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Technical Report 191

SOIL SAMPLING AND DRILLING NEAR FAIRBANKS, ALASKA EQUIPMENT AND PROCEDURES

by

R. M. Davis and F. F. Kitze

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Conducted for
CORPS OF ENGINEERS, U. S. ARMY
by
U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

Erratum - Technical Report 191

Page 1, para. 2, line 9: change 20F to 29F

NOTE: It should be pointed out that this report describes drilling and subsurface sampling techniques and equipment developed and used primarily in the 1950-1960 decade. Some of the references under "Literature Cited" describe later developments. Subsequent USA CRREL reports will also deal with these.

Many of the items included under "Literature Cited" are not actually cited in the text but were included to provide the reader with additional references.

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PREFACE

The investigations reported herein were accomplished in connection with Military Construction Investigations, Engineering Criteria and Investigations and Studies, Investigation of Arctic Construction, Sub-project 1, Field Investigations, Task 4, Development of Subsurface Exploration Techniques and Equipment for Permafrost. The Military Construction Investigations are conducted for the Office, Chief of Engineers, Directorate of Military Construction, Civil Engineering Branch (Mr. T.B. Pringle, Chief).

The information presented in this report consists of some experiences of U.S. Army Cold Regions Research and Engineering Laboratory (USA CRREL) personnel in utilization of drilling equipment and soil sampling devices in frozen and thawed soils of the Alaskan arctic and subarctic. The report summarizes soils exploration operations at Alaska Field Station (AFS), USA CRREL, at Fairbanks, Alaska, and at remote Alaskan sites. Most of the field work was performed by personnel permanently assigned to AFS and was under the direction of Mr. F.F. Kitze, Chief, Alaska Field Station.

Collection of data was started during the period when AFS was under the direction of the Permafrost Division, Corps of Engineers, St. Paul District, and was continued under the direction of Arctic Construction and Frost Effects Laboratory (ACFEL), U.S. Army Engineer Division, New England, when the Permafrost Division was consolidated with the Frost Effects Laboratory to form ACFEL. Mr. Harry Carlson was formerly Chief, Permafrost Division, and Mr. Kenneth A. Linell was formerly Chief, ACFEL. In February 1961 ACFEL was merged with the U.S. Army Snow Ice and Permafrost Research Establishment to form USA CRREL.

This report was prepared by Mr. Robert M. Davis, Geologist, Applied Research Branch (Mr. A.F. Wuori, Chief) and Mr. F.F. Kitze. Report preparation was under the general direction of Mr. K.A. Linell, Chief, Experimental Engineering Division.

Director of USA CRREL during the publication of this report was Colonel Dimitri A. Kellogg. Chief Engineer was Mr. W.K. Boyd.

The report was reviewed by Mr. G.R. Lange, Geologist, who contributed many valuable suggestions.

USA CRREL is an Army Materiel Command laboratory.

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SUMMARY

Several types of rotary drilling machines and percussion type drilling machines have been used for soils explorations at Alaska Field Station, USA CRREL, Fairbanks, Alaska. The drilling machines include a Longyear Straightline Diamond Core Drill, Model UG8; Acker Toredo Core Drill, Type TH; Chicago Pneumatic Core Drill, Model 8; Concore Exploration Drill, Type E5-48; Cyclone Churn Drill, No. 40; and a Fairbanks Churn Drill, No. 45. Various types of coring barrels and soil sampling tubes have been used with the machines, including Longyear 7 in. OD single and double tube core barrels, Acker single and double tube core barrels size NX, Acker and Sprague and Henwood split tube and solid tube samplers, 2½ in. OD, and a steel pipe sampler fabricated from 3-in. standard pipe.

Soils explorations were conducted by core drilling methods and by drive sampling methods in thawed and frozen silty soils. Temperatures of the frozen soils sampled ranged from 28F to 31.5F in the permafrost and from 20F to 27F in the active layer. Penetration of drive sampling devices through the frozen active layer during late winter or early spring is more difficult than into the underlying permafrost due to the colder soil temperatures.

The Cyclone churn drill, equipped with a field fabricated 3 in. diam pipe sampler, is a highly effective means for drive sampling in frozen silt soils to a depth in excess of 100 ft. The equipment is well adapted for drive sampling through the colder frozen active layer during the late winter and spring season. The Acker solid tube sampler adapted to the Cyclone churn drill is also effective for drive sampling frozen soils but is much more susceptible to damage than the standard pipe sampler.

Core drilling and sample recovery has been successfully accomplished using the Longyear core drill with 7 in. OD single and double tube barrels and with the Acker core drill and Chicago Pneumatic core drill using single and double tube core barrels, size NX. Samples were recovered from 30 to 40-ft depth in frozen soil using coring methods. Excellent sample recovery was experienced. Wintertime coring operations necessitate circulation of alcohol as a drilling fluid in lieu of water to eliminate freezing of water lines, water swivels and related equipment. Summertime core drilling operations necessitate pre-cooling of the water by means of ice to prevent thawing of the sample prior to recovery.

A Concore exploration drill has been very effective in obtaining core samples from 20 to 30-ft depth in frozen soils using double tube core barrel, 2 in. OD, and Acker split tube sampler, 2 in. OD. The Concore exploration drill is of aluminum construction, having a total weight of about 604 lb. The drill can be disassembled into parts whose heaviest component is approximately 130 lb. This makes the machine readily adaptable to transportation in bush type aircraft for remote site drilling.

A tripod arrangement for supporting a 350-lb drive hammer operated manually by a rope from the cathead of both Acker and Chicago Pneumatic core drills was also effective for drive sampling frozen silty soils

SUMMARY (Cont'd)

to depths up to 20 ft. Drive sampling devices used with the core drill drive arrangement were split and solid tube samplers, 2 in. OD, manufactured by Acker Drill Company and Sprague and Henwood Drill Company. Chicago Pneumatic thin wall samplers (Shelby tube) were also used for sampling through thawed soil into the permafrost utilizing the tripod and drive hammer arrangement with the Acker drill. Chicago Pneumatic samplers with square cut drive edge are effective for driving into frozen soil while samplers with spun edge are easily damaged and ineffective for sampling. In general, the Acker split and solid tube samplers have been more effective for driving into frozen soils than the split and solid tube samplers of Sprague and Henwood. In the latter samplers, the sampler shoe is believed to be too thick, necessitating greater driving energy and consequently greater susceptibility to damage.

Manual driving of a sampler fabricated from thin wall electrical conduit proved to be effective for sampling frozen soils to depths of about 10 ft. Driving of small diameter samplers into frozen soils by means of pneumatic hammer and recovery by truck mounted winchline was also effective for shallow explorations up to 10 - 15 ft depth.

SOIL SAMPLING AND DRILLING NEAR FAIRBANKS, ALASKA
EQUIPMENT AND PROCEDURES

by

R. M. Davis and F. F. Kitze

INTRODUCTION

Purpose and scope

Extensive subsurface explorations have been conducted by USA CRREL in connection with permafrost investigation studies. The majority of the explorations were made in the silt soil underlying the Alaska Field Station, Fairbanks, Alaska, but explorations were also conducted at various other locations in Alaska. This report covers some of the various types of drills and mechanical and manual sampling devices and associated techniques which have been tested by USA CRREL.

Site

The Alaska Field Station (AFS) is located approximately 2½ miles north of Fairbanks, Alaska. The mean annual temperature at Fairbanks is about +26F with extremes of -55F to +90F. The natural soil underlying the research area is principally silt to a depth of approximately 50 ft with a variable content of organic material and occasional layers of peat. Ice lenses are present throughout the silt. The seasonal frost zone varies from 2 to 6 ft under natural surface cover conditions and the thickness of the permafrost layer is in the range of 150-180 ft. The permafrost temperatures vary from about 20F to 32F under natural surface cover conditions.

Figure 1 shows the soil data for a typical boring at the AFS. Figure 2 gives the gradation range for eight silt samples from the same hole. Figure 3 gives the subsurface maximum and minimum temperatures in the soil beneath the station and the temperature range in the Fairbanks area.

Types of equipment tested

The types of drilling and sampling equipment tested are as follows:

Churn drills

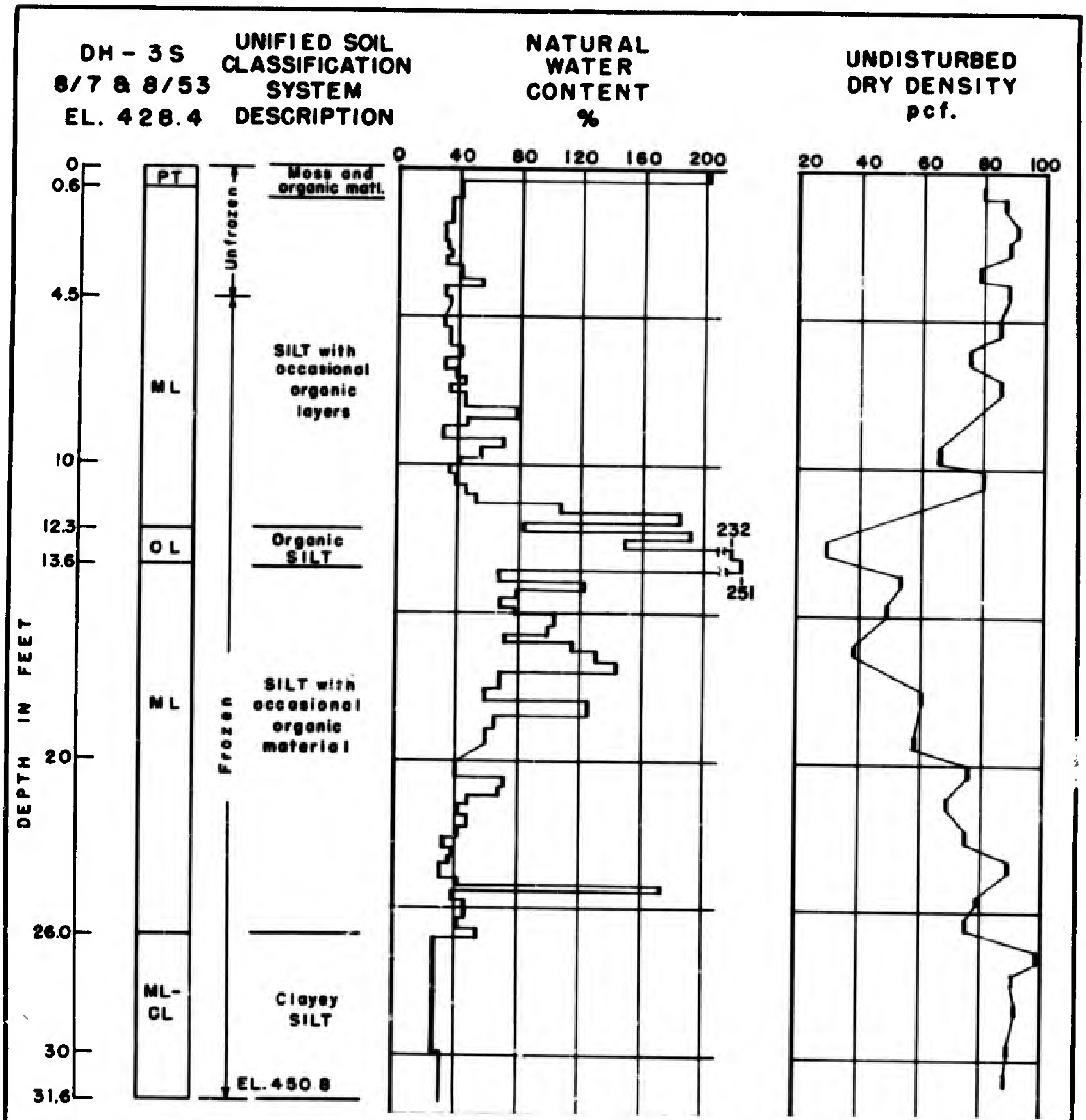
- Sanderson Cyclone Churn Drill - Model No. 40
- Fairbanks Churn Drill

Core drills

- Longyear Diamond Core Drill - Model UG8
- Acker Teredo Core Drill - Type TH
- Chicago Pneumatic Core Drill - Model 8
- Concore Exploration Core Drill - Type E5-48

Core sampling devices

- Single Tube Core Barrel, 7 in. OD, 3 ft long
- Double Tube Swivel Type Core Barrel, 7 in. OD, 5 ft long with basket-type core catcher
- Single Tube Core Barrel, Size NX 2 29/32 in. OD, 2 ft long
- Double Tube Swivel Type Core Barrel, Size NX, "L" Series, 2 29/32 in. OD, 5 ft long with basket-type core catcher
- Split Tube Sampler (Acker), 1 1/4 in. ID, 1 ft long with sawtooth shoe



NOTES:

a. 2" Shelby tube samples 0 - 4.5'

b. 6" I.D. double tube core barrel samples 4.5' - 31.6'

c. Sample recovery about 95 % of total depth.

d. Organic content determined by loss in weight upon ignition of oven dried sample.

LABORATORY TEST RESULTS				
SAMPLE DEPTH FT.	CLASS SYMBOL	% ORGANIC	L. L.	P. I.
7.5 - 7.8	ML	4.3	38.3	7.5
12.5 - 12.9	OL	10.0	48.3	12.4
19.0 - 19.4	ML	4.1	33.8	9.3
26.7 - 27.0	ML - CL	2.2	28.4	8.1
31.0 - 31.6	ML - CL	3.5	27.3	4.6

SOIL DATA FOR BORING NO DH-3S

Figure 1. Typical drill log at AFS.

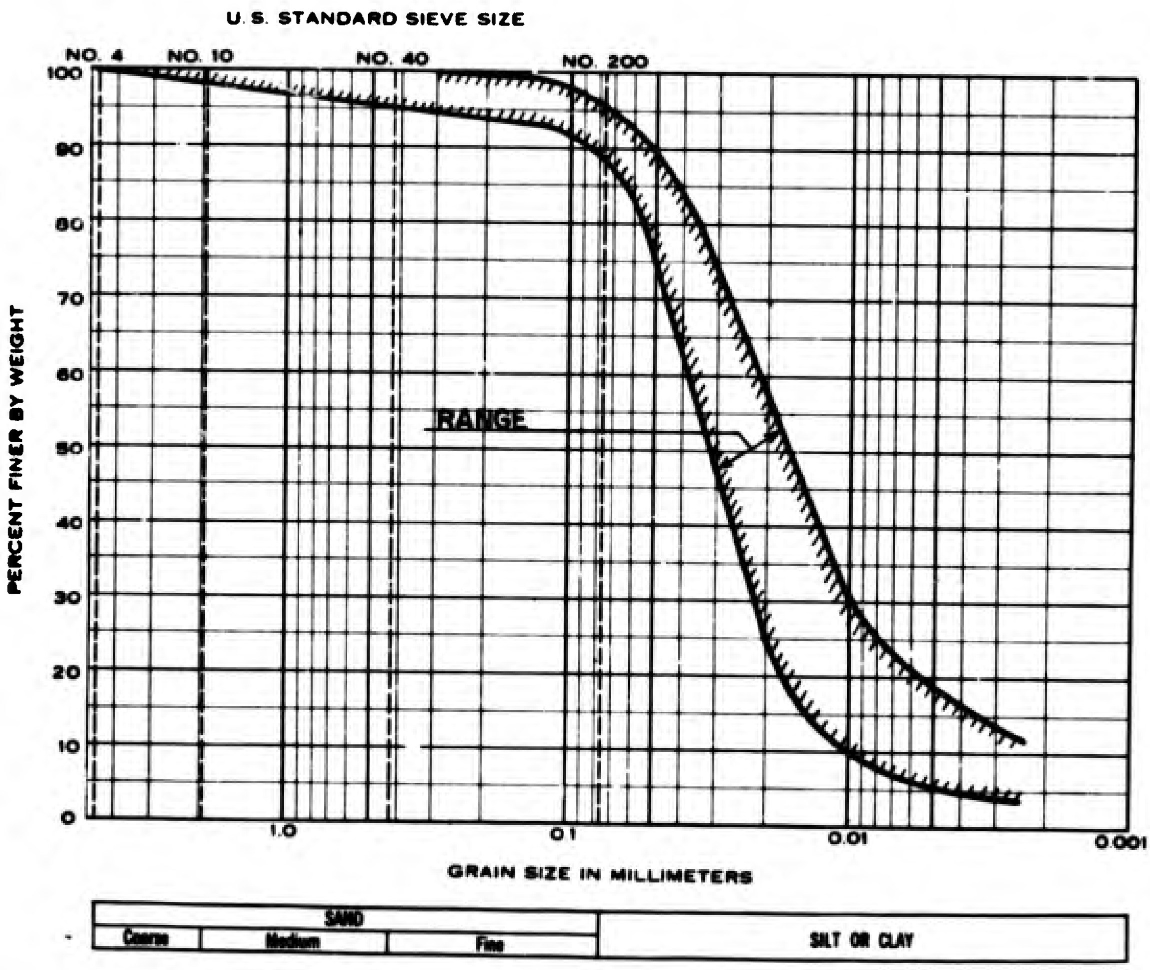


Figure 2. Gradation range of soil samples.

Drive sampling devices

- Solid Tube Sampler (Acker), 3 in. ID,. 2 ft long
- Split Tube Sampler (Acker), 11 in. ID, 1 ft long
- Steel Pipe Sampler (AFS field fabricated), 3 in. ID, standard pipe, 2 ft long
- Solid Tube Sampler (Sprague and Henwood), 2 1/2 in ID, 2 ft long
- Split Tube Sampler (Sprague and Henwood), 2 1/2 in. ID, 2 ft long
- Solid Tube Sampler (field fabricated), thin wall electrical conduit, 1 1/2 in. OD, 20 in. long
- Shelby Tube Sampler, 2 in. OD, 2 ft long
- Hvorslev Sampler, hand-operated piston type

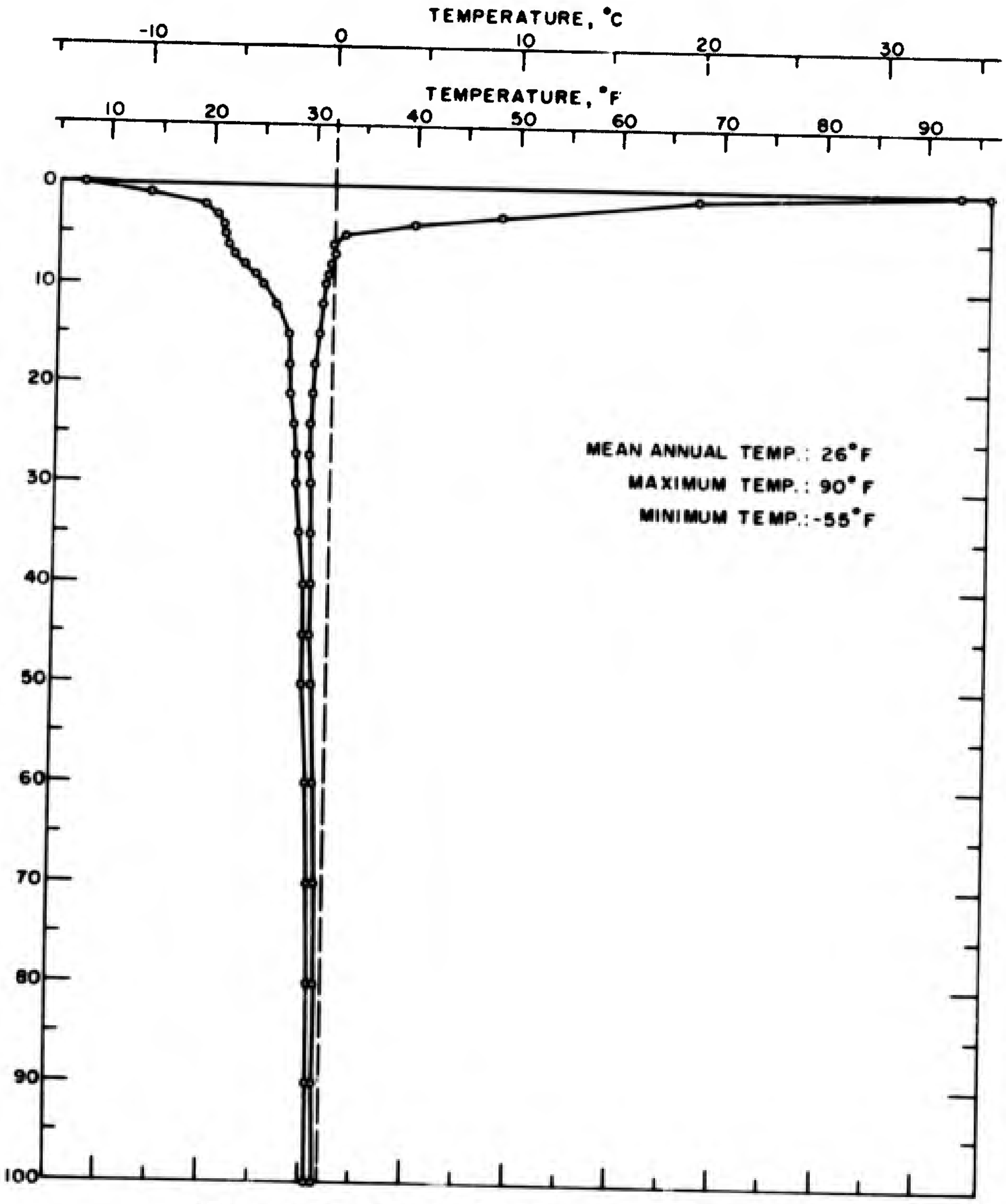


Figure 3. Temperature pattern at AFS.

Selection of equipment

In selecting the drilling and sampling equipment for a particular exploration, consideration was given to the following factors:

The type of information required. Subsurface exploration in arctic and subarctic regions is generally conducted to determine the composition and properties of the soil, the boundaries and/or depth of permafrost and the ice content of the soil. In addition to subsurface exploration it is frequently necessary to drill holes for the placing of piles or instrumentation in both the active zone and the permafrost.

Accessibility of site. Many of the outlying sites in both Alaska and northern Canada are accessible only by means of aircraft, in many cases limited by landing conditions to small "bush" type aircraft. During the thawing season the unstable conditions of the active layer prevent the use of wheeled and tracked vehicles in some locations. These factors limit the size and weight of the equipment which can be used. In some cases sites can only be reached during the winter when the ground is frozen.

Site disturbance. Due to the delicate balance of the thermal regime of most of the permafrost in the subarctic, it is frequently necessary to perform explorations with a minimum of disturbance to the natural soil cover. This may restrict the operation of trucks, tractors, and heavy drilling equipment.

Availability of water. At some outlying sites, water is not available because of lack of a nearby natural supply or because the water is frozen during the winter.

In the exploration work described herein, the choice of equipment was based primarily upon the type, size, frequency and depth of the samples or information required and then upon the other limiting factors mentioned above.

CHURN DRILLS

Two types of churn drills, the Fairbanks and the Cyclone, have been used by AFS personnel. As the operation and performance of both types were similar, only the Cyclone will be discussed in this report.

Description

The Cyclone churn drill (Fig. 4, 5) is the most versatile and useful item of drilling equipment used at AFS because of its mobility and the fact that drilling fluids are not normally required to perform ordinary soil sampling and probing.

Specifications for the Cyclone churn drill are as follows:

Weight	6500 lb (approx.)
Width	5 ft 10 in.
Length (not including tower lowered)	8 ft 10 in.
Length (with tower lowered)	31 ft 0 in.
Height from base of frame (with tower lowered)	5 ft 8 in.
Height from lowest to highest point (with tower lowered)	6 ft 11 in.
Height from ground to center of crown sheave (with tower raised)	33 ft 6 in.

The drill is essentially a spudding device mounted on a structural steel frame and powered by a 24-hp, 4-cylinder gasoline engine. The spudding arm or walking beam (Fig. 6) is connected to a string of drill tools by a cable that operates through a sheave at the top of the drill tower. The reciprocating action of the spudder arm alternately raises and lowers the cable and the tool string, causing the weight of the tools to drive the drill bit. The drilling tools have a heavy cutting bit suspended on the end of the cable (Fig. 7). A sectional steel shaft or sinker bar connected between the cable and the bit provides additional weight (Fig. 8). The flexible cable imparts both a chopping and reciprocal rotary action to the bit during drilling due to the lay of the cable.

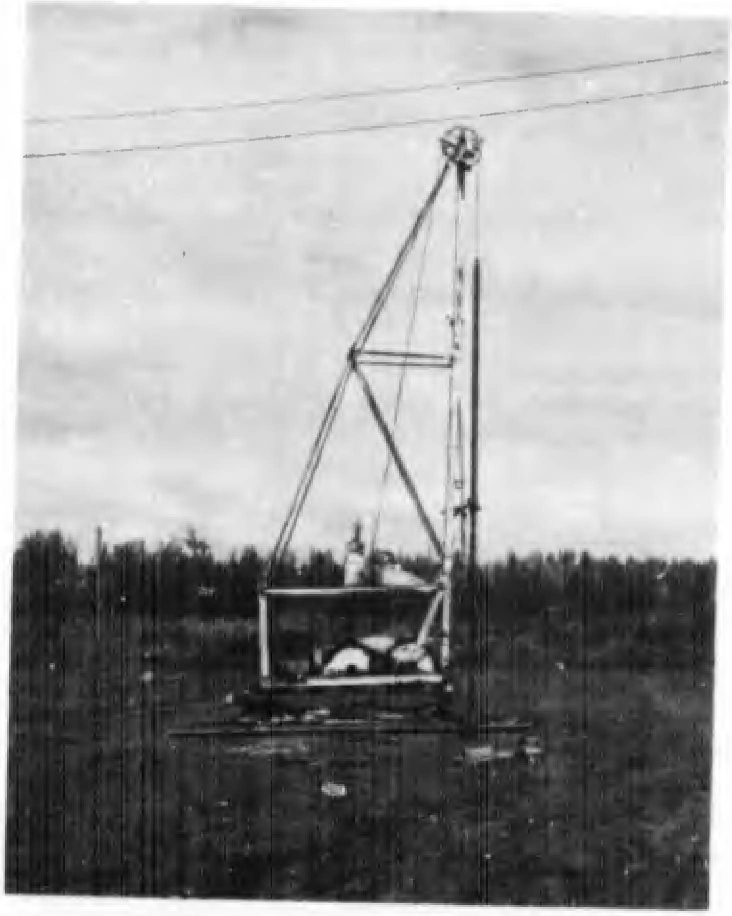


Figure 4. Skid mounted Cyclone drill in position for drive sampling.

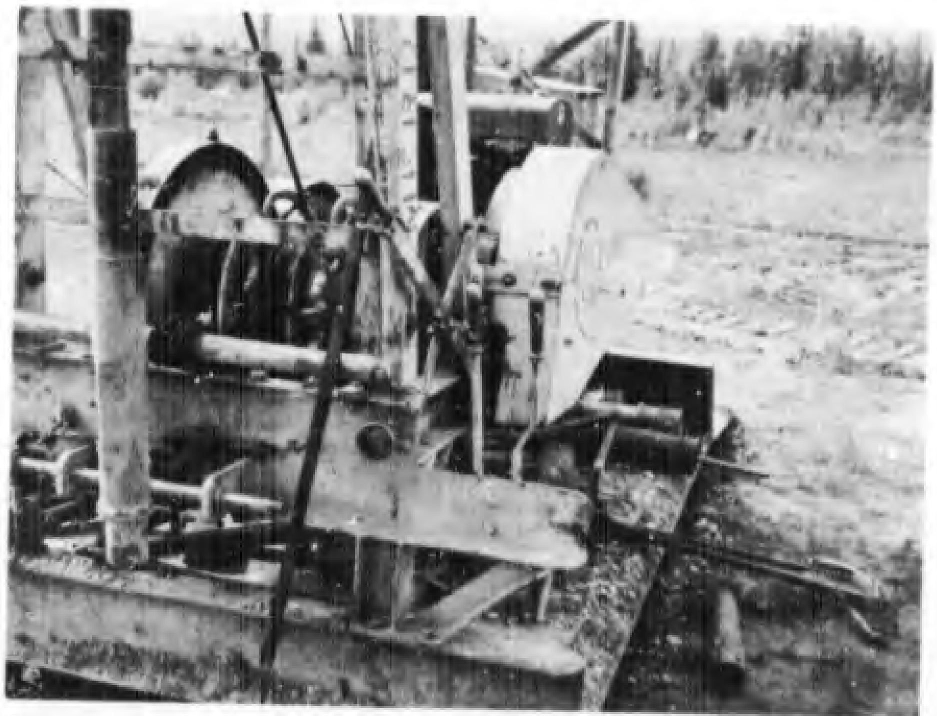


Figure 5. Controls for operating Cyclone churn drill.

Figure 6. Walking beam on Cyclone churn drill.

Figure 7. Five-in. chopping bit for Cyclone churn drill.

Figure 8. Sectional sinking bar (4 in. x 10 ft) complete with casing driving clamps.

Chopping bits up to 8 in. diam were used effectively without undue difficulty. Bits larger than 8 in. were used to drill holes whose depths do not exceed the length of the drill tools (approximately 18 ft). The deepest drilling performed at the AFS site by the Cyclone was to a depth of 137 ft with the driving of 6-in. casing to the bottom of the exploration.

The drill is relatively simple to operate and requires a crew of two, a driller and a helper.

The churn drill was originally wheel mounted with two pneumatic tire wheels on the front and two steel spoke wheels in the rear (Fig. 9). The wheel mounting was unsatisfactory for movement of the drill during the thawing season and was replaced with skids fabricated from 4 x 8-in. I-beam sections (Fig. 4, 7). These proved durable and stable. The skid-mounted drill was moved by a 3/4-ton or larger truck or by a tractor, depending on surface or snow conditions. The drill was readily adaptable to mounting on a $1\frac{1}{2}$-ton or larger truck. When the drill was truck-mounted, drilling operations were carried on from the truck bed (Fig. 10). The drill tower was readily lowered for transporting by means of a power-driven cable device on the drilling machine (Fig. 11, 12).

Operation and use

The churn drill was used extensively at the AFS site for various types of drilling such as:

a. Soil explorations to obtain relatively undisturbed drive samples for laboratory analysis.

b. Frost probings to determine the surfaces of both annual frost and permafrost.

c. Water-well drilling to provide a water supply for domestic,

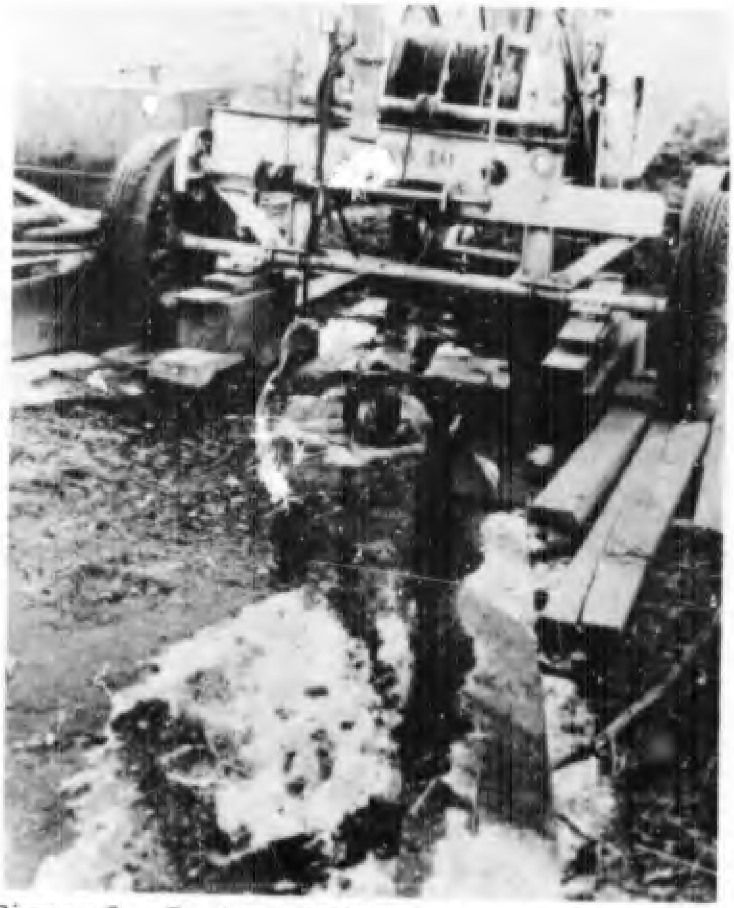


Figure 9. Cyclone drill mounted on pneumatic tires and steel spoke wheels.

Figure 10. Cyclone drill in use while mounted on $2\frac{1}{2}$-ton truck.

Figure 11. Lowering tower of Cyclone drill for movement.

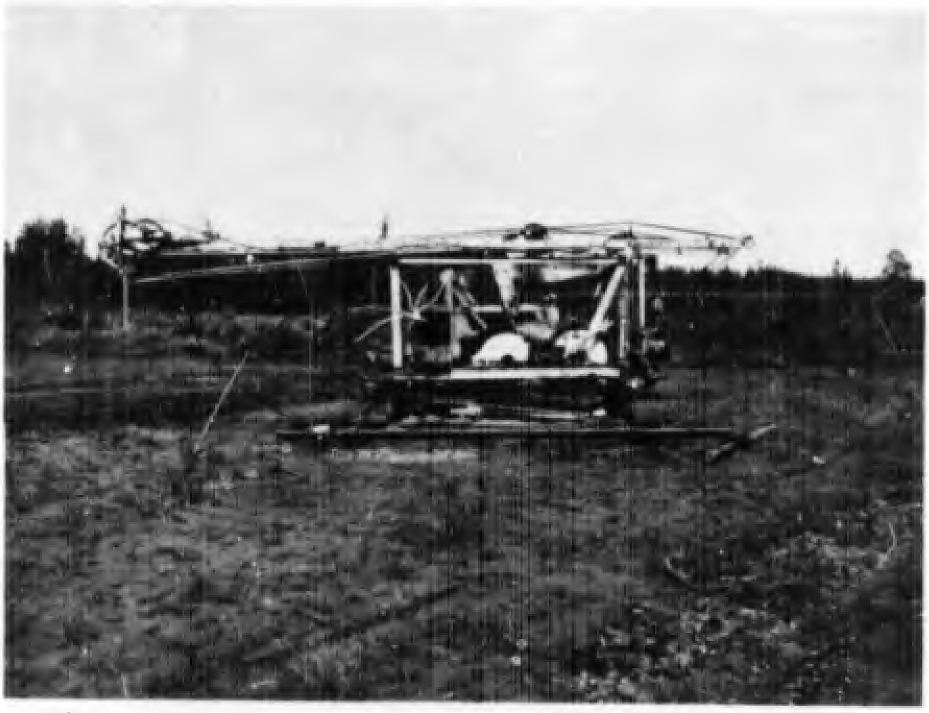


Figure 12. Cyclone churn drill ready for movement.

industrial and fire protection needs.

d. Drilling holes for installation of well points and electrical temperature-measuring equipment.

The Cyclone is adaptable to driving pipe piling and casing into frozen silty soils (29 -31.5F) for both soil sampling and pile foundations, by attaching drive clamps to the drill tools (Fig. 13). This arrangement provides a weight of 600 lb with a drop of from 24 to 30 in. (Fig. 14). Pipe or casing was removed by attaching a pulling stem hammer and socket (Fig. 15) to the threaded connection of the drill stem and raising the casing by the jarring action of the hammer beneath the head. When the Cyclone was used for installation of piles for either building foundations or supports for instrumentation, standard 4-in. pipes were driven 10 to 20 ft into the permafrost (Fig. 16).

The Cyclone churn drill has been extensively and effectively used for sampling both frozen and thawed soils by drive methods. For collecting samples by driving, it has been used to a depth of 30 ft only but is capable of sampling to a depth of 40 ft with 4-in. pipe and to 25 ft with 6-in. pipe.

For drive sampling, the drill bit was removed and a set of jars attached in the string of drill tools (Fig. 17). A suitable sampling device was attached at the lower end of the tools. Driving impact was imparted to the samples by the up-and-down intersliding of the two parts comprising the drill jars included in the string of tools. The total weight could be adjusted by adding or removing sections from the tool string, which is the actual drop weight. In essentially all cases a tool weight of 750 lb was used. The height of drop could be varied as required by controlling the vertical displacement of the drilling jars. The maximum drop of 24 in. was normally used when drive sampling in frozen soils. A vertical drop of less than 24 in. was occasionally used in thawed silty soils. The height of drop was actually the vertical displacement of the upper sliding part of the drilling jars.

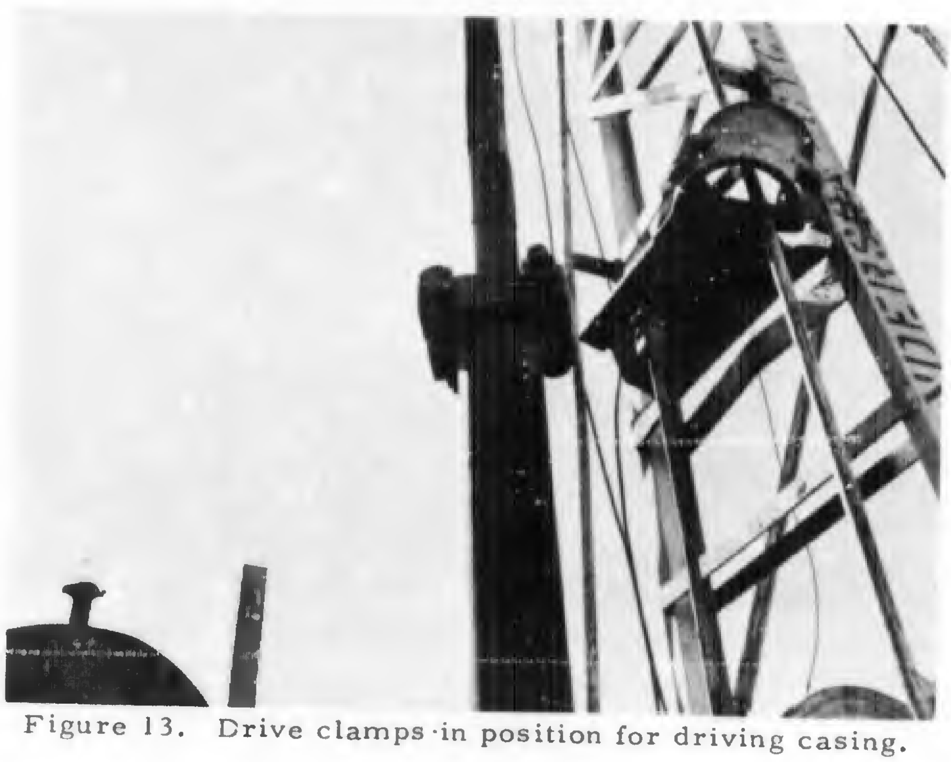


Figure 13. Drive clamps in position for driving casing.

Figure 14. Pile driving with Cyclone churn drill.

Figure 15. Pulling stem hammer and socket for casing removal.

Figure 16. Steel pipes used as foundation piles.

Figure 17. Drive sampling by use of jars.

Performance rates

The Cyclone churn drill proved very satisfactory for both drilling and driving casing. Table I gives drilling rates based on past performance at the AFS site. The rates do not include time for movement or set-up of the drill.

Experience in drilling showed that a stroke length of 24 in. at a rate of 25 to 30 blows per minute is most satisfactory. In all cases the hole was drilled ahead of the casing. It was usually difficult to pull the casing after it had been frozen in place. Use of a larger bit, larger casing or a depth in excess of 25 ft would reduce the indicated rates.

Table I. Drilling rates for Cyclone churn drill, using a 5-in. drill bit, 5-in. diam casing and a maximum hole depth of 25 ft.

Procedure	Material and condition	Rate, ft/hr
Straight churn drilling including setting and driving casing	Thawed silt	25
	Frozen silt	15
	Thawed gravel	5-10
	Frozen gravel	0.5-2
Continuous drive sampling including setting and driving casing	Thawed or frozen silt	5
Drive sampling including setting and driving casing	Thawed gravel	5-10
	Frozen gravel	Not effective Bailer samples only

Limitations

The Cyclone churn drill has some definite limitations for soils explorations at remote sites.

a. Its size and weight restrict its use to locations accessible to heavy wheeled vehicles.

b. It is not very suitable for air transport. Disassembly and reassembly of the drill for air transport is not feasible due to the weight and necessary manual handling of the components. An aircraft with the capacity of a C-119 is required for transportation without excessive disassembly.

c. Movement of the heavy equipment sometimes caused considerable disturbance to the surface cover and vegetation in areas where it was desirable to maintain the original vegetative cover in order to prevent degradation of the underlying permafrost.

CORE DRILLS

General

Four types of core drills have been used by AFS at various places:

Longyear Straightline Diamond Core Drill - Model UG8

Acker Teredo Core Drill - Type TH

Chicago Pneumatic Core Drill - Model 8

Concore Exploration Drill - Type E5-48

Figure 18. Longyear core drill on timber platform.

As the four drills vary in size, weight and use, they will be discussed separately.

Longyear core drill

The Longyear drill (Fig. 18) with a 2 5/8-in. chuck was used for several years as the main item of equipment for obtaining core samples. It was then replaced by smaller and lighter equipment. The Longyear proved satisfactory in recovering frozen soils in both the permafrost and seasonally frozen ground.

U.S. Army Engineer District, St. Paul (1950) has described procedures and methods for obtaining core samples.

Dimensions of the Longyear core drill before mounting on a field-fabricated timber platform and skid assembly are as follows:

Length	7 ft 4 in.
Width	3 ft 10 in.
Height	5 ft 0 in.

Weights of the component parts are:

Engine	675 lb
Surface frame assembly	390
Power takeoff	225
UG straightline drill assembly	500
Double hydraulic swivelhead	700
Total weight of basic machine	2490 lb

Figure 19. Longyear drill with timber housing.

A field-fabricated timber platform mounted on skids with a plywood and canvas weather housing around the drill was added to the basic assembly (Fig. 19). The timber platform was 17 ft long and 11 ft wide. Without the skid assembly the timber weighed 5300 lb. The mast was field-constructed from 2-in. standard steel pipe and angle iron and weighed approximately 500 lb including the sheave. The height of the drill assembly mounted on the timber platform was 24 ft from the ground surface to the crown sheave and total weight was approximately 8300 lb.

Two core barrels were generally used with the Longyear, a 7 in. OD x 6 in. ID single tube, 3 ft long, and a 7 in. OD x 6 in. ID double tube, 5 ft long (Fig. 20). Both were used with N-type drill rods. The hole was normally started with the single tube barrel and drilled to a depth of 5 or 6 ft; then the double tube barrel was used. The 7 in. OD barrels were satisfactory for obtaining cores of frozen silt. The original design used small slotted springs along the sides of the barrel to retain the core (Fig. 21). These proved unsatisfactory and were replaced with a leaf-spring core catcher (Fig. 22). Core drilling with the Longyear was relatively slow as the double-tube barrel weighs approximately 350 lb and had to be disassembled and reassembled each time a core was removed (Fig. 23). Core barrels smaller than 6 in. ID were not used with the Longyear as the Permafrost Division required a 6-in. core for testing. Operation of the drill required a driller and two helpers.

Figure 20. Core barrel used with Longyear drill.

Figure 21. Core barrel with slotted spring core catcher.

Figure 22. Core barrel with leaf spring core catcher.

Figure 23. Disassembling core barrel to remove sample.

In addition to taking core samples the Longyear was extensively used for drilling 12 in. diam holes in the permafrost for installation of test piles. A special boring barrel was field-fabricated from 12 in. ID standard steel pipe, 3 ft long and adapted to N-type drill rod. The barrel was made with "face hardened" cutting teeth. The original design was inadequate for advancing the hole because a core of frozen soil was left intact within the barrel. The frozen core could not be lifted with the barrel nor readily destroyed by water circulation. In the second design, cutting knives made from bulldozer blade metal were welded to the interior of the barrel to "break up" the frozen soil and permit easy removal of the cuttings by washing (Fig. 24). Some sloughing of the sides of the hole occured due to thawing of the soil and washing with water. The water was delivered at a rate of 75-80 gpm and had a temperature at the drill of approximately 40 F.

When cores were required the hole was drilled to the final depth with the 7 in. OD double tube core barrel and then reamed with the 12-in. barrel to permit installation of the piles. The 12-in. barrel was used with the Longyear drill to bore approximately 50 holes in the permafrost varying from 13 to 23 ft. It was necessary to give the cutting teeth and cutting knives a "hard facing" treatment after approximately every 100 ft of boring. This procedure was quite effective for boring large holes into frozen silt.

A Fairbanks-Morse piston type pump, 3 x 4 in. with twin disc clutch, powered by Waukesha engine $2\frac{1}{2} \times \frac{3}{8}$ was used with the Longyear. The pump operated at 500-600 psi and was capable of delivering 75-80 gpm to the drilling system.

Figure 24. Field fabricated 12-in. boring barrel.

Use of the Longyear was limited by the heavy weight and size of the entire assembly. A heavy tractor was required for movement and its use was restricted to areas where disturbance of surface vegetation could be tolerated. The access of the machine to drilling sites was greatly improved during the winter months. The Longyear was only used at the AFS site and even there its use was limited by its excessive weight. Its effectiveness could be increased by removing the skid-mounted timber platform. The drill itself was mounted on steel skids which were part of the frame assembly. This would enable the drill to be used in other locations with less chance of damage to the surface cover. The drill without the timber platform is readily adaptable for mounting on a $2\frac{1}{2}$ - ton, 6 x 6 or larger truck but was never used in this manner. The drill was equipped with a hoisting drum which permitted movement of the drill by winching action under its own power.

The drill could not be used at outlying sites which were accessible to small aircraft only. The component parts are too heavy for normal handling, and disassembly and reassembly of the drill would require lifting equipment.

Good sample recovery was obtained in frozen silts using saw-toothed bits with the 7 in. OD double tube core barrels operating 90-100 RPM. Penetration rate in frozen silt was approximately 6 in. per minute.

One of the many factors involved in obtaining good cores is the control of the wash water for both temperature and quantity. A set of gate valves on the floor of the drill platform as well as a union between the water swivel head and the gate valves provides adequate control of the water supply. Alcohol is used to keep hoses, valves and connections open in sub-zero weather. The most practicable method is to employ a barrel of undiluted, denatured alcohol so located that both pump suction and by-pass discharge can be reached. The circulation system is shown in Figure 25. Immediately after a drill run has been completed the by-pass valve (No. 1) is turned wide open, the circulating valve (No. 2) controlling flow of water to the water swivel head (No. 3) is closed and the union (No. 4) is disconnected to drain the hose to the water swivel head. Wash water is now by-passed to the wash water tank (No. 5). The suction hose (No. 6) to pump is taken from the wash water tank and placed in the alcohol barrel (No. 7). The alcohol flows through the pump (No. 8) and discharge hose (No. 9), through the by-pass valve (No. 1) and to the wash water tank. When the alcohol forces all of the water out of the hoses and pump, the discharge hose is taken from the wash water tank and placed in the alcohol barrel. The alcohol is kept circulating through pump and hoses until drilling is to be resumed. The union (between water swivel head hose and control valves) is then connected; the suction hose is put back into the wash water tank and when water shows up in the discharge hose, it is removed from the alcohol barrel and put back into the wash water tank; the circulating valve (No. 2) is opened and the by-pass valve (No. 1) is partially closed until water runs freely through the swivel head, drill rod and barrel, fills the hole, and runs out the overflow pipe (No. 10). The by-pass valve may be opened or closed to control the amount of water required to wash the cuttings from the core barrel teeth up into the wash water tank. A Herman Nelson heater tube may be used to keep valves and union from icing up.

Several methods of keeping hoses and drill rods from freezing were tried, but none proved as satisfactory as the use of straight alcohol. Alcohol mixed with the wash water required the use of too much alcohol and freezing at the smaller connections could not be prevented. Frequently, all of the alcohol was lost when circulation was lost. Stoddard solvent was substituted for wash water, but was not satisfactory because of improper circulation through the pump and core barrels. This difficulty was probably due to the

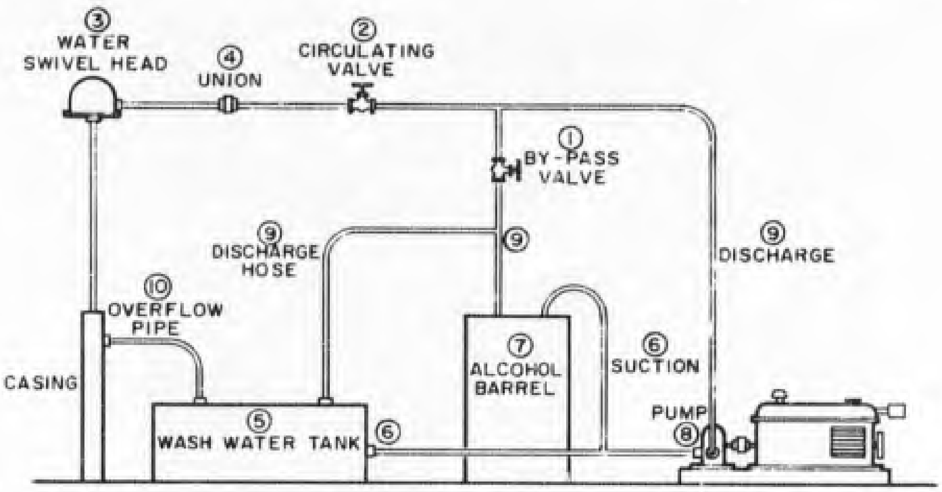


Figure 25. Core drill circulation system.

specific gravity of the solvent which was such that the pump could not build up enough pressure to wash the cuttings away from the barrel shoe.

During periods of warm weather water was used as a drilling fluid and was sometimes cooled by addition of ice. The cold water was necessary to restrict thawing of the soil core in the barrel prior to its removal from the hole.

Acker Teredo core drill

The Acker core drill, $1\frac{3}{4}$ -in. chuck (Fig. 26) has been used at the AFS site since 1953. The drill, complete with all equipment, was acquired from a research group from Boston University who had used it for core sampling frozen soils at Umiat, Alaska. They reported excellent recovery in frozen fine-grained soils but poor results in drilling and sampling frozen gravels.

The drill is equipped with a hydraulic feed which provides a length of feed of 36 in. It is powered by a 2-cylinder, 16-hp Wisconsin gasoline engine. Overall weight of the assembly is 1340 lb. The drill can be disassembled so that no part weighs more than 250 lb.

Starting in 1953, the Acker drill has been used for frost probing and drive sampling explorations. Only two explorations have been made using rotary core drilling methods. These two were for the purpose of installing thermocouples beneath the foundations prior to construction of a building at the AFS site. The holes were drilled through $2\frac{1}{2}$ ft of compacted gravel base, 2 ft of thawed silt soil and 23 ft of permafrost. A short length of $4\frac{1}{2}$ in. OD pipe casing was used through the gravel and thawed silt soil. The casing was advanced through the gravel by drilling with a 5-in. fish-tail bit and driving the casing with a 350-lb hammer from a tripod arrangement and the Acker drill (Fig. 27). A double tube core barrel, size NX, "L" series, 2 29/32 in. OD, $1\frac{3}{4}$ in. ID, 5 ft long with basket-type core catcher and a hard surfaced saw tooth bit was used for coring the permafrost. Drill runs were limited to 3 ft in order to recover frozen cores as rapidly as possible and to prevent excessive thawing. No cores were recovered from the thawed zone because of the high moisture content but recovery from the permafrost was better than 90%.

Figure 26. Acker core drill mounted on 3/4-ton truck.

The Acker drill has proved extremely suitable for deep probings through thawed silt soils or gravel. A fish-tail bit was advanced by use of the hydraulic drill head and contact with the frozen soil was readily perceptible to the driller by a sudden decrease in the rate of penetration while rotating. Probes were also made through building foundations by using rotary action and a fish-tail bit through the gravel pad, then advancing the bit by use of the hydraulic drill head (Fig. 28).

The Acker drill was also widely used for drive sampling by using a tripod and the cathead to drive a 350-lb hammer with an 18-in. drop (Fig. 29). Good results were obtained using this equipment to drive a 3-in. solid tube sampler into both permafrost (29 - 31.5F) and seasonally frozen silty soil (20 - 27F). The rate of penetration was slower through the colder seasonally frozen soil. While the Acker has not been used for drive sampling at locations where permafrost was colder than that at Fairbanks (29 - 31.5) it is believed that drive sampling could be accomplished but at a slower rate.

The Boston University project reported that the drill was not effective in obtaining cores of frozen gravel in the Umiat area. The attempts were made without the use of casing and with only a 100-lb hammer for drive sampling. It is believed that the Acker would be suitable for coring fully saturated frozen gravel if casing and a diamond bit were used. In summer it may be necessary to use a cooled drilling fluid in such an operation to prevent the cores from thawing.

Figure 27. Acker core drill rigged for casing driving.

Figure 28. Probe test using Acker core drill.

Figure 29. Drive sampling with Acker core drill.

The Acker drill was moved to remote sites by use of small aircraft. Movement of the drill from the aircraft to the site was difficult because there were seldom any prime movers in the area and the drill does not have a power hoist which would enable it to move under its own power. The drill can be disassembled so that the weight of the heaviest component is about 250 lb (except when a 350-lb hammer is added for drive sampling). The drill has been used at the AFS site, both skid- and truck-mounted (Fig. 29). The Boston University project had mounted the d.-ill on a tracked vehicle (Weasel).

Chicago Pneumatic core drill

A Chicago Pneumatic core drill, Model 8, has been used quite extensively for soils exploration at remote Alaskan Weather Bureau sites. Explorations have been made at about 12 Weather Bureau stations throughout Alaska. All were carried to about 20-ft depth in frozen silty soils. Temperatures of the frozen soil ranged from about 26F to 31.5F. One of the explorations was core drilled (Fig. 30) and the remainder used drive sampling with a 200-lb drive hammer (Fig. 31). Sample recovery was very good to excellent.

The Chicago Pneumatic core drill is quite similar to the Acker core drill in weight, size and operation. It has an overall weight of 1530 lb and overall dimensions of 83 in. long, 36 in. wide and 52 in. high. It can be disassembled into smaller components for transportation on smaller aircraft. The drill is gasoline engine driven and equipped with an 18 in. capacity screw feed swivel head. The only disadvantage of the screw type swivel head is that, unlike the hydraulic type head, it is not adaptable to pressing Chicago Pneumatic thin wall samplers through thawed soil. Hydraulic type heads are, however, available for the machine. The Chicago Pneumatic drill is equipped with both a cathead and a power hoist winch, which makes it possible to move the rig under its own power. Lack of a hoist winch on the Acker core drill is a disadvantage.

Sampling devices used with the Chicago Pneumatic drill were the same as those used with the Acker core drill and the Concore exploration drill. The devices consisted of Acker split tube and solid tube samplers, $2\frac{1}{2}$ in. OD, single and double tube core barrels, 2 in. OD and Chicago Pneumatic thin wall samplers, 2 in. and $2\frac{1}{2}$ in. OD. The drive sampling arrangement was the same as used with the Acker drill (Fig. 31). The Chicago Pneumatic drill is skid mounted but readily adaptable for mounting on trucks or other mobile equipment.

Concore exploration drill

The Concore drill (type E5-48, special portable exploration drill) was purchased primarily as a lightweight drilling machine for soils exploration sites accessible only by small "bush" type aircraft.

The drill consists of a column base frame assembly, column assembly with down ties, pumping unit and drill head (Fig. 32). The drill head has a manually operated swivel head on a rack attached to the column. The head is powered by a single cylinder, 4-cycle, 8-hp gasoline engine. The 12-gpm pumping unit is powered by a single cylinder, 4-cycle, 4-hp gasoline engine. The drill chuck, size $1\frac{1}{2}$ in., uses an E-type drill rod. When the unit was delivered it was not equipped with a clutch or a drill head chuck and the drill was modified in the field to include these features. Operation of the drill without a clutch was difficult as the engine had to be stopped to add or remove drill rods and the extra weight of the drill rods made the engine difficult to start. The drill rods had to be turned manually with pipe wrenches while the engine was being started. The clutch allows drill rods to be added without stopping the engine, which reduces the drilling time considerably.

Figure 30. Core drilling with Chicago Pneumatic core drill.

Figure 31. Drive sampling with Chicago Pneumatic core drill.

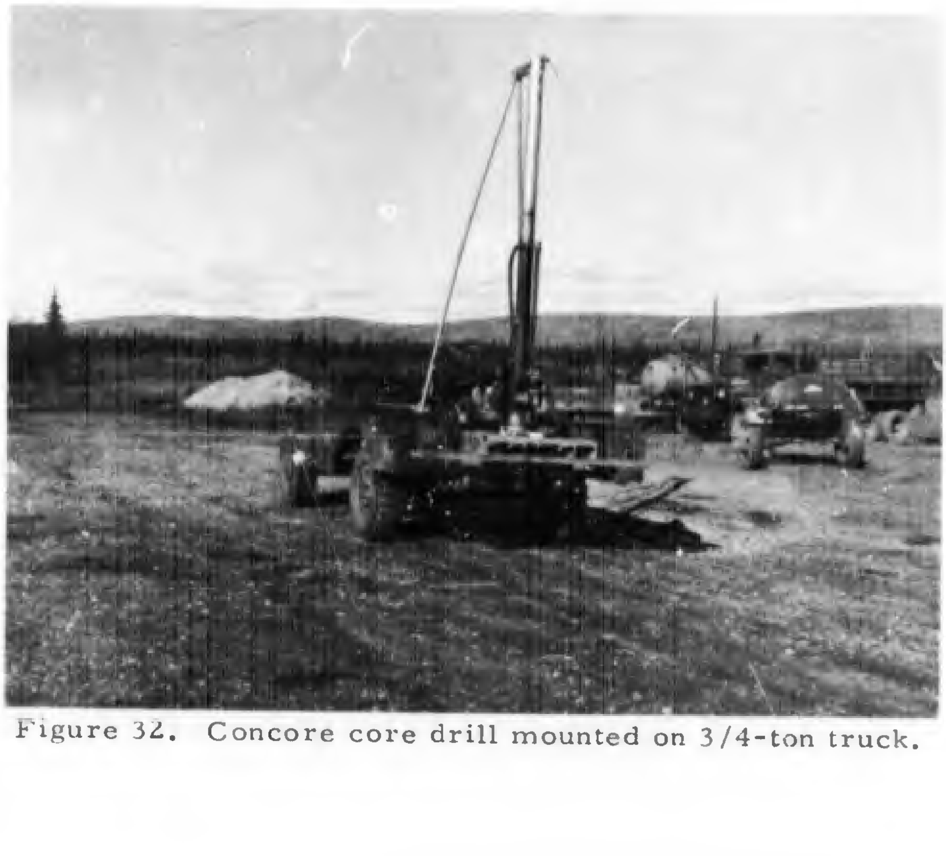


Figure 32. Concore core drill mounted on 3/4-ton truck.

The Concore drill is well adapted for disassembly and shipment. It is constructed almost entirely of cast aluminum and the total weight of the assembly complete with tools is about 650 lb; overall height is 10 ft 6 in. The drill can be readily disassembled so that the heaviest component is 127 lb and the largest 66 in. x 5 in.

The Concore drill has been used at the AFS site and at various places in Alaska and Canada, some of which were accessible only by "bush" type aircraft. With the exception of one site all drilling was done without the use of casing. In one case water had to be hauled several miles in 55-gallon drums; at other sites water was pumped directly from the ocean, a stream, or a lake. All the explorations were in permafrost areas and averaged 20 ft in depth. Using a double tube core barrel, Size NX, "L" Series, 2 29/32 in. OD, 5 ft long with basket-type core catcher, core recovery was very good at all sites. The cores had a tendency to melt slightly due to the time required to remove the drill rod and raise the core barrel following a run.

At one site three holes approximately 35 ft deep were drilled for installing thermocouples beneath a power plant foundation. The holes were drilled after the plant had been constructed and two of the holes had to be drilled from within the building. The small size of the Concore made it ideal for this situation. The third hole was adjacent to the structure on the outside.

Drilling of the two interior holes was difficult. It was expected that about 20 ft of gravel foundation would have to be penetrated in the two holes. It was decided to drive flush joint 3-in. casing behind the core barrel to penetrate the gravel fill. The casing was driven by attaching shear blocks to the building beams and manually raising and lowering the drive hammer. The permafrost table was expected to be about 15 ft below the floor surface. A 2-in. fish-tail bit was used in advance of the casing. It developed that the gravel fill (up to 3 in. maximum size) extended to a depth of at least 35 ft, which required manual driving of the casing for the full depth of the well. The frozen gravel thawed rapidly due to the use of the fish-tail bit in front of the casing but lost little water. Both of the interior wells were drilled and cased but only after considerable difficulty. No samples were recovered from the gravel.

The hole outside of the building was cored to a depth of 40 ft in frozen silty material with no difficulty, but core recovery was very poor due to melting caused by the friction of the core barrel and relatively warm temperature of the drilling water. A short section of casing (10 ft) was installed at the top of the hole by the use of a post hole digger.

The Concore has been very effective at the AFS site for drilling holes for various types of installation, probings and core drilling. A fish-tail bit and a reduced flow of drill water was used for probing. A fish-tail bit was also used to drill holes for installation of thermocouples, water wells, or other types of instrumentation. An Acker split tube sampler, $1\frac{1}{4}$ in. ID, 12 in. long with a saw-tooth bit, was used very effectively to depths of 10 - 15 ft for recovery of frozen silt soil samples at the AFS site (Fig. 33). The sampler was advanced without the use of drilling water. The procedure was used for approximately 50 linear feet and core recovery averaged 85%.

The Concore drill is a very useful item of equipment for AFS activities. Its greatest advantage is its small size and light weight. It can be easily transported by small aircraft and be carried manually to a site and reassembled with little disturbance of the soil cover. Reasonably good core recovery has been obtained by use of a double tube core barrel or other rotary samplers.

The greatest single limitation of the Concore drill is the lack of a power-driven cathead unit for driving and removing casing. Where casing had to be used it was driven manually, a difficult operation. Some explorations were unsuccessful because of the lack of a cathead. It is believed that some form of power hoisting unit could be adapted for use with this drill which would greatly improve its usefulness.

DRIVE SAMPLERS AND PROBING METHODS

Drive sampling methods for the recovery of soil samples in frozen soil have proven very effective in subsurface explorations at the AFS site and at other locations in Alaska, northern Canada, and Greenland. It was estimated that approximately 75% of the soils exploration work completed by AFS has been by drive sampling.

Both mechanical and manual methods have been used by AFS. The Cyclone churn drill and the Acker Teredo core drill have been used to drive sampler tubes.

Various types of drive samplers have been tested at the AFS site.

Acker solid tube sampler

An Acker solid tube sampler has been used with the Acker drill (Fig. 34) for about 50 drive sampling explorations at the AFS site. The explorations ranged in depth from 5 to 17 ft and included recovery of both frozen and thawed soil at each site.

The sampler is 2 ft long with a 3 in. ID and wall thickness of 3/16 in. The cutting shoe wall thickness tapers at the end from $\frac{1}{4}$ in. to 0 in $1\frac{1}{4}$ in. The inside diameter of the shoe is slightly smaller than the inside diameter of the sampler tube which serves as a sample retainer.

The sampler has proved satisfactory in sampling the frozen silt soil in both permafrost and seasonally frozen state. During a program of ground water well exploration it was used to sample about 1000 ft of frozen soil. It has been used with both the Acker core drill and the Cyclone churn drill with the majority of the work being done with the Acker. Core recovery was approximately 90% in the frozen soil.

The seasonal frost layer at the AFS site is generally harder, more brittle and more difficult to penetrate than the underlying marginal permafrost. In sampling the seasonally frozen ground, the Acker solid tube sampler was less prone to fracture the sample than the 3 in.ID pipe sampler developed at AFS. This is partly due to the tapered cutting edge on the shoe.

The Acker solid tube sampler was readily driven in the marginal permafrost (29 - 31.5F) at the AFS site with a 750-lb hammer and an 18 - 24-in. drop. The sampler could also be driven into the seasonal frost layer (20 - 27F) with a 350-lb hammer and an 18-in. drop but at a reduced rate of penetration. The sampler easily penetrated the seasonally frozen ground using the 750-lb hammer with 18 - 24-in. drop and the Cyclone churn drill but failed structurally after about 100 ft of drive sampling. Both the tube and the cutting shoe buckled and broke (Fig. 35). It is possible that the sampler had been weakened by considerable prior driving. A replacement of the sampler shoe might have prevented the failure but only one shoe was available.

Figure 33. Frozen silt sample obtained by Concore core drill.

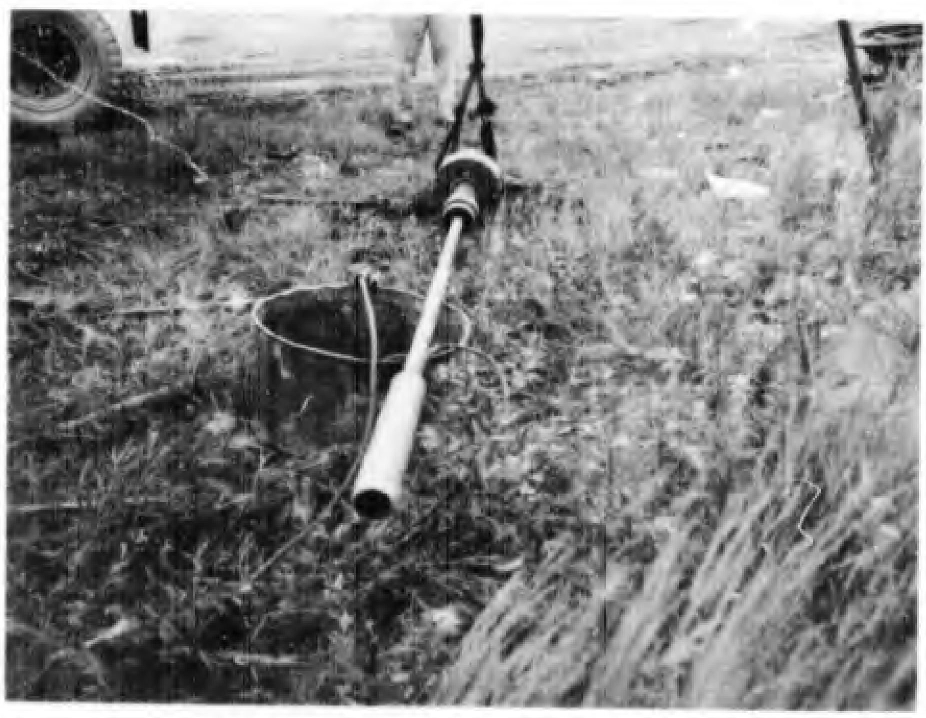


Figure 34. Acker solid tube sampler rigged for driving.

Figure 35. Acker solid tube sampler after failure.

Prior to the failure of the tube it was satisfactory for sampling frozen silt but was not suitable for unfrozen soil. The small difference between the diameter of the cutting shoe and the tube is not sufficient for retaining thawed soil in the tube. This could probably be rectified by providing a leaf spring type core catcher in the tube for use with thawed soils.

The sampler requires more time to sample a given depth than the pipe sampler described below as the head has to be completely disassembled in order to remove each sample from the tube. It is also more susceptible to damage as the assembly includes four sets of threaded connections.

Acker split tube sampler

The Acker split tube sampler is part of the Acker soil sampling kit (Fig. 36). It has a $1\frac{1}{2}$ in. ID and 2 in. OD and is 12 in. long. The sampler has a wall thickness of 0.25 in. and the sampler shoe 0.35 in. The cutting shoe tapers from 0.35 in. wall thickness to 0 in 3/4 in. The difference in diameters of the cutting shoe and the sampler tube was designed to retain a sample. The tube is provided with an adapter for connection to E-type rods and has been effectively used with a 350-lb drive hammer and an 18-in. drop.

Efforts to drive the sampler into the seasonally frozen soil (20 - 27F) using a 16-lb sledge hammer were unsuccessful due to the wall thickness and the relatively blunt taper of the cutting shoe. Excessive manual effort was required to drive the sampler to a depth of 12 in. in frozen silt and the soil recovered was insufficient for testing purposes.

The effectiveness of the sampler might be improved by increasing the length of the taper.

Figure 36. Acker split tube sampler, $1\frac{1}{2}$ in. ID and 2 in. OD, and driving equipment.

Steel pipe sampler, 3 in. ID

An efficient type of drive sampler for the recovery of soil samples was developed at AFS for use with the Cyclone churn drill. The sampler is a 2-ft length of 3 in. ID standard steel pipe with a wall thickness of 1/8 in. (Fig. 37, 38). Leaf spring core catchers were riveted to the inside of the pipe to serve as a sample retainer. A 1/16-in. welded bead was placed around the inside of the pipe about $\frac{1}{4}$ in. above the cutting edge to protect the rivets holding the leaf springs. The pipe sampler was adapted to the drill tool stem by a $\frac{3}{4}$-in. case-hardened machine bolt (Fig. 39).

The procedure followed during all drive sampling operations was to drive the sampler with a 750-lb hammer, 18 - 24-in. drop, and recover the soil at 1-ft intervals to insure better sample recovery. This sampler was effective in recovering both frozen and unfrozen silt soil samples which could be used for moisture content and other standard soil classification tests except for density determinations. Disturbance of the soil structure, especially in a thawed condition, was too great to allow reliable density values. It is estimated that approximately 100% recovery was obtained from frozen (29 - 31F) silt (Fig. 40) and 70 to 80% from unfrozen silt (Fig. 41). The largest part of the loss of the unfrozen silt took place in the zone immediately above the permafrost. In this zone the moisture content is high and the soil is too weak to be held by leaf spring type core retainers. This sampler was also used effectively to recover representative samples of thawed gravel up to $\frac{3}{4}$ in. maximum size by driving and recovering the sample at 1-ft intervals.

The sampler was still in good condition after several hundred feet of driving in frozen silt soil. The only noted construction deficiency was that driving caused distortion of the holes drilled at the top of the sampler for attachment to the drill stem. This could probably be eliminated by a reinforcing band at the top.

Figure 37. Field fabricated steel pipe sampler.

Figure 38. Side view of steel pipe sampler.

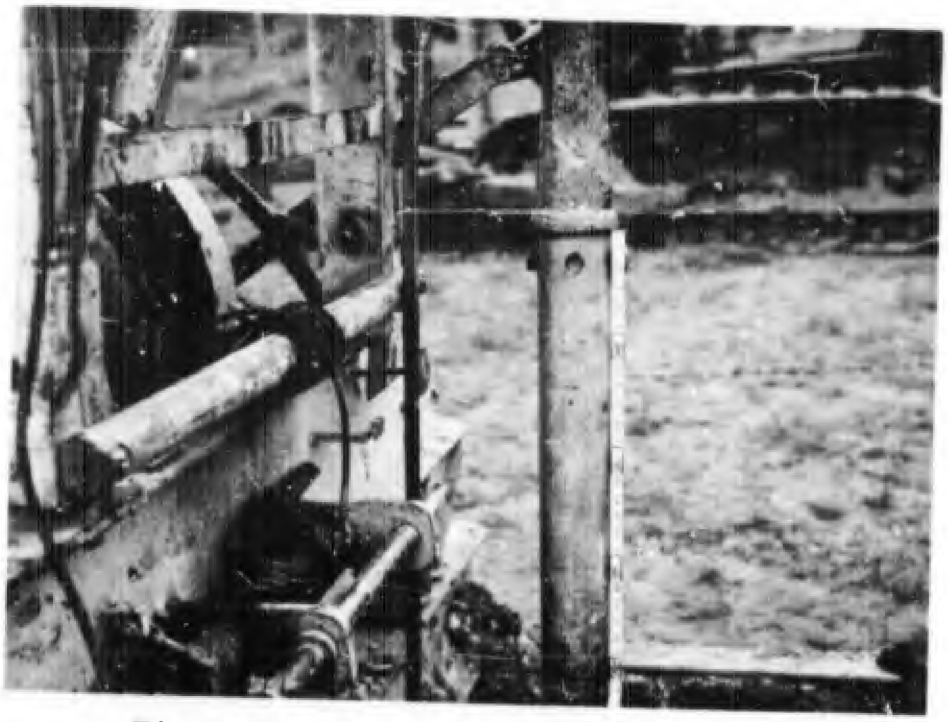


Figure 39. Sampler attached to drill rod.

Figure 40. Frozen silt core recovered with steel pipe sampler.

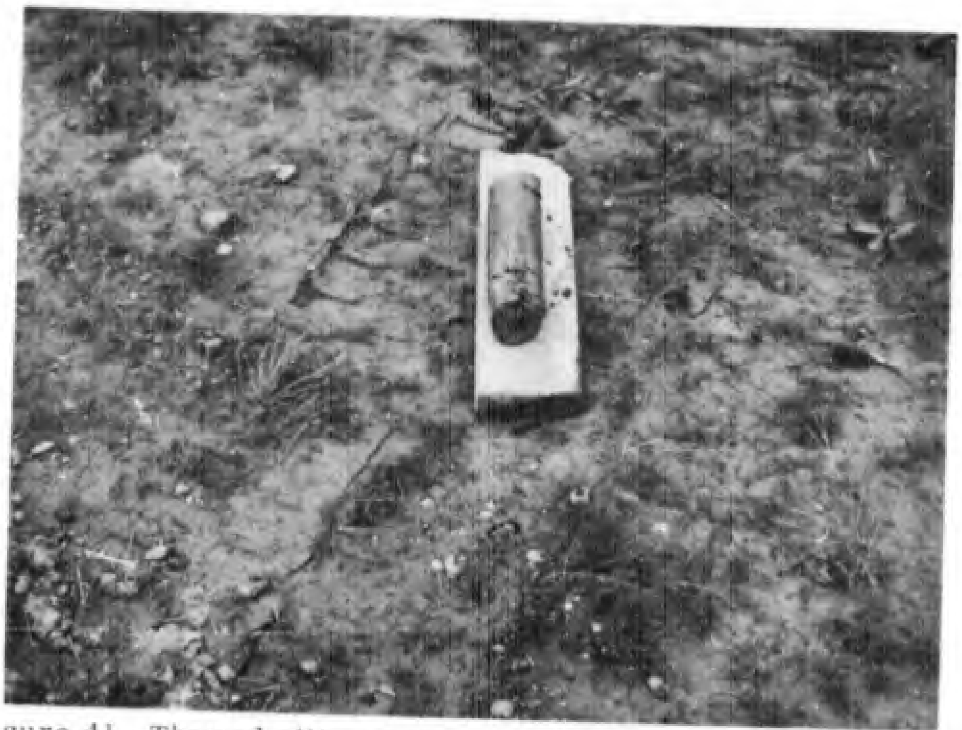


Figure 41. Thawed silt core recovered with steel pipe sampler.

Figure 42. Modified steel pipe sampler.

Various changes in the construction of the sampler were tested such as a sharpened or tapered cutting edge and variously sized welded beads for sample retainers. The tapered cutting edge flattened under limited driving in the frozen soil (Fig. 42). A welded bead larger than 1/16 in. caused fracturing of the sample in planes normal to the axis of the sampler. The welded bead was not effective as a sample retainer and the percent of recovery in thawed soil was low.

Sprague and Henwood solid tube sampler $2\frac{1}{2}$ in. ID, and split tube sampler $2\frac{1}{2}$ in. ID

The Sprague and Henwood samplers have been used very little by personnel at AFS.

Both samplers are essentially the same except that one has a split tube (Fig. 43) and the other a solid tube (Fig. 44) fitted with a flap valve sample retainer (Fig. 45). Each tube has a $2\frac{1}{2}$ in. ID and a wall thickness of $\frac{1}{4}$ in. The cutting shoe tapers from $\frac{1}{3}$ in. wall thickness to 0 in $\frac{3}{4}$ in. An auxiliary shoe with a basket type core catcher will fit either tube (Fig. 43).

The solid tube sampler was adapted to fit the Acker core drill and efforts were made to drive the sampler in seasonally frozen ground (20 - 27F) using a 350-lb hammer and an 18-in. drop. Repeated driving only caused the hammer to bounce with no penetration. Attempts to use the sampler were discontunued after the cutting edge of the sampler began to show damage (Fig. 46). The wall thickness of the sampler shoe is too great and the length of the taper of the cutting edge inadequate for use in seasonally frozen ground. Use of the sampler would have required frequent changes of the sampler shoe. The sampler was not tested in the permafrost but its effectiveness in recovering samples is questionable.

It is believed that the sampler could be improved by removing the taper, leaving a square cutting edge. The Cyclone drill with a 750-lb hammer could probably drive it into the seasonally frozen ground but damage to the sampler would be excessive.

Thin wall electrical conduit sampler, $1\frac{3}{4}$ in. OD

This sampler was field-fabricated from a 20-in. length of thin walled electrical conduit having an ID of 1.610 in. and a wall thickness of 0.065 in. A pipe coupling was welded to the end and adapted to $1\frac{1}{2}$ in. standard pipe (Fig. 47). A pipe plug on the end of the pipe served as a head for driving. The conduit was provided with a cutting head by a 1/8-in. ground taper. Driving was accomplished with a 10-lb sledge hammer (Fig. 48).

The sampler was used to a depth of 10 feet and samples were recovered from both the thawed soil and the permafrost. During the winter the explorations were started by drilling through the seasonal frost (approximately 3 ft, temperature 25 - 29F) layer with a 2 in. diam. ship's auger (Fig. 49) in winter or early spring. It was almost impossible to sample the seasonal frost material at the AFS site by manual driving of sampler tubes. When the air temperature was -10 F or lower it was necessary to remove the soil from the sampler quickly to prevent the sample from freezing to the tube. The tube was coated with glycerin to prevent this, but the treatment was effective for only a few minutes. During the summer the sampler was advanced through the thawed upper soil layer and into the permafrost (temperature 29 - 31.5F) to the desired depth. In both cases the penetration was limited to runs of 1 ft and the tube was withdrawn by the use of pipe-wrenches. Below a depth of 7 ft two men were required to withdraw the sampler. Samples were removed from the tube using a steel rod and a washer as a ram.

Figure 43. Assembled and disassembled Sprague and Henwood split tube sampler with basket type core catcher.

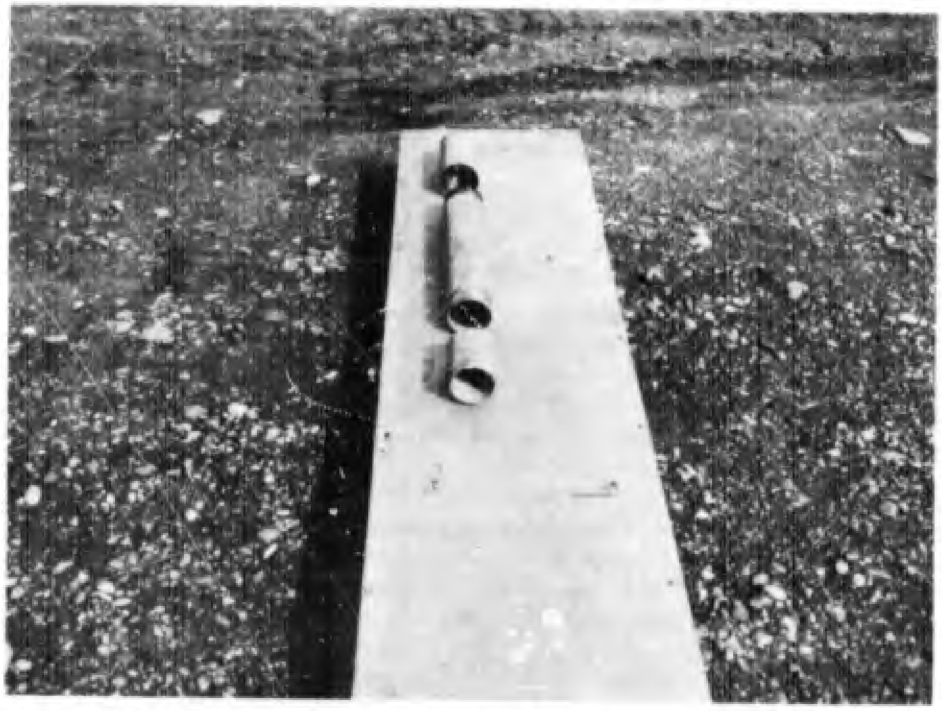


Figure 44. Disassembled Sprague and Henwood solid tube sampler.

Figure 45. Sprague and Henwood solid tube sampler with flap valve.

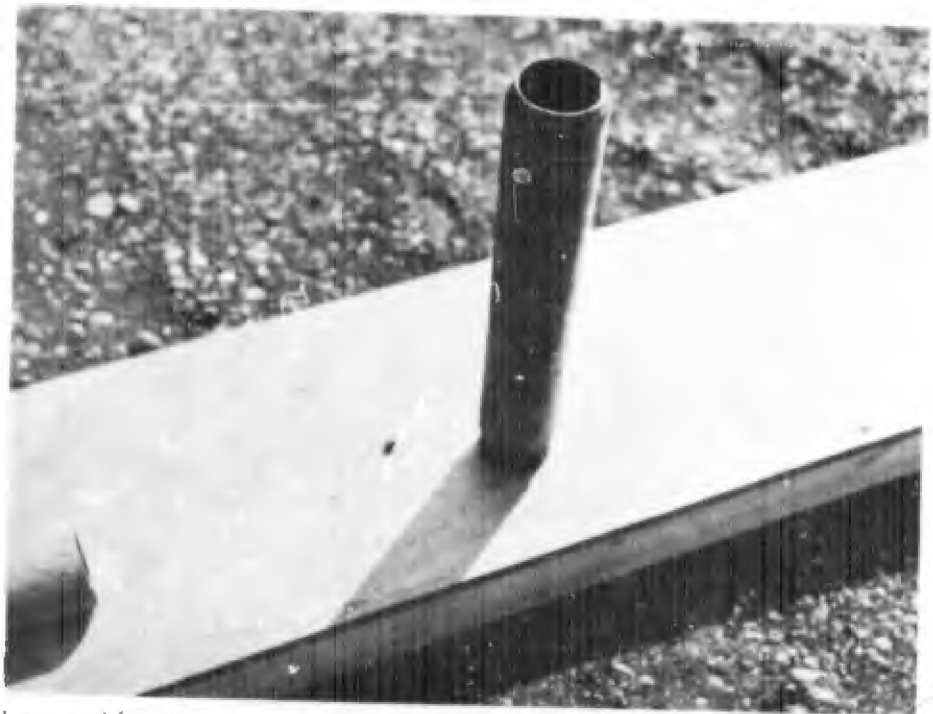


Figure 46. Damaged shoe on Sprague and Henwood solid tube sampler after limited driving.

Figure 47. Thin walled electrical conduit sampler.

Figure 48. Driving thin walled electrical conduit sampler.

Figure 49. Ship's auger used to penetrate seasonally frozen ground.

Figure 50. Driving Shelby tubes with Acker core drill.

The sampler has been very satisfactory for sampling thawed soil and permafrost by manual methods. The thin wall electrical conduit is constructed of tough and durable metal and is readily adaptable for driving through the frozen soil.

Shelby tubes

The Shelby tubes used most frequently at the AFS site are 2 in. OD, 2 ft long, with a 1/16-in. wall thickness. Some tubes with a wall thickness of 1/8 in. have been used but showed no advantage over the thinner wall. The tubes were used for sampling both thawed soil and permafrost by mechanical and manual methods. The Acker drill tripod arrangement with a 350-lb hammer and a 12 - 18-in. drop was effective in driving Shelby tubes into the permafrost (29 - 31.5 F) (Fig. 50).

Experience at the AFS site shows that the Shelby tubes with a beveled or "spun" cutting edge can not be driven into the frozen soil without damage to the tubes (Fig. 51). The beveled edge of the tubes is inadequate to withstand driving in the frozen soil. Shelby tubes witn a square cut end have proved satisfactory (Fig. 52).

Various methods were used to drive the Shelby tubes:

Method A. The tube was adapted to a short length of A-type drill rod. The driving force was supplied by a large brass bushing which was guided by the drill rod and struck manually against the tube adapter (Fig. 53). This method was only practical for a depth equal to the length of the Shelby tube.

Method B. Various equipment from the Acker soil sampling kit was effectively used for sampling with Shelby tubes and manual driving methods (Fig. 54). The tube was adapted to an E type drill rod fitted with a driving head. A 10-lb sledge hammer was used for driving (Fig. 55). Sampling to a depth of 16 ft including 12 ft into the permafrost was successfully accomplished at the AFS site. The advances were generally limited to 1 ft and the sampler withdrawn manually with pipe wrenches. When the tube was driven below 7 or 8 ft, three men were required to withdraw the sampler. One item of poor design is the adapter for the Shelby tubes to the E-rods. The adapters are provided with only one small set screw in most cases while other types have two or four set screws. The small screws were susceptible to shearing during driving, which caused loss of the tube during withdrawal. A single set screw also caused the tube to tear. It is believed that a special adapter provided with large case-hardened screws passing in four directions would be more reliable.

Method C. A Thor, Size 412 pavement breaker was very effective for driving Shelby tubes 1 1/8 in. OD, 4 ft long with a wall thickness of 1/8 in. (Fig. 56). The explorations went through seasonal frost, thawed soil and into the permafrost. The tubes were easily withdrawn by the use of a truck-mounted winch and an A-frame (Fig. 57). Manual removal of the samples from the 7/8 in. diameter tubes was extremely difficult.(Fig. 58).

Hvorslev sampler

The sampler consists of a 6 in. long tube with a 1.87 in. ID and a wall thickness of 0.065 in. (Fig. 59). The cutting end is beveled and swedged slightly. A hollow pipe is fastened to the top of the sampler; a piston arrangement retained the sample by creating a partial vacuum. The sampler is driven by a T-handle at the top (Fig. 60).

Figure 51. Shelby tube with "spun" edge damaged by driving.

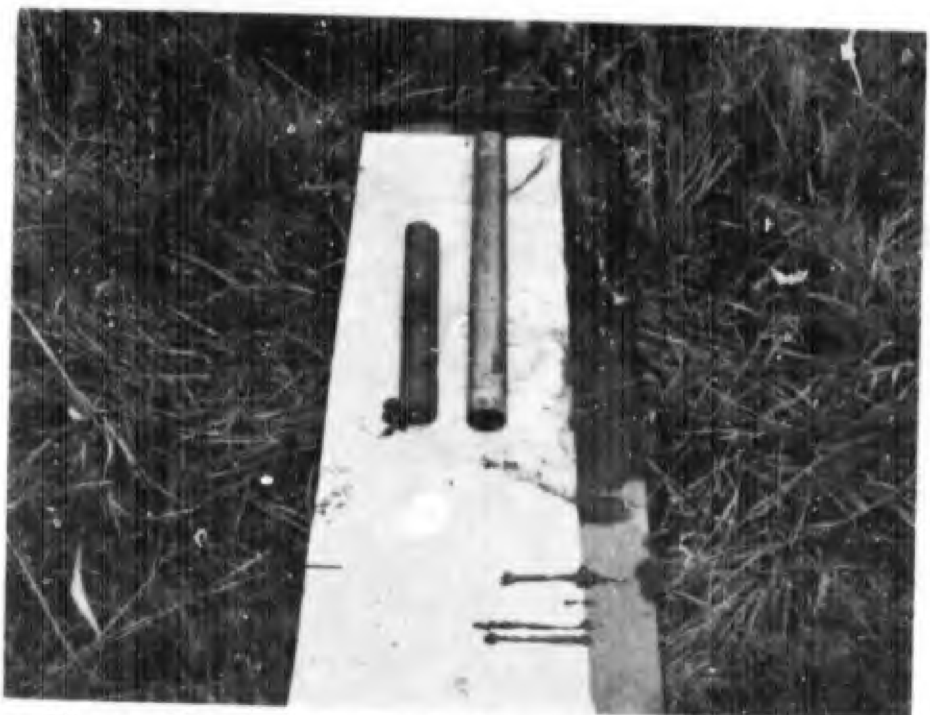


Figure 52. Square cut Shelby tube and core sample.

Figure 53. Drive arrangement for shallow soil sampling.

Figure 54. Acker soil sampling kit equipment used with Shelby tubes.

Figure 55. Driving Shelby tube with sledge hammer.

Figure 56. Driving Shelby tube with pavement breaker.

Figure 57. Removing Shelby tube with truck winch and A-frame.

Figure 58. Removing core from Shelby tube.

Figure 59. Hvorslev sampler.

Figure 60. Drive sampling with Hvorslev sampler.

This sampler proved very satisfactory for testing thawed soils at the AFS site but was inadequate for sampling either seasonal frozen soils or permafrost.

Frost probings

Subsurface probings to locate the top of permafrost or the depth of seasonal frost in silty soils (29 - 31.5F) have often been performed at the AFS site. A smooth steel rod of approximately $\frac{1}{2}$ in. diam is effective for accurate probing through thawed silt to depths of about 15 ft. The advance is abruptly halted when the frozen ground is reached. Below 15 ft the frictional resistance between the soil and the rod becomes too great and the point of contact with the frozen soil can not be accurately determined. For deep probings or probings through dry soil, a small helical soil auger ($\frac{3}{4}$ or 1 in.) adapted to $\frac{1}{2}$ or $\frac{3}{4}$-in. pipe has proved effective and accurate (Fig. 61). The advances were limited to 1 ft and the auger was withdrawn and cleaned of soil. The probing was continued until frozen soil was recovered from the auger. For deep probes it was generally more effective to auger a hole with a ship's auger for several feet before using a probe auger.

When probes were required to penetrate the seasonal frost layers the helical soil auger was advanced by a combination of twisting and light hammering. The rate of penetration was relatively slow but it was an effective method.

When probings were required through the seasonally frozen ground to check the depth of frost penetration, a $\frac{7}{8}$-in. high-speed machine drill bit adapted to a $\frac{3}{4}$-in. pipe proved very effective (Fig. 62). Ordinary wood bits were unsatisfactory for this type of work.

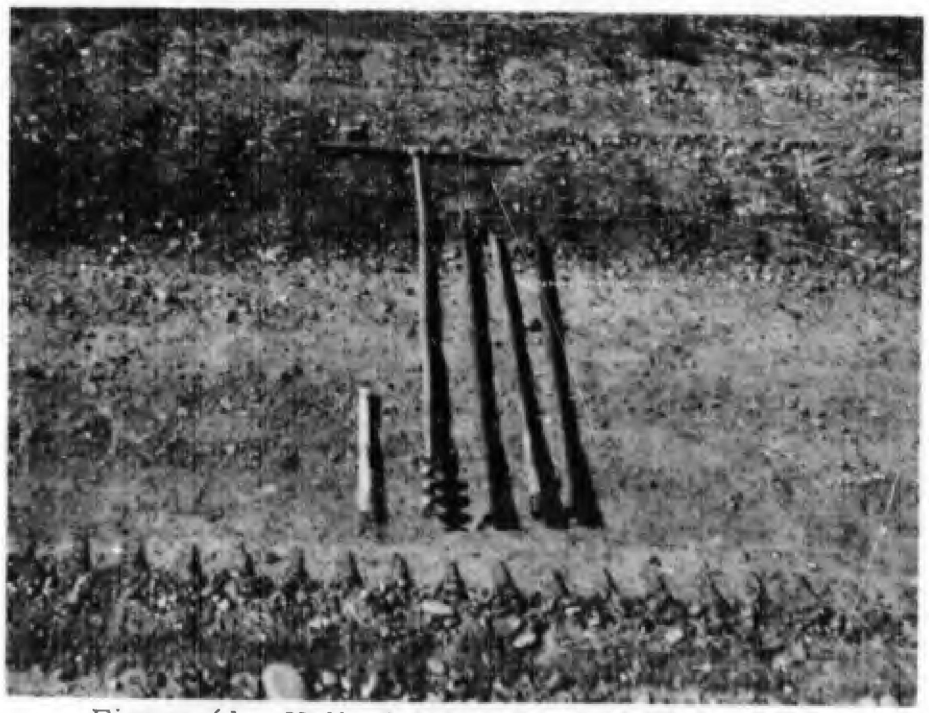


Figure 61. Helical soil auger and extensions.

Figure 62. Field fabricated probing auger using 7/8-in. machine or twist drill.

Figure 63. Pipe vise and ram arrangement for removing soil samples.

Field fabricated sample remover

A very effective device for the removal of soil samples from sample tubes was fabricated at the AFS site (Fig. 63). The device consists of a pipe vise to hold the sampler and a lever-operated ram to force the sample from the tube. The vise and the ram are mounted on a heavy plank. The ram consists of a $\frac{3}{4}$-in. standard pipe which engages the lever at one end and is fitted with a washer at the other end for bearing against the soil in the sampler. The device is adaptable for use with various size sampler tubes by interchangeable rams fitted with suitably sized washers.

RECOMMENDATIONS

a. Further investigation and development should be made of portable lightweight drilling equipment capable of transportation by bush aircraft and manual transportation to confined or remote areas. The Concore exploration drill is a good beginning for this type of equipment requirement. Further development of the equipment is needed to improve its capability for drilling and sample recovery in frozen coarse grained material at remote sites.

b. Further tests and studies are required of methods, procedures and equipment for sample recovery in frozen coarse grained soils.

c. Further tests are needed to ascertain effectiveness of drive samplers with a square cutting edge as compared to samplers having a tapered cutting edge. Tests conducted during the period of this report indicated that drive samplers with a square cut edge were less susceptible to damage by driving than samplers with a tapered cutting edge. This factor is also controversial in connection with pile driving.

d. Percussion type drilling machines have proven to be quite versatile for several operations including drive sampling of soils, water well drilling and driving of piles. Lighter weight designs of this type of equipment would be very adaptable to use at remote sites.

LITERATURE CITED

Bader, H. (1962) Scope, problems and potential value of deep core drilling in ice sheets, U. S. Army Cold Regions Research and Engineering Laboratory (USA CRREL) Special Report 58.

Boyd, W. K. and Lange, G. R. (1957) Interim report on core drilling in frozen ground, Seventh Annual Drilling Symposium, Exploration Drilling, University of Minnesota, Center for Continuation Study of the General Extension Division, Minneapolis.

Bremner, P. C. (1955) Diamond drilling in permafrost at Resolute Bay, Northwest Territories, Publication of Dominion Observatory, Ottawa, vol. 16, no. 12.

Carver, R. R. (1957) Improvement of core recovery by the freezing method, Seventh Annual Drilling Symposium, Exploration Drilling, University of Minnesota, Center for Continuation Study of the General Extension Division, Minneapolis.

LITERATURE CITED (Cont'd)

Cass, J. R. (1959) Subsurface explorations in permafrost areas, Proceedings of the American Society of Civil Engineers, Journal of the Soil Mechanics and Foundations Division, vol. 85, no. SM5, Part I. Discussions by Johnston, G. H., Lange, G. R., Stevens, H. W. and Verville, W. P. in vol. 86, no. SM3, June, 1960.

Hardy, R. M. (1963) Experience in exploration and site selection in northwest Canada, Proceedings of International Conference on Permafrost, Purdue University.

Harwood, T. A. (1963) Experiences in site selection and site exploration, Proceedings of International Conference on Permafrost, Purdue University.

Hvorslev, M. J. (1958) Subsurface exploration and sampling of soils for civil engineering purposes, Report on a Research Project of the American Society of Civil Engineers, sponsored by the Engineering Foundation, Harvard University and the U. S. Army Engineer Waterways Experiment Station, p. 306 - 307 and Appendix.

________ and Goode, T. B. (1957) Core drilling in frozen ground, Seventh Annual Drilling Symposium, Exploration Drilling, University of Minnesota, Center for Continuation Study of the General Extension Division, Minneapolis.

________ (1960) Core drilling in frozen ground, USAEWES, Technical Report no. 3-534.

Johnston, G. H. (1963 a) Engineering site investigations in permafrost areas, Proceedings of International Conference on Permafrost, Purdue University.

________ (1963 b) Soil sampling in permafrost areas, Division of Building Research, National Research Council, Ottawa, Technical Report no. 155.

________, Brown, R. J. E. and Pickersgill, D. N. (1963) Permafrost investigations at Thompson, Manitoba, Terrain studies, Division of Building Research, National Research Council, Ottawa, Technical Paper 158.

Kitze, F. F. (1956) Some experiments in drive sampling of frozen ground, New England Division, Corps of Engineers, ACFEL Miscellaneous Paper 16 (presented at 7th Alaskan Science Conference, Juneau, Alaska, September 1956).

Lange, G. R. (1963) Drilling in frozen ground, Proceedings of International Conference on Permafrost, Purdue University.

Livingston, C. W. (1956, 1959) Excavations in frozen ground, Part I: Explosion tests in Keweenaw silt (1956); Part II: Explosion tests in frozen glacial till at Fort Churchill (1959); U. S. Army Snow Ice and Permafrost Research Establishment (USA SIPRE) Technical Report 30.

McCullough, C. R. (1959) Review of frozen ground excavation methods, USA SIPRE Technical Report 51.

McDonald, L. R. and Bremner, P. C. (1956) Permafrost drilling, Canadian Mining Journal, vol. 77, no. 10.

Mohr, H. A. (1943 - 1944) Exploration of soil conditions and sampling operations, Harvard University, Graduate School of Engineering, Soil Mechanics Series No. 21.

LITERATURE CITED (Cont'd)

Pihlainen, J.A. and Johnston, G.H. (1954) Permafrost investigation at Aklavik: 1953 (Drilling and sampling), Division of Building Research, National Research Council, Ottawa, Technical Paper no. 16.

Sebastyan, G.Y. (1963) Preliminary site investigations in permafrost, Proceedings of International Conference on Permafrost, Purdue University.

Thompson, A. and Bremner, P. C. (1952) Permafrost drilling and soil temperature measurements at Resolute, Cornwallis Island, Canada, Nature, vol. 170.

U. S. Army Arctic Construction and Frost Effects Laboratory (1954) Development of power ice coring rig, New England Division, Corps of Engineers, ACFEL Technical Report 46.

U. S. Army Engineer District, St. Paul (1950) Resumé of methods of obtaining core samples of permanently frozen ground used by the Permafrost Field Operations Branch, Fairbanks, Alaska, St. Paul, Minnesota.

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13. ABSTRACT

Soils explorations were conducted by core drilling methods and by drive sampling methods in thawed and frozen silty soils. Temperatures ranged from 28° to 31.5°F in the permafrost and from 20° to 27°F in the active layer. The Cyclone churn drill, equipped with a field-fabricated 3 in. diameter pipe sampler, is an effective means for drive sampling in frozen silt soils to a depth in excess of 100 ft. Core drilling and sample recovery has been accomplished by using the Longyear, Acker, and Chicago Pneumatic core drills. A Concore exploration drill has been effective in obtaining core samples from 20 to 30-ft depth in frozen soils. A tripod arrangement for supporting a 350-lb drive hammer operated manually by a rope from the cathead of both Acker and Chicago Pneumatic core drills was also effective for drive sampling frozen silty soils to depths up to 20 ft. In general, the Acker split and solid tube samplers have been more effective for driving into frozen soils than the same type samplers of Sprague and Henwood. Manual driving of a sampler fabricated from thin wall electrical conduit proved to be effective for sampling frozen soils to depths of about 10 ft. Sampler driving by pneumatic hammer and recovery by truck mounted winchline was effective to 10 to 15 ft depth.

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