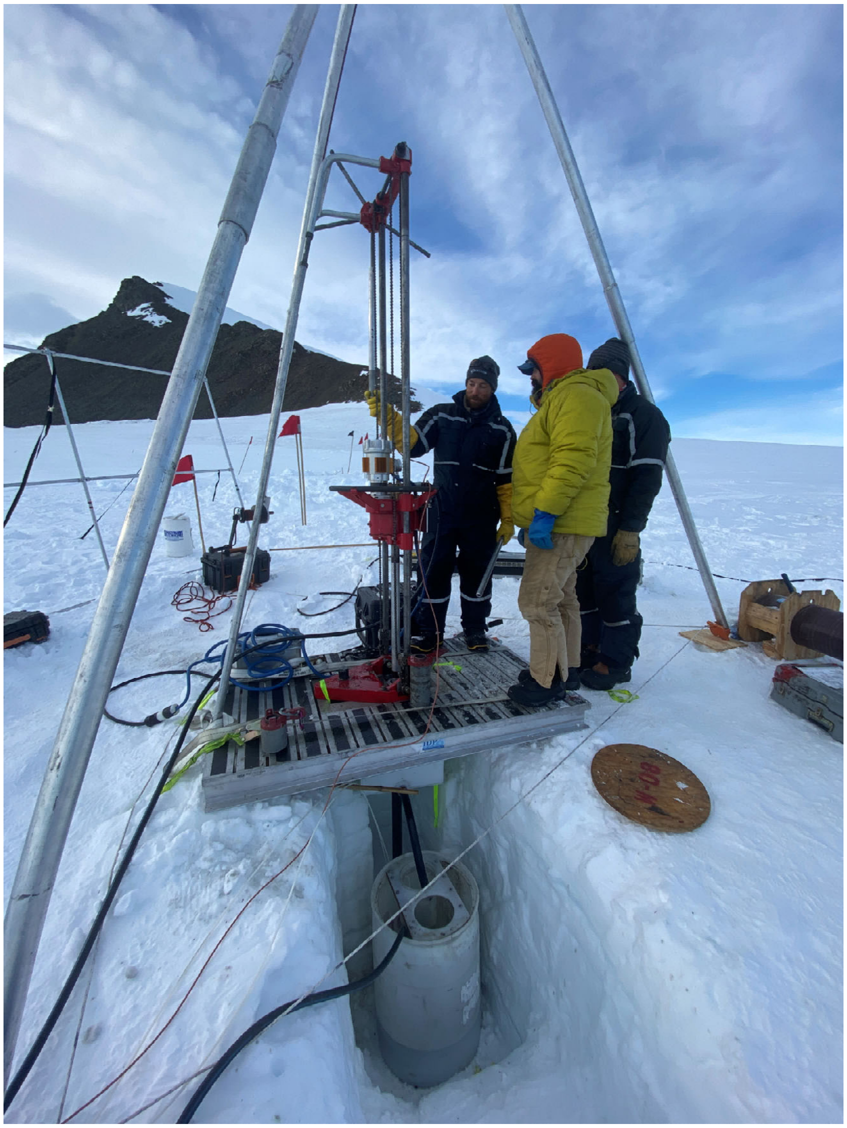

Figure 4: The filter tank can be placed in the existing slot if the Eclipse Drill is used for drilling the pilot hole.

9.2 Drill Rig Assembly

After the ice surface is prepared and wind protection is in place, the rig can be assembled. The WDS 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 powerhead. Start by anchoring the footing (section 9.2.1). Then build the unipress frame up from the footing (section 9.2.2). Finally connect the circulation system components with containment (section 9.6).

9.2.1 Footing Anchor system

Follow these steps to create the anchor system for the WDS footing.

1. Locate Footing: The force generated by the weight of the WDS, drill rod and the force of core breaks, must be spread across a large surface to ensure the drill rig does not sink into soft snow surfaces. For this purpose, an aluminum footing is included with the system. This footing must be anchored to the firn or ice to anti-torque the drill as well as hold the rig down when feed pressure is applied.
2. Begin by installing and leveling 4” x 4” x 4’ dunnage pieces on both ends of the footing perpendicular to its long axis. This dunnage will allow the footing positioning to be easily adjusted into position over the borehole. Next, place the footing over the sump pit (or the drill trench if the access hole was created using the Eclipse Drill). Locate the footing so that the bore of the slip foot clamp is centered directly above the desired location of the borehole. If an Eclipse drill slot has been cut, orient the long axis of the footing perpendicular to the slot to properly span it. Once installed, ensure that the base is level.
3. On blue ice, use either four ice screws or four v-thread anchors (one at each corner of the footing) and webbing, slings, or ratchet straps, to create a rigging system to hold the footing from lifting (this could happen if high feed pressure is applied). If drilling in snow, use pickets as deadmen instead of ice anchors. When the “anchor system" is referenced throughout this document, the above steps describe the construction.

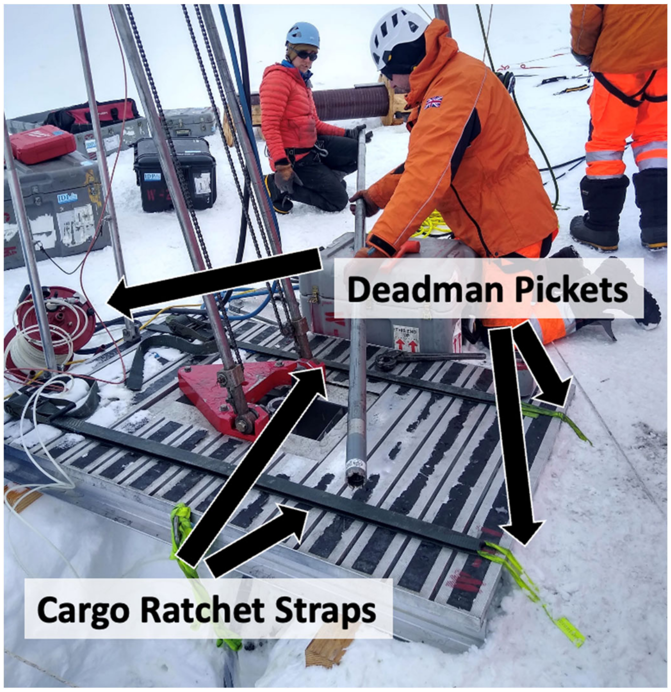

Figure 5: WDS Rig Base with locations of deadman pickets and connecting cargo ratchet straps to secure the base. Photo: K. Nichols.

9.2.2 Unipress Frame Assembly

Once the footing is secured to the ice, the WDS can safely be assembled to the footing without risk of shifting.

The unipress is the frame to support the powerhead. It consists of the rig base, including the slip foot clamp assembly, unipress extensions, hand wheel, tilting legs, chain, and chain tensioning system, Figure 5. The role of the unipress is to anti-torque the powerhead while providing linear travel as the drill string progresses.

The bushings for tilting the unipress are integrated into the WDS base. The rig base is fastened to the platform with three bolts. The unipress extensions and slip foot clamp assembly are mounted to the base. The base is also used as a rigid structure to support the auxiliary core break jack (discussed in 10.2.10).

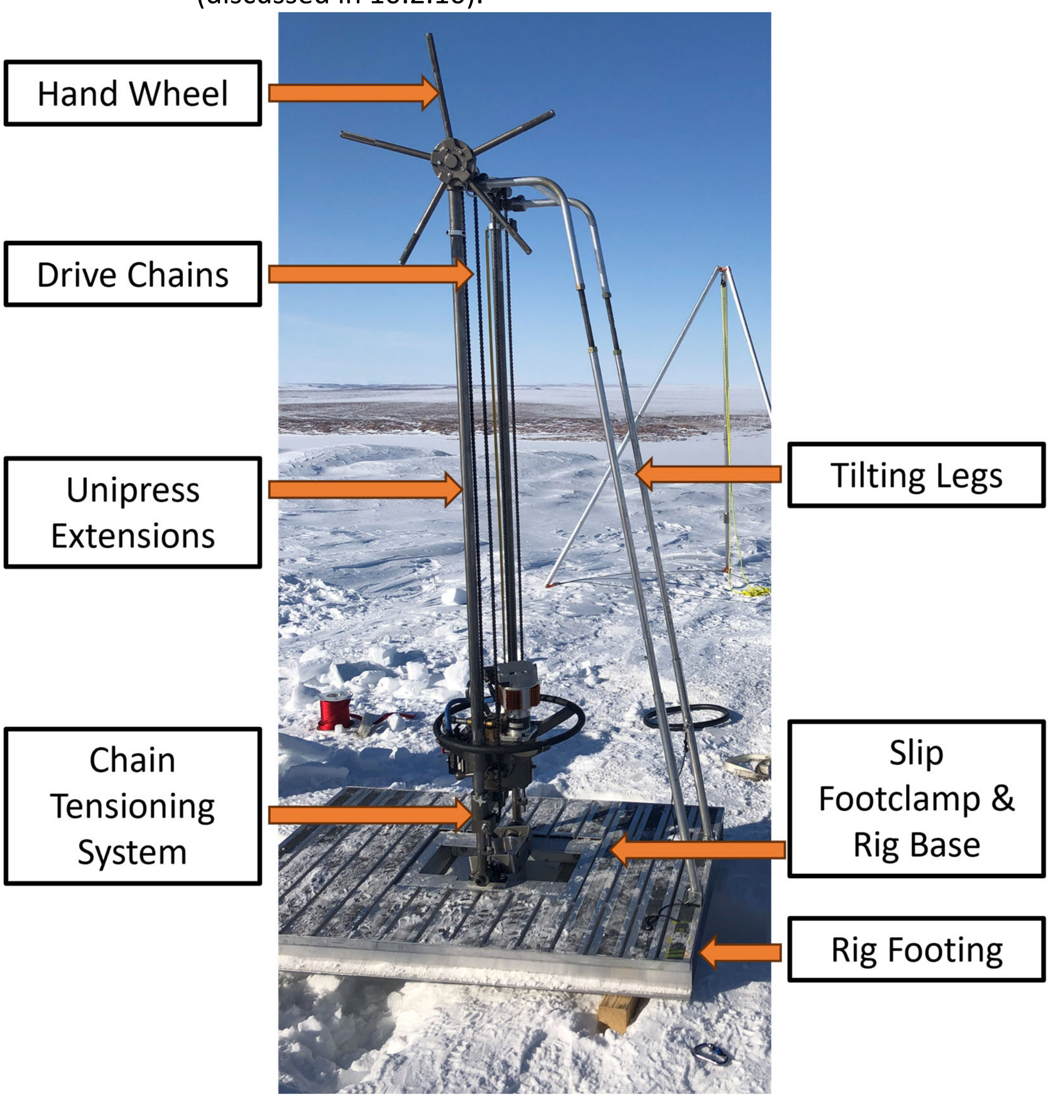

Figure 5: The assembled unipress frame.

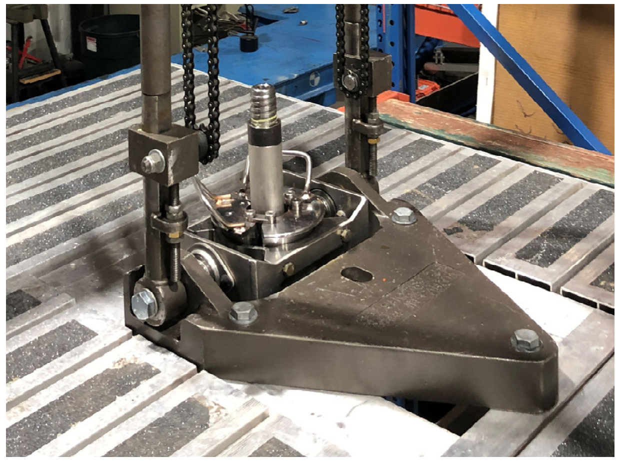

Figure 6: The slip foot clamp assembly. Note different diameter jaws exist for casing and drill rod.

The assembled WDS requires two unipress extensions to guide the powerhead. The extensions provide anti-torque structure so the powerhead can spin the downhole tooling without rotating itself. During drill operations, the two unipress extensions allow the powerhead to travel vertically as the drill string and powerhead progress downwards.

At the top of the unipress extensions is the hand wheel assembly, Figure 5. The hand wheel is the mechanism used by the operator to raise and lower the powerhead. The hand wheel is one of the primary inputs of the operator and can provide valuable feedback on downhole conditions during drilling. The WDS includes two hand wheel extensions to make operation from the ground accessible. The extensions also reduce the force required to apply feed pressure and reduce operator fatigue.

Force is transferred from the hand wheel to the powerhead by two roller chains, Figure 5. At the base of the unipress extensions is the mechanism to tension the chain. There is also adjustment at the powerhead to equalize chain tension between the two chains. See the procedure below for the chain installation and tensioning procedure.

1. To begin assembling the unipress frame, locate the triangular base, which houses the slip-foot clamp assembly. Attach it to the footing using the supplied fasteners. NOTE: Use medium strength thread locker.

2. Locate the powerhead (including the powerhead brake assembly and core run measuring tape) and unipress extensions. Have an assistant hold the powerhead in the proper position above the base while the extensions are assembled through the powerhead bushings and threaded onto the pin connections on the base. Ensure the core run measuring tape and hand brakes are also installed during this step. The hand brake is installed between the powerhead bushings so that it is retained during up and down travel of the powerhead. Allow the unipress frame to tilt forward and rest the powerhead on one of the shipping cases (they should be approximately 45° from vertical). NOTE: Use Sandvik thread compound on all unipress connections.
3. Install the hand wheel housing on top of the unipress extensions. NOTE: Ensure the hand wheel housing is orientated with the chain sprocket facing rearward away from the borehole.
4. Assemble the tilting legs to the footing and at the hand wheel housing. Verify both locking pins are active when the WDS is vertical. NOTE: Use medium strength thread locker on all threaded connections and setscrews.

9.2.3 Follow the steps below to install and tension the powerhead roller chains. Taking care to properly equalize chain tension will allow the powerhead to travel smoothly through its stroke and ensure that the powerhead drive spindle easily connects to downhole tooling. A diagram of chains and tensioner is shown below in Figure 7.

1. Adjust the chain tensioner to equalize distance of the bottom idler block from unipress extension joint.
2. Route the chains around the lower and upper sprockets taking care to align paint marks on the chain and upper sprocket teeth.
3. Join the chains using chain puller and included master links. If the two chains are not the same length, you will need to add or break links as needed.
4. Raise the powerhead to load the chains on the front side that run between the powerhead and top sprockets. Turn the threaded barrel adjuster on the powerhead, as needed, until the chains are carrying equal loads and the powerhead runs smoothly on the unipress extensions.
5. Next tension the chains by tightening or loosening the nuts on the chain tensioners at the base of the rig.
6. Check tension and float the powerhead to ensure equal adjustment. Repeat prior two steps as necessary until minimal friction between powerhead and unipress extensions is achieved.

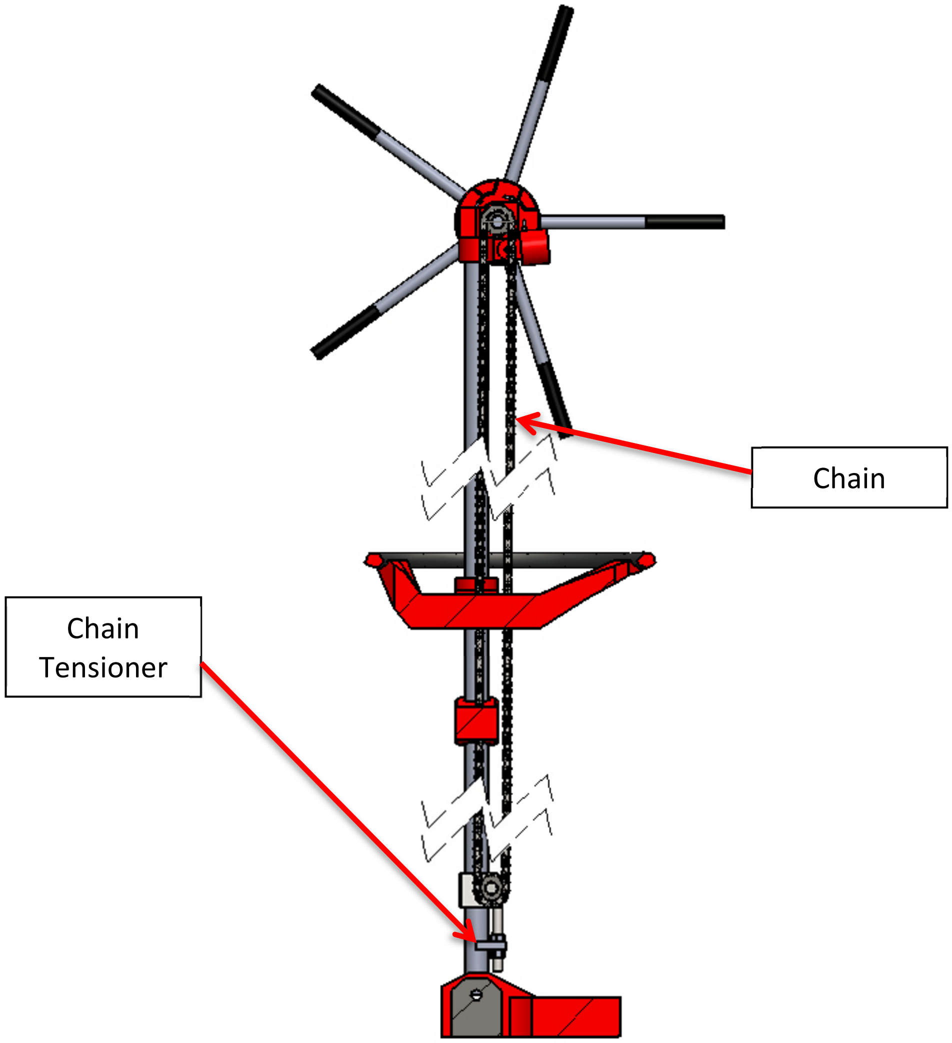

Figure 7: Section view of chain path and location of tensioner.

9.3 Tripod and Winch

In snow or firn sites, casing must be installed in the access borehole to prevent fluid loss into the firn. Installing the casing (as well as the drill string; section 9.4) requires the tripod and capstan winch to quickly trip the casing into and out of the borehole with limited fatigue to the operator.

The tripod should be assembled with at least two people. Begin by laying out the p-cord and carabiner footprint with the carabiners in the approximate location of each foot of the tripod. Next, run the static rope through the pulley at the apex of the tripod 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 so that the pulley at the peak is centered over the borehole as shown in Figure 8. Ensure the p-cord harness is tight between all the feet. This process may take several iterations to ensure that the pulley is centered directly over the borehole and that all three legs are positioned properly. Plywood footers are provided to distribute the loading of the feet if the snow surface is soft. Once the positioning is correct, anchor each leg with a snow picket.

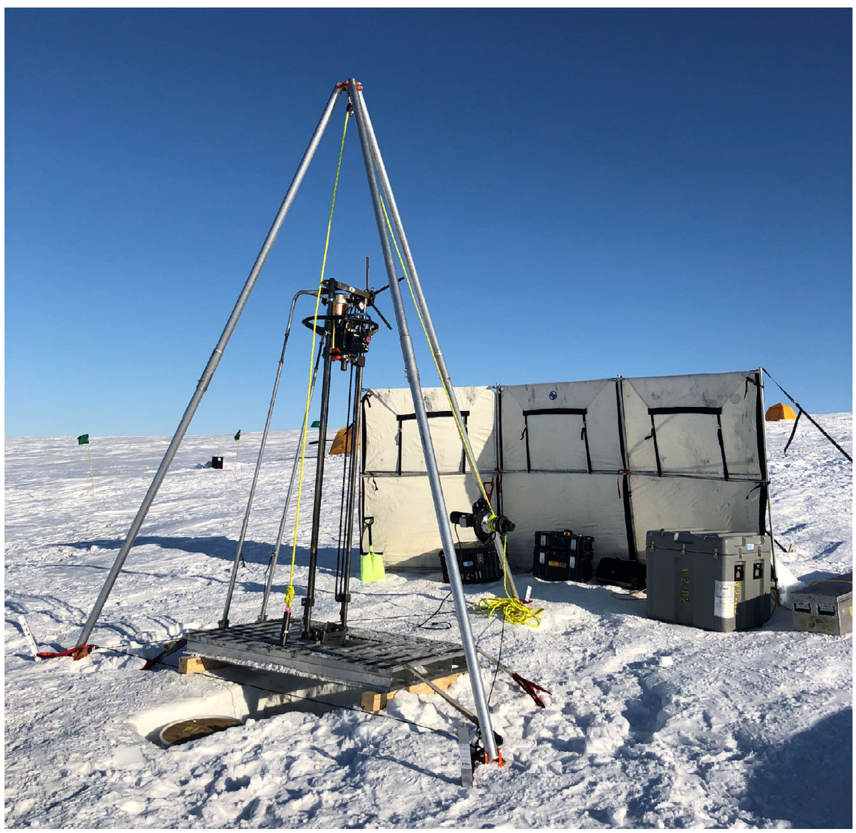

Figure 8: Tripod and capstan winch ready to trip casing.

After erecting the tripod, attach the capstan winch to the tripod leg with supplied hex bolts. The winch is a self-tailing capstan winch with two speeds and foot switch. Supplied with the winch is 40 m of static nylon rope. The rope can be attached to either the hoist ring adapter or ball-type rod puller depending on the lifting configuration required. Note the tripod assembly is rated to 1000 lbs. which limits the maximum load that be lifted to 80 m of steel BTW casing or 120 m of aluminum AW drill rod.

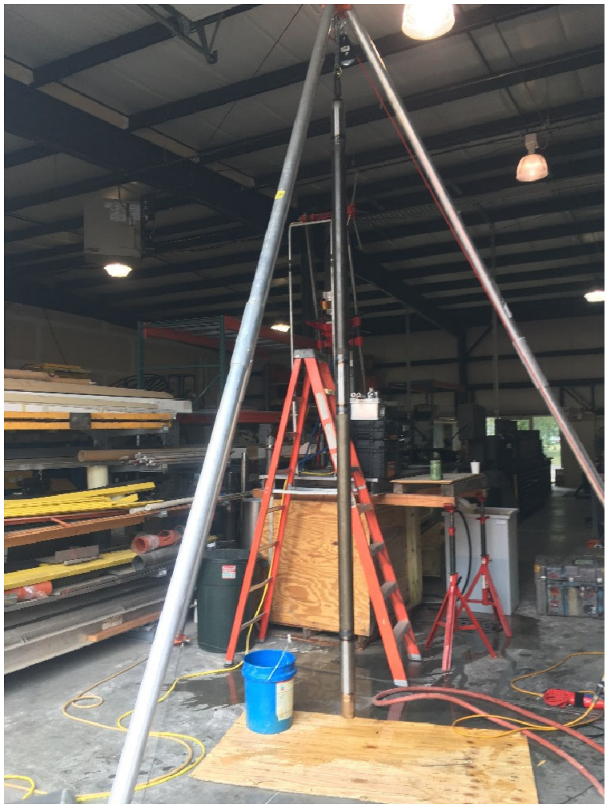

Figure 9: Tripod with suspended fluid bailer.

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

9.4 Casing

Casing is required whenever 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 to the surface. 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 (inner diameter) is 1.909"+.000/-.007, nearly perfectly matching the drilled borehole diameter. The casing weighs 3.50 lbs/ft (11.5 lbs/m).

Casing sections are lowered into the borehole using a similar technique as tripping drill rod with the tripod, hoist ring, slip foot clamp or Kwik Klamp, and tube wrenches:

1. Leak test the inflatable packer by placing the packer in the pressure-rated fiberglass tube and inflating to 200 psig. Monitor pressure overnight to verify all connections are leak free before installation.

2. Attach the inflatable packer to the first section of casing. The inflatable packer threads directly onto the casing above the yellow left hand thread recovery coupler. Use Sandvik thread compound when making all threaded connections. Take care not to accidently loosen the left-hand thread coupler while making this connection.
3. If using the inflatable packer, connect the ¼" nylon air hose to the packer with the compression fitting. If the compression fitting ferule appears excessively deformed or worn from repeated installations, re-terminate the crimp fitting before installation. A second nylon hose can be secured to the casing just above the packer to inject ethanol if the packer becomes stuck.
4. Use electrical tape to secure both the packer inflation line and the ethanol line to the outside of the casing. Make sure that packer inflation line (not the ethanol line) is connected to the packer. Both lines are made of the same high-pressure tubing, but the latter is used only in the event of the drill or casing getting stuck.
5. Attach the hoist ring to the top of the casing rod. Use thread compound on the connection.
6. Put 3-4 wraps of the static rope around the capstan winch. Use either the hand crank or the winch motor (with attached foot pedal) to take up any slack in the rope. This will also verify that your system is set up properly and can hold tension. Note that the generator must be running with 120 VAC power supplied to the winch motor if this option is to be used.
7. Once tension is established, the winch operator can remove a single wrap from the friction clamp on the winch, remove the slip foot clamp jaws, and slowly lower the casing assembly down the access hole.
8. While lowering, pause roughly once/meter to secure the inflation and ethanol lines to the outside of the casing using electrical tape.
9. Once the top of the casing is approximately 1 foot above the slip foot clamp assembly, stop lowering and install the slip foot clamp casing jaws to hold the casing string.
10. With very careful communication between the clamp operator and the winch operator, remove all tension from the winch and static rope. At this point, the casing and packer are suspended only from the slip foot clamp.
11. Prepare a new piece of casing by applying thread dope to the male connection and adding a centralizer if necessary. Centralizers are needed to support the casing from buckling, Figure: 10. Centralizers should be installed at least every 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. Free rotation is required for the use of the burn-in casing shoe described below.
12. Unscrew the lifting plug from the casing string.

13. Add the new section of casing onto the casing string. Use casing cuff wrenches to tighten the connection.
14. Thread the lifting plug onto the top of the added casing string (now ~5-6 feet above the slip foot clamp).
15. Direct the winch operator to take up the slack and raise the casing string so that the slip foot clamp jaws become unseated.
16. With very careful communication between the clamp operator and the winch operator, remove the clamp jaws. The casing string should, once again, be suspended from the tripod.
17. Repeat steps 6-15, adding new casing sections and centralizers and securing tubing all the way until the borehole is cased to the bottom of the borehole. Note that it is critical to set packer as close to the access hole bottom as possible. Failure to do so creates a large volume in the circulation loop which accumulates cuttings and can lead to poor drill performance.

Figure: 10. (A) Centralizer installed with aluminum collars for free rotation. (B) Freeze-in casing shoe with polished steel casing nose piece.

9.5 Casing Packers

There are several options 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.

9.5.1 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 method. 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 250 psi. The air compressor air treatment line is pressure rated at 250 psi and a blow-off valve will trigger if this pressure is exceeded. Pressure required to sufficiently seal the packer increases with access hole depth since the fluid column height increases. Field testing has shown that 200 psi is an effective pressure for sealing without increasing the risk of ice fracture. At room temperature, the packer will contact the wall of a 4.5" borehole at 35 psi. The inflation procedure is as follows:

1. Following installation of the casing, the ¼" nylon hose should already be connected directly to the packer at the bottom of the access hole and run along the outside of the casing to the surface. The spool of nylon hose is fitted with a ball valve, pressure gauge, and quick connect fitting to connect to the air compressor.
2. Charge the compressor, filling the tank to 500 psi. Screw out the high-pressure regulator (orange knob) to keep pressure below 250 psi through the air 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 much water as possible. If possible, let the compressor cool overnight or during casing installation before inflation.
3. Attach the inflation reel quick connect fitting to the compressor at the port downstream of the air treatment. Use the high-pressure regulator (orange knob) to increase the pressure up to 200 psi. Open the ball valve on the inflation reel slowly to inflate the packer. Note that inflation pressure will take time to equalize as air flows downhole. Close the inflation reel ball valve and disconnect the inflation reel when pressure has equalized. Monitor the pressure on the inflation reel pressure gauge periodically to ensure sufficient sealing pressure. It is normal for inflation pressure to change depending on circulation pressure and borehole fluid height.

4. Do not inflate the packer at the surface without it installed in the pressure rated inflation tube. Failure to constrain the packer when inflating will permanently damage the packer and can result in injury.

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

9.5.2 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 an option. However, it should serve as a last resort option since it has not proven effective in testing. 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.

9.5.3 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, Figure: 10B. 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.

9.6 Circulation System

Rock drilling requires forced fluid circulation to remove ice and rock cuttings from the borehole and to cool the bit. Fluid circulation must be established anytime drilling is attempted. Without fluid circulation, the bits could burn into the rock, wrecking the bit or sticking the drill string. Isopar K is the preferred drilling fluid. The Isopar K must be recovered, filtered, and reused during drill operation. There are five main components to the fluid circulation system: drilling fluid, mud pump, pit pump/sump tank, filtration tank and fluid chiller. The system layout used in blue ice zones can be seen in Figure 11.

See Figure 11 and 12 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.

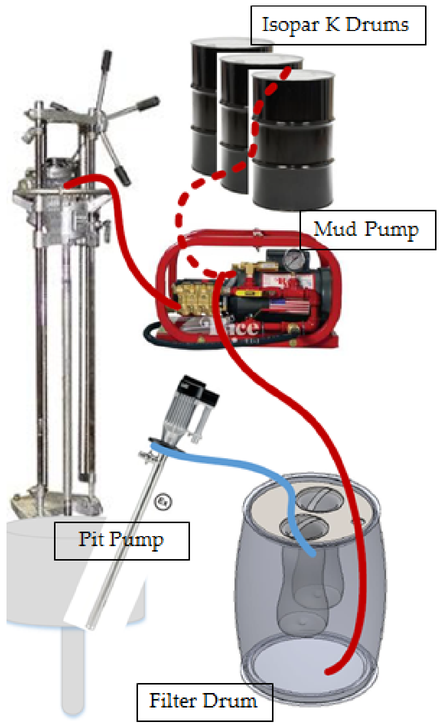

Figure 11: Wet drilling fluid circulation schematic for blue ice zones.

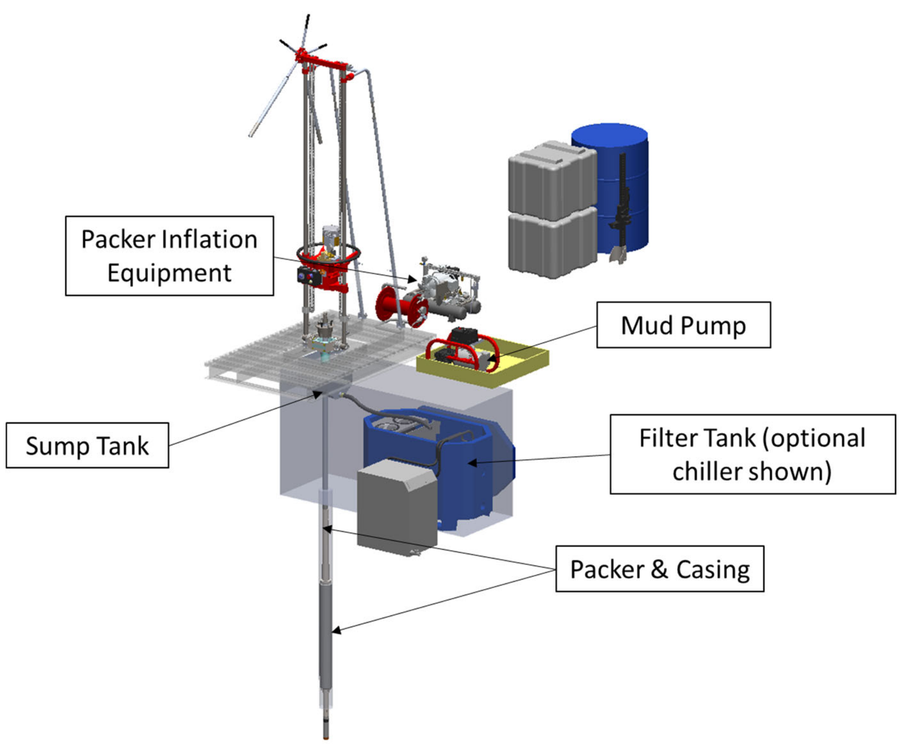

Figure 12: Fluid circulation configuration in firn show with optional fluid chiller.

9.6.1 Drill Fluid

To keep downhole environment 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 13.2, Table 5. Printed copies of all chemical Safety Data Sheets (SDS) are provided with the drilling equipment.

9.6.2 Mud Pump

A small mud pump is used to circulate clean fluid from 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. The pump is protected by an adjustable mechanical pressure relief valve (PRV) set at 300 psi. This mechanical pressure relief valve is used only to protect the pump from overpressure and does not set maximum drill fluid circulation pressure. To set the maximum circulation pressure refer to section 9.6.3 which discusses the electronic PRV. Drill fluid circulation pressure is depth, drill rpm, and downhole tooling dependent. At 100 m depth running the AW34 core barrel it was found approximately 110 psi was needed to circulate fluid without any downhole blockages. Testing conducted by IDP for the ASIG Drill System has shown that in reverse circulation excessive pressure approaching 130 psi can cause borehole hydrofracture (ice fracturing) resulting in the loss of the borehole. Since the WDS operates in normal circulation, risk from hydrofracture is reduced since the higher-pressure drill fluid supply is contained in the drill rod. In general, it has been found that increasing fluid circulation pressure is not an effective way to clear downhole blockages. Once the drill string has penetrated competent overburden/bedrock concerns from hydrofracturing are reduced and circulation pressures up to 250 psi have been used without issue.

The system requires only one mud pump during normal operation. However, a T-fitting and short hose is included so pumps can be run in parallel – producing a maximum flow rate of 6 gpm.

To set up the mud pump, connect the ½" fluid hose to the intake fitting using the JIC connector. Place the other end of the hose (which should have a metal cylindrical filter) near the bottom of the filtration tank. Connect a second hose to the pump's output. The other end of the this hose is connected directly to the water swivel on the powerhead assembly. Finally, connect the pump to 120 VAC power when it is ready for operation. In firn sites, place the pump as close as possible to the level of the filtration basin. This will ensure that the pump has sufficient power to lift the fluid from the basin to begin circulation.

Table 1: Mud Pump output flow characterized as a function of the speed control dial position.

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

9.6.3 Electronic Pressure Relief Valve (PRV)

An electronic pressure relief valve (PRV) system is used to consistently regulate fluid circulation pressure. The system consists of a manifold, Hydac electronic pressure sensor, and pressure readout box. The PRV manifold is plumbed in-line between the outlet of the mud pump and inlet to the water swivel with the standard 1/2" fluid hoses. 120 VAC power is required for the pressure readout box. The pigtail cable coming from the readout box plugs into the mud pump variable frequency drive (VFD). If both pumps are used, the pump splitter cable can be connected to the pigtail so both pumps are controlled by the PRV. Finally, the pump on/off cable is connected between the pressure readout box and the powerhead. The Hydac pressure sensor monitors the fluid pressure at the pump outlet and displays it in PSI on the pressure readout box. If fluid pressure rises to the PRV set point, the mud pump will be immediately stopped and the red light on the PRV controller and powerhead motor controller will light up. The Hydac sensor can be programmed to have a time delay to prevent the mud pump from immediately restarting after pressure drops below the set point. This gives the operator time to evaluate the cause of the pressure spike or turn the mud pump off. The pressure set point and time delay can be changed reprogramming the Hydac sensor. See 8393-0024 HYDAC_EDS300 Pressure Switch Manual for details.

9.6.4 Sump Pit and Pit Pump Setup without Casing

When the Isopar K returns to the surface, it is collected in a sump pit cut in the ice with a chainsaw that drains to the side of 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. Sump Tank Setup with Casing

When casing is used, an aluminum sump tank suspended from the rig footing collects the fluid flowing out of the top of the casing and gravity drains it to the filter tank. This filter tank is sized so that it can be installed in the slot cut for the Eclipse Drill as shown in Figure 14. Drill fluid is diverted into the sump tank with a piece of layflat tubing hose clamped to the casing end and folded over the sump tank nose piece. This setup ensures that fluid enters the tank rather than being lost by flowing around the outside of the casing and down the borehole. The sump tank outlet accepts a hose stub to gravity drain into the filter tank.

9.6.5 Filter Tank

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 filtered using a gravity filtration system, Figure 13 and reused. The fluid is pumped or gravity fed (in ice and firn sites, respectively) into 100 micron then 10 micron nested filter socks at the top of the filter tank. As the filter sock fills with chips and becomes plugged, flow is transferred to the second sock as the first is cleaned and emptied. The drum can hold up to 65 gallons of drill fluid and should be checked often to monitor fluid level.

Before installing the filter tank, make sure that the slot is wide enough to accommodate the tank, deep enough so that the top of the filter socks are below the level of the sump tank drain and level. Install the filter tank with the two filtration socks facing the casing and sump tank as shown in Figure 14. Make sure during setup to keep the tank free of any snow. Snow that falls into the tank can potentially clog the pumps or drill rods. Next, install the plastic baffles in the tank to settle fine impurities that pass through the filter socks on the side of the basin nearest the borehole. Make sure the lid is on the tank when not in use to prevent blowing snow from getting in the tank.

9.6.6 Fluid Chiller

At warm ambient drill sites, it is important to maintain drilling fluid temperature below -5°C. Cold drill fluid is critical to prevent melting and degradation of the borehole which can lead to refreezing and sticking of downhole equipment. An air-to-liquid fluid chiller is supplied to maintain the fluid at sub-freezing temperatures. Despite this, drums of fluid should be buried and shaded at warm sites to maintain cool fluid temperatures prior to drilling.

During setup, the chiller should be placed nearby the tank such that the chilling coil can be fully submerged in fluid. Connect the coil to the chiller using the provided ½" JIC hose. Next, connect the chiller to generator power using the provided 240 VAC cord splitter. Use the supplied cover to ensure that snow does not pack into the fan assembly within the chiller. Fluid temperatures of -5°C are sufficient during drilling to maintain favorable thermal conditions in the borehole.

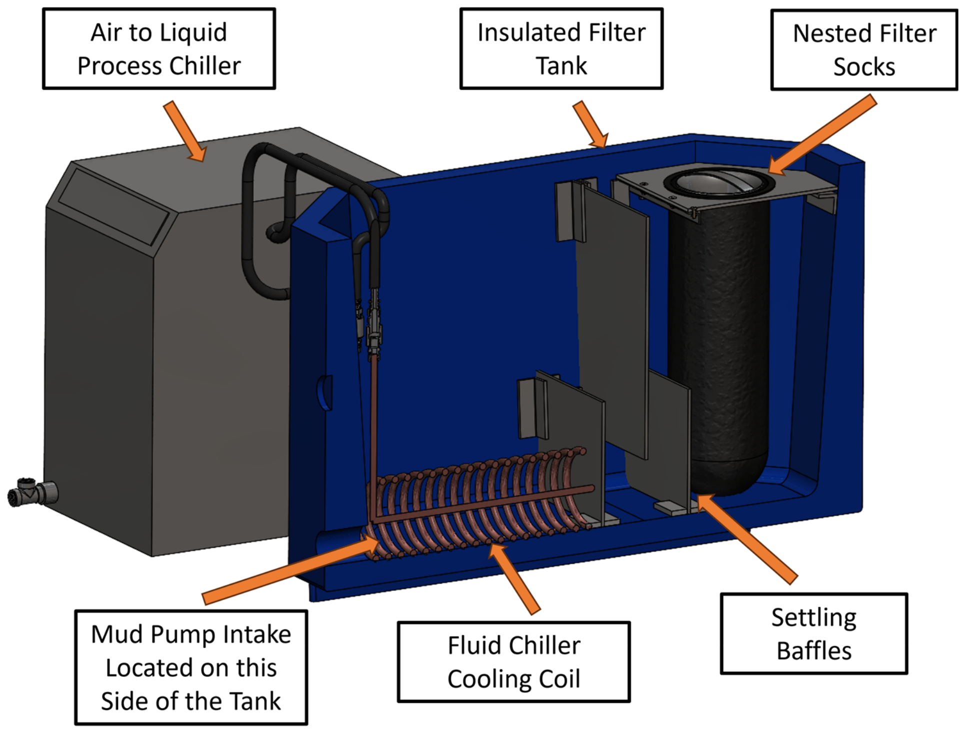

Figure 13: Section View of WDS Filtration Tank and Fluid Chiller Setup

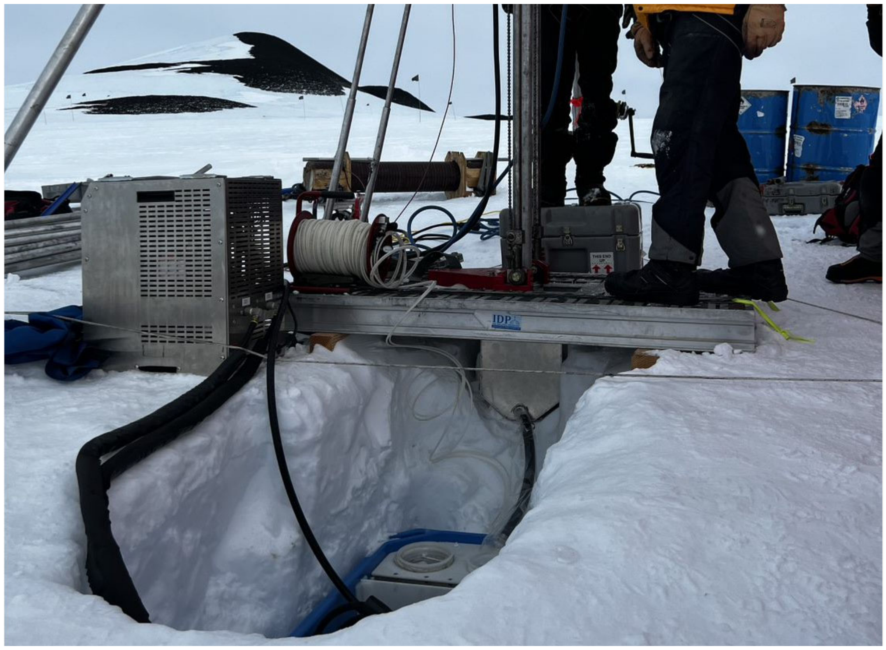

Figure 14: Filter Tank Installed in the Eclipse Drill Slot with Fluid Chiller to the Left

9.7 Tools and Spares

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

9.8 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. If using the Axion 6 x 6 m tent the drill rig platform must be recessed 50 cm below the tent base level to allow adequate internal height for tripod installation.

9.9 Transportation Equipment

Drill rig transportation between drill sites must be evaluated based on the unique limitations inherent to 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 300 lbs (136 kg).

10.0 STANDARD DRILLING OPERATIONS

10.1 Drill Configuration

Configure the drill for the core size to be collected using Table 2 below.

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	Slip foot clamp	Kwik Klamp II
Planetary Gear Reducer	Drawing# 83930081	Drawing# 83930089
Tube Wrench	1.75 inch	3.4 inch

10.2 Downhole Tooling Configuration

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 the 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 powerhead into crushing the rock or cutting the ice and collecting a core.

10.2.1 Drill Rod

Drill rods act as a rigid connection between the powerhead 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).

Prior to connecting drill rod, remove them from their bundles and remove endcaps. Inspect the drill rod for snow, dirt or any other buildup that could impede fluid circulation. Pay special attention to the drill rod bore as any contaminants found will wash downhole and plug core barrel fluid passageway. If necessary, clean both the interior and exterior surfaces of the drill rod with a brush.

10.2.2 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 allows the inner barrel to be stationary and support the core while the outer barrel rotates the bit. Threaded onto the bottom of the inner barrel is the core lifter and lifter shoe. The core lifter is a tapered collet that allows the core to slide into the barrel but then grips and breaks the core when the drill string is lifted. Figure 15 shows an exploded view of the AW34 core barrel. A detailed parts list of the core barrel can be obtained from IDP.

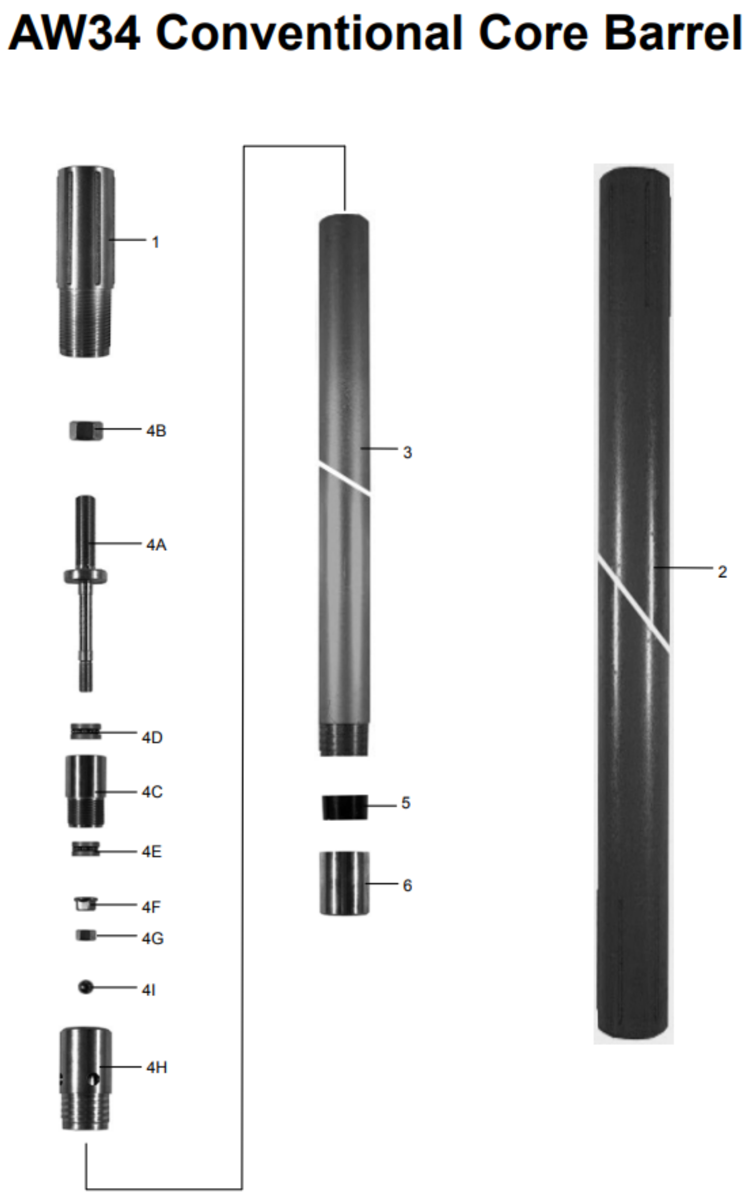

Figure 15: The core barrel components seen in an exploded view from the American Diamond Tool catalogue. 1: Core Barrel Head, 2: Outer Tube, 3: Inner Tube, 4: Bearing Assembly, 4A: Bearing Shaft, 4B: Adjusting Locking Nut, 4C: Bearing Retainer, 4D: Thrust Ball Bearing

10.2.3 Bits – General

Three rock coring bit types are included with the WDS, Figure 16, each intended for optimum performance in different media. The Geoset bit (Figure 16a) 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 (Figure 16b) 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 (Figure 16c) 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 Geoset or PDC pits. Typical AW34 speeds are around 220 rpm and 86T2 speeds are around 100 rpm.

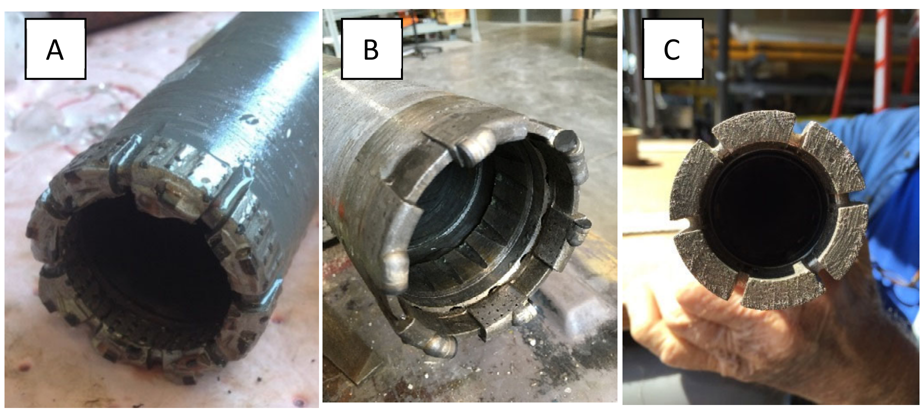

Figure 16: (A) Geoset bit – best suited for cutting solid ice, dirty ice, and suspended pebbles
(B) PDC bit – effectively cuts ice, dirty ice, suspended pebbles, and soft rock formations
(C) Impregnated bit – cannot core any type of ice; different series available depending on formation hardness and abrasiveness.

10.2.4 Full-Face Ice Bit

Often science objectives only call for core samples of the basal ice or bedrock, therefore it is desirable to drill quickly through overlying ice to access the sample objective. The WDS is equipped with a full-face ice bit for this purpose, Figure 17. During operation, the full-face ice bit requires fluid circulation to flush chips back to the surface so it can only be used in blue ice holes or in a cased hole. The ice bit threads directly to AW drill rod – no core barrel assembly is used to maximize annular clearance. It is recommended to run an AW ice reamer directly behind the bit to stabilize the drill string and size the hole. During testing at IDP, it was found that any combination of bit speed and flow rate would reliably create an access hole in the ice. However, as a reference point, 440 rpm and 3 gpm of fluid flow resulted in a penetration rate of about 0.19 m/min. See the 8393-0021 Ice Bit Test Report for full details.

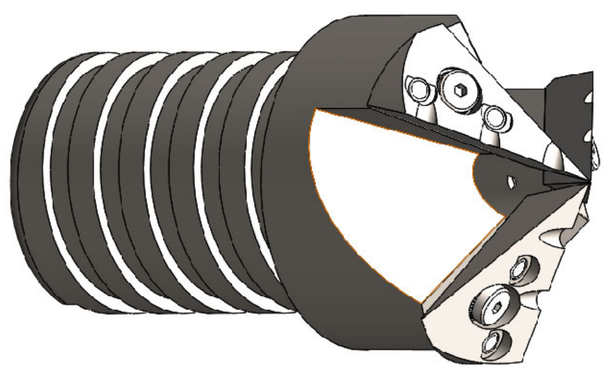

Figure 17: Full-face ice bit, used for rapid access through clean, solid ice

10.2.5 Basal Ice Coring Bit

To collect high quality basal ice cores, IDP has developed a dedicated ice coring bit that can collect a 33.5 mm ice core. The bit features interchangeable hardened steel cutters and shoes to set the coring pitch Figure 18. This bit is run with the AW34 core barrel and uses the core lifter for core retrieval. This bit has not been field tested, but it is a promising option for recovering high quality basal ice cores.

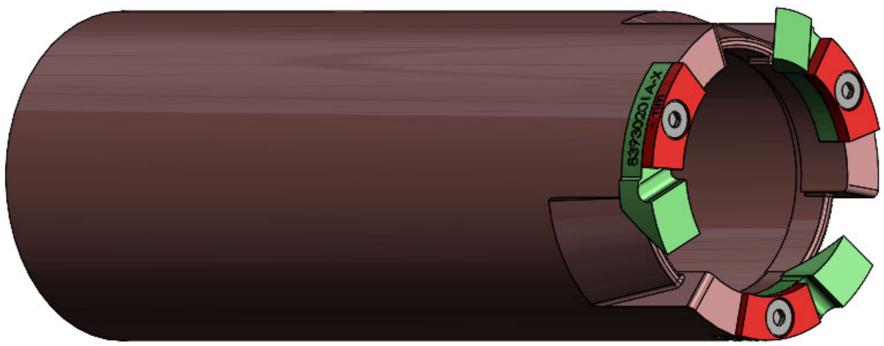

Figure 18: Basal Ice Coring Bit. Cutter and shoes shown in green and red respectively.

10.2.6 Assemble the core barrel

After selecting the appropriate bit, apply thread compound to all threaded connections in the core barrel assembly. Ensure the core lifter is free to slide in the lifter shoe and grease if necessary. If the impregnated bit is selected, ensure it is properly dressed before each run to expose new diamonds to the cutting face, Figure 19. The spacing between the core lifter shoe and the bit, referred to as bit gap, should be in the range of 1/16" to 1/8" (AW34 core barrel only). For the AW34 core barrel, grease the bearing section before each run. Install an ice reamer above the bearing section.

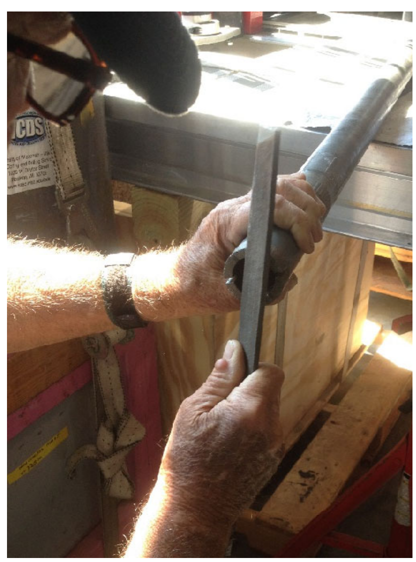

Figure 19: A bastard file is used to dress the bit; disrupt the surface of the bit to promote matrix wear and expose new diamonds at the beginning of each run.

10.2.7 Trip rods down

Begin tripping rods down the borehole by using the same procedure as for installing the casing (section 9.4). Apply thread compound to all threaded connections and use AW cuff wrenches to make connections to avoid marring the aluminum drill rod. The first section to be lowered will be the bit – core barrel – ice reamer assembly connected to the first drill rod section and finally to the hoist ring. Unlike the casing, there are no centralizers or nylon tubing to manage while tripping rods down the hole. Be sure to use the AW rod jaws for the slip foot clamp while lowering. It is important to keep track of the number of rods added downhole so that unexpected hangups or blockages can be realized. Take care to slowly pass the core barrel through the packer as bits can get caught in the transition from casing to borehole. Stop tripping rods downhole when the bit is approximately 30 cm above the hole bottom. This will ensure that the bit and core barrel does not get plugged prior to initiating fluid circulation.

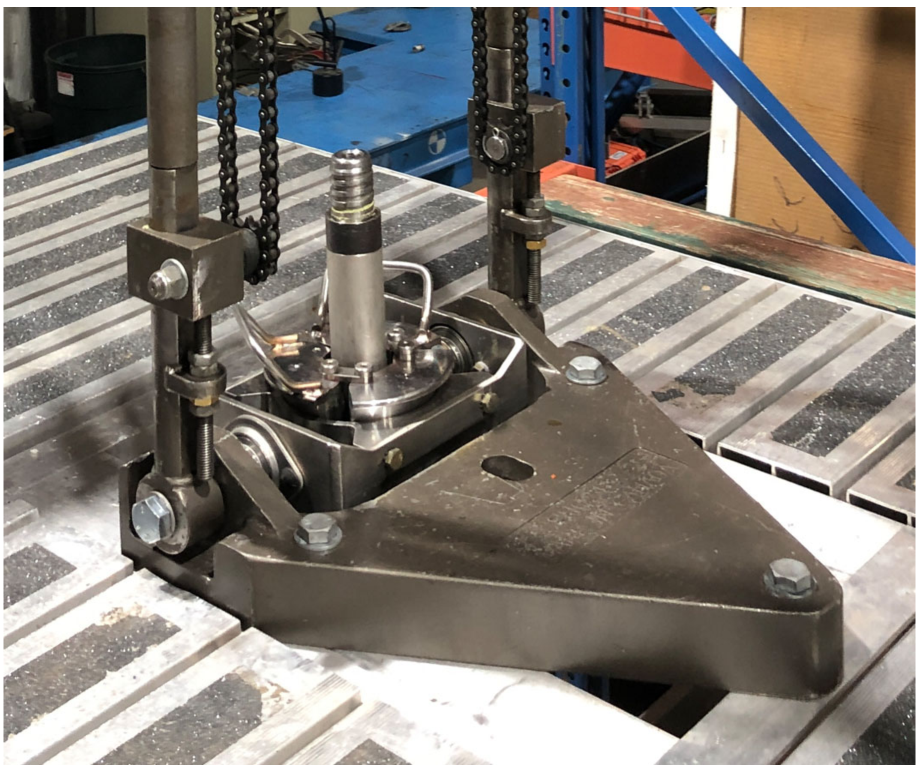

Figure 20: Slip foot clamp assembly shown with AW drill rod jaws installed. Note there are two sets of jaws that accommodate the different diameter drill rod and casing.

10.2.1 Connecting the powerhead.

After adding the final section of drill rod, connect the drill string to the drive shaft of the powerhead. It is best practice to leave a steel AW rod coupler attached to the drive shaft so that its threads are protected from damage. To make the connection, shift the powerhead transmission into neutral and spin the drive shaft onto the drill string while floating the powerhead down. Use as little force as possible to avoid damaging the threads. Use thread compound and tighten the connection with cuff wrenches. Once the connection is secure, lift the drill string using the hand wheel and remove slip foot clamp jaws. Set the powerhead brake and prepare the other WDS systems for drilling.

10.2.2 Connect the Power System

The WDS (powe-head, mud pumps, and fluid chiller) can be powered with a single 5 kW generator. The powerhead electric motor runs on 48 VDC which is supplied by an inverter power supply. This power supply requires 240 VAC power. To assemble the power system, connect the generator to the power supply, and power supply in turn to the powerhead. The WDS mud pumps run on 120 VAC and must be powered by a non-GFCI protected generator circuit to avoid generator compatibility issues with the mud pump VFD. This is typically accomplished by using a power cord adapter to plug the pumps into the 20 AMP twist lock receptacle available on most Honda generators. The fluid chiller is also powered by 240 VAC. A cord splitter is included so that the drill and fluid chiller can be powered simultaneously if desired by the operator.

10.2.3 Mudpump Operation

Set the pump flowrate by adjusting the pump speed knob between 1-10 (low to high flowrate) on the VFD drive on top of the pump. The operator can turn the pump on/off from the powerhead, but the pump flowrate must be set on each pump. If two pumps are being run in parallel, the flow rates are additive. It is possible to run the two pumps at different flow rates by changing the respective speed knobs for each pump.

1. Before starting the pump, ensure that the intake is submerged in filtration tank.
2. Start the mud pump by turning on the mud pump switch, Figure 21, on the powerhead control box.
3. Listen for the pump to prime. If the pump is not priming, bleed the air from the system by opening bypass ball valve on the mud pump manifold or crack the fluid hose connection at the powerhead water swivel.
4. It is required to have 2-3 gpm pump flow rate to properly cool the bit and transport cuttings to the surface. Before drilling, make sure that fluid is circulating properly – coming out of the casing, entering the sump tank and filtration basin/sump pit and returning downhole through the drill rods.
5. If the fluid level in the filtration tank continues dropping after establishing return drill fluid circulation stop fluid circulation immediately. Leaks (possibly downhole) are present in the circulation loop and must be fixed prior to drilling (see section 0).

10.2.4 Drill string rotation Powerhead Assembly

The Winkie Drill powerhead consists of a brushless DC (BLDC) electric motor with integrated drive, planetary gear reducer (optional), motor controller, transmission, and water swivel, Figure 21.

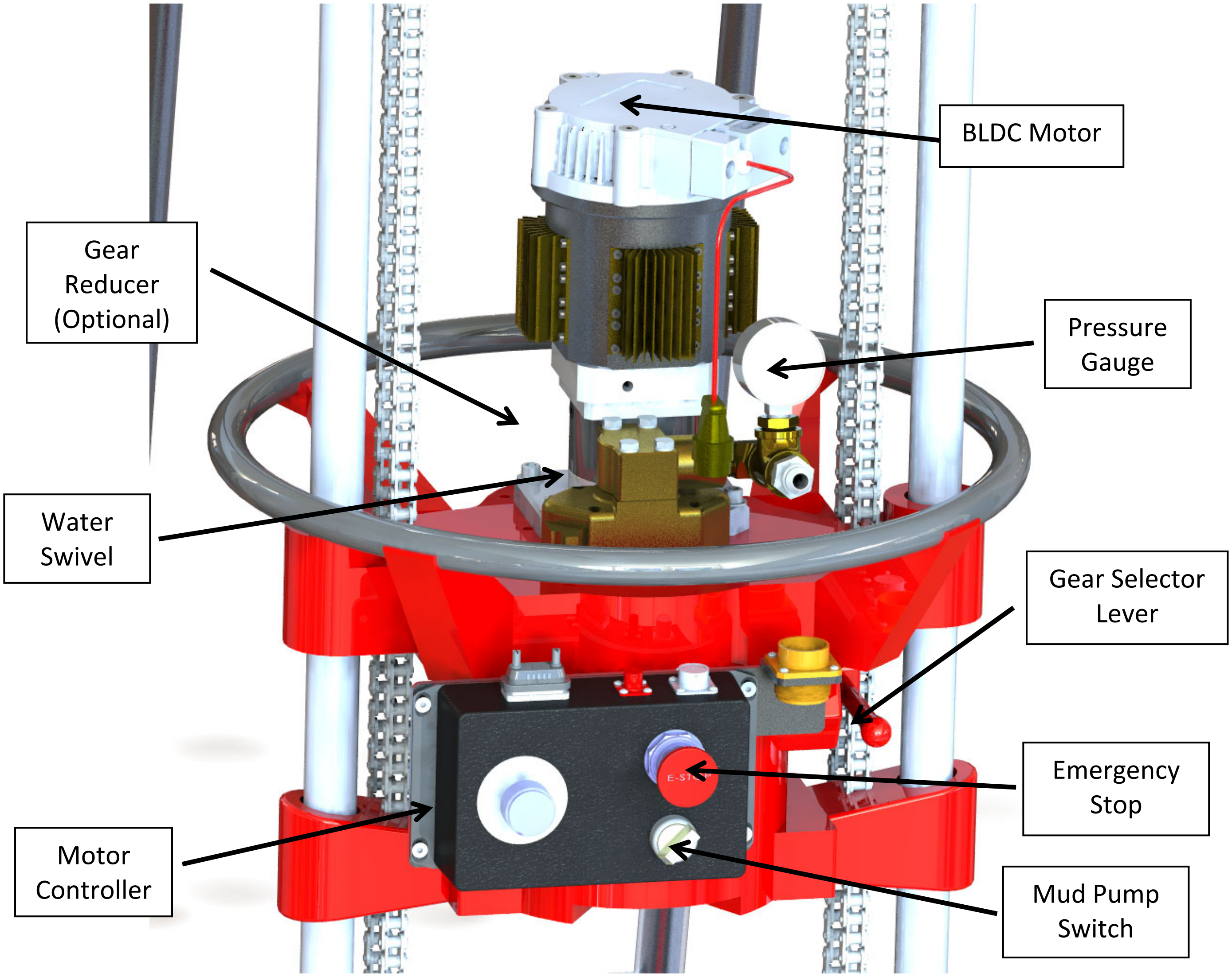

Figure 21: Winkie powerhead components.

The torque for drilling is generated by an Evo4 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 powerhead.

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. However, the gear reducer can provide a sufficient output speed, and therefore does not have to be removed, to drill ice and rock with the AW34 tooling. 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 550 ml of 75W-90 gear oil. Before drilling, verify that the transmission is filled with oil. Table 3 shows the approximate drill rod RPM for various speed dial settings with and without the 3:1 gear reducer and with the transmission in low and high gear. The purpose of the water swivel is to allow drilling fluid to be pumped into the rotating drill string under pressure.

Table 3: Relationship between the speed dial position and drill rod RPM with and without the gear reducer and with the transmission in low and high gear.

	Drill Rod RPM			
	No Gear Reducer		3:1 Gear Reducer	
Speed Dial #	Low	High	Low	High
35	Rotation starts			
40	51	129	17	43
45	90	204	30	68
50	126	288	42	96
55	150	363	50	121
60	195	453	65	151
65	225	516	75	172
70	255	606	85	202
75	294	675	98	225
80	312	750	104	250
85	354	828	118	276
90	378	876	126	292
100	411	957	137	319

10.2.5 Place the transmission in gear, turn on the power supply, disengage the E-stop, and turn the potentiometer to begin drill string rotation. These steps must be taken in exactly this order or the system will fault and will require power cycling on the power supply box.

10.2.6 While drilling, always circulate drill fluid. Begin by lowering the spinning drill slowly for the last ~30cm to wash the hole until the bit comes into contact with the hole bottom. At this moment, note the reading of the tape measure on the slide rail. Drilling progress is monitored using the tape to assess drilling efficacy as well as core recovery.

10.2.7 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 bit is engaged, RPM can be increased. If the drill rod starts to “whip”, excessively vibrates, 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.

10.2.8 Feed pressure and Fluid Circulation

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. The weight of the drill string and powerhead factor into feed pressure. The operator must balance penetration rate with the flushing rate of cuttings to prevent the bit from plugging and losing circulation. When drilling with the full-face ice bit, it is common to limit the feed pressure by holding the drill string back using the hand wheel. This will ensure a straight hole is drilled. In general, feed pressure is limited by the power of the motor, strength of the anchors, and heat generated by the bit.

- If the powerhead motor begins to stall, reduce feed pressure.
- 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.
- Always monitor the drill fluid pressure gauges. There is one at the input of the water swivel, Figure 21, and one on the manifold of the mud pump. If circulation pressure approaches the electronic PRV set point or if return flow stops, reduce feed pressure immediately and lift the bit off the bottom of the hole. It is critical to never apply feed pressure if there is not return fluid circulation. This will result in sticking of the drill string. Attempt to reestablish fluid circulation by raising or lowering the drill string while continuing to rotate 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, this can result in a core break which normally ends a coring run.
- Note that if fluid circulation becomes partially blocked or plugged at the bit or around the core barrel annulus, pressure from the mud pump can easily lift the drill string and rapidly reduce feed pressure. The operator should always maintain hold of the hand wheel during operation.

10.2.9 Drilling a Core

Continue to apply feed pressure while monitoring fluid circulation until either the powerhead reaches the bottom of the unipress extensions or the core fills the core barrel (1.5 m capacity). If the powerhead reaches the bottom of its stroke before collecting a full core, a drill rod can be added to the drill string. Before stopping to add a drill rod, continue to rotate the drill string slowly and circulate fluid until the fluid coming to the surface is clean. This flushes any chips remaining downhole to the surface so they do not settle and possibly stick the drill string. After flushing is complete, stop drill rotation and fluid circulation. Suspend the drill string using the slip foot clamp. Break the drill rod joint between the top drill rod and the powerhead. Raise the powerhead to the top of the unipress. Add a drill rod between the drill string and powerhead. Be sure to apply thread compound to all connections and tighten the joints with cuff wrenches. Restart fluid circulation. Restart drill rotation. Apply feed pressure. Continue drilling until the complete core is collected.

10.2.10 Break the core

After the core barrel is full or fluid circulation is lost, continue to rotate the drill string slowly while maintaining drill fluid circulation until return fluid is free of cuttings. Next, break the core using one of the three methods below:

- Use the unipress for the core break; lift the drill string with the necessary force to break the core by rotating the hand wheel. This method works well for weaker ice and mixed media core.
- Use the provided Hi-Lift jack to generate the required pull-back force for the core break; disconnect the powerhead 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 slip foot clamp and the rod-puller.
    - 86T2 - Screw the hoist ring adapter onto the top of the drill string and place the jaw of the jack through the hoist, Figure 22.
- 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.

Figure 22: Hi-lift jack positioned to break a rock core with the 86T2 coring barrel assembly.

10.2.11 Trip drill string out of the borehole

Trip rods out of the hole using the tripod lifting system. Using the capstan 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, set the drill string on the hole bottom using the jack and then remove core break equipment. Install the AW foot clamp jaws in the slip foot clamp. Thread the lifting plug onto the drill string. Making sure to handle only the output side of the rope from the winch, lift the drill string using the capstan until two sections of drill rod are above the slip foot clamp. Slowly release the tension on the rope, letting the slip foot clamp carry the weight of the drill string. Break the joint above the foot clamp. Have one person hold and direct disconnected drill rods while lowering the lifting plug from the top of the tripod. Remove the lifting plug and attach it to the drill string. Repeat this process until the entire drill string has been brought to the surface.

10.2.12 Extract the core

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

- AW34 – Separate the outer barrel from the bearing section using appropriate cuff wrenches. Unthread the core barrel from the bearing section using the appropriate tube wrench. Push the core through the inner barrel, Figure 23, (towards the bearing section) onto a tray for logging.
- 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.

Figure 23: Removing rock core from AW34 core barrel.

10.2.13 Fluid Recovery

When coring operations are complete, recover drill fluid from the borehole to be filtered and used in future boreholes. Assemble the fluid bailer assembly. Replace the static rope on the tripod with the longer supplied line to reach to the bottom of the borehole. Use the tripod to lower the assembly into the borehole. Lower the assembly until the fluid bailer is either submerged in fluid or reaches the bottom of the borehole. Manually hoist the assembly from the borehole taking care to pull only from the inside of the tripod footprint. The fluid bailer 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. Depressing the pin releases the contained fluid. Figure 24 shows a section view of the fluid bailer valve. Dump the fluid through the filter socks and into the fluid tank. Repeat this process until all fluid is recovered from the borehole.

In cases where several drill runs are needed to recover the desired core samples, it may be necessary to bail all of the fluid out of the hole so it can be filtered. Without bailing, progressive drill runs can result in a buildup of rock and ice chips downhole, impeding fluid circulation.

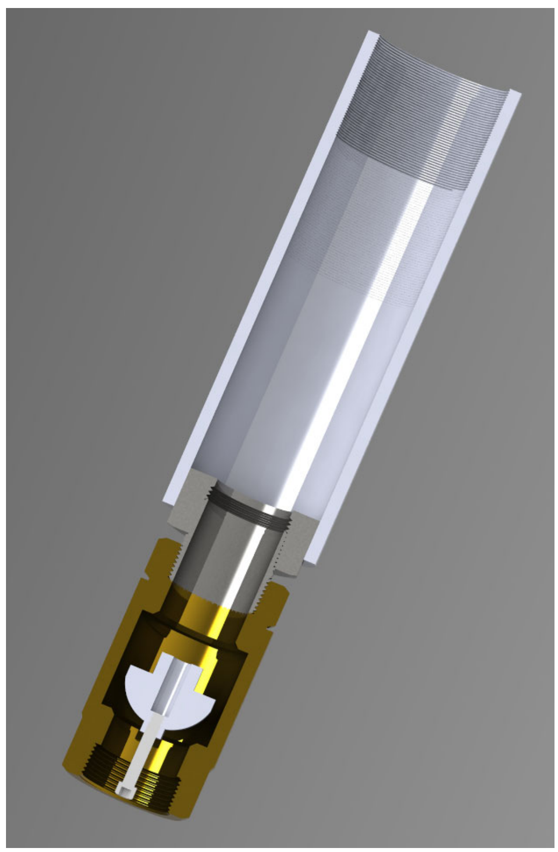

Figure 24: Fluid bailer assembly section view.

10.3 Ice Augering

When an access hole through clean ice is desired (without collecting core samples) to depths of 30 meters or less, the quickest option is to use a string of augers. Attempts to auger deeper holes resulted in the push-button connections repeatedly failing. The primary advantage of the augers is the ability to drill without drilling fluid. Without drilling fluid, the process is quick and clean. However, the augers are not able to fully remove all of the cuttings from the hole, resulting in a fill ratio of about 3-4%. 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.

10.3.1 Rig adapters

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

10.3.2 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.

Figure 25: Kovacs auger cutter head. Note the outside edge of the cutters are dulled from contact with bedrock.

10.3.3 Augering parameters and speed

The augers are used only with the powerhead 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 rotated at full speed (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.

10.3.4 Adding auger sections

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

10.3.5 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, Figure 25, but they are easily replaceable. Quickly lift the auger string so the auger head is no longer in contact with the bedrock. Increase the rotational speed to clear all possible chips to the surface.

10.3.6 Pulling the auger string

Removing the auger string is also similar to pulling the drill rod string. However, the Kwik Klamp, fitted with specialty jaws, Figure 26, will be used in place of the slip foot clamp 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.

Figure 26: Specialized Kwik Klamp jaws for use with Kovacs Enterprises augers.

11.0 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 powerhead to rest on the rig base so the rig has the lowest possible center of gravity.

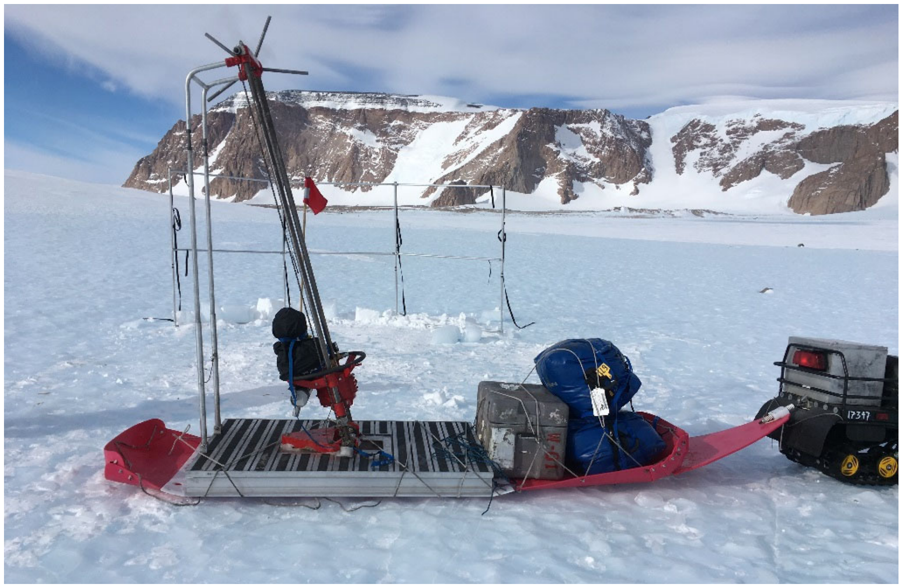

Figure 27: The WDS strapped to a Siglin sled ready for transportation to a new drill site.

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.

12.0 TROUBLESHOOTING

Table 4. Issues that may arise and solutions that can be implemented in the field.

Issue	Possible Cause	Fix
Powerhead		
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
Powerhead does not move with hand wheel	Broken chain	Remove broken links, splice in new chain section using master links
Cannot move powerhead/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

13.0 APPENDIX A: REFERENCE DRAWINGS AND SAFETY DATA SHEETS

13.1 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.

13.2 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 5 below outlines hazards for each chemical

Table 5. 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

14.0 APPENDIX B: ITEMS TO REQUEST FROM THE LOGISTICS PROVIDER

Table 6. 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. sledgehammer
1	Graduated jerry can with flex spout and funnel
1	Survey tape
1	Drum Funnel
2	5-gallon bucket

*qty is project specific

15.0 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		
POWERHEAD			
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		