DOCUMENT IDENTIFICATION	
Title:	**SCIENCE REQUIREMENTS: Electrothermal Drill**
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DOCUMENT APPROVAL	
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Science Requirements: IDDO Electrothermal Drill

Background:
The IDPO Science Advisory Board identified in the IDPO Long Range Science Plan 2017-2027 a priority need to repair and upgrade the Electrothermal Drill to allow for coring to 300 m through temperate and polythermal firn and ice. The current IDDO Electrothermal Drill (aka Thermal Drill) melts an annulus around the 3.4 inch diameter ice cores it collects. It can be substituted for the 4-Inch drill sonde or the Badger-Eclipse sonde, for use in ice warmer than about -10°C. Within the next several years, upgrades to the Thermal Drill will allow coring to 300 m through temperate and poly-thermal firn and ice. Water flow rates on the order of 10^{-4} m^3s^{-1} through firn may be encountered. The system must remain agile and light weight (transportable by helicopter sling load; less than ~400 lb not including fuel), and so use of the Badger-Eclipse drill, rather than the 4-Inch drill, may offer logistical benefits. Applications for the thermal drill include alpine regions and areas of the polar ice sheets where surface melting is significant, and where recently-discovered firn aquifers are undergoing study. For depths shallower than 30 m, a simpler tripod assembly for operation of the drill has been used with good success. The Thermal Drill is particularly useful in ice close to the pressure melting point, where electromechanical drills are at risk from melting and refreezing of the surrounding ice. From discussions organized by IDPO with iterative discussions between IDPO, scientists, and IDDO staff, the following are the science requirements for the IDDO Electrothermal Drill:

Scientific Requirements

1. **Target depths: from the surface to a potential maximum of 300 m depth**
2. **Ice core diameter: appx 3.4”**
3. **Hole diameter is not critical; less than appx 4”**
4. **Core length: 1 - 2 m per run**
5. **Target drilling rate through ice as cold as -10 C temperature is 1 m in 8 minutes.**
6. **The drill should be operable in ice temperatures down to -25 C and up to 0 C.**
7. **The drill design should enable minimal time for unloading of the core on the surface between runs.**
8. **The drill components should be compatible with mechanical coring of the top ~ 10 m.**
9. **The heat rings should be replaceable in the field using a simple mechanical method, and the wires should have water-tight connectors. Soldering should not be required in the field. Spare heat rings should be included with the drill kit.**
10. **The control panel should have an amp meter or other method of determining whether the heat rings are making good thermal contact with the ice.**
11. **All electrical connections and control boxes should be sealed to function well in damp environments.**
12. **Direct occasional delivery of ethanol or anti-freeze to the drill sonde/head should be available, to prevent refreezing in polythermal or -2 C ice.**

13. **IDDO should identify a portable tent or structure for the drill that would enable 24-hour drill operations.**
14. **The surface equipment should be operable in ambient temperatures from -20 to +5 C with winds up to 25 knots.**
15. **The drill system may include a selection of winch sizes and cable lengths from the IDDO inventory, sized to meet project-specific logistics demands.**
16. **Drilling depth should be available during drilling.**
17. **Core quality requirements:**
    a. **Core recovery over the entire borehole, as close as possible**
    b. **Ice pieces to fit together snugly with minimal gaps**
    c. **The packed core should have no more than 12 pieces of ice per 10 m section of core**
18. **Absolute borehole depth measurement accuracy: 0.2% of depth**
19. **Air transport type: drill to be transported by sling load from a Bell 206 or similar helicopter (~900 lb up to 3,000 m elevation)**
20. **Drill components should be sized and packed appropriately to be easily handled by 2 people by hand, without heavy equipment on site. The goal for the total system weight including aircraft packaging (but not including fuel weight) is to be less than approximately 2,400 lb.**
21. **The drill should be portable to be pulled on a sled between adjacent holes.**
22. **The drill control should be simple and intuitive for use in the field by a scientist who has had training before going into the field. Two personnel (including one trained IDDO driller and one assistant from the science team) should be able to set up and do the drilling operations in the field.**
23. **Setup time for the drill should be within 4 hours after initial unpacking on site.**
24. **Drill storage in the field at the end of the day or during a storm should be planned and designed. The SOP for storage should be designed for storms with 80 knot winds and blowing snow.**
25. **Drill use instructions and parts for field maintenance should be included with the drill.**
26. **Core packaging materials (tubes, boxes, straps) shall be provided by the logistics provider.**

Discussion:

1. *IDDO:*

a. The current Thermal Drill system consists of a sonde (barrel) and heat ring heads that are no longer in production. Currently, the system requires use of the 4-Inch Drill winch, tower and control box for operation. IDDO will explore adaptation of the Thermal Drill sonde to the Eclipse Drill winch, tower and control box, if desired. For shallow deployments, a 75 m water-shedding cable has been belayed by hand using a simple tripod system.

b. The lower ice temperature limit for which the drill will collect good cores has not been determined. However, when drilling in ice that is homogenous and at the freezing point, the Thermal Drill collects beautiful cores. In colder ice, the Thermal Drill would likely function acceptably with more power to the heat ring and the addition of minimal amounts of ethanol to the hole to limit borehole freeze-back.

c. Too much dirt or other debris in the ice will bring the drilling to a halt.

2. *Eric Steig and Peter Neff*:

The major problem we had at Mt. Waddington was re-freezing. This occurred because the ice is polythermal (we drilled through near-freezing point ice down into -2°C ice and back into near-freezing point ice.) This situation is rare, but even in a purely temperate ice, meltwater will refreeze, because the freezing point of the water is higher than the melting point of the ice (because of impurities).

We believe some sort of delivery system is needed, that gets ethanol directly to the drill head. Victor Z's drill has this, and his design should be examined for ideas.

There has been some recent success in drilling temperate ice with an electromechanical drill, by having two sondes, one with core-dogs, the other without. This is third hand via Seth Campbell, but our understanding is that what was done was to first drill without the core-dogs, leaving the core in the hole. This then allows chip/meltwater removal. Then core is removed.

3. *Lora Koenig*:

Make sure the drill components are compatible with a mechanical drill. For aquifers you want to drill with a mechanical for ~10 m and then the Thermal.

Minimize the amount of ethanol in the borehole to avoid polluting the aquifer.

4. Rick Forster:

Make sure spare heat rings are included in the kit and are field replaceable. This implies the rings are attached with a simple mechanical method (e.g. Allen bolts) and the wires have a water tight connector that ideally does not require soldering in the field.

Control panel should have an amp meter or some method of evaluating whether the heat rings are making good thermal contact with the ice (maybe even a temperature sensor at the heat ring?).

5. From the group teleconference discussion and Kyle Zeug follow-up: It is desirable to be able to cut two 35mm x 35mm sticks from the core for use in CFA measurements. The smallest core diameter that could do that would be 3.116”. Having a core diameter of approximately 3.4” diameter allows for two sticks to be cut even in sections where the diameter of the core might be a little smaller than 3.4” to do possible core imperfections from the heat ring.