performance.

As shown by B. L. HANSEN and N. GUNDESTRUP, liquid density is not a negligible factor at all. To maintain a borehole for long term logging, say 20 years, the greatest care must be taken in controlling liquid density.

This issue is discussed further in the report "Status of Borehole Liquid" in this edition.

Core quality is a very critical issue. As there is a separate report on "Status of Core Quality" in this edition, I only introduce here J. J. KELLEY's comments: The definition of "high quality ice core" is still somewhat elusive. It needs clarification in light of the fact that there are multidisciplinary needs for information from the core; and from the long term use of the hole. Presently, the analytical chemical technology is much better than in the past. Measurements of chemical constituents in the ice can be made in the parts-per-trillion or more. Does this imply that high quality cores mean "no cracks of any dimension" ?

Cracks within core (its shape, size and number) depend on drill type, ice hardness, cutter shape, cutting speed, cutting thickness and cutter load. But there are few data to discuss cracks in relation to these factors. So, let's keep them in mind until the next workshop.

The answer for K. KUSUNOKI's question whether there are specific problems on patent properties in the deep drilling business is obviously "No!". Information is open to anybody who is interested in drill systems. Concerning this, M. A. WUMKES comments: Many differences in methods of approach to deep drilling depend on the experiences of drill designers. It would be helpful if we could somehow share information, not necessarily in peering reviewed papers, but in a manner that would benefit all who design drills, preferably more frequently than every 4 years at ice core drilling workshops.

I would like to close this report introducing comments from H. T. UEDA one of the pioneers of deep drilling: A large part of deep drill system design is in the design philosophy of the designer or designers of the system. There is nothing wrong in approaching the problems in different ways. In fact it probably is desirable, at least for now. However, it would be beneficial for everyone to have easy access to objective and unbiased experimental results from the drilling community.

(Chaired by N. GUNDESTRUP; Documented by Y. TANAKA)

Report 4. Methods of Maintaining a Vertical Borehole

S. HANSEN: At present, the most successful method of maintaining a vertical borehole is to keep the contact pressure of the drill head to a minimum. It is therefore desirable to run an electromechanical drill using a head, and carefully control the descent rate of the drill. Also it is important to keep the center of gravity in the drill as close as spacers may be mounted onto the tube.

M. WUMKES: I agree with Sigfus' observations on the factors affecting borehole deviation, especially cable feed rates vs. cutter penetration rates. We have seen this at GISP on a number of occasions. We see accurate cable feed rate, stable drill head, stiff drill string and negative cutter loading as being desirable in minimizing borehole inclination.

K. STANFORD: (1) Penetration rate and bit weight control

(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) decom-