SMALL HOT WATER DRILL
Operations and Maintenance Manual

July 23, 2025

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 Small Hot Water Drill.

2.0 SCOPE

2.1 This document applies to all personnel working with the Small Hot Water Drill.

3.0 REFERENCES

3.1 8514-0094 Small Hot Water Drill Safety Documents

4.0 DEFINITIONS

4.1 IDP – U.S. Ice Drilling Program

4.2 PSL – Physical Sciences Laboratory

4.3 QAS – Quality Assurance and Safety group

4.4 SmHWD – Small Hot Water Drill

4.5 SSEC – University of Wisconsin-Space Science & Engineering Center

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 Small Hot Water Drill.

6.0 RECORDS

6.1 None.

7.0 SAFETY NOTES

7.1 Only operators approved by IDP may operate this drill. All operators must complete the IDP SmHWD Safety Training before operating the drill.

7.2 Hot water

7.2.1 This system creates hot water up to 100 C. Use appropriate PPE to prevent burns. Note that this heat will transfer from the water to a lot of the metal parts of the system. Take care to avoid burns from accidentally touching hot components.

7.3 High pressure

7.3.1 This system creates pressure up to 1000 psi. Frequently check for small leaks and fix them before they become large ones. Do not disconnect fittings while they are still under pressure.

7.4 Super-heated water

7.4.1 This system has the potential to create super-heated water. Do not disconnect fittings while the water inside is near peak temperature.

7.5 Combustibles, hot exhaust

7.5.1 This system uses combustible fuels while also creating lots of heat. Take care to properly store all combustibles away from all major heat sources.

7.6 Electricity

7.6.1 This system uses 120 VAC electrical circuits. Take care and wear appropriate PPE when handling electrical components. Ensure that all components are properly grounded to each other before energizing the system.

8.0 SYSTEM OVERVIEW

8.1 The IDP Small Hot Water Drill (SmHWD) is designed for fast drilling in firn (Figure 1). It employs a lost-water hot drilling technique, meaning no water is recirculated back from the hole. Thus, in addition to providing thermal energy to melt the hole, the system also has a local hot water recirculation loop to aid in melting snow to provide makeup water.

IDP maintains two SmHWD systems, differentiated as the “Red” system and the “Blue” system. Both systems adhere to the schematic shown in Figure 1, except there are differences in the heat transfer rates of the heaters, resulting in different water temperature outputs that can be attained with each system. These differences are detailed in Table 1.

	Red System	**Blue System**
Heater Coil Material	Steel	Stainless Steel
Heater 1 Heat Transfer Rate	71 kW	48 kW
Heater 2 Heat Transfer Rate	60 kW	49 kW
Total Heat Transfer Rate	131 kW	97 kW
Maximum Water Temperature Increase at 7 GPM Flow Rate	+71°C	+52°C

Table 1: Differences between the “Red” and “Blue” SmHWD systems.

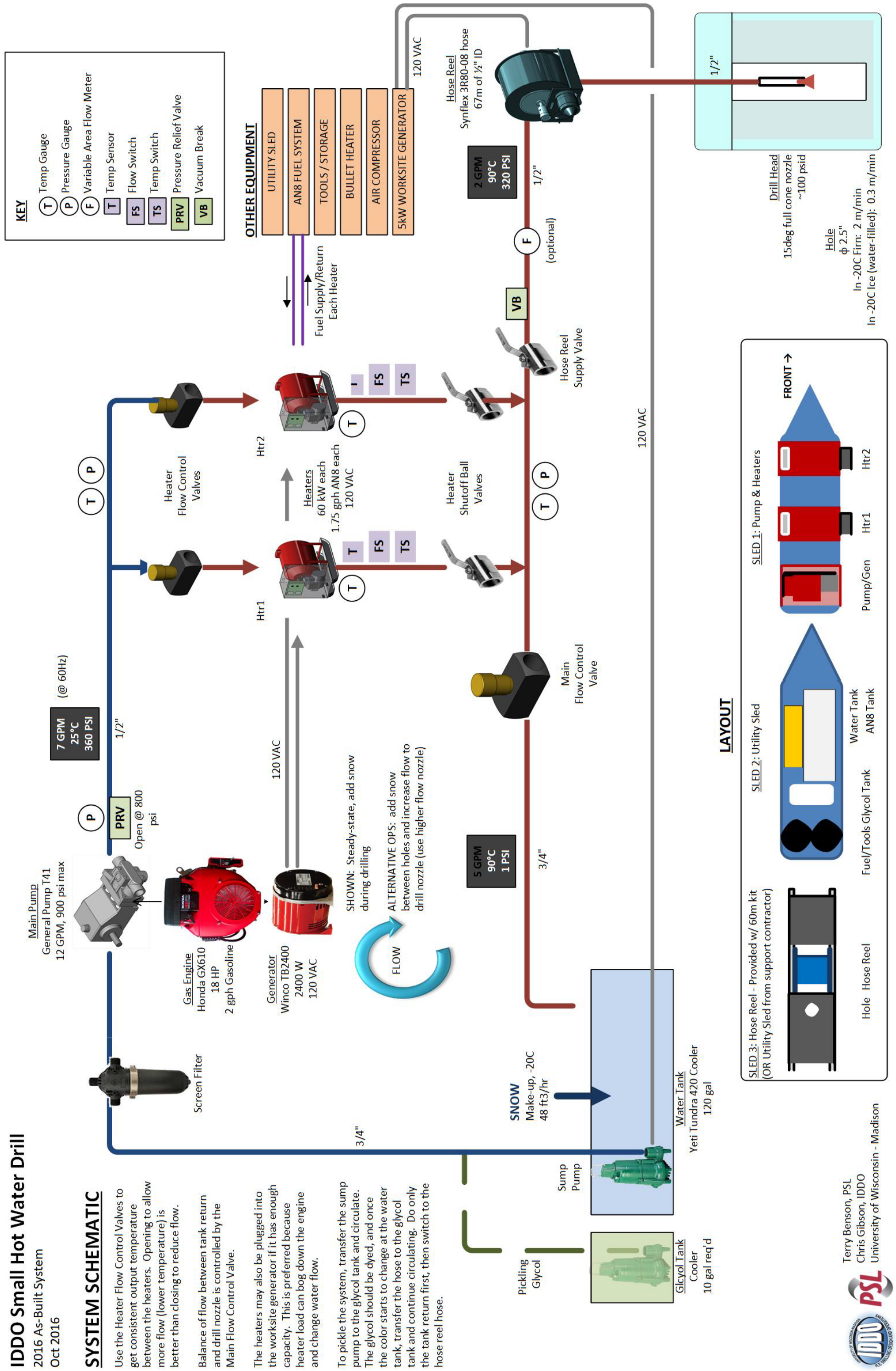


Figure 1: IDP Small Hot Water Drill system schematic. Note that a 90°C output water temperature is not always attainable depending on the water temperature in the tank and which system is being used.

8.2 The main system components consist of a gasoline-powered pump/generator module and two fuel-fired water heaters (Figure 2), a water tank (large white tank) an AN8 fuel tank (yellow color tank) for the heaters and a small tank for glycol (Figure 3).

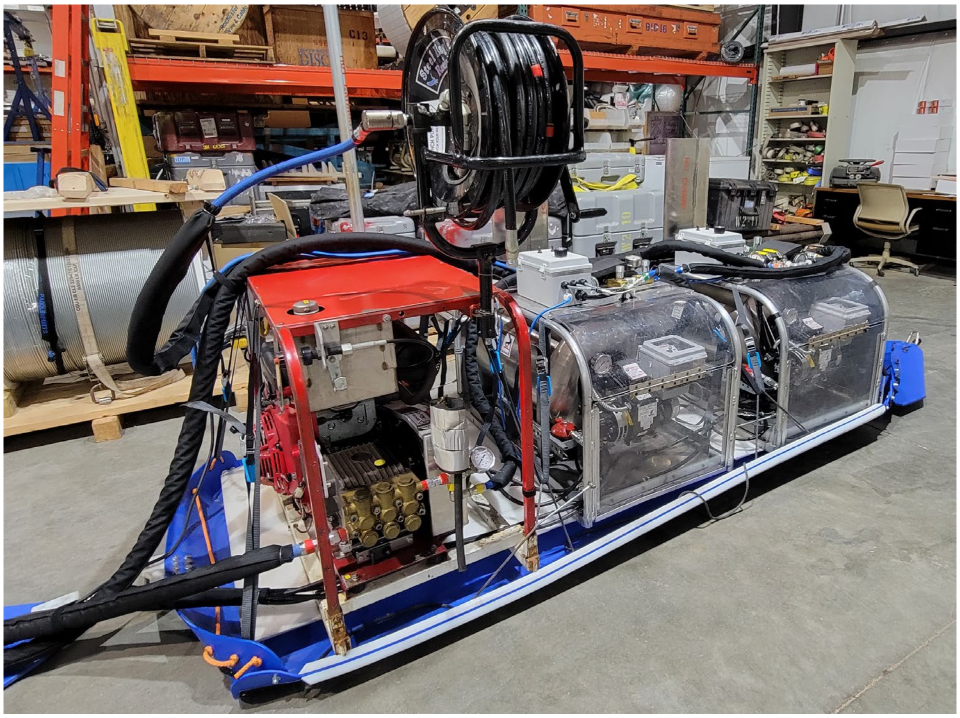


Figure 2: Sled containing the pump/generator (red unit) and heaters (two silver-colored units).

Figure 3: Sled containing the water tank (large white tank), fuel tank (yellow color tank), and glycol tank (small white cooler/tank).

8.3 The water loop starts at the water tank, where water is drawn from the tank with a sump pump to pressurize the inlet to the high-pressure pump. This is done to avoid negative suction pressure and cavitation of the high-pressure pump. A screen filter is installed between the sump pump and high-pressure pump; this relatively course filter prevents debris from melted snow entering the system. It will also clog quickly after initial system startup if there is debris in the system. Check this filter daily and keep it clean.

8.4 The high pressure pump pushes the water through the system. It is driven by an 18 HP Honda gasoline engine. The Honda engine also drives an onboard AC generator. The heaters and sump pump can be powered from this generator; however, a separate contractor-provided 5kW generator can be substituted for more reliable independent power. For the given belt ratio, the pump provides 7 gpm of flow when the generator reads 60 Hz. Engine speed is adjusted via the throttle control knob and should be adjusted so the generator hertz meter reads 60 Hz. The Max discharge pressure of the pump is 1000 psi, and there is a pressure relief valve on the discharge line to protect the system from overpressure. The relief valve starts to open around 700-800 psi. Do not adjust the pressure setting without consultation. Relief valves of this type tend to drip-leak. Although the relief valve is positioned near a heat source (engine), it is possible for the vent line to become frozen shut from leakage. It is very important to check the vent line periodically to make sure it is not plugged with ice.

8.5 After the pump, the water enters the cold manifold where it is instrumented with pressure and temperature gauges (Figure 4). Flow is then split between the two water heaters. Flow balancing between the heaters is accomplished by adjusting the brass needle valves on the input side of the heaters (on cold manifold). Do not open these valves beyond the purple band.

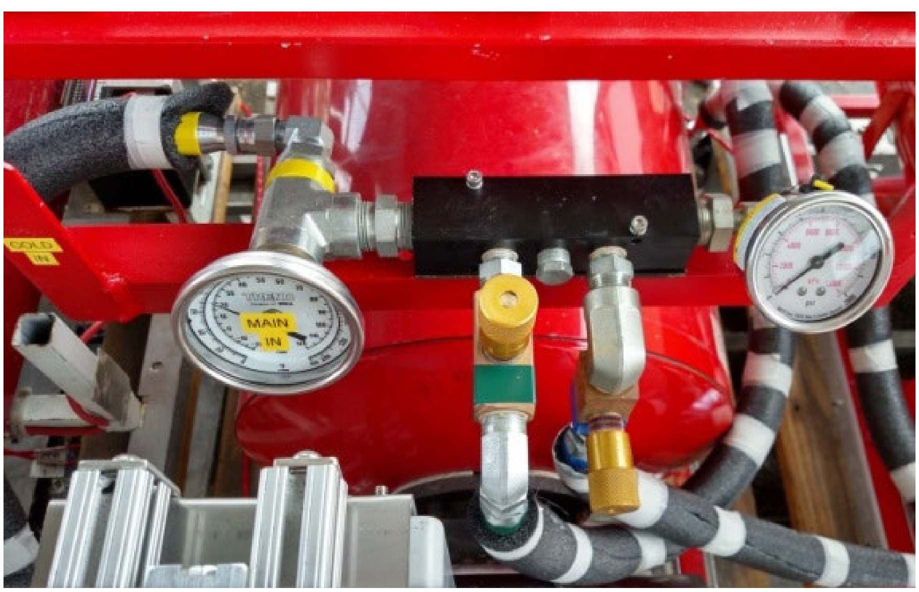


Figure 4: Cold manifold above Heater 1. Flow from pump enters on the left and then goes to the two heaters (middle hoses). Flow balancing between the heaters is controlled with the gold color knobs on the flow control valves. Incoming water temperature and pressure can be monitored on the two gauges.

8.6 The water gains thermal energy in the heaters. The heaters are AN8-fired with an internal pancake water coil. The output is instrumented with a temperature gauge and a series of safety interlocks: thermostat-controlled temperature, low flow switch, and over-temperature switch (Figure 5). Combustion is provided by a standard forced-air burner, comprised of a blower fan, fuel pump, igniter and igniter coil, and burner control module.

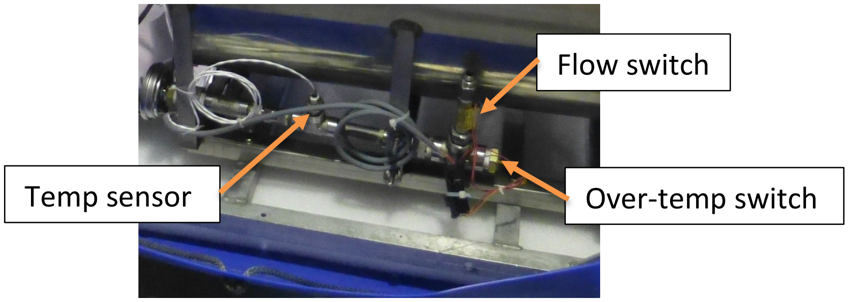


Figure 5: Sensors on the side of each heater include a temperature sensor, flow switch, and over-temperature switch.

8.7 Flows from both heaters are then combined in the hot manifold, which is also instrumented with pressure and temperature gauges (Figure 6). Each heater circuit is equipped with a shutoff ball valve on its output side.

Figure 6: Hot manifold above Heater 2. Hot water in from heaters in middle with shutoff ball valves, bypass to tank with main flow control valve heading out back, and drill supply with valve and vacuum break on right side.

WARNING! NEVER CLOSE BOTH INLET NEEDLE VALVE AND OUTLET BALL VALVE WITHOUT UNPLUGGING HEATER (LOCAL LOCKOUT). IF THE HEATER INTERLOCKS ARE DEFEATED AND THE HEATER RUNS WITH BOTH VALVES CLOSED, THE HEATER COIL CAN EXPLODE.

8.8 Hot water is then split again to the two primary system loops: 1) Local recirculation back to water tank, and 2) Drill flow. Local recirculation water is hot water sent back to the water tank to aid in snow melting. The drill flow is sent to the hose reel and used for creating the borehole. To adjust the flow between the two loops, a flow control needle valve is provided on the lower-impedance recirculation loop. Throttling down this valve will send more flow to the drill nozzle. A vacuum break is also provided on the drill flow circuit at the hot manifold. This will allow the hose to drain after drilling to prevent freezing of the main drill hose.

WARNING! Valving off both the bypass loop and drill hose at the same time when the high-pressure pump is running will cause pressure to quickly build and the pressure relief valve to open, discharging water or glycol onto the ground. Shut down the high-pressure pump if system flow must be stopped for any reason to prevent an accidental discharge through the pressure relief valve.

8.9 Depending on the system, the drill flow is sent through either a small hand-powered reel (for shallow configuration) or an electric-powered hose reel (for deep configuration). Hose from the hand reel can either be paid-out by hand or with the assistance of the provided tripod sheave. The electric hose reel is activated via footswitch, with direction and speed controlled by the small control box. It can be powered from the built-in generator or an independent contractor-provided generator.

8.10 The drill nozzle stem is perhaps one of the most critical pieces of hardware. It provides weight so that drilling can be steered straight by gravity, and also integrates the drill nozzle. Drill nozzle selection is made on system configuration, specifically whether the operator chooses to operate in a normal or high flow mode. The goal is to maintain a high velocity jet at the nozzle for the given drill flow.

8.10.1 <u>Normal Flow:</u> Melting snow while drilling. In this mode, snow is being melted during the drilling process to keep the system water reserves intact. To thermodynamically balance the system, more water is needed to melt snow than can be used for drilling. In this mode, about 2 gpm is used for drilling while 5 gpm is used for snow melting. Thus, a smaller nozzle is required.

8.10.2 <u>High Flow:</u> If water reserves can be topped off between holes, then the operator can choose to direct most of the flow down-hole for faster drilling. Here, a larger nozzle is required; otherwise, system pressures will be too high.

8.10.3 The choice comes down to field operations. Typically, it is easier to melt snow during drilling, since the system is stationary and personnel are available. Note that using a large nozzle in the normal flow mode will result in poor drilling performance. In this case, the water dribbles out more so than jetting out and the effective heat transfer from an impinging jet is lost.

8.11 The fuel tank has a capacity of about 27 gallons. The fuel lines between the tank and the heaters are fitted with quick connectors to prevent leaks and simplify the connection and removal process. More fuel than required is drawn by the heater fuel pump, after which excess is returned to tank. This system avoids having to bleed air from the fuel lines. The tank is refueled in place using a hurdy-gurdy pump or other delivery system. The burn rate is about 4 gallons per hour of AN8 fuel.

9.0 UNPACKING AND SETUP

9.1 Uncrating

9.1.1 The heater modules and engine module are shipped from IDP in individual crates. One end panel on each crate is labelled “Open this end”. Remove the screws securing these panels and then the modules can easily be slid out.

9.1.2 If the system is being transported by small aircraft without heavy equipment support at the destination, it is best to remove the three modules from their crates and ship them loose.

9.2 Breaking down and assembling engine module

9.2.1 If the system is being unloaded / loaded without heavy equipment support, it will be highly beneficial to break down the engine module into a few components.

9.2.2 The generator and pump are each mounted on a self-tensioning base. Remove the entire assembly from the main frame, while keeping the component attached to its self-tensioning base.

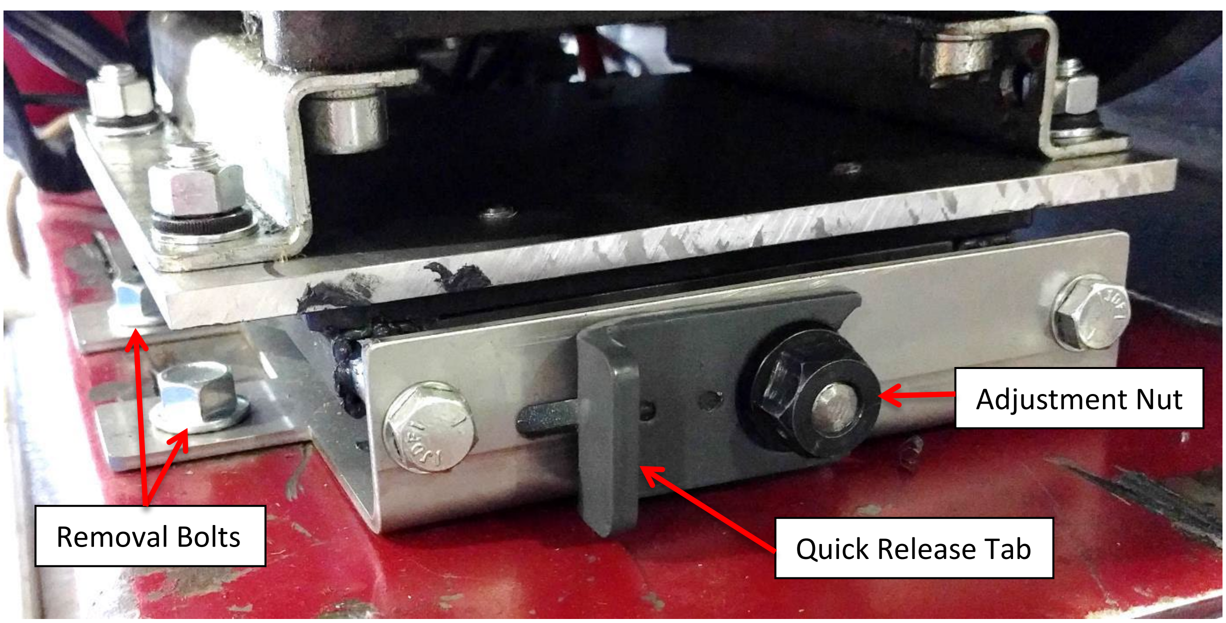


Figure 7: Self-tensioning base.

9.2.3 How to remove a self-tensioning base: (Figure 7)

- Loosen the adjustment nut until the quick release tab is loose.
- Slide the quick release tab to the left, clear of the adjustment nut.
- Push the generator / pump as close to the engine as it will go.
- Remove the door of the metal safety guard on the engine module.
- Slip the V belt off of the pulley.
- Loosen the four removal bolts. Do NOT completely remove them.
- Slide the self-tensioning base away from the engine until the ear tabs are clear of the removal bolts.
- Lift the assembly from the engine frame.

9.2.4 How to mount a self-tensioning base: (Figure 7)

- Set the assembly onto the engine frame.
- Loosen the four removal bolts as necessary to slide the ear tabs fully underneath them.
- Tighten down the four removal bolts.
- Slide the quick release tab to the left. It may be necessary to loosen the adjustment nut to do so.
- Push the generator / pump as close to the engine as it will go.
- Loop the V belt around the pulley, then pull the generator / pump away from the engine.
- Slide the quick release tab to the right, behind the adjustment nut. It may be necessary to loosen the adjustment nut to do so.
- Tighten the adjustment nut until it is finger tight. Then do 5 complete rotations using a wrench.
- Replace and secure the door of the metal safety guard on the engine module.

9.3 Putting equipment on sleds

9.3.1 The system ships from Madison with two Siglin sleds and one large piece of foam.

9.3.2 If the towing tongues shipped separately from the Siglin sleds, attach those first.

9.3.3 Place the large piece of foam into the bed of the Siglin sled that will hold the heaters and engine module.

9.3.4 Load the engine module and two heater modules onto the foam such that the engine module is at the very rear, Heater 1 in the middle, and Heater 2 at the very front. The exhaust stack of each unit should be on the left side of the sled (Figure 2).

9.3.5 Adjust the position of three modules until all four solid rod linkages (Figure 8) can be screwed into place between the modules.

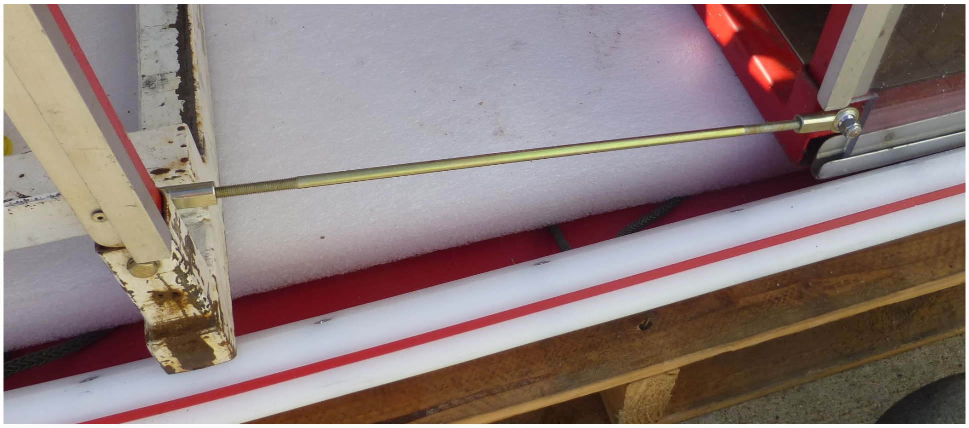


Figure 8: Solid rod linkage.

9.3.6 Secure each of the modules to the sled using the provided cam straps (Figure 9).

Figure 9: Engine and heater modules secured to the Siglin sled using the supplied cam straps.

9.3.7 Load the Yeti water tank, fuel tank, and glycol tank onto the second sled. Secure the components using the supplied ratchet straps (Figure 10).

Figure 10: Yeti water tank, fuel tank, and glycol tank secured to the Siglin sled using the supplied ratchet straps.

9.4 Water connections

9.4.1 All water connections are made with ½” or ¾” JIC hose fittings, and are labelled with colored, heat resistant electrical tape.

9.4.2 Tighten these fittings with two wrenches and periodically check for leaks during the season.

9.4.3 Starting from the sump pump and moving through the system, the water connections are as follows:

- Yellow ¾” hose – sump pump to filter
- Red ¾” hose – filter to main pump
- Red ½” direct – main pump to pressure relief valve
- Yellow ½” hose – pressure relief valve to manifold 1 cold input
- Green ½” hose – manifold 1 heater 1 output to heater 1 cold input
- Blue ½” hose – manifold 1 heater 2 output to heater 2 cold input
- Orange ½” hose – heater 1 hot output to manifold 2 input
- White ½” hose – heater 2 hot output to manifold 2 input
- Black ½” hose – manifold 2 drill output to hose reel
- Green ¾” hose – manifold 2 tank output to Yeti cooler

9.5 Fuel connections

9.5.1 All fuel connections are made with quick connect fittings.

9.5.2 The send and return fuel lines use different connectors so they cannot be hooked up wrong.

9.5.3 The fill port should be kept closed except for when filling the tank, Figure 11.

9.5.4 The breather vent should always be open when the heaters are running to prevent a vacuum from being drawn, Figure 11.

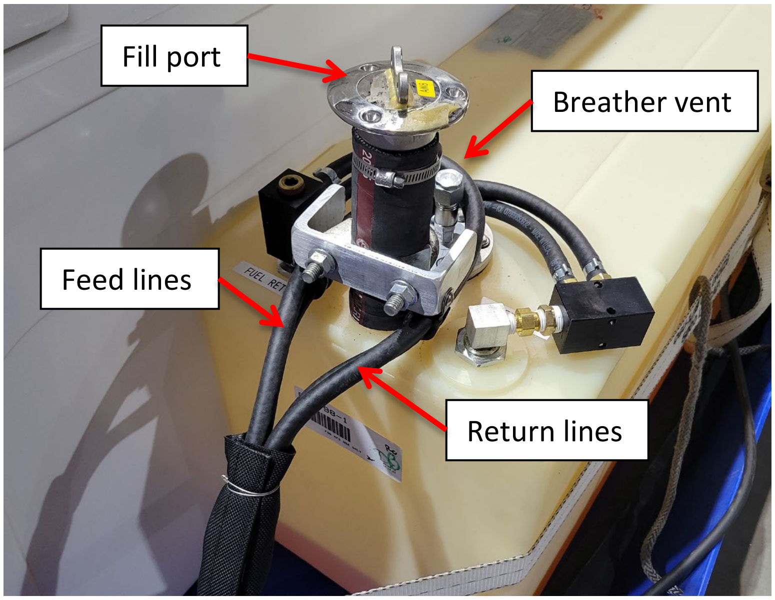


Figure 11: Fuel tank fittings.

9.6 Electrical connections

9.6.1 The only electrical connections that should need to be made are to plug in the 120 VAC power cords for the submersible pump, hose reel (if being used), and the two heater modules.

9.6.2 If further electrical work needs to be done, see Appendix A: Electrical Schematic.

9.7 Cover

9.7.1 Each system ships with a vinyl coated polyester cover that fits the entire Siglin sled including the three modules.

9.7.2 The cover should only be used when the system is not powered on. It does not provide access to controls, fresh air inlet, or exhaust venting.

9.7.3 The cover will fit over the exhaust stacks of all three modules but if doing so, a piece of foam should be placed on top of each stack to prevent unnecessary wear/damage to the cover.

9.7.4 The cover secures to the sled with a combination of Velcro strips and a drawstring rope to cinch the cover around the sled, Figure 12.

Figure 12: Sled Cover.

10.0 COMMISSIONING

10.1 See Appendix E

11.0 OPERATIONS

11.1 See Appendix H

12.0 END OF SEASON

12.1 At the end of the season, the system should be pickled and also blown out with compressed air. Use the provided air-to-water system adapter to connect the air compressor discharge into the upstream part of the system (high pressure pump suction hose). Work fluid out of the system in spurts. Allow the air compressor tank to fully fill, and then fully exhaust it each cycle using a valve. Open the valve quickly to shock-load the system and shake liquid droplets loose. Work all parts of the system, all valves. Continue this until very little liquid droplets are spraying out of each main loop (local recirculation and drill).

12.2 Once blown out, disconnect the interconnect hoses and cap/plug all open fittings. Leave all valves in their open position.

12.3 Disconnect all the hoses and solid rod linkages.

12.4 Remove the modules from the Siglin sleds and repack them in their crates.

12.4.1 Reminder: The pump and generator can be removed from the engine module for easier moving without heavy equipment support (see 9.3).

12.5 Refer to the original packing lists to repack the remaining equipment as it was shipped out from Madison (or as close as possible).

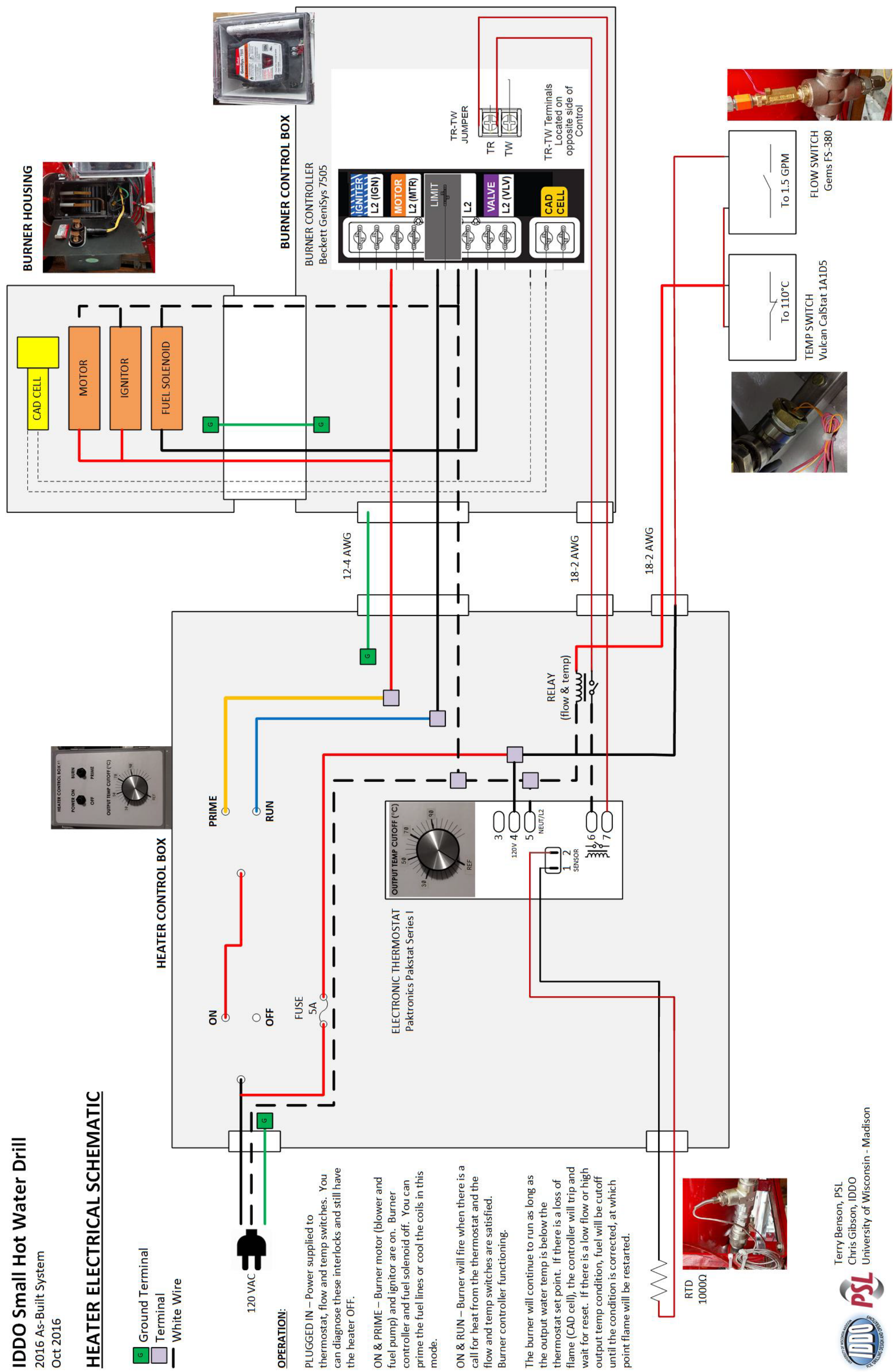
12.6 Dry all equipment as much as possible before repacking.

12.7 Return contractor supplied equipment to the support contractor.

12.8 Work with the support contractor and the IDP Field Support Manager to return the cargo to IDP in Madison WI.

12.8.1 Contact the IDP Field Support Manager for assistance, if needed.

13.0 APPENDIX A: ELECTRICAL SCHEMATIC



14.0 Appendix B: Bill of Materials

Location	Qty	Part Number	Description	Vendor
HW-2, Loose	1	N/A	Winch Sled	IDDO
HW-2, Loose	1	K01-2024	Hose Reel	Steel Eagle Reels
HW-2, Loose	2	85140077	Drill head	IDDO
HW-2, Loose	1	PSB70GREEN	70 qt Muck Tub	Jet
HW-2, Loose	1	41AA75	Funnel	Grainger
HW-2, Loose	5	615096	10qt bucket	Fastenal
HW-2, Loose	2	4204022	Water hose	Fastenal
HW-2, Loose	1	032627	Moeller 27 gal fuel tank	EasternMarine
HW-2, Loose	2	Wide	Siglin Sled	Northern Sled Works
HW-2, Loose	2	PLNK-2.2#-WHT-20-LAM	Polylam foam sheet	WI Foam
HW-3, Loose	1	Tundra420	Yeti Tundra Cooler	WestMarine
HW-3, Loose	1	SS6815-3/4HSS	Piston Relief Valve Assembly	IDDO
HW-3, Loose	1	FC300	Main Aeroquip hoses	Price Engr
HW-3, Loose	1	3VE48	Oil Fired Torpedo Heater 50000 BtuH	Grainger
HW-3, Loose	1	N/A	Set of spare short hoses	IDDO
HW-3, Loose	1	N/A	Tool Bag	IDDO
HW-3, Loose	1	38H466	Submersible Pump	Grainger
HW-3, Loose	1	N/A	Tool Box	IDDO
HW-3, Case #1	2	3X634	V belt B35	Grainger
HW-3, Case #1	2	1A106	V belt B47	Grainger
HW-3, Case #1	1	31620-ZG5-033	Honda Voltage Rectifier	PartsPak
HW-3, Case #1	1	16100-ZJ0-833	Carburetor Assembly	HondaPartsNation
HW-3, Case #1	1	28461-ZE2-W03	Grip Starter	HondaPartsNation
HW-3, Case #1	1	28462-ZE3-W01	Rope recoil starter	HondaPartsNation
HW-3, Case #1	1	28469-ZE2-W01	Reinforcement Grip	HondaPartsNation
HW-3, Case #1	2	7131	NGK Spark Plug	Auto Anything
HW-3, Case #1	1	85434751	13/16 1/2 dr deep socket	MSC Direct
HW-3, Case #1	1	15400-PLM-A01PE	Honda Oil Filter	HondaPartsNation
HW-3, Case #1	1	36912848	Gasoila thread sealant 8oz	MSC Direct
HW-3, Case #1	1	20875	CoxReels variable speed controller	Fastool Now
HW-3, Case #1	1	SS6815-3/4HSS	Piston Style Pressure Relief Valve 1200psi	Dultmeier
HW-3, Case #1	2	1ALY2	Liquid Flow Switch	Grainger
HW-3, Case #1	2	36CU67	Fuel Filter	Grainger
HW-3, Case #1	1	H713A-020	Flowmeter	Amazon
HW-3, Case #1	1	7505A0000U	genisys control	Sid Harvey
HW-3, Case #1	2	P14-A0318-901	Pakronics Maxitrol Pakstat	Sid Harvey
HW-3, Case #1	2	C554A1463	Cad cell kit	Sid Harvey
HW-3, Case #1	1	A10-SQ10	ignition transformer	Sid Harvey
HW-3, Case #1	1	94340	200 PSI gauge	Ben's Cleaner
HW-3, Case #1	2	MHF8-00.5-32T-06-M1	RTD Sensor 1000 ohm	ThermX
HW-3, Case #1	2	MC-U-F	2pin Female Miniature Connector	ThermX
HW-3, Case #1	20	0217005.HXP	5A 5x20 fuse	Arrow
HW-3, Case #1	2	16910-ZE8-015	Fuel Filter	HondaPartsNation
HW-3, Case #1	1	P212-2x36	Driller Tape	Electro Insulation Corp
HW-3, Case #1	1	SWS0890FF	Super Swivel 1/2 90 F x F	Kleen-RiteCorp
HW-3, Case #1	1	N/A	Case of high pressure spares	IDDO
HW-3, Case #1	1	N/A	Case of fuel burner spares	IDDO
HW-3, Case #1	1	N/A	Case of fuel nozzle spares	IDDO
HW-3, Case #5	1	45C175	Tie Down Ratchet Strap	Grainger
HW-3, Case #5	1	3LJT4	Tape Measure 1/2 x 100/30	Grainger
HW-3, Case #5	1	25J852	Web Sling 8ft	Grainger
HW-3, Case #5	1	39EP27	Multipurpose cutter	Grainger
HW-3, Case #5	2	4R261	Eyebolt 3/8	Grainger
HW-3, Case #5	1	38XH96	Quick Link 1/4	Grainger
HW-3, Case #5	2	2XY24	Anchor Shackle	Grainger
HW-3, Case #5	2	TR2500-14.500	Solid Rod Linkage	Midwest Control Products Corp
HW-3, Case #5	1	33M313	Socket Wrench Set Metric 1/4 3/8	Grainger
HW-3, Case #5	1	N/A	Case of nuts and bolts	IDDO
HW-3, Case #5	1	N/A	Case of plumbing fittings	IDDO

Location	Qty	Part Number	Description	Vendor
HW-3, Case #6	1	TM-08	AccuMate battery charger 6/12V	Amazon
HW-3, Case #6	1	013-41SA-PNAJ-AJ-B3	Crompton Frequency Meter	Galco
HW-3, Case #6	1	22KY41	Heat Shrink Tubing Kit	Grainger
HW-3, Case #6	1	3YWR4	Heat Shrink Tubing Kit	Grainger
HW-3, Case #6	1	980178	Solderless Terminal Kit	NorthernTool
HW-3, Case #6	1	5VYL1	Twist On Connector kit	Grainger
HW-3, Case #6	1	40J772	Cable tie kit	Grainger
HW-3, Case #6	1	39DT62	Scissors	Grainger
HW-3, Case #6	1	B000PIIJIW	Goop Multipurpose hand cleaner 5oz tube	Amazon
HW-3, Case #6	1	7DX31	electric tape colored set	Grainger
HW-3, Case #6	1	29EK23	Self Fusing Silicone Tape 1"	Grainger
HW-3, Case #8	1	34UH68	Funnel	Grainger
HW-3, Case #8	1	1FBH6	RTV Silicone Sealant 3oz	Grainger
HW-3, Case #8	3	178067	Stackon 19 tool box	NorthernTool
HW-3, Cooler	1	13D724	nozzle kit	IDDO
HW-3, Cooler	1	SS124A-3/4AL-50	Strainer housing	Dultmeier
HW-3, Cooler	1	SS16903-4	50 mesh strainer	Dultmeier
HW-3, Cooler	1	4HWK2	Heat Gun Kit	Grainger
HW-3, Cooler	2	1XUP6	Extension Cord 25ft	Grainger
HW-3, Cooler	1	4GAC1	Extension Cord 50ft	Grainger
HW-3, Cooler	1	35XF51	Web Sling 16ft x 2in	Grainger
HW-3, Cooler	1	14A811	Bulk Webbing 51ft x 1in orange	Grainger
HW-3, Cooler	1	23PF95	Paracord Nylon Braid 9/64	Grainger
HW-3, Cooler	2	1YTA5	Valve Brush 15oal 1.5	Grainger
HW-3, Cooler	1	1YTB4	Valve Brush 15oal 2	Grainger
HW-3, Cooler	1	32GM10	Chemical resistant gloves XL	Grainger
HW-3, Cooler	1	2YEN7	Chemical resistant gloves XL	Grainger
HW-3, Cooler	1	2YEP2	Chemical resistant gloves XL	Grainger
HW-3, Cooler	1	4JY15	Chemical resistant gloves L	Grainger
HW-3, Cooler	1	2AT52	Chemical resistant gloves L	Grainger
HW-7, Loose	1	Whitco Stinger	Heater 1	Bens Cleaner
HW-8, Loose	1	Whitco Stinger	Heater 2	Bens Cleaner
HW-9, Loose	1	8010 Pumper	Engine Module	Whtico
HW-10, Loose	100	3R30-08-250BX	Synflex Hose, per foot	MotionIndustries
HW-10, Loose	1	TS1041	General TS1041 Triplex Plunger Pump	Kleen-RiteCorp
HW-10, Loose	1	GX610-QYF	Honda 18hp engine	Honda
HW-10, Loose	1	42-960	Oregon 6 qt oil drain container	Amazon
HW-10, Loose	2	A2VA-7116	Suntec Fuel Pump	PatriotSupply
HW-10, Loose	1	2XA98	Deck Screw Flat head 8x2 pk635	Grainger
HW-10, Loose	1	3VE48	Oil Fired Torpedo Heater 50000 BtuH	Grainger
HW-10, Loose	1	A10-SQ10	ignition transformer	Sid Harvey
HW-10, Loose	1	20554M	Blower motor	Marathon Electric
HW-10, Loose	1	21854	Wayne blower fan wheel	General Supplies Inc
HW-10, Loose	1	5YKP0	V Belt Pulley 9.75od	Grainger
HW-10, Case #9	6	363853	20 Non Detergent Motor Oil, 1qt	SHC Supply
HW-10, Case #9	4	553169274	5W-30 synthetic oil, 1qt	Walmart
HW-10, Case #9	2	553168991	5W-20 oil, 1qt	Walmart
HW-10, Case #9	1	69211984	Cover Gasket	Kleen-RiteCorp
HW-10, Case #9	1	31156K	Burner tune up kit	PatriotSupply
HW-10, Case #9	1	BK45H	Browning Bushed Sheave	Amazon
HW-10, Case #9	1	5UHD1	Browning Bushing Pulley BK45118	Grainger
HW-10, Case #9	1	H X 1-1/8	Browning Split taper bushing	MotionIndustries
HW-10, Case #9	1	5YLH1	QD bushing SDS bore 1in	Grainger
HW-10, Case #9	1	5YLH5	QD bushing SDS bore 1-3/8in	Grainger
HW-10, Case #9	1	GPK100783	Packing Extractor Kit	Kleen-RiteCorp
HW-10, Case #9	1	ZMVTOOL	Packing Insertion Tool	Kleen-RiteCorp
HW-10, Case #9	1	17957-ZV4-000	Bush Linkage	HondaPartsNation
HW-10, Case #9	2	17228-ZG8-003	Gasket air cleaner	HondaPartsNation
HW-10, Case #9	1	16263-883-W10	Joint rod	HondaPartsNation
HW-10, Case #9	2	16221-ZJ1-840	Gasket carburetor	HondaPartsNation
HW-10, Case #9	1	SA 1/4MEG-0020	Stainless steel spray tip	Kleen-RiteCorp

15.0 APPENDIX C: HEATER TUNING

15.1 Re-plumb the system to include a larger water reservoir to add thermal mass if possible.

15.1.1 If only a small reservoir is available, these steps must be done quickly because overall water temperature will quickly rise. Having lots of ice and dumping it into the water tank will slow down the temperature rise.

15.1.2 Another option is to discharge the hot water (rather than recirculating) and continuously fill the reservoir from a cold source.

15.2 Turn on sump pump in large reservoir and watch for water returning to the large tank as expected.

15.3 Adjust valves so both heaters are open and all needle valves are fully open.

15.4 Here again we want the digital flow meter to only read flow through one heater at a time, but still want to be able to split the flow between heaters to allow for flow adjustment, so some re-plumbing of the turbine flow meter assembly is required.

15.5 Circulate with the high pressure pump at 60 Hz to check performance of the new loop, especially any hose collapse or loud noises from the pump which would indicate too much pressure drop in the suction line and/or cavitation. If this occurs, a higher capacity sump pump or larger diameter hose is needed on the suction side.

15.6 Balancing flow between the heaters is accomplished using the needle valves on the heater inputs. Start by adjusting flow so the heater being tested has 3.5 gpm going through it. Note that flow increase can be accomplished by closing some flow off to the heater.

15.7 Starting with heater 1, start the heater in RUN mode and allow output temperature to stabilize. You may have to work up in steps, adjusting the thermostat each step to allow for higher output temperature. If the output temperature gets above 90°C, the heater needs more flow. Predict ahead of time by carefully watching the rate of rise of temperature, because there will be a delay between any flow adjustment and output temperature. If you adjust the flow too late, the water temp will overshoot, spike, and create superheated water (safety concern and bad for the hose).

15.8 As the heater warms up, add a calibrated tick mark at 60°C.

15.9 Try to get the output water stabilized at 90°C. Adjust the thermostat down to determine location of a 90°C tick mark and make the mark. There now should be two tick marks for the thermostat.

15.10 Turn on the combustion analyzer and allow it to perform its warmup procedure.

15.11 Put the combustion analyzer probe into the stack hole and push RUN on the analyzer. Combustion data will be displayed in real time. Allow it to stabilize, then press stop, which will freeze the display. Write down initial combustion data.

15.12 Check EA value, or excess air. If this is approximately 40%, then air-fuel mixture is pretty good. High 20s to low 40s is acceptable. If it is low, adjust the air inlet in very small increments to allow more air in, or vice versa.

15.13 After making any adjustments, make another logbook entry recording final combustion analyzer values.

15.14 You can also do a smoke test if you want. We aim for "2". If the smoke paper is darker this suggests you might want to let more air in.

15.15 Verify after combustion tuning that the burner fires up without any pops or rough burn.

15.16 While the heater is running in a stable mode, record: Flow, Water temp IN, Water temp OUT.

15.17 Estimate fuel consumption rate during steady running. This can be done by placing the fuel tank on a scale and recording weight with time.

15.18 Perform the following calculations to solve for heat transfer rate and efficiency.

15.18.1 $\dot{Q} = \dot{V} * \rho * c_p * (T_{out} - T_{in})/(15850.326\ \ galsec/m^3min)$

15.18.2 $\dot{Q} = Heat\ Transfer\ Rate\ (kW)$

15.18.3 $\dot{V} = Flow\ (gpm)$

15.18.4 $\rho = density = 1000\ \ kg/m^3$

15.18.5 $c_p = specific\ heat = 4.186\ \ (Wsec)/(g°C)$

15.18.6 $T_{out} = Temp\ Out\ (°C)$

15.18.7 $T_{in} = Temp\ In\ (°C)$

15.18.8 $\eta = \dot{Q}/(\dot{m}_{fuel} * LHV * (453.5924\ \ g/lb))$

15.18.9 $\eta = efficiency\ (\%)$

15.18.10 $\dot{m}_{fuel} = fuel\ flow\ (lb/sec)$

15.18.11 $LHV = lower\ heating\ value \cong 44\ MWsec/kg$

15.19 Repeat for the other heater

16.0 APPENDIX D: SYSTEM SPECS

Type	Hot water drill
Layout	Towable 2- to 3- sled train
Nominal Hole Diameter	6 cm (2.5 in)
Maximum Hole Depth	30 m to 60 m, depending on system
Capabilities	Fast dry firn holes Wet holes in ice to 60 m (slower rates in ice) Transportable by Twin Otter or helicopter (in pieces) Transportable by snowmobile (assembled) Snow melting Manual or reel-driven hose payout, depending on system
Capacities	Red System: 131 kW thermal / Blue System: 97 kW thermal 7 gpm total flow Red System: +71°C temp increase / Blue System: +52°C temp increase 1000 psi max system pressure 120 gal insulated water reservoir 10 gal system volume 2400/2000 W onboard 120 VAC generator, depending on system 27 gal AN8 fuel tank 3.5 gal gasoline tank
Electric Power Consumption	Approximately 3 kW
Crew Size	2
Auxiliary Equipment Required	5 KW Worksite Generator Drills and Bits for Uncrating Glycol for Pickling (10 gal) and dye AN8 Fuel and Gasoline Utility Sled (Siglin or equivalent), depending on system Tow Ropes and Cargo Straps Shovels Hurdy-gurdy pumps (2x) First aid kit Fire extinguishers Blankets Lock Out Tag Out kit
Weight Est. (dry)	4235 lb
Target Hole Performance	
Hole Specs	6 cm (2.5 in) diameter x 30 m DRY in -20°C firn @ sea level
System Configuration	Melt snow while drilling
Drill Time	15 min
Cycle Time	30 min
Fuel	1 gal AN8, 0.5 gal gasoline

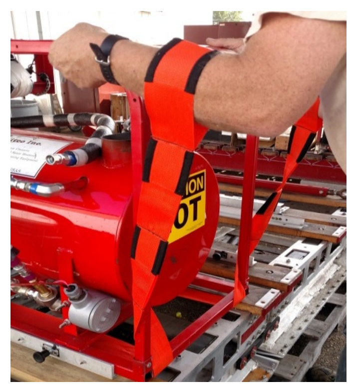
17.0 APPENDIX E: SEASON COMMISSIONING

1) Gather items from support contractor (see right).
2) Unpack the equipment. Use the orange appliance straps for handling heavier items.
3) Start a log.
4) Configure drill system train as shown in system schematic, placing items on Siglin sleds appropriately. Refer to manual for specific installation. Hook up fuel lines and plug heater power cords in. It's easiest to power everything from the worksite generator at first.
5) Connect ground straps. Check cables and hoses for damage, loose fasteners, or plumbing.
6) Install battery, check oil in engine and pump, and top off gas tank and AN8 tank. Dye glycol and put 10 gal in small cooler (or use contractor-supplied storage container).
7) Starting at the water and/or glycol reservoir, work downstream and familiarize yourself with all plumbing paths, valves, and instrumentation.
8) Heat up Honda engine and heater blower motors with bullet heater if needed.
9) Heater Dry Run – turn heaters to ON/PRIME, verify proper start and stable fuel pressure. Look for any fuel leaks.
10) Adjust all flow control valves to wide open (but do not open past the purple band).
11) Circulate glycol using the sump pump: Glycol reservoir – main pump – heaters – back to glycol reservoir. Make sure thermostats are set to a low setting.
12) Check for leaks and proper operation of all equipment while commissioning the system.
13) Start the Honda engine and allow to circulate for a while.

ITEMS NEEDED FROM SUPPORT CONTRACTOR:

- 5 KW Worksite Generator
- Drills and Bits for Uncrating
- Glycol for Pickling (10 gal)
- Seed water (25+ gal if possible)
- Dye / Food Coloring for Glycol
- AN8 Fuel (est. 1 gal per hole)[1]
- Gasoline (est. 1/2 gal per hole)[1]
- Utility Sled
- Tow Ropes and Cargo Straps
- Shovels
- Hurdy-gurdy pumps (2x)
- First Aid Kit
- Fire Extinguishers (2x)
- Blankets
- Lock Out Tag Out kit

Assuming a ϕ6cm x 30m dry firn hole. Also consider base fuel for idling between holes. Gas ~2 gph, AN8 ~3.5 gph with both heaters



14) Heater Wet Run – Briefly test function of each heater with circulation by test firing (ON/RUN). Note if the glycol is cold, there may not be enough flow to satisfy the heater and it will not turn on. Try closing one heater or allow the glycol to heat up (or wait for water).
    a) Test thermostat: Cycle the heater by turning the thermostat up and down. Does thermostat position seem to be consistent with temperature gauges?
    b) Test flow switch: Use the heater flow control valves to reduce flow in each heater one at a time. Does the heater shut down before the flow is completely stopped?
    c) Adjust thermostat to between 90°C - 95°C.
       Note: this sets the upper limit of the water temperature but reaching that temperature is dependent on the water tank's temperature.
15) Install the drill head, verifying correct nozzle selection (see Nozzle Guide).
16) Make sure nozzle end of drill head is feeding back into the glycol tank, then open path to hose reel and circulate through that. If necessary, force flow towards the hose reel by throttling down the main flow control valve.
17) Fill the water reservoir with seed water, or put a hot glycol hose loop into the water reservoir and begin melting snow. Fill the tank with melted snow water.
18) The system is in a pickled state and you can continue circulating, stop circulating, or switch to water. Circulation may be continued using the sump pump alone. If switching to water soon, it is best to keep circulation going with warm glycol to keep everything warm.

18.0 APPENDIX F: NOZZLE GUIDE

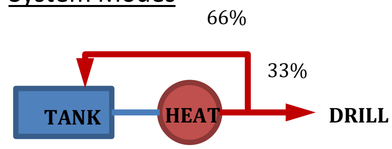
0° Jet

- Fast pilot hole + ream to diameter by conduction through drill stem body
- Smooth borehole walls
- Best option beyond pooling depth

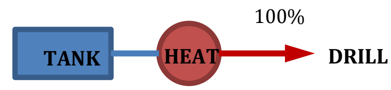
15° Full Cone

- Nozzle makes hole, no conduction through drill body
- Irregular borehole walls
- Best option through firn

System Modes



Melting snow while drilling (**low flow** drill)



All flow to drill (**high flow** drill)

MINIMUM system pressure to prevent vacuum in the drill hose at surface:
43 psid for 30 m, 86 psid for 60 m.

Table 2: Flow rate vs. system pressure for the various nozzle options. Operating at pressures below 43 psi (lower pressures in red) will draw the system into vacuum at 30 m depth or more. Operating at pressures above 300 psi (higher pressures in red) create an unnecessarily high pressure drop through the nozzle.

Preferred	p/n	Description	PSI @ 2GPM	PSI @ 4GPM	PSI @ 6GPM
→	1/8GG-SS1514	15° Full Cone, Low Flow	82	327	735
	1/4GG-SS1530	15° Full Cone, High Flow	18	71	160
	1/8MEG-0013	0° Jet, Low Flow	93	370	833
	1/4MEG-0020	0° Jet	40	159	357
	1/4MEG-0030	0° Jet	18	71	161
	1/4MEG-0040	0° Jet, High Flow	10	40	89

19.0 APPENDIX G: START/END OF DAY

START OF DAY

1) Start worksite generator, begin warming things up, and top off fuel tanks.
2) Clean the water suction filter.
3) Circulate glycol using the sump pump: Glycol reservoir – main pump – heaters – both paths back to glycol reservoir (tank return and hose reel). Check for leaks.
4) Open the gasoline supply valve under the gasoline tank.
5) Start the Honda engine and set to 60 Hz, then test fire each heater. Allow glycol to heat up slightly.
6) Make sure end of hose reel is feeding back into the tank, then open path to hose reel and circulate through that. If necessary, force flow towards the hose reel by throttling down the main flow control valve.
7) Check for leaks and proper operation of all equipment while warming the system up.
8) Close off the hose reel and valve so flow is fully directed through the heaters and back to the glycol reservoir. Make sure both heaters are fully open. Turn off the sump pump and move it to the water tank.
9) Turn on sump pump to start pumping water. The water will push the glycol out. Be ready with local bypass hose in hand, and when the fluid starts to turn clear, quickly transfer the hose to the water tank. You are now circulating closed loop with water.
10) Repeat previous step, but through the hose reel. Adjust main flow control valve so a decent amount of fluid is being forced through the nozzle and into the glycol tank. When the fluid turns clear, put the drill-head into the water tank. It can be left in the water tank until ready for drilling.
11) To prevent the system from freezing, there must be circulation through both loops whenever water is in the system. Even a small trickle is enough to keep lines from freezing.

Warning: Valving off both the bypass loop and drill hose at the same time when the high-pressure pump is running will cause pressure to quickly build and the pressure relief valve to open, discharging water or glycol onto the ground. Shut down the high-pressure pump if system flow must be stopped for any reason to prevent an accidental discharge through the pressure relief valve.

END OF DAY

1) Turn off heaters, main pump, and sump pump.
2) Put sump pump into glycol tank.
3) To keep glycol/water mixing to a minimum, the system must be pickled one loop at a time, and the heaters must both be fully open.
4) First, close the hose reel supply ball valve to circulate water through the water tank return loop. Start the sump pump with tank return hose returning to the water tank. With tank return hose end in hand, when the color changes quickly swap the hose end from the water tank to the glycol tank. Circulate a minute longer.
5) With the nozzle (or end of hose reel hose if nozzle has been removed) in the water tank, open the hose reel supply ball valve and start flushing that line. The main flow control valve can be closed to send more flow to the hose reel if needed. When the color changes, quickly swap the nozzle/hose end to the glycol tank.
6) Glycol should now be circulating through both loops. Circulate this way for 5-10 minutes, exercise the valves while waiting.
7) Make sure heater switches are in the OFF/PRIME positions.
8) Close the AN8 supply valves at the fuel tank. Close the gasoline supply valve under the gasoline tank.
9) Reinstall panels if needed, put away tools, cover/weatherize all equipment.

20.0 APPENDIX H: DRILLING OPERATIONS

1) Assumed: Locally circulating warm/hot water.
2) Position sled over hole location, stop flow to nozzle and position reel so nozzle is hanging just above the snow surface.
3) Open the flow to nozzle and adjust main flow control valve to set nozzle flow.
4) Turn on heaters. Once the heaters approach steady state, adjust heater flows using the heater flow control valves to get even output temperatures.
5) Flow balancing depends on many factors. In general:
    a) If melting snow during drilling, maintain enough recirculation flow to melt enough snow to maintain tank level.
    b) If melting snow between holes, more water can be sent down hole and drilling will be faster, just be careful not to run out of water before target depth.
    c) If the tank gets too hot, send more hot water down hole and add snow to the tank.
    d) Pressure out of the main pump should be 200-400 psi. To lower pressure, send more water back to the tank or try opening heater flow control valves (by same amount each). Also verify proper nozzle selection.
6) The system has a small overall water capacity, so circulating hot water will heat up the system rapidly. As the water tank temperature rises, so does the heater output temperature. Target tank temperature is 25°C.
7) Once the nozzle is up to temp enough to commence drilling, slowly start paying out hose.

NOTICE!

- Many burn hazards – the plumbing is HOT!
- You are working around pressurized hot water! It is typical to periodically superheat the water, which can result in dangerous steam jets. THINK FIRST!
- Always wear eye protection when working around hot, pressurized water.

TIPS:

- Do not kink any hose and monitor hose condition during each hole.
- Always think first and close valves slowly.
- Make periodic scans of pressure and temperature.
- A thermal system like this has slow response time and overshoot is common. Make adjustments in small increments and wait for temperatures to respond.
- When balancing flows using the flow control valves, always try opening rather than closing the valve. This keeps pressure drop lower.
- Keep an eye on fuel levels, you do not want to run out of fuel during drilling.
- Keep system temperature in check; add more snow to cool things down if needed.
- Nozzle selection is very important for performance.
- Pressure on the surface should always be positive, not in vacuum.
- Check the drain of the pressure relief valve often to make sure it has not frozen shut.
- Always close the gasoline supply valve before traversing without the engine running.

8) Monitor hose tension during drilling. The strategy is to drill fast but always have the full down-hole weight on the hose. This assures the drill is hanging free and straight in the hole. If the hose starts to become slack it will steer itself off track: slow down or stop if this happens.
9) Once target depth is achieved, switch off heaters or lower thermostats to 20-40°C.
    a) You may decide to drain the hose (though this wastes water). To do so, fully open the main flow control valve, and slowly close the hose reel supply ball valve. This puts the system in local recirculation mode. The vacuum break should open and allow the hose to drain (this prevents freezing).
    b) Alternatively, to save water, adjust flows so a trickle is maintained down-hole while most water is recirculated back to the tank.
    c) Begin raising the drill at a comfortable rate. Manual level winding will be required to keep the hose wrapping correctly onto the reel.
10) Leave enough hose out so the nozzle can be placed into the water tank. Open the hose reel supply ball valve and make sure water is being circulated through both loops. You may choose to circulate using only the sump pump to save on gasoline and cut down on noise.
11) Close the water tank lid to minimize water sloshing out of the tank. The drill is ready to be moved to the next hole.

THINGS TO LOG:

- Fuel levels @ start/end of drilling, before/after fills.
- Hole ID, sequence number, start/end time.
- Final hole depth.
- Temperatures during drilling (cold and hot manifold water temps).
- Flow and/or generator frequency during drilling.
- Pump discharge pressure.
- Equipment performance or issues.
- Nice-to-Have lists.
- Retro cargo list.
- Take pictures!

21.0 Appendix I: Troubleshooting

PROBLEM	POSSIBLE CAUSE	TRY THIS
Engine won't start	No fuel	Fill tank, open gasoline valve
	Cold start	Start with full choke, warm engine with bullet heater if needed
	Dead battery	Charge battery
	Ignition problem	Verify key/switch position is ON
	Blown fuse	Replace 25A automotive fuse found behind key switch
	Starting under load	Unplug electrical loads Open all valves and verify return flow from sump pump
	Other	Refer to Honda engine manual
Pump not running well	Too much electrical load	Move electrical loads to worksite generator
	Pump cavitation	See "system pressure too low" below. Try running sump pump with high pressure pump.
Heater won't start (prime)	Motor too cold	Warm motor casing with heat gun (but do not overheat)
Heater won't fire, Genysis fault	Loss of fuel pressure/air in fuel line	Fill tank, trace fuel supply and check for leaks/bubbles, make sure fuel tank vent valve is open
	Light leak to CAD cell	Block front of burner from sun or reposition burners relative to sun
Heater flow switch stuck open/closed	Stuck debris, reed switch failure	Tap on flow switch body or replace
	Control circuit fuse blown	Replace fuse, seek cause for blown fuse
Heater thermostat not functioning or out of calibration	Knob position changed on shaft	Turn shaft fully CCW and reset knob to reference mark. Check tightness of knob locking screw.
	Control circuit fuse blown	Replace fuse, seek cause for blown fuse
Heaters cycling on/off a lot	Water tank temperature too hot	Add snow to tank
	Flow too low	Check engine speed Check pressure (is pressure relief valve opening?)
	A known system design quirk	No action necessary. At 7 gpm water flow, the heaters tend to overshoot their thermostat setting and may cycle on and off continuously.
System pressure too high	Incorrect nozzle selection	Choose larger nozzle (see nozzle guide)
	Valves closed too much	Open flow control valves
System pressure too low	Incorrect nozzle selection	Choose smaller nozzle (see nozzle guide)
Crooked holes	Lowering too fast	Drill slower, maintain hose tension at all times

22.0 APPENDIX J: LOG SHEET

Date	
Hole ID	
Page #	of
Nozzle	
Starting Fuel Dip, JP8 / Gas (inches)	
Starting Water Tank Dip (inches)	
Start Time	
End Time	
Comments	

Time	Depth (m)	Frequency (Hz)	Pump Discharge Pressure (psi)	Cold Manifold Temp (C)	Hot Manifold Temp (C)	Water Tank Dip (in)	Melting Snow? (check)

23.0 Appendix K: Pre-Shipment Checklist

23.1 Engine Maintenance

23.1.1 Change engine oil and air filter, if necessary.

23.1.2 Clean or replace spark plugs, as needed.

23.1.3 Re-jet engine for high altitude, if necessary.

23.2 Pump Maintenance

23.2.1 Change pump oil, if necessary.

23.2.2 Replace or clean valves, seals, and pistons, as needed.

23.3 Verification Testing (see Appendix C: Heater Tuning)

23.3.1 Verify that the engine module and both heaters are functioning properly.

23.3.2 Verify pressure relief valve limit of 1000psi.

23.3.3 Verify low flow cutoff switch triggers below 1.5 gpm on both heater modules.

23.3.4 Verify set points of each heater module thermostat.

23.3.5 Verify that the heater modules are tuned so that combustion excess air is approximately 40.

23.3.6 Note system performance parameters (flow, heat transfer rate, fuel efficiency) for tracking the efficiency of the system over time.

23.4 Packing

23.4.1 Verify all parts are packed with the shipment. See Appendix B: Bill of Materials.

23.4.2 Run the engine dry.

23.4.3 Drain fuel holding tank and fuel lines.

23.4.4 Leave all valves in the open position.

23.4.5 Blow out the water lines of both heater modules using compressed air.

23.4.6 Blow out the long hoses and reels using compressed air.

23.4.7 Plug or cap all open fittings to prevent leaking.

23.4.8 Disconnect the engine module battery and tape its terminals.

23.4.9 Tighten all fasteners.

23.4.10 Pack all equipment with appropriate padding.

23.5 Create packing lists and shipping labels.

23.5.1 Update shipping lists, as needed.

23.6 Send electronic copies of the manual to field operators.