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DEVELOPMENT OF JAPANESE MECHANICAL DRILLS —PERSONAL REMINISCENCES—

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It is my great honor to be invited to this workshop. It is also my pleasure to see many my old friends here. But, I am now not so happy, because the organizer asked me to speak in English. I have had few chances to speak English after I retired four years ago and my poor English has become poorer. I am afraid if you could understand my English.

Now, another problem is what to talk. As it was seven years ago that I made my last drill, I have nothing new to talk about ice drilling technology. The organizer suggested me a talk about the history of Japanese mechanical drills. I will follow his advice. But my talk will be rather my personal reminiscences than a general history.

I will start my talk from the days of the first Japanese drilling project.

The project was officially approved in May 1969. It consisted of two stages, the first test drillings in winter of 1971 and of 1972 and the second a deep drilling in summer 1974–75.

I took the responsibility of the detailed planning. Without any hesitation, I set a target for the first stage to reach 400 m with a thermal drill, simply because I had known the CRREL thermal drill. We asked CRREL more informations and, by their courtesy, I got a full set of blueprints of the CRREL-II system in that summer.

As I recall now, we asked not CRREL, but the designer. I understand that we have here Mr. Herbert T. UEDA, the designer.

All Japanese thermal drills and winches, including those successfully used in 1983 and 1984 to reach 700 m, are based essentially to his design. I would like to express our thanks to him on this occasion.

I will now back to the main theme. As we had already used the famous SIPLE hand augers, our first idea of a mechanical drill (I mean a cable-suspended mechanical drill) is a SIPLE auger driven by a suspended motor with an antitorque device. Two such drills were tried during the project which were mainly carried out with thermal drills. One was made by Mr. KIMURA, the leader of the 1971 drilling team, and used in 1971 at Mizuho, and the other was made by me (SUZUKI, 1976) and tested at Ice Island T-3 in 1973. The antitorque was too weak to be practical. When externally supported, the drill went at 15 m/h, but stopped by clogged chips in a minute or two, showing the limit of a single barrel drill.

At the first workshop in 1974, three double barrel drills were presented by CRREL (RAND, 1976), Swiss (RUFLI *et al.*, 1976) and Iceland (THEODÓRSSON, 1976). The use of a fixed outer barrel, or a jacket, is a key technology for an auger drill. First, the jacket cuts the torque transfer between the hole wall and the rotating inner barrel, except at its exposed part. So, we can reduce the capacity of the antitorque device. Secondly, the jacket provides

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a stable passage of chips.

In December 1976, I was allowed to join the RISP operation. Mr. Lyle HANSEN was supervising ice drilling with a wire-line drill at J-9. Mr. John RAND and Mr. Henri RUFLI were also there. Followed to Lyle's advice, I joined a shallow drilling team of SUNYAB. We drilled down to 51.54 m with the Rufli drill. The winch was a very compact one with the reducer installed in the drum. I borrowed the idea for all my winches.

In 1977, JARE-geologists asked me to make large cavities in ice to charge dynamite (SUZUKI and SHIRAISHI, 1982). As they allowed 100 hours for each one, I decided to drill holes 14 cm in diameter and 150 m deep. I began to design a double barrel drill, ID-140, and a 180-m winch, W-12-180. In due course, I invented two new antitorque devices, side drills and side cutters. The drill was so designed as to test any of them or a conventional three leaf-spring device. Test of them in January 1979 in Antarctica showed the superiority of side cutters, which was used in all my later drills. As for the drill itself, I failed to design an effective jacket. So the drill was used as a single barrel drill. As the antitorque was effective, it reached 62 m in 66 hours, though core length in a run was only 20 to 30 cm.

To search an effective jacket, we, that is Mr. SHIMBORI and I, made a test drill ILTS-140 in the machine shop of the Institute of Low Temperature Science. The jacket and the inner barrel are both made of seamed steel pipes, O.D. 139.8 mm and 114.3 mm. The bottom of the jacket was straight. The drill worked well at the first test in laboratory. The seam worked as a rib. The inner surface of the jacket of ID-140 was too smooth to work without ribs. A simple mistake. The drill was used by Dr. NISHIO in December 1979 at Allan Hills and by Dr. NISHIMURA in 1981 at Mizuho.

Based on the experiences of ID-140 and ILTS-140, a new drill MID-140 B and a winch W-9-150 were ordered from a factory in 1979. It weighs 65 kg. The barrel can take a 0.6 m core. After augers were welded, it was tefloncoated. The drill reached 143 m in 81 hours in 1980. A modified version was made in 1981 for JARE-23.

In late 1980 Nagoya University asked me to make a light drill to be used in Himalaya, which we made in 1981 and named ILTS 130A (SUZUKI, 1984). Three drills, 130B, C and D, using the barrel of the same size [Mk-I:109 mm OD, 1 m long, 0.4 m core] were made in that year. They are different in power: 450 W for A, 220 W for B, and 350 W for C and D. The 130°C drill is only 1.4 m long and weighs 21 kg. The 130 series are not merely a shortened version of 140B. Their design and manufacturing process are greatly simplified. Two polyethylene belts are screwed to a steel pipe of O.D. 109 mm to make a barrel. Then the barrel is finished with lathe to fit the jacket. Because of the ability of our lathe, the barrel length is limited to 1 m.

The barrel clearance (the difference of the inner radius of the jacket pipe and the outer radius of the barrel pipe) is 7.4 mm for 130's with Mk-I barrel while 11.2 mm for 140B. The jacket of 130's is 127 mm (5 inch) OD and 1.6 mm thick. Chip transportation of the former seemed better than the latter. So, I tried a barrel clearance of 4.75 mm in summer 1982. At that time polyethelene belt, 3 mm thick and 20 mm wide, became available. We fixed it with adhesive tape to a steel pipe of 114.3 mm (4.5 inch) OD. The belt is enough flexible, and no finish machining is needed. The barrel of this diameter is called Mk-II. We made a 2-m Mk-II. It worked well for cold ice. Chips literally ran up and hardly stayed along the barrel. Narrow clearance is no problem even for a 4-m Mk-II barrel tested in late 1983. We tested Mk-II for wet ice. Wet chips could go up to the inlet but often made thin ice layer and did not enter in the barrel. The final version of 130 with Mk-II (ILTS-GT-BAS-130) and a winch W-5-250 was made for BAS, assembled in ILTS machine shop in April 1985.

In 1983, we made a large drill ILTS-150A to drill a hole up to 170 mm in diameter (SUZUKI and SHIMBORI, 1984). We also made a small one ILTS-100A (13.4 kg) to take a 80 mm core. The barrel is made of aluminum pipe 88 mm OD and the jacket of steel 101.6 mm (4 inch). The length of the barrel is 1.5 m.

We made two types of double barrel auger; U-and S-types (SUZUKI and SHIMBORI, 1985). In this conventional U-type (U for a unit compartment for core and chips), chips move up and fall into the barrel. Stored chips are compacted by gravity only. Hence they are bulky and require a longer storage. In the S-type (S for separate compartments for chips and core), chips go up and be compacted by the booster screw. Higher compaction, shorter storage, hence a shorter drill. The Iceland drill was this type. The first S-type drill was made in 1984. The density of the compacted chips was 750 kg/m^3. A 100B type drill to take a 2.5 m core of 8 cm in diameter can be as short as 4.5 m and as light as 25 kg. An S-type drill can be used in liquid, because it does not use gravity to collect chips in the storage. We began simulated tests of liquid filled hole drilling with S-type 130 drills late in 1985. The drill is inserted in the transparent pipe, fixed to the top of ice box, containing ice block. The jacket of the drill is also partly transparent. Colored water is filled in the standing pipe. As soon as drilling began, chips were seen floating in the storage and gradually compacted. The compaction depends on the size of storage. (In dry hole drilling with an S-type drill, compaction depends mainly on the friction of chips with the storage wall and on the capability of the booster.) In our test, chips were compacted to the dry density of about 600 kg/m^3. This is a little dense to remove chips easily. The storage size may be such that the dry density of chips is less than 550 kg/m^3 for easy chip removal.

According to my note, our last simulated test of liquid hole drilling was done on March 28, 1986, and that was the end of my active participation in the drilling technology.

I am glad to know that my idea has been adopted by JARE for their deep drilling project and hope to see the success of the project.

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