ICE DRILLING AND CORING EQUIPMENT

BY

KENNETH LINELL
CHIEF, FROST EFFECTS LABORATORY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS, U.S. ARMY

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INTRODUCTION

In 1948 the Frost Effects Laboratory of the New England Division, Corps of Engineers, U.S. Army, was requested by the Division of Oceanography, Hydrographic Office, U.S. Navy, to develop an ice mechanic's test kit which would include portable hand-operated equipment for penetrating ice to a depth of 15 feet or more and for obtaining ice specimens, together with apparatus for measuring for ice thickness, densities, salinity, temperature and compressive strength.* In the original proposed usage of this kit, it was visualized that it would be carried in a light, low speed plane, having a weight load capacity for this purpose of 200 pounds, in addition to the pilot and one passenger. Upon descending on the ice at a particular location, the kit would be unloaded from the plane by the two men, moved to the desired test location and set up and operated by them. Lightness in weight of equipment was obviously of first importance.

The primary problem was obviously that of penetrating the ice and obtaining intact specimens for tests. Ice chisels of various designs have been used for many years for cutting holes through ice by hand, supplemented in deep holes by the use of a spoon-shaped device attached to a long rod for removal of the cuttings from the hole. This method has the advantage that holes of any desired diameter can be made with the same simple tools; however, cores are not obtained and the work is very tiresome and slow when the ice is many feet in thickness.

A considerable study was made of the literature and contacts were made with a number of glaciologists and other experts who might have knowledge of potentially usable ice coring equipment; however, it was found that there was no suitable equipment for obtaining ice cores to the depths required. Such experimental equipment as had been developed suffered from various major deficiencies, such as failure to provide for removal of cuttings from the cutting zone, or required enormously excessive amounts of horsepower to operate. Therefore, it was necessary to design an original coring device.

HAND CORING AUGER

In the first experiments with various types of designs and devices to develop a hand coring device, it was found that the major deficiency was the absence of a means of removing the ice cuttings from the vicinity of the cutting blades. If the cuttings were allowed to remain and interfere with cutting action, or with rotation of the core, the device at once became inefficient or ineffective. It was not possible to employ the system used in porous compressible materials such as snow of moderate to low density in which cuttings are displaced laterally by pressing them against and into the walls of the bore holes, such as the Mount Rose snow sampler. Use of compressed air or a liquid to move cuttings up out of the hole was out of the question for our purpose, primarily because of the weight of added equipment which would be required. However, a spiral helix such as used in an ordinary metal drill or wood bit provided a satisfactory and simple method of accomplishing this.

As shown on Photographs 1 through 5, the ice coring auger as presently developed consists basically of one or more cutting blades fastened to bottom edge of a thin-wall cylindrical tube. Helices fastened to the outside of the

FIGURE 1 — Coring a block of ice. T-handle is being used to rotate augur in place of the brace normally used. Additional drilling equipment components shown are extension rod, core remover barrel, and helix barrel.

FIGURE 2 — Ice cores may be removed by sliding them up into the core remover barrel as shown.

*Work was performed under the Airfields Branch, Engineering Division, Military Construction, Office, Chief of Engineers, U.S. Army, Washington, D.C.

tube assist in the removal of the cuttings from the vicinity of the cutting blades during the cutting action, guide the auger as it rotates and assists with the withdrawal of the auger from the hole by distributing force through the mass of cuttings which accumulate between the tube and the wall of the hole. The cutting blades cut a hole with just enough clearance so that the auger will turn freely, but so that cuttings do not pass through the clearance space between the blades and the wall of the hole. Clearance is also provided between the core and the inside of the tube by tapering the inside of the cutting shoe so as to make an opening smaller than the remainder of the barrel. The cutting shoe is so formed that the cuttings cannot pass up between the tube and the core, but pass up on the outer side of the tube. It was found that if this was not accomplished the cuttings would accumulate between the core and the barrel and produce a blocking action. The tube wall thickness is made as thin as possible in order to provide as much volume for the ice shavings as possible, in the space cut by the blades. A wall thickness of 1/16-inch has been used for steel tubing and 0.08-inch for cast and machined aluminum.

FIGURE 3 — Ice cuttings move upward along helix barrel as coring auger penetrates ice block.

Thus far, it has proved most feasible to form the cutting blades into a single-unit removable cutting shoe, for convenience in changing worn or damaged blades. This scheme is somewhat expensive, but does have the advantage of keeping the cutting blades in exact alignment so as to give proper clearances and cutting angles, thereby insuring efficient action and smooth uniform cores.

In designing the auger, it was found that the angle included between the front and back faces of the cutting blade should be as small as practicable, consistent with adequate strength. The angle between the back of the blade and the cut surface of the ice was selected to give a positive back clearance angle. In the hand-operated equipment, it has been found desirable to make this angle quite large. It is imperative that this surface be maintained without any trace of rounding off, to the extreme edge of the blade. The angle between the front surface of the blade and the surface of the ice being cut is made as low as the selection of the other angles will permit.

The cutting action of the blades will, of course, be different in different types of ice. That is, in hard, fresh water ice, at very low temperatures, the blades will scarcely penetrate the ice unless appreciable pressure is applied, whereas in snow or soft sea ice, the blades may tend to take too great a cut. In the hand coring augers, constructed to date, this has been controlled by addition of riding shoes attached to the lower edge of the cutting shoe, as shown on Photographs 4 and 5. The amount of projection of these shoes below the main surface of the shoe may be varied to produce different depths of cut of the blades.

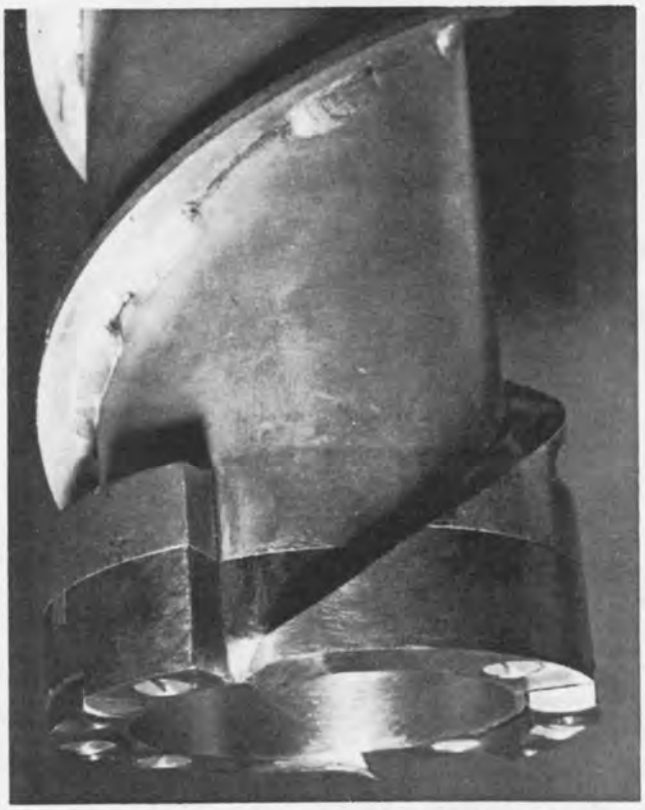

FIGURE 4 — Side view of coring auger cutting shoe, showing shape of cutting blades. Riding shoes are here shown in two different adjustments.

FIGURE 5 — End view of coring auger cutting shoe. Note riding shoes used for adjusting depth of cut.

In present models, a section of tubing has been added above the coring auger barrel from which one side has been cut out so as to permit the recovered cores to be removed. This is necessary because the constriction of the opening at the bottom edge of the cutting shoe is so tight that it is impossible to push the core back out through the cutting shoe. Photographs 1 through 3 show this feature.

The hand-operated coring auger is normally turned by a modified carpenter's bit brace, and aluminum extension rods are added as the depth of the hole increases. The auger is generally started in a small depression, chipped with an ice chisel or other tool. Until it has penetrated the full length of the coring barrel the cuttings fluff out on the surface of the ice as shown in Photograph No. 3. If the blades are properly sharp, very little vertical loading is necessary to cause the blades to cut when drilling in ice above 0°F., and the weight of the equipment itself is generally sufficient.

After the auger barrel has penetrated below the surface of the ice, it is removed as soon as the accumulated cuttings fill the helix space. This is not always easy to judge. However, it is determined by experience that a certain number of turns, such as twelve, will fill the helix, and the operator of the auger then gives the auger this number of turns each time he puts the device down the hole, before removing it. A core catcher has not been found necessary to date with this device, when drilling in ice, since the core is normally retained within the barrel, breaking off as the auger is withdrawn. In snow, however, the auger does not retain the core as readily, and a core catching device is now being developed for this application.

By successive steps of drilling and removing the auger from the hole, removing the cored ice from the auger, clearing the auger of cuttings and re-inserting the auger in the hole, a boring may be carried into ice or snow to a considerable depth with the aid of the extension rods. In snow containing ice layers, it has definite advantages over the Mount Rose sampler, in that it will cut very rapidly through ice which stop the Mount Rose sampler.

Several borings have been made with this device on glacier surfaces containing alternate layers of snow and ice. A depth of slightly over 30 feet was reached in one instance in about 5 hours working time with 2 pairs of men, each pair spelling the other at intervals; the first 12 feet were cored in about 15 minutes by one man. In another case, depth of about 60 feet was reached in approximately a week's work by two men. In the sea ice of Point Barrow, five feet of ice was drilled completely through in about 10 minutes by one man. Recoveries are close to 100% so long as the snow or ice is sufficiently cemented together to be recovered in the form of a core. The cores obtained in sea ice and glacier ice, and in fresh water lake ice at above 0°F. are apparently flawless. At temperatures below 0°F. fresh water lake ice tends to spall into pancake-like slices, apparently due to temperature stresses, and no practicable way is known at present to avoid this.

In its present design the auger has been made as light as possible at the price of considerably increased cost. Possibly its cost may be reduced by redesign for routine ice studies in the future. However, it has already accomplished explorations in Arctic studies which were feasible with no other available device.

POWER AUGER EQUIPMENT

Some experiments have been performed using the hand coring auger attached to a 5 h.p. portable earth auger motor. This device is held by two men and the auger penetrates vertically downward between them. The power of 5 h.p. is really too much for the purpose, since only a fraction of the horsepower is required to operate the auger and for holes to a few feet in depth, it is easier to turn the auger in by hand than to go to the trouble of bringing along an extra man and of carrying the motor and transmission.

However, we have also used a plain 6-inch diameter earth auger with this 5 h.p. motor and have been able to drill up to 2½ feet of ice in 25 seconds. A specially designed cutting blade is used on the auger. From the purchase cost standpoint, this is a much cheaper combination than the hand auger with the McCulloch motor and it appears to have excellent possibilities where it is desired to make holes rapidly through ice which is only a few feet thick.

A ski-mounted rig has also been developed for purposes of drilling numerous shallow holes where we wish to explore an ice or a snow surface in detail. The rig proper is mounted on a frame which is, in turn, supported on the skis. The rig is driven by a 6 h.p. air-cooled engine which delivers power to a drive-head mounted on a vertical frame. Auger barrels, 2 ft., 4 ft., and 6 ft. permit us to obtain longer individual coring runs than are obtainable with the hand auger. Using the 6-foot barrel, we should be able to reach a depth of 9 to 10 feet in only two runs of the auger. If desired, holes can be extended to greater depths.

The types of designs for ice coring and drilling equipment which have been described are not needed where only soft snow is involved. In such cases, devices such as the Mount Rose sampler will handle the problem. However, where glacier studies are being made and where studies are being made on floating sea, lake or river ice, which must be penetrated, devices of these types will provide means of recovering cores, for those interested in the properties of the snow and ice materials themselves, and for drilling holes where it is desired to let instruments through for bottom soundings, current measurements or scientific observations. The coring devices are not inexpensive in their present designs. However, they do function, and with the knowledge now available, it seems likely that less expensive designs can be developed.