(2) Cutter design optimization
(3) Stabilization of the barrel carrying the cutting head
(4) Drill string flexibility
The above factors exert the greatest effect on boreholes (in that order, I think).

N. GUNDESTRUP: (1) Thermal drilling in liquid: Basically a very stable situation. The drilling can be performed with close to no force at the head. Thus, the drill should simply follow gravity. Victor has shown that this works in practice.

(2) Thermal drilling in open hole: Almost as above. But the operator needs to control the load on the head with the utmost care. If there are too much load on the head, the hole will incline. At Dye 3, the casing hole was made by thermal drilling, and it was inclined 1.5° at a depth of 80 m! This is possibly the worst hole yet made. The other extreme is the Milcent and Crete drillings. At 400 m, a disc on the cable was free floating just above the bottom of the hole. If too little force is exercised at the drill head, it may loose contact with the ice and thermal head will burn.

(3) Mechanical drilling: Basically unstable. Having a low center of gravity of the drill (like the PICO drill) improves the stability; and PICO showed that they can decrease the inclination using a low load on the cutters. The ISTUK auger has a high center of gravity. In spite of this, the hole can be stabilized using a negative cutter load, thereby effectively lowering the center of gravity. This worked well at Dye 3 and Summit. But this is not enough to ensure a self stabilizing drill. It seems that the flexible part of the drill –the core barrel– should be very symmetrical too. The mechanism is not understood, and the experiment not well defined, so there are still some unknowns.

(4) Shallow drilling: Comments as above. But because it is not possible to obtain a negative cutter load, the holes will deviate. Measurements have shown that 3 of our shallow holes were almost vertical until a depth of 40 m. Below this, the hole deviated, and the inclination was 1.2° at a depth of 100 m. For normal shallow drilling, this inclination has little impact. But when the shallow hole is used as primer for a casing, an inclination of 1° is quite high.

V. ZAGORODNOV: A self-driven device may keep a thermal drill close to the vertical position. A simple optical sensor may provide an output signal corresponding to the drill direction and inclination. The device should have three spring loaded smooth and round end pins touching the borehole wall. Each pin should be driven by an electrical motor. An optical sensor will switch motors according to the drill inclination. The length of this device can be close to 10 cm.

(Chaired by S. HANSEN; Documented by N. AZUMA)

Report 5. Status of Core Quality

This session specified the main factors causing ice sample changes as (1) decompression, (2) fracture, (3) internal physical transformation (clathrate, diffusion), (4) surface contamination, (5) diffusion out of sample, (6) diffusion into sample and (7) internal chemical reactions. J. SCHWANDER pointed out that things to be considered for each factor include (1): compression container, (2): drill design, processing design and relaxation of core, (3): compression container and storage temperature, (4): tools (choice of material) and particles in air (smoke), (5): sample size, (6): sample size, surface cleaning and storage atmosphere and (7): storage temperature and sunlight, respectively. The open discussion can be summarized as follows.

1) B. KOCI stated that core quality factors include depth of cut, chip packing around core, stick slip motion/general vibration of the drill and core cutter shape. Good core quality in dry drilling seems to be limited to about 100 m below the firn/ice transition by bubble pressure and the stress level in the core.

2) Decompression: H. UEDA commented on CRREL tests during the Camp Century drilling. The results of decompression tests lasting several days showed no apparent improvement of quality.

3) Deep core: N. GUNDESTRUP stated that the mechanical drill gives almost ideal performance except for the brittle zone. Only a few millimeters of the core from the surface has to be removed even for critical chemistry analysis. The core quality is relatively poor in thermal drilling. B. KOCI commented that thermal drills can take good quality cores provided that the ice temperature is above −10°C. V. ZAGORODNOV proposed a modified thermal-drill head, which limits the heated zone to a few millimeters to improve core quality.

4) Shallow core: J. SCHWANDER proposed a type of cutter that will improve the quality from a dry hole, and commented that a round-shaped cutter is not likely to reduce core fracture if the chipping depth is large (about 3 mm). M. WUMKES mentioned that chips packed between the core and the inner core barrel sometimes cause core twist-off/wafering. B. KOCI suggested use of a vacuum system to remove fine chips generated by slow drilling. A special shape of drill bit was proposed to scrape chips away from the core. He also suggested adding a small amount of fluid to reduce crack propagation (S. HANG suggests the capillary tension effect as a possible means). His drill needed a pump to transport chips. A test in Summit, Greenland in 1990 was quite successful. J. SCHWANDER mentioned another test with fluid at the bottom of the hole for Eurocore in 1989, which showed no difference in quality between dry and fluid drilling. N. GUNDESTRUP commented on SCHWANDER's test, pointing out that the test was done with very small cutting depth which could mask the effect of the hole fluid. His test result with the fluid level 3300 m below the surface supports KOCI's result. He explained that lubricating the cutting is another important effect of the fluid in addition to the crack prevention effect.

(Chaired by J. SCHWANDER; Documented by H. SHOJI)

Report 6. Status of Borehole Liquid

The following discussions and comments were presented by participants.

K. STANFORD: As was mentioned by a number of participants, selection of a drilling fluid is always reflected in the choice of the available compromises. No one