pression, (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 fluid meets all requirements. Recent drilling projects have evidenced an emphasis on health and environmental aspects of ice coring fluid. These components of the overall ice drilling picture have not received as much emphasis in the past. It would appear that these two considerations will hence forth be perceived as having the same importance as those relating to core quality and borehole preservation.

V. MORGAN: Antarctica is a special place for environmental considerations. There may be some problems with any large volume of fluid put into the ice sheet. We must be mindful of the environmental view when selecting fluid.

M. WUMKES: (1) Wear mechanism: The view in regard to the effect of butyl acetate on the cable seems confused, judging by comments here. The butyl acetate did not affect the Kevlar fiber itself. What was affected was the lubricant that the Kevlar fiber is coated with. Kevlar wears very quickly against itself. What this means is that this type of construction is not correct for this application.

(2) Butyl – not available for use in Antarctica: Another consideration for choice of a drilling fluid is political. Butyl acetate has been approved for use in Antarctica, but not any of the HCFC's or CFC's. As a result, the only fluid available for US program use is n-butyl acetate.

B. KOCI: The dissolving of the wax lubricant in the Kevlar cable may not be particularly important in length of the cable life. A more important consideration for Kevlar cables in particular is never to let sleeve diameter be less than 30 times the cable diameter nor the working load more than 10% of cable strength. Similar failures have occurred with loads and sleeve diameter ratios close to those used in GISP while working in sea water. The importance of cable lubricant may not be as high as assumed given the short cable life expected in a deep drilling project.

N. GUNDESTRUP: (1) The primary point is that there is no ideal liquid available. Butyl imposes some severe problems for the operators. Although the vapor pressure can be kept below the safety limit, this limit assumes some sort of a static environment. The real problem is the spray created by handling and cleaning the drill. We experienced that at Dye 3. And butyl extremely aggressive solvent.

(2) Alcohol cannot be used in deep drilling because the high liquid density will introduce significant differences between the pressure in the ice and that in the hole. If a deep hole is drilled relatively fast in a cold place (cold also at the bottom) alcohol may work. But then the hole will be lost after a few years. The result will be that the ice flow with depth will not be known. And to my belief, all relevant deep cores will be relatively warm, if not melted, at the bottom.

(3) D60-F113 was close to the ideal hole liquid. But it is no longer available. Some HCFC's, HFC or HFE substitutes may be available. But the availability, price, health and political problems are yet to be known.

V. ZAGORODNOV: It seems to me that a very limited amount of quantitative data about ice core contamination have been obtained. To study a major process which permits the admixture to penetrate into the ice core it is necessary to conduct parallel test-drilling with thermal and mechanical drills, using hydrophobic and hydrophilic liquids.

(Chaired by T. YAMADA; Documented by S. FUJITA)