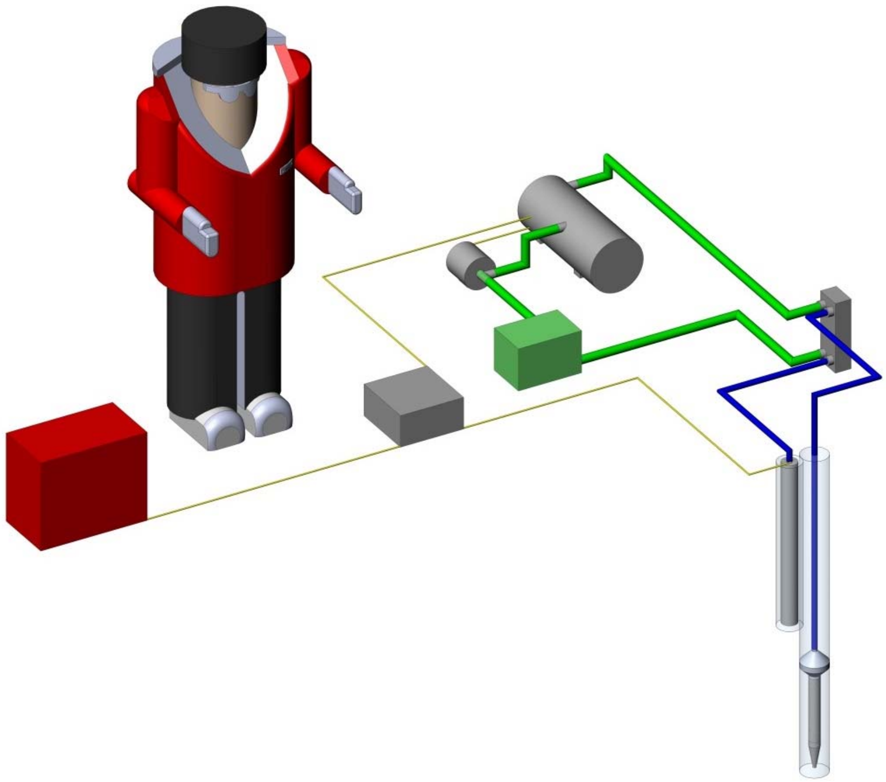
# IDDO Sediment Laden Lake Ice Drill

## Concept Overview

**4/5/17**




**Josh Goetz**
Mechanical Engineer
Ice Drilling Design and Operations
University of Wisconsin-Madison
joshua.goetz@ssec.wisc.edu

**Chris Gibson**
Mechanical Engineer, Project Manager
Ice Drilling Design and Operations
University of Wisconsin-Madison
chris.gibson@ssec.wisc.edu


Contents:

## INTRODUCTION and REQUIREMENTS

The IDPO Long Range Science Plan 2014 identified science goals for ice drilling that spanned a wide range of science targets. For long term ecological studies in environmentally sensitive areas such as the Dry Valleys, the ability to drill through several meters of sediment-laden ice will enable science in a variety of disciplines. Currently ice fishing type gas augers are used in the sea ice and lake ice, which are not designed for this environment. A new drill is needed to create pilot holes which could then have a hot finger inserted in them to widen the hole. This pilot hole drill should also be useful for freeing instrument cables from the ice and accessing equipment deployed beneath the ice. Using mechanical drills has caused problems by cutting cables, and especially in the Dry Valley Lakes, drill bits do not stay sharp in the dirty ice. Hot water technology will allow a new tool to enable safe servicing of science instruments deployed in the lakes and ocean, and will allow for making more sample acquisition holes which is often a limiting factor in doing research in the sub-ice environments. From discussions organized by IDPO with iterative discussions with the scientists and with IDDO staff, the following are the science requirements for the drill:

***Scientific Requirements***

1. Produce access holes through 6 m of clean ice, or ice containing some soil particles.
2. The drill should be field portable, with the modules less than 50 lbs that can be carried by one person or dragged over very rough ice containing melt pools, by hand on one sled (not including the generator if needed). Upper weight of the system must be less than the weight of a 5 kW generator including its protective case.
3. Diameter of holes needed will vary, with most likely in the 13-25 cm diameter.
4. The drill should be operable in borehole and/or ambient temperatures down to -30 C.
5. The drill should require very little water to start the drilling, and would preferably recirculate the ice melt and seed water to avoid loss or contamination to the environment.
6. Setup time for the drill should be within a half hour after initial unpacking on site.
7. Drilling speed should be less than 30 minutes for a 5” hole through a 6 m ice cover.
8. The drill should be transportable inside one helicopter flight, packed in cases that can be lifted by a maximum of two people.
9. The drill should have stand-alone capability for operation at small field camps at remote sites with no heavy equipment.
10. Once the drill is set-up, one scientist should be able to do the drilling operations in the field.
11. Permanent indicators on the hose indicating depth and the distance to the tip should be included.
12. The drill should be able to be used to free up cables frozen in the ice, including riding them down through the ice (i.e. if coupled with something like bailing wire)
13. Materials used should be non-corrosive from fresh to sea water salinities.
14. The downhole apparatus and interior should be easily cleansed from biological organisms with standard solvents/sterilants.
15. The drill should be easily maintainable in the field by scientists to avoid freeze damage.

For clarification, IDDO offers the following details regarding the second requirement which describes the weight of the system. From prior projects, IDDO estimates the weight of a shipped 5 kW generator as 300 lbs. The expectation of this design is that the drill system will weigh approximately 250 lbs. This weight does not include a generator or any fluids. The estimates for these are 50 lbs for the generator and 130 lbs for fluids, which includes water, glycol, diesel, and gasoline. Every individual piece will weigh less than 50 lbs; however, it is neither practical nor efficient to transport all of the components as loose loads. Per discussions with potential users it would be better to have a protective case that can be moved by two people than a fabric backpack that can be moved by one person. In order to protect the equipment for transportation, it will be stored in lightweight aluminum Zarges cases. Final weights will depend on exactly how the equipment is packed, but it is estimated that one case will weigh approximately 70 lbs while the rest will weigh 50 lbs or less. However, if it were deemed necessary, the system could be repackaged in duffel backpacks such that each load could be carried by one person. This would require extra care to be taken during transport and additional set-up time.

Given this clarification, IDDO expects the Sediment Laden Lake Ice Drill (SLLD) design will fully meet all of the science requirements.

## BACKGROUND and DESIGN DECISIONS

There are limited existing designs of small scale hot water drills with the majority being focused on getting deeper than 30m depth. However, some science only needs to be done in the upper few meters and in these cases the existing systems are very oversized and limit the selection of potential drilling sites. Therefore, the goal of this design is to develop a lightweight, portable hot water drill that can access virtually any site with ease, but be limited to a depth capability of 6m.

A modified version of the Hotsy drill in conjunction with an auger has been used to accomplish similar science goals. This system is oversized for the needs and the excess weight makes it difficult to deploy to a variety of sites; however, the system has field tested a variety of components and concepts. This SLLD design will strive to make use of this existing information in order to provide an already tested and reliable design.

It would be ideal to design the system as a one fuel system; however, this does not seem feasible. In order to get a high enough heat potential for the weight the combustion fuel should be diesel. On the other hand, small generators are typically gasoline powered. A few diesel versions do exist but they are significantly heavier (90+ lbs versus 46 lbs), and therefore not viable for this project.

IDDO recently refurbished the Small Hot Water Drill (SmHWD) system. During this process, a few upgrades were made to the system. One noticeable upgrade was the simplification of the drill head. In order to provide some standardization across IDDO systems the SLLD design will utilize components of the SmHWD such that all components are interchangeable.

## SYSTEM DESCRIPTION

***Drill System Layout***
Figure 1 shows a conceptual layout for the SLLD system.

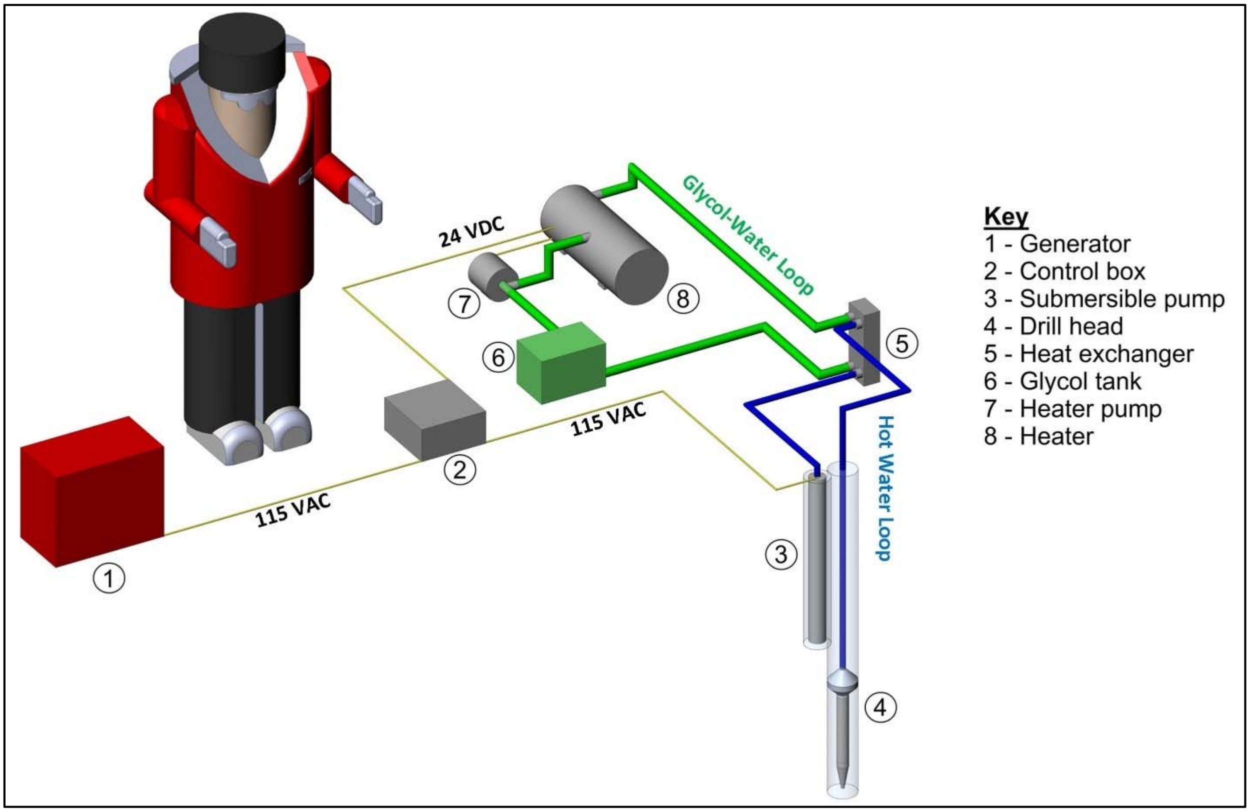



**Figure 1:** Conceptual scale model view of the proposed SLLD system as deployed to the field.

***Equipment***

A summary of the major equipment of the system is listed below (with Figure 1 labels):

- (8) HL2-35 Espar Hydronic heater
- (7) 6000SC Flowtronic pump
- (6) 5 gallon tank with NPT fittings
- (5-6-7-8) RC2 HoseCraftUSA 1.5” hose
- (5) B3-32A-40 DudaDiesel heat exchanger
- (3-4-5-6-7-8) Cam and groove hose couplings (PT Coupling: 1070310SL, 1400110, 1400610, 1070315SL, 1400115, 1400615, 1400515)
- (3-4-5) Oroflex20 JGB 1” lay-flat hose
- (3) 5SQ05-180 Grundfos submersible pump
- (4) IDDO designed drilling head
- (4) 3/8GG-SS3014 iSpray nozzle
- (4) H1/4U-SS0012 iSpray nozzle
- (4) 1/4GG-SS1530 iSpray nozzle
- (4) 1/4GG-SS3009 iSpray nozzle
- (2) IDDO designed control box
- (-) IK-115630 Nils USA High Velocity Hand Auger 4.5”
- (-) Zarges cases
- (1) EU2000i Honda generator (provided by ASC)

***Operations***

Operation of the SLLD system is expected to be accomplished by a single scientist operator. The system should be able to be set up within half an hour and a single hole melted to 6m deep with a 5" diameter.

*Initial Setup*

The components of the glycol-water heating loop will be removed from their cases and connected together quickly with cam and groove hose couplings. A mixture of 2 gallons of glycol and 2.5 gallons of water will be combined in the glycol tank. The heater will be powered on and the glycol-water allowed to reach its operating temperature.

Meanwhile, a well hole that is 4.5" diameter by 30" deep will be created manually using the Nils Hand Auger if sedimentation allows.  Alternatively, a reservoir of water can be used to create the hole with hot water.

The water loop components will be assembled with cam and groove hose couplings. The submersible pump will be lowered into the well hole along with 2.5 gallons of seed water, which is the estimated volume of the water loop hoses plus the pilot hole minus the submersible pump. The drill head will be set up with the small diameter head and a 0 degree jet.

*Drilling Operations*

Once the heating loop has reached its operating range of 85C to 118C, then the submersible pump can be turned on. The drill head spray will be used to widen the pilot hole in one direction and create the main borehole. Once widened sufficiently the drill head can be lowered into this new borehole.

The drill head can be lowered as quickly as it will descend without binding until slightly more than the desired bottom depth is reached. This method will create an approximately 3" diameter hole while using a 0 degree hot water jet. The idea of this is that the narrow jet will stir up any sediment in the water and prevent it from settling on the bottom of the hole. Additionally, the narrow diameter will melt a minimum volume of borehole and therefore introduce the least amount of sediment into the hole. By drilling slightly deeper than needed this will give an area for all of the sediment to settle into without impacting the desired range of the borehole.  A sediment cup on the drill head to catch some of the sediment stirred-up in the water is also being evaluated as a way to enhance initial penetration through sediment laden ice.

Next, the drill head can be pulled back to the surface and the 0 degree jet replaced with a 30 degree jet. Reaming runs can then be run up and down the borehole until a sufficient diameter is reached. If there is a minimum diameter requirement, a drill head top of that diameter should be installed, which can then be used as a check. If the borehole is not wide enough, the drill head will hang up until the body of the head can conduct enough heat to the borehole walls to widen it appropriately. If this is happening the rate of penetration should be decreased so that this is no longer the primary means of reaming.

*Packing*

The submersible pump can be used to recover a volume of seed water from the current site to take to the next site. The system is designed to be quick to pack up as well as setup. All hose connections are made with cam and groove lock coupling for ease of (dis)assembly. The water hoses are lay-flat hoses that can be quickly drained of water. The submersible pump is field proven and has even recovered from being frozen solid. The heat exchanger will need to be drained between holes, which can be quickly done into the glycol-water mixture tank. If only transporting a short distance between drill sites, the heater can be left filled with the glycol-water mixture. The glycol-water hoses are all short lengths and can easily be drained into the holding tank prior to transport. All components will fit into several lightweight Zarges cases for transportation.

***Transport Logistics***

The entire drill system can easily be transported in one helicopter flight. The total weight, including fluids and generator, is expected to be around 425 lbs. Cases will be packed such that they are easily manageable by two people with no single piece weighing more than 100 lbs and the majority being less than 50 lbs.

## SCHEDULE and COST

Table 1 shows a high-level schedule of activities. The project schedule has the system ready for production drilling in the 2017-2018 Antarctic field season.

This schedule is meant to support the discussion of the timing of the development of the drill and its availability. A detailed project schedule will be used in the management of the SLLD drill development project.

**Table 1: Project Schedule**

| *SLLD Development Project Milestones* | |
|---|---|
| Complete Design | 3/31/2017 |
| Complete Fabrication | 8/28/2017 |
| Complete Documentation | 10/27/2017 |

Table 2 shows estimated pricing for the major components of the system without spares.

**Table 2: Equipment Costs**

| *Component* | *Price (Each)* | *Quantity* | *Price (Total)* |
|---|---|---|---|
| HL2-35 Espar + 6000SC Flowtronic (heater kit) | $5000 | 1 | $5000 |
| 5 gallon tank with NPT fittings | $150 | 1 | $150 |
| RC2 HoseCraftUSA 1.5” hose – 25’ | $500 | 1 | $500 |
| B3-32A-40 DudaDiesel heat exchanger | $300 | 1 | $300 |
| Cam and groove hose coupling sets | $40 | 12 | $480 |
| Oroflex20 JGB 1” lay-flat hose – 50’ | $500 | 1 | $500 |
| 5SQ05-180 Grundfos submersible pump | $700 | 1 | $700 |
| IDDO designed drilling head | $1500 | 1 | $1500 |
| iSpray nozzles | $100 | 4 | $400 |
| IDDO designed control box | $1000 | 1 | $1000 |
| IK-115630 Nils USA High Velocity Hand Auger 4.5” | $130 | 1 | $130 |
| Zarges cases | $500 | 3 | $1500 |
| Misc fittings | $500 | 1 | $500 |
| Total | | | $12660 |

## CONCLUSION

The drill proposed in this concept augments the IDDO equipment inventory per IDDO's Long Range Drilling Technology Plan to significantly broaden the range of science that can be supported. It meets the science requirements identified by the research community while minimizing technical risk. The proposed drill minimizes logistical burden for field projects with a reduced system weight compared to existing systems. The development of the drill will be performed with an attention to detail that will provide safety and ease of use for the operators.